INVESTIGATION OF THE EFFECT OF CHANGE OF METEOROLOGICAL PARAMETERS ON FLOOD DISASTER; EASTERN BLACK SEA CASE STUDY

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Abstract - Flood is one of the main types of disasters that causes the most loss of life and property in the world. Determining the causes of floods is the most important stage of the studies carried out for protection purposes. Floods can be affected by many natural and human factors. Many reasons such as people building settlements that will trigger flood disasters, damaging flood protection structures, interfering with the natural beds of rivers are human reasons. Many parameters such as precipitation, altitude, soil moisture index, soil type, aspect, slope, drainage density are among the natural causes of floods. However, as revealed by many studies conducted in recent years; Meteorological events such as flash rains and snowmelt with very short flow times also cause floods.

Within the scope of this study, the Eastern Black Sea region, which is most exposed to flood disasters in Turkey, was determined as the study area. More than 100 flood disasters occurred in this region in the last 60 years, and serious losses of life and property occurred in these disasters. Within the scope of the study, the relationship between the periods of disasters occurring in this basin and the trend of meteorological parameters will be examined. As a method, the Şen-ITA method, which is an innovative method that has been frequently used in climate change studies in the literature recently, as well as Mann-Kendal and Spearman Rho tests, whose success has been proven by many studies, were used. The changes in the data obtained and the trends of the data were examined and interpreted.

Keywords - Climate Change, Flood, Mann-Kendal, Spearman Rho, Şen-ITA, Trend Analysis.

I. INTRODUCTION

Global warming, which is one of the most important consequences of climate change, causes an increase in flood events (IPCC., 2012). For this reason, with the increasing flood and flood events in recent years, serious studies are being carried out on these issues. The most serious studies carried out to prevent flood events are those aimed at preventing the occurrence of disasters (Milly et al., 2002). For these purposes, basin planning, taking into account the effects of climate change, is the most important work for the future.

One of the main methods used to examine climatic data is trend analysis. These statistical methods have been used in most studies with meteorological data and very successful results have been obtained (Yükseler et al., 2021). Detecting meaningful changes in meteorological data and identifying possible risks that may arise as a result of these data are among the main purposes of these studies. However, there are some difficulties in examining meteorological data with statistical methods. Main; The fact that these data are complete over a long time series and that they are purified from factors other than natural factors creates difficulties in working with meteorological data using these methods.

In this study, the Eastern Black Sea region, which is located within the borders of Turkey and includes the provinces most exposed to flood disasters, was examined. Located within the department; Disasters experienced in Rize, Trabzon, Artvin, Gümüşhane, Ordu and Giresun provinces from 1960 to 2020 were examined. An attempt was made to reveal the relationship between the period in which these disasters occurred and rainfall values, which are the most important meteorological parameters that cause floods. In order to reveal the relationship between the change in the flood time period and the monthly total precipitation in the basin, Trend tests such as the Mann-Kendal and Spearman Rho tests, which are the most frequently used in the literature, were used, as well as the Şen-ITA method, which is the most innovative.

II. LITERATURE

There are many studies in the literature on the effects of climate change or floods. Some of these studies are based on modeling methods, while others are based on statistical methods. When some studies on this subject are examined; Fofana et al. (2022) examined the trends of urban sudden and extreme rainfall events in the Bamako region of Mali in their study. As a result of the study, it was emphasized that approximately 58% of the flood events experienced in the Bamako region between 1982 and 2019 were caused by normal rainfall and 33% were caused by excessive rainfall. Madsen et al., (2014) examined the tendency of excessive precipitation to cause floods in Europe in their study. By adding climate projections to this study, flood events that may occur in Europe

in the future have been tried to be predicted. Song et al., (2015) conducted a trend analysis of annual flow and flood data in China's Sanchahe River in their study. It has been revealed that there has been a decrease in flood events with the Puding and Yinzidu dams and that these structures have positive effects in terms of floods. In their study, Chaladdee et al., (2022) conducted an investigation with trend analysis to reveal the relationship between floods and meteorological data in order to reduce the risk of floods. As a result of the study, it was emphasized that such studies should be implemented in many regions in terms of adaptation to climate change and urban planning. Liu et al., (2013) examined the flood disasters in China with trend analysis and emphasized the difficulties that China will face in terms of floods in the future. As a result of the studies carried out using the Mann-Kendall method, it was emphasized that the areas affected by floods in China increased. As a result of their study, Rana et al., (2023) established flash flood susceptibility modeling using trend analysis of rainfall data with a new hybrid approach in a region with limited data. Retrospective studies revealed that approximately 97.54% of flash floods were caused by normal rainfall and 2.45% were caused by abnormally heavy rainfall.

III. STUDY AREA

The study area is the part of Turkey on the Black Sea coast, where flood events occur the most due to its mountainous and rugged structure, with the highest average rainfall in the country. The department includes the provinces of Rize, Trabzon, Ordu, Giresun, Gümüşhane and Artvin. More than 600 flood events of different scales have occurred in the basin between 1929 and 2023. Rize province, located within the basin, has an annual total precipitation value of over 2300 mm and is distributed equally in all seasons, making it the rainiest province in Turkey. Within the scope of the study, disaster points of each province were visualized with Arcmap 10.5 software as a result of disaster records received from the General Directorate of State Hydraulic Works (Figure 1).



Figure 1. View of the study area

IV. METHODOLOGY

4.1 Şen-ITA Method

The data used in the Şen-ITA method is divided into two equal parts. The data set is divided into two and sorted separately from smallest to largest. The first data set is then drawn on the X-axis and the second data set on the Y-axis (Figure 2). If the data lines up on the x=y line, there is no trend. If the data is in the decreasing trend region of the x=y line, three situations may occur. If the values in the decreasing regions are in the lower triangle, it is concluded that there is a decreasing trend in the minimum values, if they are in the middle area, there is a decreasing trend in the middle values, and if they are in the high area, it is concluded that there is a decreasing trend in the

maximum values. If the data is above the x=y line and located in the upper triangle, it is concluded that there is an increasing trend in the maximum values, if it is located in the middle area, there is an increasing trend in the median values, and if it is located in the lower triangle, there is an increasing trend in the minimum values. If the trend direction in the maximum, median and minimum values is not in the same direction, it is concluded that there is a very regular (non-monotonic) increasing or decreasing graph. (Şen, 2012; Çeribaşı, 2019).

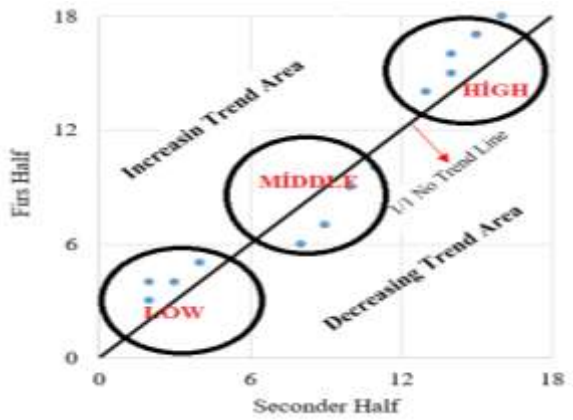


Figure 2. Chart of Şen-ITA Trends graph (Çeribaşı 2017)

4.2 Mann-Kendall (MK) Method

Since the Mann-Kendall test is based on the principle of calculating the correlation value, it is known as the Kendall correlation statistic. Working principle of this test; It is sorted in order of size from the data range to x1≤x2≤x3≤….≤xn. In this test, the number of ordered pairs (xi, xj) with xi<xj for i<j is defined as P, and the number of pairs xi>xj for i<j is defined as M.

With S=P-M, Kendall correlation coefficient τ is calculated as given in Eq. 1:

$$\tau = \frac{S}{n.(n-1)/2} \qquad (1)$$

The value in this equation varies between -1 and +1.
If the number of data is greater than 10, the variance and expected value of S are calculated with the formula given in 2:

$$E(S)=0 \qquad (2)$$

$$Var(S) = \frac{[n(n-1)(2n+5)-\sum t(t-1)(2t+5)]}{18} \qquad (3)$$

The t value specified in Equation 3 refers to the number of observations that are equal. ∑t given in the equation represents the sum of equal observations. If there are no dependent variables in the application, Equation (4) is used instead of equation (3).

$$Var(S) = \frac{[n(n-1)(2n+5)]}{18} \qquad (4)$$

When the number of data used in the study is greater than 10, Equation 5 is applied to find the trend value:

$$z = \begin{cases} \frac{S-1}{\sqrt{Var}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{Var}} & S < 0 \end{cases} \qquad (5)$$

The Z value found with the values of 1.96 and 2.58, which are accepted as the 95% and 99% significance levels chosen as the study significance level, is compared and the significance status of the trend values is expressed.

4.3 Spearman's Rho (SR) Method

Spearman Rho test is an analysis method used to determine the correlation between two data sets. The Rxi expression is considered as the rank statistic and is determined by ordering the data sets from largest to smallest or vice versa (Gumus and Yenigun, 2006). In this study, 95% and 99% confidence intervals were used, as in the Mann-Kendall test.

V. DISCUSSION

In this study, Şen-ITA, Mann-Kendall and Spearman Rho tests, which are among the trend analysis tests, were applied to reveal the relationship between the number of recurrences of flood months and the monthly total precipitation values in the basin. When the applied Şen-ITA test chart is examined, it can be seen that there is a trend from the periods when floods occur to later dates of the year. The frequency of disasters increases significantly, especially in August-September-October (Figure 3.a). When the total precipitation averages of the stations in the Eastern Black Sea basin are examined, although there has been an increase in the total precipitation level in recent years, this increase level remains below the trend line (Figure 3.b). As a result of the findings of the Şen-ITA method, the change trend value of the disaster months was determined as 0.056, and the 95% significance critical value was found to be 0.002. As a result of these findings, a 95% probability of significance reveals that there is a trend in the months when disasters occur in this region. However, the trend value of monthly rainfall balls was determined as 1.416, and the 95% significance critical value was found to be 1.132. These findings show that there are significant changes in total precipitation with a probability of 95%.

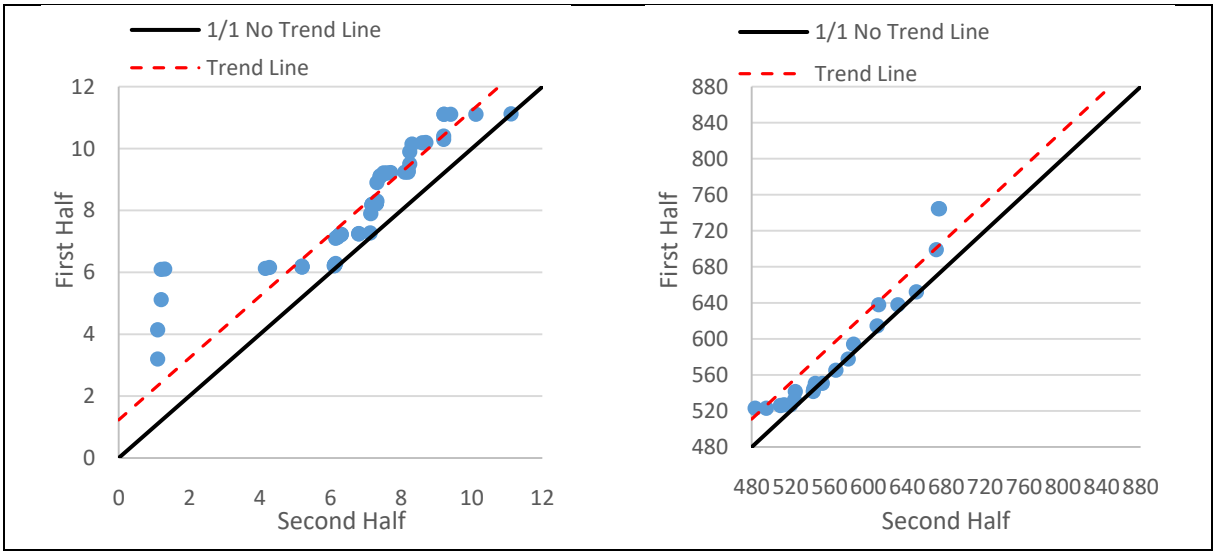


Figure 3. Result of Şen-ITA Method
(a; Distribution of flood disasters, b; Total Annual Precipitation in the Basin)

When the Mann-Kendall test results were examined, the trend value of the disaster values was determined as 3.96, which caused it to remain above the 99% probability coefficient of 2.56. As a result of these findings, it is revealed that the changes in the disaster months in the region show a trend with a probability of 99%. The trend value of the same method in total precipitation values was found to be 1.13, which is below the significance value. The findings show that, as a result of the Mann-Kendall test, although there was a significant change in the month in which the disasters occurred, the partial increase in total precipitation values did not reveal a significant value.

Looking at the results of the Spearman Rho test, the trend value in the month in which the disaster occurred was found to be 3.77, and the trend value in the total precipitation value was found to be 1.22. The findings of this method are similar to the findings of the Mann-Kendall method and confirmed the finding that although there was a significant change in the month in which the disasters occurred, the partial increase in total precipitation values did not reveal a significant value.

VI. CONCLUSION

Flood disasters have long been one of the most common types of disasters that have caused loss of life and property to human beings. For these reasons, people have always looked for ways to protect themselves from this disaster. For this purpose, many studies with different content have been carried out. Recently, the frequency of flood events has been increasing as a result of global warming, which is the biggest indicator of climate change. Many studies are being carried out to determine how this increase will continue in the future, and adaptation studies are continuing for precautionary purposes.

In this study, the Eastern Black Sea region, which includes the 6 provinces of Turkey most exposed to floods, was studied. By using trend analyzes such as Şen-ITA, Mann Kendall and Spearman Rho tests, an attempt was made to reveal the relationship between the period in which floods occurred and the amount of precipitation. As can be seen in the study, although there is a significant change in the disaster period in all three methods in the study basin, this does not directly contribute to the change in the total precipitation value. Especially when disaster records are examined, it has been observed that serious heavy rains fall in a short time, although the total rainfall does not increase significantly, it causes sudden floods as the duration of the rain decreases. As a result of climate change, sudden floods as a result of heavy rainfall in this basin in a short time are seen as an issue that should be taken into consideration in disaster planning in the future.

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