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-RESEARCH ARTICLE-

Determination of Groundwater Level Fluctuations by Artificial Neural Networks

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Abstract

Groundwater level change is important in the determination of the efficient use of water resources and plant water needs. Groundwater level fluctuations were investigated using the variable of groundwater level, precipitation, temperature in the present study. The daily data of the precipitation, temperature and groundwater level are used which is taken from PI98-14 observation well station in Minnesota, United States of America. These data, which include information on rainfall, temperature and groundwater level of 2025 daily, were used as input in ANN method. The results were also compared with Multiple Linear Regression (MLR) method. According to this comparison, it was observed that the ANN and MLR method gave similar results for observation. The results show that ANN model will be useful for estimation of groundwater level to monitor possible changes in the future.

Keywords:
Ground water level, Artificial neural networks, Multiple linear regression, Modeling

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Introduction

Groundwater level determination is an important for determining water resources planning. Since the available data generally do not fully reflect the sum of the process, the process

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needs to be modeled in order to make more reliable decisions. Models can be used to generate data for planning and design, or to estimate the future value of processes.

If the values taken over time by a random variable are independent of each other, the time series of these values is called the stochastic process. In order to determine a stochastic process, it is necessary to indicate the intrinsic dependence between successive elements of the series, except for the probability distribution of the random variable (Bayazıt,1981). Multivariate stochastic analysis and multivariate modeling is an important issue, as planning, design and operation of water resources systems often involve meteorological and hydrological (precipitation, flow, evaporation, groundwater etc.) series (Pegram ve James, 1972).

Artificial neural networks (ANN), which is an artificial intelligence method, is a black box model that is frequently used in hydraulic and water structures planning in recent years. Artificial neural networks collect information about the samples, make generalizations and then make decisions about the samples by using the information they have learned compared to the samples they have never seen before. The artificial neural network model demonstrates the ability to successfully solve complex problems due to its learning and generalization features (Ergezer et al., 2003). Artificial intelligence approaches have been also widely used to in water resource management (Demirci et al (2017), Kaya et al (2018), Unes et al (2015a, 2015b), Tasar et al (2017, 2018)).

In this study, the data obtained from the observation well reservoir of PI98-14, near the island of Prairie in the state of Minnesota in the United States of America. The data used was taken from the USGS. The map and satellite images of the study area are shown in Figures 1 and 2, respectively.

Figure 1. Selected Study area map image

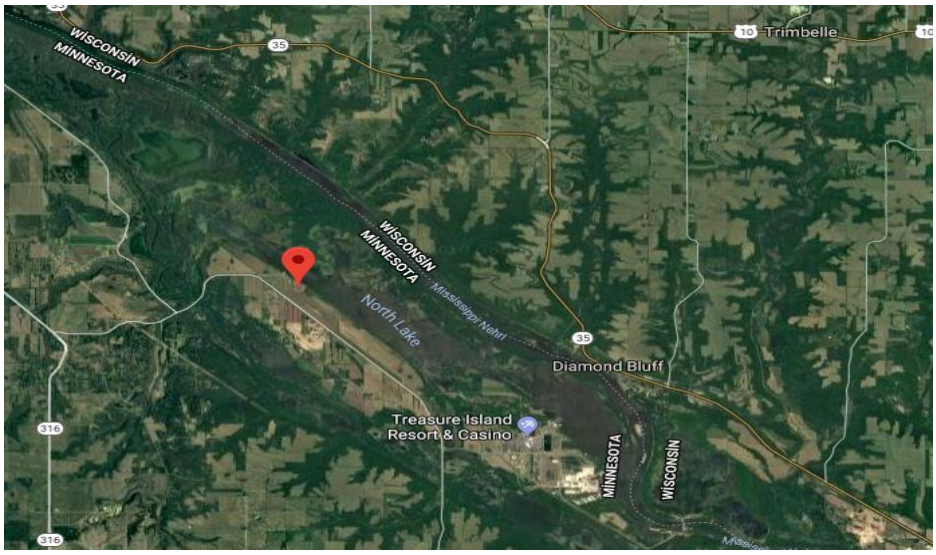

Figure 2. Selected Study area satellite image

Materials and Methods

Multiple Linear Regression method, Artificial Neural Network Method and Data set are introduced in this part of the study. In the all models, Monthly Mean Precipitation (MP), Monthly Average Temperature (MT), Monthly Ground Water Level (GWL+1) were used for the Ground Water Level Estimates.

Attificial Neural Networks (ANN)

The superior characteristics of the human brain forced scientists to work on it and inspired by the neurophysical structure of the brain to try to extract the mathematical model. Various artificial cell and network models have been developed with the idea that the physical components should be modeled correctly in order to fully model all the behavior of the brain (Detienne, K. B et all., 2003). Thus, a new branch of science, which is different from the algorithmic calculation method of new and modern computers called Artificial Neural Networks, has emerged. In general, ANN can be defined as a system designed to model the method of performing a function of the brain. The ANN is composed of various forms of artificial nerve cells connected to each other and is usually arranged in layers (Koç, M. L et all., 2004). In accordance with the brain's information processing method, ANN is a parallel scattered processor capable of storing and generalizing information after a learning process (http://www.akademiyapayzeka.com). Artificial neural networks are basically a technology that has been completely exemplified by the human brain (Ergezer et all., 2003).

Multiple Linear Regression (MLR)

In engineering problems, we see that the values taken by two or more random variables during the same observation are not statistically independent from each other, and therefore, there is a relationship between these variables. For example, the relationship between flow and precipitation in a river basin arises from the effect of flow by precipitation. The relationship between the flows in the neighboring two basins depends on both of them being affected by rainfall in that region (Bayazıt, M., and Oğuz, B., 2005).

The multivariate regression relationship Y is assumed to be influenced by the independent variable of dependent variable X_1, X_2,…., Xm and if a linear equation is chosen for the relationship between them, the regression equation for Y can be written as follows:

$$y = a + b_1x_1 + b_2x_2 + \_\_ + b_mx_m \quad \textbf{(1)}$$

a, b_1, b_2, …., b_m regression coefficients are the sum of the squares of the distance from the plane indicated by the regression equation of the observation points, similar to that in the simple regression,

$$\sum_{i=1}^{N} e_{yi}^2 = \sum_{i=1}^{N} (y_i - a - b_1x_{1i} - b_2x_{2i} - \ldots b_mx_{mi})^2 \quad \textbf{(2)}$$

is calculated to make a minimum of the expression (Bayazıt, M., and Oğuz, B., 2005).

Data set used for the study

Figure 3-5 are drawn to see the distribution of daily average air temperature (T_{ort}), daily precipitation high and daily groundwater level changes, respectively.

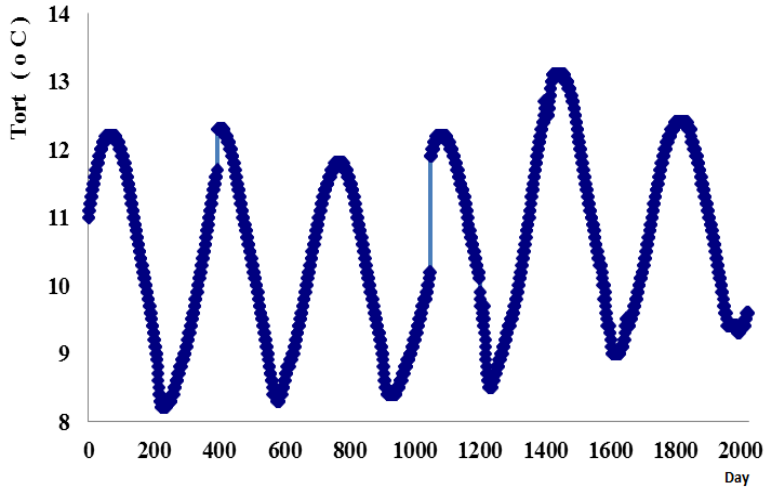

Figure 3. Daily average air temperature distribution

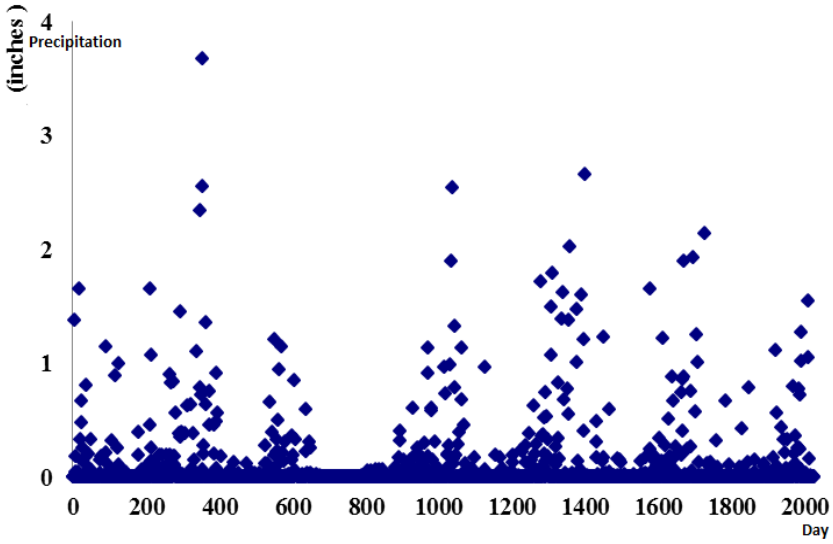

Figure 4. Daily precipitation high distribution

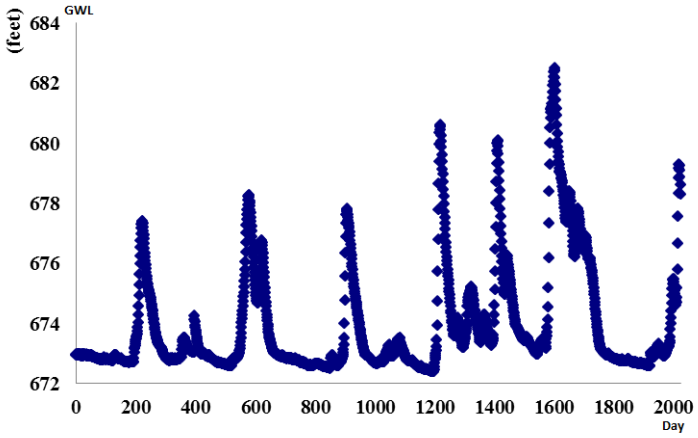

Figure 5. Daily groundwater level distribution

Results and Discussion

Within the scope of the study conducted for the relationship between Precipitation, Temperature and Ground Water Level, a total of 2025 daily data from the station was used. 1419 daily data are used for training models and remaining 606 daily data are used for testing. Mean Absolute Error (MAE), Mean Square Error (MSE) and correlation coefficient (R) statistics are calculated for comparison of methods used. Artificial neural network results and MLR results are compared in Table 1.

Table 1. Comparison statistics

MODELS	INPUTS	MSE	MAE	R
MLR	MP,MT, GWL+1	0.04	0.11	0,996
ANN	MP,MT, GWL+1	0.14	0.26	0,985

*MSE: Mean square error, MAE: Mean absolute error, R: Correlation coefficient

To see the relationship between created ANN model and observed values distribution graph are drawn in Figure 6 and scatter chart belong to this model was drawn in Figure 7.

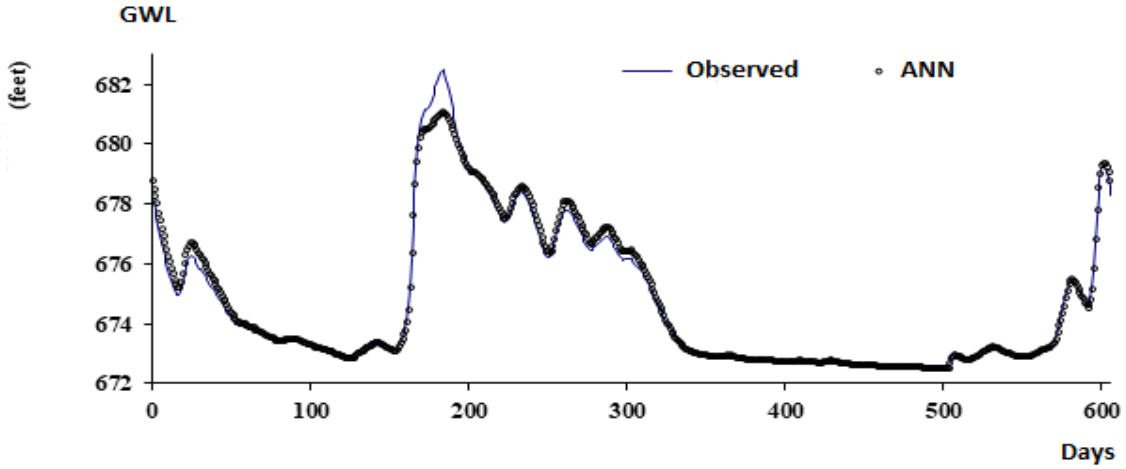

Figure 6. Distribution of ANN model results

Figure 6. shows that distribution of ANN model test results are quite close to observed values of groundwater level for the study area.

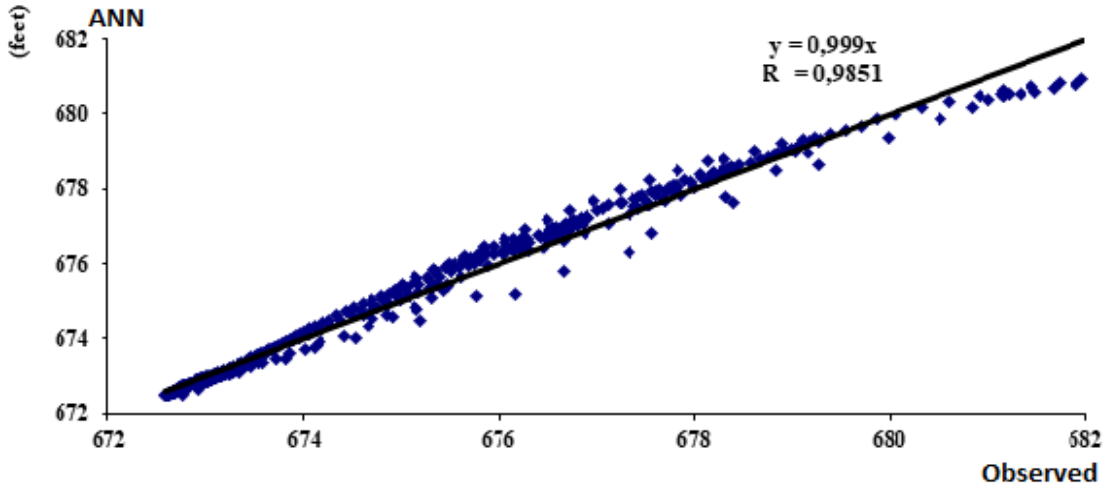

Figure 7. Scatter chart of ANN model results

As it is seen in Figure 7. Correlation coefficient is calculated as 0.985 for test set of ANN method. In distribution and scatter charts, values are close to the actual values.

Distribution of MLR method results and scatter chart is given with Figure 8. and Figure 9., respectively.

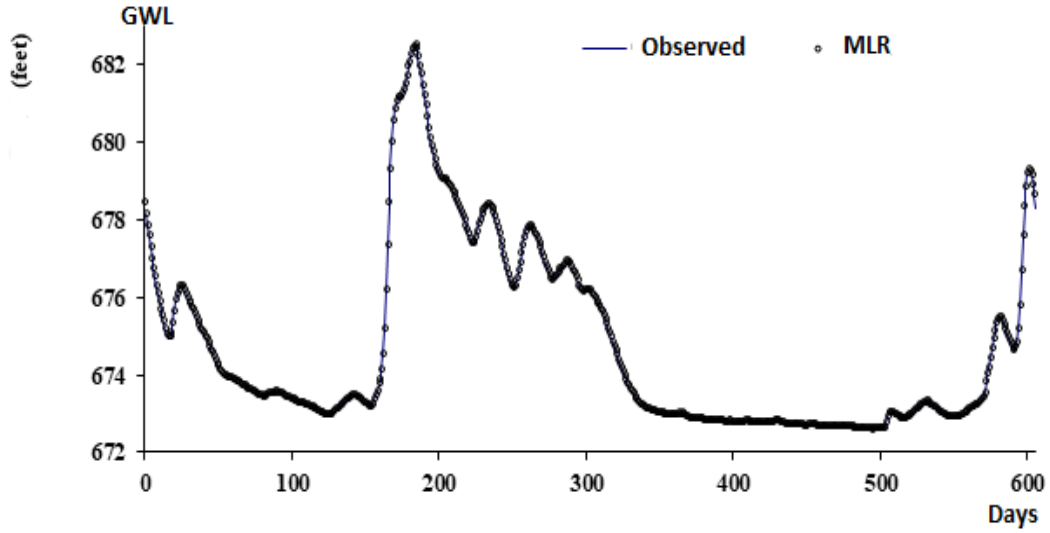

Figure 8. Distribution of MLR method results

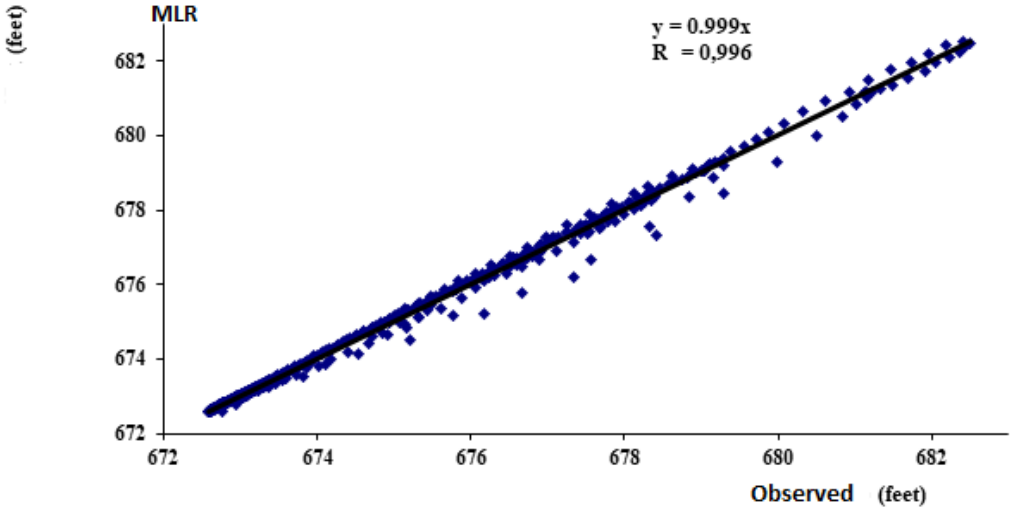

Figure 9. Scatter chart of MLR model results

Results of MLR model show that the correlation coefficient is high and the groundwater level estimate is closer to the actual values shown in figure 8. Correlation coefficient is calculated as 0.996 for MLR results as it is seen in Figure 9.

Conclusion

In this study, the relationship between the precipitation, temperature and groundwater level data of 2025 days of observation station 07040001 in the Goodhue County, Minnesota Reservoir was investigated by Artificial Neural Networks (ANN) method and the obtained values were compared with the Multiple Linear Regression (MLR) method. When the

correlation coefficients and error calculations are evaluated it is understood that MLR results and ANN model gave similar results.

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