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FULL LENGTH ARTICLE

Neural network modeling of energy use and greenhouse gas emissions of watermelon production systems

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Abstract This study was conducted in order to determine energy consumption, model and analyze the input–output, energy efficiencies and GHG emissions for watermelon production using artificial neural networks (ANNs) in the Guilan province of Iran, based on three different farm sizes. For this purpose, the initial data was collected from 120 watermelon producers in Langroud and Chaf region, two small cities in the Guilan province. The results indicated that total average energy input for watermelon production was 40228.98 MJ ha^{-1}. Also, chemical fertilizers (with 76.49%) were the highest energy inputs for watermelon production. Moreover, the share of non-renewable energy (with 96.24%) was more than renewable energy (with 3.76%) in watermelon production. The rate of energy use efficiency, energy productivity and net energy was calculated as 1.29, 0.68 kg MJ^{-1} and 11733.64 MJ ha^{-1}, respectively. With respect to GHG analysis, the average of total GHG emissions was calculated about 1015 $kgCO_{2eq.}$ ha^{-1} The results illustrated that share of nitrogen (with 54.23%) was the highest in GHG emissions for watermelon production, followed by diesel fuel (with 16.73%) and electricity (with 15.45%). In this study, Levenberg–Marquardt learning Algorithm was used for training ANNs based on data collected from watermelon producers. The ANN model with 11–10–2 structure was the best one for predicting the watermelon yield and GHG emissions. In the best topology, the coefficient of determination (R^2) was calculated as 0.969 and 0.995 for yield and GHG emissions of watermelon production, respectively. Furthermore,

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the results of sensitivity analysis revealed that the seed and human labor had the highest sensitivity in modeling of watermelon yield and GHG emissions, respectively.

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1. Introduction

Watermelon (*Citrullus lanatus*) is a vine with large crinkled leaves and also a heat-lover crop, it will grow once established and too much attention is not required. It is the best sown by seed in spring. Watermelon needs a long growing season (at least 80 days) and warm ground for seeds to germinate and grow. The soil temperature should be about 21 °C or warmer at planting time. In farming systems, the watermelon seeds should be sown 1 in. deep and keep well watered until germination. To get a jumpstart in cooler climates, the planting area can be covered with black plastic to warm up the soil and start seeding indoors two or three weeks before they are set out in the garden. Watermelon production is very important to Iran in terms of both export and domestic consumption. Iran has the second place of watermelon production in the world (FAO, 2011). Guilan province has the main share of watermelon production in Iran. Also, watermelon is mostly planted in Langroud city and Chaf region in the Guilan province (Ministry of Jihad-e-Agriculture of Iran, 2013). The amount of energy used in agricultural production, processing and distribution is significantly high. Adequate amount of energy and its effective and efficient use are necessary for an improved agricultural production. It has been realized that crop yields and food supplies are directly linked to energy (Mohammadi and Omid, 2010). The increased use of agricultural inputs in modern farming has resulted in an increase in the energy inputs for fertilizers and crop protection chemicals, higher yields have increased the energy output per unit area and per unit of input (Pimentel et al., 1973).

A greenhouse gas (sometimes abbreviated as GHG) is a gas in an atmosphere that absorbs and emits radiation within the thermal infrared range. The GHG emissions of agriculture come from several sources such as machinery, diesel fuel, chemical fertilizers, biocides and electricity. So, increase in the energy inputs can cause increase in the GHG emissions in agricultural activity.

In general, ANN has been applied in a wide range area, such as mathematics, engineering, medicine, economics, environment, and agricultures. The main advantage of neural networks is that they are able to use prior information (i.e., historical underlying process data) to model complex non-linear systems. Capturing the underlying process is called the learning of a neural network (Safa and Samarasinghe, 2011).

The modeling of energy required and GHG emissions in agricultural activity can reform the pattern of input consumption and grow clean products. Also, the energy resources can be saved by energy modeling. Moreover, clean environment is the main advantage of GHG emission modeling. The developed models can give satisfactory predictions in the studied region and appear to be an appropriate tool for prediction of energy required and GHG emissions of watermelon production. Many researchers have conducted experiments on energy use and GHG emissions in agriculture (Gezer et al., 2003). Mohammadi et al. (2010) examined energy consumption of inputs and output used in kiwifruit production, and evaluated the relationship between energy inputs and yield. Also, Rahman and Bala (2010) developed a network to predict jute production in Bangladesh. In another study, energy use patterns and the relationship between energy inputs and yield were examined for double crop (fall and summer) glasshouse tomato production in Turkey (Ozkan et al., 2011). Banaeian and Namdari (2011) studied the amount of input–output energy of watermelon farms under different farming technologies in the Hamadan province, Iran. Their results disclosed that the total energy consumption was estimated about 93290 MJ ha^{-1}. Pishgar-Komleh et al. (2012) studied the energy consumption and CO_2 emission of potato production in three different farm sizes in the Esfahan province of Iran. In another study, Tabatabaie et al. (2013a) determined energy use pattern and investigate the relationships between energy inputs and yield, cost inputs and income for pear production using linear regression model. In other work, ANNs were applied for modeling energy consumption in wheat production in the Canterbury province, New Zealand (Safa and Samarasinghe, 2011). Khoshnevisan et al. (2013a) predicted yield and GHG emissions of wheat production using ANNs. ANN model with eleven input and two output variables was applied to predict the desired variables (yield and GHG emissions).

The main objective of this study was to apply ANNs to predict yield and GHG emissions of watermelon production in the Guilan province of Iran. Accordingly, several ANN models were developed and their prediction accuracies were evaluated using quality parameters.

2. Materials and methods

2.1. Data collection and processing

Data used in this study were collected from 120 watermelon producers from Langroud city and Chaf region in the Guilan province of Iran using a face-to-face questionnaire in March and April 2013. This province is located in the north of Iran, within 36°34′ and 38°27′ north latitude and 48°53′ and 50°34′ east longitude (Ministry of Jihad-e-Agriculture of Iran, 2013). The simple random sampling method was used to determine the survey volume, as described by Kizilaslan (2009):

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

where n is the required sample size; s, is the standard deviation; t, is the value at 95% confidence limit (1.96); N, is the number of holding in target population and d, is the acceptable error (permissible error 5%). Consequently calculated sample size in this study was 112, but it was considered to be 120 to ensure the accuracy. For the calculation of sample size, criteria of 5% deviation from population mean and 95% confidence level were used.

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