Application of Fuzzy Neural Networks and Genetic Algorithm Neural Network in Predicting Water Retention

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Introduction

Soil hydraulic properties, SHP, are necessary input variables for running most of the computer models in irrigation, drainage, soil physics and related areas. While direct measurements of SHP are still costly and time consuming, estimating them with pedotransfer function, PTF, is the most accepted way to overcome this problem. Although the powerful performance of Fuzzy neural network, Fuzzy-NN, and Genetic algorithm neural network, GA-NN, have been proved in some related area to hydrology and soil physics, to our knowledge, they have not been used for deriving water retention PTFs. The objective of this study was to test the ability of Fuzzy-NN PTF and GA-NN PTF in estimating water retention of soil.

Material and Methods

Sampling and lab experiments

One hundred and thirty five disturbed and undisturbed (100 cm^3) soil samples were collected from the surface soil (0-30 cm) of different parts of Turkey. Two undisturbed samples were taken from each location by using a dedicated soil sample ring kit (Eijkelkamp Agrisearch Equipment, Giesbeek, The Netherlands). The water retention of the samples was measured at -5, -10, -33, -100, -400, -700, -1000, -1500 kPa using sand box apparatus (Eijkelkamp Agrisearch Equipment, Giesbeek, The Netherlands) and pressure plates equipment (Soilmoisture Equipment, Santa Barbara CA, USA). Common methods were hired to measure the basic soil characteristics of samples. Table 1 shows the physical attributes of samples.

Fuzzy-NN and GA-NN based PTFs

While Fuzzy neural network, Fuzzy-NN, model integrates adaptable fuzzy inputs with a modular NN to rapidly and accurately approximate complex functions, application of Genetic algorithm neural network, GA-NN, the most popular approach for dealing with the optimization problems, in the structure of NN model helps training process.

Three different PTFs were derived in this study;

- NN based PTF,
- Fuzzy-NN based PTF and
- GA-NN based PTF.

A common 3 layer feed forward perceptron was used for deriving NN based PTF containing Levenberg-Marquardt algorithm for the network training process and tangent hyperbolic activation function in the hidden layer and a linear activation function in the output layer. The number of neurons in the hidden layer changed from 1 to 15. The Sugeno fuzzy model using a generalized bell membership function was hired in this study for deriving Fuzzy-NN based PTF while the number of membership functions was 3 for each network input. In GA-NN PTF, a genetic algorithm was used for optimizing the network parameter. The chromosome and generation numbers were 50 and 100, respectively. The components of GA-NN based PTF were similar to NN based PTF.

In all PTFs, the sand, silt and clay content, SSC, bulk density, BD, and organic matter content, OM, were used as the input predictors. The output variables were measured water contents at 8 matric potential points. The samples were divided randomly into three subgroups; training, 65%, cross-validation, 15%, and testing, 20%. All of the PTFs were derived using Neurosolutions 5.07 software.

Table 1: Physical characteristics of soil samples

property	Max	Min	Average	SD
Sand (%)	83.6	5.9	35.1	15.8
Silt (%)	57.6	5.2	30.4	8.2
Clay (%)	62.2	8.0	34.4	13.6
OM (%)	3.85	0.01	1.24	0.65
BD (g cm^{-3})	1.66	0.93	1.25	0.17

Results and Discussion

The average values of root mean squared error, RMSE, and correlation coefficient, *r*, were 0.038, 0.047 and 0.035 m^3 $m^{-3}$and 0.92, 0.89 and 0.93 for NN based PTF, Fuzzy-NN based PTF and GA-NN based PTF, respectively. According to the statistics, all of the PTFs had good performances. However, the best result belongs to the GA-NN based PTFs, which in turn demonstrate the effectiveness of adding genetic algorithm to the NN based PTF. The Scatter plots of measured versus predicted water contents showed in Figure 1. Regarding to the Figure 1, there is no trend to over or under estimation in GA-NN based PTF and NN based PTF but most of the estimated points of the Fuzzy-NN based PTF located on the above the 1:1 line which proves a moderate trend of over estimation.

Akbarzadeh et al. (2009) found Fuzzy NN works better than feed forward NN for predicting cation exchange capacity. Sarmadian and Taghizadeh Mehrjardi (2010) showed that the Fuzzy NN model gives better estimation than NN for estimating infiltration rate and deep percolation. The differences of the performance of Fuzzy NN between these researches and the current one could be related to the differences between output predictors and soil sample characteristics.

The good result of GA-NN based PTF in this research is in agreement with the finding of Parasuraman and Elshorbagy (2007) who emphasized on the power of GA-NN model for modeling hydrological processes.

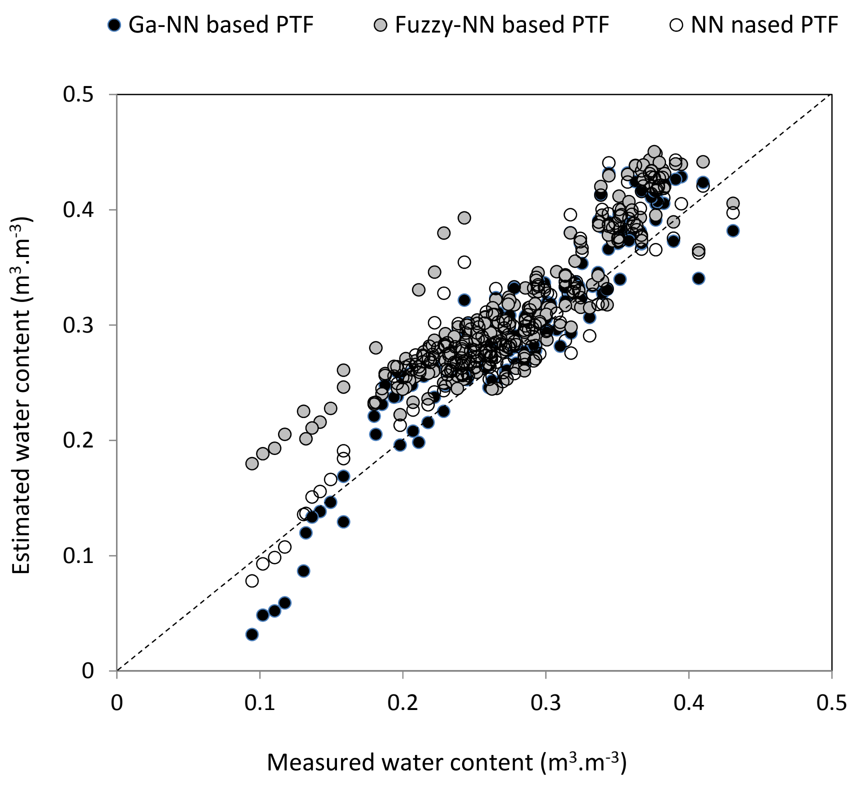

Figure 1. The Scatter plots of measured versus predicted water contents

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