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Original Research Article

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 Iznik 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

İznik Gölü Minimum Su Seviyelerinin Zaman Serisi Yöntemleri İle Modellenmesi

ÖZET

Minimum göl su seviyesi göllerin ekolojisinde (su içi bitki gelişimi, göl içi besin tuzu konsantrasyonları, göllerin fizikokimyasal özellikleri, göllerin biyoçeşitliliği ve birincil üretimleri vb.) önemli etkilere sahiptir. Bunun yanında göl kıyısındaki yapıların dizaynı, yapımı ve işletilmesi için havza yönetimi açısından ve içme suyu amaçlı tatlı suların kullanımının yönetimi açısından da önemlidir. Bu makalede otoregresif hareketli ortalama (ARMA) teknikleri, modellerin öngörülebilirlik gücünü test etmek için kullanılmıştır. 1955-2002 yılları arasındaki ölçüm verileri kullanılarak farklı modeller (AR,MA and ARMA) test edilip değerlendirilmiştir. Elde edilen sonuçlar ARMA (2,2) modelinin diğer modellere göre daha iyi performans ortaya koyduğunu göstermiştir. Ayrıca sonuçlarımız başka herhangi bir veri setine ihtiyaç duymadan sadece kendi minimum su seviyesi veri seti ile minimum su seviyesinin tahmin edilebileceğini göstermiştir.

Anahtar Kelimeler: Zaman serisi, Göl, Modelleme, 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 Iznik (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 km^2. It has a water volume of 12.2 billion cubic meters. The location of Lake İznik was shown in Figure 1.

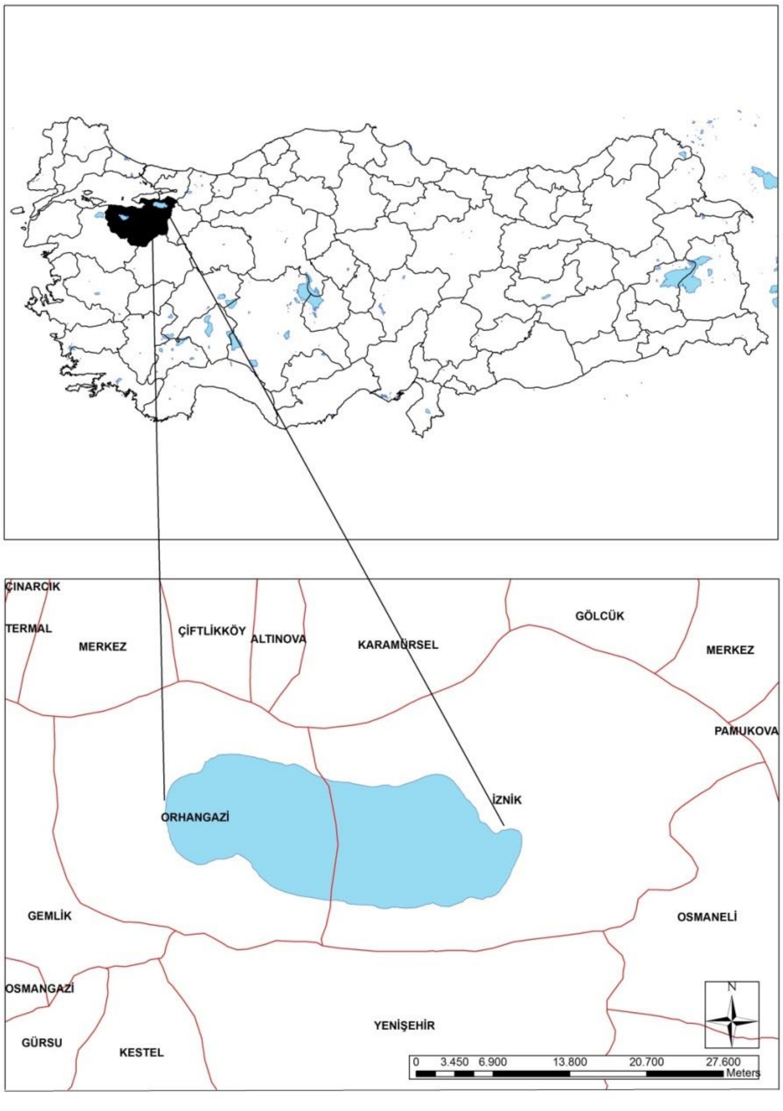


Figure 1. Location map of Lake İznik.

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 analyssis were done by using Eviews software. All collected data were evaluated by ARMA model structure. ARMA 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 l976).
ARMA models can be expressed as:

$$\mathbf{Zi = \Phi_1 Z_{i-1} + \ldots\ldots + \Phi_p Z_{i-p} + \varepsilon_i - \Theta_1 \varepsilon_{i-1} + \ldots\ldots + \Theta_q \varepsilon_{i-q}}$$
$$\mathbf{\Phi(B)\ Y_t = \Theta_1(B)\varepsilon_t}$$

where $\Theta(B) = 1 - \Theta_1 B - \Theta_2 B^2 - \ldots - \Theta_p B^p$ is the autoregressive operator, p is the number of autoregressive terms, q(B) = 1 - q1B - q2B2 -…- qqBq is the moving average operator, q is the number of moving average terms, et 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.

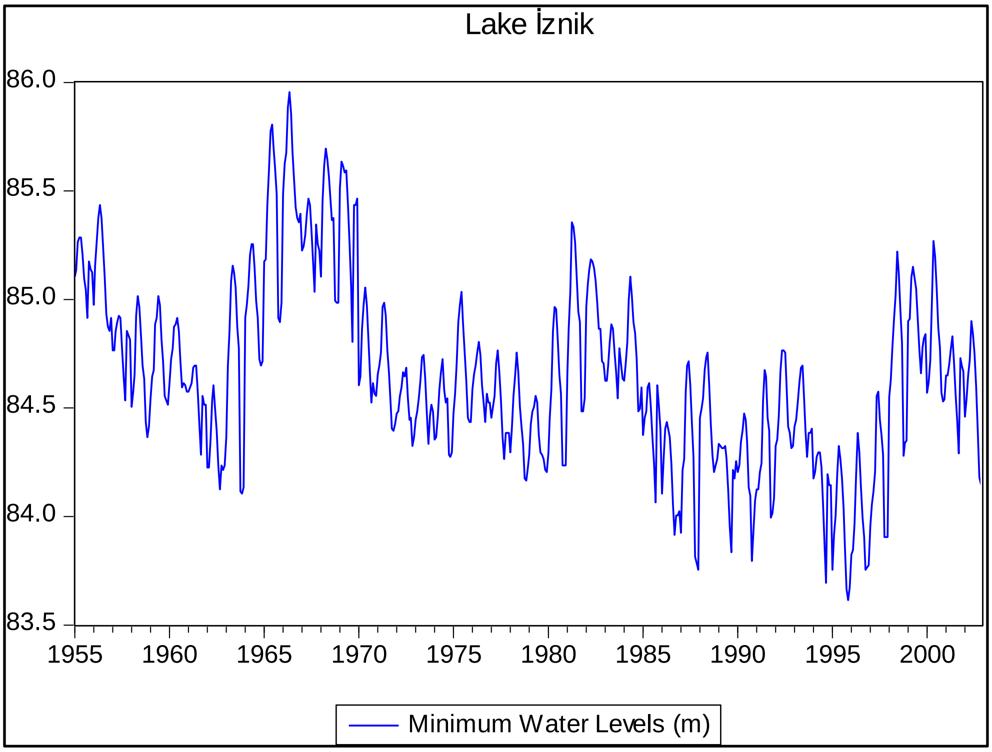
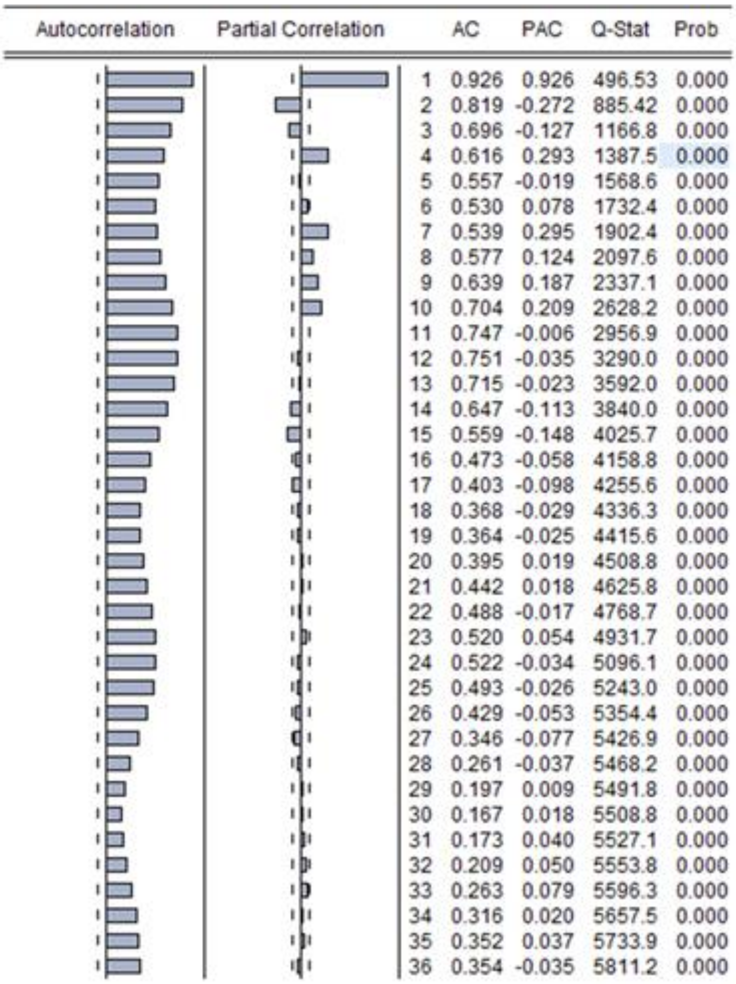


Figure 2. Minimum Water Levels of Lake İznik between the years of 1955 and 2002.

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).



	AC	PAC	Q-Stat	Prob
1	0.926	0.926	496.53	0.000
2	0.819	-0.272	885.42	0.000
3	0.696	-0.127	1166.8	0.000
4	0.616	0.293	1387.5	0.000
5	0.557	-0.019	1568.6	0.000
6	0.530	0.078	1732.4	0.000
7	0.539	0.295	1902.4	0.000
8	0.577	0.124	2097.6	0.000
9	0.639	0.187	2337.1	0.000
10	0.704	0.209	2628.2	0.000
11	0.747	-0.006	2956.9	0.000
12	0.751	-0.035	3290.0	0.000
13	0.715	-0.023	3592.0	0.000
14	0.647	-0.113	3840.0	0.000
15	0.559	-0.148	4025.7	0.000
16	0.473	-0.058	4158.8	0.000
17	0.403	-0.098	4255.6	0.000
18	0.368	-0.029	4336.3	0.000
19	0.364	-0.025	4415.6	0.000
20	0.395	0.019	4508.8	0.000
21	0.442	0.018	4625.8	0.000
22	0.488	-0.017	4768.7	0.000
23	0.520	0.054	4931.7	0.000
24	0.522	-0.034	5096.1	0.000
25	0.493	-0.026	5243.0	0.000
26	0.429	-0.053	5354.4	0.000
27	0.346	-0.077	5426.9	0.000
28	0.261	-0.037	5468.2	0.000
29	0.197	0.009	5491.8	0.000
30	0.167	0.018	5508.8	0.000
31	0.173	0.040	5527.1	0.000
32	0.209	0.050	5553.8	0.000
33	0.263	0.079	5596.3	0.000
34	0.316	0.020	5657.5	0.000
35	0.352	0.037	5733.9	0.000
36	0.354	-0.035	5811.2	0.000

Figure 3. Correlogram of monthly minimum water levels in Lake İznik.

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.

Model Types	Akaike info criterion	Schwartz criterion	Log likelihood	Adjusted R^2
AR(1)	-1,177124	-1,161979	340,4232	0,845848
AR(2)	-1,172779	-1,150031	339,5877	0,845608
MA(1)	-0,12883	-0,11370	39,10154	0,55998
MA(2)	-0,79494	-0,77225	231,94290	0,77435
ARMA(1,1)	-1,17433	-1,15161	340,61930	0,84568
ARMA(1,2)	-1,17701	-1,14672	342,38920	0,84636
ARMA(2,1)	-1,16931	-1,13898	339,59180	0,84534
ARMA(2,2)	-1,22650	-1,18858	357,00510	0,85419

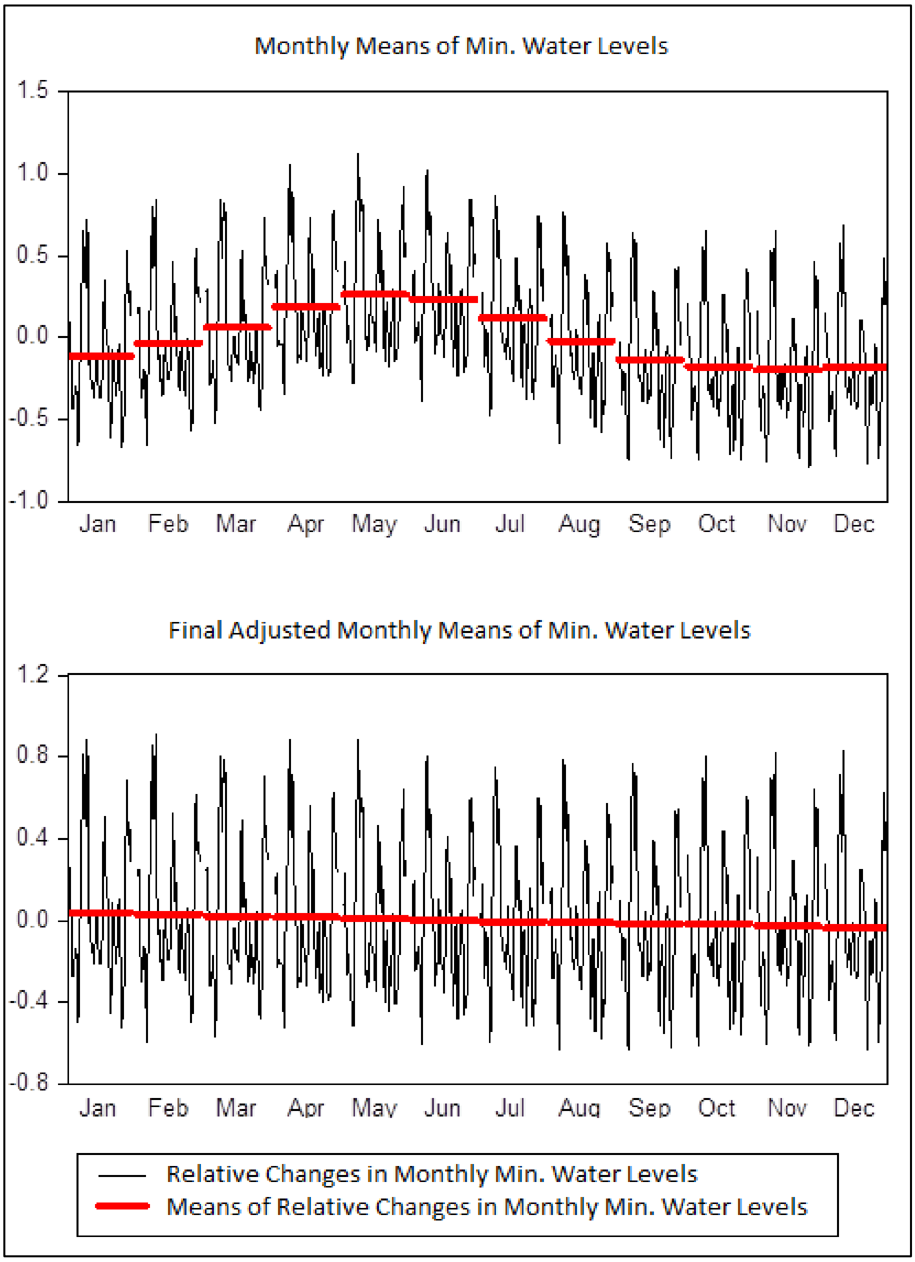


Figure 4. Monthly Minimum Water levels variance in Lake İznik between the years of 1955 and 2002.

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 it's 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.

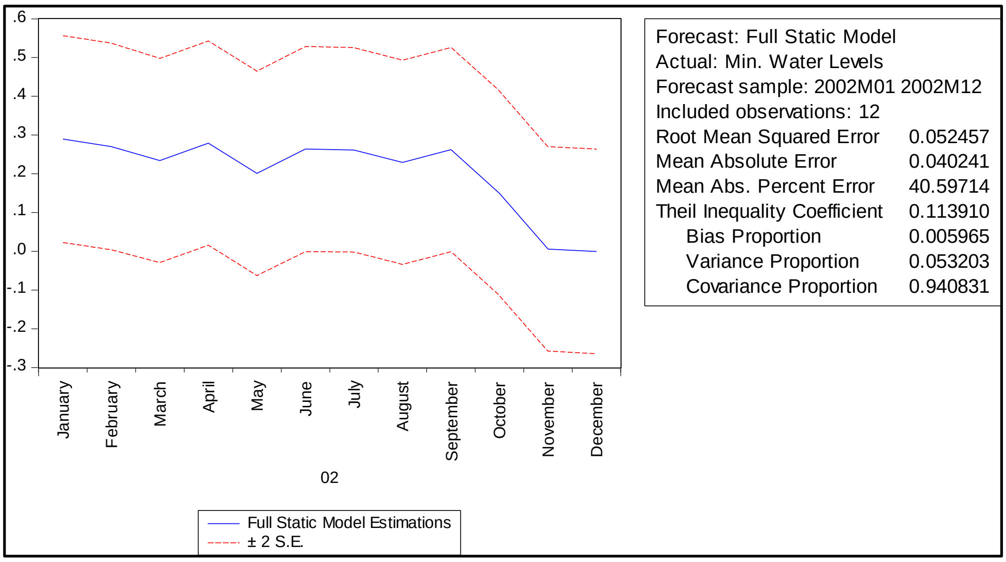


Figure 5. Estimated values of model for the minimum Lake İznik's water level in 2002.

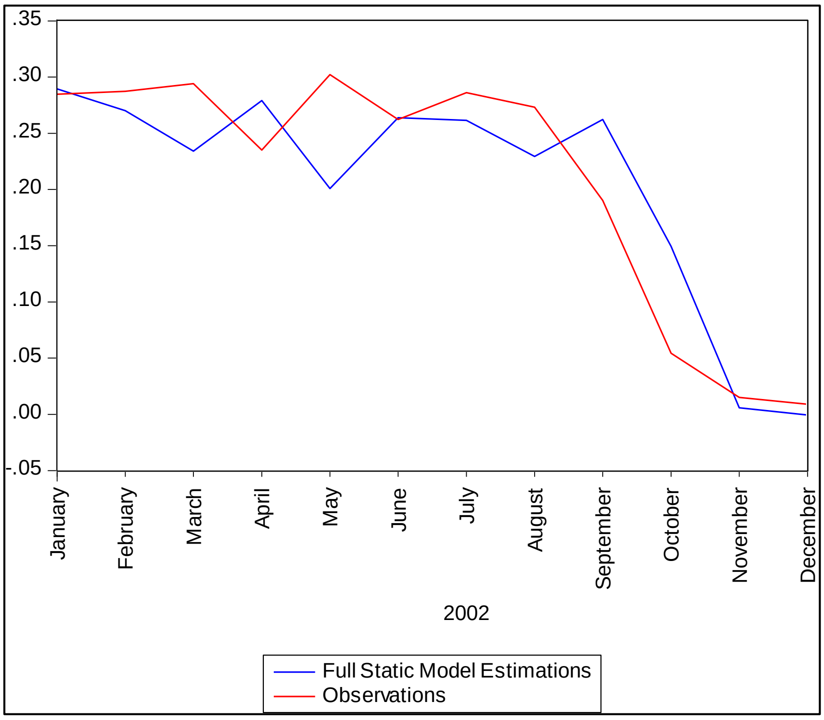


Figure 6. Observed and Predicted values of the minimum lake water level in 2002.

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 İznik 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).

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