MODELING THE CLIMATE IN THE AREA OF TECHIRGHIOL LAKE (ROMANIA)

ALINA BARBULESCU[1], CARMEN MAFTEI[2]

[1]Doctoral School of Technical University of Civil Engineering, 122–124 Lacul Tei Blvd. Bucharest, Romania,
E-mail: alinadumitriu@yahoo.com, alinaemmabarbulescu@gmail.com
[2]Ovidius University of Constanta, Romania, 124, Mamaia Blvd., Constanta, Romania,
E-mail: cemaftei@gmail.com

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The water quality of Techirghiol Lake is of great importance for preserving its therapeutic properties. It is known that the water temperature is one of the factors that influence the production of sapropelic mud. Therefore, in this article we built a model that emphasizes the high dependence of the water temperature on the air temperature and we propose models that describe the evolution of daily and monthly air temperature in the study area using artificial neural networks. All the results prove a climatic stability, important for preserving the curative quality of the water of Techirghiol Lake.

Key words: Techirghiol Lake, air temperature, water temperature, model.

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1. INTRODUCTION

Paralittoral Techirghiol Lake constitutes an ecosystem with a special structure and an interesting geological past [1]. This Lake is located in Dobrudja, a zone of Romania, with a mean altitude of about 200–300 m, situated between the lower Danube River and the Black Sea, in a temperate continental climatic area, influenced by the sea (Fig. 1a). The average annual temperatures range from 11 °C inland and along the Danube to 11.8 °C on the coast and less than 10 °C in the higher parts of the region.

Techirghiol Lake is situated at a distance of 15 km, in the southern part of Constanta City and is a fluvial-marine bank with an area of 10.68 km², separated from the sea by a sand-belt with a maximum depth of 9 m. It has a hypersaline system, the salinity varying the last 12 years between 55 g/l and 66 g/l. The presence of sapropelic mud (with therapeutic qualities for rheumatism) as a result of bacterial decomposition of aquatic organisms (Artemia salina filopod and the Cladophora eurihaline algae) attributes it a high curative importance. Techirghiol Lake is supplied with groundwater and surface water from three rivers (Movilita, Biruinta and Techirghiol) and the fresh water springs located at the Lake limit.

In the hydrological year 1961–1962, the water inflow to the lake was approximately of 0.4 million m^3, and in 1972–1973 it reached 6 million m^3, a big contribution being that of the irrigation system. For this reason a hydrotechnical system has been built to separate the saline water of the lake and the freshwater. The Techirghiol Lake water zonation can be seen in Fig. 1(b).

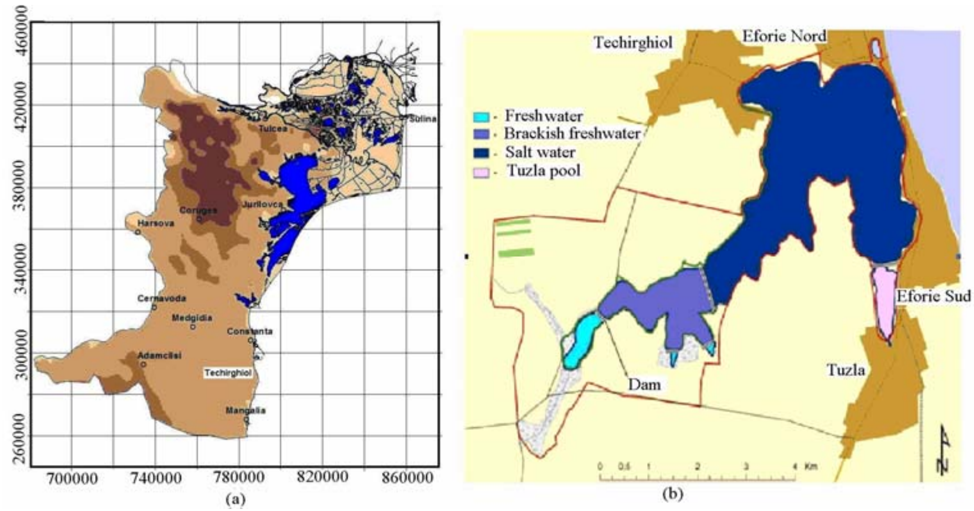

Fig. 1 – (a) The map of Dobrudja; (b) Zonation of water area in Techirghiol Lake.

Monitoring the environmental quality in this zone started in 2000, when Techirghiol Lake was declared protected area. Also, a Life Project on Improvement of wintering of the red-necked goose has been developed from 2004, carrying out the monitoring of physico-chemical parameters of this lake. After 2007 Techirghiol Lake has been included in Natura 2000 network based on the EU Birds Directive.

Results of studies concerning the genesis of the South Dobrogea lakes are presented in [2–4]. Contributions regarding the ecological and hydro-chemical features of the lakes have been brought in [5–9]. Even if the morphometrical and hydrological features of the lakes have been determined and analyzed in [10–14], only few recent studies concerning the air temperature evolution in Dobrudja region are registered [15, 16].

The analysis of annual precipitation recorded at the Techirghiol meteorological station in the period 1965–2005 reveals a variation of annual precipitation from a minimum of 244.7 mm (1997) to a maximum of 806.5 mm (in 2005). Between 1976 and 1994 the precipitation values were under the average of multi-annual precipitation – 424.1 mm (Fig. 2a). The mean annual temperature varied between 10.3 ^{o}C and 13.1 ^{o}C (in 1999), the multi-annual average temperature being of 11.7 ^{o}C (Fig. 2b).

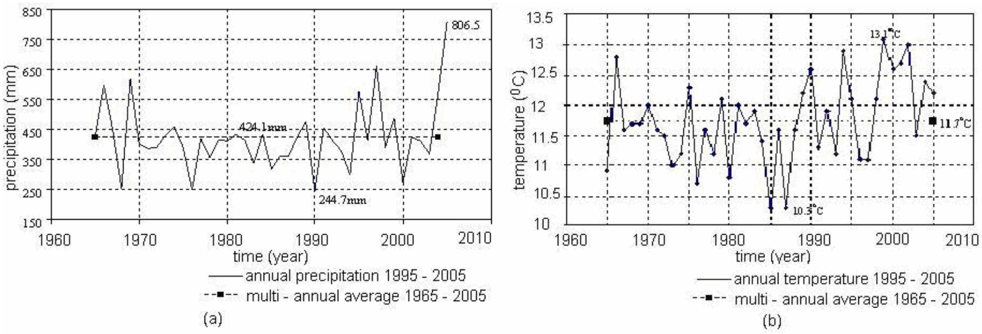

Fig. 2 – Mean annual (a) precipitation; (b) temperature at Techirghiol in the period 1965–2005.

Since the air temperature influences the evaporation and the lake' salinity, we present in this article some models for the daily and monthly air temperature and a model for the dependence of the water temperature on the air one.

We mention that our study comes to fill a gap in the knowledge about the climate of this protected area. All the results prove the existence of a relatively stable trend of temperature and precipitation, which contribute to maintain a stable climatic environment for the protected species and also for preserving the therapeutic quality of the lake's water.

2. EXPERIMENTAL

For modelling purposes we used General Regression Neural Networks – GRNN [17], since it gave good results on series with high variability [18, 19], that do no satisfy some restrictive hypotheses (as, for example, a certain type of distributions). Such an artificial neural network is formed of four layers: the input layer, the hidden layer, the summation layer and the decision one.

The Input layer contains a neuron for each explicative variable. In our problem we work with two types of explicative variables, function of the problem of hand. In the problem of modeling the temperature evolution in time, (X_t), the explicative variable is the lag one temperature (X_{t-1}), for daily data, or the lag 12 temperature (X_{t-12}), for monthly data. In the problem of modeling the water temperature function of the air temperature, the explicative variable is the air temperature and the explained one is the water temperature.

The hidden layer stores the values of the predictor variables and the target ones.

The summation layer is formed by the denominator summation unit and the numerator summation unit. The former adds up the weight values that enter this layer from the previous one; the last adds up the results of the multiplication of the weight values with the actual target values of the neurons from the previous layer.

The decision layer contains the output of the network, obtained by dividing the values from the denominator and the numerator neurons from the previous layer.

In our applications, the exponential was used as activation function, the Gaussian as kernel function and the method of the conjugate gradient, for optimization of the parameters estimates.

The data series were collected at Techirghiol and consist of daily and monthly average air temperature – from 1st of January 1961 to 31th of December 2009, daily water and air average temperature – from 1st of January to 31th of December 2010.

The series were divided in two parts – one for training (test) and one for validation, in a ratio on 90:10% as suggested in [20].

The models' quality was estimated using the mean absolute error (MAE), the root mean squared error (RMSE), and the correlation between the actual and predicted values in the model.

3. RESULTS AND DISCUSSION

The first model, called in the following Model 1, describes the dependence of the daily average water temperature on the air daily average air temperature for the period 1st of January 2010 – 31th of December 2010. Here, the explained variable is the mean water temperature and the explicative one – the mean daily water temperature. The values of the indicators of the quality of Model 1 for the training and validation sets are presented in Table 1. The correlation between the actual and predicted values is very close to 1, proving the good performance of the model. Also, RMSE and MAE have small values, which confirm the model quality.

Figure 3 contains the charts of the predicted values (calculated by the model) and the actual ones (those measured). We remark their distribution close to the first bisectrix of the axes of coordinates, proving the strong correlation between these two groups of values.

Table 1

Indicators of the quality of Model 1

	Training	**Validation**
Correlation between actual and predicted values (%)	96.29	96.05
Root mean squared error (RMSE)	2.59	2.67
Mean absolute error (MAE)	2.01	2.08

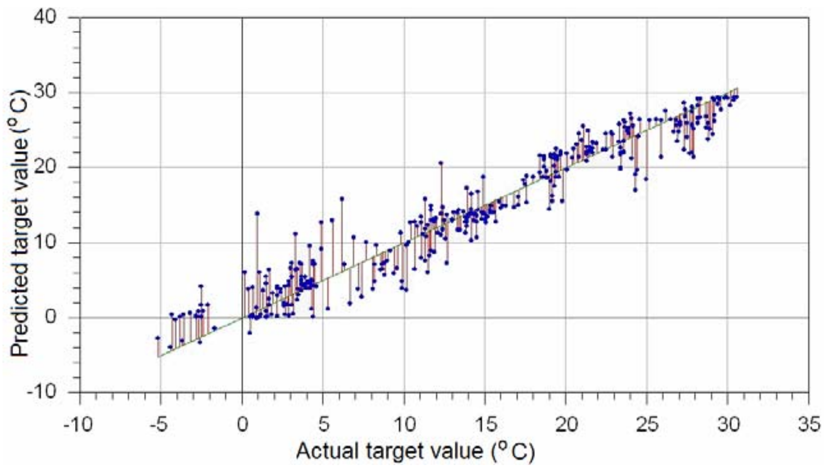

Fig. 3 – Predicted target values *vs*. actual target values in Model 1.

The second model, called Model 2, describes the evolution of the daily average air temperature registered in the period 1st of January 1961 – 31th of December 2009 at Techirghiol.

Let us denote by (X_t) the series of daily mean temperature, $t=\overline{1,17898}$ the time, 17898 being the number of days in the study period. For modeling purposes, the daily series was firstly detrended; then, GRNN was used for building the model for the detrended data. The trend equation is:

$$X_t = 11.52334 + 0.00553 * e^{0.00033*t}, \ t=\overline{1,17898}.$$

The indicators of the quality of Model 2 are presented in Table 2.

Table 2

Indicators of the quality of Model 2

	Training	Validation
Correlation between actual and predicted values (%)	96.74	61.20
Root mean squared error (RMSE)	2.16	9.86
Mean absolute error (MAE)	1.58	0.02

Analyzing the correlation between the actual and predicted values, we remark that the network learns very well the data, but it is less competent for predicting it, fact confirmed by the values of RMSE, that are 4.5 times bigger on the validation set, even if the mean absolute error is smaller on the last set.

Since the number of data is very high, we can say that the model performs well.

The third model, called Model 3, describes the evolution of the monthly average air temperature in the period January 1961 – December 2009. In this case, the series was also detrended, by subtracting the trend given by the equation:

$$X_t = 11.47704 + 0.00530 * e^{0.01022*t}, \; t = \overline{1,\ 588}.$$

Then, GRNN was used for modeling the resulted series. The indicators of the model quality are presented in Table 3. They prove that the model performs better on the validation set, meaning that the network learned well the data and uses it for forecasting. The chart of Model 3 is presented in Fig. 4.

Table 3

Indicators of the quality of Model 3

	Training	**Validation**
Correlation between actual and predicted values (%)	96.72	98.66
Root mean squared error (RMSE)	2.02	1.26
Mean absolute error (MAE)	1.44	0.95

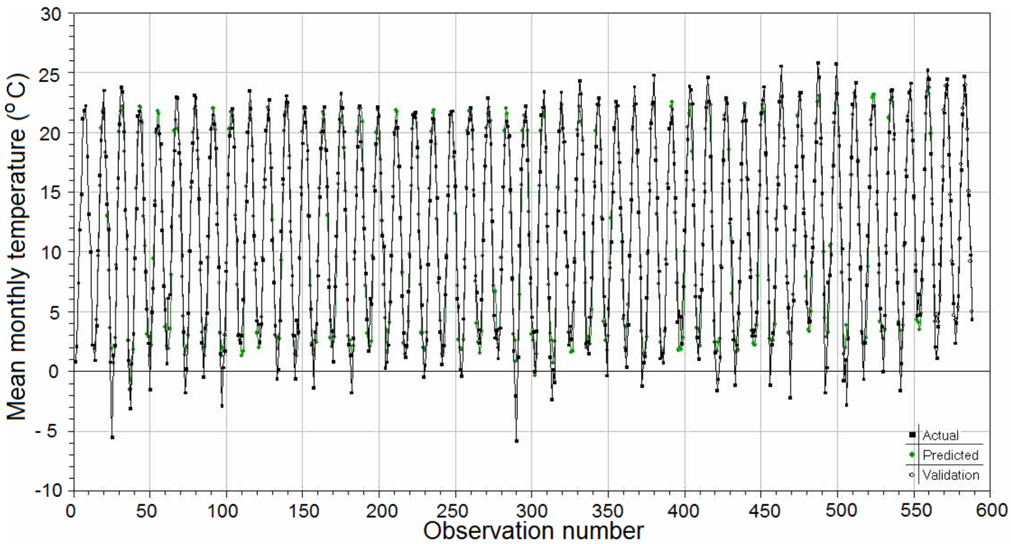

Fig. 4 – Actual and predicted values in Model 3.

4. CONCLUSION

In this article we presented models for the mean air and water temperature and for the dependence between them, in the area of Techirghiol Lake.

Model 1 is better than those obtained, for example, by Gene Expression Programming, for which the indicators' values are, for the training dataset:

correlation between actual and predicted values – 95.07 %, RMSE – 2.97, MAE – 2.28. Also, it is better that the linear one, for which the correlation coefficient is 95.01%, having also the advantage that no restriction is imposed on the data.

The trends in Models 2 and 3 emphasize a relatively constant average air temperature for the period 1965–2009. These remarks, together with the analysis of Techirghiol Lake's water quality [5] lead to the conclusion that there are the climatic conditions for preserving the therapeutic properties of this lake.

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