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Prediction of the future impact of climate change on reference evapotranspiration in Cyprus using artificial neural network

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Abstract

Evapotranspiration is considered as one of the fundamental and primary components of paramount significance to hydrological water cycle. But due to global warming, numerous regions especially arid and semi-arid regions are faced with insufficiency of water. Therefore, this research was aimed at forecasting the effect, climate change may have on reference evapotranspiration (ETo) for Girne and Larnaca regions of Cyprus for the next 3 decades (2017 – 2050). CROPWAT 8.0 software computed the past using Penman-Monteith method while Artificial Neural Network (ANN) predict for the future. A three-layer network trained by FFBP (Feed Forward Back Propagation) and LM (Levenberg-Marquardt) optimization algorithm was used. Two approaches were adopted for the study; in the first approach, the input parameters remained static while changing the number of hidden neurons; in the second approach, the inputs varied from 2 to 6 parameters and the hidden neurons doubled the inputs. Determination Coefficient (R^2) and Root Mean Square Error (RMSE) were used as the criterion for performance evaluation of the network. The results disclosed that ANN can efficiently predict future ETo in the regions even with limited climate parameters, but the performance significantly increased by adding more inputs, as R^2 difference from 0.8959 – 0.9997 and 0.8633 – 0.9996 in the regions were observed.

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Keywords: Feed forward backpropagation; determination coefficient; Penman-Monteith method, artificial neural network; evapotranspiration.

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1. Introduction

Shortage of water is gradually becoming a world challenge. Many areas of the globe particularly arid and semi-arid regions, are faced with inadequacy or lack of water which has been attributed to the increase in the world population and global warming due to rise in climate change as a result of more released carbon-dioxide by industries (Jahanbani and El-shafie, 2011). The continual emission of CO_2 to the atmosphere has been on increase since 1950s (Yu et al., 2002).

Evapotranspiration is among the fundamental components of hydrological water cycle. It has a wide significance in many fields of research including crop yield simulation, optimization of water lost, management and irrigation system design, water usage improvement in agriculture, and hydrologic water balance (Jahanbani and El-shafie, 2011; Kumar et al., 2002). Measuring evapotranspiration can be done by using instruments or by reference evapotranspiration calculations (Gocić et al., 2015). Moreover, among all the methods for ETo calculations, Penman-Monteith method happens to be the greatest and most accurate (Allen et al., 1998).

Evapotranspiration is a nonlinear and complex phenomenon caused by a handful of interactions between climatological factors which are temperature, solar radiation, wind speed, sunshine hours and humidity (Kumar et al., 2002). For such a high complexity, considering every physical effective parameter will be tedious, hence, a model which convert variables from input to output in ways contrary to reality happenings, may have more concrete results than models which are physically based. A tool for black box modelling which is lately applied in multiple of disciplines including environmental engineering and hydrology called artificial neural network (ANN) is suitable. ANN is a nonlinear mapping tool for input-output, suitable for modelling problems that are complex in nature, with additional ability advantage of learning from examples without the need for obvious physics. Usually, the results produced by ANN are faster and accurate in comparison to its physical counterparts, although, within only the limits of the observed data of the values utilized in building the model. ANNs development can be traced to 1940s, even though in recent years, great interest is placed on the model application due to improvement in computer science and information technology (Nourani and Kalantari, 2010). A feed forward (FF) network was established by Hornik et al. (1989) which could be generally considered as a nonlinear approximator.

In the recent decades, substantial attention has been given to ANN in many fields of hydrological cycle, its successful applications led to many researches including Earth dam seepage analysis (Nourani et al., 2012a); Soft computing approach for ETo forecasting (Gocić et al., 2015); Spatiotemporal modelling of rainfall-runoff (Nourani and Kalantari, 2010); Estimation of missing rain-gauge data (Nourani et al., 2012b); Sensitivity analysis for evaporation simulation (Nourani and Fard, 2012); Estimating evapotranspiration (Kumar et al., 2002); Monthly time series ETo (Jahanbani and El-shafie, 2011) to mention few.

In view of the ability of ANN to predict future expected events (nonlinear complex events), and by employing CROPWAT 8.0 software to calculate the past years ETo using Penman Monteith equation, the main objectives of the research are to forecast the yearly time series of monthly reference evapotranspiration for Girne and Larnaca regions of Northern and Southern Cyprus for the future years (2017 – 2050), evaluate the network performance in the regions, and draw conclusion by analyzing ANN ability in predicting the impact of climate change (global warming) on ETo in Cyprus Island.

2. Artificial Neural Networks (ANNs)

An ANN can be interpreted as a neurons (also called nodes) of networks that are interconnected. The ANNs structures composed of input, output and hidden layers. An ideal neural network is completely connected, implying that connection do exist between every neurons of each given layer with every next layer neurons. A processing element is the one whose model components are comparable to the actual neuron components. The series of input parameters are saved in the input layer, whereas every input variable is expressed by a neuron. Each input is altered by a function of a weight which is a biological neuron can be comparable to synaptic junction. There are two parts in processing elements. The weighted inputs are simply aggregated in the first part, while a transfer function also called activation which is nonlinear filter is essential in the second part. The transfer of activation function confines the output values within two asymptotes of a neuron. The activation function that is most commonly used is sigmoidal function. The function is continuous and varies generally between -1 and +1 or 0 and 1 (Kumar et al. 2002; Nourani et al., 2012b).A typical FFBP network is given in Fig. 1.