Computers and Electronics in Agriculture 114 (2015) 277–284

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Determination of the most influential weather parameters on reference evapotranspiration by adaptive neuro-fuzzy methodology

Dalibor Petković [a], Milan Gocic [b], Slavisa Trajkovic [b], Shahaboddin Shamshirband [c,*], Shervin Motamedi [d,e], Roslan Hashim [d,e], Hossein Bonakdari [f]

[a] University of Nis, Faculty of Mechanical Engineering, Department for Mechatronics and Control, Aleksandra Medvedeva 14, 18000 Nis, Serbia
[b] University of Nis, Faculty of Civil Engineering and Architecture, Aleksandra Medvedeva 14, 18000 Nis, Serbia
[c] Department of Computer System and Technology, Faculty of Computer Science and Information Technology, Kuala Lumpur 50603, Malaysia
[d] Department of Civil Engineering, Faculty of Engineering, University of Malaya, Kuala Lumpur 50603, Malaysia
[e] Institute of Ocean and Earth Sciences (IOES), University of Malaya, Kuala Lumpur 50603, Malaysia
[f] Department of Civil Engineering, Razi University, Kermanshah, Iran

ARTICLE INFO

Article history:
Received 25 September 2014
Received in revised form 13 March 2015
Accepted 18 April 2015

Keywords:
Reference evapotranspiration
Adaptive neuro-fuzzy inference system
Penman–Monteith method
Variable selection

ABSTRACT

The adaptive neuro-fuzzy inference system (ANFIS) is applied for selection of the most influential reference evapotranspiration (ET_0) parameters. This procedure is typically called variable selection. It is identical to finding a subset of the full set of recorded variables that illustrates good predictive abilities. The full weather datasets for seven meteorological parameters were obtained from twelve weather stations in Serbia during the period 1980–2010. The monthly ET_0 data are obtained by the Penman–Monteith method, which is proposed by Food and Agriculture Organization of the United Nations as the standard method for the estimation of ET_0. As the performance evaluation criteria of the ANFIS models the following statistical indicators were used: the root mean squared error (RMSE), Pearson correlation coefficient (r) and coefficient of determination (R^2). Sunshine hours are the most influential single parameter for ET_0 estimation (RMSE = 0.4398 mm/day). The obtained results indicate that among the input variables sunshine hours, actual vapor pressure and minimum air temperature, are the most influential for ET_0 estimation. The maximum relative humidity and maximum air temperature are the most influential optimal combination of two parameters (RMSE = 0.2583 mm/day).

1. Introduction

Evapotranspiration (ET) is a physical process that refers both to evaporation from soil and vegetative surface and transpiration from plants. Allen et al. (1998) defined reference evapotranspiration (ET_0) which represents a complex nonlinear process. Its accurate estimation is needed for water resource planning and management, irrigation system design and irrigation scheduling. In recent years, ET_0 plays a crucial role in the drought characterization by using in drought indices (Tsakiris et al., 2007; Vicente-Serrano et al., 2010; Gocic and Trajkovic, 2014a, 2015). In addition, report from the Intergovernment Panel on Climate Change (2014) states global warming is causing irreversible environmental change. At present researchers have limited understanding on the far reaching impact of such changes on human race.

Numerous methods have been proposed for estimating ET_0, which can be categorized as combination-type, pan evaporation based, radiation based and temperature-based (Trajkovic, 2010). Extensive researches have reported the superiority of the FAO-56 Penman–Monteith equation (FAO-56 PM) for estimating ET_0 (Pereira and Pruitt, 2004; Lopez-Urrea et al., 2006; Gavilan et al., 2007; Tabari et al., 2013a; DeJonge et al., 2015). Therefore, the FAO-56 PM equation is incorporated in this study.

Artificial neural networks (ANNs) approaches have been successfully applied in ET_0 estimation in the last decades (Trajkovic et al., 2000; Kumar et al., 2002; Kisi, 2006, 2007; Rahimi Khoob, 2007; Landeras et al., 2008; Shiri et al., 2014). Kumar et al. (2011) discussed the ANNs in ET modeling including performance criteria, selection of training algorithm and ANN architecture. Recently, the new soft computing methods have been successfully applied in ET_0 estimation such as genetic algorithm (Aghajanloo et al., 2013; Kim and Kim, 2008; Irmak and Kamble, 2009; Shiri et al., 2012, 2015; Traore and Guven, 2013), fuzzy-logic (Kisi and Cengiz, 2013; Shiri et al., 2013), support vector machines (Kim et al., 2012; Tabari et al., 2013b; Kisi, 2013), and wavelet regression technique (Cobaner, 2013). The development of soft computing methods and their applications in biological and agricultural

* Corresponding author. Tel.: +60146266763.
E-mail address: shamshirband@um.edu.my (S. Shamshirband).

http://dx.doi.org/10.1016/j.compag.2015.04.012
0168-1699/

engineering has been reviewed by Huang et al. (2010). The review highlighted the use of soft computing in precision agriculture.

The adaptive neuro-fuzzy inference system (ANFIS) (Jang, 1993; Jang et al., 1997) was used in the present study. The basic idea behind ANFIS is to provide a method for the fuzzy modeling procedure to learn information about data (Petković and Ćojbašić, 2012; Petković et al., 2013; Aldair and Wang, 2011; Dastranj et al., 2011; Motamedi et.al., 2015a; Motamedi et.al., 2015b; Motamedi et.al., 2015c; Gocic et.al., 2015a; Gocic et.al., 2015b) and to organize the fuzzy inference system with given input/output data pairs (Wahida Banu et al., 2011). For example, ANFIS for ET_0 estimation was applied by Lin et al. (2007) and Tzimopoulos et al. (2008). Moghaddamnia et al. (2009) conducted the combination of ANN and ANFIS models for evaporation estimation. Keskin et al. (2009) evaluated ANFIS and fuzzy sets to estimate evaporation based on meteorological data. Shiri et al. (2011) and Pour-Ali Baba et al. (2013) compared ANFIS to ANN to estimate daily ET_0 values from climatic data and concluded ANFIS to be better than ANN. Karimaldini et al. (2012) investigated the potential of the ANFIS for daily reference evapotranspiration modeling under arid conditions from limited weather dataset. Kim et al. (2013) concluded that ANFIS can be successfully employed for estimating daily pan evaporation in South Korea. Citakoglu et al. (2014) estimated monthly mean ET_0 using combination of ANFIS and ANN models. It is found that the ANFIS and ANN schemes can be employed successfully in modeling the monthly mean ET_0. Kişi and Zounemat-Kermani (2014) compared two different ANFIS approaches, the ANFIS with grid partition (GP) method and the ANFIS with subtractive clustering (SC) method, in modeling daily ET_0. It was concluded that the ANFIS-SC model was more sensitive to the training data length than the ANFIS-GP model. Cobaner (2011) also compared the ANFIS-SC and the ANFIS-GP models and concluded that the ANFIS-SC model had better performance than the ANFIS-GP.

The main objectives of the study are: (1) to determine how the seven weather parameters affect the ET_0 estimation using ANFIS, and (2) to identify which parameters are significant for the ET_0 estimation using a monthly dataset from Serbia.

2. Materials and methods

2.1. Study area and collected data

The study area was Serbia, which is located in the central part of the Balkan Peninsula. Climate of Serbia can be described as moderate-continental with more or less pronounced local characteristics. The geographic features affecting the climate of Serbia include: the Alps, the Mediterranean Sea, the Pannonian Plains, the Morava valley, the Carpathian and the Rhodope Mountains. The average annual air temperature in the areas with the altitude up to 300 m is 11 °C, in the mountainous regions over 1000 m its around 6 °C, and at altitudes over 1500 m around 3 °C. The autumn is warmer than the spring. The coldest month is January, while the warmest month is July. The wettest month is June, while the driest month is February. The mean annual amount of rainfall for the entire country is 896 mm. The central and the west Serbia have the mean annual ET_0 values between 700 and 800 mm/year. The North and the East parts of Serbia have the ET_0 values between 800 and 900 mm/year. The ET_0 values were calculated using FAO-56 Penman–Monteith equation and service-oriented approach presented in Gocic and Trajkovic (2011).

Series of monthly data of maximum (T_{max}) and minimum (T_{min}) air temperatures, maximum (RH_{max}) and minimum (RH_{min}) relative humidities, actual vapor pressure (e_a), wind speed (U_2) and sunshine hours (n) were used. The full weather datasets were collected from twelve weather stations (Fig. 1) for the period 1980–2010 and then were averaged for whole country. The mean annual T_{max} and T_{min} for most locations varied between 12.3 and 17.9 °C and between 3.8 and 8.4 °C, respectively. The mean RH_{max} and RH_{min} for these locations are ranged from 78.0% to 86.0% and from 53.9% to 65.5%, respectively. The mean annual e_a is ranged from 0.9 to 1.4 kPa, while the mean annual U_2 varied for all locations between 0.9 and 1.9 m s^{-1}. The mean monthly n varied for all locations between 153.6 and 182.5 h. Mean annual values of the meteorological variables for twelve weather stations used in this study during the period 1980–2010 are presented in Fig. 2.

Minimum, maximum and mean values with standard deviation of the variables used in this study for the observed period are summarized in Table 1, while the detailed trend analysis of the observed parameters can be found in Gocic and Trajkovic (2013, 2014b).

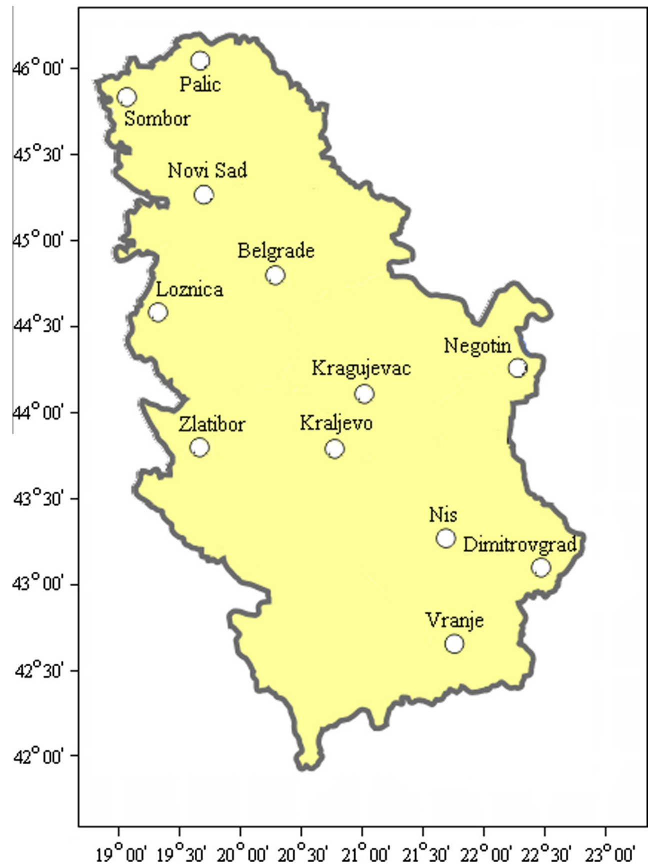

Fig. 1. Location of the weather stations in Serbia.

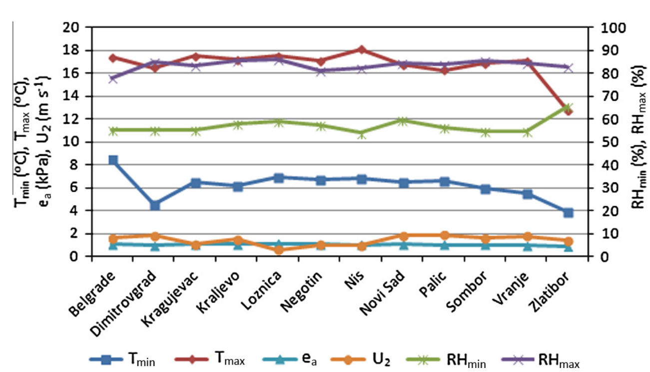

Fig. 2. Mean annual values of the meteorological variables for twelve weather stations during the period 1980–2010.