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An overview on energy inputs and environmental emissions of grape production in West Azerbayjan of Iran

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ABSTRACT

The present investigation is aimed at the assessment of the energy consumption of grape production in West Azerbayjan along with the assessment of environmental indices during the cultivation. The studies were carried out in terms of energy input and output, yield, energy use efficiency, specific energy, energy productivity, and net energy gain where CO_2 emission was investigated as the substantial emission. As well, the portions of different direct, indirect, renewable and nonrenewable energy sources were encompassed. A supervised Artificial Neural Network was employed to prognosticate the energy and environmental indices for grape production in the studied region. Energy inputs included human labor, machinery, diesel fuel, herbicide, insecticide, chemical fertilizers, manure, irrigation water and electricity. The results showed that the total energy input and output for grape production were at 39968.49 and 218713 MJ ha^{-1}, respectively. Among the energy inputs, Nitrogen with 35.6% and irrigation water with 21.81% allocated the greatest shares. The value of total greenhouse gas emission was estimated at 858.621 kg CO_{2eq} ha^{-1} for grape production with the greatest portions for chemical fertilizers and irrigation, respectively. Of diversified Artificial Neural Network approaches, Levenberg–Marqardt training algorithm with root mean square equal to 0.2171 was achieved at 14 neurons in the hidden layer whilst the coefficient of determination values of 0.9927 and 0.9935 were obtained for energy input and environmental emission prediction, respectively.

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Contents

1. Introduction

Grape (*genus Vitis*) is extensively cultivated and is vastly consumed as raw and processed material such as raisin, juice, jelly, jam and vinegar. Grape is a nutritious crop that contains minerals, dietary fiber, and various compounds such as vitamin C, vitamin B-6 and antioxidants [1]. According to the Food and Agriculture Organization (FAO) statistics, 75,866 square kilometers of the world are dedicated to the grape cultivation that indicates the

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great importance of this strategic product. By the area of grape being planted, Iran with 2860 km^2 is the 5th in the world before Romania and after the United States. However, in the list of the top grape producing countries, Iran is ranked 9th in 2012 with 2,150,000 t of grape before South Africa and after Argentina [2]. West Azerbayjan with 7% share in the total production (158025 t) of grape plays a strong role in the economics of Iran [3].

Agricultural production is beneficial for the social and economic development of the countries. Wherein agriculture is both energy consumer and energy provider, the efficient use of energy is one of the major requirements of a sustainable agriculture [4]. Owing to the ever increasing world population, limitations in food production and high expectations of living standards, energy has become a dynamic studying interest and a crucial component for to achieve sustainable development. Furthermore, the increasing demand for food production led to excessive use of inputs such as chemical fertilizers, pesticides, agricultural machinery and electricity that result in perilous environmental problems and energy consumption. It is noteworthy that energy calls more and more attention owing to the social–political turmoil of crude oil providers [5]. Energy efficiency contributes to the minimization of agricultural inputs which have detrimental effect on the environment and destruction of natural resources and economic growth of the crop providers.

The investigation of the relationship between energy input–output can determine the share of each input from the total consumed energy and the crop yield. This would also indicate the efficient use of each input and provides helpful information regarding the optimization of crop production from both aspects of greenhouse gas emissions and crop yield. In Ref. [6] an investigation was carried out concerned with a non-parametric Data Envelopment Analysis approach for improving energy efficiency of grape production and a two-stage methodology was used to find the association of energy efficiency and performance explained by farmers' specific characteristics. Ozkan et al. [7] examined the energy use patterns and cost of production in greenhouse and open-field grape production in Turkey and reported that production costs for greenhouse grapes were higher than open-field grapes but greenhouse grapes were more profitable than open-field due to premium prices for greenhouse grapes. A study was conducted for the energy use patterns and relationship between energy input and yield for grape production in Malayer region of Hamadan Province, Iran, and developed three econometric models to predict the effect of energy inputs on yield [8]. The results showed that the influence of chemical, fertilizer and water on crop production were significant at 1% probability level.

Recently, the Iranian governments have taken drastic measures on energy efficiency and optimization of fuel and energy consumption in all sectors of economy including agriculture. Availability of detailed information on the manner that how efficiently the limited energy resources are consumed is an essential step and prerequisite for the policy makers and modeling of energy input–output as well as environmental emissions. Considering the great portion of grape production in West Azerbayjan from both local and global standpoints [3], there is an inevitable demand for the comprehensive studies which have concentrated on energy input–output, crop yield and environmental emissions in the West Azerbayjan. As far as our literature review is concerned, there is no study dedicated to cover the abovementioned aspects and modeling the problem in West Azerbayjan as an important economic hub of Iran with extensive area under cultivation of grape product.

2. Materials and method

2.1. Data collection

The required data for the study were collected from grape orchardists using face to face interviews and the responses were recorded in questionnaire in Urmia city as the capital of West Azerbayjan Province. West Azerbayjan is a province of Iran located within 37° 33′ 10.08″ N, 45° 4′ 33.24″ E (Fig. 1). The required orchards were randomly selected from the rural communities in the studying location. The sample size of each stratification was computed on the basis of Neyman technique by Eq. (1) [9].

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

where n is the required sample size; N is the number of farmers in the target population; Nh is the number of the farmers in the h stratification; s_h^2 is the variance of the h stratification; d permitted error ratio deviated from average of population $\bar{x}-\bar{X}$, z is the reliability coefficient (1.96 which represents 95% confidence); $D^2 = d^2/z^2$; the permissible error in the sample population was defined to be 5% within 95% confidence interval [4]. Accordingly, it was obtained to be 48 farms using face to face questioner method. However, data were collected from 50 farmers to ameliorate the accuracy of inquiry step. The obtained data consisted hours or amount of different input energy sources such as human labor, machinery, diesel fuel, chemicals, farmyard manure, water for irrigation and electricity. Also the grape yield as the output energy source was obtained. Energy in agricultural processes is classified within direct, indirect, renewable and nonrenewable sources [10]. Direct energy includes labor work, fossil, and electricity while indirect energy sources are incorporated of fertilizers, manures, spray pesticide and machinery. For instance, human labor and manure typify the renewable energy sources where diesel fuel, chemical fertilizers and machinery are representatives of non-renewable energy supplies. Furthermore, input energy resources were incorporated of human labor, chemical fertilizers, manure, biocides, machinery, diesel fuel, electricity, natural gas and seeds while grape yield was considered as output energy parameter. The required irrigation and pumping energy in this study is encompassed as the electricity input. Energy efficiency has close relation with the outputs to inputs ratio [11]. Different energy sources have separate energy values. The inputs and output yield were transformed to energy term by multiplying with the appropriate coefficient of energy equivalents as detailed in Table 1. The corresponding energy coefficients were extracted from the mentioned references in order to compute the consumed energy at different operations or energy content of various inputs.

It is essential to assess the energetic efficiencies of the agricultural system by the energy ratio between the outputs and the inputs. Based on the energy equivalents (Table 1), the energy use efficiency, the energy productivity, the net energy gain, the energy intensiveness and the specific energy were computed as [12]

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

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

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

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

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