Trend Analysis of Lakes and Sinkholes in Konya Closed Basin, Turkey

Vahdettin DEMIR (vahdettin.demir@karatay.edu.tr)
KTO Karatay Üniversitesi https://orcid.org/0000-0002-6590-5658

Research Article

Keywords: Konya Closed Basin, sinkhole, Mann-Kendall trend test, Linear Trend test, Innovate Sen trend test

Posted Date: February 22nd, 2021

DOI: https://doi.org/10.21203/rs.3.rs-161951/v1

Version of Record: A version of this preprint was published at Natural Hazards on April 15th, 2022. See the published version at https://doi.org/10.1007/s11069-022-05327-6.

Trend analysis of lakes and sinkholes in Konya Closed Basin, Turkey

Vahdettin Demir[1]

[1] KTO Karatay University, Department of Civil Engineering, Konya, Turkey

Corresponding author (vahdettin.demir@karatay.edu.tr)

telephone number: +90 332 444 1251

Abstract

Determining changes in the water level of lakes is essential in terms of flood control, water resource management, economic development, water-supply planning sustainability, and the sustainability of the ecosystem. Trend analysis is one of the most commonly used tools for detecting changes in the hydrological time series such as lake levels, precipitation and temperature. Trend analyses of meteorological variables and groundwater levels (baseflow components) are crucial toward the assessment of long-term changes in lake levels. This study aims to investigate the trend of long-term change in lakes (Lake Tuz and Lake Beyşehir) and sinkholes (Timraş and Kızören) in the Konya Closed Basin in Turkey. Changes in these lakes and sinkholes were examined along with changes in precipitation and groundwater trends representing the climate in the region. With the assistance of Thiessen polygons, precipitation stations, which affect the lakes and sinkholes, were determined. Several statistical tests exist that help determine the significance of hydrological trends over time. These tests are divided into two categories: parametric and nonparametric. In this study, the non-parametric Innovative Sen trend test, the Modified Mann–Kendall trend test, and the parametric Linear Trend test were used. As a result of the trend analysis, it was observed that the water levels of Kızören and Timraş sinkholes decreased over time, and the water levels of Tuz Gölü and Beyşehir lakes increased over time. These results are supported by the trends of precipitation data and groundwater level data of the stations determined by the Thiessen polygons and sub-basin boundaries.

Key Words: Konya Closed Basin, sinkhole, Mann-Kendall trend test, Linear Trend test, Innovate Sen trend test

1. Introduction

Humans, who have a significant position in the environment of terrestrial and aquatic ecosystems, need the presence of lakes, which are valuable water resources. Many lakes around the globe are facing multiple types of threats owing to combined effects such as water withdrawals resulting from human activities and climate variation. These effects, which have a critical influence on regional sustainable development, can adversely impact both water quality and quantity. The fluctuation of lake water levels plays an important role in lake ecosystems. It is necessary to establish sustainable management of the lakes to detect long-term changes in water levels.

Fluctuations in lake water levels are known to be sensitive indicators of changes in climate and groundwater, and can play an important role in monitoring climate changes today and in the future. Therefore, differences in lake levels and their relationship with measured climate variables are important not only for understanding and monitoring the effects of climate change but also analyzing impacts on relevant ecosystems. Lake water level fluctuations can result from the complex relationship of various water balance components. These components include the flow entering or leaving the lake, direct precipitation to the lake surface, and groundwater change (Pan et al. 2018). In addition to meteorological factors such as precipitation on the lake drainage area, evaporation from the lake surface, wind speed, humidity, and temperature in the adjacent subatmosphere play an important role in water level fluctuations in the lakes. Gradual (trend) or sudden (shifting) climate change problems have been particularly notable in recent years. Researchers have found that most of the changes in the lake level are related to meteorological variables such as temperature and precipitation.

Understanding long-term trends in hydrometeorological variables and groundwater changes is highly significant for sustainable water resource management. Meteorological parameters can change for many reasons, depending on the time and space. These observed changes should be determined by various statistical methods. The trend and homogeneity analysis are two important statistical methods that are widely used around the world for assessing the long-term changes in meteorological variables.

A limited number of studies in the literature on the hydrological relationship between trends of lake, sinkhole (a type of lake), groundwater levels and meteorological variables are available. Few examples are as follows: Yenilmez et al. (2011) analyzed the trend of water quality parameters, precipitation, lake volume and temperatures recorded in Eymir Lake (Turkey) using the Mann–Kendall test and Linear trend methods. Bahadır (2012) analyzed the precipitation and the trend of the water level of Kovada lake (Turkey) using the Linear trend method. Yagbasan et al. (2017) used the Mann–Kendall trend test in temperature, precipitation, and water levels of Mogan and Eymir lakes. Göncü et al. (2017) examined the change of climate variables and four lake levels (Burdur, Eğirdir, Sapanca, and Lake Tuz) in Turkey using Mann–Kendall, Seasonal Kendall, Regional Kendall, and Linear trends methods. Belete et al. (2017) used the Mann–Kendall test for long-term precipitation, streamflow, and potential evapotranspiration trends for the water level of Lake Hawassa (Etiyopya). Yagbasan et al. (2020) used the Mann–Kendall, Modified Mann–Kendall, and Linear trend test for trends in climate variables and changes of the water levels in Mogan and Eymir lakes.

Precipitation and underground waters are the main source of water in sinkholes. The sinkholes are formed by natural factors (tectonic, climate, and lithological character), human activities (maximum use of groundwater, military ammunition trials), and the collapse of the ceilings of underground cavities, such as underground caves. Therefore, the emphasis in this research is focused on the determination of monthly trends of changes in the underground water levels and precipitation of lakes and sinkholes. In literature, statistical analysis results showed that precipitations and underground water levels have a crucial influence on the variations in the water levels of lakes. Precipitation is the main element in the hydrological system. Hence, any change in the long-term trends of precipitation will have a direct effect on water resources, particularly on the lake water levels. In addition, climate changes and human effects are the probable causes of changes in lake water levels.

This study aims to investigate the long-term fluctuations of precipitation and groundwater changes in the lakes located in the Central Anatolia region of Turkey. In this study, the homogeneity characteristic of the time series was investigated. Next, trend analyses were conducted. The Standard Normal Homogeneity Test (SNHT) was used to test whether the hydrological data came from the same population. For trend analyses, nonparametric Modified Mann–Kendall (MMK), Innovative Sen trend test (ST) and parametric Linear trend (LT) methods were used. The trends and homogeneity tests were examined at a 95% confidence level. The potential impact of precipitation and groundwater variables on sinkholes and water level fluctuations in the lakes has not yet been examined. This study takes that point into consideration, and analyzes the causes and hydrological consequences of variations in the water levels of sinkholes and lakes.

2. Materials and Methods

2.1. Materials

Konya closed basin is located in the central and southern parts of the Central Anatolia Region. According to the long-term data of the meteorological stations located in the Konya closed basin; the average annual temperature is 11.6 ° C; the highest temperature is 40.6 ° C and the lowest temperature is -28.2 ° C. The average annual precipitation is 323.3 mm. Precipitation is in the form of convective in the region. The most important lakes of the region are Beyşehir and Tuz lakes (Figure 1).

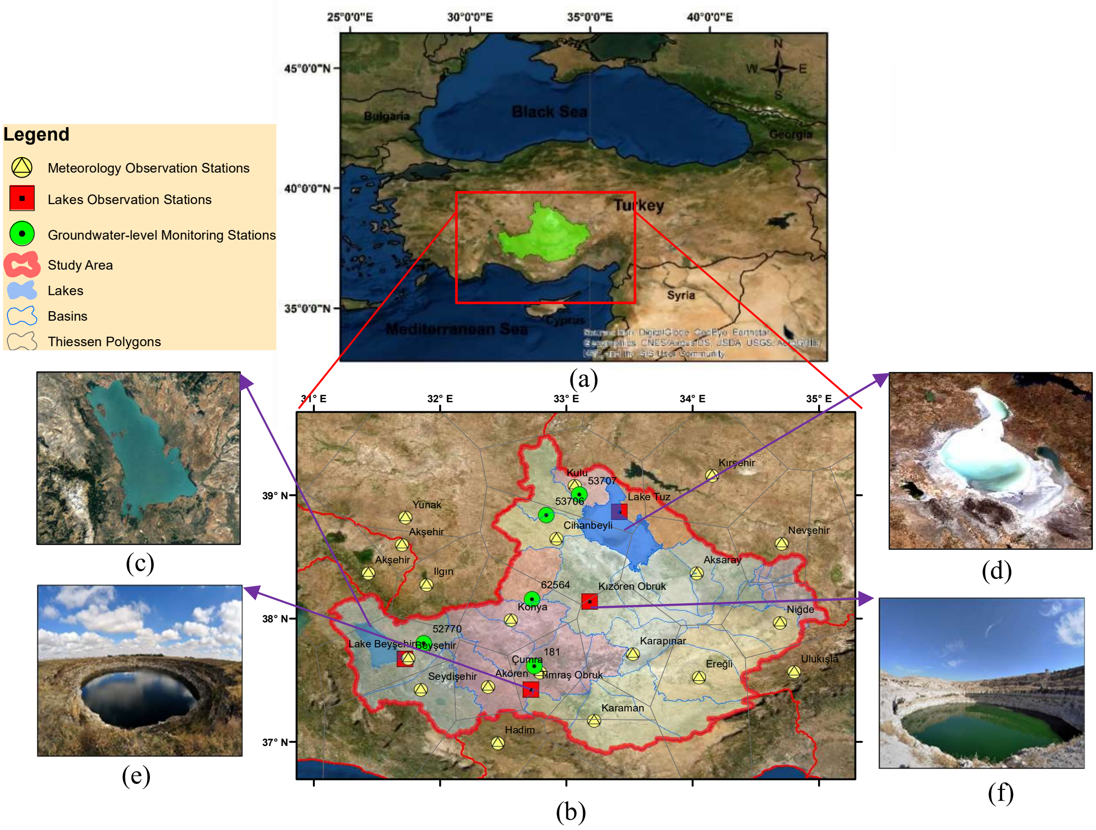

Fig. 1 The study area (a), Thiessen polygon in the study area (b)
Lake Beyşehir (c), LakeTuz (d), Timraş Sinkhole (e), Kızören Sinkhole (f)

Lake Tuz is very shallow and the second largest lake in Turkey with its surface area. That the lake is shallow, and the evaporation happens severe causes concentration of salts in the lake. Fifty-five percentage of Turkey’s salt need is provided from this lake. Lake Tuz is a closed basin lake that does not flow out and its surface area is 7414 km^2 (Dengiz et al. 2010). Despite the wide area of precipitation, the feeding sources are weak. The streams that bring water to the lake are the streams whose waters decrease in the summer or dry out completely. The average water depth of the lake is around 40 cm, it is 110 cm in May when precipitation increases. The lake dries greatly in August. Both Lake Tuz and its surroundings are a special protection area. It is the main breeding center of many special bird species (Anonymous 2020). Lake Beyşehir is Turkey's largest freshwater lake (Guler et al. 2008). It is the third largest lake after Lake Van and Lake Tuz. It is located in a tectonic deposit with a surface area of 650 km^2 and surrounded by mountains. While the average depth of the lake is 5-6m, the maximum depth of it is 8-9 m. Lake Beyşehir is one of the protected areas of the country (545 plant, 163 bird and 16 fish species live), like Lake Tuz. Many migratory waterbirds come to Lake Beyşehir to hunt and breed (Bucak et al. 2018). Besides the lakes in the water ecosystem of the Konya basin, it plays an important role in the structures called "sinkhole". There are more than 20 sinkholes in the Konya Basin, which hosts 33.3% of the country's groundwater. The underground water flow from Konya Plain is towards the Lake Tuz, which is located at the lowest level of the plain. During the groundwater flow from Konya Plain to Lake Tuz, the groundwater dissolves karstic rocks in contact with and underground cavities are formed. As a result of the lowering of the groundwater level that fills these gaps, the surface layers whose balance is disturbed collapses and karstic shapes which we call “sinkhole” are formed (Recep and Tapur 2009). There are the aforementioned many sinkholes in the plain and the most important ones whose water levels are recorded are Timraş and Kızören sinkhole (Günay et al. 2011, 2015). Kızören sinkhole was formed within the Neogene aged lacustrine formations and Paleozoic aged with crystallized limestones (Recep and Tapur 2009). It is located 75 kilometers away from the city of Konya in Turkey (Figure 1(f)). It has an approximately elliptical shape with a long axis of 180 m and a short axis of 150 m. It is 300 m wide and up to 145 meters deep from the surface of the water. The water level in the sinkhole fluctuates during winter and summer, which generally do not exceed 1–2 m (Günay et al. 2011). Lake Obruk (sinkhole), which gives its name to the region, has a natural beauty that changes every hour of the day. The sinkhole (or sinkhole lake) is a miraculous lake that drives those who see it to surprise and excitement. The most significant feature of the sinkholes is that they are very special geographical formations. These are sinkhole lakes, called karst lands, which are usually found on the plains containing limestones and carbonates evaporation products, that water can easily dissolve. Timras Sinkhole is located approximately 40 km southeast of Konya and 46 km of Konya-Karaman highway (Figure 1(e)). It is composed of limestones. Ellipse shaped sinkhole whose large diameter is 325 m and small diameter is 250 m. The most depth point of the sinkhole has been measured as 32 m (Recep and Tapur 2009). Due to the sweetness of the lake Obruk (sinkhole), there are carp-type fish. Besides, caves and limestone cavities on the slopes are a habitat for pigeons. The number of visitors is high because it is close to the road (Tapur and Bozyiğit 2016). Underground waters are fed from the Taurus Mountains in the south of the Konya basin. Some of these underground waters, which progress from the land on the mountain slopes, forms lakes and sinkholes in long-term periods. Sinkholes form with the collapse of ground a result of decreasing of underground currents over time. In addition, there is a hydrological relationship between the sinkhole and lakes in the study area. The groundwater coming from the south of the study area runs northward and ends in the Lake Tuz (Günay et al. 2011).

2.1.1 Data

Monthly total precipitation data (mm) were obtained from the General Directorate of Meteorology in meteorology stations. Other information about the stations is given in Table 1. Unfortunately, due to various regulations made by the government agency, the data could not be obtained after 2017. Table 1 shows the location of the meteorological lake level observation and the groundwater level observation stations used in the study. Table 2 shows the statistical properties used in the study. The distribution of long-term, average groundwater levels in the study area is given in Figure 2.

Table 1 Location information of the stations used in the study

Station Type	Station Name	Station No	Latitude (N)	Longitude (E)	Elevation (m)
Meteorology Observation Station	Karapınar	17902	37.72	33.52	996
	Çumra	17900	37.56	32.79	1014
	Kulu	17754	39.08	33.06	1005
	Cihanbeyli	17191	38.65	32.92	969
	Beyşehir	17242	37.68	31.75	1141
	Konya	17244	37.99	32.56	1031
	Aksaray	17193	38.38	34.03	965
Lake Observation Station	Kızören	16-050	38.14	33.19	974.72
	Timraş	16-052	37.43	32.72	1011.52
	Lake Tuz	1619	38.87	33.42	903.97
	Lake Beyşehir	D16G175	31.72	37.68	1121.80
Groundwater-level Observation Stations	Cihanbeyli	53706	32.84	38.84	968.5 (Depth, -100)
	Selçuklu	62564	32.73	38.16	987.99 (Depth, -83)
	Beyşehir	52770	31.87	37.80	1220.5 (Depth, -140)
	Çumra	181	32.75	37.62	1011.2 (Depth, -250)
	Kulu	53707	33.10	39.01	997.21 (Depth, -150)

Table 2 Statistical properties of the stations.

Station Name	Max	Min	Mean	SD	SC	Period
Karapınar	109.20	0.00	23.86	21.21	1.04	64-17
Çumra	114.80	0.00	25.79	23.61	1.15	78-17
Kulu	130.90	0.00	31.49	26.19	0.93	64-17
Cihanbeyli	122.40	0.00	26.58	22.41	1.11	64-17
Beyşehir	231.20	0.00	40.71	38.09	1.59	64-17
Konya	124.00	0.00	27.74	24.37	1.09	64-17
Aksaray	119.00	0.00	28.78	23.99	0.79	64-17
Kızören	978.35	945.30	971.27	8.57	-1.24	64-17
Timraş	1015.53	987.68	1007.19	7.38	-1.02	78-15
Lake Tuz	905.98	903.97	905.04	0.18	0.52	64-16
Lake Beyşehir	1125.49	1121.03	1123.14	1.12	0.13	64-17
Cihanbeyli	-21.9	-26.3	-24.06	0.79	-0.51	00-17
Selçuklu	-1.66	-42.55	-11.02	9.97	-1.23	67-17
Beyşehir	-7.49	-18.49	-12.29	2.75	-0.60	04-17
Çumra	-1.27	-25.16	-7.30	5.57	-1.14	67-17
Kulu	-8.1	-15.09	-11.18	1.81	-0.41	00-17

SD: Standard Deviation, SC: Skewness Coefficient

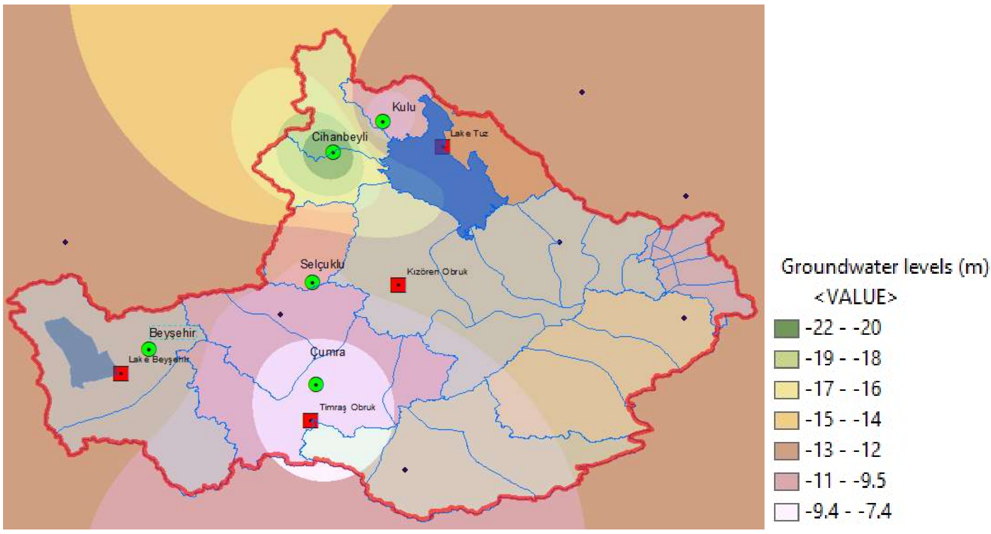

Fig. 2 Distribution of long-term average groundwater levels

2.2. Methods

In this study, an investigation of the long-term monthly lake level, sinkhole level, groundwater level and precipitation series change analysis was performed. Firstly, the homogeneity conditions were examined. Later trend analyses were carried out.

2.2.1. Standard Normal Homogeneity Test (SNHT)

This method developed by Alexandersson is used to test the homogeneity of many hydro meteorological series (Khaliq and Ouarda 2007). Calculates the value of T (c) by Equation 3 by dividing it into two parts with reference to a "c" point of the studied series (Equation 1 and 2).

$$\overline{z}_1 = \sum_{i=1}^{c} (y_i - \overline{y}) / \sigma) / c \quad (1)$$

$$\overline{z}_2 = \sum_{i=1+c}^{n} (y_i - \overline{y}) / \sigma) / (n - c) \quad (2)$$

$$T(c) = c\overline{z}_1 + (n - c)c\overline{z}_2^2 \qquad c=1, 2, 3, \ldots.., n \quad (3)$$

Where "n" is the number of data, "y" is years, z is the standardized work series of length n, $\overline{z}_1$ and $\overline{z}_2$ are arithmetic mean values of the series. If the change occurs at a point "h", it reaches the maximum value of T(c) at point c = h. T_0 test statistic is as in Equation 4.

$$T_0 = \max_{1<0<n} T(c) \quad (4)$$

If the test statistic T_0 exceeds the T_0 critical value, the null hypothesis (H_0) is rejected. T_0 test values depending on the number of data and 95% confidence level is given in Table 3 (Alexandersson 1986).

Table 3 T_0 test critical values depending on the number of data

Number of data	30	40	50	70	100	200	500	700	1000
CL (95%)	7.65	8.10	8.45	8.80	9.15	9.55	10.20	10.45	10.50

2.2.2. Modified Mann-Kendall (MMK)

This method tests if there is a trend in the time series data (Mann 1945; Kendall 1975). It is a non-parametric rank-based procedure, robust to the influence of extremes and suitable for application with skewed variables (Hamed 2008). Test statistic value is calculated with the help of Equation 5 and 6.

$$\mathrm{sgn}(x_j - x_i) = \begin{cases} 1; & \text{if} \quad x_j > x_j \\ 0; & \text{if} \quad x_j = x_i \\ -1; & \text{if} \quad x_j < x_i \end{cases} \tag{5}$$

In Equation (5), xi and xj are the data values in time series i and j, respectively and in Equation (6), n is the number of data points, sgn (xj – xi) is the sign function as;

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}(x_j - x_i) \tag{6}$$

After that the variance is computed as;

$$\mathrm{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{P} t_i(t_i - 1)(2t_i + 5)}{18} \tag{7}$$

In Equation (7), n refers to the number of data, P shows the number of tied groups, and t_i indicates the number of ties of extent i. A tied group is a set of sample data and has the same value. Finally, with the help of Equation 8, Mann-Kendall Z value is calculated.

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{\mathrm{Var}(S)}}; & \text{if} \quad S > 0 \\ 0 & \text{if} \quad S = 0 \\ \dfrac{S+1}{\sqrt{\mathrm{Var}(S)}} & \text{if} \quad S < 0 \end{cases} \tag{8}$$

The Modified Mann-Kendall (MMK) method is obtained by rearranging the variance in the original Mann-Kendall method. This process is used to calculate the new Z value by determining the auto correlation effect. Adjusted variance value is calculated as given Equation 9 and10 (Yue et al. 2002).

$$V(S) = \mathrm{Var}(S) * \frac{n}{n_s^*} = \frac{n(n-1)(2n+5)}{18} * \frac{n}{n_s^*} \tag{9}$$

$$\frac{n}{n_s^*} = 1 + \frac{2}{n(n-1)(n-2)} x \sum_{i=1}^{n-1} (n-i)(n-i-2)\rho_s(i) \tag{10}$$

In Equation (10), n/n_s^*, represents a correction due to automatic correlation in the data. “n” is the actual number of observations and $\rho_s(i)$ is the auto-correlation of the observation ranks (González-Hidalgo et al.

2011). The calculated Z value is compared with normal distribution confidence levels. If the calculated Z value is greater than $|Z| \geq |Z_{1-\alpha/2}|$, the null hypothesis ($H_0$) is rejected and thus the H_a (alternative hypothesis) hypothesis is accepted. H_0 hypothesis states that the trend is statistically insignificant, H_a hypothesis states that the trend is significant (Mann, 1945; Kendall, 1975).

2.2.3. Linear Trend (LT)

This method basically rests on the slope of a line. It is a widely used method to determine the tendency of dependent and independent variables in hydrological time series. The regression equation is given below (Keskin et al. 2018).

$$Y = \beta_0 + \beta_1 X \tag{11}$$

In Equation (11), β_0 is a constant value and β_1 is the slope of the line. It is also referred to as regression analysis, and trends (increasing or decreasing) are interpreted according to the Student's t-test critical level value of the slope value (β_1). If $|t_{cal}|$ exceed $\pm t_{cri}$, there is statistically significant trend (Yagbasan et al. 2020).

2.2.4. Sen Trend (ST)

In this method, first, time series is divided into two sub-series. Each sub-series is sorted in an ascending manner. Then, the first sub-series (X_i) is located on the X-axis, and the other sub-series (X_j) is located on the Y-axis in the Cartesian coordinate system (Figure 3). If data are collected on the 1:1 (45˚) straight line, it can be said that there is no trend (a trendless time series). If data are accumulated in the triangular area below the 1:1 (45˚) straight line, it is said that there is a decreasing trend. If data are accumulated in the upper triangular area of the 1:1 (45˚) straight line, it is said that there is an increasing trend (Şen 2012, 2014).

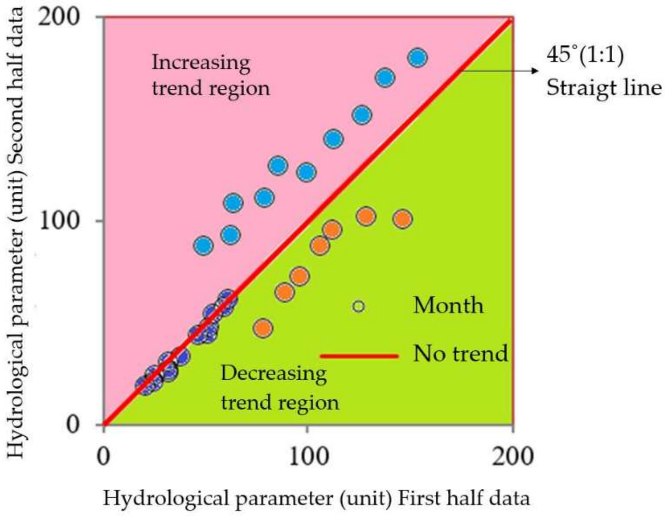

Figure 3. Decreasing and increasing trends versus trend-free time series (Keskin et al. 2018).

Sen developed a new mathematical process by the method (Şen 2017). The steps of this method are given in Equations (12-16).

$$E(s) = \frac{2}{n}\left[E(\overline{y}_2) - E(\overline{y}_1)\right] \tag{12}$$

$$\sigma_s^2 = \frac{4}{n^2}\left[E(\overline{y}_2^2) - 2E(\overline{y}_2\overline{y}_1) - E(\overline{y}_1^2)\right] \tag{13}$$

$$\rho_{\overline{y}_2\overline{y}_1} = \frac{E(\overline{y}_2\overline{y}_1) - E(\overline{y}_2) - E(\overline{y}_1)}{\sigma_{\overline{y}_2}\sigma_{\overline{y}_1}} \tag{14}$$

$$\sigma_s^2 = \frac{2\sqrt{2}}{n\sqrt{n}}\sigma\sqrt{(1-\rho_{\overline{y}_2\overline{y}_1})} \tag{15}$$

$$CL_{(1\text{-}\alpha)} = 0 \pm S_{critical}\sigma_s \tag{16}$$

Where $\bar{y}_1$, mean of the first data set; $\bar{y}_2$, mean of the second data set; ρ, correlation between first and second data; s, slope value; n, number of data; σ, standard deviation of all data; σ_s, slope standard deviation; Z critical values in one-way hypothesis at 95% (for example) confidence level. Critical upper and lower values are established for hypothesis test limits (Equation 16). If each station's slope value, s, is outside the lower and upper confidence limits, the alternative hypotheses, H_a, is verified, indicating a trend (Yes) in time series. The type of trend is stated depending on the slope value (s) sign. Slope (s) can be positive or negative. While positive slope (+) is indicating an increasing trend in time series, negative slope (-) shows a decreasing trend (Yagbasan et al. 2020).

3. Results

In this study, the homogeneity of the trends was first tested with the SNHT. The test values were compared with the critical limits (T_0) in 95% of the confidence interval, and the results are given in Table 4. Later, trend analyses were conducted by using the MMK, LT, and ST methods. The MMK and ST methods used in the study are nonparametric tests, whereas LT is a parametric test. The results of the MMK, LT, and ST trends, as well as their critical limits, are given in Table 5 (in 95% of the confidence interval). Depicted in Table 5, if the stations' Z, t, and s values are higher than critical limits, precipitation groundwater and lake levels are considered to have a statistical trend at the time series. The direction of the trend is determined by the sign of the Z, s, or t value. The positive and negative signs indicate increasing and decreasing trends, respectively.

Table 4 Results of SNHT test

Station Type	Station Name	T_0 Value	Critical T_0 Value (α=5%)	P value	H_0
Meteorology Observation Station	Karapınar	4.158	10.348	0.649	Accept
	Çumra	2.973	10.140	0.843	Accept
	Kulu	4.023	10.348	0.685	Accept
	Cihanbeyli	2.434	10.348	0.944	Accept
	Beyşehir	2.110	10.348	0.965	Accept
	Konya	2.240	10.348	0.961	Accept
	Aksaray	4.094	10.348	0.672	Accept
Lake Observation Station	Kızören	504.88	10.310	<0.0001	Reject
	Timraş	370.41	10.096	<0.0001	Reject
	Lake Tuz	25.11	10.290	<0.0001	Reject
	Lake Beyşehir	323.09	10.350	<0.0001	Reject
Groundwater-level Observation Stations	Cihanbeyli	49.82	9.45	<0.0001	Reject
	Selçuklu	471	10.28	<0.0001	Reject
	Beyşehir	126	9.42	<0.0001	Reject
	Çumra	473	10.28	<0.0001	Reject
	Kulu	51.33	9.41	<0.0001	Reject

SNHT results showed that the H_0 hypothesis is accepted because the T_0 value of all meteorology stations is lower than the T_0 critic, and the P value (H_0 hypothesis) is greater than 0.05, which is the critical value. This situation shows that the precipitation data are homogeneous. However, as the homogeneity conditions of the lake and groundwater stations are examined, the H_0 hypothesis has been rejected, and it has been determined that the data are nonhomogeneous. Trends typically occur when data are nonhomogeneous (Demir et al. 2018). These results show that the lake water and groundwater levels tend to trend rather than produce homogeneous precipitation data.

Table 5 Results of trend methods

Station Type	Station Name	MMK Z value	Z Critical Value	MMK trend	LT t value	t Critical Value	LT trend	ST s value	±CL	ST trend
Meteorology Observation Station	Karapınar	-0.20	±1.96	No	-0.25	±1.96	No	**-0.0019**	0.00024	**(-)**
	Çumra	-0.61	±1.96	No	-0.02	±1.96	No	-0.00027	0.0011	No
	Kulu	-1.32	±1.96	No	-1.12	±1.96	No	**-0.0045**	0.00043	**(-)**
	Cihanbeyli	-1.82	±1.96	No	-0.36	±1.96	No	**-0.00085**	0.0004	**(-)**
	Beyşehir	0.23	±1.96	No	0.16	±1.96	No	**-0.0049**	0.00073	**(-)**
	Konya	-0.97	±1.96	No	-0.38	±1.96	No	**-0.0027**	0.00063	**(-)**
	Aksaray	-0.56	±1.96	No	-0.28	±1.96	No	**-0.023**	0.00038	**(-)**
Lake Observation Station	Kızören	**-13.94**	±1.96	**(-)**	**-38.82**	±1.96	**(-)**	**-0.0395**	0.00044	**(-)**
	Timraş	**-6.56**	±1.96	**(-)**	**-37.81**	±1.96	**(-)**	**-0.046**	0.0071	**(-)**
	Lake Tuz	-1.17	±1.96	No	**-2.104**	±1.96	**(-)**	**-0.00017**	0.00001	**(-)**
	Lake Beyşehir	**-8.97**	±1.96	**(-)**	**-16.36**	±1.96	**(-)**	**-0.0047**	0.00007	**(-)**
Groundwater-level Observation Stations	Cihanbeyli	-0.57	±1.96	No	**2.02**	±1.97	**(+)**	**0.0029**	0.00047	**(+)**
	Selçuklu	**-14.86**	±1.96	**(-)**	**-43.56**	±1.96	**(-)**	**-0.049**	0.0005	**(-)**
	Beyşehir	**9.42**	±1.96	**(+)**	**16.35**	±1.96	**(+)**	**0.045**	0.001	**(+)**
	Çumra	**-7.47**	±1.96	**(-)**	**-44.11**	±1.96	**(-)**	**-0.028**	0.0003	**(-)**
	Kulu	0.57	±1.96	No	**2.03**	±1.96	**(+)**	**0.017**	0.0006	**(+)**

(+): Increasing trend, (-): Decreasing trend

The MMK and LT methods showed similar results. No significant trend could be detected at the precipitation stations. The lake levels do not show any tendency, according to the Lake Tuz MMK method. Other stations show a decreasing trend with the MMK and LT methods. When the underground water levels were examined, a decreasing trend in the Selçuklu and Çumra stations and an increasing trend in Beyşehir station were determined according to the three trend methods. While the increasing trend detected at Kulu and Cihanbeyli stations is statistically significant for the ST and LT methods, it is not significant for the MMK method. According to the ST method, a decreasing trend was determined at all precipitation stations except for the lake levels and the Çumra station. The ST method is sensitive compared to other trend methods. In other words, its critical level is lower (Yagbasan et al.2020). ST graphs on the Cartesian coordinate system are given for precipitation in Figure 4, lake levels in Figure 5, and underground water levels in Figure 6.

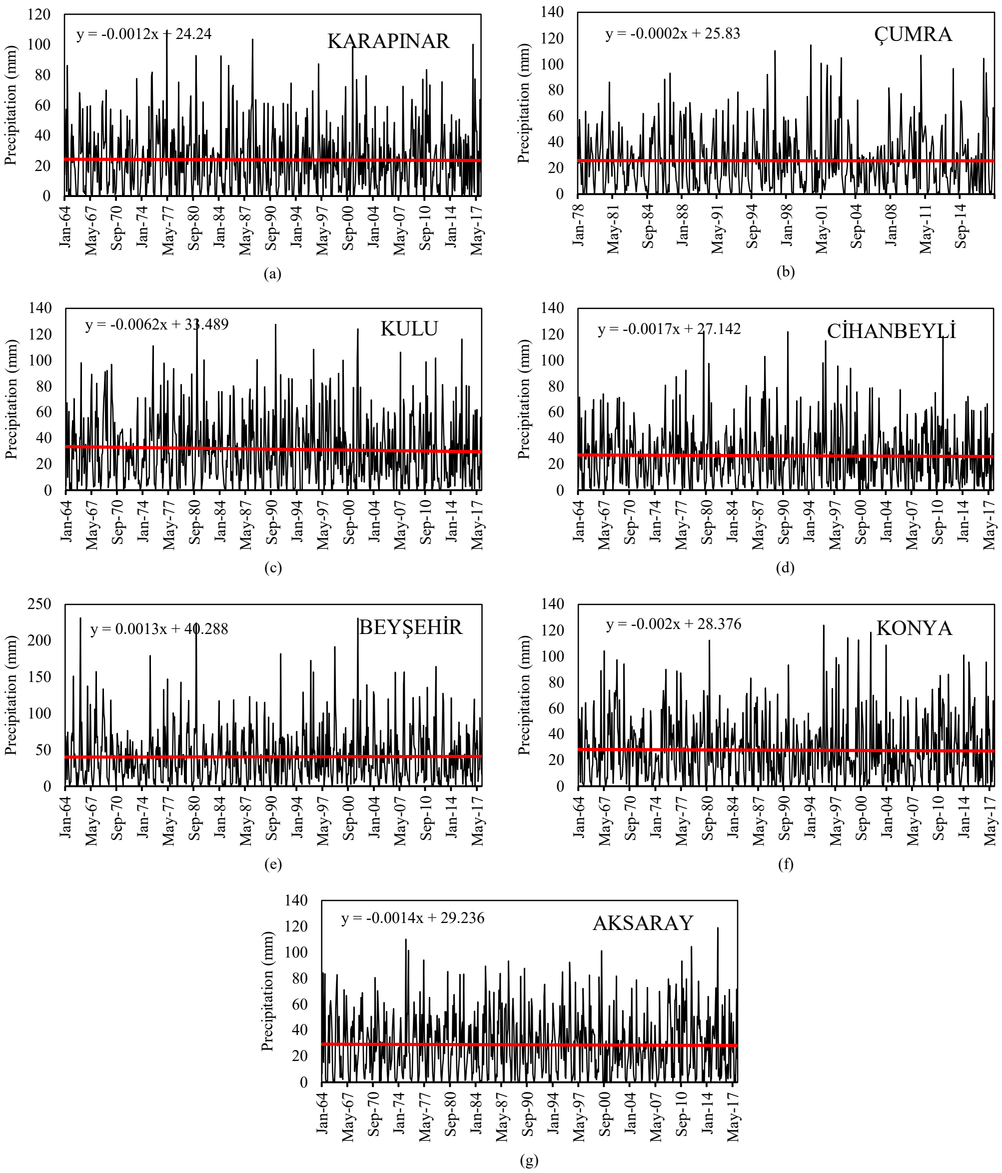

Fig. 4 Time series of precipitation data; Karapınar (a), Çumra (b), Kulu (c), Cihanbeyli (d), Beyşehir (e), Konta (f), and Aksaray station (g)

In Figure 4, the long-term precipitation series depicts that precipitations have been decreasing in the Konya closed basin, except for the Beyşehir station. According to the linear trend slope equation, it was determined that the precipitation data of the Beyşehir station increased by 0.0013 mm per month. Meanwhile, the precipitation data of the Karapınar, Çumra, Kulu, Cihanbeyli, Konya, and Aksaray stations decreased by 0.0012, 0.0002, 0.0062, 0.0017, 0.0020, and 0.0014 mm/month, respectively.

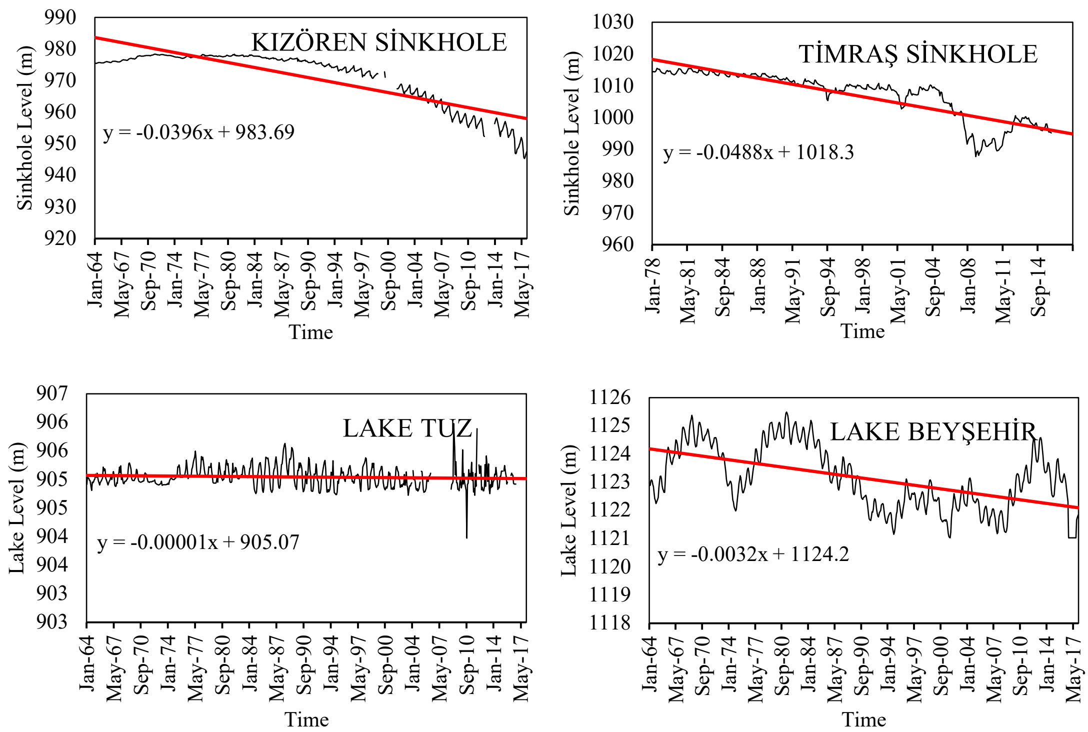

Fig. 5 Time series of water level data; Kızören Sinkhole (a), Timraş Sinkhole (b), Lake Tuz (c) and Lake Beyşehir station (e)

Figure 5 shows a decreasing trend in both lakes and sinkholes. This decrease is 0.0396 m/month for Kızören sinkhole, 0.0488 m/month for Timraş sinkhole, 0.000001 m/month for Lake Tuz and 0.0032 m/month for Lake Beyşehir.

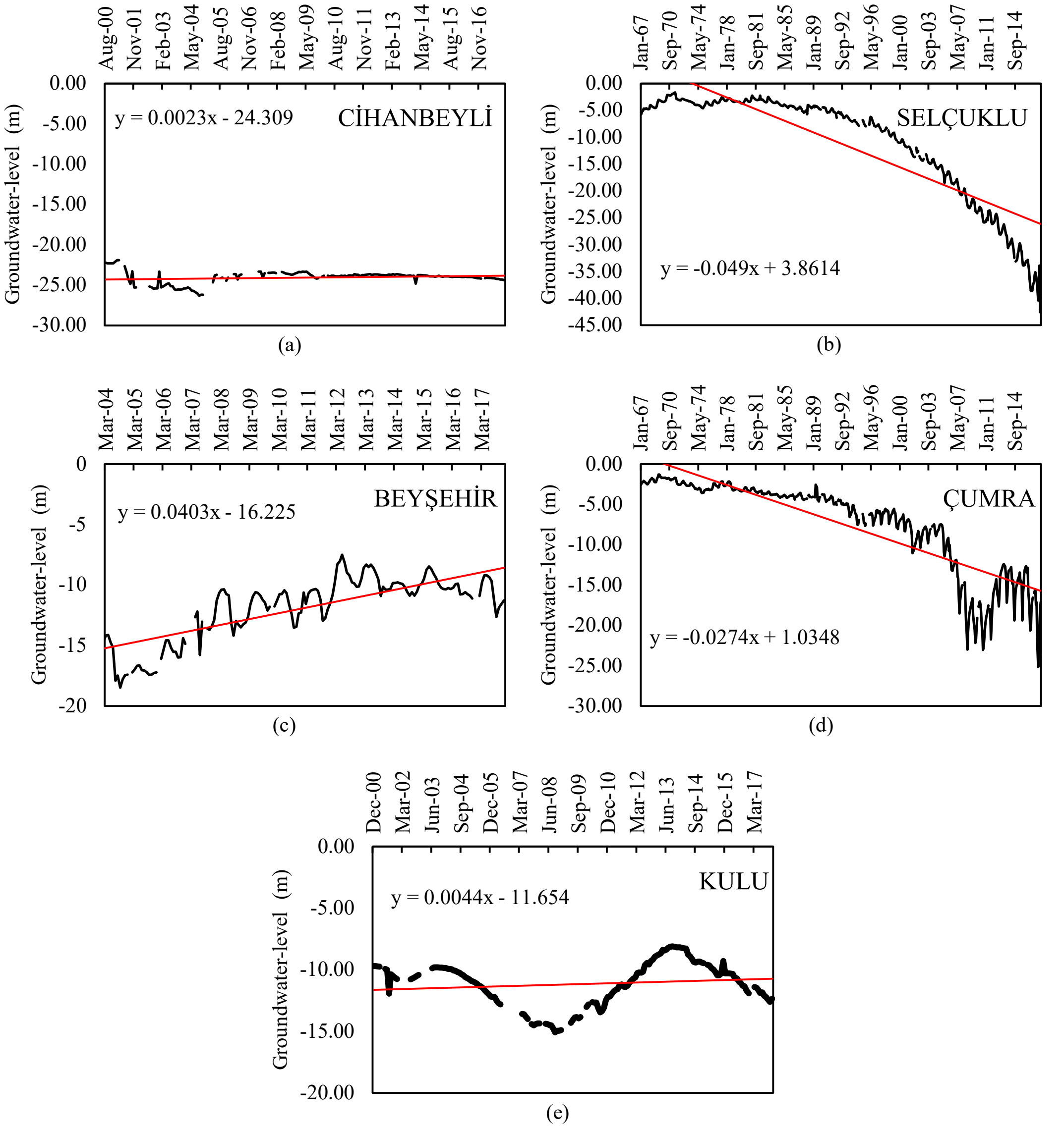

Fig. 6 Time series of groundwater level data; Cihanbeyli (a), Selçuklu (b), Beyşehir (c), Çumra (d) and Kulu groundwater-level observation station (e)

In Figure 6, the long-term groundwater level series shows that water levels in wells have been decreasing at the Beyşehir, Kulu, and Cihanbeyli stations. However, water levels show a dramatic decrease at the Selçuklu and Çumra stations. According to the linear trend slope equation, it was determined that the groundwater level of Beyşehir, Kulu, and Cihanbeyli stations increased.

ST trend graphs prepared in the Cartesian coordinate system are shown for precipitation, lake, sinkhole and groundwater levels in Figures 7–9, respectively. If the data are concentrated in the upper triangular region on the 1:1 line (45), this indicates an increasing trend. If the data are concentrated under the 1:1 line, the parameter in the time series is interpreted as showing a decreasing trend.

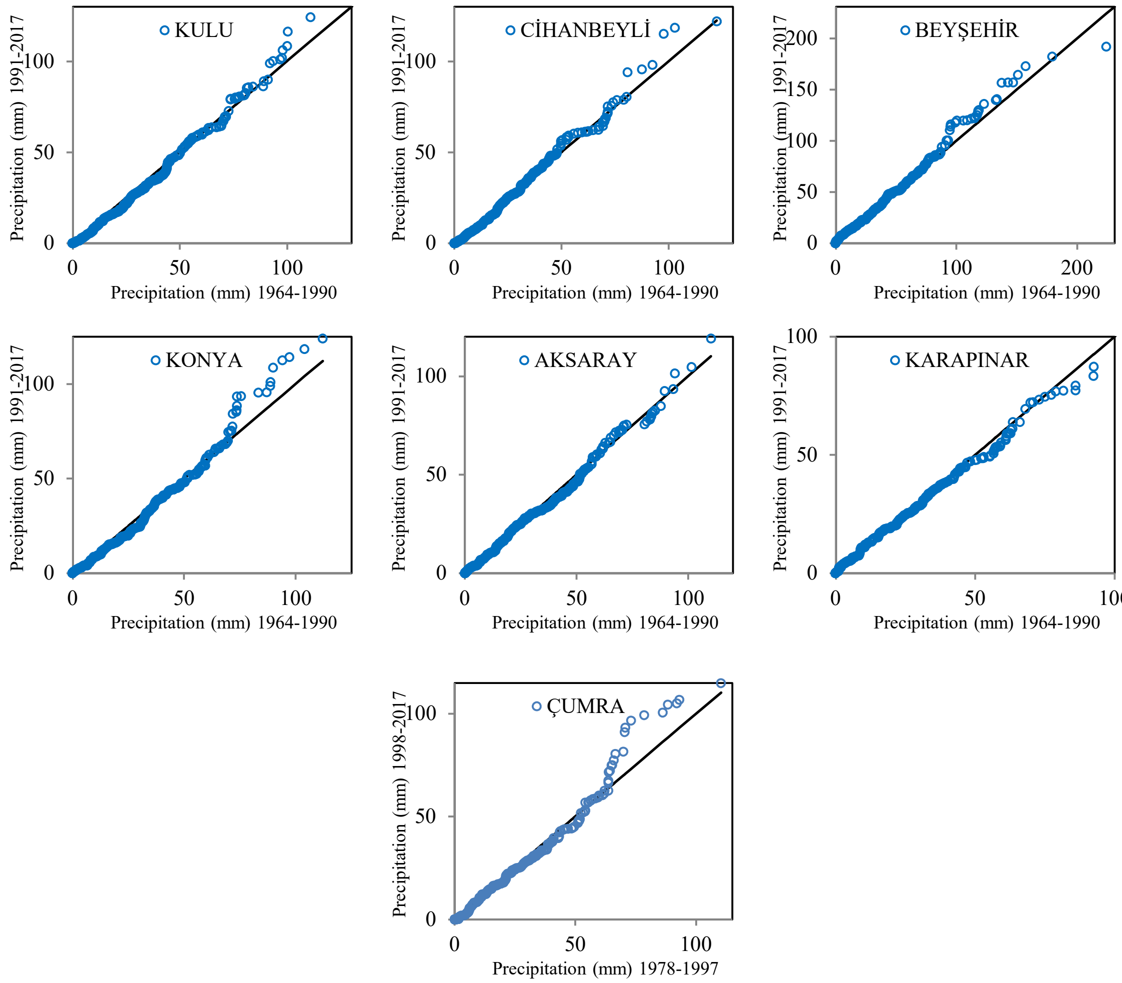

Fig. 7 ST graphical results for precipitation stations

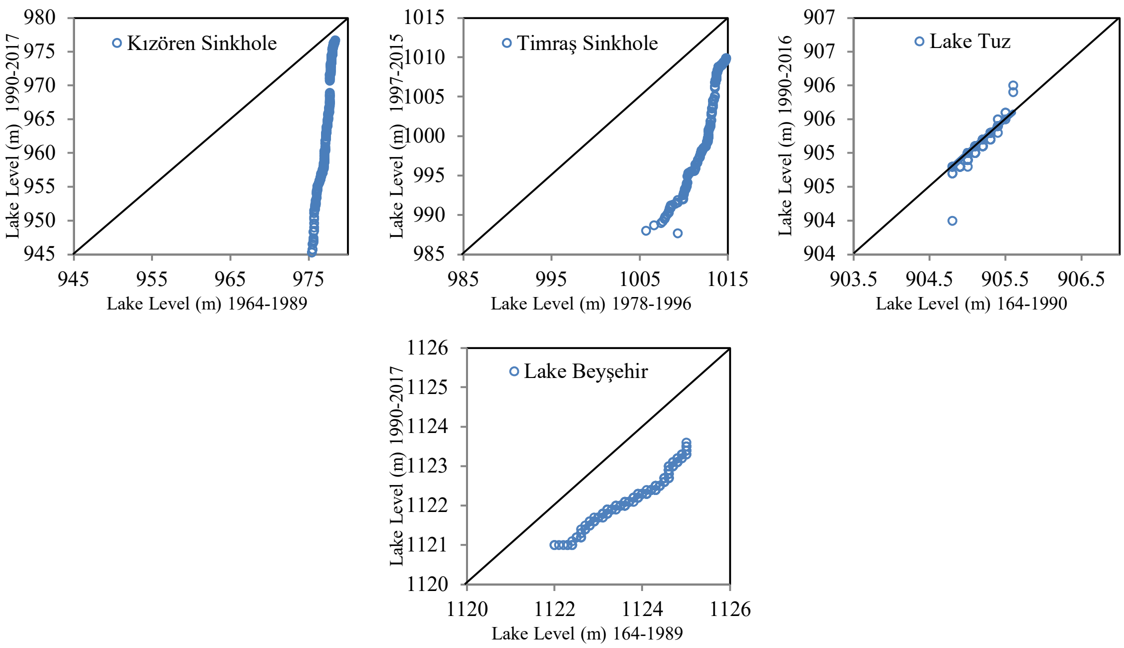

Fig. 8 ST graphical results for lake and sinkhole stations

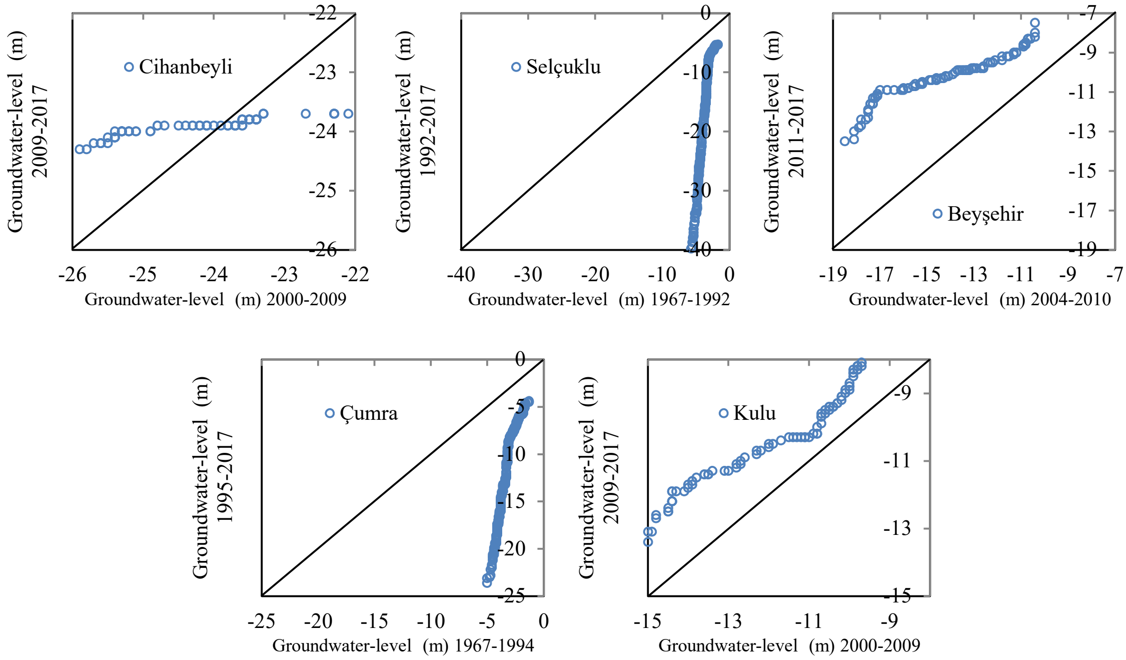

Fig. 9 ST graphical results for groundwater level observation stations

In Figure 7, it could not be exactly determined whether the precipitation data concentrated in the lower triangular region or the upper triangular region. This is the disadvantage of the method (Sen 2012). However, when the averages of the data are analyzed, it was determined that the average of the data is in the lower triangular region, similar to the ST test result in Table 5. Here, the data demonstrate a decreasing trend. When Figure 8 is examined, it is seen that the data of Lake Beyşehir and sinkholes are concentrated in the lower triangular region. When the graph is analyzed by taking the average of the data in Lake Tuz, it was determined that the data are in the decreasing direction. In Figure 9, the Cihanbeyli, Kulu and Beyşehir stations are concentrated in the upper triangular region, and show an increasing trend. Other stations show a decreasing trend in the lower triangular region.

When the sub-basin and Thiessen polygons (drawn for the study area) are examined as a second approach, it is determined that Lake Tuz is in the polygon belonging to the Cihanbeyli, Kulu precipitation stations, and the Cihanbeyli (53706) and the Kulu (53707) groundwater stations. Beyşehir Lake is in the polygon belonging to the Beyşehir precipitation station and the Beyşehir (52770) groundwater station. The Kızören sinkhole is in the polygon belonging to the Cihanbeyli and the Karapınar stations. The Timraş sinkhole is in the polygon belonging to the Çumra station and the Beyşehir (52770) groundwater station (Figure 1). Therefore, these stations are considered directly affected by precipitation (Thiessen 1911). As a result of the abovementioned idea, time series and trend directions are shown in Figures 10, 11, 12, 13 and 14.

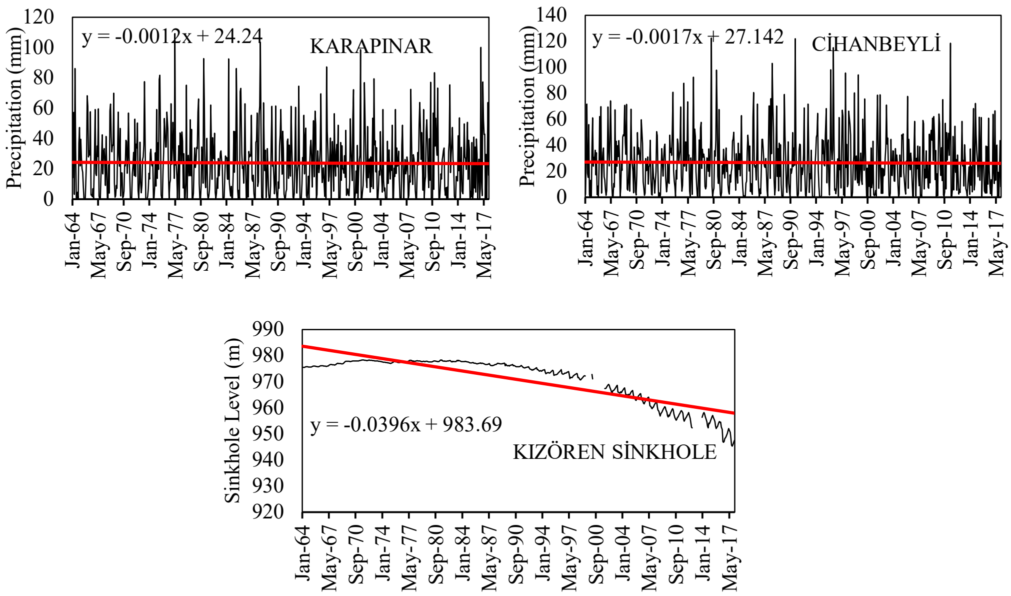

Fig. 10 The graph of Kızören sinkhole, Cihanbeyli and Kulu stations in the same periods

Figure 10 examines the water level in the Kızören sinkhole, which shows a decreasing trend. According to the Thiessen polygons, when the graphs of the precipitation data affecting this sinkhole are examined in the same periods, it was noted that decreasing trends were observed in the Cihanbeyli and Karapınar stations. Since there is no underground water observation station near the Kızören sinkhole, the change of the Kızören obrugu in this section is interpreted only with precipitation data.

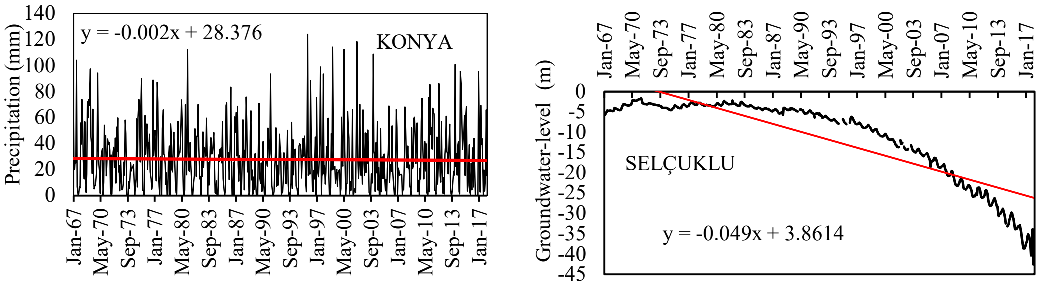

Fig. 11 The graph of Konya precipitation station and Selçuklu groundwater level observation station in the same periods

Figure 11 is examined. Levels decrease in precipitation and groundwater level observation stations located in the same Thiessen polygon. According to the precipitation data, the decrease in the underground levels is more dramatic, and they increase their speed toward the last years.

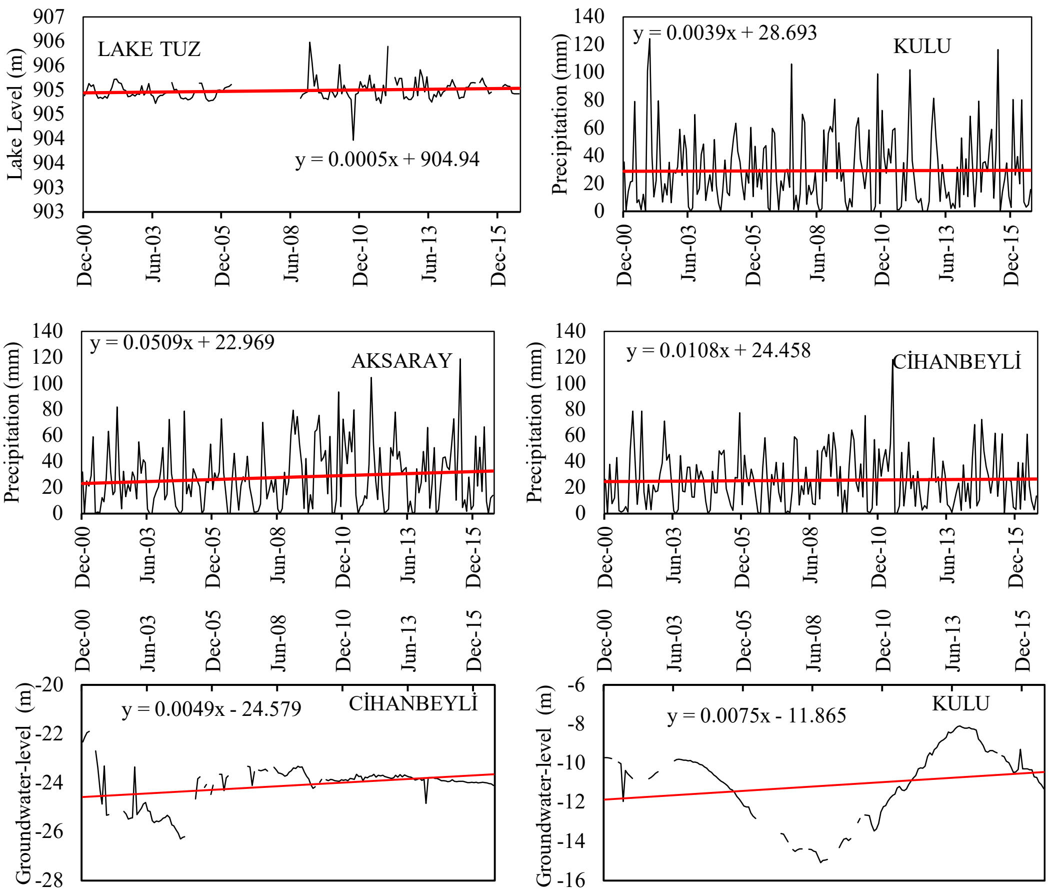

Fig. 12 The graph of Lake Tuz, Cihanbeyli, Kulu and Aksaray precipitation stations, Cihanbeyli and Kulu groundwater level observation station in the same periods

According to Thiessen polygons between 1964 and 2017, a decrease was observed in the Cihanbeyli, Kulu, and Aksaray stations, which are thought to have affected Lake Tuz (Figures 4 and 5). Depending on this situation, decreases were detected in Lake Tuz. When Figure 12 is examined, an increasing trend was observed in precipitation data between 2000 and 2016. Similarly, an increasing trend was observed in the groundwater levels and Lake Tuz levels. This increase in lake levels was supported by the increase in precipitation data and underground water levels.

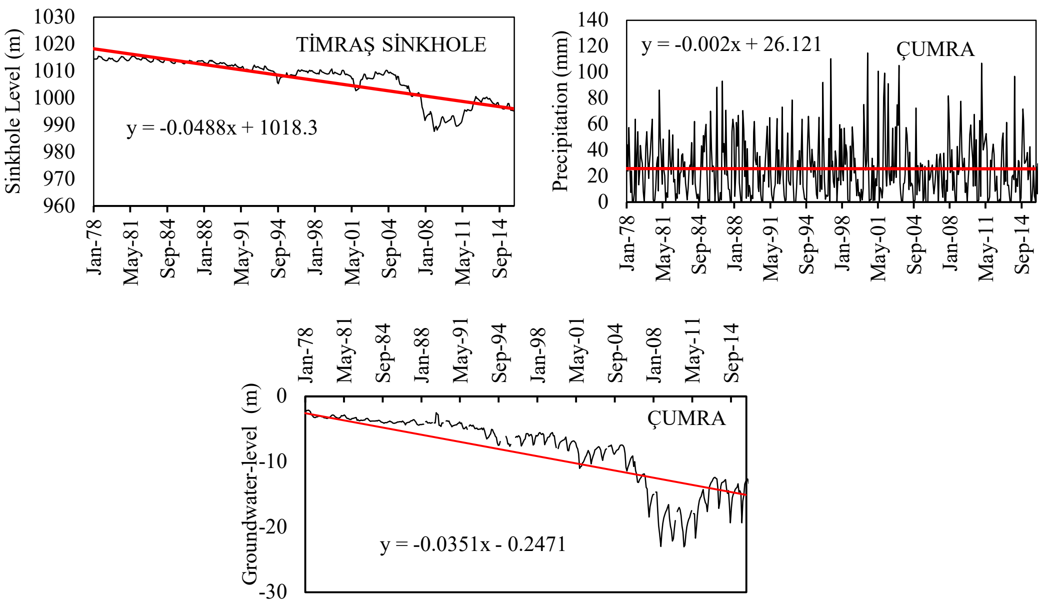

Fig. 13 The graph of Timraş Sinkhole, Çumra precipitation and Çumra groundwater level observation station in the same periods

Figure 13 shows the decreasing trends in the Çumra precipitation station and Çumra underground water-level observation stations, which are thought to affect the sinkhole, according to the Thiessen polygons. The decreasing trend in the Çumra underground water-level observation station, and the Timraş sinkhole, are close to each other. In addition, the correlation coefficient between these two data sets is 0.968.

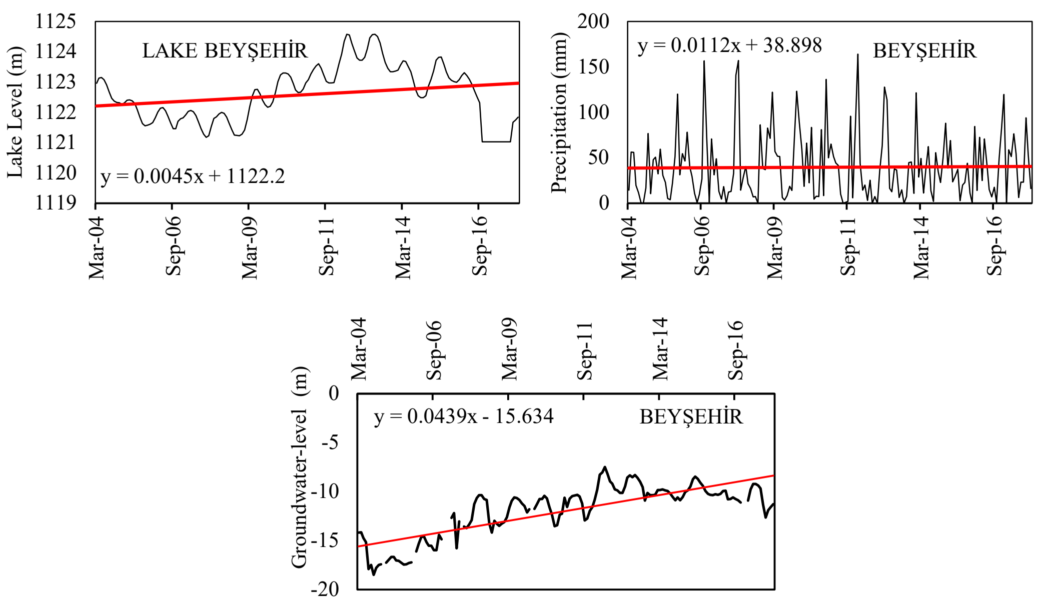

Fig. 14 The graph of Lake Beyşehir Sinkhole, Beyşehir precipitation and Beyşehir groundwater level observation station in the same periods

4. Discussion

According to homogeneity test results, the precipitation data are homogeneous and do not show any trend. However, the lake, sinkhole and groundwater level data are nonhomogeneous, and show a trend. The opposite relationship between homogeneity and a trend is similar in other studies (Taxak et al. 2014; Demir et al. 2018; Demir and Keskin 2020). The overall evaluation and comparison of the trend test results for all methods are summarized in Table 6.

Table 6 Comparison of trend analysis results over long-term periods

Type	Name	Long-term period		
		MMK	**LT**	**ST**
Meteorology Observation Station (MOS)	Karapınar			(-)
	Çumra			
	Kulu			(-)
	Cihanbeyli			(-)
	Beyşehir			(-)
	Konya			(-)
	Aksaray			(-)
Lake Observation Station (LOS)	Kızören	(-)	(-)	(-)
	Timraş	(-)	(-)	(-)
	Lake Tuz		(-)	(-)
	Lake Beyşehir	(-)	(-)	(-)
Groundwater-level Observation Stations (GOS)	Cihanbeyli		(+)	(+)
	Selçuklu	(-)	(-)	(-)
	Beyşehir	(+)	(+)	(+)
	Çumra	(-)	(-)	(-)
	Kulu		(+)	(+)

(+): Increasing trend, (-): Decreasing trend

Although the trend analysis results give similar data, they differ from each other at some points. For example, while there is no trend in precipitation stations compared to the MMK and LT methods, decreasing trends are observed compared to the ST method. Although this data shows a difference between method results, it is consistent with the signs of trend analysis test values in Table 5, except for the Beyşehir station. The LT and ST methods gave similar trends in lake and sinkhole water levels. Alternatively, the MMK method did not show a trend in Lake Tuz, Cihanbeyli and Kulu stations, while other methods detected a trend. Again, when Table 5 is examined for the other two stations except Cihanbeyli station, the MMK method gave similar trends with the ST and LT methods. However, these trends are not statistically significant. In other words, just the sign of the MMK test values alone is compatible with the ST and LT methods. Therefore, the reason for all these differences depends on the methodology of obtaining critical account values. While the ST method calculates CL according to one-tail Z distribution, and according to the correlation between data (Equation 16), the LT method calculates critical values according to t distribution and the MMK method according to the Z distribution (Equation 8). In Table 7, trend analysis results performed in the same periods are given for the lake and sinkhole regions.

Table 7 Comparison of trend analysis results at the same periods

Region	Station	Same period MMK (Z)	Same period LT (t)	Same period ST (s)
Kızören	Kızören Sinkhole (LOS)	-13.94	-38.820	-0.0395
	Karapınar (MOS)	-0.105	-0.215	-0.0037
	Cihanbeyli (MOS)	-0.479	0.054	-0.0005
Konya	Konya (MOS)	-1.183	-1.031	-0.0070
	Selçuklu (GOS)	-14.86	-43.80	-0.0492
Lake Tuz	Lake Tuz (LOS)	2.898	1.637	0.0016
	Kulu (MOS)	0.151	0.069	0.0111
	Aksaray (MOS)	0.692	0.250	0.0616
	Cihanbeyli (MOS)	0.410	0.735	0.0236
	Kulu (GOS)	2.607	2.680	0.0238
	Cihanbeyli (GOS)	0.407	2.288	0.0091
Timraş	Timraş (LOS)	-6.899	-36.96	-0.0496
	Çumra (MOS)	-0.612	-0.285	-0.0007
	Çumra (GOS)	-6.405	-37.47	-0.0363
Lake Beyşehir	Lake Beyşehir (LOS)	1.731	3.235	0.0111
	Beyşehir (MOS)	0.467	0.187	-0.033
	Beyşehir (GOS)	6.499	15.394	0.0469

(+): Increasing trend, (+): Statistically Insignificant Increasing trend,
(-): Decreasing trend, (-): Statistically Insignificant Decreasing trend

In Table 7, the changes in lakes and sinkholes are more significant than the results obtained in long-term periods. Significantly, according to the ST method, decreases or increases in lakes and sinkholes are meaningful due to the amount of precipitation. Although the precipitation increase and decrease are compatible with lakes and sinkholes compared to other methods, these trends are not statistically significant. In addition, Table 7 shows that trends in lake and sinkhole levels are significant with changes in groundwater levels rather than precipitation. Therefore, monitoring groundwater levels is more important for trend studies of lakes. This situation is seen in Lake Tuz, the Timraş sinkhole and in Lake Beyşehir.

Trends in lake levels are statistically consistent with trends in groundwater levels. While examining trend directions, groundwater level movement (from high point to low point), the Thiessen polygons and sub-basin boundaries given in Figure 2 were taken into high consideration. When other studies in the literature are examined, the movement of groundwater levels supports this study (Recep and Tapur 2009; Doğan and Yilmaz 2011; Günay et al. 2011). Groundwater levels move from south to north, toward Lake Tuz in other sub-basins, except for the Lake Beyşehir basin, where underground waters move toward Lake Beyşehir within themselves, particularly in the study area.

5. Conclusions

Homogeneity tests were performed before trend analysis. The homogeneity test was performed using the SNHT. Later, trend analyses were conducted and the MMK, ST, and LT methods were used. Analyses were examined in 95% of the confidence interval, and the following results were highlighted.

- As SNHT was applied to data, it was observed that the precipitation data were homogeneous, and the lakes, sinkholes and groundwater data were nonhomogeneous.

- When long-term trend analyses were performed on precipitation, lake, sinkhole and groundwater level data, the trend has not been determined in the homogeneous precipitation data, except for the ST method. In addition, the trends in nonhomogeneous lakes, sinkholes and groundwater levels were detected. This indicates that the trends are stronger in nonhomogeneous stations.
- The results of the MMK, ST and LT method trend analysis directions are similar. As a result of the recorded long-term trend analysis, it was observed that the precipitation, lake and sinkhole water levels decreased. Groundwater levels, on the other hand, tend to increase in some stations, and decrease in some stations.
- As a result of the above-mentioned analyses, it was determined that it is difficult to accurately determine the changes in lakes and sinkholes according to long-term precipitation. However, this issue can be explained by considering the same period for all data.
- Finally, at the same and last periods, it was observed that the water levels of the Kızören and Timraş sinkhole decreased, while the water levels of Lake Tuz, Lake Gölü and Lake Beyşehir all increased. These results are supported by the trends of precipitation data and groundwater level data of stations determined according to Thiessen polygons and sub-basin boundaries.

In summary, the trends of the water levels of lakes and sinkholes have significant effects on the country's water resources management, agricultural and socio-economic activities. The decreases in groundwater levels, precipitation and lake levels observed in the Çumra–Timraş, Konya–Selçuklu, and Kızören–Cihanbeyli–Karapınar regions are also a sign of drought and further inefficiency of agricultural areas for the region. Therefore, measures should be taken to assist lakes and sinkholes with adaptation to changing climatic conditions and reduce the negative effects.

Acknowledgments: The author thank the Meteorology General Directorate and State Hydraulic Works for the data.

Conflicts of Interest: The authors declare no conflicts of interest.

Funding: No funding or support has been received for research from funding institutions.

Author's Contribution: All chapters have been prepared by Vahdettin Demir.

6. References

Alexandersson H (1986) A homogeneity test applied to precipitation data. J Climatol 6:661–675. https://doi.org/10.1002/joc.3370060607

Anonymous (2020) Salt Lake and Flamingos. http://www.aksaray.gov.tr/tuz-golu-ve-flamingolar. Accessed 24 Mar 2020

Bahadır M (2012) A Statistical Analysis of the Level Changes of Kovada Lake. J Turkish Stud Volume 7 I:441–452. https://doi.org/10.7827/TurkishStudies.2465

Belete MD, Diekkrüger B, Roehrig J (2017) Linkage between water level dynamics and climate variability: The case of lake hawassa hydrology and ENSO Phenomena. Climate 5:.

https://doi.org/10.3390/cli5010021

Bucak T, Trolle D, Tavşanoğlu N, et al (2018) Modeling the effects of climatic and land use changes on phytoplankton and water quality of the largest Turkish freshwater lake: Lake Beyşehir. Sci Total Environ 621:802–816. https://doi.org/10.1016/j.scitotenv.2017.11.258

Demir V, Keskin AÜ (2020) Water level change of lakes and sinkholes in Central Turkey under anthropogenic effects. Theor Appl Climatol 142:929–943. https://doi.org/10.1007/s00704-020-03347-5

Demir V, Zeybekoglu U, Beden N, Keskin AU (2018) Homogeneity and Trend Analysis of Long Term Temperatures in the Middle Black Sea Region. 13th International Congress on Advances in Civil Engineering, 12-14 September 2018, Izmir/TURKEY, pp 1–8

Dengiz O, Ozcan H, Koksal ES, et al (2010) Sustainable natural resource management and environmental assessment in the Salt Lake (Tuz Golu) Specially Protected Area. Environ Monit Assess 161:327–342. https://doi.org/10.1007/s10661-009-0749-4

Doğan U, Yilmaz M (2011) Natural and induced sinkholes of the Obruk Plateau and Karapidotlessnar-Hotami{dotless}ş Plain, Turkey. J Asian Earth Sci 40:496–508. https://doi.org/10.1016/j.jseaes.2010.09.014

Göncü S, Albek EA, Albek M (2017) Trend Analysis of Burdur, Eğirdir, Sapanca and Tuz Lake Water Levels Using Nonparametric Statistical Methods. Afyon Kocatepe Univ J Sci Eng 17:555–570. https://doi.org/10.5578/fmbd.57389

González-Hidalgo JC, Brunetti M, de Luis M (2011) A new tool for monthly precipitation analysis in Spain: MOPREDAS database (monthly precipitation trends December 1945-November 2005). Int J Climatol 31:715–731. https://doi.org/10.1002/joc.2115

Guler GO, Kiztanir B, Aktumsek A, et al (2008) Determination of the seasonal changes on total fatty acid composition and ω3/ω6 ratios of carp (Cyprinus carpio L.) muscle lipids in Beysehir Lake (Turkey). Food Chem 108:689–694. https://doi.org/10.1016/j.foodchem.2007.10.080

Günay G, Çörekçioğlu I, Övül G (2011) Geologic and hydrogeologic factors affecting sinkhole (obruk) development in Central Turkey. Carbonates and Evaporites 26:3–9. https://doi.org/10.1007/s13146-011-0044-7

Günay G, Güner N, Törk K (2015) Turkish karst aquifers. Environ Earth Sci 74:217–226. https://doi.org/10.1007/s12665-015-4298-6

Hamed KH (2008) Trend detection in hydrologic data: The Mann-Kendall trend test under the scaling hypothesis. J Hydrol 349:350–363. https://doi.org/10.1016/j.jhydrol.2007.11.009

Kendall MG (1975) Rank Correlation Methods. Chtirles Griffin, London

Keskin AÜ, Beden N, Demir V (2018) Analysis of Annual, Seasonal and Monthly Trends of Climatic Data: A Case Study of Samsun. E-Journal New World Sci Acad 13:51–70. https://doi.org/10.12739/NWSA.2018.13.3.4A0060

Khaliq MN, Ouarda TBMJ (2007) Short Communication On the critical values of the standard normal homogeneity test (SNHT). Int J Climatol 687:681–687. https://doi.org/10.1002/joc

Mann HB (1945) Nonparametric Tests Against Trend. Econometrica 13:245–259

Pan Z, Jiang X, Lei M, et al (2018) Mechanism of sinkhole formation during groundwater-level recovery in karst mining area, Dachengqiao, Hunan province, China. Environ Earth Sci 77:0. https://doi.org/10.1007/s12665-018-7987-0

Recep B, Tapur T (2009) The Affect Of Groundwaters For Formation Of Obruk In Konya Plain And Around Recep. J Selcuk Univ Inst Soc Sci 21:137–155

Şen Z (2017) Innovative trend significance test and applications. Theor Appl Climatol 127:939–947. https://doi.org/10.1007/s00704-015-1681-x

Şen Z (2012) Innovative trend analysis methodology. J Hydrol Eng 17:1042–1046. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000556

Şen Z (2014) Trend Identification Simulation and Application. J Hydrol Eng 19:635–642. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000811

Tapur T, Bozyiğit R (2016) The Tourism Potential of Sinkholes in Konya Province. Marmara Geogr Rev 34:253–267

Taxak AK, Murumkar AR, Arya DS (2014) Long term spatial and temporal rainfall trends and homogeneity analysis in Wainganga basin, Central India. Weather Clim Extrem 4:50–61. https://doi.org/10.1016/j.wace.2014.04.005

Thiessen AH (1911) PRECIPITATION AVERAGES FOR LARGE AREAS. Mon Weather Rev 39:1082–1089. https://doi.org/10.1175/1520-0493(1911)39<1082b:PAFLA>2.0.CO;2

Yagbasan O, Demir V, Yazicigil H (2020) Trend Analyses of Meteorological Variables and Lake Levels for Two Shallow Lakes in Central Turkey. Water 12:414. https://doi.org/10.3390/w12020414

Yagbasan O, Yazicigil H, Demir V (2017) Impacts of climatic variables on water-level variations in two shallow Eastern Mediterranean lakes. Environ Earth Sci 76:. https://doi.org/10.1007/s12665-017-6917-x

Yenilmez F, Keskin F, Aksoy A (2011) Water quality trend analysis in Eymir Lake, Ankara. Phys Chem Earth, Parts A/B/C 36:135–140. https://doi.org/10.1016/j.pce.2010.05.005

Yue S, Pilon P, Phinney B, Cavadias G (2002) The influence of autocorrelation on the ability to detect trend in hydrological series. Hydrol Process 16:1807–1829. https://doi.org/10.1002/hyp.1095

Figures

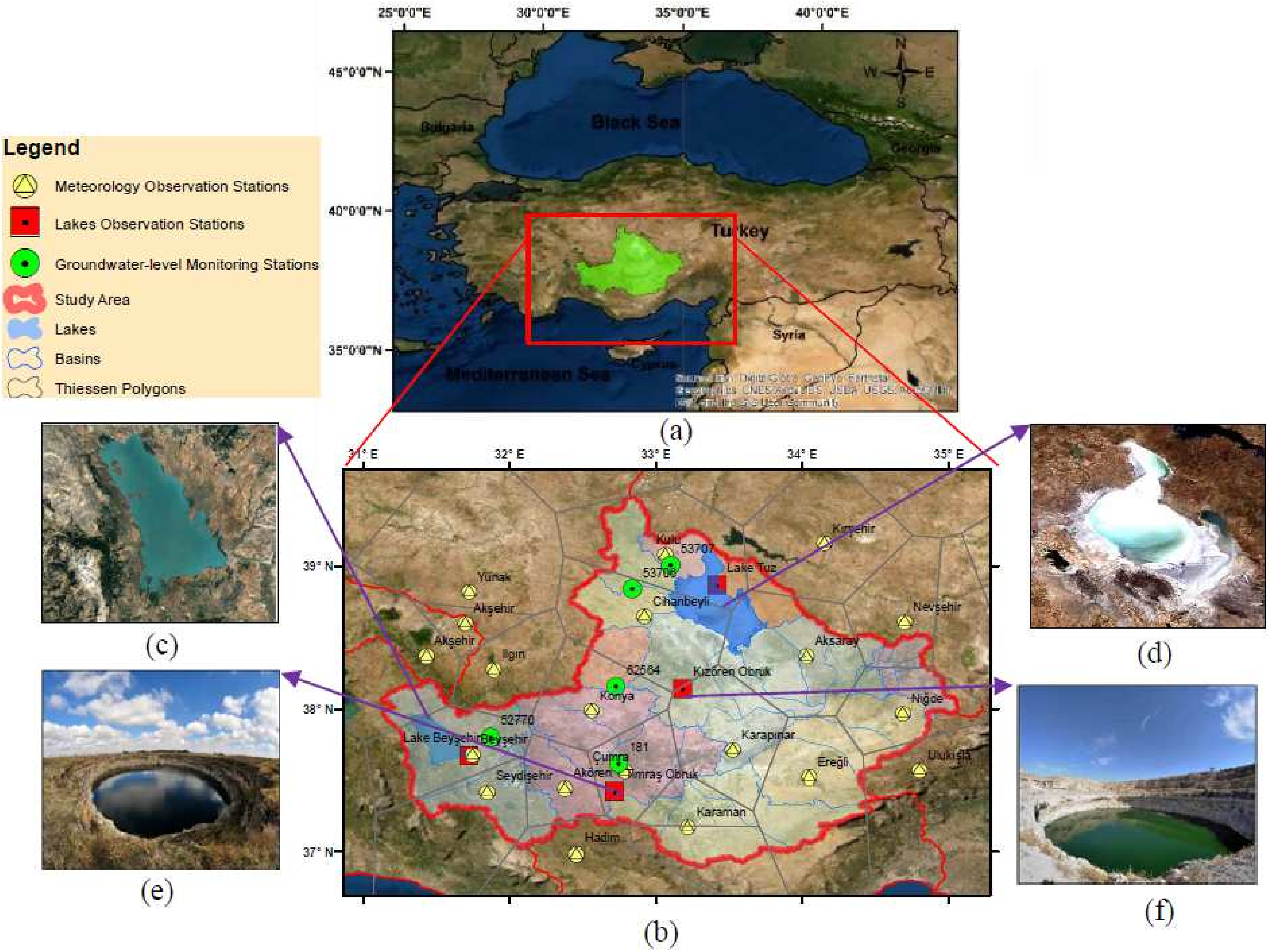

Figure 1

The study area (a), Thiessen polygon in the study area (b) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

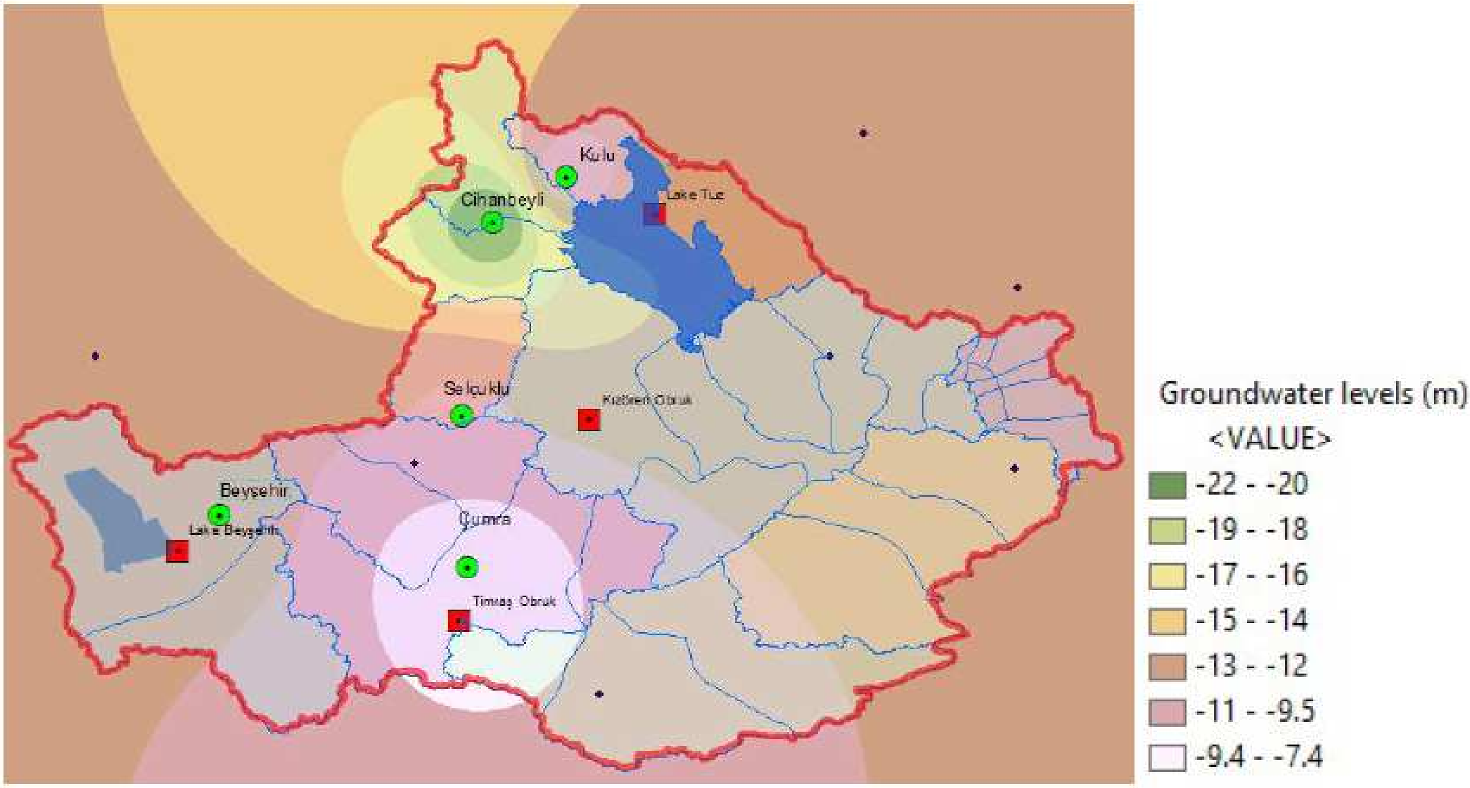

Figure 2

Distribution of long-term average groundwater levels Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

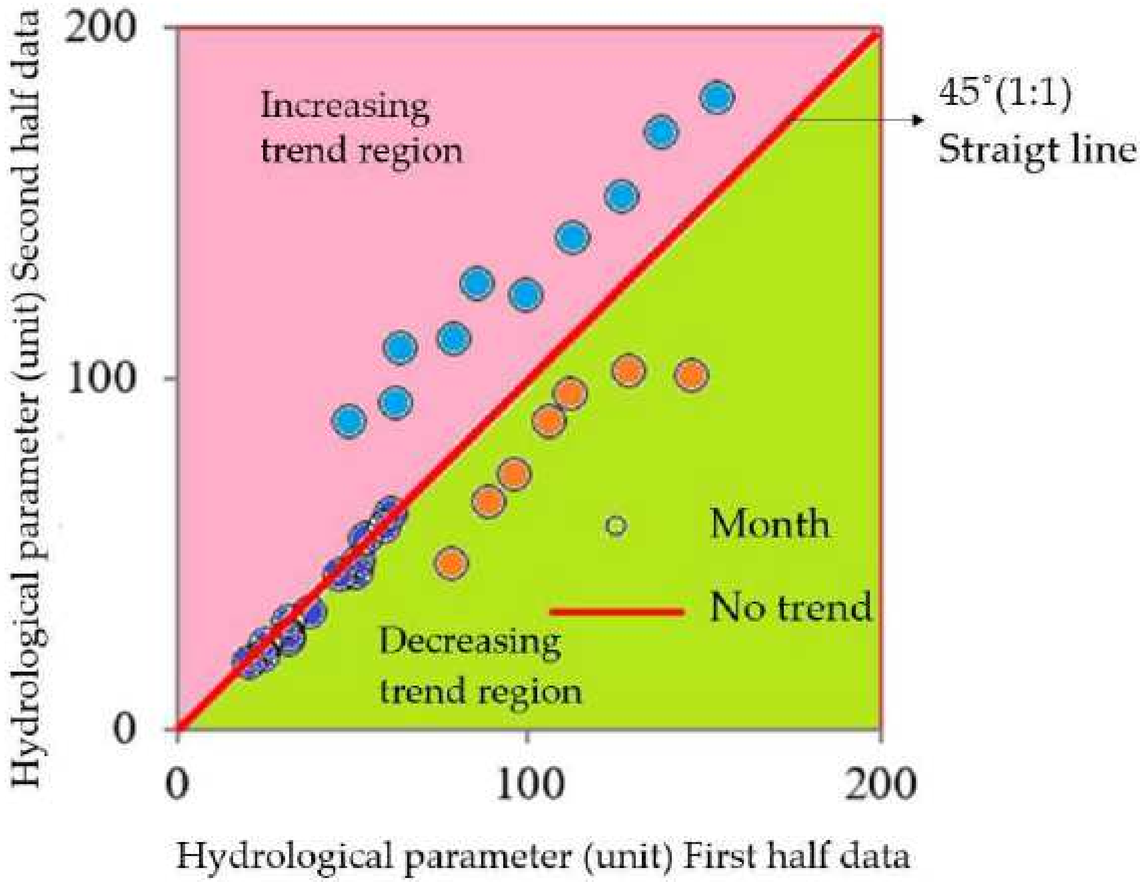

Figure 3

Decreasing and increasing trends versus trend-free time series (Keskin et al. 2018).

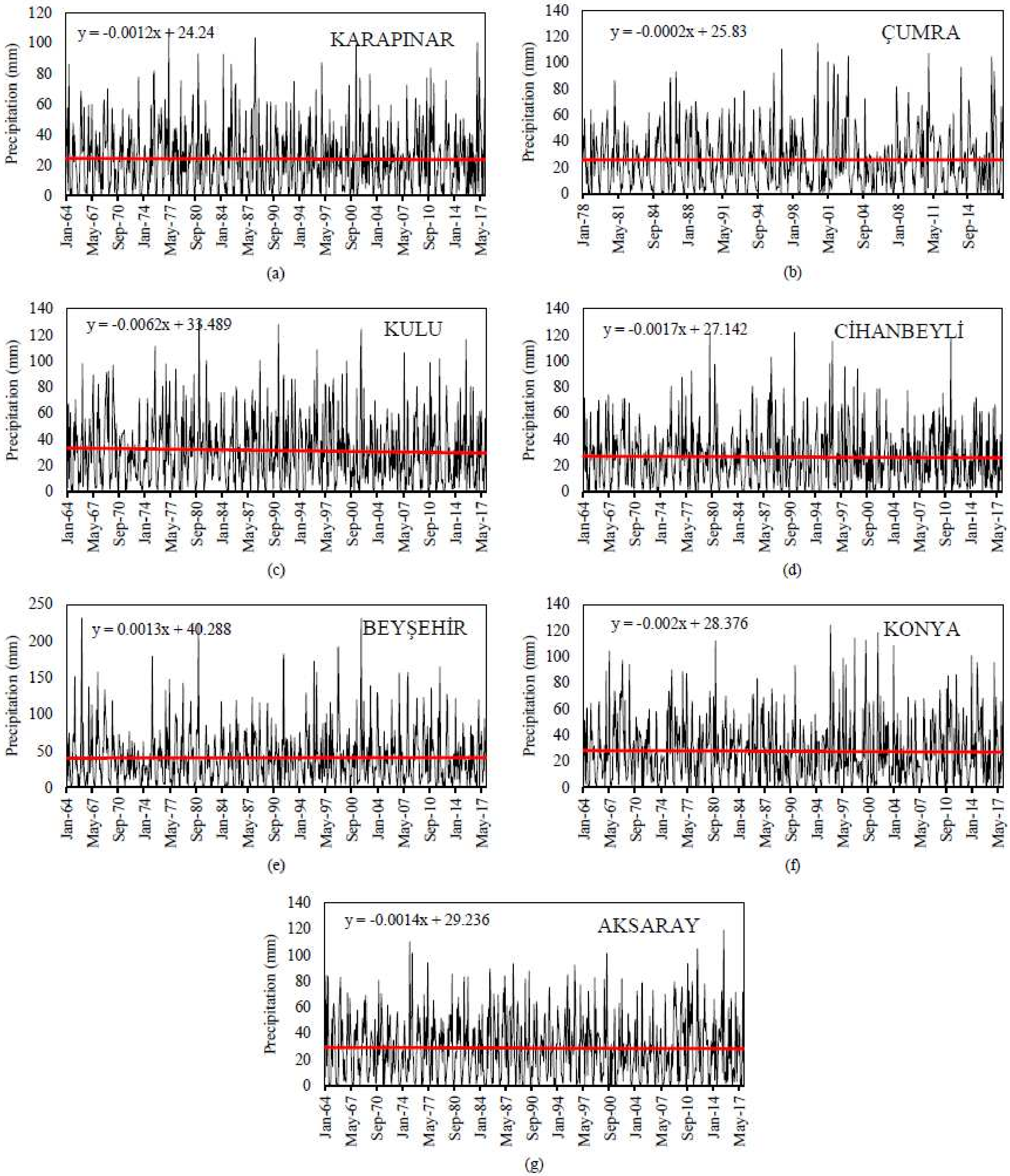

Figure 4

Time series of precipitation data; Karapınar (a), Çumra (b), Kulu (c), Cihanbeyli (d), Beyşehir (e), Konta (f), and Aksaray station (g)

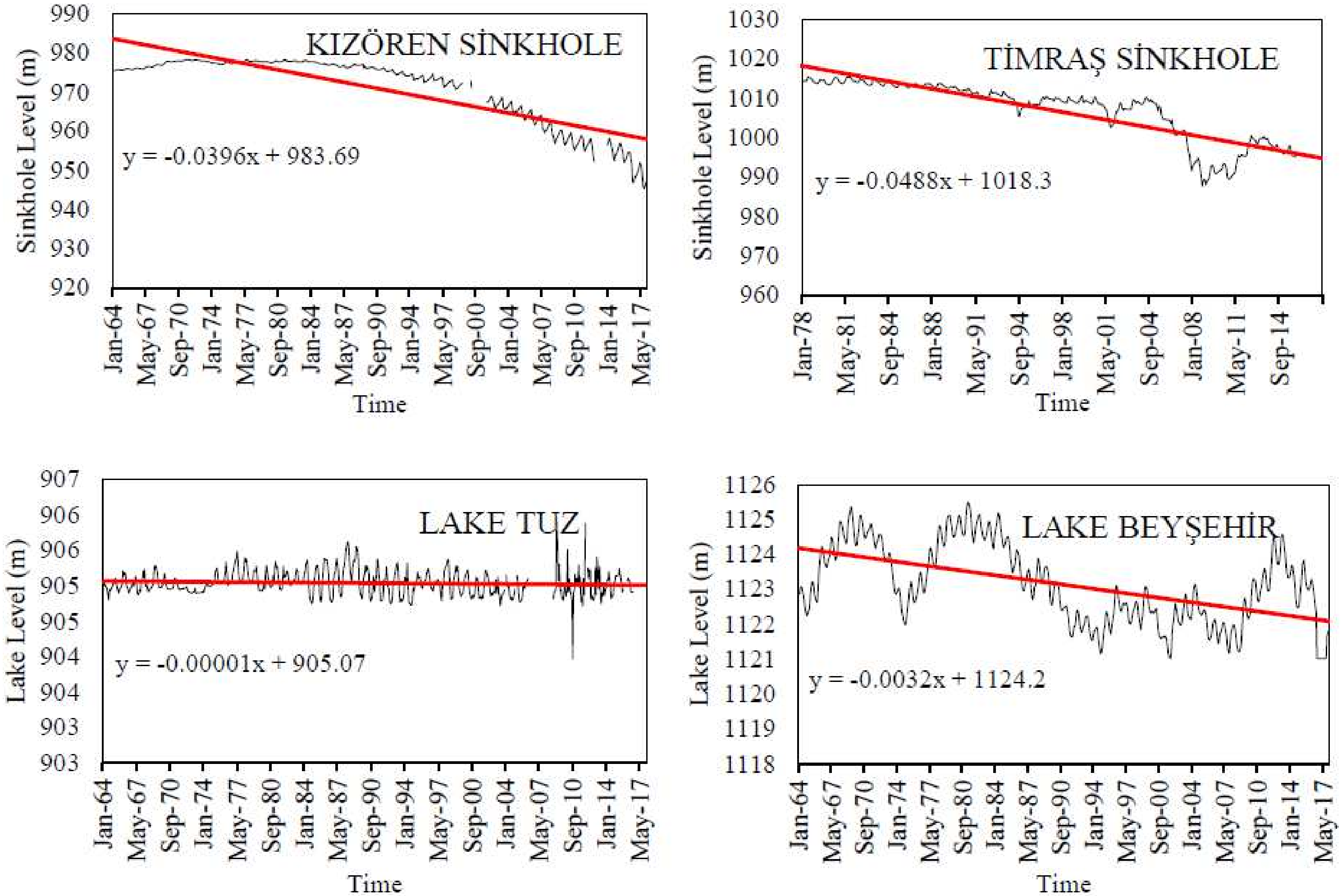

Figure 5

Time series of water level data; Kızören Sinkhole (a), Timraş Sinkhole (b), Lake Tuz (c) and Lake Beyşehir station (e)

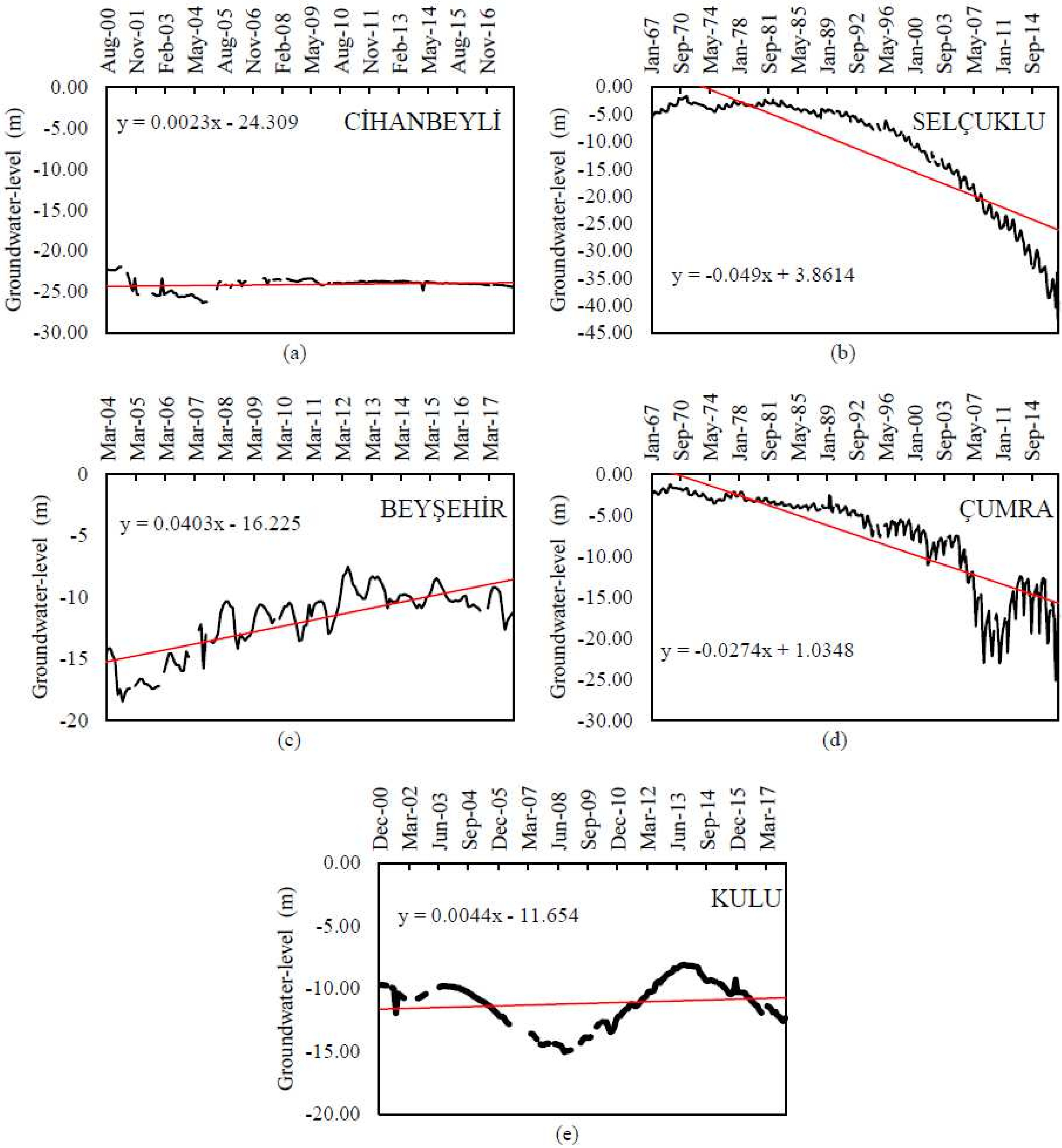

Figure 6

Time series of groundwater level data; Cihanbeyli (a), Selçuklu (b), Beyşehir (c), Çumra (d) and Kulu groundwater-level observation station (e)

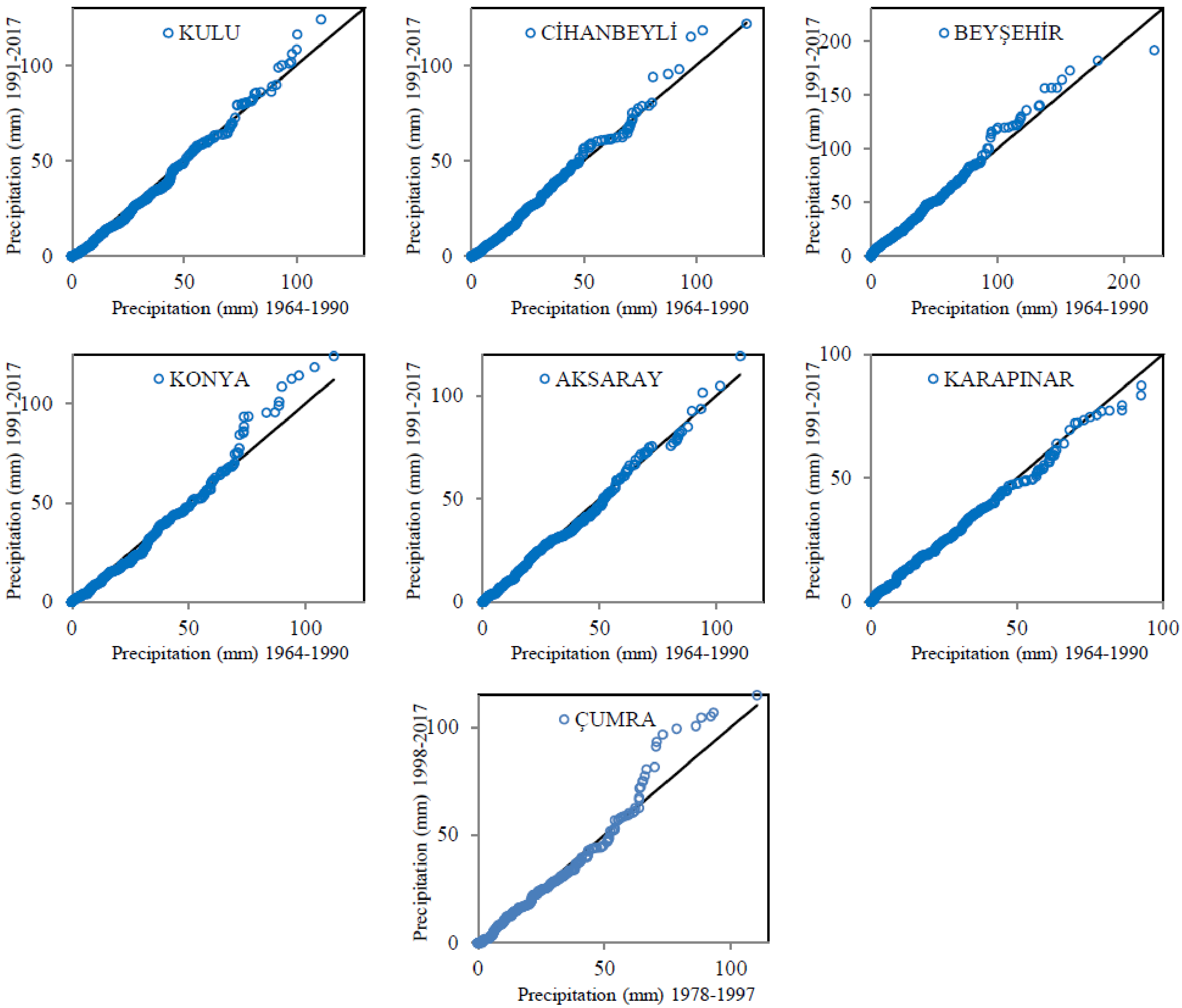

Figure 7

ST graphical results for precipitation stations

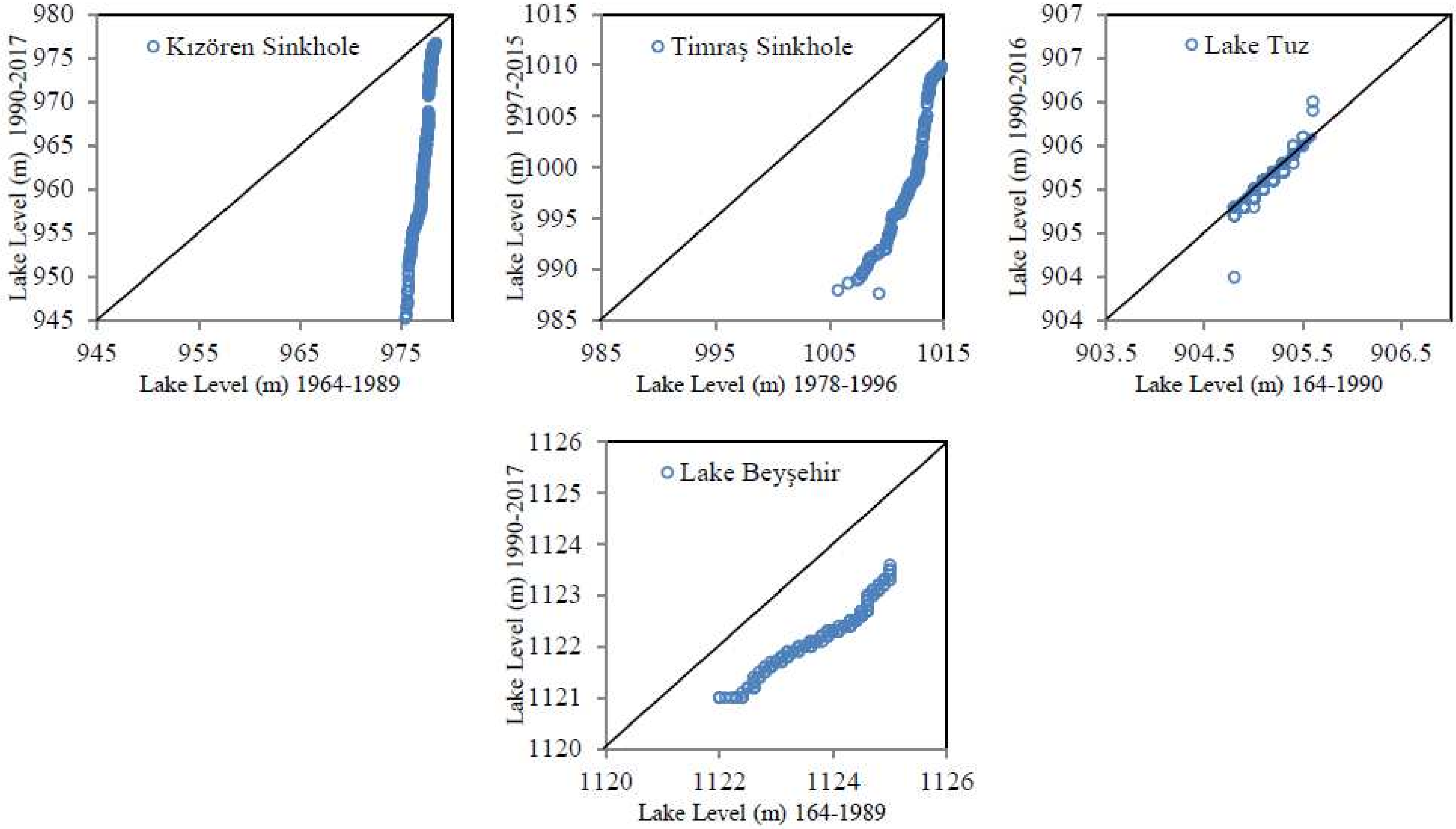

Figure 8

ST graphical results for lake and sinkhole stations

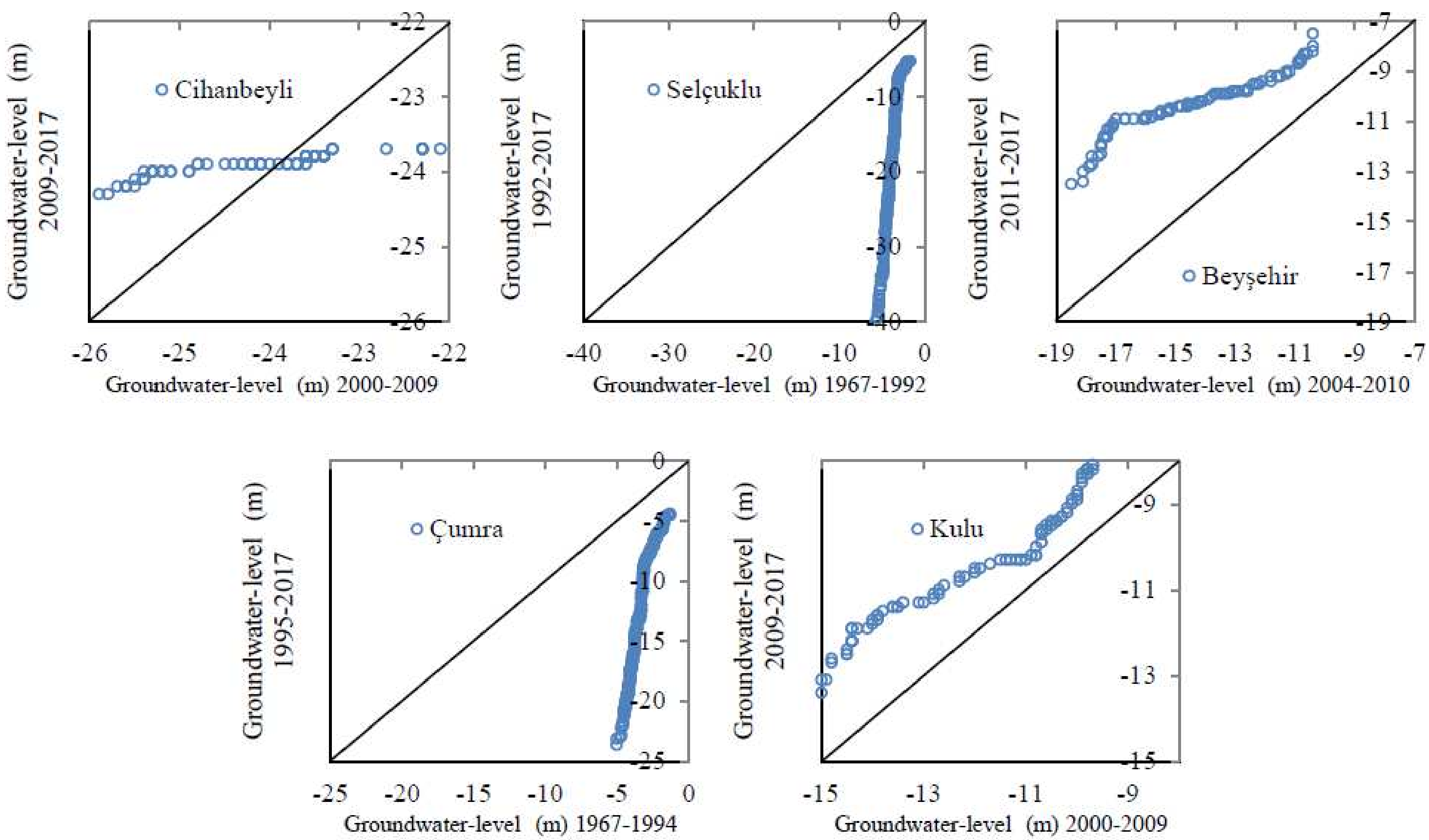

Figure 9

ST graphical results for groundwater level observation stations

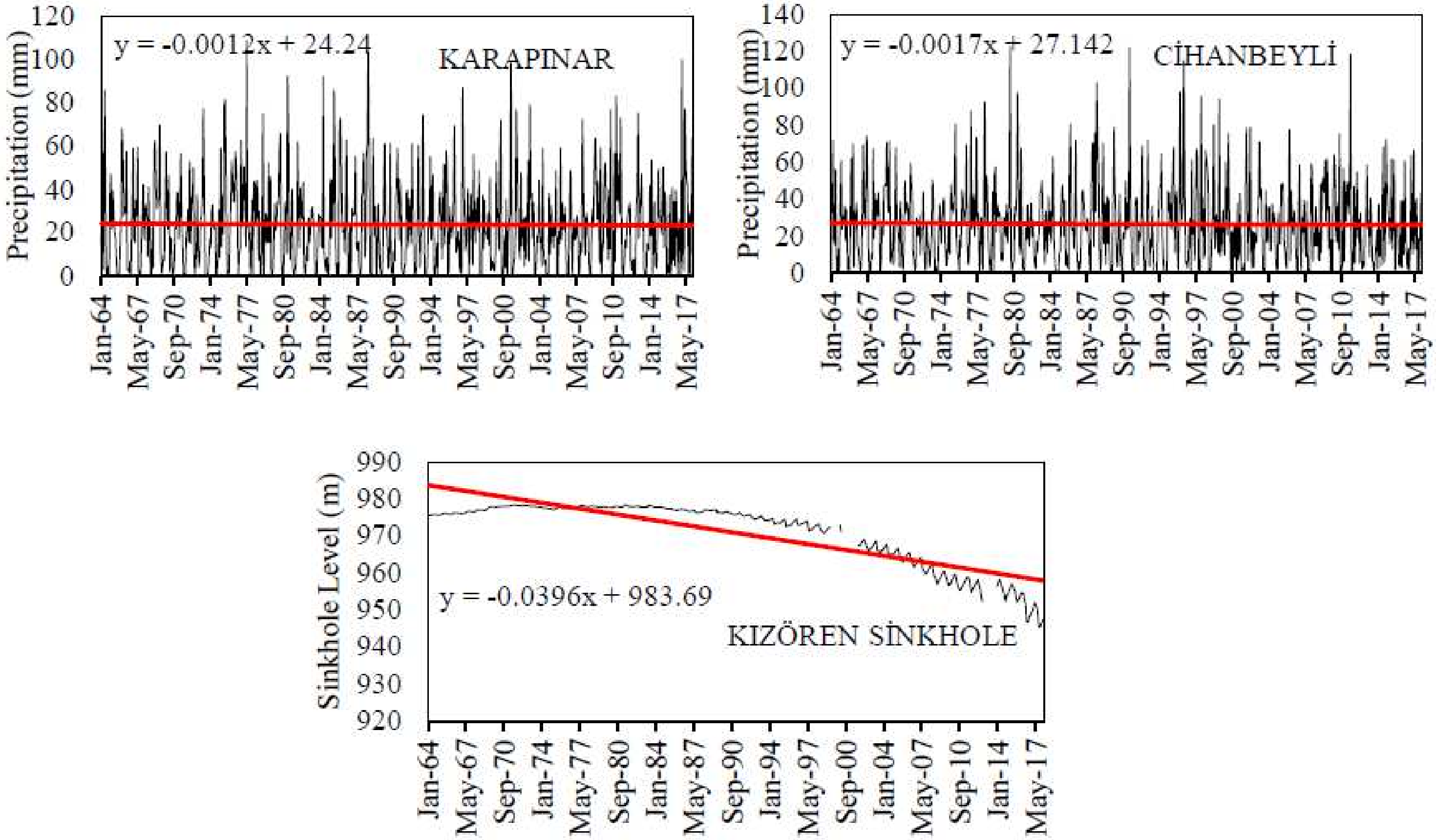

Figure 10

The graph of Kızören sinkhole, Cihanbeyli and Kulu stations in the same periods

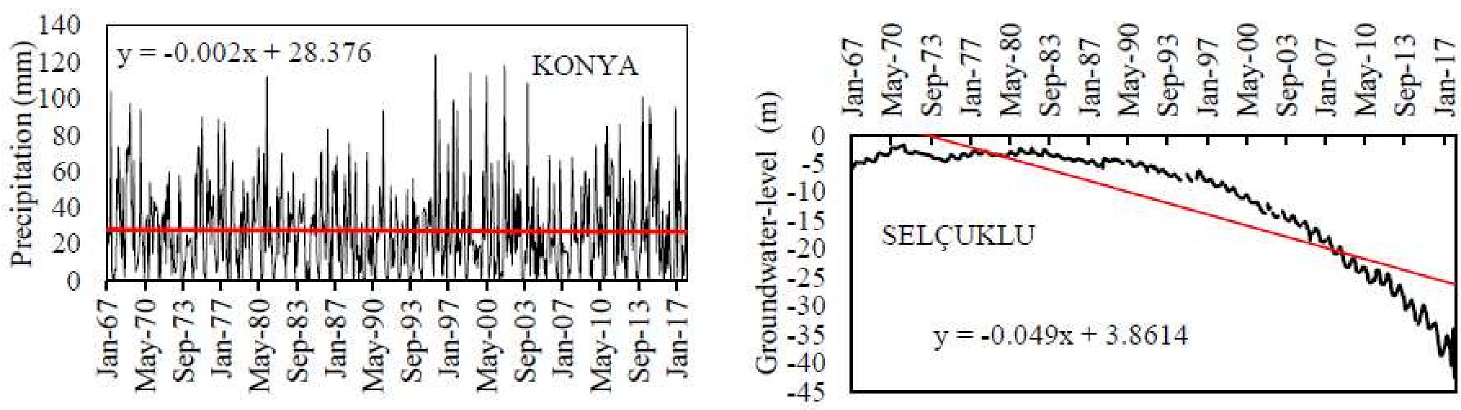

Figure 11

The graph of Konya precipitation station and Selçuklu groundwater level observation station in the same periods

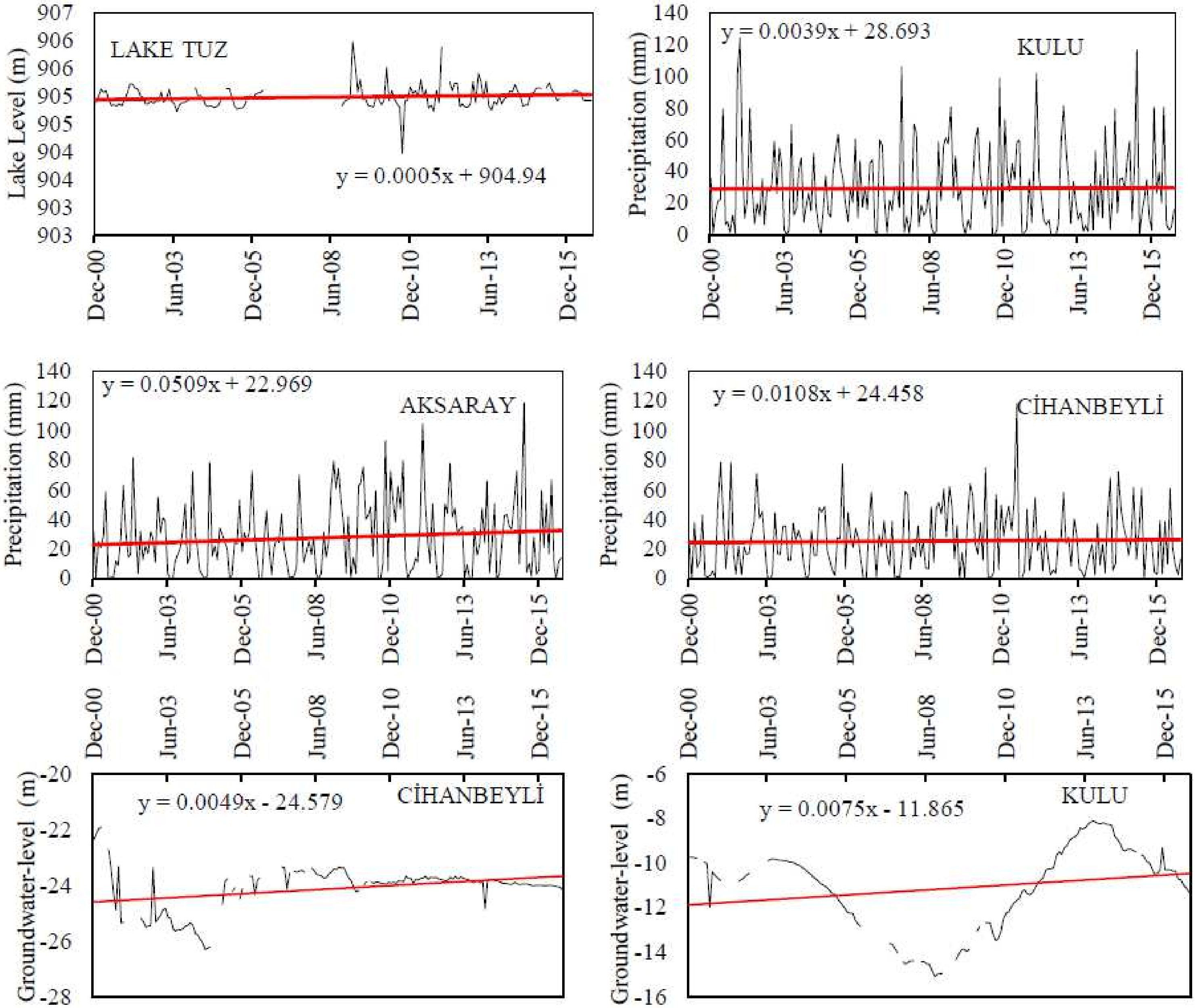

Figure 12

The graph of Lake Tuz, Cihanbeyli, Kulu and Aksaray precipitation stations, Cihanbeyli and Kulu groundwater level observation station in the same periods

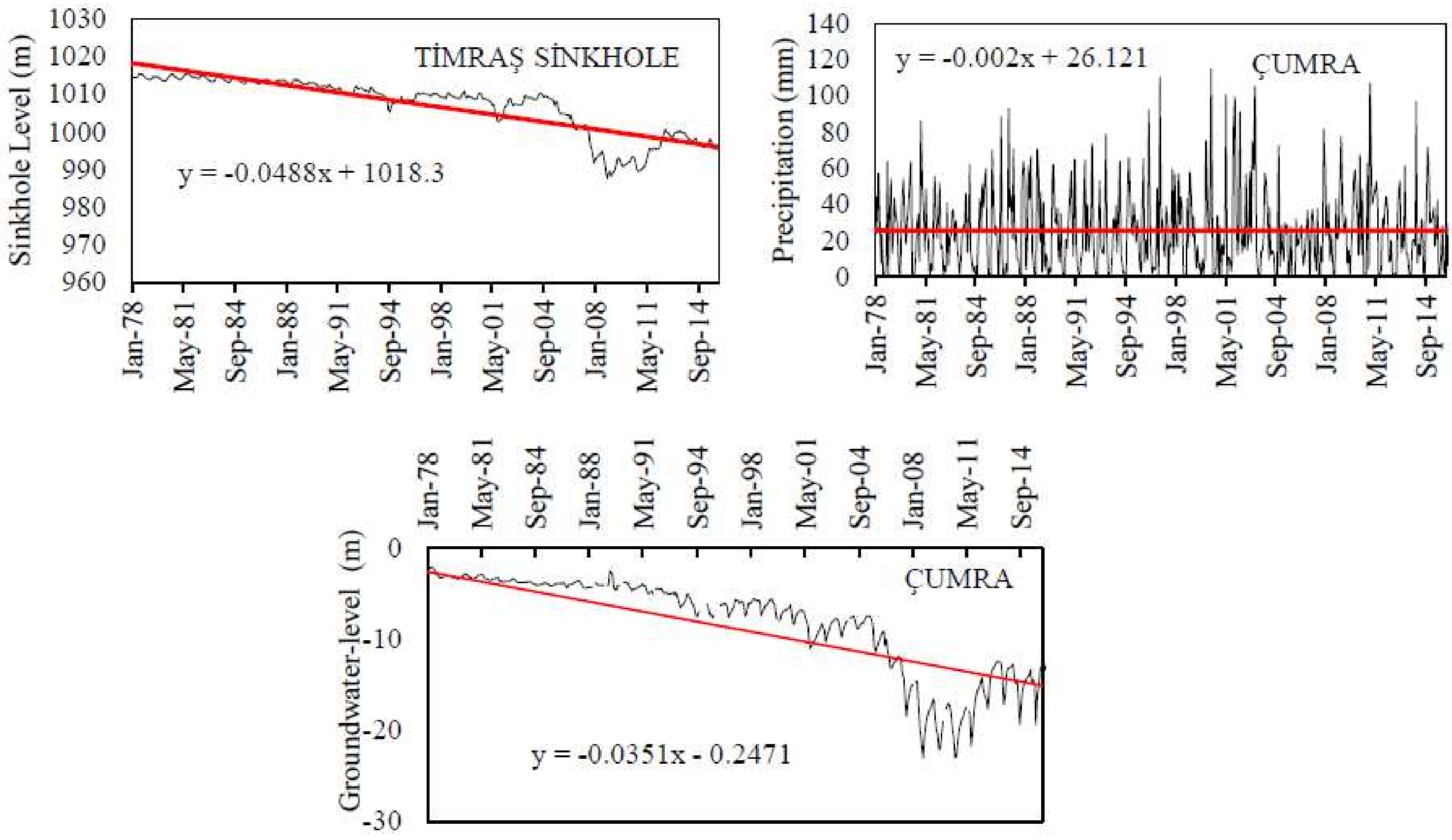

Figure 13

The graph of Timraş Sinkhole, Çumra precipitation and Çumra groundwater level observation station in the same periods

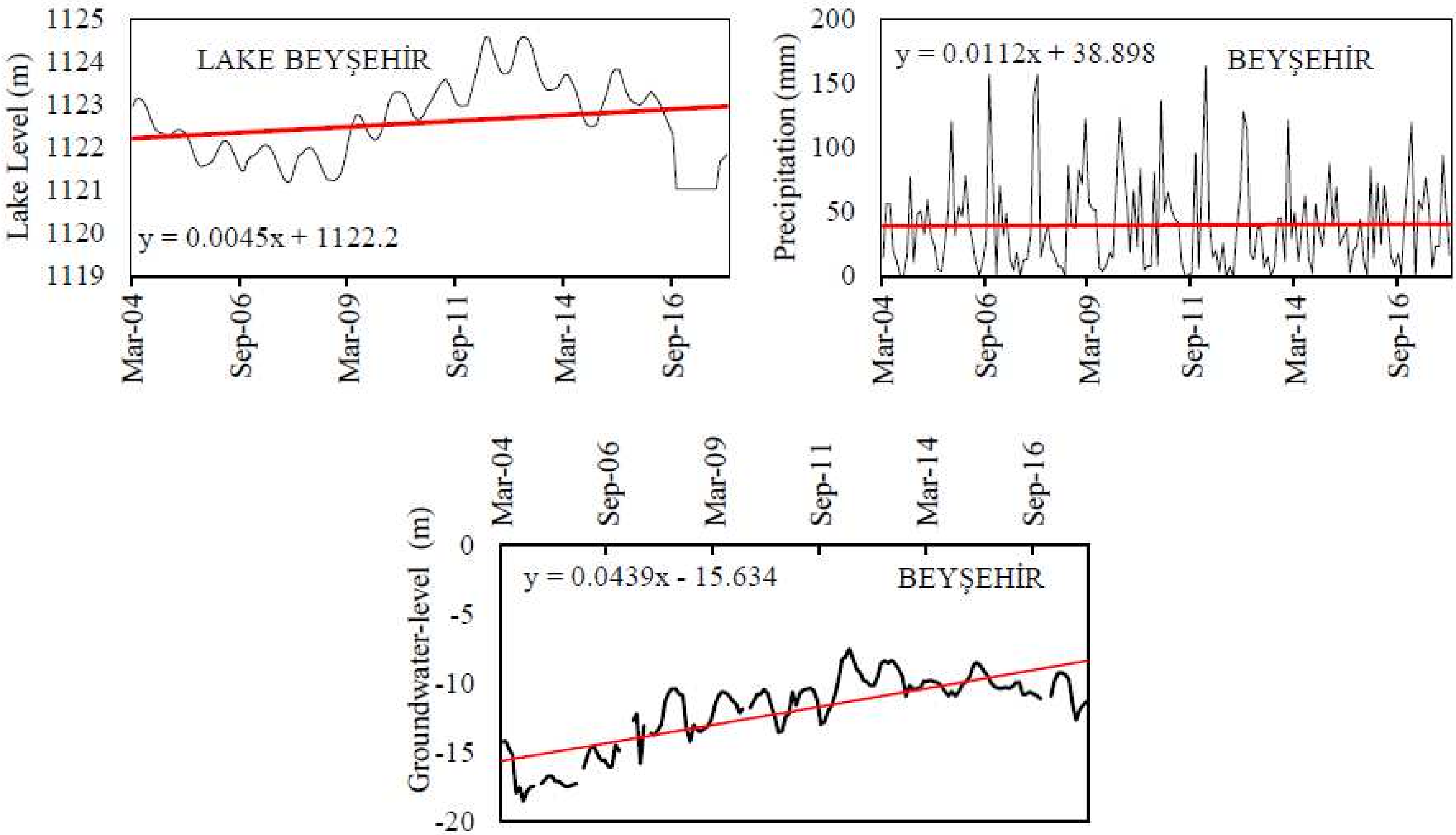

Figure 14

The graph of Lake Beyşehir Sinkhole, Beyşehir precipitation and Beyşehir groundwater level observation station in the same periods