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RAINFALL TRENDS ANALYSIS IN TÂRGU MUREȘ CITY, ROMÂNIA

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Abstract: The aim of this study is the detection of trends of precipitation from (1986-2020) over Târgu Mureș city. Precipitation data for 35 years were processed with MS Excel spreadsheets to find monthly, seasonal and annual variability of rainfall. The Mann-Kendall test was used for trend analysis of precipitation and the Sen's slope estimator was used for the magnitude of variation. The calculations of the two methods were performed using the MAKESENS program. The standard deviation and the coefficient of variation were used to highlight the dispersion. Results show that all three scales (annual, seasonal and monthly) show a tendency to increase rainfall. The highest monthly average of precipitation is 227.70 mm (August, 2005), and the lowest monthly average of precipitation is 0.80 mm (November, 2011). The maximum value of annual precipitation is 852.60 mm and was registered in 2005, and the minimum value was 408.70 mm registered in 2000.

Key words: trend analysis, Mann-Kendall test, rainfall, Sen's slope estimator, annual average, Z and Q-Statistics

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INTRODUCTION

The general geographic features of the Carpathians and the complex structure of the underlying surface are responsible for a series of local characteristics of the climate which, in broad outlines, define a multitude of complexe and elementary topoclimats (Gaceu, 2002).

Rainfall is one of the key climatic variables that affect both, the spatial and temporal patterns of water availability. One of the challenges posed by climate change/climate variability is ascertainment, identification and quantification of trends in rainfall and their implications on river flows in order to assist in formulation of adaptation measures through appropriate strategies for water resources management (De Luis et al., 2000).

Trend detection in precipitation time series is one of the interesting research areas in climatology. It is noted that the changes in precipitation are not globally uniform. Regional variations can be much larger, and considerable spatial and temporal variations may exist between climatically different regions (Yue and Hashino, 2003).

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Trend analysis of rainfall time series includes determination of increasing and decreasing trend and magnitude of trend and its statistical significance by using parametric and non-parametric statistical methods. One of the best methods which is preferred by various researchers is Mann-Kendall test (Jain and Kumar, 2012).

The aim of this study is to analyze the average monthly, seasonal and annual precipitation in the study area, over a period of 35 years (1986 - 2020) to establish possible trends.

STUDY AREA

The study area is the city of Târgu Mureș located in the center of Romania, in the Transylvanian Depression. The geographical location is lat. 46 ° 32 ' N and lon. 24 ° 32' E, altitude is 308 m. It is a medium-sized city with approximately 145,000 inhabitants. The total area of the city is 66.96 square kilometers and the Köppen Climate Classification is „Dfb" (Warm Summer Continental Climate).

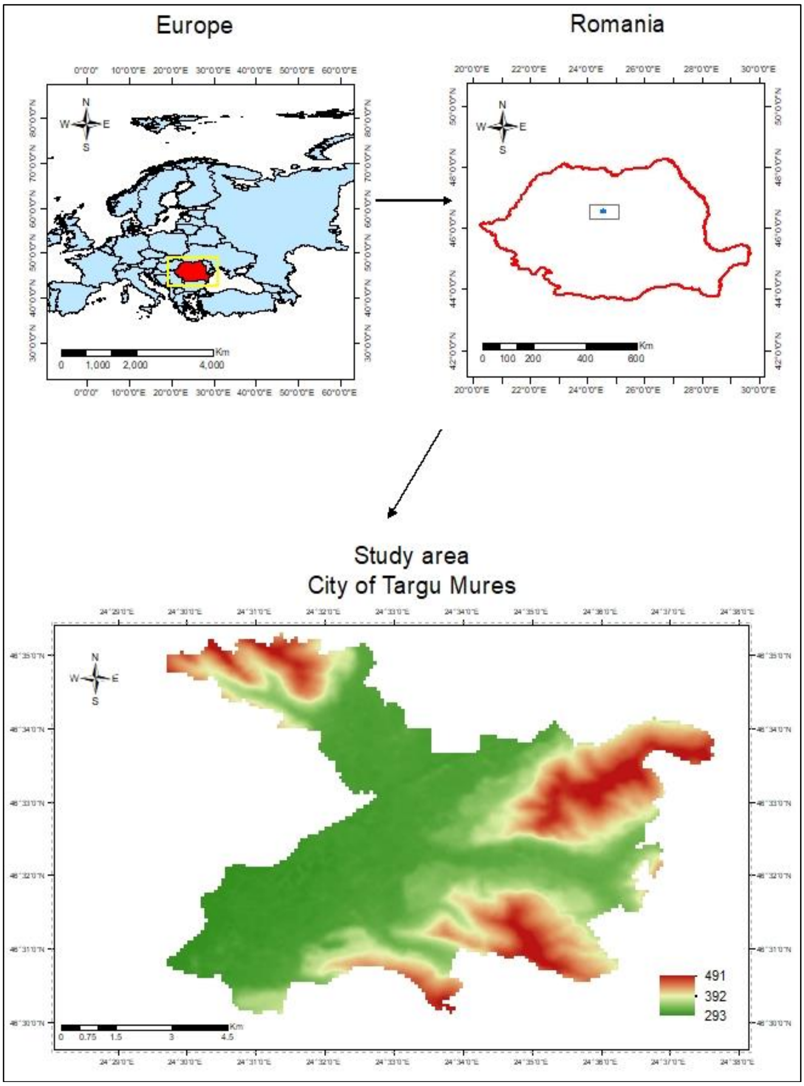

Figure 1. The study area

RESEARCH METHOD

The data used in this study were collected at the Târgu Mureș meteorological station, between 1986 and 2020 and provided from the archive of the National Meteorological Administration (ANM). In order to determine the precipitation trends in the study area, the monthly, seasonal and annual averages were calculated, using Excel spreadsheets.

Different statistical testing methods are used to evaluate the trends of the hydro-meteorological time series. These are classified into parametric and nonparametric tests (Chen et al., 2007; Dahmen and Hall, 1990; Zhang et al., 2006). Parametric trends are more powerful than nonparametric, but they require independent data which is normally distributed.

The nonparametric tests only require the data to be independent and are tolerant to the presence of outliers in the data (Funk et al., 2008; Camberlin and Okoola, 2003; Kumar et al., 2008).

Statistical analysis is used to determine the magnitude of the trend (Mann - Kendal Test, Sen's slope estimator) and the dispersion (standard deviation, coefficient of variation, skewness and kurtosis) for rainfall data of city of Târgu Mureș. Mann-Kendall test does not require that datasets to follow normal distribution and show homogeneity in variance (Duhan and Pandey, 2013).

The following tools and statistical tests were used in the present study to analyze precipitation trends:

1. Linear regression - is one of the simplest and most widely used methods to calculate the trend of data in time series. The equation of linear regression line is given by:

$$y = a + b x \quad (1)$$

where:

a = the intercept
b = slope line
x = explanatory variable

2. Mann - Kendal Test - the most common non-parametric tests for working with time series trends are the Mann - Kendall (Mann, 1945; Kendall, 1975). The World Meteorological Organization (WMO) has suggested the Mann-Kendall test for assessing the temporal trends in the time series of environmental data (Shi et al., 2013). The Mann-Kendall statistic S is given by:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\ (x_j - x_i) \quad (2)$$

where:

n = length of the data
x_j, x_i = sequential data values
sgn = signum function
sgn $(x_j - x_i)$ is calculated using equation:

$$\text{sgn}\ (x_j - x_i) = \begin{cases} 1\ if\ x_j - x_i > 0 \\ 0\ if\ x_j - x_i = 0 \\ -1\ if\ x_j - x_i < 0 \end{cases}$$

The upward or downward trend of the data string is represented by the positive or negative value of the S value.

3. Sen's slope estimator - this is another non-parametric test, which is applied in cases the trend is assumed to be linear, depicting the quantification of change per unit time (Sen, 1968; Gilbert, 1987; De Lima et al., 2007). The slope (Ti) of all data is given by:

$$T_i = \frac{x_j - x_k}{j - k} \quad \text{for i = 1,2,3...,N} \qquad (3)$$

where x_j and x_k are the data values at times j and k (with j > k), respectively.

4. Skewness - is the degree of deviation of a variable from the average value. The formula for skewness is:

$$S = \frac{\sum_{i=1}^{N}(Xi-\bar{X})^3}{(N-1)s^3} \qquad (4)$$

where: N = sample size
X_i = individual score
$\bar{X}$ = mean
s = standard-deviation

5. Kurtosis - is a measure of peakedness of the data in standard deviation. The formula is:

$$K = \frac{\sum_{i=1}^{N}(Xi-\bar{X})^4}{(N-1)s^4} - 3 \qquad (5)$$

where: N = sample size
X_i = individual score
$\bar{X}$ = mean
s = standard-deviation

RESULTS AND DISCUSSION

1. Monthly rainfall trend analysis - the total monthly average was 48.80 mm as shown in (figure 2).

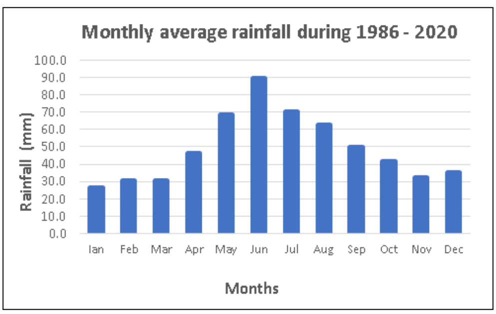

Figure 2. Monthly average rainfall during 1986 – 2020

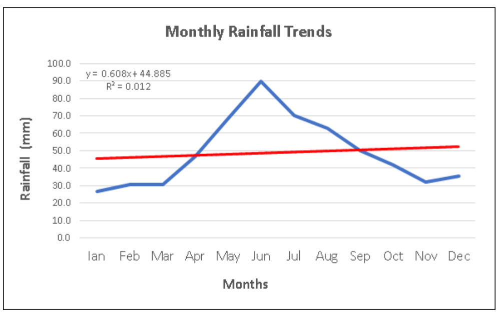

Figure 3. Monthly Rainfall Trends during 1986 – 2020

For the analysis of the monthly precipitation trend, the most representative statistical methods were used: the Mann-Kendall test for the trend and Sen's slope estimator for magnitude shown in (figure 3). It was analyzed whether there are significant variations in the tendency of precipitation to increase or decrease.

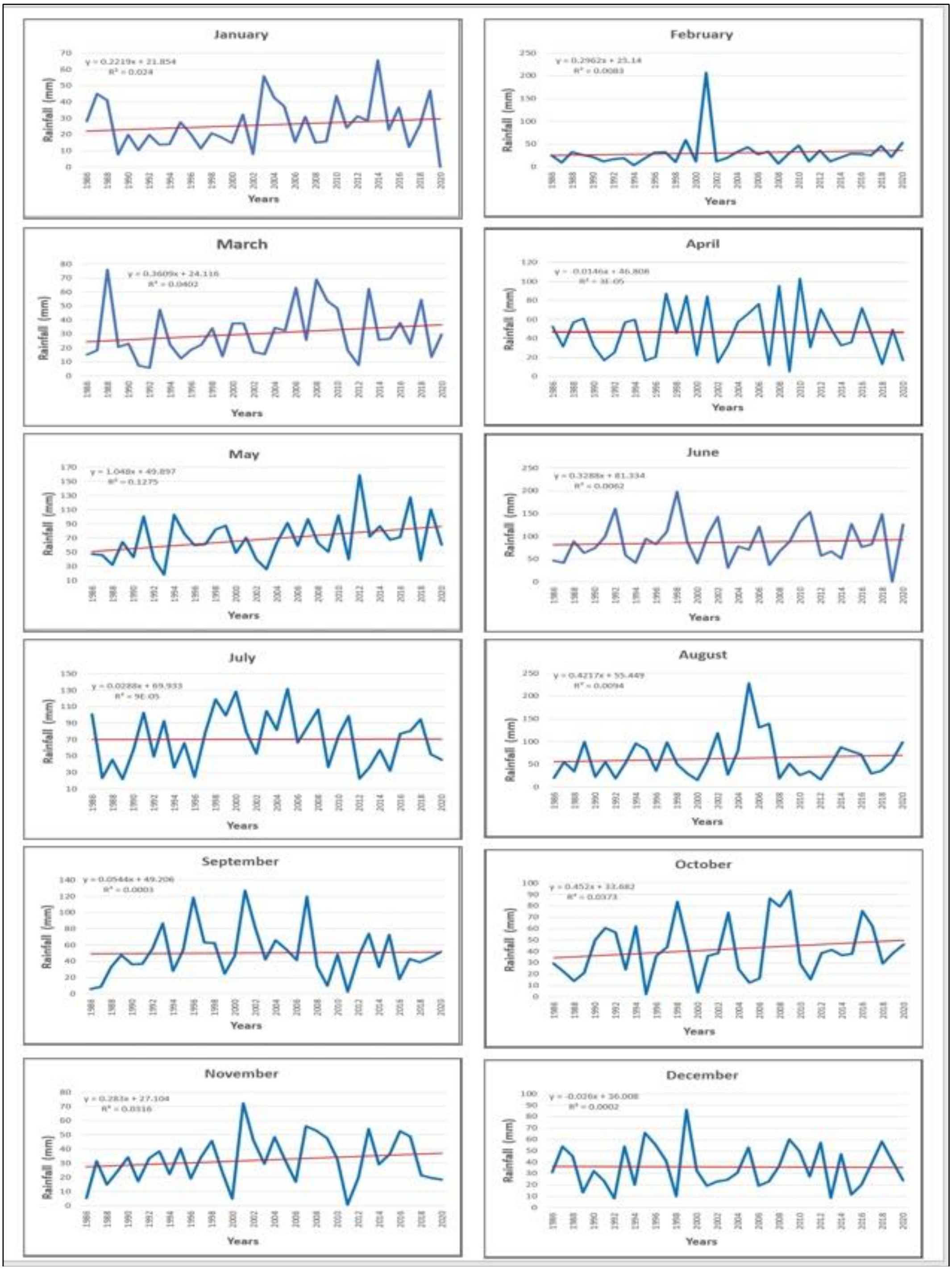

Figure 4. Monthly Rainfall Trend Analysis

Nine months (January, February, March, May, June, August, September, October, November) they had positive values which represent rising trend, two months (April, and December) represent falling trend, July showed an invariable trend as shown in (figure 4). The Sen's slope was calculated for each month separately, and the months of January, February, March, May, June, August, September, October, November, show an increase in the declivity, compared to April and December which showed a decrease trend. In July alone, it showed no change in the magnitude of Sen's slope. The driest month was November, recorded in 2011, with a minimum of 0.80 mm, and the maximum value was recorded in 2005, August, with a maximum of 228 mm.

Eleven months (January, February, March, May, June, July, August, September, October, November and December) show positive values for Mann-Kendall Z statistics, which shows an upward trend, while only April shows negative values, representing a decreasing trend, as shown in (figure 5). The estimated Sen's Slope (Q), presents increasing variation of magnitude for January, February, March, May, June, August, September, October and November. July and December indicate non-significant increasing trend and April show significant decreasing value of Q statistics exemplified in (figure 6).

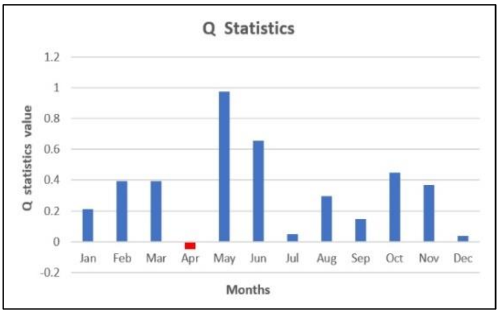

Figure 5. Z-Statistics for Monthly Trend Analysis

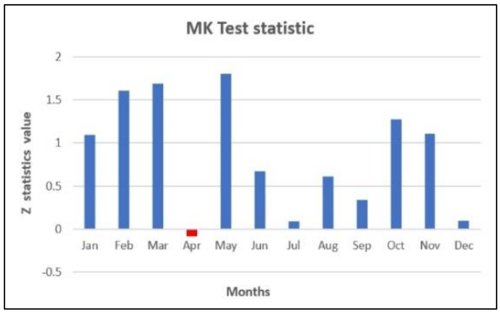

Figure 6. Q-Statistics for Monthly Trend Analysis

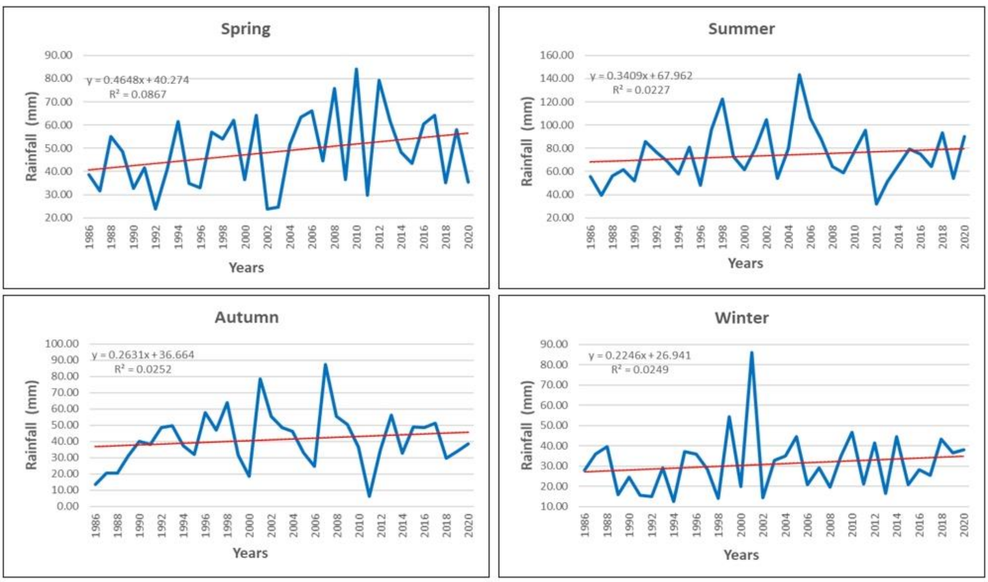

Figure 7. Seasonal Variation of Rainfall

2. Seasonally rainfall trend analysis - to analyze seasonal trends, monthly precipitation data were grouped into four seasons: spring (March-April-May), summer (June-July-August), autumn (September-October-November), winter (December-January-February).

This was done by studying the seasonal values of the non-parametric indices Z and Q-Statistics, and the result of the analysis are presented in (figure 7). The statistics for all four seasons: spring, summer, autumn and winter are positive, which showed a significant trend of increasing precipitation values in the studied interval. In the non-parametric Mann-Kendall test, the precipitation trend for all four seasons describes an upward trend, more pronounced for spring and less pronounced, but almost symmetrical for the other seasons. Seasonal distribution of mean rainfall in study area shown in (figure 8). The average most rainfall occurs during the summer season which contributes 74.40 % to the annual rainfall totals.

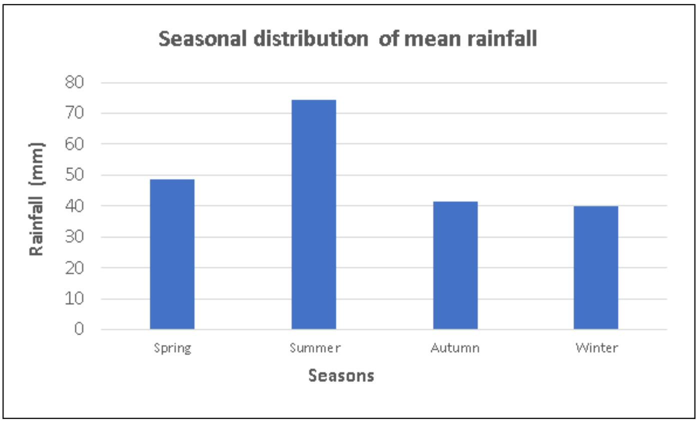

Figure 8. Seasonal distribution of mean rainfall

3. Annual rainfall trend analysis - rainfall data records were analysed for 1986-2020 period, (figure 9) shows the variation of the total amount of precipitation over the period of 35 years and shows a maximum precipitation of 852.60 mm in 2005 and a minimum of precipitation in 1987 of 384.00 mm. The highest annual average precipitation was measured in 2001 and had the value of 77.18 mm, while the lowest annual average precipitation was in 1987, with 32.00 mm as shown in (figure 10).

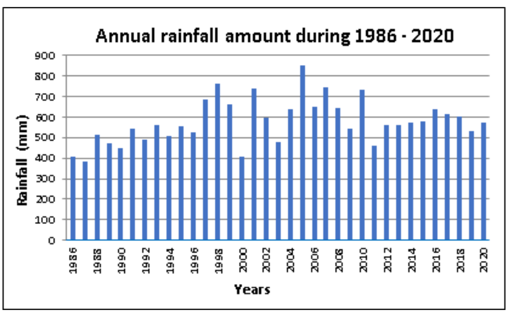

Figure 9. Annual rainfall amount during 1986-2020

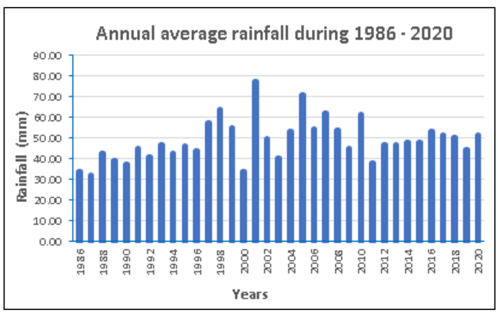

Figure 10. Annual average rainfall during 1986-2020

The trend of the total annual precipitation data of 35 years is represented in (figure 11). The positive value of the Mann-Kendall (Z) and Sen's Slope (Q) statistics indicates an upward trend of the precipitation.

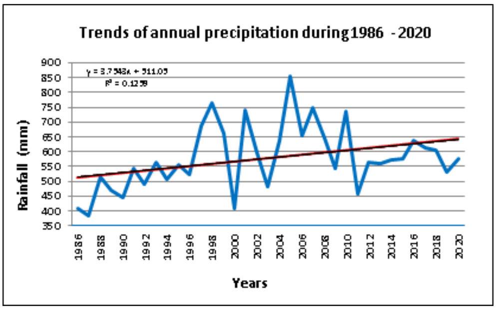

Figure 11. Trends of annual precipitation

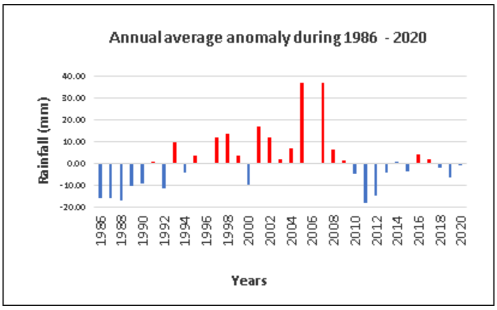

Figure 12. Annual average anomaly

Figure 12 above shows the precipitation deviations in the study area for the period 1986-2020. The results indicate a drier period of the interval, followed by a wet period with a maximum average in 2005 and 2007 of 36.80 mm, followed again by a drier period with a minimum average of -18.40 mm in 2011. Dry periods they alternated with wet periods almost after a cyclical pattern. The descriptive statistics of rainfall: standard deviation (δ), coefficient of variation (%), Mann-Kendal statistics (Z_c), significant (α), Sen's slope (Q), coefficients of skewness (S), coefficients of kurtosis (K), are presented in (table 1).

Table 1. Statistical Analysis of Rainfall data along with Mann-Kendall Trend and Sen's Slope magnitude (Data source: ANM, 2021)

Time Series	**Mean (mm)**	**Median (mm)**	**Min (mm)**	**Max (mm)**	**S.D. (δ)**	**C.V. (%)**	**M.K. (Z_C)**	**Signific. (α)**	**Sen's Slope (Q)**	**Skewness (S)**	**Kurtosis (K)**
January	26.6	23.5	5.8	65.6	14	53	1.094		0.211	0.884	0.358
February	30.4	24.9	3.4	207	33	110	1.605		0.391	4.645	24.606
March	30.6	25.8	5.8	76.1	18	63	1.690	+	0.393	0.879	- 0.104
April	46.5	45.7	5.3	102.8	26	58	- 0.085		-0.048	0.326	- 0.837
May	68.7	63.0	18.2	159.2	30	44	1.804	+	0.976	0.841	0.989
June	89.8	82.7	30.8	197.9	40	46	0.668		0.656	0.729	0.021
July	70.4	74.2	22.3	131.4	31	45	0.085		0.050	0.111	- 0.979
August	63.0	53.9	15.2	227.7	44	69	0.611		0.297	1.699	4.221
September	50.1	46.2	2.8	127.3	30	62	0.341		0.145	0.924	1.012
October	41.8	38.2	2.5	93.2	24	58	1.278		0.447	0.487	- 0.495
November	32.2	32.6	0.8	72.2	16	50	1.108		0.368	0.213	- 0.229
December	35.5	32.2	7.9	86.1	23	54	0.099		0.038	0.544	- 0.127
Spring (M-A-M)	48.6	30.6	5.3	159.2	16	12	1.662	+	0.423	0.322	- 0.716
Summer (J-J-A)	74.4	70.4	15.2	227.7	23	9	1.065		0.393	0.864	1.208
Autumn (S-O-N)	41.4	41.8	0.8	127.3	16	17	1.051		0.247	0.459	0.863
Winter (D-J-F)	30.9	30.4	3.4	207	14	33	1.264		0.264	1.574	4.664
Annual	48.8	44.1	0.8	227	10	18	18	*	0.367	0.807	0.969

Note: SD=Standard Deviation, CV=Coefficient of variation, MK=Mann-Kendal statistics, *Signific=Significance; (+)= 0.1 significance level having 99 % significance interval, (*)= significance level 0.05 having 95 % significance interval*

CONCLUSION

In this study rainfall data from 1986-2020 where used to identify monthly, seasonally and annually trends in Târgu Mureș. At the end of the analysis, the following observations are noted: the monthly statistical result of the study indicates eleven months (January, February, March, May, June, July, August, September, October, November and December) that show an increasing trend in the variation of precipitation. April is the only one that showed a decreasing trend. The monthly trend of precipitation in the period 1986-2020 is an increasing one, with a monthly maximum of 228 mm and a minimum of 0.8 mm, represented in table; the series of statistical data for the four seasons, indicates a significant positive trend of increasing the precipitation values in the studied interval. From the analysis of the series of annual data on precipitation, over the period of 35 years, shows a significant positive trend represented, by the positive value of Z and Q-Statistics, and a high value of R^2.

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