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Trend Analysis of Meteorological Variables in the Lake Van Basin, Turkey

Nadire ÜÇLER [1,*]

[1] *Van Vocational School of Higher Education, Van Yuzuncu Yil University, Van, 65040, Turkey,* ***ORCID:*** *0000-0001-6407-121X*

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Abstract

Climate change is one of the most important issues of our century and its effects are manifested in different ways around the world. In this study, both the aligned and the intra-block methods were used to detect trends to see climate change's impact. 6 meteorological parameters were selected in the Lake Van basin, which contains Turkey's largest lake. The 47-year time series of mean monthly temperature (°C), total monthly rainfall (mm), mean monthly relative humidity (%), total monthly surface evaporation (mm), mean monthly snow depth (cm), and total monthly insolation intensity (cal/cm^2) parameters of 15 stations in the basin were evaluated for each month using non-parametric tests. In the series in which a statistically significant trend was detected, the beginning year and slope of the change were also determined. For the temperature parameter, the increasing trends were detected at all seasons. In the total monthly rainfall series, the upward trends were determined in March and September in the northeastern part of the basin. Upward trends were detected in the average monthly relative humidity series in winter. From the total monthly insolation intensity time series, autumn and spring were determined to have increasing trends. The trend analysis of mean monthly snow depth showed that there were downward trends in November and February. For the evaporation parameter, a decreasing trend was detected only in October.

1. Introduction

As a result of climate change, the increase in surface temperature, rise in sea level, deterioration in the water cycle, decrease in glaciers, changes in ecosystems, and excessive salinization in agricultural soils are becoming common problems in many countries. While factors such as the current growth rate and water consumption habits put significant pressure on water resources, climate change affects especially the hydrological cycle, spatial and temporal distribution of water. Additionally, with the impact of climate change on the hydrological cycle, there may be more variability in precipitation and water flows, and the intensity of extreme hydrological events may increase. In this case, significant changes are estimated to occur in the supply and quality of water resources. These changes will negatively affect energy, health, tourism, transportation, flood and drought events, and ecosystem integrity, including drinking use and agricultural production, where water is vital. Therefore, the assessment of the climate change effect has recently received great concern.

Since changes in the seasonal distribution and amount of precipitation are among the main effects of climate change, numerous studies have been conducted to detect these changes throughout the world over the years. For instance, Serrano et al. [1] analyzed total monthly and annual precipitation data for the Iberian Peninsula using the Mann-Kendall test for trends. Duhan and Pandey [2] studied annual and seasonal records to detect the trend of precipitation in Madhya Pradesh, India. Monotonic trend direction was detected by the Mann–Kendall test and Sen's slope estimator test was applied to detect the magnitude of a trend over time. Limsakul and Singhruck [3] applied Kendall's slope estimator to detect trends in the precipitation records of Thailand during 1955–2014. The Mann–Kendall test and Modified Mann–Kendall test were applied to ascertain the trends in rainfall and temperature values in India [4]. The Mann-Kendall test and the Sen's T test were applied to the precipitation records of Turkey to detect variability [5]. In addition, temperature [6-9], humidity [10,11], snow depth [12,13], evaporation [14,15], and sunshine [16,17] are among the parameters that are

* Corresponding Author: nadireucler@yyu.edu.tr

worth examining.

Because of its geographical location, Turkey is among the countries that will be influenced significantly by climate change, and it has already experienced an increased rate of sudden rains, floods, and drought [18]. For example, as a result of heavy rains in the Western Black Sea region of Turkey on August 11, 2021, floods occurred in the cities of Bartın, Kastamonu, and Sinop and eleven people lost their lives [19]. Besides floods, Turkey is under the threat of desertification and drought due to its climatic characteristics and topographic structure. Considering the winter season and the annual precipitation changes in Turkey, the most severe and widespread drought events occurred in 1971-1974, 1983-1984, 1989-1990, 1996, 2001, and 2007-2008 [20]. Considering the 30 years, annual maximum rainfall data by 2010 in Turkey, Mann-Kendall and linear regression trend test results specified that about 90% of them are trend-free while the increasing and decreasing trends are around 10 % and 2%, respectively [21].

Due to the decreasing precipitation amounts and drought reasons, decreases are observed in the water levels of the lakes in Turkey [22]. For instance, the results of a study on Lakes Mogan and Eymir located in Central Anatolia indicated that precipitation and temperature have a significant effect on the lakes' levels, and an estimated rise in temperature and reduction in precipitation in the future may cause the drying of both lakes [23]. Additionally, in another study, besides temperature, and precipitation; wind speed, cloud cover, humidity, sunshine duration, and pan evaporation parameters were also examined to understand the mechanism of the variations of the levels of these lakes [24].

To see the climate change-induced changes in hydro-meteorological parameters in the Kizilirmak basin, the precipitation, temperature, streamflow, and groundwater data were analyzed using linear regression and Mann–Kendall, modified Mann–Kendall, and Spearman's Rho tests. According to the results, generally decreasing trends were observed in streamflow, and the majority of the stations had increasing trends in groundwater levels [25].

As there is a hydrologic relationship between water resources and meteorological parameters, learning more about the long-term trends of meteorological parameters is crucial for sustainable water resource management [26]. The Van Lake basin, chosen as the study area, is an important region in terms of hosting the largest lake in the country. For this reason, it is important to investigate the effects of climate change in this region, take the signals of possible extreme meteorological events in advance, and consider the necessary precautions. Therefore, almost all meteorological parameters with long-term data in the basin were used. Furthermore, both intrablock and aligned rank types have been applied and the results were compared by applying three different methods to determine the trend. The severity of climate change was investigated by determining the inclinations of trends. Trend starting years were determined to compare with previous and next studies.

2. Materials and Methods

2.1. Study Area

Lake Van is the largest soda lake in the world located in Eastern Anatolia, Turkey (Figure 1). High salinity prevents the usage of lake water for drinking and irrigation purposes. Rainfall, stream flows, and snowmelt feed the lake and there is no artificial or inartificial outlet except evaporation. The change in meteorological variables directly affects the lake level. The Lake Van basin is one of the most important basins of Turkey with a 1788007-hectare area.

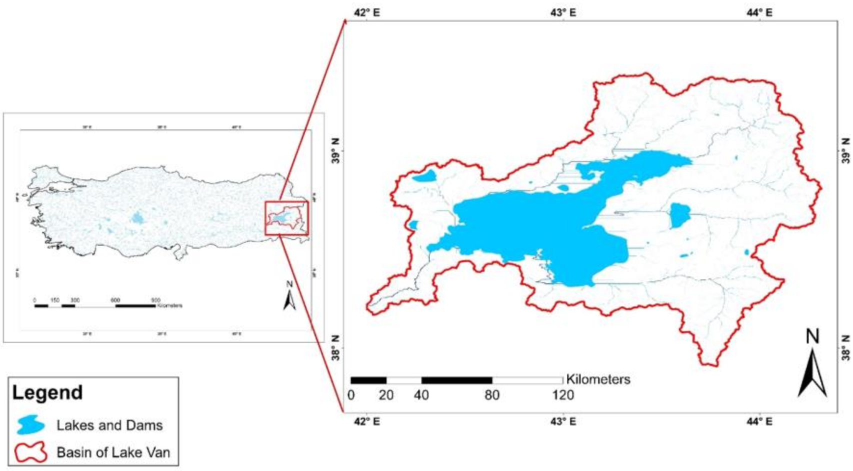

Figure 1. Map of Turkey and Lake Van basin.

2.2. Data

The methods were applied to the time series of meteorological variables obtained from the Turkish State Meteorological Service to reflect regional hydroclimatic conditions. The time series of five rainfall (mm) stations (Ercis, Baskale, Ozalp, Muradiye, Gevas), four temperature (℃) stations (Tatvan, Ahlat, Van, Muradiye), three relative humidity (%) stations (Tatvan, Ahlat, Van), one insolation intensity (cal/cm^2) station (Van), one snow depth (cm) station (Van) and one evaporation (mm) station (Van) were used to detect a trend. Locations of stations have been shown in Figure 2. All stations have continuous records for the period of 47 years (1970–2016) on a monthly basis except the Gevas-rainfall, Van-insolation intensity, and Van-snow depth station which have 37 years' worth of records from 1980 to 2016.

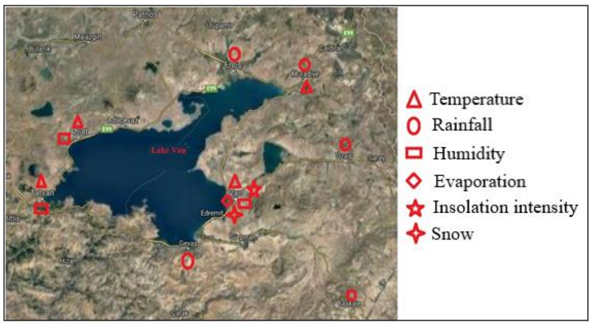

Figure 2. Location of stations used in the study.

Before the application of the tests, outliers were investigated for all meteorological variables at each station and month. Although outliers were found in almost every variable, especially in the rainfall variable, it was preferred to use raw data instead of extracting outliers, since these values were not so extreme as to be considered to cause incorrect measurements or incorrect recordings.

2.3. Methodology

Classical parametric methods have some assumptions such as normality, linearity, and independence while general meteorological data do not have these characteristics due to missing values or seasonality. Therefore, several more flexible nonparametric tests that can cope with these problems more easily in meteorological records have been used for trends. Van Belle and Hughes [27] defined two types of methods namely intrablock and aligned ranks. Intrablock methods calculate the statistics for each block and then sum up these to create the overall statistics. Aligned ranks at the beginning move away from the block impact of data and then sum the data over blocks, and finally use these sums to generate statistics. In this study, the results are compared using intrablock and aligned rank methods respectively. The methodology is summarized in Figure 3. The first step is applying the Sen's T test, Seasonal Mann-Kendall test and Spearman's Rho test for specifying trends. The second step is estimating slopes of time series with Sen's estimator and the last one is using Mann-Kendall Rank Correlation test for estimating the starting year of possible climate changes.

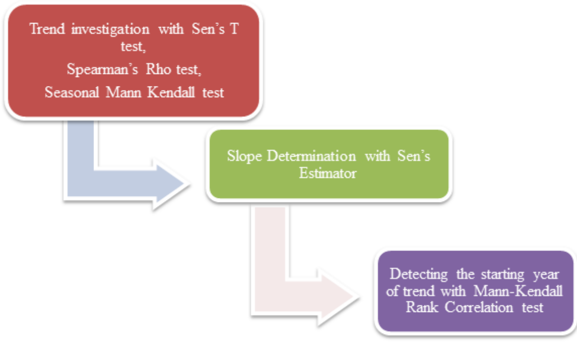

Figure 3. The methodology of study.

2.3.1. The Sen's T test

The Sen's T Test, an ordered rank test, was originally propounded by Sen in 1968 and was improved by Farrell in 1980 [28]. The test statistics, which are independent of the distribution and are not affected by seasonal events, can be calculated in the following order of operation.

X_{ij} is the variable value measured at the observation station.

here;

i: years (i = 1, 2, ..., n) and j: months (j = 1, 2, ..., 12).

The average for j (months) is calculated with equation 1.

$$X_{.j} = \frac{\sum_i X_{ij}}{n} \quad (1)$$

The average for each month is calculated and afterward removed from corresponding months in the n-year data. Therefore, the seasonal effects are eliminated.

The order of all differences from 1 to 12xn is calculated with the following equation 2.

If the results have the same value (bindings), the average of the rank values should be taken.

$$R_{ij} = Rank(X_{ij} - X_{.j}) \quad (2)$$

The average of the ranks is calculated by implementing equation (3) for each month.

$$R_{.j} = \frac{\sum R_{ij}}{n} \quad (3)$$

Finally, the Sen's T test statistics are calculated with (4). (Here m = 1)

$$T = \left[\frac{12m^2}{n(n+1)\sum_{i,j}\left(R_{ij}-R_{.j}\right)^2}\right]^{\frac{1}{2}}\left[\sum_{i=1}^{n}\left(i-\frac{n+1}{2}\right)\left(R_{i.}-\frac{nm+1}{2}\right)\right] \quad (4)$$

If the value of the statistical test $|T|$ is larger than the normal distribution value z, which is determined at the significance level α, the zero (H_0) hypothesis is that there is no trend rejected and the alternative hypothesis (H_1) claims that there is a certain trend accepted.

2.3.2. The Spearman's rho test

This test is used to determine whether there is a correlation between two observation series. It is a quick and simple test to investigate the presence of linear trends and is a metric based on sequence statistics. The rank statistic R (x_i) is determined by the order of the data from small to large or the other way around.

The observation series is represented by the vector X = (x_1, x_2, ..., x_n). According to the H_0 hypothesis, x_i (i = 1, 2, 3, ..., n) are all equally probable distributions. According to the H_1 hypothesis, x_i (i = 1, 2, 3, ..., n) values increase or reduce with time. Spearman's Rho test statistic, r_s, is calculated using the following equation.

$$r_s = 1 - 6\frac{\left[\sum_{i=1}^{n}\left(R(x_i-i)^2\right)\right]}{(n^3-n)} \quad (5)$$

Here:

(x_i): i. the sequence number of the observation.

i: the observation sequence of the data.

n: total observation adjective [29].

Spearman has given a table of maximum r_s values that show no correlation between rank numbers at a given significance level. Since the r_s distribution for n> 30 approaches normal, normal distribution tables can be used for hypothesis testing [30]. Therefore, the test statistic for r_s is found.

$$z = r_s\sqrt{1/(n-1)} \quad (6)$$

If the value of z is bigger than the value of z defined from the standard normal distribution tables at the significance level α, the hypothesis that the xi values are homogeneous is rejected, and the hypothesis that there is a specific trend is accepted.

2.3.3. The seasonal Mann–Kendall test

Hirsch and Slack [31] analyzed nonparametric trend tests applied to serially dependent seasonal data and proposed the Seasonal Mann-Kendall test and the modified Mann-Kendall test for the trend. They proved the superiority of this test against the serially dependent Monte Carlo Experiment.

For X = (x_1, x_2, ..., x_{12}) and X_i = (x_{i1}, x_{i2}, ..., x_{in}) arrays; X represents the observed values for each month and X_i represents the annual values for the i-th month; according to the H_o hypothesis, X is an example of the independent random variable x_{ij} while X_i (i = 1, 2, 3, ..., 12) is a sub-sample of independent and coarse random variables. According to the alternative hypothesis, sub-examples do not have a uniform distribution. Before the Seasonal Mann-Kendall test statistics are calculated, the test statistics are calculated separately for each month with the following equations.

$$S_i = \sum_{k=1}^{n_i-1}\sum_{J=k+1}^{n_i} sgn\left(x_{ij}-x_{ik}\right) \quad (7)$$

$$sgn\left(x_j-x_k\right) = \{\left(x_j-x_k\right) > 0 \rightarrow +1 \; \left(x_j-x_k\right) = 0 \rightarrow 0 \; \left(x_j-x_k\right) < 0 \rightarrow -1 \quad (8)$$

The variance of the test statistic S_i which has an asymptotically normal distribution and with zero mean is calculated by the following equation.

$$Var(S_i) = \frac{n_i(n_i-1)(2n_i+5)}{18} \quad (9)$$

In the case of similar values (ties) in each month, the following equation is used instead of the variance (Var) calculation.

$$Var(S_i) = \frac{n_i(n_i-1)(2n_i+5)-\sum_{t_i} t_i(t_i-1)(2t_i+5)}{18} \quad (10)$$

After the individual test statistics and variance calculations are made for each month, the Seasonal Mann-Kendall test statistic S' is defined with the equation (11). The variance of the test is found by equation (12).

$$S' = \sum_{i=1}^{12} S_i \quad (11)$$

$$Var(S') = \sum_{i=1}^{12} Var(S_i) + \sum_{i=1}^{12}\sum_{j=1}^{12} cov\left(S_i, S_j\right) \quad (12)$$

S_i and S_j are functions of independent random variables such that S_i = f (X_i) and S_j = f (X_j). Since all X_i and X_j values are independent i and j monthly data, the covariance term in (12) is neglected. Hence, the variance is calculated by (13).

$$Var(S') = \sum_{i=1}^{12} Var(S_i) \quad (13)$$

Once the monthly variance values are calculated using equations (9) or (10), the variance of the Seasonal Mann-Kendall test statistic is calculated by equation (13). Whether the Seasonal Mann-Kendall test is important is determined by comparing the standard normal variable z with the critical z value by calculating the following equation [26].

$$z = \{S' > 0 \ \rightarrow \ \frac{S'-1}{\sqrt{Var(S\prime)}} \ S' = 0 \ \rightarrow \ 0 \ S' < 0 \ \rightarrow \ \frac{S'+1}{\sqrt{Var(S\prime)}} \quad (14)$$

Accordingly, if the value of $|z|$ less than or equal to the value of $z_{\alpha/2}$ determined from the standard normal distribution tables at the α significance level, the H_o hypothesis is accepted, otherwise, it is rejected. If the calculated S' value of the Seasonal Mann-Kendall test is positive, it is an upward trend, while if negative it is a downward trend.

2.3.4. The Sen's estimator

Linear slopes of the trends (change in unit time) were calculated using a nonparametric method introduced by Sen [27]. This method is not affected by datum failures or deficient values. xj and xk, are the data at times j and k respectively; Q_i (i = 1, 2, ..., N) is a parameter and is calculated according to the equation (15). Then, the Q_i values are sorted from the smallest to the largest.

$$Q_i = \frac{x_j - x_k}{j-k} \quad (15)$$

After the determination and sequencing of the Qi values, the median is estimated by computing the following steps; if the number N is odd, the change in the unit of observation is determined by using the equation (16); if the number N is even, the equation (17) is used for determining the change in the unit of observation.

$$Q = \left\{Q_{(N+1)/2}\right\} \quad (16)$$

$$Q = \left\{\frac{1}{2}\left[Q_{(N)/2} + Q_{(N+2)/2}\right]\right\} \quad (17)$$

The statistical significance of the Q value at 100(1-alpha) % is performed by computing the two-sided test.

2.3.5. The Mann-Kendall rank correlation test

This non-parametric test is used to find whether the applied series has an upward or downward trend over time. The test, which graphically expresses the results, can also detect the starting year of the trend. Since three different tests were used to determine whether there was a trend in this study, and the results were supported by the slope method, the Mann-Kendall Rank Correlation test was performed to detect the trend starting year.

In this test, the rank (y_i) in the series is used instead of the actual data. Each y_i is defined by an integer number such as n_i, counting the largest of the previous ranks. If the consecutive sums of these integers are denoted by t, it is defined as:

$$t = \sum_{i=1}^{n} n_i \quad (18)$$

The mean E(t) and the variance Var(t) of that, and the Mann-Kendall test statistic u(t) are calculated using the equations (19), (20), and (21) respectively [32].

$$E(t) = \frac{n(n-1)}{4} \quad (19)$$

$$t \ = \frac{n(n-1)(2n+5)}{72} \quad (20)$$

$$u(t) = [t - E(t)]/\sqrt{t} \quad (21)$$

u′(t) is calculated backward in the series similar to u(t). Graphically, u(t) and u′(t) converge at the spot where the change begins and then move away from each other and show where the trend begins. If there is no trend in the series, u(t) and u′(t) will approach each other several times and make close oscillations.

3. Results and Discussion

Trend-detected stations and months, test statistics, trend results, trend slope values, and trend-starting years are given separately for each parameter in tables. If the absolute value of the test statistic values is greater than the 5% significance level value (±1.96), it is concluded that there is a trend. The sign of the Seasonal Mann-Kendall test statistic gives information about the trend direction. If the test statistic value is negative, the trend is downward and if it is positive, it is upward. Likewise, if the slope value is negative, it means that the trend is downward, and if it is positive, it means that the trend is upward.

3.1. Results of Tests in Temperature Parameter

Table 1 shows stations, slope values, and trend-starting years of the temperature parameter. It is seen from the results that Sen's T and Spearman's Rho tests yield almost the same results. Although the Seasonal Kendall test did not detect the trend at Tatvan station in January, as Sen's T test and Spearman's Rho test detected trends at this station, these two tests' results were considered. Trends were determined in a span of 10 months. A trend was not detected in September and November. Only in June and August, the trend was determined at Ahlat station. All trends were an increasing direction. The slope values ranged between 0.028 and 0.094. The highest slope was determined at the Van station in February. The trend beginning years varied between 1978 and 2012.

Table 1. Results of the trend tests for the parameter of temperature.

Months	Stations	Sen's T	Spearman's Rho	Seasonal Mann-Kendall	α= % 5	Trend	Slope Value	Slope Starting Year
January	Tatvan	-2.09	-2.12	1.54	±1.96	upward	0.034	1978
	Van	-3.29	-3.31	2.71	±1.96	upward	0.082	1984
	Muradiye	-2.93	-3.04	2.50	±1.96	upward	0.066	1993
February	Van	-3.27	-3.34	3.03	±1.96	upward	0.094	1998
	Muradiye	-3.39	-3.34	3.13	±1.96	upward	0.085	1998
March	Van	-2.61	-2.65	2.55	±1.96	upward	0.058	2006
	Muradiye	-2.34	-2.31	2.36	±1.96	upward	0.078	2003
April	Van	-2.46	-2.48	2.49	±1.96	upward	0.040	2012
May	Van	-2.65	-2.70	2.75	±1.96	upward	0.040	2008
June	Tatvan	-3.15	-3.19	3.07	±1.96	upward	0.040	1997
	Ahlat	-2.51	-2.46	2.22	±1.96	upward	0.033	1998
	Van	-3.96	-4.08	3.94	±1.96	upward	0.050	1996
	Muradiye	-2.87	-2.96	2.97	±1.96	upward	0.046	2003
July	Tatvan	-2.89	-2.97	2.74	±1.96	upward	0.028	2007
	Van	-3.40	-3.32	3.36	±1.96	upward	0.043	1997
August	Tatvan	-3.56	-3.78	3.87	±1.96	upward	0.037	2002
	Ahlat	-2.31	-2.31	2.46	±1.96	upward	0.030	2009
	Van	-4.65	-4.80	4.85	±1.96	upward	0.064	1996
	Muradiye	-3.45	-3.56	3.87	±1.96	upward	0.050	2011
October	Van	-3.28	-3.36	3.70	±1.96	upward	0.044	1992
	Muradiye	-2.46	-2.51	3.12	±1.96	upward	0.040	1995
December	Muradiye	-2.46	-2.43	2.49	±1.96	upward	0.064	1978

The direction of temperature trends was upward across the basin in all seasons, in contrast to the study of Turkes et al. [33] which deduced that there was a cooling tendency in the last twenty years across Turkey. This result discloses the warming over the Van Lake basin due to climate change.

3.2. Results of Tests in Relative Humidity Parameter

Table 2 shows stations, slope values and trend-starting years of humidity parameter. Trends were determined in 9 months. The trend was not detected in July, October, and December. The Seasonal Kendall test did not detect the trend at the Ahlat station in February. However, Sen's T test and Spearman's Rho test detected trends at this station, so these two tests' results were considered. The trend was determined at Van station only in August. While the trends at the Ahlat station were increasing in January and February, the other trends were decreasing. The negative slope values ranged between -0.128 and -0.393. The highest slope was determined at the Tatvan station in August. The trend starting year varied between 1986 and 2013 being more common after 2010.

Table 2. Results of trend tests for the parameter of humidity.

Months	Stations	Sen's T	Spearman's Rho	Seasonal Mann-Kendall	α= % 5	Trend	Slope Value	Slope Starting Year
January	Ahlat	-2.93	-2.88	2.75	±1.96	upward	0.113	1986
February	Ahlat	-2.25	-2.29	1.90	±1.96	upward	0.090	2008
March	Tatvan	3.15	3.16	-3.25	±1.96	downward	-0.190	1992
April	Tatvan	2.63	2.62	-2.75	±1.96	downward	-0.211	2013
	Ahlat	2.00	1.97	-1.99	±1.96	downward	-0.128	2012
May	Ahlat	2.54	2.53	-2.40	±1.96	downward	-0.153	2012
June	Tatvan	2.08	2.09	-2.35	±1.96	downward	-0.246	2010
	Ahlat	3.51	3.50	-3.36	±1.96	downward	-0.261	2004
August	Tatvan	2.84	2.83	-3.66	±1.96	downward	-0.393	2012
	Ahlat	2.49	2.51	-2.40	±1.96	downward	-0.235	2013
	Van	2.37	2.37	-2.29	±1.96	downward	-0.164	2012
September	Tatvan	2.37	2.37	-2.29	±1.96	downward	-0.289	2010
November	Tatvan	2.46	2.45	-2.47	±1.96	downward	-0.209	2013

Upward trends were found in the monthly mean relative humidity time series in winter, while downward trends were obtained for other seasons. Alobaidi [10] analyzed surface relative humidity for the period 1951-2010 in Iraq which is the southwest neighbor of Turkey. Results showed a downward tendency in winter, spring, and autumn which differs from our results due to the winter and summer upward trends.

3.3. Results of Tests in Evaporation Parameter

The evaporation time series were recorded only at the Van station and in May, June, July, August, September, and October. Therefore, the tests were applied to these months. The results are shown in Table 3. The trend was detected only in October, which was downward. The slope of the trend is -0.67 and the trend starts in 2007.

Table 3. Results of trend tests for the parameter of evaporation.

Months	Stations	Sen's T	Spearman's Rho	Seasonal Mann-Kendall	α= % 5	Trend	Slope Value	Slope Starting Year
October	Van	2.72	2.54	-2.57	±1.96	downward	-0.67	2007

3.4. Results of Tests in Rainfall Parameter

The time series of 5 rainfall stations (Ercis, Baskale, Ozalp, Muradiye, Gevas) were used to detect trends but the trends were determined only at the Muradiye station in March and September. The slope values and trend-starting years of March and September were determined as 0.566 in 1999 and 0.465 in 1991, respectively. Results are shown in Table 4.

Table 4. Results of trend tests for the parameter of rainfall.

Months	Stations	Sen's T	Spearman's Rho	Seasonal Mann-Kendall	α= % 5	Trend	Slope Value	Slope Starting Year
March	Muradiye	-2.10	-2.11	2.10	±1.96	upward	0.566	1999
September	Muradiye	-2.93	-2.91	3.06	±1.96	upward	0.465	1991

In the total monthly rainfall series, the trend was determined only in one station and in two months. Contrary to a study by Partal and Kahya [5] for January, February and September over the period 1929-1993, the trends for March and September were upward.

3.5. Results of Tests in Snow Depth Parameter

The snow depth parameter was measured only at the Van station, and data is available only in November, December, January, February, and March. Tests were carried out during these months. The results can be seen in Table 5. In snow depth parameters, the Sen's T test results differ from other tests. It is thought that this is due to a lot of zero value measurements in the snow series. The Seasonal Kendall test did not detect the trend in November. However, the Sen's T test and the Spearman's Rho test detected trends at this station, so these two tests' results were considered. Decreasing trends were observed only in November and February with slope of -0.058 and -0.218, and the starting year of 2003 and 2007, respectively.

Table 5. Results of tests trend tests for the parameter of snow depth.

Months	Stations	Sen's T	Spearman's Rho	Seasonal Mann-Kendall	α= % 5	Trend	Slope Value	Slope Starting Year
November	Van	7.25	2.69	-1.80	±1.96	downward	-0.058	2003
February	Van	9.61	2.46	-2.40	±1.96	downward	-0.218	2007

3.6. Results of Tests in Insolation Intensity Parameter

Table 6 shows slope values and trend-starting years of insolation intensity parameter at the stations. Increasing trends were detected in March, April, May, and November with slopes between 0.964 and 1.161. These slope values are higher than the other parameters' slope values. Observations show that the trend began the late 1980s for March and May, whereas it was observed in early 2010 for April and November. In the insolation intensity parameter, Sen's T test results are higher than other tests. Although the Seasonal Kendall test did not detect the trend at Van station in March and November, the trend was still considered to exist since Sen's T test and Spearman's Rho test showed significant results.

Table 6. Results of tests in the insolation intensity parameter.

Months	Stations	Sen's T	Spearman's Rho	Seasonal Mann-Kendall	α= % 5	Trend	Slope Value	Slope Starting Year
March	Van	-7.48	-2.01	1.90	±1.96	upward	1.059	1986
April	Van	-9.11	-2.24	2.01	±1.96	upward	1.161	2010
May	Van	-8.44	-2.28	2.18	±1.96	upward	0.964	1988
November	Van	-7.63	-2.14	1.85	±1.96	upward	1.091	2012

The stations with a trend are shown on the map in Figure 4 for each month. The stations, where the upward trend was detected, are shown as solid and the others as empty. During October, trends were detected only in temperature and evaporation parameters in the middle and northeast part of the basin. This month showed both positive and negative trends. When November came, parameters turned to humidity and snow and trend changes were only downward. Stations at which trends were detected, were located in the West and middle part of the basin. While August was the month with the highest number of trends, December was the month with the least number of trends. In July, the trend was determined only in the temperature parameter. In the rainfall parameter, trends could not be detect at Ercis, Gevas, Baskale, and Ozalp stations, but only at Muradiye station.

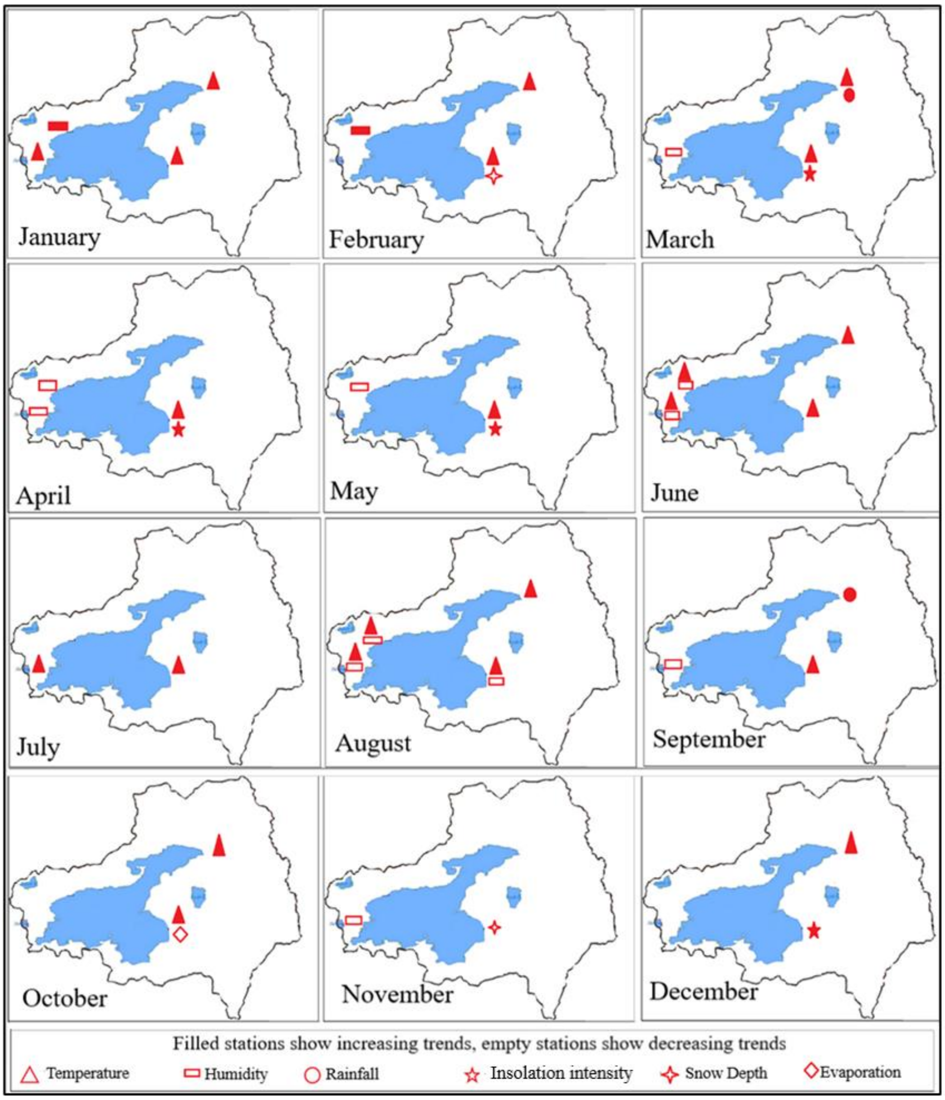

Figure 4. Distribution of significant monthly trends at the 5% significance level.

4. Conclusion

In this study, the trend analysis of the meteorological data of the stations in the Van Lake basin was made to identify the effects of climate change. It was found that the temperature had an increasing trend in all seasons, while rainfall and insolation intensity had an increasing trend in spring and autumn. Upward trends were detected in the average monthly relative humidity and the evaporation series in winter, and for the mean monthly snow depth parameter in autumn and winter. The reason for these detected trends may be climate change and significant inclinations in hydrological cycle parameters.

The highest slope was determined in the insolation intensity parameter as 1,161 in April and the lowest slope (0.028) was determined in the temperature parameter at the Tatvan station in July. Generally, significant trends start between 1990 and 2000 for temperature, while for other parameters the starting year is after 2000.

Declaration of Ethical Standards

The author of this article declares that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Conflict of Interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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