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Modeling Techniques for Predicting Hydrological Processes - A Literature Review

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***Abstract*-The importance of groundwater for the existence of human society cannot be overemphasized. Groundwater is the major source of drinking water. During the past two decades, the water level has been falling rapidly due to an increase in extraction. The water levels if properly predicted well in advance can help the administration to plan better ground water utilization. This paper surveys literature review of articles for the past many years in order to explore how various prediction methodologies have been developed during this period in order to take care of the precious depleting groundwater resources.**

Keywords- ANFIS, MATLAB Simulation, Soft Computing, Groundwater level.

1. Introduction

The importance of groundwater for the existence of human society cannot be overemphasized. Groundwater is the major source of drinking water, as well as for agricultural and the industrial sector. Being an important and integral part of the hydrological cycle, its availability depends on the rainfall and recharge conditions. The ever increasing demand for water has led to water scarcity in many parts of the world. The situation is aggravated by the problem of water pollution or contamination.

Groundwater crisis is not the result of natural factors; it has been caused by human actions. During the past two decades, the water level in several parts of the country has been falling rapidly due to an increase in extraction. Thus constant monitoring of the ground water levels is extremely important. The water levels if properly predicted well in advance can help the administration to plan better ground water utilization. Also, for an overall development of the basin, a continuous forecast of the ground water levels is required to effectively use any simulation model for water management. These models based on observed data or theoretical principles, provide a framework for decision making for water users and water regulators.

The groundwater prediction models can be divided into two groups, namely, i) physical and ii) system theoretic. The main drawback of the physical model is the complexity of the models, which increases with increase in model parameters. Further, the development of these models is based on understanding of the physical processes in the system. On the other hand, the system theoretic model is based on data driven techniques, where the mapping or learning of the models is done through data itself. In recent years, the system theoretic models have gained recognition in the field of surface as well as subsurface hydrology. Among the data driven models, artificial neural network (ANN) model has been successfully applied to a wide variety of hydrologic problems. The application of a more promising data driven technique, the fuzzy inference system (FIS), has recently been increasing in hydrology. Further, in recent years many advancements of ANN, which includes, Radial Basis Function (RBF), Generalized Regression Neural Network (GRNN) And Adaptive Neuro-Fuzzy Inference Systems (ANFIS) has been adapted to hydrologic problems. The combination of ANN and FIS into the adaptive neuro-fuzzy inference system (ANFIS) has advantages in a computational framework. The learning capability of ANN can be used effectively for automatic fuzzy if-then rule generation and parameter optimization. Several researchers have used ANFIS in hydrology.
The paper is organized as follows: a review of literature survey on various techniques for groundwater level forecasting is presented in section 2, followed by Section 3, with conclusion and future research directions.

2. Literature Review

Holger R. Maier, Graeme C. Dandy, (2000) described the steps used in the devlopement of Artificial Neural Network models are described. The choices available to scientists at each of these steps are discussed and the issues that should be considered are discussed. A review of 43 papers dealing with the use of neural network models for the prediction and forecasting of water resources variables is undertaken in terms of the modelling process adopted. The vast majority of these networks are trained using the back-propagation algorithm.

P. C. Nayak, Y. R. Satyaji Rao and K. P. Sudheer, (2006) have reported a research study that investigates the potential of artificial neural network technique in forecasting the groundwater level fluctuations in an unconfined coastal aquifer in India. The most appropriate set of input variables to the model are selected through a combination of domain knowledge and statistical analysis of the available data series. Several ANN models are developed that forecasts the water level of two observation wells. The results suggest that the model predictions are reasonably accurate as evaluated by various statistical indices. In general, the results suggest that the ANN models are able to forecast the water levels up to 4 months in advance reasonably well. Such forecasts may be useful in conjunctive use planning of groundwater and surface water in the coastal areas that help maintain the natural water table gradient to protect seawater intrusion or water logging condition.

Shaoyuan Feng, Shaozhong Kang, Zailin Huo, Shaojun Chen, and Xiaomin Mao, (2008) developed artificial neural networks (ANNs) and applied to investigate the effects of these factors on ground water levels in the Minqin oasis, located in the lower reach of Shiyang River Basin, in Northwest China. Using data spanning 1980 through 1997, two ANNs were developed to model and simulate dynamic ground water levels for the two sub-regions of Xinhe and Xiqu. The ANN models achieved high predictive accuracy. Sensitivity analyses were conducted with the models demonstrating that agricultural ground water extraction for irrigation is the predominant factor responsible for declining ground water levels exacerbated by a reduction in regional surface water inflows.

Edvin Aldrian, and Yudha Setiawan Djamil, (2008) investigated the use of multi variable Adaptive Neuro Fuzzy Inference System (ANFIS) in predicting daily rainfall using several surface weather parameters as predictors.
It was seen that relative humidity is the best predictor with a stable performance regardless of training data size and low RMSE amount especially in comparison to those from other predictors. Other predictors showed no consistent performances with different training data size. Performances of ANFIS reach a slightly above 0.6 in correlation values for daily rainfall data without any filtering for up to 100 data in a time series..

Amutha R and Porchelvan P, (2011) carried out a study in Malattar sub-watershed, located in Vellore district, Tamilnadu, India. The results showed that both the models were able to predict the seasonal ground water levels with sufficient accuracy. However, it is observed that the ANFIS model is able to capture the dynamics of the surface water and ground water interactions better when compared to RBF and thus able to predict the seasonal ground water levels accurately.

Jawad S. Alagha, Md Azlin Md Said, Yunes Mogheir, (2012) did an introductory review of application of two AI techniques namely, artificial neural networks (ANNs) and support vector machine (SVM) in various hydrological applications. Here, ANNs and SVM theoretical background together with their strength points that make them suitable for hydrological modeling were briefly described. Moreover, various examples of successful applications of ANNs and SVM for modeling different hydrological processes were also provided.

Hadi Galavi and Lee Teang Shui, (2012) studied the application of ANFIS in water resources context and reviews the common architecture of ANFIS models been used in this area of research. The aim is to make the researchers aware of the ANFIS application process in water resources studies.

Sanjeev Kumar, Ajay Indian, Zubair Khan, (2013), made an attempt for more accurate prediction of groundwater levels with the data of shorter period for the observation wells located in Delhi (India). Feed Forward network trained with training algorithm 'Levenberg Marquardt' and found very effective to predict the ground water levels quarterly.

P. Abbasi Maedeh, N. Mehrdadi, G.R. Nabi Bidhendi and H. Zare Abyaneh, (2013), setup five distinct neural network scenarios of different total dissolved solids (TDS) input and output parameters in an attempt to examine groundwater quality in Tehran with respect to the consumption pattern in the last ten years. It was observed that, in order to forecast with a great deal of trial and error, the tangent algorithms with the momentum-training algorithm turns out to be less erroneous in contrast to the sigmoid algorithms with Levenberg-Marquet.

Manouchehr Chitsazan, Gholamreza Rahmani, Ahmad Neyamadpour, (2013) applied Artificial Neural Network (ANN) approach for forecasting groundwater level fluctuation in Aghili plain, southwest Iran. An optimal design is completed for the two hidden layers with four different algorithms: gradient descent with momentum (GDM), levenberg marquardt (LM), resilient back propagation (RP), and scaled conjugate gradient (SCG). FFN-LM algorithm has shown best result in the present study for all three hydrogeological groups. At last, to evaluate applied division, a unit network with all data and using LM algorithm was trained. Validation of the network shows that dividing the piezometers into different groups of data and designing distinct networks gives more focus on simulating groundwater level in the plain..

M. Rezaeianzadeh, H. Tabari, A. Arabi Yazdi, (2013) studied the use of artificial neural networks (ANN), adaptive neuro-fuzzy inference systems (ANFIS), multiple linear regression (MLR) and multiple nonlinear regression (MNLR) for forecasting maximum daily flow at the outlet of the Khosrow Shirin watershed, located in the Fars Province of Iran. Precipitation data from four meteorological stations were used to develop a multilayer perceptron topology model. The results showed that the area weighted precipitation as an input to ANNs and MNLR and the spatially distributed precipitation input to ANFIS and MLR lead to more accurate predictions.

Vahid Nourani, (2014), showed that employing Artificial Neural Network (ANN) for modeling suspended sediment load leads to acceptable results, but in past few years more attentions have been paid to apply hybrid models. Genetic Programming (GP) also eventuates applicable results, but most of studies show that ANN is more powerful tool than GP. Employing Support Vector Machine (SVM), showed accurate results than other approaches; especially, when using selected kernels. No coincidence, application of hybrid models leads to better results in comparison with sole AI-based models. Pre-processing of data and handling non-stationary data are the main reasons of such results.

Jignesh Patel, Dr.Falguni Parekh, (2014) developed an efficient model to forecast monthly monsoon rainfall for Gandhinagar station using Adaptive Neuro Fuzzy Inference

System (ANFIS). Eight models were developed using various membership functions and climatic parameters as inputs. In this study, the generalized bell-shaped built-in membership function has been used as a membership function in both Hybrid and Back propagation method for ANFIS. The four evaluation parameters Root mean square error, Correlation Coefficient, Coefficient of Determination and Discrepancy ratio were used to evaluate the developed model. The study revealed that hybrid Model with seven membership functions and using three inputs, temperature, relative humidity and wind speed gives best result to forecast rainfall for study area.

Faramarz Keshvari and Seyed Amir Shamsnia, (2014) evaluated the system for predicting the flow of the QAREAGHAJ river has been given. For this purpose gauging, rainfall, temperature, evaporation and monthly discharge of the BANDE BAHMAN station on QAREAGHAJ River in 30-year period (October 1982 to October 2012) were used for the model. The results showed that the artificial neural network can predict monthly discharge of the river with solidarity coefficient of 75.0..

Naser Almanaseer; A. Sankarasubramanian, M., Jerad Bales, (2014) analysed the potential in developing 6-month-ahead groundwater-level forecasts based on the precipitation forecasts from ECHAM 4.5 General Circulation Model Forced with Sea Surface Temperature forecasts. Ten groundwater wells and nine stream gauges from the USGS Groundwater Climate Response Network and Hydro-Climatic Data Network were selected to represent groundwater and surface water flows, respectively, having minimal anthropogenic influences within the Flint River Basin in Georgia, United States. Two low-dimensional models [principle component regression (PCR) and canonical correlation analysis (CCA)] for predicting groundwater and streamflow at both seasonal and monthly timescales were employed. Results from the work showed that using precipitation forecasts in climate models improves the ability to predict the inter annual variability of winter and spring streamflow and groundwater levels over the basin.

3. Conclusion

This paper presents a literature review of the use of various techniques for prediction of water resource variables. This literature review is very useful, since it brings a better understanding of the field of study, and this is an important contribution of this paper. From the literature review it can be concluded that this subject attracts a great deal of interest by researchers.

For almost all hydrological problems, physical models were the default modeling tools worldwide during the last decades. However, the accuracy of these models highly depends on the availability of detailed and accurate data about the complex hydrological system properties, which are not usually available due to cost and time limitations, especially in the developing countries resulting in model uncertainties and unsatisfied performance, which in turn result in insufficient water resources management decisions.

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