Trend analysis of drought indices in the eastern Slovakia

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Abstract. Extreme weather changes have been increasing in the recent times also in the eastern Slovakia. Extremely dry periods alternate with above-average precipitation. In the paper, the drought indices were evaluated: Standardized Evapotranspiration Index (SPEI) and Standardized Precipitation Index (SPI). Using the non-parametric statistical Mann-Kendall test. The evaluated period was 1960–2015 at selected river and climatological stations in the eastern Slovakia. The results showed that no clean significant trends occurred in all evaluated indices and stations.

1. Introduction
Climate change is a global phenomenon of the scientific community and the public. Recently, global air temperature has risen, potentially increasing global temperature [1-2]. The increase in temperature is associated with a basic hydrological cycle that modifies precipitation changes, evapotranspiration changes, and thus increases the risk of extreme events such as drought and tidal floods from extreme precipitation [2]. The characteristics of the drought may vary with respect to the area where the drought occurs, the time in which climate area and various other aspects. Drought events are also occurring in the Central Europe, which is in a temperate climate zone and where are located the selected weather stations [3].

Drought classification is a prerequisite for research on dry and wet seasons. Many different drought indices are currently being developed and are used according to the area we want to explore [4-6]. Indices can be classified mainly into four basic areas: meteorology, soil moisture, hydrology and remote sensing. I dealt with meteorological indices, which are Standardized Precipitation index (SPI) and Standardized Evapotranspiration Index (SPEI). The World Meteorological Organization recommends the non-parametric Mann-Kendall trend test to detect trends in climate variables [7-8].

2. Materials and Methods
2.1. Methods
The Standardized Precipitation Index (SPI) is a simple drought index that characterizes the meteorological drought in time periods ranging from 1 month to 36 months. In the paper, 12 months SPI...
was used. The SPI can calculate them on the basis of a minimum time series of 20 years. I had available time series data of 30 or more years. The Drinc software was used for SPI calculation [9-11].

Standardized evapotranspiration index (SPEI), is based on water balance. The input data for this index calculation are precipitation and air temperature. This index combines potential evapotranspiration (PET) and precipitation. The PET calculated using the Thornthwaite method and the SPEI is calculated be using the Rgui statistical program [13-14].

The Mann-Kendall trend test is a statistical non-parametric test method and is considered as a good tool for trend analysis. The Mann-Kendal test is independent of data distribution and less sensitive to missing data and is therefore most commonly used to assess trends for various climatological and hydrological variables [12].

2.2. Datasets and study area
For calculation of SPI and SPEI indices I used monthly average temperatures and precipitation from selected climatological stations in eastern Slovakia. Table 1 describes selected climatological stations. It presents the evaluated period for which we had available data and average, minimum, maximum values of climatological variables. The were provided by the Slovak Hydrometeorological Institute branch office Košice. Seven climatological stations were assessed. The climatological stations Červený Kláštor, Poprad and Mníšek nad Hnilcom are located in the north of the eastern Slovakia, the stations Streda nad Bodrogom and Košice are located in the south of Slovakia. Humenné, Kamenica nad Cirochou and Krásny Brod are located in the eastern part of eastern Slovakia and the Mníšek nad Hnilcom and Švedlár are located in the western part of the eastern Slovakia.

| Station            | Value variables | Evaluated period | Min monthly | Max monthly | Average monthly |
|--------------------|-----------------|------------------|-------------|-------------|-----------------|
| Poprad             | Precipitation [mm] | 1960-2014        | 0.4         | 220.4       | 50.1            |
|                    | Air temperature [°C] | 1960-2014        | -24.7       | 25.65       | 6.15            |
| Chmeľnica          | Precipitation [mm] | 1980-2010        | 4.6         | 259.3       | 64.7            |
| Červený Kláštor    | Air temperature [°C] | 1961-2014        | -29.9       | 26.7        | 6.34            |
| Mníšek nad Hnilcom | Precipitation [mm] | 1980-2010        | 1.1         | 261.2       | 59.8            |
| Švedlár             | Air temperature [°C] | 1961-2014        | -22.4       | 25.4        | 6.56            |
| Humenné            | Precipitation [mm] | 1980-2014        | 4.8         | 271.7       | 61.4            |
| Kamenica nad Cirochou | Air temperature [°C] | 1960-2014        | -21.1       | 29.6        | 8.7             |
| Krásny brod        | Precipitation [mm] | 1986-2010        | 1.4         | 245.5       | 69.2            |
| Tisinec-Stropkov   | Air temperature [°C] | 1963-2010        | -22.3       | 26.8        | 8.14            |
| Streda nad Bodrogom | Precipitation [mm] | 1980-2014        | 0.6         | 260         | 53.1            |
| Košice             | Air temperature [°C] | 1960-2014        | -18.4       | 29.75       | 9.1             |

As you can see from table 1 precipitation varies from 0.4 to 271.7 mm per month. Air temperature varies from -29.9 to 29.75.
3. Results

Using the nonparametric Mann Kendall test, it is possible to identify trend in indices. In Table 2, 12-month Standardized Precipitation Index in the evaluated climatological stations are interpreted. There is no trend in Poprad station resulting from the alternation of dry and wet seasons, and in other stations there is a negative trend, with dry periods prevail.

| Climatological station seasons | Mann-Kendall trend test | Test interpretation |
|-------------------------------|-------------------------|---------------------|
| Poprad 1960-2014              |                         |                     |
| Kendall's tau                 | 0.154                   | H0: There is no trend H1: There is a trend | There is no trend |
| S                             | 221.000                 |                     |
| Var(S)                        | 17967.000               |                     |
| p-value (Two-tailed)          | 0.101                   |                     |
| alpha                         | 0.05                    |                     |
| Mníšek nad Hnilcom 1980-2010  |                         |                     |
| Kendall's tau                 | 0.631                   | H0: There is no trend H1: There is a trend | There is a trend |
| S                             | 773.000                 |                     |
| Var(S)                        | 14291.667               |                     |
| p-value (Two-tailed)          | < 0.0001                |                     |
| alpha                         | 0.05                    |                     |
| Humenné Humenné 1980-2010     |                         |                     |
| Kendall's tau                 | 0.384                   | H0: There is no trend H1: There is a trend | There is a trend |
| S                             | 471.000                 |                     |
| Var(S)                        | 14291.667               |                     |
| p-value (Two-tailed)          | < 0.0001                |                     |
| alpha                         | 0.05                    |                     |
| Krásny Brod 1986-2010         |                         |                     |
| Kendall's tau                 | 0.552                   | H0: There is no trend H1: There is a trend | There is a trend |
| S                             | 676.000                 |                     |
| Var(S)                        | 14290.667               |                     |
| p-value (Two-tailed)          | < 0.0001                |                     |
| alpha                         | 0.05                    |                     |
| Chmeňnica 1980-2010           |                         |                     |
| Kendall's tau                 | 0.520                   | H0: There is no trend H1: There is a trend | There is a trend |
| S                             | 637.000                 |                     |
| Var(S)                        | 14291.667               |                     |
| p-value (Two-tailed)          | < 0.0001                |                     |
| alpha                         | 0.05                    |                     |
| Streda nad Bodrogom 1980-2010 |                         |                     |
| Kendall's tau                 | 0.411                   | H0: There is no trend H1: There is a trend | There is a trend |
| S                             | 501.000                 |                     |
| Var(S)                        | 14275.000               |                     |
| p-value (Two-tailed)          | < 0.0001                |                     |
| alpha                         | 0.05                    |                     |

In Table 3 is presented in the evaluated climatological stations. There is a trend in the stations Poprad, Mníšek nad Hnilcom and Chmeňnica in the SPEI index and it is decreasing, so there are more dry periods. In Humenné, Krásny Brod and Chmeňnica there is no trend characterized by alternating periods.
Table 3. Mann-Kendall trend test of 12 months SPEI.

| Climatology station season | Mann-Kendall trend test | Test interpretation |
|----------------------------|-------------------------|---------------------|
|                            | Kendall's tau           | -0.201              |
|                            | S                       | -393.000            |
|                            | Var(S)                  | 28427.000           |
|                            | p-value (Two-tailed)    | 0.020               |
|                            | alpha                   | 0.05                |
| Poprad 1960-2014           | 0.05 (Two-tailed)       | H0: There is no trend |
|                            | 0.05 (Two-tailed)       | H1: There is a trend |
|                            | There is a trend         |                     |
|                            |                        |                     |
| Mníšek nad Hnilcom and Švedlár 1980-2010 | Kendall's tau           | 0.365               |
|                             | S                       | 148.000             |
|                             | Var(S)                  | 2842.000            |
|                             | p-value (Two-tailed)    | 0.006               |
|                             | alpha                   | 0.05                |
|                            | H0: There is no trend    |                     |
|                            | H1: There is a trend     |                     |
|                            | There is a trend         |                     |
|                            |                        |                     |
| Humenné and Kamenica nad Cirochou 1989-2010 | Kendall's tau           | -0.067              |
|                             | S                       | -29.000             |
|                             | Var(S)                  | 3141.667            |
|                             | p-value (Two-tailed)    | 0.617               |
|                             | alpha                   | 0.05                |
|                            | H0: There is no trend    |                     |
|                            | H1: There is a trend     |                     |
|                            | There is no trend        |                     |
|                            |                        |                     |
| Krásny Brod and Tisinec-Stropkov 1980-2010 | Kendall's tau           | 0.225               |
|                             | S                       | 62.000              |
|                             | Var(S)                  | 1625.333            |
|                             | p-value (Two-tailed)    | 0.130               |
|                             | alpha                   | 0.05                |
|                            | H0: There is no trend    |                     |
|                            | H1: There is a trend     |                     |
|                            | There is no trend        |                     |
|                            |                        |                     |
| Chmeľnica and Červený Kláštor 1986-2010 | Kendall's tau           | 0.448               |
|                             | S                       | 182.000             |
|                             | Var(S)                  | 2842.000            |
|                             | p-value (Two-tailed)    | 0.001               |
|                             | alpha                   | 0.05                |
|                            | H0: There is no trend    |                     |
|                            | H1: There is a trend     |                     |
|                            | There is a trend         |                     |
|                            |                        |                     |
| Streda nad Bodrogom and Košice 1980-2014 | Kendall's tau           | -0.200              |
|                             | S                       | -87.000             |
|                             | Var(S)                  | 3141.667            |
|                             | p-value (Two-tailed)    | 0.125               |
|                             | alpha                   | 0.05                |
|                            | H0: There is no trend    |                     |
|                            | H1: There is a trend     |                     |
|                            | There is no trend        |                     |

4. Conclusions

The work was focused on occurrence of trend in climatological indices Standardized Precipitation Index (SPI) and Standardized Evapotranspiration Index (SPEI). The results show that in the SPI no trend was only in the station Poprad, in other stations evaluated the trend has a decreasing character. In the SPEI, no trend is in three stations: Humenné/Kamenica nad Cirochou, Krásny Brod/Tisinec, Streda nad Bodrogom/Košice and the other three: Poprad, Mníšek nad Hnilcom/Švedlár, Chmeľnica/Červený Kláštor. Where the trend does not occur is the alternation of dry and wet periods but is not possible to determine the frequency of the alternation of periods. The results would be useful for further research into climate and hydrological models, which would be relevant for strategic water resource planning and drought prevention.

The main factors of climate change are decreasing precipitation and rising air temperature, which contribute to drought formation. As the temperature rises, the surface water vapor increases, which
implies that precipitation should increase but this is not the case. Drought occurrence continuous research and should be given more attention. Reducing the length and intensity of droughts would be possible if the drought could be more accurately predicted and water management could be better managed. During the dry season it is necessary to increase the soil moisture, which would be beneficial for agriculture, overestimating water levels in the river basins and in wet periods it was necessary to retain water in the country.

5. References

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