An investigation of water potential of lakes district, Turkey

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Abstract

Recent increase in urban population, water pollution due to industrialization, and climate changes revealed the need to revisit water utilization policies, to use water resources adequately, redo critical analysis for existing prevention plans and prepare new prevention plans. In the present study, current state of the water potentials of Eğirdir, Kovada regions, located at lakes region, are investigated in terms of precipitation, temperature, evaporation, and water level change by using the monthly and annual data available. Therefore, the data is processed by using Run homogeneity test, Mann Kendall and Sen analysis. In addition, water budget analysis is carried out for Lake Eğirdir. It is found that analysis results and water budget results overlap for Lake Eğirdir. Provided that, preventive measures are not taken immediately, at the end of a 100-year period. Level of Lake Eğirdir is estimated to decrease 24-%, annually. To prevent the water level decrease in Lake Eğirdir, there are some necessary precautions should be taken-: (a) Inactive underground resources should be activated,-. (b) Irrigation lands which use water from Lake Eğirdir should not be allowed,-. (c) Future water storage within the rainfall watershed should be prevented,-. (d) The lands that have shown no signs of development and expected not to improve in the future should be detected and these lands should be removed from future irrigation plans,-. (e) Efficient methods of economical use of water resources for the currently cultivated irrigated lands should be explored and developed,-. (f) Throughout the use of intelligent farming methods economic utilization of water should be performed. Concurrently, there will be effects on Lake Kovada since Lake Kovada is controlled by Lake Eğirdir through a water channel.

Keywords: Precipitation, Temperature, Evaporation, Water Level, Eğirdir Lake, Kovada Lake,

Introduction

There are four main regions having water potential in Turkey that the lakes are concentrated: Göller Region (Eğirdir Lake, Burdur Lake, Beyşehir Lake, and Acıgöl Lake), South Marmara (Sapanca Lake, İznik Lake, Ulubat Lake, and Kuş Gölleri Lakes), Van Lake and it surroundings, and Tuz Lake and its surroundings. Göller Region lies in Isparta. Eğirdir Lake is the second largest fresh water lake in Turkey while (-Beyşehir Lake is the largest-). Eğirdir Lake is fed by precipitation over the lake. Lake basin surface flow, and subsurface flow (including the springs). Water loss is due to the southern outlet of the lake, evaporation, doline, and synthetic outflow (irrigation, energy production, and domestic water utilization) [1]. The formation of Kovada Lake is similar to the formation of the karstic lakes in western Toros mountains.

Kovada Lake is a small lake located in Isparta. Kovada Lake forms the upper part of the Antalya basin and it is a natural extension of Eğirdir Lake. The lake is a tectonic polje shaped by the addition of tectonic earth motion to the physical and chemical erosion effects of rain falling over the lake basin. Kovada Lake which is the southern extension of Eğirdir Lake is formed by the filling of the narrow valley by alluvium and took its current shape [2]. Extra water in Eğirdir Lake flows to the Kovada Lake through a channel.

Decrease in water levels of Eğirdir Lake and Kovada Lake which is connected to Eğirdir Lake through a channel is observed, on daily basis. The factors contributing to the decreases are: (i) overutilization of the water of Eğirdir Lake by too many projects, (ii) existence of unutilized subsurface water sources, (iii) permitting over storage over the rain fall basin, (iv) waste of irrigation water in majority of farms due to the use of wrong irrigation techniques, and (v) the lack of economical water utilization due to the failure in planning, and use of intelligent farming techniques and policies. Since Kovada Lake is controlled by Eğirdiri Lake through a channel, such factors are affecting Kovada Lake eventually.

In the present study, it is imperative to obtain estimates on the state of the lakes encompassing the 100_year period by employing the monthly and annual analyses of the data obtained from the observation stations on temperature, precipitation, evaporation, and water level change in parallel to global warming.

Annual and monthly data obtained from observation stations on temperature, precipitation, evaporation, and water level change of Eğirdir and Kovada lakes are used in Run homogeneity test, Mann Kendall test, and Sen Analysis to uncover the trends in temperature, precipitation, evaporation, and water level change of Eğirdir and Kovada lakes over the course of 100 _year period.

Investigation of Eğirdir and Kovada lakes

Annual and monthly data are gained from the State Meteorology General Directorate and State Water Works General Directorate of Turkey. Among the all data received with the intervals matching the same time periods are taken into account. Later, the homogeneity of the data is checked by using the Run test. If the data obtained from an observation station has a monotonically increasing or monotonically decreasing characteristic then the series can be said to have a meaningful trend. To determine the trends on annual and monthly temperature, precipitation, evaporation, and water level change, Mann Kendall order correlation coefficient method is used. In case of a linear trend in the series, the level of change is determined by using the Sen Method. Series obtained from the raw data are first visually inspected. The significance of the increase or decrease in series is determined by using Mann Kendall order correlation coefficient method in $\alpha = 0.05$ significance level. This test compares the relative magnitudes rather than the absolute magnitudes [3]. In this study, MS Excel Run Test program is used for Run test. Mann-Kendall Z values and Sen Slope Q values are obtained by using MAKESENS 1.0 software.

Data analysis

Climate data inherently includes randomness, therefore, investigation of monotonic decrease or increase derived from such data necessitates the use of special techniques [4]. Through the statistical trend tests the hypothesis on “the existence of a trend in the analyzed data” is checked and a final decision is made. The final decision depends on the selected meaningfulness level [5]. Meaningfulness level is equal to the outcome of the existence of a trend, whereas, there is no trend in the data. There are many tests that can be employed on a time series or a data set to determine the trend and express it quantitatively. Graphical method, linear regression, Mann Kendall Test, and Sen Test are the methods used in detection and analysis of trends [6]. Although each method has its cons and pros, the method that fists the best to the data at hand should be employed. Graphical representation of the data is appropriate to show the general trends, yet, it is not sufficient. It is possible to make trend estimation by using linear regression. Furthermore, it can be employed for multiple independent variables; however, it cannot be used if there are hidden variables. In addition, it is affected by the statistical distribution of the data. Mann Kendall trend analysis tolerates incomplete data and it does not necessitate any particular statistical distribution, hence, it is extremely convenient [7].

In the present research, annual and monthly analyses on temperature, precipitation, evaporation, and water level change data of Eğirdir and Kovada lakes obtained from State Meteorology General Directorate and State Water Works General Directorate. These data sets are first tested for homogeneity (-in a process of data quality control-) and later trend analysis are performed on sufficiently high quality data sets. Run test is used for homogeneity check and distribution independent non parametric Mann Kendal order correlation and Sen tests are used for trend analysis [8].

Eğirdir lake

Water level data of Eğirdir Lake for a period of 1962 to 2010, is analyzed by using Run test (annual water level data) and by Mann Kendall and Sen methods (annual and monthly data).

Run test

Annual water level data and Run test results for Eğirdir Lake are given in Table 1. Since z = -4.47439 value is out of ±2.54 band the series is not within % 90 confidence interval which is (not homogeneous). Water level trend graph of Eğirdir Lake between 1962 and 2010 are presented in Figure 1.

Table 1**.** Annual water level data and Run test results for Eğirdir Lake.

Median	r	N	NA	NB	z
917.6	8	49	25	24	-4.47439

Figure 1. Eğirdir Lake 1962-2010 years annual water level trend graphic.

Mann-Kendall method

Mann Kendall test is performed on both annual and monthly water level data from 1962-2010 period. The existence of a trend is assumed to be an indicator of a change in water level. Mann-Kendall Z values for Eğirdir Lake from 1962-2010 period annual and monthly water level data is presented in Table 2.

Table 2. Mann-Kendall Z values for Eğirdir Lake from 1962-2010 period annual and monthly water level data.

Time series	First year	Last year	n	Test S	Test Z	Meaningfulness
October	1962	2010	49		-3.08	
November	1962	2010	49		-2.90	
December	1962	2010	49		-2.84	
January	1962	2010	49		-2.77	
February	1962	2010	49		-2.76	**
March	1962	2010	49		-2.76	
April	1962	2010	49		-2.62	
May	1962	2010	49		-2.55	
June	1962	2010	49		-2.47	*
July	1962	2010	49		-2.62	**
August	1962	2010	49		-2.72	**
September	1962	2010	49		-2.88	**
Annual	1962	2010	49		-2.82	**

+ α=0,1 confidence interval, * α=0,05 confidence interval,
** α=0,01 confidence interval, *** α=0,001 confidence interval

As seen in The table 2, from the water level point of view, there is a significant decrease for α=0.01 confidence interval for February, July, August, September and annual rows. Likewise, for α=0.05 confidence interval there is a significant decrease in June. Mann Kendall test graphic for water level data obtained from Eğirdir Lake station between 1962 and 2010 is given in Figure 2

Mann Kendall test graphic for water level data obtained from Eğirdir Lake station between 1962 and 2010, only in June, is presented in Figure 3. Mann Kendall test graphics presented in Figure 3 shows that annual and February water levels exhibit a significant decreasing trend, likewise June, July, August, and September water level trends exhibit some decreasing trend.

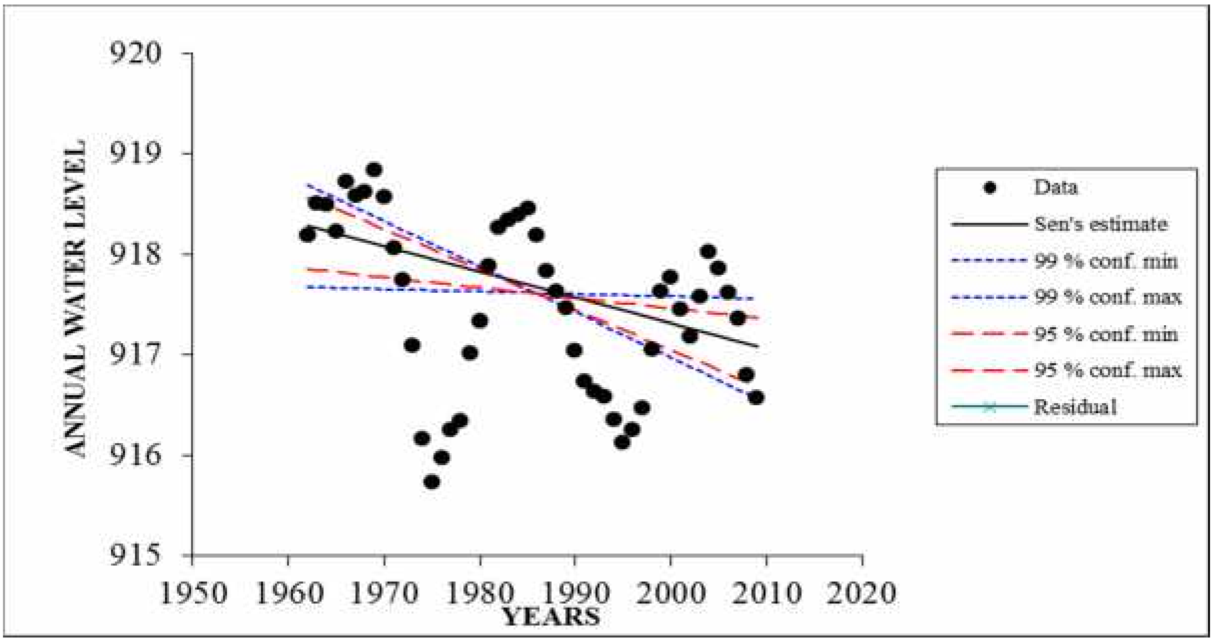

Figure 2. Mann Kendall test graphic for water level data obtained from Eğirdir Lake station between 1962 and 2010.

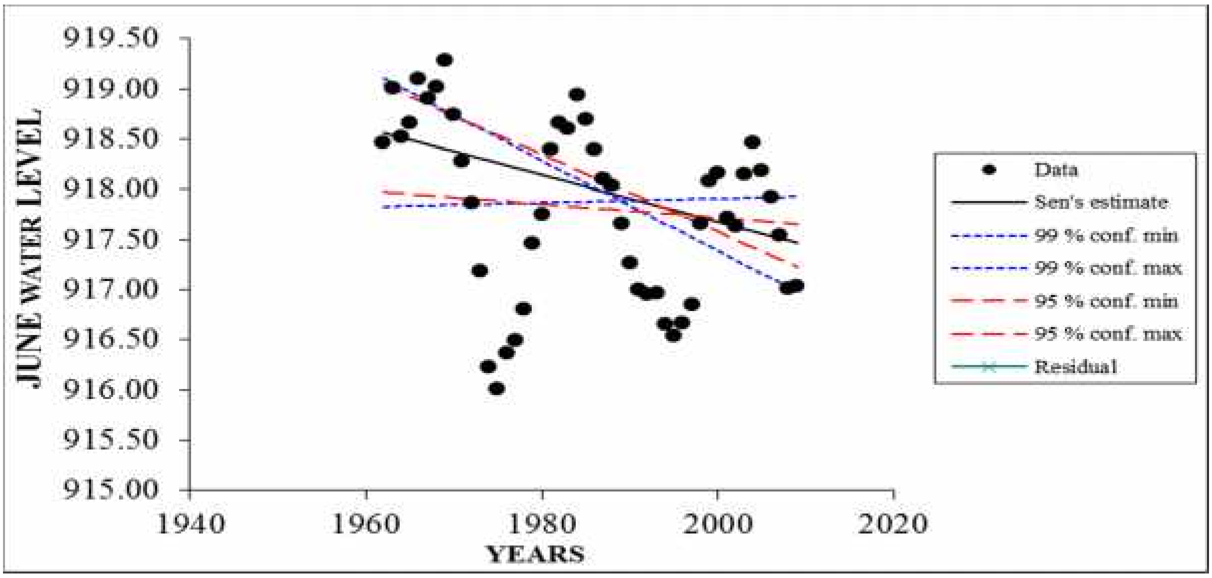

Figure 3. Mann Kendall test graphic for water level data obtained from Eğirdir Lake station between 1962 and 2010, only in June.

Sen method

Linear tendencies of the trends observed in time are calculated through the use of a non parametric method developed by Sen. To determine the slopes of the annual and monthly changes in water level data collected by Eğirdir Lake station, Sen test is performed. Sen slope and upper/lower limit values for % 95 and % 99 confidence interval of the monthly and annually water level data for 1962-2010 period obtained from Eğirdir station is presented in Table 3.

Table 3. Sen slope and upper/lower limit values for % 95 and % 99 confidence interval of the monthly and annually water level data for 1962-2010 period obtained from Eğirdir station.

Time series	First year	Last year	Q	Qmin99	Qmaks99	Qmin95	Qmaks95
October	1962	2010	-0.028	-0.050	-0.005	-0.045	-0.010
November	1962	2010	-0.027	-0.048	-0.005	-0.042	-0.011
December	1962	2010	-0.025	-0.046	-0.003	-0.041	-0.010
January	1962	2010	-0.025	-0.044	-0.004	-0.039	-0.009
February	1962	2010	-0.025	-0.045	-0.003	-0.040	-0.009
March	1962	2010	-0.024	-0.045	-0.001	-0.039	-0.009
April	1962	2010	-0.025	-0.045	0.000	-0.039	-0.007
May	1962	2010	-0.024	-0.045	0.000	-0.038	-0.008
June	1962	2010	-0.023	-0.045	0.002	-0.039	-0.007
July	1962	2010	-0.024	-0.045	-0.001	-0.040	-0.008
August	1962	2010	-0.026	-0.047	-0.001	-0.041	-0.008
September	1962	2010	-0.028	-0.049	-0.004	-0.044	-0.010
Annual	1962	2010	-0.026	-0.045	-0.002	-0.040	-0.010

Data in Table 3 give that annual, February, April, June, July, August, and September water levels exhibit a statistical decrease trend. Statistically meaningful decrease trend for June (α=0.05) and for February, April, June, July, August, September, and annual (α=0.01) can be observed. Water level decrease slope for June is approximately -0.023 m and the expected minimum is -0,007 m and the expected maximum is -0.039 m. If all conditions continue as they are now then in 100_year period June water level decrease can be 2.3 m (0.7-3.9 m) . If the average depth of the water level is assumed to be 11 m then June water level decrease can be 1069. 92 hm^3 (approximately % 21).

Annual water level decrease slope is approximately -0.026 m the expected minimum is -0.002 m and the expected maximum is -0.045 m. If all conditions persist as they are existing now, then, in 100_ year periods, June water level decrease is expected to be 2.6 m (0.2-4.5 m) . If the average depth of the water level is assumed to be 11 m then June water level decrease can be 1209.47 hm^3 (approximately % 24).

Kovada lake

Water level data of Kovada Lake for a period encompassing 1964 to 2009, is analyzed by using Run test (annual water level data) and by Mann Kendall and Sen methods (annual and monthly data).

Run test

Annual water level data and Run test results for Kovada Lake are shown in Table 4. Since z = -3.60781 value is out of ±2.54 band the series is not within % 90 confidence interval (not homogeneous). Water level trend graph of Kovada Lake between 1964 and 2009 are presented in Figure 4.

Table 4**.** Annual water level data and Run test results for Kovada Lake.

Median	r	N	NA	NB	z
905.0	11	49	25	24	-3.60781

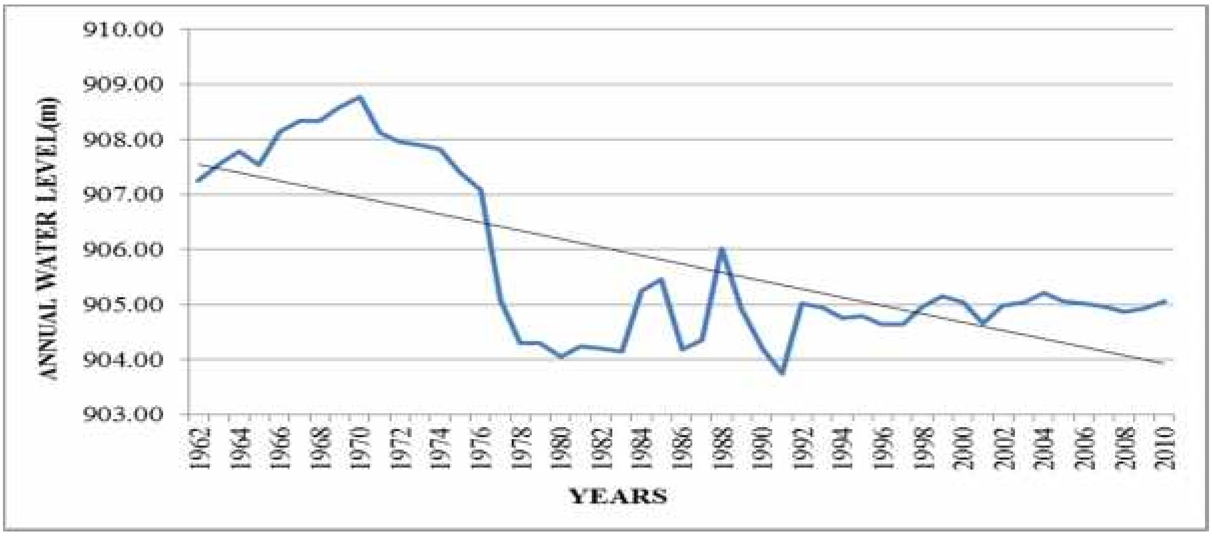

Figure 4. Water level trend graph of Kovada Lake between 1964 and 2009

Mann-Kendall method

Mann Kendall test is performed on both annual and monthly water level data from 1962-2010 period for Kovada Lake. The existence of a trend is assumed to be an indicator of a change in water level. Mann-Kendall Z values for Kovada Lake for 1962-2010 period annual and monthly water level data is presented in Table 5.

As it is seen in the table, from the water level point of view, there is a significant decrease for α=0.01 confidence interval for January, February, March, April, June, October, December, and annual rows. Likewise, for α=0.05 confidence interval there is a significant decrease in May and November. In addition, for α=0.001 confidence interval there is some decrease in July, August, and September. Mann Kendall test graphic for water level data obtained from Kovada Lake station between 1962 and 2010 is shown in Figure 5

Table 5. Mann-Kendall Z values for Kovada Lake 1962-2010 period annual and monthly water level data.

Time series	First year	Last year	n	Test S	Test Z	Meaningfulness
October	1962	2010	49		-3.09	**
November	1962	2010	49		-3.09	**
December	1962	2010	49		-2.93	**
January	1962	2010	49		-2.64	**
February	1962	2010	49		-2.48	*
March	1962	2010	49		-3.03	**
April	1962	2010	49		-3.86	***
May	1962	2010	49		-3.82	***
June	1962	2010	49		-3.66	***
July	1962	2010	49		-2.96	**
August	1962	2010	49		-2.47	*
September	1962	2010	49		-2.74	**
Annual	1962	2010	49		-3.11	**
+ α=0.1 confidence interval, * α=0.05 confidence interval, ** α=0.01 confidence interval, *** α=0.001 confidence interval						

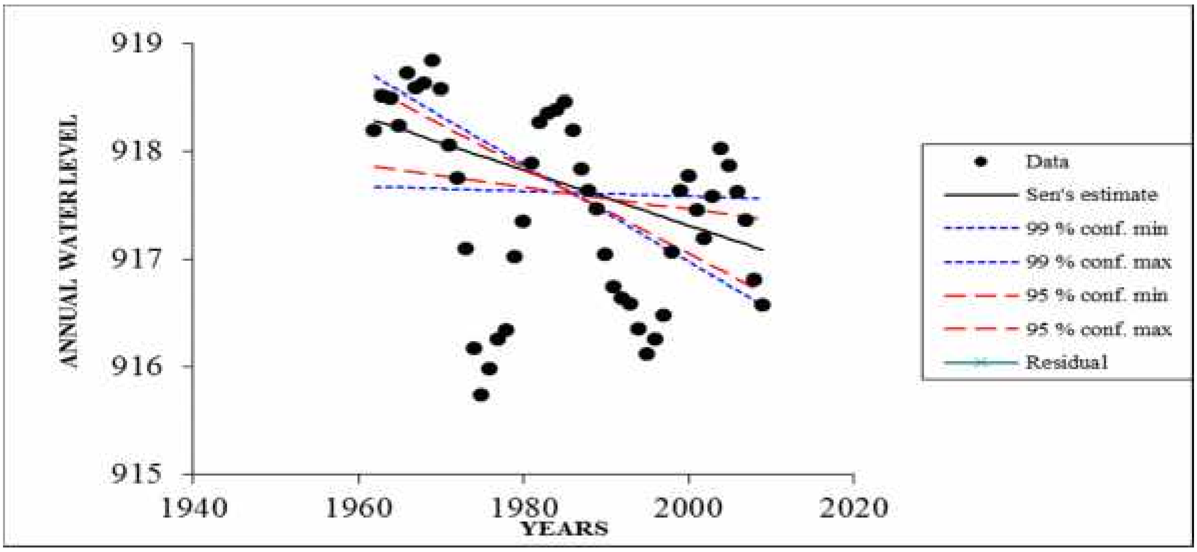

Figure 5. Mann Kendall test graphic for water level data obtained from Kovada Lake station between 1962 and 2010.

Mann Kendall test graphic for water level data obtained from Kovada Lake station between 1962 and 2010, only in June, is presented in Figure 6.

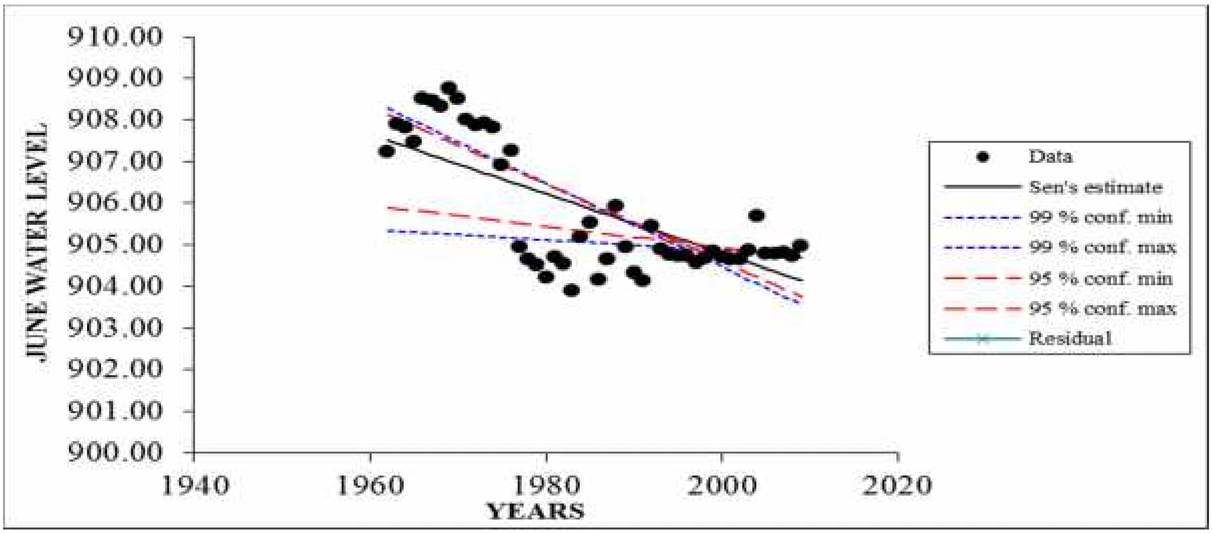

Figure 6. Mann Kendall test graphic for water level data obtained from Kovada Lake station between 1962 and 2010, only in June.

Mann Kendall test graphics presented in Figure 6 shows that annual and January, February, March, April, May, June, October, November, and December water levels exhibit a significant decreasing trend, likewise July, August, and september water level trends exhibit some decreasing trend.

Sen method

Linear tendencies of the trends observed in time are calculated through the use of a non parametric method developed by Sen. To determine the slopes of the annual and monthly changes in water level data collected by Kovada Lake station, Sen test is performed. Sen slope and upper/lower limit values for % 95 and % 99 confidence interval of the monthly and annually water level data for 1962-2010 period obtained from Eğirdir station is presented in Table 3.

In Table 6, Sen slope and upper/lower limit values for % 95 and % 99 confidence interval of the monthly and annually water level data for 1962-2010 period obtained from Kovada station is presented.

Table 6. Sen slope and upper/lower limit values for % 95 and % 99 confidence interval of the monthly and annually water level data for 1962-2010 period obtained from Kovada station.

Time series	**First year**	**Last year**	**Q**	**Qmin99**	**Qmaks99**	**Qmin95**	**Qmaks95**
October	1962	2010	-0.073	-0.106	-0.018	-0.100	-0.032
November	1962	2010	-0.073	-0.108	-0.010	-0.099	-0.025
December	1962	2010	-0.068	-0.100	-0.009	-0.092	-0.025
January	1962	2010	-0.060	-0.089	-0.001	-0.082	-0.016
February	1962	2010	-0.058	-0.084	0.001	-0.077	-0.013
March	1962	2010	-0.057	-0.087	-0.010	-0.080	-0.029
April	1962	2010	-0.072	-0.103	-0.032	-0.094	-0.039
May	1962	2010	-0.069	-0.096	-0.021	-0.090	-0.036
June	1962	2010	-0.072	-0.100	-0.012	-0.093	-0.026
July	1962	2010	-0.070	-0.102	-0.006	-0.094	-0.018
August	1962	2010	-0.064	-0.100	0.001	-0.093	-0.013
September	1962	2010	-0.073	-0.107	-0.005	-0.098	-0.027
Annual	1962	2010	-0.063	-0.092	-0.008	-0.086	-0.018

Data in Table 6 shows that annual, October, November, December, January, February, March, April, May, June, July, August, and September water levels exhibit a statistical decrease trend. Statistically meaningful decrease trend for May and November (α=0.05) and for April, June, and annual (α=0.01) can be observed.

Water level decrease slope for June is approximately -0.057 m and the expected minimum is -0.01 m and the expected maximum is -0.087 m. If all current conditions persist, then, in 100_year period June water level decrease can be 5.7 m (1.0-8.7 m) . If the average depth of the water level is assumed to be 6.5 m then June water level decrease can be 50.41 hm^3 (approximately % 88).

Annual water level decrease slope is approximately -0.063 m and the expected minimum is -0.008 m and the expected maximum is -0.092 m. If all current conditions persist, then in 100_year period,s June water level decrease can be 6.3 m (0.8-9.2 m) . If the average depth of the water level is assumed to be 6.5 m then June water level decrease can be 55.71 hm^3 (approximately % 96).

Conclusion

Evaluation of the water budget of Eğirdir Lake shows that in conjunction with February, June, July, August, and September monthly results and annual results have similar water level decrease. To prevent the water level as presented up to now, following preventive measures should be taken immidiatly-:

1) New irrigation projects fed from Eğirdir Lake should not be permitted.
2) Currently operational irrigation projects not showing any progress should be removed from the scope of irrigation.

3) Currently operational irrigation projects should be rehabilitated by introducing minimum water utilization based irrigation systems.
4) Better planning and more intelligent water utilization in farming should be enforced for economical water usage.

In 100_year period the water level decrease in June at Kovada Lake can be as high as 5.7 m. This is equivalent of 50.41 hm^3 of water. In terms of percents, the expression of water decrease is % 88. In 100_year period the annual level of water level decrease at Kovada Lake can be as high as 6.3 m. This is equivalent of 55.71 hm^3 of water. In terms of percents, the expression of water decrease is % 96.

As an ongoing discussion, although, the water level decrease in Kovada Lake can be excessive sometimes due to water holding for the hydroelectric power plant, water level at Kovada Lake is controlled by the exit channel from Eğirdir Lake. If the water level of Eğirdir Lake exceeds 904.60 m then water is channeled to Kovada Lake. In such a case, Kovada Lake will not completely dry.

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