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USE OF ARTIFICIAL NEURAL NETWORKS FOR MODELING INFLOW AND OUTFLOW AND SALINITY OF LAKE FETZARA IN THE REGION-ANNABA (NE ALGERIA)

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Abstract: *Lake Fetzara is one of the important lakes in the northeast of Algeria; the water supplying this lake comes from different precipitation and wadis. Moreover, Meboudja wadi constitutes the drainage channel. The water of the lake and the underlying groundwater is exposed to excessive overuse; which seriously threatens the hydrological and ecological balance. The overexploitation is explained by the increase in water mineralization, which poses a risk of soil salinization. To this end, this article deals with the subject of current salinity and predict its evolution over time by means of the modeling of the artificial neural network (ANN), according to the period of low water and the period of high water. The ANN were trained using three different algorithms: the Scaled Conjugate Gradient back propagation (SCG) algorithm and One Step Secant back propagation (OSS) algorithm and Quasi-Newton algorithm (BFGS). The performance results indicate that the three algorithms provided satisfactory simulations according to the determination coefficient (R^2) and the performance criteria of the mean square error (RMSE), with priority to the BFGS algorithm; where the coefficient of determination using the BFGS algorithm varies between 69.5% and 95.3%. The BFGS method presents better results in order to design appropriate institutional mechanisms, capable of leading to the protection of the quality of these resources essential to the promotion of sustainable development.*

Keywords: *Inflow, Outflow, Drainage, Salinity, Oued, Water table, Artificial neural network.*

1. Introduction

Water is necessary element for the life of human beings, fauna and flora. The quality of groundwater has been degraded due to climate change, the intensive use of fertilizers, domestic wastewater and various discharges from factories rejected directly into the streams; particularly in the wadis feeding the lake Fetzara. [1]

The hydrographic network of the lake Fetzara is composed of four streams, which are: the Mellah stream, with a length of nearly 8 km, the El Hout stream, with a length of 10 km, the Zied stream, with a length of about 10.5 km and finally the Bou Messous stream which has a length of 9 km. All these streams flow into Fetzara Lake with a very irregular regime, torrential in winter and dry in summer. [2]

The degradation of quality and quantity threatens hydrological and ecological balance. The increase of water mineralization leads to the risk of soil salinization. [2]

To this end, this article deals with the subject of current salinity and predict its evolution over time by means of the modeling of the artificial neural network (ANN) according to the period of low and

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high water and weekly measurement of the flow of wadis along two hydrological cycles.
Regarding the provision of water resources and the management of application, it is undeniable to predict the quality of groundwater, various factors contributes to the variation in water quality. Their uncertainly inherent in weight, as more than one variable effects water quality. The inhomogeneity the environment reflect the prediction of quality and approaches into complexity. The salinity parameter is one of the fundamental parameters for potable and agricultural water. [3] This is directly related to the conductivity of the water and its dissolved salt (Sodium Chloride, Magnesium Chloride, Magnesium Sulfate, etc.) and the quality of potable water.
Salinity was examined in this study as such a suitable approach to examine the behavior of groundwater by model system; it is necessary to know the mechanism of quality fluctuations over time in order to have an idea about the situation of the water table and the quantity of accessible water. [4]
Artificial neural network are "the black box" non-linear mathematical models capable of establishing relationships between inputs and outputs of a system.[5] ANN is considered practical substitutes for regression and empirical models to predict the behavior of water ressources; due to their temporal reliability and adaptability to unforeseen changes. These are applied not only in qualitative forecasting, but also in forecasting the situation and the volume of groundwater, much of the modeling has been done in this regard. [6] As for prediction based on the neural network, [6]

2. Materials and methods

1.2. Description of study area

Lake Fetzara is cosedered as wetland. Its location is about 18 km southwest from the chief state of Annaba (Daïra and municipality of Berrahal), it covers 18.600hectares. [7] Several small tows border it: to the north, the municipality of Berrahal, to the south the municipalities of ElEulma (crosseb by ElHout wadi) and Cheurfa, to the east the small villages of ElGantra and Zied wadi. (Figure 1)
Lake Fetzara has been listed on the RAMSAR list of wetlands of international importance since 2002. Its large extent and relatively temporary nature make it a representative wetland of the Mediterranean region [7]. The hydrological function of the lake contributes to flood control, as well as to the recharge of the water table.
Lake Fetzara stretches 17km length and 13km width. The open water area, which depends almost exclusively on the intensity of rainy season, occupies an area of more than 5800hectares. In addition, there are several thousand hectares of flood plains forming vast wet meadows. [7]

2.2. Analytical method

To ensure rigorous monitoring of the quality and quantity of water entering and leaving the lake, weekly monitoring of the flow of the wadis during two hydrological cycles (2016/17) and (2017/18) as well as seasonal piezometric campaigns has been realized. For sampling, the sites chosen are in near-urban areas and nearby the industrial zone of the municipality of Berrahal. The number of the wells selected is 39 wells. In-situ parameters were measured using multi-parameter band HANNA instruments INC (made in Romania). The main elements presents in the water analyzed using a Metrohm 883 basic IC plus ion chromatography apparatus (made in Courtaboeuf, France) with a conductometric detector. Prior to their chemical analysis. The water samples are filtered through a nylon membrane (0.22 µm).

Fig. 1. Geographic location of Fetzara lake in the wilaya of Annaba. Algeria. (Design by P. Pentsch) [8]

The mobile phase used is mixture of $NaHCO_3$ (168mg) and Na_2CO_3 (678mg) dissolved in two liters of ultra-pure water. The injection rate is 0.7ml/min and the volume injected is 20 µL. The chromatograph was calibrated using five standard solutions containing a concentration of cations or anions ranging from 1 to 50mg/l. The prediction of salinity of groundwater is done using three different artificial network algorithms.

2.3. Data analysis

The data set is arranged into two layers:

- The first one is the training part (72% of the data)
- The second one is used for model validation (28% of data).

Several tests were made to ensure that all training and validation modules were examined in a trial and error manner, in order to obtain better results. In order to detect model perturbation, a portion of data is used for training and another portion is reserved for testing the performance of the model in order to decide to stop training with optimal hidden nodes [9]. This stop is made when the model validation error starts to increase. [10]

The conductivity is directly proportional to the water mineralization; [11] for this purpose, we have seven descriptor parameters: Conductivity, Chloride, Sulphates, Bicarbonates, Calcium, Magnesium and Sodium. The sampling date is from the 08/11/2016 to 15/05/2018. Simple descriptive statistic of the raw data is shown in (table 1).

The correlation corresponding to the statistical data collected from the sampling of 39 wells in the region surrounding lake Fetzara and the wadis that feed it, shows that the most significant correlation with the conductivity parameter is observed among the other parameters, in which the correlation was established through the software statistica 8 (table 2)

Table 1. Statistical description of parameters.

Variables	Training dataset					Validation dataset				
	Min	Max	Mean	SD	CV	Min	Max	Mean	SD	CV
EC [µs/cm]	281	6800	1789.75	1225.67	0.68	276	2440	1093.43	621.71	0.57
Cl^- [mg/l]	85.2	2996.2	675.02	523.60	0.78	35.5	1065	402.02	268.04	0.67
SO_4^{2-} [mg/l]	19.2	725.3	231.11	133.25	0.58	19.2	528	171.29	106.88	0.62
HCO_3^- [mg/l]	23.18	1284.53	357.88	209.51	0.59	34.77	614.88	301.55	140.96	0.47
Ca^{2+} [mg/l]	33.6	672	167.33	106.71	0.64	43.2	348.8	139.36	77.89	0.56
Mg^{2+} [mg/l]	1.92	886.4	63.87	89.85	1.41	4.8	176.64	32.38	30.24	0.93
Na^+ [mg/l]	46	2622	382.33	390.66	1.02	23	575	196.02	126.12	0.64

Selection of the input combination:

Table 2. Correlation matrix (Pearson) between variables.

Variables	EC	Cl^-	SO_4^{2-}	HCO_3^-	Ca^{2+}	Mg^{2+}	Na^+
EC	**1**	0.941	0.474	0.500	0.748	0.465	0.789
Cl^-	0.941	**1**	0.409	0.407	0.746	0.464	0.776
SO_4^{2-}	0.474	0.409	**1**	0.216	0.359	0.296	0.425
HCO_3^-	0.500	0.407	0.216	**1**	0.274	0.331	0.504
Ca^{2+}	0.748	0.746	0.359	0.274	**1**	0.250	0.492
Mg^{2+}	0.465	0.464	0.296	0.331	0.250	**1**	0.419
Na^+	0.789	0.776	0.425	0.504	0.492	0.419	**1**

Different combination of inputs used in the modeling:

No.	Combination
01	Cl^-
02	Cl^- & Na^+
03	Cl^-, Na^+ & Ca^{2+}
04	Cl^-, Na^+, Ca^{2+} & HCO_3^-
05	Cl^-, Na^+, Ca^{2+}, HCO_3^- & SO_4^{2-}
06	Cl^-, Na^+, Ca^{2+}, HCO_3^-, SO_4^{2-} & Mg^{2+}

Training algorithms

The performance of the neural artificial network was constructed in order to determine which algorithm would be the most effective in predicting the salinity of groundwater in the region by the following algorithms:

- BFGS: quasi-Newton back propagation (Brayden 1970; Fletcher 1970; Goldfarb 1970; Shanno 1970).
- SCG: Scaled Conjugate Gradient back propagation
- OSS**:** One-Step Secant back propagation

3. Results and discussion

In this research, we created a model to predict the total variables of groundwater salinity based on different water quality states of lake Fetzara and the underlying aquifer. The artificial neural network is used to estimate the relationship between different variables. The results of the prediction show that the neural network approach has good and wide applicability for modeling the salinity of waters of the region. (Figure 2) presents the calibration of predicted salinity according to the BFGS, SCG and OSS algorithms with the observed salinity by ANNO5.

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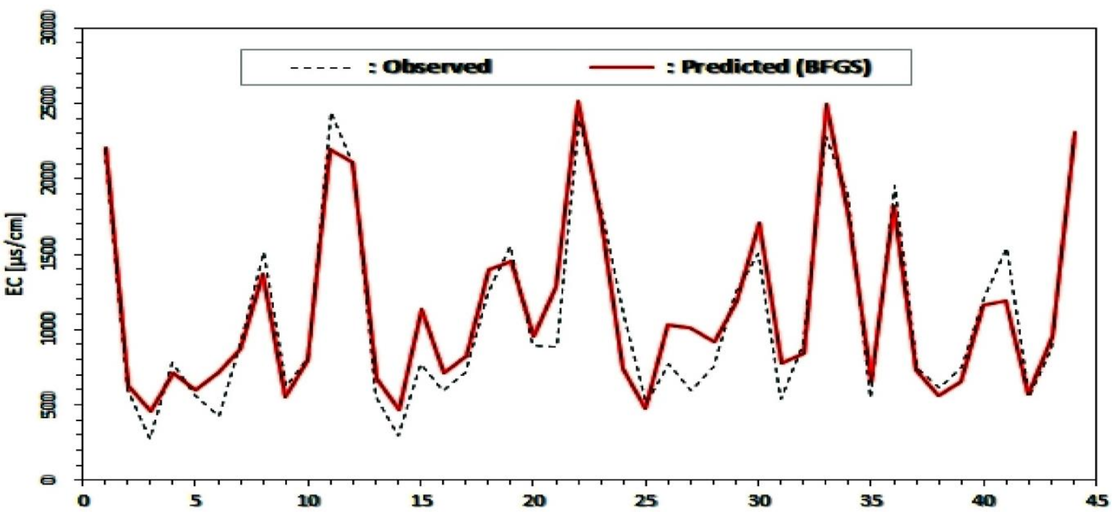
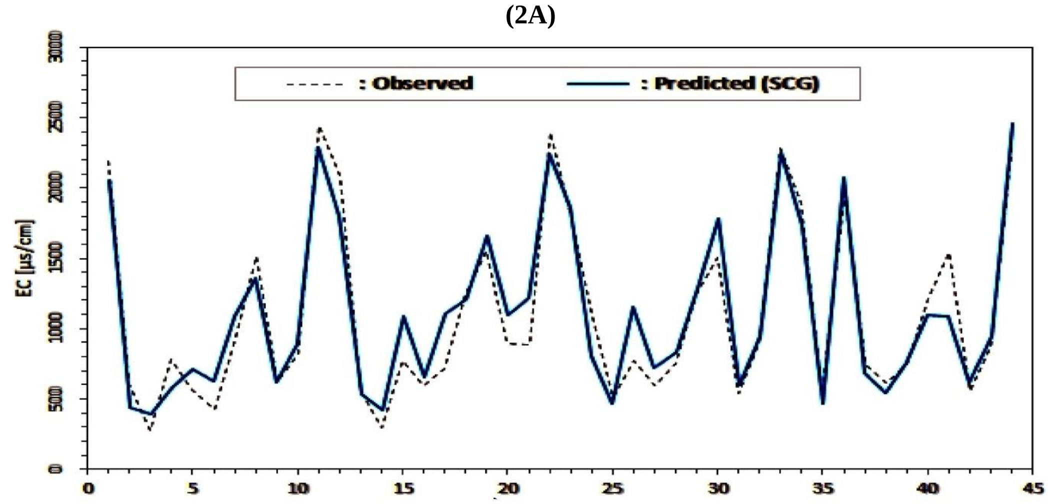


(2A)



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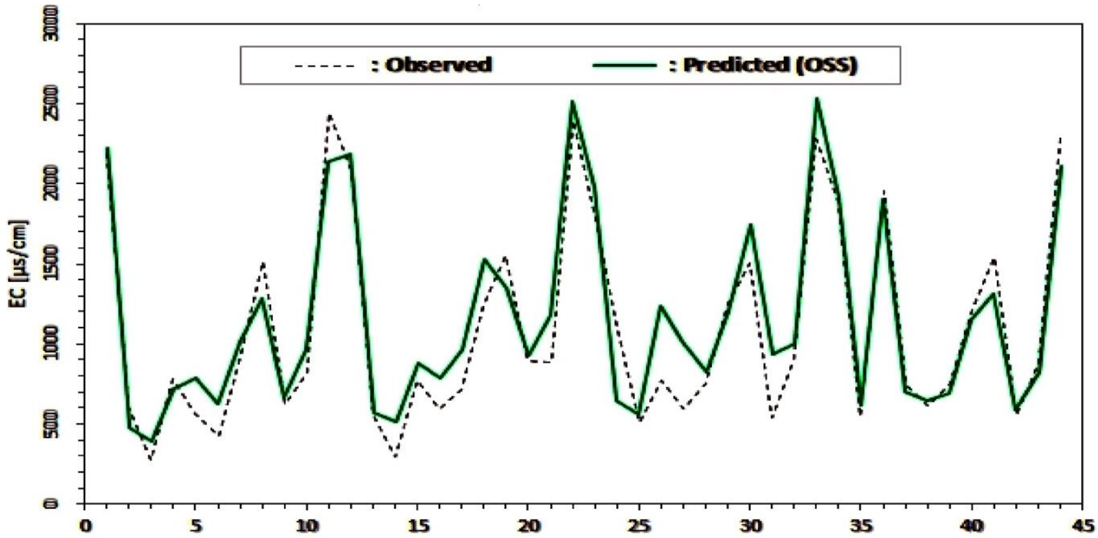

Fig. 2C.

Fig. 2. Observed and predicted salinity "EC" according to BFGS (2A), SCG (2B) and OSS (2C) algorithms using ANN05 in the validation phase.

The (figure 3) presents the calibration of the values of observed salinity simulated by the BFGS, SCG and OSS algorithms and those of the predicted salinity by ANNO6 for each water point in the validation phase. The error graph indicates the observations of the observed salinity values with the predicted salinity values in the trainig phase (figure 4). Note that R^2 is a measure of the rate of explanation of phenomenal reality by the model adopted. The predicted salinity versus the observed salinity with the best improvement of the region's water is well presented in ANNO6. Note that R^2 is around 0.9 for calibration and validation, which proves that the model retains the statistical characteristics linked to the values observed with almost unchanged coefficients of variation.

By comparing between the model's values by ANN with experimental data (Table 3) reveals that the MLP model (BFGS) (provides values: R^2=0.99, RMSE= 114.98 for the training phase and R^2=0.95, RMSE=138.41 for the validation phase) is the best model.

In this study we use the artificial neural network to estimate groundwater salinity based on other quality analisis parameters.

4. Conclusion

Lake Fetzara is the main source of irrigation for the surrounding town. [13] The deterioration of the supply and the quality of its waters can cause irreparable damages to the environment. Monitoring to predict future conditions needs precise models. These tasks are the foundation for planning to conserve and manage critical resources.

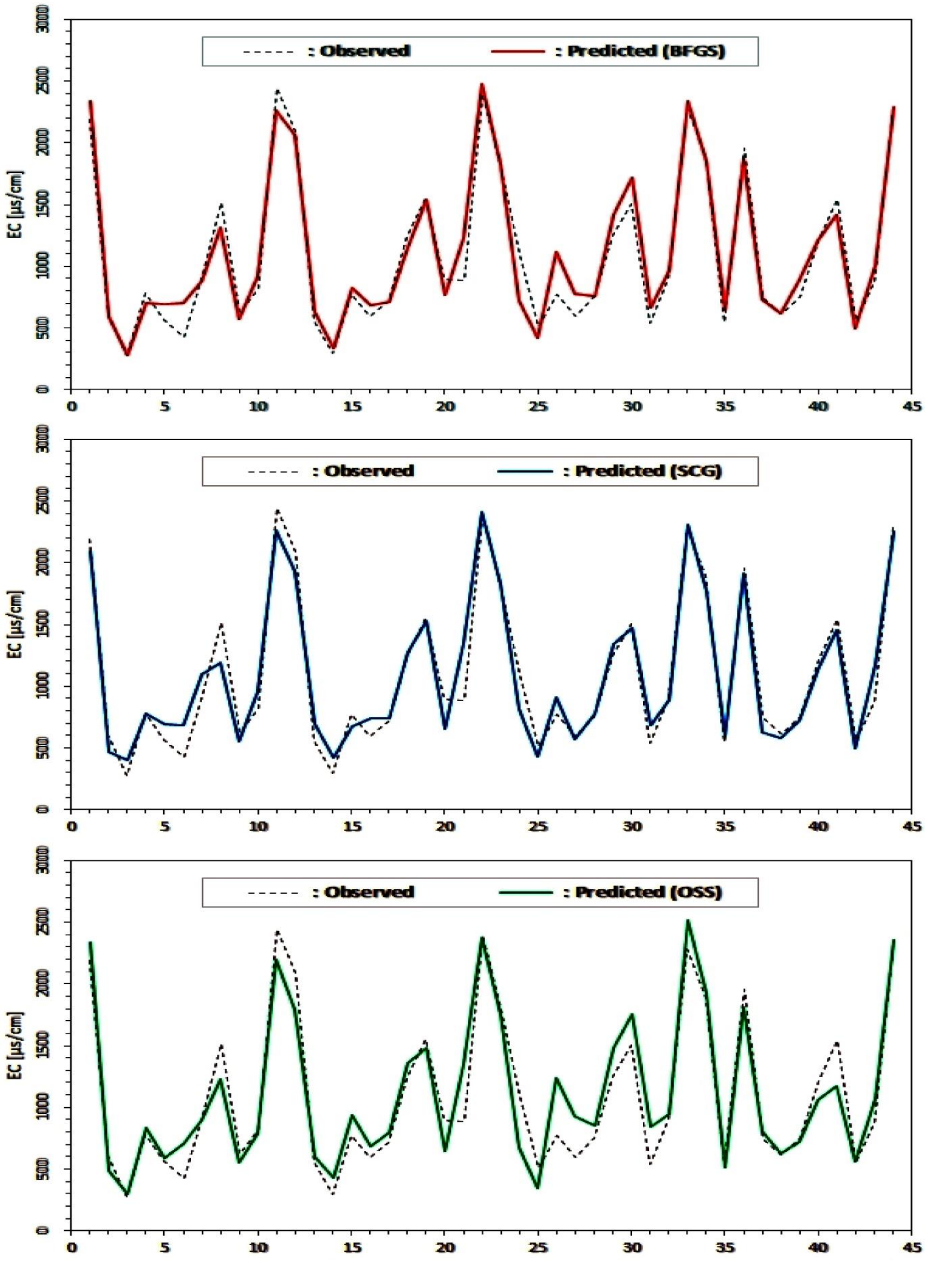

Fig. 3. Observed and predicted salinity "EC" according to BFGS, SCG and OSS algorithms using ANN06 in the validation phase.

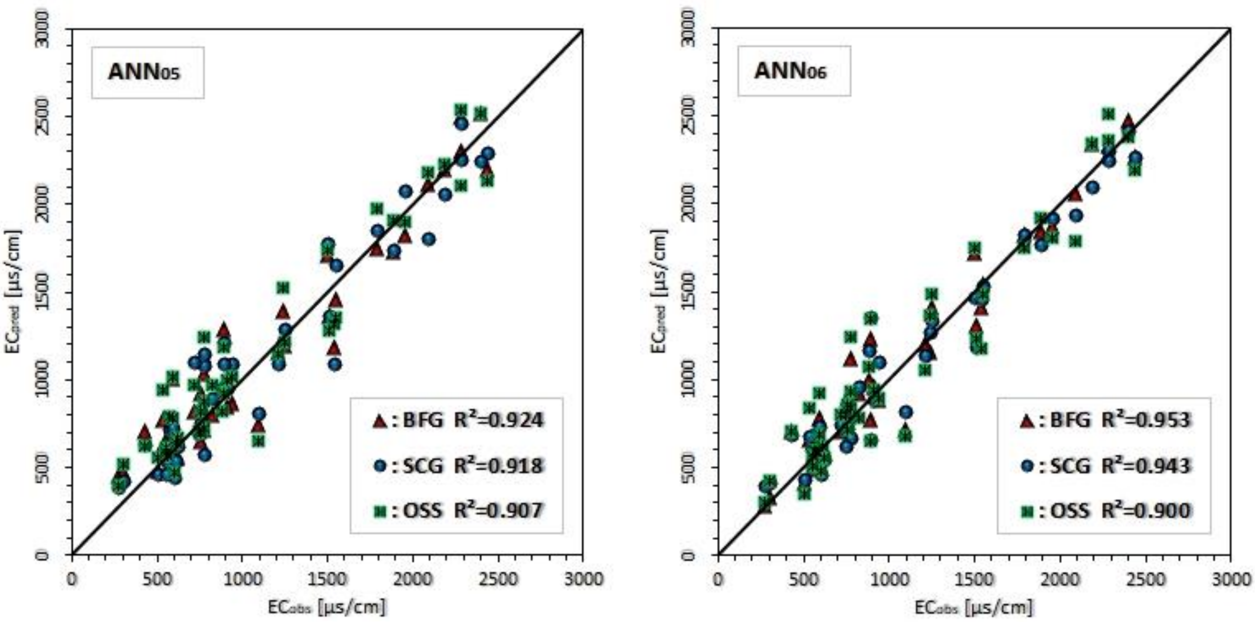

Fig. 4. Observed versus predicted salinity by BFGS, SCG and OSS algorithms using ANN05 and ANN06 models for training phase.

This study consists of the use of three autonomous hybrid algorithms to determine and predict the salinity of the lake and the water of the underlying aquifer.
We used the method of artificial neural network: multilayer perceptron (MLP) with three algorithms (BFGS, SCG and OSS). The collected weekly flow measurement and physico-chemical analyzes of the water over two hydrological cycles were used to construct several sets of combinations of variables as inputs for the model construction and evaluation. Qualitative and qualitative criteria were applied to validate and compare the models. The results reveal that the most suitable model for modeling the salinity of groundwater in a future studies is the MLP (BFGS), where the RMSE=114.98 and the coefficient of determination R^2=0.99 for the training phase and RMSE=138.41, R^2=0.95 for the validation.
The analysis of the data acquired and the impact of the environmental factors show the qualitative and quantitative degradation of the inputs water of the lake. To this end, it is recommended to carry out geophysical studies to determine the extension of the underlying aquifer and to carry out regular measurement campaigns in order to encourage organic farming in vulnerable sectors.

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