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Research paper

Prediction and simulation of monthly groundwater levels by genetic programming

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Abstract

Groundwater level is an effective parameter in the determination of accuracy in groundwater modeling. Thus, application of simple tools to predict future groundwater levels and fill-in gaps in data sets are important issues in groundwater hydrology. Prediction and simulation are two approaches that use previous and previous-current data sets to complete time series. Artificial intelligence is a computing method that is capable to predict and simulate different system states without using complex relations. This paper investigates the capability of an adaptive neural fuzzy inference system (ANFIS) and genetic programming (GP) as two artificial intelligence tools to predict and simulate groundwater levels in three observation wells in the Karaj plain of Iran. Precipitation and evaporation from a surface water body and water levels in observation wells penetrating an aquifer system are used to fill-in gaps in data sets and estimate monthly groundwater level series. Results show that GP decreases the average value of root mean squared error (*RMSE*) as the error criterion for the observation wells in the training and testing data sets 8.35 and 11.33 percent, respectively, compared to the average of *RMSE* by ANFIS in prediction. Similarly, the average value of *RMSE* for different observation wells used in simulation improves the accuracy of prediction 9.89 and 8.40 percent in the training and testing data sets, respectively. These results indicate that the proposed prediction and simulation approach, based on GP, is an effective tool in determining groundwater levels.

Keywords: Genetic programming; Adaptive neural fuzzy inference system; Prediction; Simulation; Groundwater level

1. Introduction

Groundwater contained in aquifer systems is affected by various processes, such as precipitation, evaporation, recharge, and discharge. Groundwater level is typically measured as the elevation that the water rises in, for example, a test well. Mathematical models are used to simulate various conditions of water movement over time. However, mathematical simulation necessitates values of several parameters which may not be measured or their measurements incur considerable expenses.

Artificial intelligence is a branch of computer science that is capable to predict and simulate groundwater levels by using models such as ANFIS and GP. Chang and Chang (2006) used ANFIS to predict water levels in a reservoir during flood periods in Taiwan. Results showed that the model provided accuracy and reliability for reservoir water-level forecasting in the next 3 h Chen et al. (2006) proposed an ANFIS methodology for flood forecasting. Results showed that upstream flow information was one of the key effects for forecasting floods, and the watershed's average rainfall provided further information and enhanced the accuracy of the model performance. Kholghi and Hosseini (2008) compared the efficiency of ordinary kriging and ANFIS in groundwater level interpolation in an unconfined aquifer in Iran. Results showed that ANFIS

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