Effect of Landuse Types and Rainfall on Some of the Elements in the Zayanderood River

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ABSTRACT

Complexity of some process caused that cannot used suitable model and equation to predict the pollution of rivers yet. Artificial Neural Network (ANN) technique is suitable tools. Rivers are the most important source of agriculture, industry and drinking water. But today they have been shifted to channels for evacuating waste waters. Usually there are no data for estimation of water quality, therefore use of ANN are suitable for estimating and surveying water quality. In this investigation, using satellite pictures and GIS information, different kinds of landuse were determined, and with regard to hydrology station, the area of each landuse was estimated and together with rainfall was used as the input in (ANN). Also the estimated some elements in 12 hydrology stations along the River were selected as the output. Totally 2736 entered as input and 1872 as output. After training the network with various neurons and layers, the best network with highest correlation coefficient (R) and lowest Mean Square Error (MSE) was elected. Result show that the highest correlation was obtained for EC, Cl, SO4, K, Na, Mg, Ca, SAR and TDS (up to 0.80) and the lowest correlation for pH, CO3 (less than 0.50).

Key words: River, landuse, GIS, ANN and Hydrology Stations

Introduction

Rivers have changed the surface of the earth. Accumulation of ecological and human populations along the rivers is one of these changes change. Generally, due to soil fertility, available water for irrigation, industry and drinking, and human gatherings and concentration, River basins are areas with high concentration of pollution [8]. The amount of salts is rising in the Rivers and in most Rivers it has risen to 2 - 7 times of the initial salts in average. Nowadays, pollution in water resources in many parts of the world has resulted in useable condition [14]. Currently, water pollution, threaten human health and life and other organisms on the earth. Salinization fresh water resources as a result of indiscriminate harvesting and reduced rainfall are the main factor of water pollution. Drought is one of natural disasters which have very harmful effects on the ecological environment [9].

ANN is a computational method that with the help learning process and using processors called neurons, tries to make a connection between input and output layer through recognizing the inherent relationships between the data [4]. Hidden layer or layers process the information received from the

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input layer and transfer it to the output layer. Each network is trained with examples. Training is a process that will ultimately cause learning. Learning the network occurs when the weights between the layers change in a way that differences between the predicted and calculated values are acceptable. Achieving these conditions results in the learning process. These weights show memory and knowledge of the networks. Trained neural network can be suitable for predicting outputs with new set of data with regard to the (ANN) structure, its main features, high processing speed, learning ability, the ability to generalize the knowledge after learning, flexibility in unwanted errors against and lack of a significant the knowledge disruption in case of errors in connecting parts of the network is due to the weight distribution [14].

In recent years, several models to estimate water quality have been presented since the water quality depends on many factors, usually the information and data for estimation of water quality do not exist, therefore the use of artificial neural networks is suitable for prediction and estimation of water quality [24].

Many researches have been conducted in the world about the neural networks, predicting rainfall, groundwater modeling and predicting River flow can be referred to in this regard [23]. Among them, the following can be mentioned: salinity in rivers [10] benthic communities [3] in streams, eutrophication and algal blooms in lakes [19] predict rainfall, groundwater modeling and predict river flow [23].

Maier and Dandy (2000), in a study of estimate salinity of Mary River with using ANN, concluded that ANN model is a precise instrument in the estimation of river quality decrease, and differences between observed and simulated values are between 46 to 53 µmhos per centimetre. They suggested that a comparison be conducted between these models with other physical or mathematical models.

Ha [5], estimated the daily dissolved oxygen (DO) in Tualatin River during the years 2000-1991 and successfully predicted the variation with 0.9 (mg/L) error and developed the network for other parameters such as the biological oxygen demand (BOD) and chemical oxygen demand required COD, ammonia nitrogen and other cases.

Ying [24] found ANN a suitable method in the prediction of pollution (BOD, DO) in basin of Yuqiao China, which was fast and easy with few errors.

Mohsenifar et al. [15] simulated the effect of rainfall on the pollution of hydrology Leng station in Zayanderood River with ANN with correlation coefficient of 0.99.

Several researches have been done on water pollution sources and the following factors have been found to affect rivers. A) Landuse and land cover [12,2,18] B) River discharge [21,6] C) rainfall [1]

The main objective of this study is to show and model pollutant (landuse and rainfall) and polluting (Ca, Mg, Na and etc.) factors in the Zayanderood River with the use of GIS and ANN.

Materials and Methods

Zayanderood River is the only central river in Iran which originates in the West from Zardkooh Bakhtiyari (50.130 - 32.454 degrees longitude and latitude respectively) in Chaharmahal&Bakhtiyari province, [22] and discharges in the Gavkhoni swamp East of Esfahan (52.892 longitudes and 32.244 degrees latitude) and is 400.580 km long. Zayanderood River basin, area is 41533.457 km, with a height range of 1470 to 3974 meters and includes arid to very wet climates. (Fig.1).

Table 2 shows the positions of the stations along the Zayanderood based on which the following classification has been done.

Then various landuses were specified (based on Water Organization of cheharmahal&bakhtiyari and Esfahan provinces) in each sub-basin and the whole basin. Table 3 shows different landuses and the area for total basin.

It should be mentioned that only data with satellite images in this yare (2005) existed and that is why this year was analyzed. The daily rainfall was collected.

Data on daily rainfalls of these stations in 2005 from the Water provinces of Isfahan and Chaharmahal&Bakhtiyari were converted to monthly data of the rainfall [15].

Data about water including pH, EC, Cl, CO3, SO4, HCO3, K, Na, Mg, Ca, SAR and TDS in hydrometric stations related to the 2005 year were collected.

The most important factors among them are: 1) type and area of land use 2) rainfall

Therefore, these two factors was determined as input and each water quality parameters of Zayanderood river (includes: pH, EC, Cl, CO3, SO4, HCO3, K, Na, Mg, Ca, SAR and TDS) were considered as output. (Fig.2)

After normalized the data, they were entered in network using the Matlab software 2009. With change of the number of neurons and layers, the Mean Square Error (Eq. 1), correlation coefficient (R2) and error (Eq. 2) for each parameter were calculated.
Fig. 1: Location of Zayanderood Basin and stations.

Table 1: Area of Zayanderood sub basin in each hydrometric station

<table>
<thead>
<tr>
<th>Row</th>
<th>Sub-Basin name</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Toonel 1</td>
<td>11.638</td>
</tr>
<tr>
<td>2</td>
<td>Toonel2</td>
<td>21.280</td>
</tr>
<tr>
<td>3</td>
<td>CheshmeDimeh</td>
<td>300.8444</td>
</tr>
<tr>
<td>4</td>
<td>GhaleShahrokh</td>
<td>1431.903</td>
</tr>
<tr>
<td>5</td>
<td>Sad Tanzimi</td>
<td>4022.513</td>
</tr>
<tr>
<td>6</td>
<td>Pol Zamankhan</td>
<td>4430.925</td>
</tr>
<tr>
<td>7</td>
<td>Pol kalle</td>
<td>5357.822</td>
</tr>
<tr>
<td>8</td>
<td>Diziche</td>
<td>8014.828</td>
</tr>
<tr>
<td>9</td>
<td>Lenj</td>
<td>8084.196</td>
</tr>
<tr>
<td>10</td>
<td>Mosiyan</td>
<td>11368.600</td>
</tr>
<tr>
<td>11</td>
<td>Pol Choom</td>
<td>20974.530</td>
</tr>
<tr>
<td>12</td>
<td>Varzaneh</td>
<td>41533.460</td>
</tr>
</tbody>
</table>

Table 2: Location of stations in Zayanderood River

<table>
<thead>
<tr>
<th>No.</th>
<th>Stations</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Toonel1</td>
<td>50.1308</td>
<td>32.4567</td>
</tr>
<tr>
<td>2</td>
<td>Toonel2</td>
<td>50.1511</td>
<td>32.4575</td>
</tr>
<tr>
<td>3</td>
<td>CheshmeDimeh</td>
<td>50.2161</td>
<td>32.5011</td>
</tr>
<tr>
<td>4</td>
<td>GhaleShahrokh</td>
<td>50.4581</td>
<td>32.6581</td>
</tr>
<tr>
<td>5</td>
<td>Sad Tanzimi</td>
<td>50.7875</td>
<td>32.7115</td>
</tr>
<tr>
<td>6</td>
<td>Pol Zamankhan</td>
<td>50.8947</td>
<td>32.4983</td>
</tr>
<tr>
<td>7</td>
<td>Pol kalle</td>
<td>51.2306</td>
<td>32.3731</td>
</tr>
<tr>
<td>8</td>
<td>Diziche</td>
<td>51.5197</td>
<td>32.3733</td>
</tr>
<tr>
<td>9</td>
<td>Lenj</td>
<td>51.5636</td>
<td>32.3922</td>
</tr>
<tr>
<td>10</td>
<td>Mosiyan</td>
<td>51.5258</td>
<td>32.5767</td>
</tr>
<tr>
<td>11</td>
<td>Pol Choom</td>
<td>51.77</td>
<td>32.5856</td>
</tr>
<tr>
<td>12</td>
<td>Varzaneh</td>
<td>52.6472</td>
<td>32.4275</td>
</tr>
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</table>
Table 3: Different landuses and area of Zayanderood river basin

<table>
<thead>
<tr>
<th>Row</th>
<th>Land Use</th>
<th>Area Km²</th>
<th>Row</th>
<th>Land Use</th>
<th>area Km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pasturedense</td>
<td>1453.953</td>
<td>10</td>
<td>Fallow</td>
<td>116.794</td>
</tr>
<tr>
<td>2</td>
<td>Semi-dense pastures</td>
<td>2016.097</td>
<td>11</td>
<td>Forest with low canopy</td>
<td>12.299</td>
</tr>
<tr>
<td>3</td>
<td>Water farming</td>
<td>5515.327</td>
<td>12</td>
<td>Surface water</td>
<td>91.600</td>
</tr>
<tr>
<td>4</td>
<td>Grassland</td>
<td>337.347</td>
<td>13</td>
<td>Canebrake</td>
<td>50.919</td>
</tr>
<tr>
<td>5</td>
<td>Garden land</td>
<td>8.280</td>
<td>14</td>
<td>Rocky outcrops</td>
<td>5914.358</td>
</tr>
<tr>
<td>6</td>
<td>Forest with moderate canopy</td>
<td>0.007</td>
<td>15</td>
<td>Saline soil</td>
<td>322.732</td>
</tr>
<tr>
<td>7</td>
<td>Dry farming</td>
<td>482.570</td>
<td>16</td>
<td>Desert</td>
<td>1514.480</td>
</tr>
<tr>
<td>8</td>
<td>Low-dense pasture</td>
<td>22275.390</td>
<td>17</td>
<td>Swampland</td>
<td>487.054</td>
</tr>
<tr>
<td>9</td>
<td>Urban</td>
<td>870.573</td>
<td>18</td>
<td>Sandy area</td>
<td>64.376</td>
</tr>
</tbody>
</table>

Fig. 2: Input and output of ANNs.

Fig. 3: BP neural network with a single hidden layer.

\[ MSE = \frac{1}{n} \sum_{i=1}^{n} \frac{y_i(t) - d_i(t)}{2} \]  \hspace{1cm} (1)

\[ Et = \frac{1}{2} \sum_{i=1}^{n} \frac{y_i(t) - d_i(t)}{2} \]  \hspace{1cm} (2)

Where:

- \( Et \): is Error function at the time \( t \),
- \( MSE \): is Mean Square Error,
- \( q \): is number of neurons in output layer,
- \( S2 \), \( j \): is number of neurons in \( y_j(t) \),
- \( y_j(t) \): is real values in the output layer at the time \( t \),
- \( d_j(t) \): is estimated values by the ANNs in the output layer,
- \( n \): is number of inputs or outputs \([6]\).

To determine the effects of land use and rainfall on the pollution of the Zayanderood river, Multilayer Perceptron (MLP) network was used. The network includes an input layer, one or more hidden layers and an output layer. For training the network was used Back Propagation Algorithm (BP). In training of the Network, BP was used.
MLP Network with learning algorithm BP, first was calculation of the input network to the output network was done. Then the calculated error values were applied to the prior layers.

Learning procedures using this algorithm are as follows:

a) Assigning random weight matrix to each connection
b) Selecting the appropriate input and output
c) Calculating the output neurons in each layer, and thus calculating the output neurons in the output layer
d) updating weights with propagation error network method in which the error is due to the difference is the actual output and the calculated output.
e) Evaluating the performance of the trained network with some per-defined factors such as Root Mean Squared Error, and finally returning to the final part of training.
f) Selecting the appropriate input and output

The model used in this paper is a BP neural network model with a single hidden layer. In Figure 3 shows the structure of an ANN with a single layer. Where R: input layer, S1: the hidden layer, S2: the output layer, IW1.1: the weight matrix of the input layer, LW2.1: the weight matrix from the hidden layer to the output layer, b1 and b2 threshold values of the hidden and output layers respectively and f1 and f2 the neuron transfer functions of the hidden and output layers respectively [24].

After determining the area of 18 different land uses and the amount of rainfall in the 12 sub-basins monthly, the total number of 2736 as input and 13 pollutants in 12 river stations in the total number as 1872 output network were entered to the neural network. Of these 60 percent were used as the training network and the remaining 40 percent were used for testing the network.

Result and discussion

Figure 4 illustrates the correlation coefficient of the network for training, test and the whole network. According to this figure, correlation coefficient for the three parameters pH, CO3, and discharge are low (0.39, 0.31, and 0.653 respectively), but for the other outputs regression coefficient is above 80 percent.

It seems this is due to low changes of CO3 all along the river. In fact land use did not affect the two factors pH and CO3. Mas [11] using artificial neural network did modeling pollution in the Charles River watershed in Massachusetts [6]. He pointed to the limited research on the use of ANNs for predicting indicator organism concentrations in freshwater and surface waters under dry weather conditions. The results show that, in this watershed setting, ANNs were unable to correctly generate precise predictions. And modeling results show that ANNs are the weakest at predicting extreme values, but are capable of correctly classifying indicator organism concentrations relative to a threshold.

Based on researches by Hafizan [8] for DO, BOD, Suspended Solids (SS) and Ammoniacal-Nitrate (AN), (R=0.735, 0.786, 0.809, 0.821 respectively), Najah, A. [16] for EC, TDS and Turbidity (r=0.767, 0.767 and 0.91 respectively) and Talib, A. [23] for monitoring a month data of Pulau Pinang River for BOD (R=0.72), have been done. They point that the ANN is a suitable method for predicting water pollution.

But in this research they selected the whole Zayanderood basin and 12 hydrology stations in the river side and considered land use as the most important factor on the river pollution. Any change on the landuse of the river basin, can effect elements of river. The dam and factories along the river, are effective on discharge and increase of the elements in water of the river. Because these two factors are not considered in the network, it cannot naturally establish relationship whit river pollution. Also, because pH changes are low in the long of the river and pH is more affected by lithology of basin, ANN dose not establish a relationship between these two factors.

So EC, Cl, SO4, K, Na, Mg, Ca, SAR and TDS factors, have direct effect on landuse and rainfall, ANN has been simulated with high accuracy in this study.

Fig. 5 shows changes of these two factors throughout the glen of river. But regarding the discharge, because its value depends on the dam rather than the rainfall, discharge is not a function of land use and rainfall. Figure 6 shows the position of Zayanderood dam in the Zayanderood River Basin.

Figure 6 Location of Zayanderood dam

Figure 7 shows the MSE. Value of pH, Cl and discharge is high, (0.102, 0.162 and 0.078 respectively) Error related to the actual and simulation values were calculated and are shown in the fig 8 and 9 in percentage. As can be seen in Figure 8 for Mg, Na, SO4, TDS and SAR there is a similar pattern. Error value until the 11th station is less than 18 percent but suddenly at the 12th station, it increases to 100 percent. The reason is the discharge of agriculture and municipal (urban) sewage of Isfahan into the river. From the 1th station to the 7th station the error value is less than 2 percent, but at the 8th station error reaches to twice that error at least, and increases to 4 percent. Because at the 8th Station is Zobahan factory and it
**Fig. 4:** Correlation coefficient, Training, Test and All data for different elements in the (ANNs).

**Fig. 5:** $\text{CO}_3$ and pH values changes throughout the glen Zayanderood River.

**Fig. 6:** Location of Zayanderood dam.
discharges the sewage into the river. But for discharge, pH, HCO3, and K, the percentage error for most stations is high (Fig. 9). For discharge until station number 3, error value is 26 percent at maximum, but in station No. 4 it increases to 100 percent because the Zayanderood dam is in distance and discharge is not affected by the rainfall rate but on the dam.

Landuse has a direct relation with river pollution and for factors (EC, Cl, SO4, K, Na, Mg, Ca and TDS), correlation coefficient is over the 0.81 in Zayanderood River basin. As Sandhu and Phinch [20], Maier and Dandy [10] and Noroziyan [17] for EC, Sandhu and Phinch [20] for TDS and ShadmanMotlagh [21] for runoff of discharge, was simulated the ANN with R up to 98%.

Many factors affect the river pollution; landuse is most important one which is considered in this study. However, it is suggested that other factors such as geology, soil texture and etc. Also be studied.

**Conclusion:**

With attention to the effective factors on River pollution as in this article study, ANN is a suitable factor for predication of water quality of the Zayanderood River.

More facts EC, Cl, SO4, K, Na, Mg, Ca and TDS (R>81%) high dependency, and discharge, pH, HCO3, and K factors are less dependent on variety of land use and rainfall in the catchment considered.

In the end stations due to industrial pollutants entry (large industries: Isfahan melt steel and Mobarakhe steel) and urban (Isfahan city), reduced this correlation.

In addition to review factors in this article, also it is necessary to consider the effect of other factors such as soil texture, amount of industrial pollution.

**Acknowledgment**

The result of project Effect of Slope and Rainfall Zaynderood River in river pollution with ANN.
References


