PRECIPITATION AND AIR TEMPERATURE TREND INVESTIGATION OF THE KOSICE BY TRADITIONAL APPROACHES

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Abstract
Trend investigation of the hydrometeorological variables is a critical component of the adaptation to global climate change. Accurate determination of the ongoing hydrometeorological trends will help to make more reliable plans for a sustainable future. This study examined 50 years of monthly and annual data belonging to Kosice station using Mann-Kendall, Spearman's rho, and Sen's slope approaches. Trends of the precipitation and maximum and minimum air temperature were analyzed by applying the traditional methods mentioned. The Kosice station records start in 1972 and end in 2022, the same as for all three parameters. While trends were not identified for the precipitation as statistically meaningful, significantly increasing trends were found for minimum and maximum air temperature.

Keywords: Climatological Trend, Mann-Kendall Test, Spearman's Rho Test, Sen's Slope, Trend Magnitude

Introduction

Precipitation and air temperature change on a regional scale over the last decades have been important issues for water managers, hydrologists, irrigation engineers, etc. Detection of the past variabilities in the precipitation and the air temperature may help planners to develop their strategies or completely revise them. As recent reports about global warming say, the average air temperature has increased, and it keeps increasing, causing changes in the hydrological cycle. Due to the importance of the phenomenon, much recent research about climatological changes has been published on regional scales.
Gocic, M., & Trajkovic, S., 2013 used Mann-Kendall and Sen's Slope statistics to analyze the meteorological trends in Serbia. They recommended that Mann Kendall and Sen's Slope approach be very useful and reliable in the case of hydrometeorological trend investigations. Soltani, M., et al., 2013 performed statistical analysis for the long-term precipitation trend of the Gorgan Weather Station. They used a monthly data set of precipitation from 1956 to 2015. According to the time series analysis, they did not obtain any significant trends. Kocsis T. et al., 2017 conducted research for detecting the signs of climate change based on long-term precipitation trends. They used both parametric and non-parametric evaluations for the detection of trends. Longobardi, A., & Villani, P., 2010 published an annual and seasonal study about the trends of rainfall. They used 211 station records located in Italy for analysis and underlined that Italian territory has already started to suffer from the decreasing rainfall trends. Salami, A. et al., 2016 conducted research on the trends of the hydrometeorological parameters2 trend and the significance of the trends. They used the Mann-Kendall test and standard anomaly index to detect the nature of the trends. According to their outputs for the Lagos coastal area, they found that rainfall, humidity, wind speed, and sea level rise have tended to increase while the air temperature has a tendency to decrease. Yadav, R. et al., 2014 also applied the Mann-Kendall test to detect the trends of the precipitation and air temperature in Uttarakhand. They used a monthly data set for analysis, and they evaluated the magnitude by using Sen's Slope. Ahmad, I., 2015 performed a study for Swat Basin, Pakistan, using Spearman's rho and Mann Kendall's tau tests. They found both increasing and decreasing trends mixed for seasonal and monthly detection. Mahato, L. L., 2021 investigated the long-term climatic trends of the Jharkhand from 1901 to 2002. They found some significant trends for climatic variables and suggested the study outputs will benefit policymakers and water managers. More previous studies about the usage of the Mann-Kendall test and Spearman's Rho test can be found in Krishnan, M. N., et al., (2019); Abghari, H., et al., (2013); Malarvizhi, R., & Ravikumar, G. (2021); Huang, Y. F., et al., (2015); Cerıbası, G., et al., (2014); Zhang, Y., et al., (2022).

In this study, the authors focused on the maximum and minimum air temperature and precipitation changes in Kosice, Slovakia, for a 50-year period. Non-parametric Mann-Kendall and Spearman's Rho

tests were used for the calculations. Also, the significance of the trends was investigated by using Sen's slope.

Methodology

In this study, air temperature and precipitation trends of Kosice, Slovakia, were investigated by using traditional Mann-Kendall and Spearman's rho tests. The magnificence of the trends was evaluated by calculating Sen's slope values. Records belonging to the Kosice range from 1972 to 2022, according to the hydrological year. The beginning of the hydrological year is November, according to the Slovak arrangements. Therefore, the results of each approach were shared in Tables by using November as the starting month. Precipitation and maximum and minimum air temperature were analyzed monthly and annually.

Mann Kendall and Spearman's rho test are both non-parametric tests. The decision of the trends for Mann-Kendall and Spearman's rho tests was made based on the null hypothesis. In this case, while the null hypothesis (H_0) indicates no trends, the alternative hypothesis (H1) indicates a trend. All calculations were done by accepting the confidence interval of 95 percent, while alpha was taken as 0.05.

Mann-Kendall Test

The Mann-Kendall test is one of the most popular traditional tests in use for climatologic trend investigation. As it is mentioned before, this test is a non-parametric test. It is mainly developed by Mann, 1945 and Kendall, 1975. Calculation steps of the Mann-Kendall is given below;

$$S = \sum_{k=1}^{n-1}\sum_{j=k+1}^{n} sgn(x_j - x_k) \quad (1)$$

In eq.1. "S" is the Mann Kendall stat and the calculation of the $sgn(x_j - x_k)$ is given in eq 2.

$$sgn(x_j - x_k) = \begin{cases} +1; & if \ (x_j - x_k) > 0 \\ 0; & if \ (x_j - x_k) = 0 \\ -1; & if \ (x_j - x_k) < 0 \end{cases} \quad (2)$$

For the purpose of the acceptation or rejection of the null hypothesis the Z stat based on the obtained "S" value must be calculated. The calculation of it is shared in equation 3.

$$Z = \begin{cases} \frac{S-1}{\sigma} \ if \ S > 0 \\ 0 \ if \ S = 0 \\ \frac{S+1}{\sigma} if \ S < 0 \end{cases} \quad (3)$$

In equation 3. "σ" is the variance of the slope value. The calculated value must be compared to the critical Z value of the two-tailed normal distribution.

Spearman's Rho Test

The Spearman's rho test is also a non-parametric test, and it is based on the rank of each value of the time series. Spearman's rho calculation steps are as follows;

$$D = 1 - \frac{6\sum_{i=1}^{n}(R_i - i)^2}{n(n^2-1)} \quad (4)$$

$$Z_{SR} = D\sqrt{\frac{(n-2)}{(1-D^2)}} \quad (5)$$

In equation 4, „n" is the time series length, and „Ri" is the ith rank of each monthly record. In equation 5, ZSR is the Z stat calculated according to Spearman's rho value, and it will be used to accept or reject the null hypothesis.

Sen's Slope

This approach is generally used to evaluate the significance of the trends. The larger the slope value, the more important the trend is. Sen's slope formula is given in equation 6.

$$\beta = median\left\{\frac{x_j - x_i}{j - i}\right\} \quad (6)$$

Equation 6 x_j and x_i shows the records of the time series in the j_{th} and i_{th} time steps (Sen, 1968).

Results and Discussions

Kosice meteorological station precipitation and air temperature records for last 50 years were analyzed by using traditional trend investigation methods. Results of the precipitation and maximum and minimum air temperature were shared in separate tables. Sen's slope values were calculated and added to the Mann-Kendall results tables to show the significance level of the detected trends.
Mann-Kendall test results of the precipitation are given in Table 1.

Tab. 1: Mann-Kendall test and Sen's Slope results for precipitation

Hydrologic Time Scale	Alpha	MK Stat.	Critical Z Value	Z Stat.	Trend	Sen's Slope
November		149.00		1.24	-	0.19
December		-94.00		-0.78	-	-0.13
January		-129.00		-1.07	-	-0.28
February		-25.00		-0.20	-	-0.07
March		-73.00		-0,60	-	-0.25
April		38.00		0.31	-	0.11
May	0.05	-32.00	1.96	-0.26	-	-0.13
June		35.00		0.28	-	0.11
July		-12.00		-0.09	-	-0.05
August		3.00		0.02	-	0.00
September		46.00		0.38	-	0.08
October		139.00		1.15		0.17
Annual		-33.00		-0.27	-	-0.35

When Table 1 is examined, it will be seen that no trends were detected within the given confidence interval. Even if any trends were not detected for precipitation by using the Mann-Kendall test, a significantly negative slope was calculated by Sen's slope in the annual evaluation.
Spearman's rho precipitation results are shared in Table 2. Same as the Mann-Kendall test, alpha was considered as 0.05. The two-tailed test was used for the decision of the null hypothesis within the 95 percent confidence interval.

Tab. 2: Spearman's rho test precipitation results

Hydrologic Time Scale	Alpha	Sr Value	Critical Z Value	ZSr	Trend
November		0.17		1.22	-
December		-0.10		-0.67	-
January		-0.17		-1.17	-
February		-0.01		-0.10	-
March		-0.09		-0.62	-
April		0.09		0.59	-
May	0.05	-0.05	1.96	-0.34	-
June		0.02		0.14	-
July		0.01		0.06	-
August		0.00		0.01	-
September		0.06		0.39	-
October		0.16		1.12	-
Annual		-0.03		-0.22	-

Spearman's rho test results were similar to the Mann-Kendall test for the precipitation. No trends were found for this approach too.

Mann-Kendall and Sen's slope test minimum temperature results are shared in Table 3.

Tab. 3: Mann-Kendall test and Sen's Slope results for minimum air temperature

Hydrologic Time Scale	Alpha	MK Stat.	Critical Z Value	Z Stat.	Trend	Sen's Slope
November		145.00		1.21	-	0.04
December		168.00		1.40	-	0.05
January		18.00		0.14	-	0.00
February		82.00		0.68	-	0.03
March		-27.00		-0.22	-	0.00
April		21.00		0.17	-	0.00
May	0.05	215.00	1.96	1.79	-	0.05
June		433.00		3.61	Positive	0.08
July		354.00		2.96	Positive	0.06
August		451.00		3.77	Positive	0.07
September		184.00		1.53	-	0.03
October		56.00		0.46		0.01
Annual		447.00		3.73	Positive	0.04

According to the Mann-Kendall test results of the minimum air temperature parameter, which is given in Table 3, some increasing trends were detected. The most striking aspect of the results was that all detected belong to the summer season. Also, a significantly increasing trend for the minimum air temperature was calculated for the annual evaluation.
Sen's slope was calculated for June as the maximum, as it shows the most significant trend according to the slope calculation. The following highest slopes were calculated for August and July, respectively. Also, the direction of each Sen's slope value was positive, which is compatible with the Mann-Kendall outputs.
Spearman's rho test results for the minimum air temperature are shared in Table 4.

Tab. 4: Spearman's rho test minimum air temperature results

Hydrologic Time Scale	Alpha	Sr Value	Critical Z Value	ZSr	Trend
November		0.18		1.24	-
December		0.23		1.64	-
January		0.04		0.31	-
February		0.11		0.80	-
March		-0.01		-0.07	-
April		0.04		0.31	-
May	0.05	0.27	1.96	1.91	-
June		0.47		3.73	Positive
July		0.46		3.62	Positive
August		0.55		4.59	Positive
September		0.25		1.79	-
October		0.07		0.47	-
Annual		0.53		4.36	Positive

The monthly and annual evaluation of the minimum air temperature calculated by Spearman's rho was found to be consistent with the other method. Like the Mann-Kendall approach, positive trends were examined for the summer season months and annually. The maximum Z value of Spearman's rho test was calculated for August. Only in March was a trend that tended to be negative observed.

Trend investigation of the maximum air temperature recorded in Kosice station is given in Table 5 for the Mann-Kendall and the Sen's Slope.

Tab. 5: Mann-Kendall test and Sen's Slope results for maximum air temperature

Hydrologic Time Scale	Alpha	MK Stat.	Critical Z Value	Z Stat.	Trend	Sen's Slope
November		375.00		3.13	Positive	0.08
December		154.00		1.28	-	0.03
January		120.00		1.00	-	0.03
February		219.00		1.82	-	0.06
March		129.00		1.07	-	0.03
April		306.00		2.55	Positive	0.07
May	0.05	210.00	1.96	1.75	-	0.03
June		478.00		3.99	Positive	0.09
July		471.00		3.93	Positive	0.08
August		469.00		3.92	Positive	0.07
September		183.00		1.52	-	0.04
October		83.00		0.69	-	0.01
Annual		628.00		5.24	Positive	0.05

The results in Table 5 indicate common trends with minimum and maximum air temperatures for Kosice. Positive trends were detected for maximum air temperature in the summer and annually. Different from the minimum air temperature, meaningful increasing trends were detected in November and April. All calculated Mann-Kendall stats are positive. Unless the trends were not detected for every month, the max. air temperature tends to increase with each time step. The maximum Sen's slope was calculated for June, the same as for the min. air temperature parameter.

Spearman's rho test results of the max. air temperature are given in Table 6 lastly. The evaluation was done within the 95 percent confidence interval, and trends were identified based on the acceptance of the null hypothesis.

Tab. 6: Spearman's rho test maximum air temperature results

Hydrologic Time Scale	Alpha	Sr Value	Critical Z Value	ZSr	Trend
November		0.44		3.40	Positive
December		0.20		1.38	-
January		0.15		1.05	-
February		0.27		1.93	-
March		0.14		0.97	-
April		0.38		2.87	Positive
May	0.05	0.26	1.96	1.83	-
June		0.58		4.92	Positive
July		0.54		4.46	Positive
August		0.56		4.74	Positive
September		0.25		1.81	-
October		0.12		0.82	-
Annual		0.70		6.73	Positive

When the Spearman's rho max. air temperature results are considered, the first thing that catches the eye is that the annual trend tends to rise excessively. The max. Spearman's rho Z value was

calculated for June on a monthly scale. The same as the Mann-Kendall results, all trends tend to rise as all Sr values are positive.

Conclusion

Climatic conditions influence the condition for recreation in the area. In this study, trends of the hydrometeorological variables of the Kosice were investigated by using various traditional methods. The reason of this research is also for recreation purposes. Results showed that Mann-Kendall and Spearman's rho tests have quite similar outputs for this particular study area. Maximum and minimum monthly air temperature records were evaluated separately to see the possible extremums. The Analysis done for the precipitation revealed there are no statistically significant trends in monthly or annual evaluation. However, min. and max. air temperature analysis demonstrated that there is a significantly rising trend in summer for both minimum and maximum air temperature. Moreover, the annual trend is statistically meaningful, which is highly positive for both min. and max. air temperature. Sen's slope values confirmed that the time steps with trend detection have high slope values. One of the other main outputs of the study was that no decreasing trends were detected from any of the approaches used. However, the precipitation outputs of the mentioned approaches have some negative values, which may show that the trend may tend to decrease.

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Souhrn
Zkoumání trendů hydrometeorologických proměnných je důležitou součástí adaptace na globální změnu klimatu. Přesné určení probíhajících hydrometeorologických trendů pomůže vytvořit spolehlivější plány pro udržitelnou budoucnost. Tato studie zkoumala 50 let měsíčních a ročních údajů patřících stanici Košice s použitím přístupů Mann-Kendall, Spearman's rho a Sen's slope. Trendy srážek a maximální a minimální teploty vzduchu byly analyzovány za použití uvedených tradičních metod. Záznamy ze stanice Košice začínají v roce 1972 a končí v roce 2022, stejně jako u všech tří parametrů. Zatímco u srážek nebyly identifikovány statisticky významné trendy, u minimální a maximální teploty vzduchu byly zjištěny výrazně rostoucí trendy.

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