SEASONAL PRECIPITATION TREND ANALYSIS IN CLIMATIC STATIONS IN THE EASTERN SLOVAKIA

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ABSTRACT

The weather in Slovakia changes a lot by the influence of dry continental air from the west and the humid ocean air from the north. The Eastern Slovakia lowland is the warmest and the driest region of eastern Slovakia with an annual average temperature around 8°C and precipitation around 600 mm. The coldest places are mountainous area – the High Tatras in the north of eastern Slovakia with the average temperature of -3°C and with precipitation over 2000 mm. The non-parametric Mann-Kendall statistic test was applied to detect trends and to assess the significance of the trends in the time series. The significance of trends in 53 years precipitation and temperature time series was assessed. The application of trend detection in eastern Slovakia has resulted in the identification of a few increasing significant trends in precipitation but clear increasing significant trends in temperature data. As expected, trends show large variability in magnitude and direction of trend from one station to another related to the topography of the country. It is clear that slight climatic changes may have affected the magnitude and timing of the atmospheric variables within the study area.

Keywords: precipitation, statistical analysis, trend, eastern Slovakia

1. INTRODUCTION

Atmospheric precipitation is usually considered as the most important meteorological parameter. It belongs also to the most changeable meteorological elements of both spatial and temporal point of view. Atmospheric precipitation is most influenced by geographic location area, altitude, windy area to the predominant flow, bringing moist air masses and frontal systems. The Intergovernmental Panel on Climate Change provides a comprehensive review of the potential impacts on the hydrological variables of the man induced climate changes. It states that such changes will likely increase runoff in the higher latitude regions because of increased precipitation; also, the flood frequency is expected to change in some locations and the severity of drought events could also increase as a result of the changes both in precipitation and evaporation.

Observations show that changes are occurring in the amount, intensity, frequency and type of precipitation [1].

In Slovakia, as in many other European countries (Romania, Portugal, Greece), the fresh water related risk, and specifically the droughts are expected to become more frequent, intense and prolonged due to climate change [1]. At the same time, most of the studies about the issue are focused on specific regions or aspects rather than aiming at a comprehensive characterization of the phenomenon for the whole country, based on extensive hydrological ground data e.g. [2] - [7].

This paper presents results of spatial precipitation and temperature trends using Mann-Kendall non-parametric test and geostatistics tools in climatic stations in the eastern part of Slovakia.

2. MATERIAL AND METHODS

2.1 Statistical analysis

Trend analysis for hydrological time series is an important and popular tool for better understanding the effects of climate variation and anthropogenic activities.

In this study non-parametric Mann-Kendall test is used for the detection of the trend in a time series. This test is widely used in the environmental science because it is simple, robust and can cope with missing values and values below a detection limit. The first proposal of the test was by [8], [9]. The Mann-Kendall (MK) test is a rank-based nonparametric test for assessing the significance of a trend, and has been widely used in hydro-meteorological trend detection studies [10]. A serious problem in detecting and evaluating trends in hydrologic data is the effect of serial dependence [11].

Mann-Kendall test is following statistics based on standard normal distribution (*Z*), by using Eq.(1).

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if \quad S < 0 \end{cases} \qquad \textbf{(1)}$$

in which,

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \; sgn(x_j - x_k) \qquad \textbf{(2)}$$

$$sgn(x_j - x_k) = \begin{cases} +1 & if \left(x_j - x_k\right) > 0 \\ 0 & if \left(x_j - x_k\right) = 0 \\ -1 & if \left(x_j - x_k\right) < 0 \end{cases} \qquad \textbf{(3)}$$

$$Var(S) = [n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i - 1)(2t_i + 5)]/18 \qquad \textbf{(4)}$$

Where n is the number of data points,

m is the number of tied groups (a set of sample data having the same value).

Hypothesis H0 - no trend is if ($Z < Z_{\alpha/2}$) and H1 - there is a trend if $Z > Z_{\alpha/2}$. Positive values of Z indicate increasing trends, while negative values of Z show decreasing trends.

The magnitude of the trend was determined using Sen`s estimator. Sen's coefficient is calculated by

$$\beta = Median\left(\left(x_j - x_k\right)/(j-k)\right) \qquad \textbf{(5)}$$

for $i = 1, 2, ..., N$,.

where x_j and x_k are data values at time j and k ($j > k$), respectively and

N is a number of all pairs x_j and x_k.

A positive value of β indicates an upward (increasing) trend and a negative value indicates a downward (decreasing) trend in the time series.

The non-parametric Mann-Kendall statistic test was applied to detect trends and to assess the significance of the trends in the time series. The non parametric Mann-Kendall statistical test has been widely applied to assess the significance of trends in climatological time series. The significance of trends in 53 years climatological time series was assessed by the Mann-Kendall test at the significance level of 0.05. We investigated the precipitation data in study area – eastern part of the Slovak Republic – in 16 climatic stations in which no gaps in the data were presented.

2.2 Spatial distribution of trends

We have used modelling and analysing tools of ArcGIS – Geostatistical Analyst – in modelling of spatial distribution of precipitation and temperature trends. Geostatistics is based on the regionalization of random variable in a given area. A set of random variables generated random function. Random function model is based on a study of the spatial variability of the studied phenomenon in different directions – experimental variogram. Calculation of empirical semivariogram is written in the form [12]:

$$\gamma(h) = \frac{1}{2n(h)} \sum_{i=1}^{n(h)} [z(s_i) - z(s_i + h)]^2 \qquad (6)$$

Where γ (h) is estimated semivariation for the distance h;

n (h) is the number of pairs of measured points separated by a distance h;

$z(s_i)$ is a measured value in point (s_i).

The results of spatial distribution of precipitation time series trends are presented in Figures 2 – 5.

2.3 Study area

Slovakia belongs to the northern moderate climatic zone. There are four seasons during the year – spring, summer, fall and winter. The topography of Slovakia is very diverse and the altitude is an important factor affecting the precipitation. Area under the study and location of climatic stations in eastern Slovakia is depicted in Figure 1.

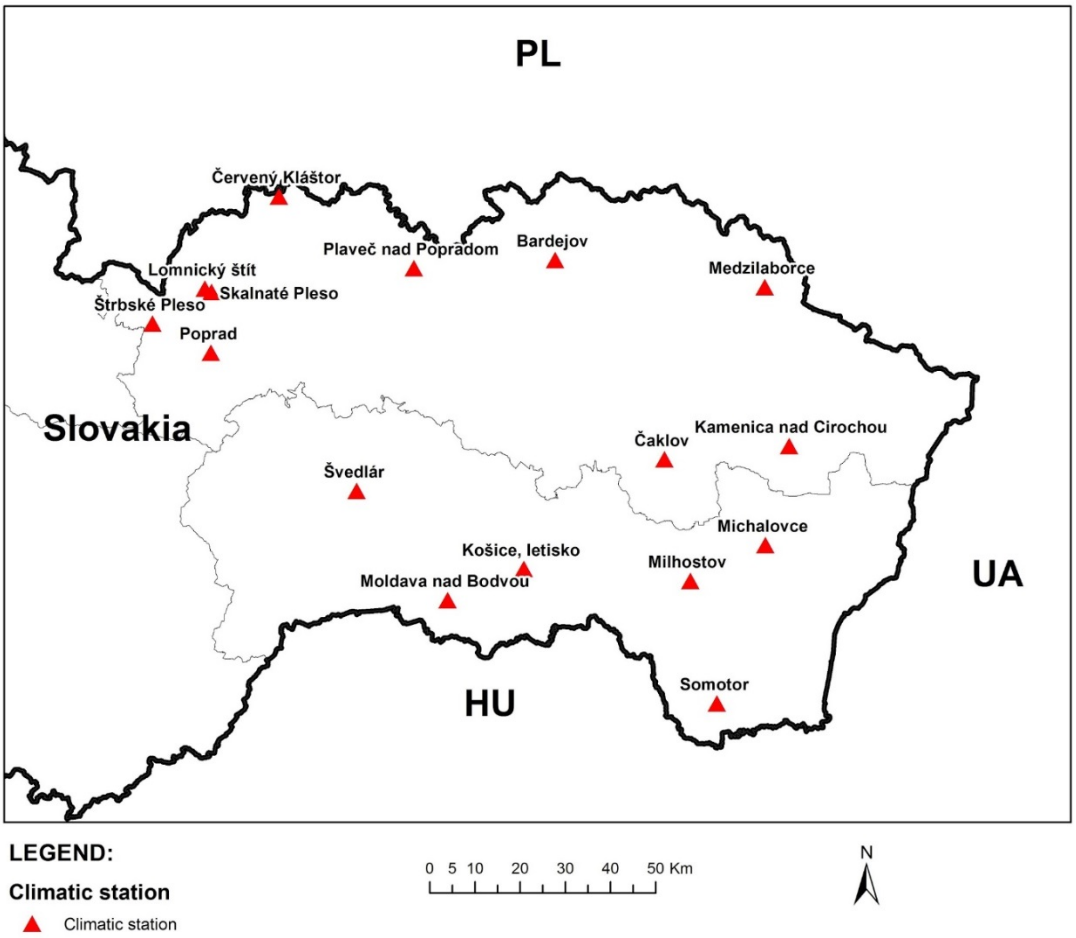

Fig. 1: Study area

Monthly precipitation data recorded at 16 climatic stations in eastern Slovakia operated by Slovak Hydrometeorological Institute were useded for this study. A climatic stations network data length from 1962 to 2014, it means 53 years of data for hydrological year in Slovakia (from November to October), were set up to study seasonal precipitation trends in eastern Slovakia.

3. RESULTS

3.1 Trend analysis

Results of precipitation analysis are presented for seasonal data (Table 1). Data series for the 53 years period, from 1962-2014, were considered for trend detection. The evaluation was done for the seasons of the year – winter (November, December, January) (XI –I), spring (February, March, April) (II –IV), summer (May, June, July) (V –VII) and fall (August, September, October) (VII –X).

Tab. 1: Seasonal precipitation trends in climatic stations

Climatic station	Season			
	XI - I	II - IV	V - VII	VIII - X
Lomnický peak	**0.4871**	**0.6000**	**0.3678**	0.1188
Skalnaté Pleso	0.0500	**0.1333**	0.0965	-0.0400
Štrbské Pleso	0.0512	0.0729	0.1526	0.0135
Poprad	-0.0227	0.0159	**0.1464**	0.0178
Švedlár	0.0149	-0.0176	**0.2100**	0.0878
Moldava nad Bodvou	-0.0144	-0.0258	0.0637	-0.0560
Červený Kláštor	-0.0284	0.0479	**0.2063**	0.0524
Plaveč nad Popradom	-0.0146	0.0412	**0.2667**	0.0333
Bardejov	0.0011	0.0060	**0.1462**	-0.0226
Čaklov	0.0264	-0.0036	0.0821	0.0000
Košice. airport	0.0023	-0.0290	0.0702	-0.0635
Medzilaborce	0.0185	0.0386	**0.1380**	-0.0432
Milhostov	-0.0102	-0.0222	0.0483	0.0139
Somotor	0.0165	0.0185	0.0333	0.0077
Michalovce	0.0408	0.0154	0.0500	0.0186
Kamenica nad Cirochou	-0.0102	-0.0362	0.0286	-0.0148

The results of spatial distribution of precipitation trends in climatic stations in the eastern Slovakia are presented in Figures 2, 3, 4 and 5.

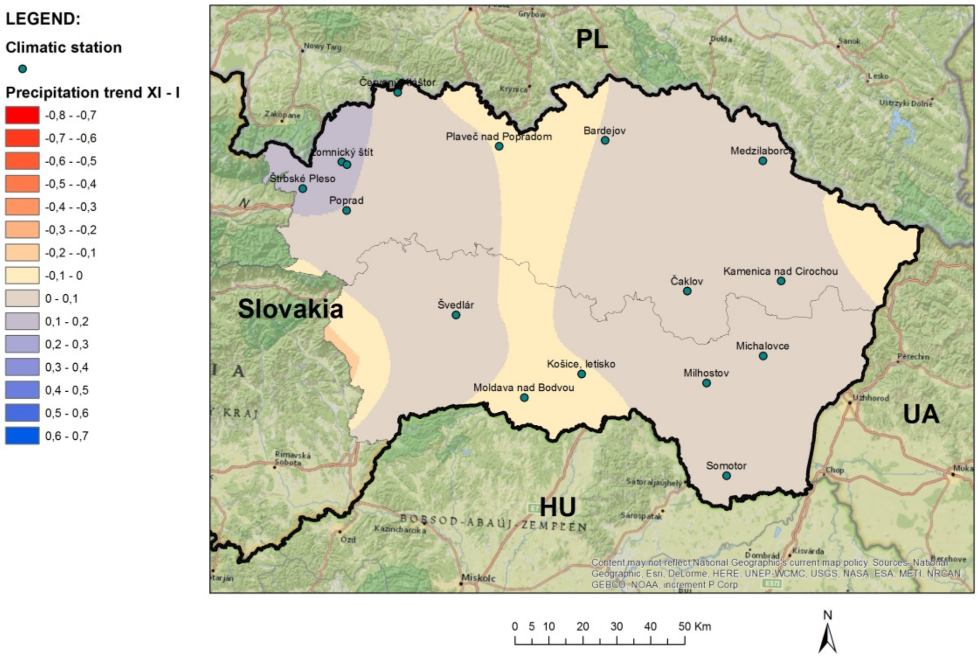

Fig. 2: Precipitation trends in winter

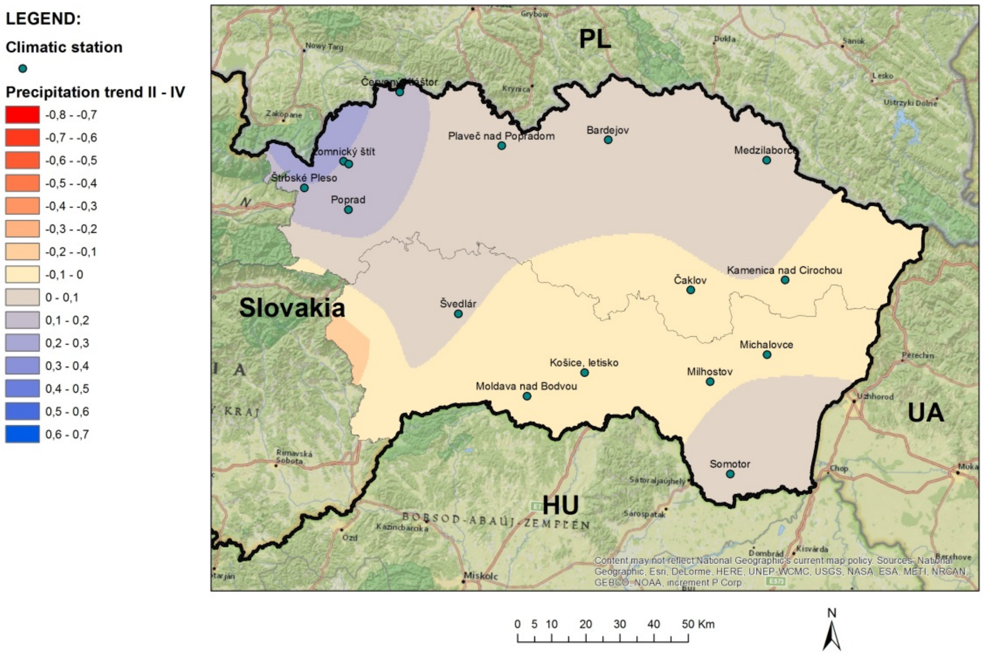

Fig. 3: Precipitation trends in spring

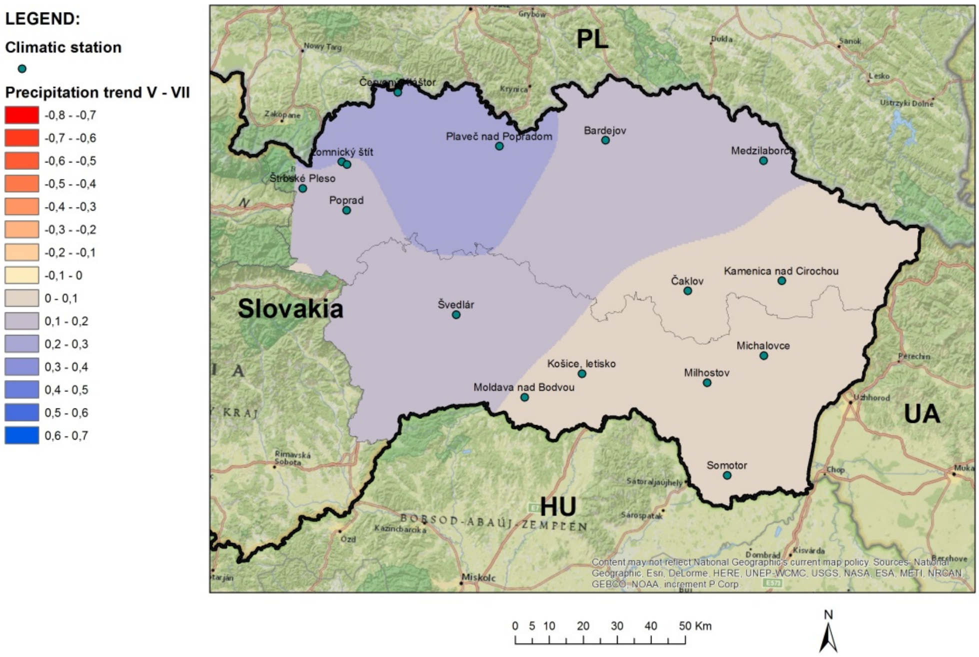

Fig. 4: Precipitation trends in summer

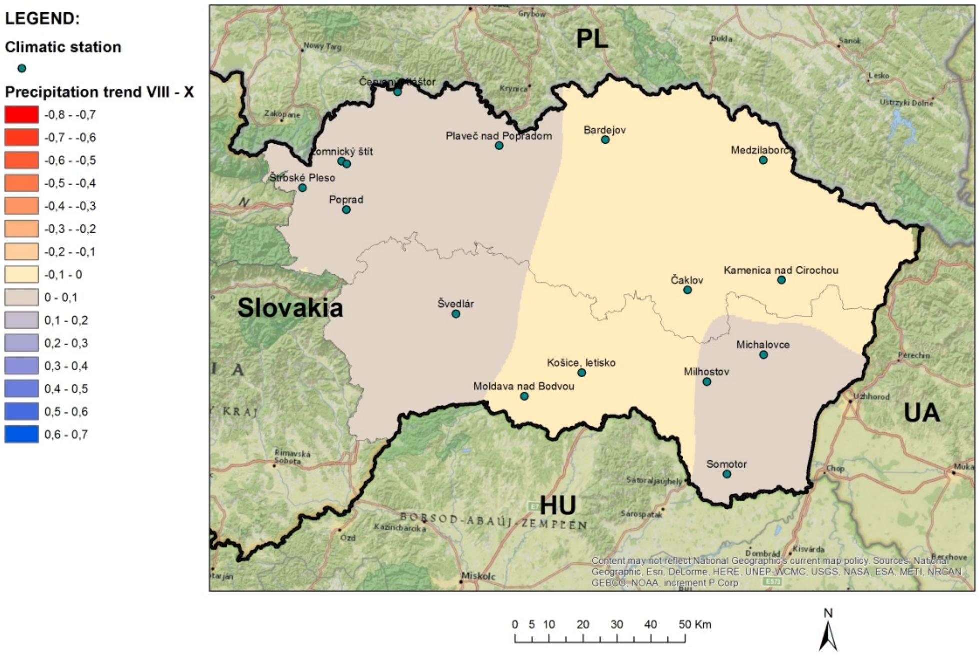

Fig. 5: Precipitation trends in fall

Seasonal trend analysis proved mostly increasing trend in precipitation in the study area although not significant trends (Table 2). Significant positive trends are found in station

Lomnický štít in the mountains – the High Tatras (north part of Slovakia). Significant positive trends in precipitation are obvious during the summer season. No significant trends are found in fall. Trends in precipitation are also mostly positive during winter and spring, although some negative trends were also found during these seasons.

4. CONCLUSION

In this paper, the results of seasonal trend analysis applied to precipitation data is presented for the hydrological year (from November to October) in sixteen climatic stations in eastern Slovakia. The topography of this part of the country is very diverse and it affects the climate. The Mann-Kendall non parametric test coupled with the Sen's slope was applied to identify the significant long-term climatic trends, as well as the magnitude of those trends. Trends in precipitation are mostly positive during winter and spring, although some negative trends were also found during these seasons. Spatial distribution of precipitation trends was modelled in ArcGIS using geostatistical analysis.

The application of trend detection in eastern Slovakia has resulted in the identification of a few increasing significant trends in precipitation data. Spatial differences in the trend results can be expected to occur as a result of spatial differences in the changes in precipitation over the study area and spatial differences in the country characteristics. As expected, trends show large variability in magnitude and direction of trend from one station to another related to the topography of the country. It is clear that slight climatic changes may have affected the magnitude and timing of the atmospheric variables within the study area.

This paper develops a picture of recent precipitation trends in climatic stations across the region of eastern Slovakia, which should be of interest to future agriculture and water resource management.

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