Trend Analysis of Annual Total Precipitation Data in Konya

Naci Büyükkaracığan

***Abstract*—**Hydroclimatic observation values are used in the planning of the project of water resources. Climate variables are the first of the values used in planning projects. At the same time, the climate system is a complex and interactive system involving the atmosphere, land surfaces, snow and bubbles, the oceans and other water structures. The amount and distribution of precipitation, which is an important climate parameter, is a limiting environmental factor for dispersed living things. Trend analysis is applied to the detection of the presence of a pattern or trend in the data set. Many trends work in different parts of the world are usually made for the determination of climate change. The detection and attribution of past trends and variability in climatic variables is essential for explaining potential future alteration resulting from anthropogenic activities. Parametric and non-parametric tests are used for determining the trends in climatic variables. In this study, trend tests were applied to annual total precipitation data obtained in period of 1972 and 2012, in the Konya Basin. Non-parametric trend tests, (Sen's T, Spearman's Rho, Mann-Kendal, Sen's T trend, Wald-Wolfowitz) and parametric test (mean square) were applied to annual total precipitations of 15 stations for trend analysis. The linear slopes (change per unit time) of trends are calculated by using a non-parametric estimator developed by Sen. The beginning of trends is determined by using the Mann-Kendall rank correlation test. In addition, homogeneities in precipitation trends are tested by using a method developed by Van Belle and Hughes. As a result of tests, negative linear slopes were found in annual total precipitations in Konya.

***Keywords*—**Trend analysis, precipitation, hydroclimatology, Konya, Turkey.

I. Introduction

CLIMATE change can be defined as long-term and slowly developing changes, with large-scale and significant local effects in climate conditions whatever their cause. During the period from daylight formation of earth, the balance of our world has been ruined for various reasons and the climate has changed greatly. The effects of population growth, technology, industrialization and uneven urbanization have led to the gradual deterioration of ecological balance. In the meantime, consumption of fossil fuels such as petroleum, coal and natural gas for industrial, transportation or daily use has caused the increase of the greenhouse gases such as carbon dioxide, methane and ozone in the atmosphere [1].

Climate change has a negative impact on agricultural production, especially with a decrease in water resources. The expansion of arid and semi-arid areas increases annual average temperature, desertification, salinization and erosion. At the same time, the snow-covered period shortens because of the area covered by seasonal snow and snow cover decreases. The change in flow time and volume due to snowfall affects the water resources, agriculture, transportation and energy sectors negatively. In addition, global warming also causes changes such as melting of glaciers, elevation of sea level, and shifting of climate zones [2], [3].

The changes in the temperature regime affect the amount of rain, snowfall time and hence the amount of underground and surface water. The increase in temperature accelerates the evaporation, which causes the irrigation water volume to fall. The great wells and aquifers of Asia, Africa and America are low, the ground-water levels are falling, and wetlands and swamp areas are gradually disappearing. However, the increase in evaporation will result in a more humid atmosphere on the earth and an increase in precipitation will be observed accordingly. Excessive rainfall conditions increase the risk of floods. In addition, drought may occur due to increase in evaporation in extreme temperature areas where precipitation is high [4].

The impact of climate change on water resources is due to changes in precipitation characteristics. The variability in water balance, in precipitation, time and time scale is the most important variable for hydroclimatology. Therefore, changes in the climate caused by precipitation in the rains cause very important consequences for hydrology and water resources. The hydrological variability that occurs over time in a given water basin is influenced by variability in precipitation in daily, seasonal, annual and decade cycles.

The frequency of floods and droughts is due to the variations observed in precipitation intensity and the differences in the amount of short-term rainfall. Atmospheric variables researches revealed that due to climate change, there will be significant reductions in summer precipitation, with little increase in winter precipitation. As a consequence of the decrease in rainfall adversely affecting the water resources, the amount of water per capita will be reduced considerably by the effect of population growth. Excessive use of groundwater in arid periods will cause sea water to enter these areas and cause irreversible degradation of water quality. The snow cover will decrease, the snow melting time will change and shift to earlier times. As a result, new water storage facilities and irrigation systems will be needed [2].

Depending on natural causes, the climate, which has been changing gradually over many years, has entered a period of rapid change that can now be felt at an important level. The changes in the climate have come about in the various regions of the world as large changes in mean temperatures, as well as

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precipitation changes. Increases and decreases in precipitation are evidence for climate change. The amount of precipitation changes most in terms of time and space within the climate system. At the same time, certain geomorphologic conditions of the hydrologic regime of a stream describe a river basin which responds to various climatic factors. Climate change such as groundwater flow and hydrological cycle and the phase cause changes in atmospheric temperature [5].

Planning and design of flood control works in the design of all kinds of water structures (dam, pond, irrigation and drainage channels, sewerage etc.) is important for controlling the floods which cause the loss of life and property together with optimum utilization today.. This reveals that rainfall values must be collected reliably and predicted for the future.

In the design of water resources, the relationship between precipitation and flow must be determined in a way that accurately reflects the true state of nature. In a large number of researches on the development of the precipitation-flow relationship, different set of states are established for any basin. However, these methods require the use of variables that are effective in calculating the flow in known rainfall values [6].

Trend analysis is an aspect of statistics analysis that tries to predict the future movement of a stock based on past data. The theory of trend analysis was established to predict what will happen in the light of the past. These trends are short, medium and long term forecasts. Trend analysis is significant in terms of hydraulic structures projects.

The purpose of this research is to explain these needs and components of the total precipitation data in Konya deterministic characteristics. In this study, Sen's T, Spearman's Rho, Mann-Kendall, and the mean-square tests were applied for trend analysis. Slope of the linear trend (change in unit of time) and the non-parametric Sen's trend were calculated with the gradient method. Also, Van Belle and Hughes method were tested for trend homogeneity

II. Data and Methodology

A. Data

Konya Basin is a closed basin and it is located in Central Anatolia Region of Turkey. The basin is formed by the movement of air in an old riverbed rising in the middle of Anatolia. About 10,000 years ago at the end of the Ice Age, the glaciers melted and the seas rose and causing the sediment to evaporate in Anatolia and to remain here in large quantities. Today, a flat plain (a height of 900-1050 m) covers the majority of the basin and forms the main section of the Central Anatolian Plateau. As a result of insufficient drainage, the soil is generally alluvial and saline. The plains are covered with limestone and volcanic mountainous areas (up to 3534 meters in height) which form the upwind basin of the basin. The same mountains prevent drainage to the sea and effectively constitute Turkey's largest basin [7].

The water in the basin ends up in constant water, marsh or half marsh. The absence of a river in this large area, low amounts of precipitation and high evaporation rates have created a relatively uncommon positive water balance in the basin. Approximately 3 million people live in the Konya Basin. 45% of them are in rural areas and 55% are in urban areas. It is observed that in the whole basin, in urban areas where population is gradually decreasing in rural areas. There are 39 districts including the provinces of Konya, Aksaray, Karaman, Isparta, Niğde, Ankara, Nevşehir, Antalya provinces, in basin [7].

The least precipitation area of Turkey is Tuz gölü (Salt Lake) and Karapınar area. Central Anatolia is generally one of the least rainfall regions, except for high places, although the amount of rainfall increases slightly from here to the periphery. When the rainfall map of the Konya region is examined, it is seen that the plain and its surroundings have very low rainfall values due to the amount of rainfall (Fig. 1) [7].

When the rainfall data of the Konya Plain are examined, significant increases in precipitation are observed towards the edges of the ovary and depending on the elevation. The total annual rainfall varies from 300 to 400 mm across the plain. However, in the high parts of the mountains, the total annual precipitation exceeds 1000 mm. In places such as Hotamış, Karapınar, Kamışlıkuyu, Ayrancılar Dam and Savran, the precipitation falls below 300 mm. In the north, near the Salt Lake, and in places higher than the Hodulbaba Mountain (715 m), the amount of precipitation increases considerably with the effect of elevation and cascade. The annual precipitation seasonal distribution charts. It is shown in Fig. 1 that spring and winter seasons constitute about four quarters of the total annual precipitation. It is observed that about 33-38% of annual total rainfall in the whole of the plain is in the winter, 32-37% in the spring, 10% in the summer and 20% in the autumn. While this distribution is mostly in winter in Konya and Karaman, it is the most spring in all other stations. However, the precipitation rates of the winter and spring seasons in Konya are very close to each other. This shows us that the Lagged Mediterranean precipitation regime is effective in the Konya Plain [7].

Oraj precipitation, which is known as the "ragged rains" seen in the closed waters of Konya, is heavy torrential rainfalls that occur due to the nature of the region. Due to its orographic properties, it is seen that these rainfalls are more effective on the mountains. The air masses bringing rainfall affect the basin generally in the northwest direction. However, it also comes from the southwest through the Lake District.

Total annual precipitation values obtained from 15 stations in Konya Basin in 1972 and 2012 were used in this study. It has been noted that the stations are spread uniformly in the basin.

A. Trend Analysis

Non-parametric trend tests Sen's T, Spearman's Rho, Mann-Kendal, Sen's T trend, Wald-Wolfowitz and parametric test mean square test were applied to data of annual total precipitations, in this study. Sen's non-parametric estimator test was used for finding out the linear slopes of trends. The Mann-Kendall rank correlation test was also used for determining the beginning of trends. Finally, homogeneities in trends are tested by Van Belle and Hughes test.

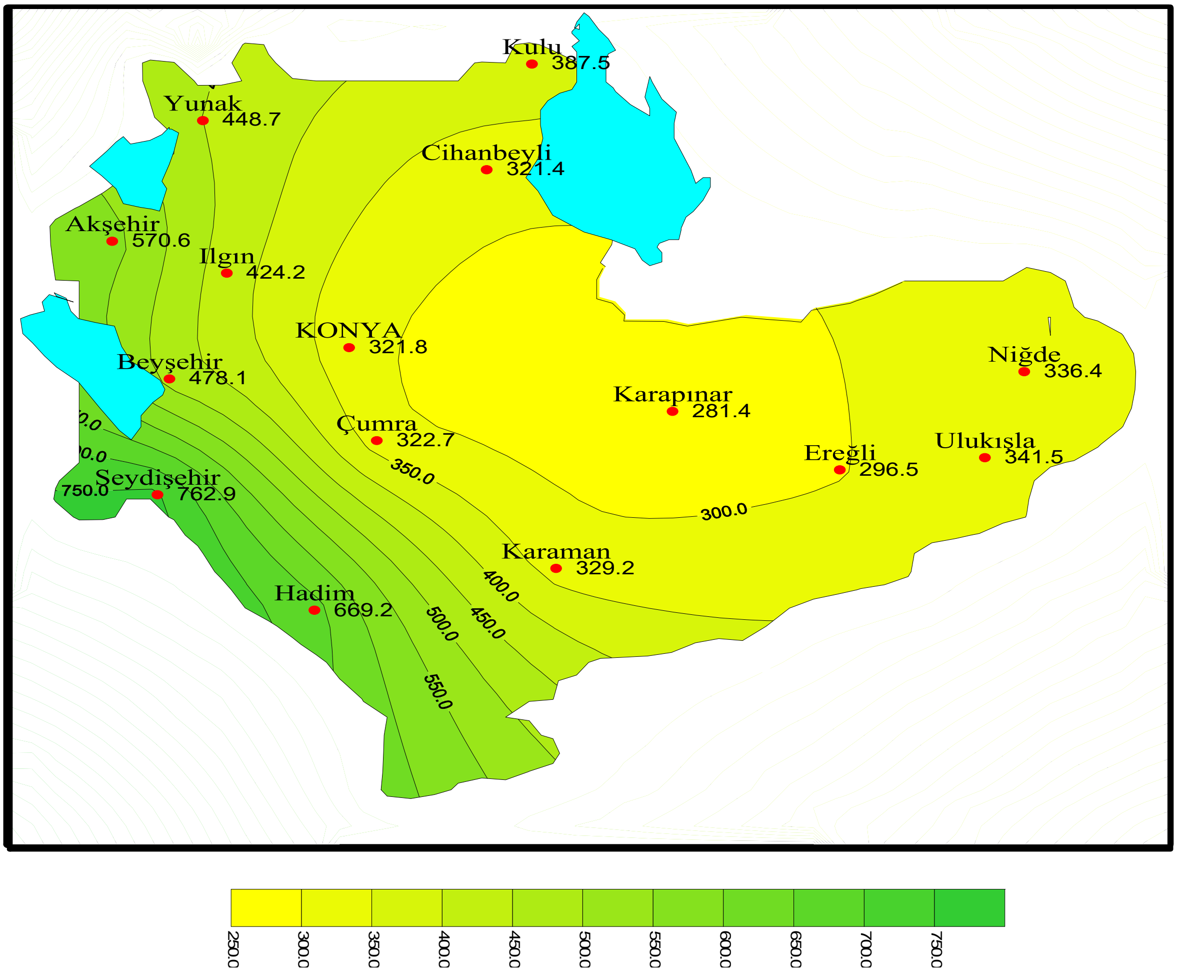

Fig. 1 Total annual precipitation of Konya region [7]

1. Sen's T Test

According to this test, a simple nonparametric estimator of trend which is particularly useful for environmental monitoring application. This method is robust to outliers, missing and uncontrolled data.

Sen's method for the estimation of slope requires a time series of equally spaced data. This test is an aligned rank method having procedures that first remove the block effect from each datum, then sum the data over blocks, and finally produce a statistic from these sums. The aligned rank test is more powerful than its counterpart [8].

2. Mann-Kendal Test

This test is based on randomness against trend in hydrology and climatology. It is a rank-based procedure, which is robust to the influence of extremes and good for use with skewed variables. This test is based on the null hypothesis H_0. Hypothesis Ho and contrary hypothesis (H_1) advocate that the data belong to the same group.

The run test should be run from small to large to find their current median value, and if the number of data is even, the average of the two middle values is used. For this reason, the value set gives the numbers that give the value.

As in the other non-parametric tests, if the Mann-Kendall test is not registered, then there is no requirement for the normal distribution to fit. Therefore, this test gives good results when applied to many hydrological data which have no normal distribution.

3. Spearman's Rho Test

A rank correlation coefficient that may be used as an alternative to Kendall's test. Individuals are arranged in order according to two different criteria (or by two different people). The null hypothesis is that the two orderings are independent of one another. It is based on the differences in the ranks given in two orderings. Suppose that the *j*th individual is given rank x_j in one ordering and rank y_j in the second ordering. The main idea of this test is to take two rankings and to make a numerical relation from 1 to -1. After applying test, a score of 1 means that the lists are identical (1,2,3,4 vs. 1,2,3,4). -1 means that the lists are reversed (1,2,3,4 vs. 4,3,2,1), and at last, 0 (zero) score means that there is no relation whatsoever between the two lists [9].

4. Wald-Wolfowitz (Run) Test

Aim of this test is to check a randomness hypothesis in a two-valued data sequence. For this, this test is used for testing the independent hypothesis of elements of sequence. It examines whether an observation value influences the value of observation after itself. It is the fact that it is an agent, and it is random to be in the background. In addition, a sample selected from the mainstream prevents it from becoming a test. According to results of test, the independence hypothesis can be rejected if there are too many run values more or less than envisaged values. [10].

5. Mean Square Test

This parametric test exposes a functional relationship between time and the results. To identify the best type of trend function to be selected:

1. When X, the value of the event was marked on the Y axis of the event graph is drawn. Graph of mean square test shows what type of function can be expressed and how long-term development of the incident, according to the bending point is determined the level of spinning.
2. Function is not possible to determine the type of graph, the function of the type of standard error is calculated, the smallest type of functions from the standard deviation is selected [7].

6. Sen's T trend Slope Test

If a linear trend in time series is available a real slope (change in unit time), this non-parametric method may be identified by using the data. This method of data error is not affected by extreme values. At the same time missing values can be applied to the records. The methodology of this test is based on [7].

7. Van Belle and Hughes Test

This test is used for homogeneity analysis of trend direction at different stations in every basin. This test also is disposed for learning some general trends. Basin is combined for a global trend, by using few station data. For this purpose, to test the homogeneity of the seasonal trend of given a station, test procedure with the statistical account is developed by Van Belle and Hughes [8].

III. Results and Discussion

The numerical results of trend tests are shown in Table I. According to test statistics of the absolute value of all the tests, the 0.05 (95%) as the significance level α, z (1.96) value was greater than the existence of trends. Otherwise, the trend is statistically insignificant as a result of the interest is not.

The negative numerical value of Mann-Kendall, Sen's T test and Spearman Rho test represents a negative trend (↓). As a result of trend tests, all station data to the decreasing trend were found according to at least two test results.

TABLE I
Results of Trend Test

Station	M-K	S'Rho	S'T	S'T Slope	W-W	M-SQ	Trend
Konya	-2.24	1.50	1.90	-0.0106	-1,44	-1.96	↓
Çumra	-2.11	-1.02	1.97	-0.1210	-0,99	-1.97	↓
Akşehir	-2.68	-1.14	2.22	-0.0623	-2,02	-2.21	↓
Yunak	-2.31	1.06	2.01	-0.0359	-1,92	1.15	↓
Ilgın	-2.16	0.81	1.01	-0.0689	-0,11	0.21	↓
Kulu	-2.01	0.99	0.16	-0.1567	-2,29	-1.99	↓
Cihanbeyli	-2.11	-1.05	1.66	-0.0898	1.99	-2.61	↓
Beyşehir	-1.98	-1.27	-0.11	-0.0906	-1.78	-1.11	↓
Seydişehir	-2.22	0.92	1.99	-0.0568	-1.68	-1.66	↓
Hadim	-1.99	-0.51	1.88	-0.1158	-2.56	-0.99	↓
Karaman	-2.04	-0.99	2.03	-0.2356	-2,17	-2.00	↓
Ereğli	-2.44	1.11	-0.63	-0.0555	-1.98	-3.00	↓
Karapınar	-3.26	-1.43	-1.89	-0.2368	-1.69	-1.91	↓
Niğde	-1.98	-1.23	3.22	-0.4111	2,26	-2.37	↓
Ulukışla	-2.21	-1.35	2.67	-0.0236	-1.26	-1.99	↓

Three statistics for global trend analysis were examined in the following cases:

1. When all three tests are insignificant, the χ^2 trend statistic is compared to the χ^2 criterion (3.84) at 1 degree of freedom to test a general trend in a pond.
2. When χ^2 is important (seasonal trends are heterogeneous) but $\chi2$ is not significant (cross-station trends are homogenous), each trend in different trends is tested.
3. When the condition in (b) is reversed χ^2 is important (seasonal trends are heterogeneous) but χ^2 is not significant (trends between stations are homogeneous)), the trend for each station should be tested.

And also all stations in the absence of trend can be explained by the case of serial independence. According *Van Belle and Hughes test* results, global trend was found in Konya basin.

TABLE II
Results of Van Belle and Hughes Test

Van Belle and Hughes Test		Independence rate	χ^2_{critic} α=0.05
χ^2_{total}	45.47	k.m=24	36.42
$\chi^2_{homogeneous}$	37.54	k.m-1=23	35.17
χ^2_{season}	18.82	m-1=11	19.68
$\chi^2_{station}$	1.64	k-1=1	3.84
$\chi^2_{station-season}$	17.07	(k-1).(m-1)=11	19.68
χ^2_{trend}	7.93	1=1	3.84
seasonal homogeneous		χ^2_{season}..... χ^2_{critic}	<
stationary homogeneous		$\chi^2_{station}$...... χ^2_{critic}	<
Interaction		$\chi^2_{istation-season}$..... χ^2_{critic}	<
Explanation			χ^2_{trend}
Global trend		χ^2_{trend}..... χ^2_{critic}	>
TREND			AVAILABLE

IV. Conclusion

According to the Trend analysis, it was found that there is a decline trend in long-term precipitation. A significant decrease trend is observed in the level of statistical significance in any month and season except for September. The long-term average of precipitation during the period of 1972-2012 shows the existence of a negative trend. This result is due to the fact that under most of the months there are reductions in precipitation, below the critical value. However, this study shows that there is a general trend for a decrease in precipitation days, although there is no significant change in the total amount of precipitation over the long term average. This tendency to decrease is mainly due to the natural environment, energy, industry, agriculture, urbanization, transportation and so on. For this reason, multi-dimensional researches and studies should be carried out in order to predict the results of similar climate trends, especially on the regional scale, and systematic and continuous observation and modeling should be established.

In case of inadequate rainfall, excessive consumption on natural resources will also cause deterioration of the natural environment. Therefore, more emphasis should be given to the climatological studies in Konya Basin and the environmental potential should be put in order to remove the negative effects of such variability and contribute to the future work.

As a result of study, it is found that, decrease trend in total precipitation series of Konya was parallel to global warming since the beginning of the 20th century, especially begging of 1990's in Turkey.

The Konya region is the agricultural capital of Turkey. Therefore, the following solutions can be produced as a decreasing trendy remedy. The irrigation schedule should be rearranged according to the hours when the evaporation is less. For this, watering should be done very early in the morning or in the evening.

Irrigation programs should be developed in such a way that the plants that consume less water are planted together with plants with similar water consumption. Improvement of irrigation efficiency with modern irrigation techniques should be increased. Finally, use of luminaire for water saving, adaptation of climate change and ecology adaptation landscapes, use of wastewater in irrigation of ornamental plants in parks and horticulture and new tasks for water management studies should be done for contributing to the protection of water resources.

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