Modelling of Minimum Water Levels of Lake İznik by Using Time Series Models

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ABSTRACT

Minimum lake-level has important impacts on lake ecology (such as submerged plant growth, in-lake nutrients concentrations, physicochemical properties of lakes, lake biodiversity and lake primary production). However, prediction of lake water levels is important in watershed management for planning, design, construction, and operation of lakeshore structures and also in the management of freshwater lakes for water supply purposes. In the present paper, autoregressive moving average (ARMA) techniques were applied to test the power of predictability of models for minimum lake-level variations in Lake İznik. The measurements at the Lake İznik in Bursa, for the period of 1955-2002 were used for training, testing, and validating the employed models (AR, MA and ARMA). The results obtained by the ARMA (2, 2) model indicated that it performs better than other models in predicting minimum lake-levels. Our results also showed the possibility of predicting minimum lake water levels by using its own minimum lake levels data without the need of using any other data.

Key Words: Time series, Lake, Modelling, İznik

INTRODUCTION

Water level fluctuations (WLFs) are complex outcomes of whether natural environmental factors such as variations in net precipitation, surface runoffs, evaporation, air and water temperature and interactions between the lake and the low lying aquifers (Kisi et al. 2012) or the result of human activities such as excessive water consumption for agriculture and drinking water (Pimentel et al. 2004, Coops and Havens, 2005). WLFs problem has been the subject of many researches due to large economic losses, environmental problems and profound impact on management, ecology and functioning of lakes (Coops et al. 2003, Leira and Cantonati, 2008). Too low water level in winter and in summer may damage the expansion of plants in the littoral zone through ice and wave action in winter and desiccation in summer (Blindow 1992, Blindow et al. 1997, Beklioglu et al. 2001, Beklioglu et al. 2006). Decrease in summer water level results in lack of thermal stratification. This, in turn, enhances phytoplankton growth by continuous supply of nutrients through increased internal loading both in deep and shallow lakes (Naselli-Flores 2003, Ozen et al. 2010).

To predict the lake water level at various time intervals using the records of past time series became an important issue in water resources planning due to importance of WLFs in lakes. Several methods have been developed for forecasting lake water level and one of the most famous techniques is the Autoregressive

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Moving Average (ARMA) models (Maier and Dandy 1997). Time series models continued to improve itself with new updates during the past years and maintained its continuity. In 1990’s, Hydrological models and time series analysis were used to estimate the stream flow data in Turkey (Oğuz et al. 2010, Topçuoğlu 2010, Baran and Bacanlı, 2006, Çevik and Yürekli 2002, Yürekli and Öztürk 2003) and were used to estimate lake depth lately (Aksoy et al. 2013).

The objective of this paper is to find a time series model which is appropriate for Lake İznik by using its long term water level data set without use of any other data set. The ARMA time series model is considered for modelling and forecasting the minimum lake water level in the future.

MATERIALS AND METHODS

Study Area
Lake İznik (40°23’ and 40°30’ N latitudes, E 29°20’and 29°42’ E longitudes) is situated in Province of Bursa. The lake which located at 85 m.a.s.l. has a length of 32 km (West-east) and maximum width of 12 km (North-south), and covers an area of approx. 313 km². It has a water volume of 12.2 billion cubic meters. The location of Lake İznik was shown in Figure 1.

Figure 1. Location map of Lake İznik.
Used Data
In this paper daily lake-level records of Lake Iznik in the Bursa Province in Turkey were used. Records were obtained from the General Directorate of Electrical Power, Resource Survey and Development Administration (EIE). Data sample consisted of 47 years of daily lake minimum level data. Monthly minimum lake levels were calculated from these daily data set. For each model, the first 46 years of data were used for training, the last year data was used for validating the optimal models.

Analysis
All analysis were done by using Eviews software. All collected data were evaluated by ARMA model structure. ARMA (p, q) models are linear stochastic models and they are dependent on a stochastic components of a time series. ARMA (p, q) models are linear models that are used in the simulation of hydrological processes. These models are combination of autoregressive (AR) model and moving average (MA) models. ARMA (p, q) models are used in the case of the stationary series. ARMA (p, q) models are used only when the series are stationary. An ARMA (p, q) model is given in general form by the following equation (Box and Jenkins 1976).

ARMA models can be expressed as:

\[ Z_i = \Phi_1 Z_{i-1} + \ldots + \Phi_p Z_{i-p} + \epsilon_i - \Theta_1 \epsilon_{i-1} - \ldots - \Theta_q \epsilon_{i-q} \]

\[ \Phi(B) Y_t = \Theta(B) \epsilon_t \]

where \( \Phi(B) = 1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_p B^p \) is the autoregressive operator, \( p \) is the number of autoregressive terms, \( \Theta(B) = 1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q \) is the moving average operator, \( q \) is the number of moving average terms, \( \epsilon_t \) is the random component (residuals) of the model, and \( B \) is the backward operator (defined as \( B^m Y_t = Y_{t-m} \)). ARMA models have been successfully applied to various types of series (Granger and Newbold 1976, Mujumdar and Kumar 1990). Commonly used transformations, which are needed to fulfill the normality requirement, are logarithmic and square roots (McLeod et al. 1977).

RESULTS AND DISCUSSION
In this study, ARMA models were run in 3 steps by using the minimum monthly water level data for Lake Iznik. The data set were tested for stability and trend in the first step. In the second step, data were examined for the effect of seasonality. In the third and last step, AR, MA and ARMA models were tested and appropriate model were selected by using adjusted data set free from trend and seasonality.

Minimum monthly water level values of Lake Iznik (1955-2002) (Figure 2) was found to have a normal distribution according to the Kolmogorov-Smirnov test.
Trend was tested to determine the stability of the minimum lake water level data and significant negative trend was determined (p <0.01). In the next step, data was examined with a correlogram diagram and we observed positive AFC values and fluctuations in AFC values by the time (Figure 3). It was also determined that data was under the influence of autocorrelation and conjunctural effects according to probability values (Figure 3).
Effect of seasonality in the data set were examined with the TRAMO / SEATS test and seasonality effect was detected and then data were adjusted for seasonality (Figure 4).

There are some criterias to select the appropriate model (Sevüktekin and Nargeleçekenler 2010). These are:

- Predicted parameters should be significant.
- Model should have a high coefficient of determination.
- Model’s F statistics should be significant.
- Model’s information criteria of Akaike (AIC) ve Schwarz (SIC) should be small
- Sum of error squares (SSR) should be small.
- Likelihood ratio (LR) should be high as possible.
- Q statistics, should be meaningless and insignificant

Model estimation results were given in Table 1 according to criterias mentioned above.

AR (1), AR(2), MA(1), MA(2), ARMA (1,1), ARMA (1,2), ARMA (2,1) and ARMA (2,2) models were used with new seasonally adjusted data set. ARMA (2,2) model was selected since it had the smallest AIC (-1.22650) and SIC (-1.18858) values (Table 1).
Table 1. Testing statistics (AIC and SIC) of ARMA models.

<table>
<thead>
<tr>
<th>Model Types</th>
<th>Akaike info criterion</th>
<th>Schwartz criterion</th>
<th>Log likelihood</th>
<th>Adjusted $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR(1)</td>
<td>-1.177124</td>
<td>-1.161979</td>
<td>340,4232</td>
<td>0.845848</td>
</tr>
<tr>
<td>AR(2)</td>
<td>-1.172779</td>
<td>-1.150031</td>
<td>339,5877</td>
<td>0.845608</td>
</tr>
<tr>
<td>MA(1)</td>
<td>-0.12883</td>
<td>-0.11370</td>
<td>39,10154</td>
<td>0.55998</td>
</tr>
<tr>
<td>MA(2)</td>
<td>-0.79494</td>
<td>-0.77225</td>
<td>231,94290</td>
<td>0.77435</td>
</tr>
<tr>
<td>ARMA(1,1)</td>
<td>-1.17433</td>
<td>-1.15161</td>
<td>340,61930</td>
<td>0.84568</td>
</tr>
<tr>
<td>ARMA(1,2)</td>
<td>-1.17701</td>
<td>-1.14672</td>
<td>342,38920</td>
<td>0.84636</td>
</tr>
<tr>
<td>ARMA(2,1)</td>
<td>-1.16931</td>
<td>-1.13898</td>
<td>339,59180</td>
<td>0.84534</td>
</tr>
<tr>
<td>ARMA(2,2)</td>
<td>-1.22650</td>
<td>-1.18858</td>
<td>357,00510</td>
<td>0.85419</td>
</tr>
</tbody>
</table>

Figure 4. Monthly Minimum Water levels variance in Lake İznil between the years of 1955 and 2002.
**Calibration and Validation of the ARMA (2,2) Model**

Root Mean Square Error (RMS) index was used to evaluate the model’s power of prediction and it was found 0.052 (Figure 5). This was a good score because RMS index values which are closer to zero values indicates higher prediction power estimation of the model (Oguz et al. 2010). So we decided that this model (ARMA 2,2) could do best predictions for minimum lake water level than others since its values were more close to the zero. The impact of season on predictions were appeared when the predicted and observed values compared with each other after the calibration (Figure 6).

Predicted values were higher than observed values in autumn. Thus, the model might be perceived an increase in the lake water as a tank at the end of the year when used the seasonally adjusted data set.

![Figure 5](image1.png)

**Figure 5.** Estimated values of model for the minimum Lake İznil’s water level in 2002.

![Figure 6](image2.png)

**Figure 6.** Observed and Predicted values of the minimum lake water level in 2002.
CONCLUSIONS

Natural (climatic, morphological or watershed originated) or anthropogenic (excessive water use for agriculture and drinking water) factors could cause decrease in the lake water level. The Lake İznilk data showed both autoregressive and autoregressive moving average properties. Our study revealed the possibility of predicting minimum lake water levels by using its own minimum long term lake levels data without the need of using any other data (autoregressive) in the case of change in the conditions of the natural (drought, excess rainfall, etc.) and anthropogenic (excessive water use for agriculture and drinking water, the deforestation) impacts (autoregressive moving average). However, Our results showed the possibility of modelling the minimum lake water level with the ARMA (2,2) from its own past long term lake water level data without using any other parameter data with a high correlation (Adj R2: 0.85).

REFERENCES