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Comparison of energy flow and economic performance between flat land and sloping land olive orchards

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ABSTRACT

The aim of this research was to compare the production systems of flat and sloping olive orchards and analyze the effect of land situation (flat and sloping) on use of energy input resources. The study conducted on olive orchards of Rudbar region, the origin of olive plant in Iran. The results showed that total energy input was 15.9 GJ ha^{-1} for flat orchards and 23.3 GJ ha^{-1} for sloping orchards. Energy ratio and energy productivity were higher for flat orchards by 1.60 and 0.14 kg MJ^{-1}, instead sloping orchards had higher specific energy and net energy values with 8.03 MJ kg^{-1} and 11.9 GJ ha^{-1}. An econometric model based on Cobb–Douglas production function was applied to show the impact of inputs on olive yield for both orchard types. The benefit to cost ratio was 1.52 and 1.35 and net return was 707.63 \$ ha^{-1} and 726.41 \$ ha^{-1} for flat orchards and sloping orchards, respectively. Sloping orchards produce higher level of olive yield, but energy and economic analysis revealed that their efficiency in use of energy inputs and capital is lower than flat orchards. Inordinate consumption of chemical inputs to increase yield, will impose risk to natural resources together with environmental pollution.

1. Introduction

The common olive (*Olea europaea* L.), which belongs to the family oleaceae, is an evergreen tree. This tree grows up to near 12 m in height with a spread of about 8 m and grown primarily between 30 and 45 ° latitude in both hemispheres [1,2]. Olive is a long-lived plant, with a life expectancy of greater than 500 years. Some trees grown in Middle Eastern regions are believed to be more than 1000 years old [2]. In 2008 total harvested area was over 10,500,000 ha, 95.5 percent of which was concentrated in ten countries surrounding the Mediterranean Sea. The world cultivated area of olives in 2009 was over 9.2 M ha with an average yield of 2.1 ton ha^{-1} [1]. Iran is 11th country of world with 131,000 ha olive orchards and total of 65,000 tons yield, regarding cultivation area. Rudbar area of Guilan province has most attribute in production of this crop and is named as origin of olive in Iran. With last year's development of olive growing, Guilan ranked as third producer with 6000 ha orchards and about 12000 tons olive yield, after Zanjan and Qazvin provinces in Iran [4].

Traditionally, the majority of olive orchards around the Mediterranean are not irrigated. Olive cultivation was traditionally developed and established in areas receiving about 500 mm rain annually [2]. Some study on irrigation systems of olive production have shown that proper irrigation in intensive cultivation system could make most of the olive cultivars highly productive, even in desert conditions [16,17]. The systems of spacing in olive production were quite wide, with 10–12 m between plants and rows in not irrigated orchards. These days in intensive cultivation system orchards designed with closer spacing, such as 6 × 5 m or 6 × 6 m, to accommodate about 300 plants per hectare and the most common olive tree densities are 250 trees per hectare [2]. Guilan province located at northern of Iran in fringe of Caspian sea and encompass the western edge of Alborz mountains and west part of green plains surrounding the Caspian sea; So, this region has both of plain and foothill lands in topological view. According to climate conditions and lands situations, the intensive cultivation system is prevalent system for olive production in flat and sloping lands of study region. Different tree densities in flat and sloping orchards will cause to make difference in use of agricultural inputs and yield level in olive production.

Energy, economics, and the environment are mutually dependent. Agriculture is an energy user and energy supplier in the form of bio-energy and this subject represent close relationship between agriculture and energy. Currently, the productivity and profitability of agricultural productions depend upon energy consumption [3].

Energy auditing can be used as building blocks for life-cycle assessments that include agricultural products, and can also

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serve as a first step towards identifying crop production processes that benefit most from increased efficiency [5]. Irregular use of inputs in agriculture to access higher amount of yield, will along to strike rapidly decreasing of the natural resources, considerably increasing amount of contaminants on the environment and enhancement concentration of greenhouse gases [6]. So, because of serious problems in human health and environment pollution, efficient use of inputs has become important in terms of sustainable agricultural production [7]. Today, modern farming is going on to centralized on energy. Energy use in agricultural production has become more intensive due to the use of fossil fuel, chemical fertilizers, chemical biocides, machinery and electricity to provide substantial increases in food production [7]. There is a great need to balance the use and availability of energy, especially in the agricultural sector [10].

Energy consumption by the agriculture sectors can be broadly categorized into direct and indirect energy use [8]. Direct energy is straightly used at the farm such as human labor usage for different operations, water for irrigation, diesel fuel consumed for machinery operations or pumping water and electricity used for pumping water. On the other hand indirect energy is not directly consumed in the farm, such as fertilizers, machinery and chemical biocide energy inputs. For some indirect energy inputs like machinery or chemical fertilizers or biocides, energy equivalent is described as sum of the energy consumed in producing process and the energy content of constitutive materials. Also total energy input can be divided into renewable and non-renewable energy forms [22]. Renewable energy consists of human labor, farmyard manure and water for irrigation, and non-renewable energy sources consist of machinery, diesel fuel, chemical fertilizers, chemical biocides, and electricity.

Assessment of the energy balance for crop production systems may be implemented by different methods, depending on the goal of the study and no method has been standardize yet for computing the energy balance [9]. Energy input–output analysis is usually used to evaluate the efficiency and environmental impacts of agricultural production systems.

Several researches have been done in evaluation of energy inputs and yield relationship and computing energy indices on different countries; Jekayinfa et al. (2012) evaluated energy consumption pattern and economic analysis of plantain production in Nigeria [37]. Kuswardhani et al. (2013) compared the energy consumption and financial analysis of vegetable production between greenhouse and open field production units Indonesia [38]. Soni et al. (2013) studied on energy input–output relation and CO_2 emissions for rainfed integrated agricultural production systems in Thailand [39]. Also, several studies have been done on energy analysis of agricultural production with respect to Iran; such as kiwifruit [13], apple [22], plum [25] and pear [34]. However, no researches have been conducted on comparison of energy consumption pattern and economic analysis of flat orchards and sloping orchards for olive crop or other horticultural products in Iran.

In recent years, regarding increase in olive consumption capitation, olive oil production industry and non-oil exports, development of olive production is one of the main goals of horticultural branch in Iran. Limited available lands and lack of proper distribution of resources show the necessity of study on existing lands and abilities for construction and expansion of olive orchards. There has been no study to determine the effect of land situation (flat and sloping) of orchards on use of inputs and economic efficiency for horticultural production in Iran. So, the purpose of this study was to present a comparison of inputs usage, level of yield and economic performance between flat and sloping orchards for olive production in Guilan province of Iran. In order to conduct a mathematical relation between inputs and yield, Cobb–Douglas production function was developed on both types of flat and sloping olive orchards.

Table 1
Classification of olive orchards by land situation, in study region.

Orchard type	Average number of tree per ha	Average area (ha)	Min (ha)	Max (ha)
Flat land	200	17.4	3.2	62.0
Sloping land	250	65.8	6.0	165.0

2. Materials and methods

Rudbar region of Guilan province located in the north of Iran; within 36.49 ° north latitude and 49.25 ° east longitude. In this region, most of old orchards were below 3 ha. Because of outdate and inefficient cultivation system of old orchards, this research based on newer orchards (under 30 years) with more than 3 ha cultivation area. The study volume was determined using the Cochran method, as described by Kizilaslan (2009) [12]:

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

where n is the required sample size; s is the standard deviation; N is the number of holding in target population; t is the reliability confidence limit (1.96 which represents the 95% reliability) and d is the acceptable error (permissible error 5%). Consequently sample size of this study was 50 and according to land situation data were divided to two groups of flat orchards (28) and sloping orchards (22) as shown in Table 1. The land situation of sloping orchards was moderate to moderately steep by average of 10–25% slope.

In the study region input resources of intensive olive production were human labor, machinery, diesel fuel, chemical fertilizer, farmyard manure, chemical biocide, water for irrigation and electricity and the only output was olive yield.

Based on energy equivalent of inputs and the output (Table 2), amount energy in olive production was calculated as shown in Table 3. Using the value of energy inputs and output in olive production system, energy indices such as energy ratio (energy

Table 2
Energy equivalents of inputs and output in olive production. Energy equivalents of inputs and output in olive production.

Item	Unit	Energy equivalent (MJ unit^{-1})	Reference
Input			
Human labor	h	1.96	[29]
Machinery	kg	62.7	[29]
Diesel fuel	l	47.8	[30]
Chemical fertilizers			
Nitrogen (N)	kg	78.1	[30]
Phosphate (P_2O_5)	kg	17.4	[30]
Potassium (K_2O)	kg	13.7	[30]
Micro elements	kg	120	[14]
Farmyard manure	kg	0.3	[8]
Chemical Biocides	kg	120	[14]
Water for irrigation	m^3	1.02	[28]
Electricity	kWh	12	[30]
Output			
Olive	kg	11.8	[23]