ANALYSIS OF TREND IN ANNUAL PRECIPITATION ON THE TERRITORY OF SERBIA

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Summary: *In this paper, the annual precipitation was analyzed for the 29 principal meteorological stations in Serbia over the period 1946-2011. Analysis of precipitation was done by using the non-parametric tests, Mann-Kendall and Spearman's Rho test, to determine trends. The analysis also includes the spatial distribution of annual precipitation trends for the territory of Serbia.*

Keywords: *annual precipitation, trend analysis, Mann-Kendall test, Spearman's Rho test, Serbia.*

1. INTRODUCTION

The elements of time series are represented with trend, cyclic, seasonal and irregular variations. Trend describes primary characteristics of phenomena and represents its tendency for increasing or decreasing development in a time period. The knowledge of trend can provide us information about the behavior of the observed variables in the future, which can be of the great importance in the design of hydraulic structures.
In recent years, a plethora of scientists worldwide have compared and analyzed the precipitation trends [1-5] using non-parametric tests such as Mann-Kendall, Sen's slope estimator and Spearman's Rho test. In Serbia, the analysis of precipitation, drought and reference evapotranspiration trends was presented in [6-10].
The paper presents analysis of annual precipitation trend in Serbia for the period 1946-2011. For that purpose, the Mann-Kendall test and Spearman's Rho test were used to determine trends in annual precipitation.

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2. STUDY AREA

Serbia is located in the central part of the Balkan Peninsula. The largest part of the country has the continental precipitation regime with an average precipitation of 896 mm. For the purpose of analysis, 29 precipitation time series were used.

3. METHODOLOGY

Non-parametric tests have been used to identify trends within time series. In this study, the Mann-Kendall and Spearman's Rho tests were used in order to analyze the annual precipitation trends.

3.1. Mann-Kendall trend test

The Mann-Kendall test statistic S is calculated using the formula [11, 12]:

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

where n is the number of data points, x_i and x_j are the annual values in years i and j (j > i), respectively, and

$$\operatorname{sgn}(x_j - x_i) = \begin{cases} +1, \text{ if } x_j - x_i > 0 \\ 0, \text{ if } x_j - x_i = 0 \\ -1, \text{ if } x_j - x_i < 0 \end{cases} \tag{2}$$

where $\operatorname{sgn}(x_j - x_i)$ is the sign function.

For sample size n > 10, the mean and variance are given by:

$$\mu(S) = 0 \tag{3}$$

$$\sigma^2(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18} \tag{4}$$

where m is the number of tied groups and t_i is the number of ties of extent i. If there are no ties between the observations, the variance is computed as:

$$\sigma^2(S) = \frac{n(n-1)(2n+5)}{18} \tag{5}$$

The standard normal test statistic Z_S is computed as:

$$Z_S = \begin{cases} \dfrac{S-1}{\sqrt{\sigma^2(S)}}, & \text{if } S > 0 \\ 0, & \text{if } S = 0 \\ \dfrac{S+1}{\sqrt{\sigma^2(S)}}, & \text{if } S < 0 \end{cases} \quad (6)$$

In this study, the significance level of $\alpha = 0.05$ was used for testing the trends. The null hypothesis (H_0 – no monotonic trend) is rejected if $|Z_S| > 1.96$, at 5 % significance level. Positive values of Z_S indicate increasing trends while the negative values show decreasing trends.

3.2. Spearman's Rho test

Spearman's Rho test is a non-parametric test that is used to verify the absence of trends. The test statistic D and the standardized test statistic Z_D are given as [13, 14]:

$$D = 1 - \frac{6\sum_{i=1}^{n}(R(X_i) - i)^2}{n(n^2-1)} \quad (7)$$

$$Z_D = D\sqrt{\frac{n-2}{1-D^2}} \quad (8)$$

where $R(X_i)$ is the rank of i-th observation X_i in the sample of size n.

The null hypothesis is rejected if $|Z_D| > 2.08$ for the 5 % significance level, and positive values of Z_D indicate increasing trends while negative indicate decreasing trends. The Z_D corresponds to the Student's t-distribution with n-2 degrees of freedom.

4. RESULTS AND DISCUSSION

The results of applied Mann-Kendall and Spearman's Rho tests were summarized in Table 1. The significant increasing trends were found for Palic, Zlatibor, Loznica, Kopaonik and Sjenica stations for both statistical tests.
Spatial distribution of weather stations with their trends is shown in Figure 1. It is evident that the stations in the western part of Serbia have the significant increasing trend in annual precipitation. The significant decreasing trend is not identified.

Table 1. Results of the applied non-parametric tests

Station	Mann-Kendall test, Z_S	Spearman's Rho test, Z_D	Station	Mann-Kendall test, Z_S	Spearman's Rho test, Z_D
Nis	1.660	1.635	Sremska Mitrovica	0.393	0.251
Vranje	- 0.769	- 0.785	Banatski Karlovac	0.708	0.614
Palic	**2.114**	**2.097**	Valjevo	1.682	1.604
Negotin	- 1.118	- 1.117	Veliko Gradiste	0.144	0.081
Belgrade	0.758	0.698	Smederevska Palanka	1.450	1.317
Novi Sad	1.771	1.667	Pozega	1.018	0.928
Zlatibor	**4.178**	**4.527**	Cuprija	1.616	1.651
Kragujevac	1.145	1.130	Krusevac	1.135	1.020
Loznica	**2.966**	**2.932**	Zajecar	- 0.050	- 0.203
Kraljevo	- 0.952	- 0.941	Kopaonik	**5.291**	**6.335**
Sombor	1.859	1.764	Sjenica	**2.939**	**3.063**
Dimitrovgrad	0.813	0.773	Crni Vrh	0.935	0.819
Kikinda	0.642	0.673	Leskovac	1.792	1.731
Becej	0.304	0.404	Kursumlija	1.727	1.629
Zrenjanin	0.514	0.557			

Note: Bold characters represent trends identified by 2 statistical methods together.

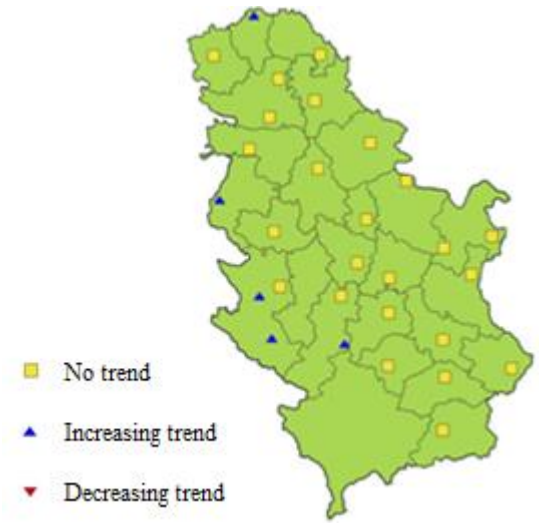

Figure 1. Spatial distribution of weather stations with their trends, according to Mann-Kendall and Spearman's Rho tests

Annual precipitation time series for the stations with the significant increasing trends with the linear trend and coefficient of determination are presented in Figure 2.

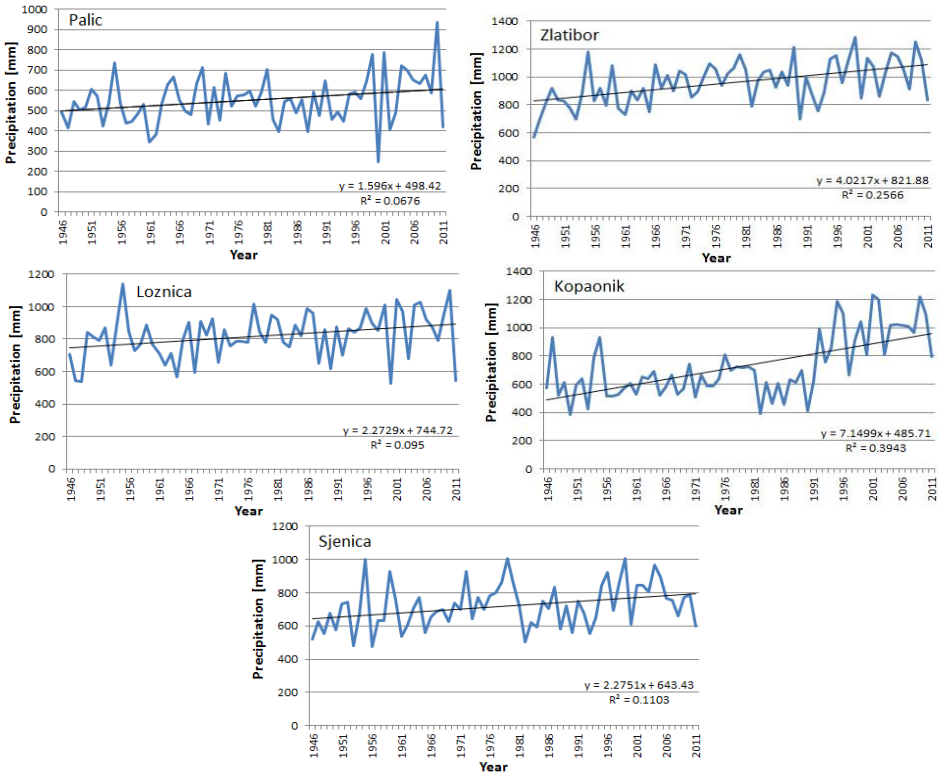

Figure 2. Annual precipitation, linear trend and coefficient of determination

5. CONCLUSION

The main aim of this study is to analyze trend of annual precipitation from 29 stations in Serbia for the period 1946-2011. For that purpose, the Mann-Kendall and Spearman's Rho tests were applied.

The Mann-Kendall and Spearman's Rho tests showed the same results for the observed stations. The five stations were identified with the significant increasing trends, while the other stations had no trend. The spatial distribution showed that four of five stations with the significant trend are located in the western part of Serbia.

The presented results are starting point of future work, which will be oriented into analysis of significance of trends of precipitation on design of irrigation systems.

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ANALIZA GODIŠNJIH PADAVINA NA TERITORIJI SRBIJE

***Rezime**: U radu su analizirane godišnje padavine za 29 glavne meteorološke stanice u Srbiji za vremenski period od 1946. do 2011. godine. Analiza padavina je sprovedena korišćenjem neparametarskih testova, Mann-Kendall i Spirmanov ro test, sa ciljem da se ispitaju trendovi. Analizom je obuhvaćena i prostorna raspodela trendova na teritoriji Srbije.*

***Ključne reči**: godišnje padavine, analiza trenda, Mann-Kendall test, Spirmanov ro test, Srbija.*