IMPACT OF REGIONAL CLIMATE IN SLOVAKIA ON WATER RESOURCES MANAGEMENT

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ABSTRACT

The study of climatological data is performed with goal to reduce impacts of droughts and floods and thus to ensure sustainable and proper water resources management. Based on the precipitation time series obtained from Slovak Hydrometeorological Institute at a number of climatic stations over a considerable span of time, a comprehensive analysis for the entire Slovakia is being carried out. Some of methods applied as well as some of the results achieved are briefly mentioned in this paper, namely (i) the treatment of the monthly rainfall series (filling of the gaps), (ii) trend analysis applied to climatological time series (iii) the division of climatological stations by applying principal component analysis, and (iv) the temporal and spatial evolution of climatological hazards in the area. For the time scale adopted, the study showed that it is possible to clearly identify four homogenous regions in Slovakia. It is found increasing trends in precipitation time series in the most of stations. Although it is also proved that the droughts are recurrent in Slovakia. The paper finally identifies climatological extremity in the country that significantly influences water resources management.

Keywords: Precipitation, Climatological stations, Statistical analysis, Water resources

1 INTRODUCTION

The European Parliament and the Council of the European Union establishing a framework for Community action in the field of water policy on 23 October 2000 by Directive 2000/60/EC, in short EU Water Framework Directive or WFD. One of the purpose of this Directive is to contribute to mitigating the effects of floods and droughts. Effective water management, as required by the WFD, helps Member States prepare for extreme weather events which, due to climate change, are becoming more frequent and cause tremendous damages. Under the no-adaptation scenario (i.e. assuming continuation of the current protection against river floods up to a current 100-year event), EU damages from the combined effect of climate and socioeconomic changes are projected to rise from EUR 6.9 billion/year to EUR 20.4 billion/year by the 2020s, EUR 45.9 billion/year by the 2050s, and EUR 97.9 billion/year by the 2080s (Rojas et al., 2013).

Directive 2007/60/EC on the assessment and management of flood risks entered into force on 26 November 2007. This Directive now requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk. While Europe is by large considered as having adequate water resources, water scarcity and drought is an increasingly frequent and widespread phenomenon in the European Union. The major challenge from water scarcity and droughts has been recognized in the Communication "Addressing the challenge of water scarcity and droughts" from the European Commission adopted in 2007 (COM, 2007).

The aim of this contribution is assessment of the impact of regional climate in Slovakia, one of the EU Member States, on water resources management.

2 MATERIAL AND METHODS

The regional climate in Slovakia and its impacts on water resources management were assessed by evaluation of precipitation time series by the common methods – statistical analysis (trend analysis) and drought indexes. There are 634 rain gauging stations operated by Slovak Hydrometeorological Institute (SHMI) in Slovakia. For evaluation of precipitation over whole Slovakia we considered 487 (for Mann Kendall trend analysis) or 491 stations (for Principal Component Analysis) for period from 1981 to 2013. In the rest of stations we do not have complete data series.

(i) The selected stations also had a few some missing data that were filled based on linear regression analysis. For that purpose and for each gap in a given rain gage, *RG1*, a near rain gage, *RG2*, was identified provided that (Portela et al., 2015): a) *RG1* and *RG2* had at least 10 years of simultaneous records in the month where the gap occurred; b) the correlation coefficient, *R*, between the two monthly historical series was the highest from all the possible nearest stations that verify condition; and necessarily higher than 0.7 ($R \geq 0.7$).
This procedure allowed filling all the gaps, except in three months that were filled with the respective monthly averages.

(ii) Trend analysis for hydrological time series is an important and popular tool for better understanding the effects of climate variation and anthropogenic activities. The Mann–Kendall (MK) test (Kendall, 1975; Mann, 1945) is a rank-based nonparametric test for assessing the significance of a trend, and has been widely used in hydro-meteorological trend detection studies (Lettenmaier et al., 1994; Burn, 2002; Pauling & Paeth, 2006; Partal & Kahya, 2006; Sayemuzzaman & Jha, 2014). The magnitude of the trend was determined using Sen`s estimator. Sen's method assumes a linear trend in the time series and has been widely used for determining the magnitude of trend in hydro-meteorological time series (Sen, 1968), etc. We used the mentioned methods for trend detection and its magnitude statement in precipitation time series during the mentioned period.

(iii) The definition of homogeneous regions regarding the temporal pattern of the Standardized Precipitation Index over a 3-month period (SPI3) field utilized Principal Component Analysis (PCA), which can be define as a technique that allows decomposing the multisite data set of a given variable (e.g., the SPI3 field) into univariate representations of that variable (McKee et al., 1993). By this way, the original intercorrelated variables can be reduced to a small number of new linearly uncorrelated variables that explain most of the total variance (Bonaccorso et al., 2003; Vicente-Serrano et al., 2004; Santos et al., 2010). The evaluation of the results of the principal components was based on the analysis of the eigenvalues (Bryant & Yarnold, 1995), on the correlations between PCs and the original variables (mapping of the factor loadings) and on percentage of the variance explained by the model.

(iv) For the temporal analysis we have used analyzing tools of Microsoft Office Excel 2010 and R software environment and for the spatial analysis we have used modelling and analyzing tools of ArcGIS 10.3 – Geostatistical Analyst – Kriging and Inverse Distance Weighting.
The results of mentioned calculations and analysis for precipitation series are discussed in section 3.

2.1 Study area

The territory of Slovakia is in the light of global climate classification in the northern temperate climatic zone with a regular alternation of four seasons and variable weather, with a relatively even distribution of rainfall throughout the year. In Slovakia, according to the Slovak Hydrometeorological Institute (SHMI), are in average 600 mm of precipitation per year. Mountains in northwest and north of the country are generally richer in atmospheric precipitation than the lowlands in central, southern and eastern regions of Slovakia. Great variability of precipitation caused mainly in the lowlands frequent and sometimes prolonged periods of drought. In winter, much of the rain falls, particularly in the middle and the high mountain ranges, in the form of snow. The rainiest month is usually June or July, and the less rainfall is from January to March (SHMI, 2015).

The daily data for trend analysis were obtained from Slovak Hydrometeorological Institute (SHMI) in Košice, Slovakia. The network of rain gauge stations over the Slovak Republic is depicted in Fig. 1. There are 634 rain gauging stations operated by SHMI. For evaluation of trend analysis over whole Slovakia we considered 487 stations for period from 1981 to 2013 and for the definition of homogeneous regions regarding the temporal pattern of the SPI3 field utilized Principal Component Analysis we considered 491 stations for the same period.

3 RESULTS AND DISCUSSIONS

This section presents the main results of the contribution and discussion.

(i) From the total number of months of 491 x 33 x 12 = 194436, there were gaps in 3248 (i.e., in approx. 1.67% of the months) that were filled by linear regression analysis. This procedure allowed filling all the gaps, except those in three months that were filled with the respective monthly averages.

(ii)

(ii) Trend analysis for precipitation time series by Mann–Kendall (MK) non-parametric statistical test was programmed in Microsoft Excel. Number of stations of positive and negative trend in 95% confidence level are shown in Fig. 1, respectively of annual and seasonal time scale precipitation data series during the period 1981–2013.

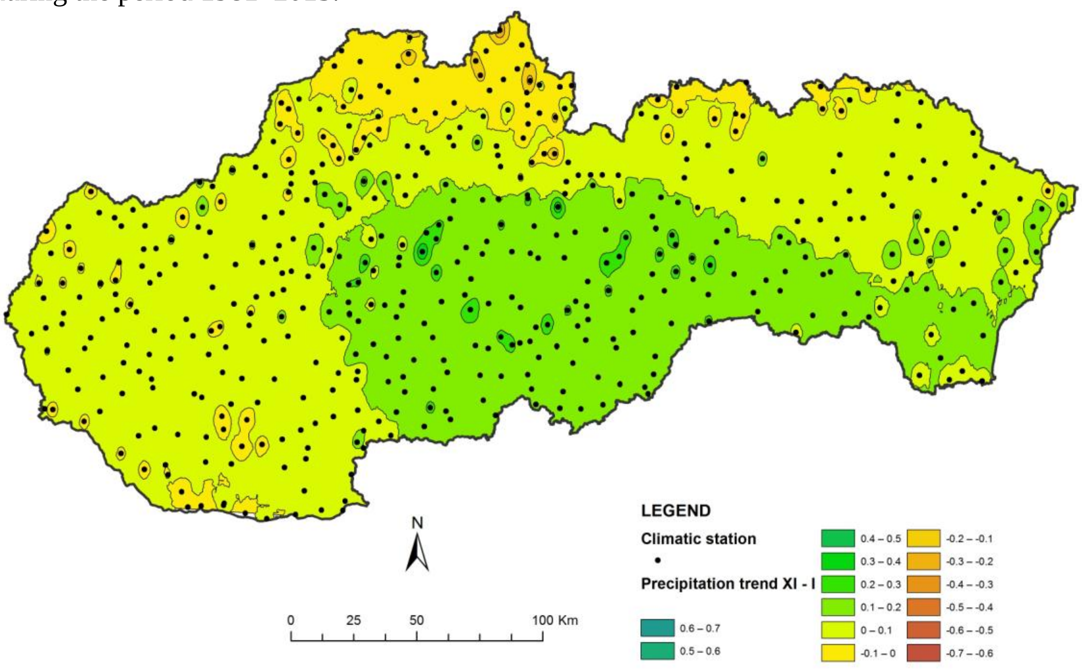

Figure 1. Precipitation trends in Slovakia.

Analysis of the annual precipitation time-series using MK test identified in almost all stations a positive trend (452 of 487 stations or 93%) and rest with a negative trend. The level of significance using Sen estimator value identified 157 stations having significant trend with 95% confidence level (155 stations with positive trend and 2 stations with negative trend) (Fig. 1). Significant negative trends are found only in north part of the study area, significant positive trends are identified over all the area.

(iii) Based on the results from the PCA regionalization (Fig. 2), the regions where the values of the correlation coefficient, *R*, between each rotated principal component and the at-site SPI3 time series were equal or higher than 0.6 were delimited, as represented in Fig. 2.

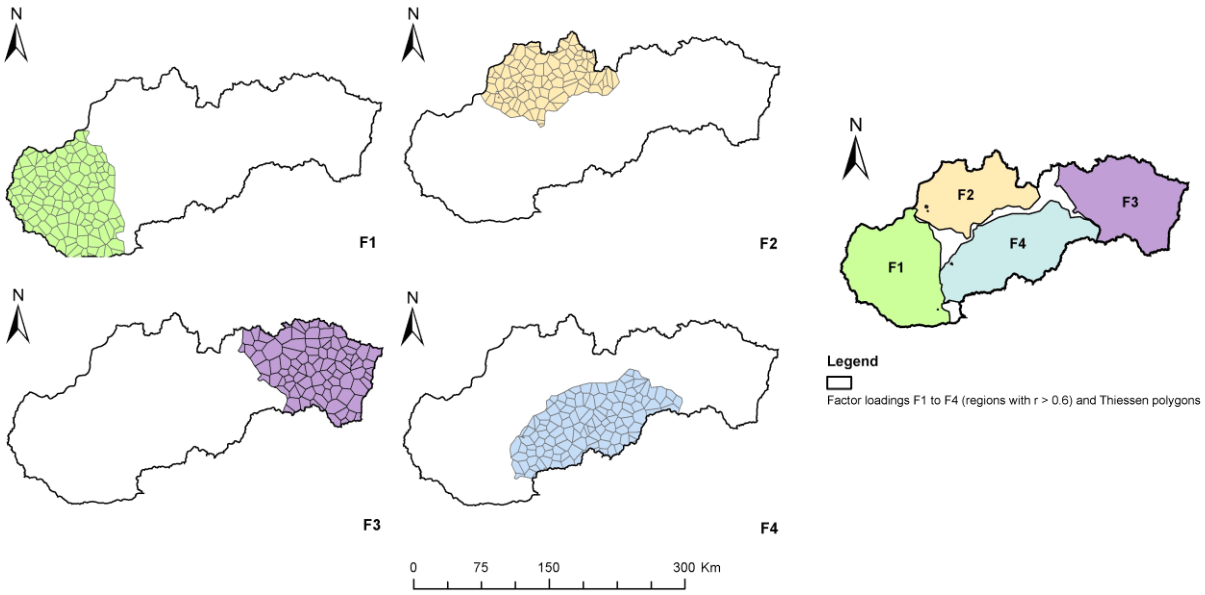

Figure 2. Homogeneous regions in Slovakia

For each one of the regions affected by moderate (-1.28<SPI3<-0.84), severe (-1.65<SPI3<-1.28), and extreme drought (SPI3<-1.65), according to the SPI categories, were identified based on the Thiessen polygons for the rain gages included in the region.

Drought events identified based on the SPI3 occurred regularly in Slovakia along the study period (1981–2013). Two important drought events occurred simultaneously in all four regions – in the beginning of 1982 and in April 2011 a generalized extreme drought started with duration of approximately three months. Increased rainfall and floods are expected in some regions while other regions will experience smaller rainfall and longer droughts, meaning water scarcity.

4 CONCLUSIONS

The floods and drought effects have been observed on all continents and over the past decade the frequency of floods and drought increases mainly in consequences of climate variability. Knowledge of the occurrence and distribution of precipitation is an important input for many sectors of the national economies, mainly:

- Civil engineering – the design of water works – dams construction, hydropower plants, water course regulation;
- Agriculture – irrigation and drainage;
- Water management – water supply for the population and for industry, flood protection measures, drought mitigation measures, rainwater management;

The main overall objective of EU water policy is to ensure access to good quality water in sufficient quantity for all Europeans, and to ensure the good status of all water bodies across Europe. Therefore, policies and actions are set up in order to prevent and to mitigate water scarcity and drought situations as well as flood situations, with the priority to move towards a water-efficient and water-saving economy.

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