The impact of climate changes on the variation of the groundwater level in the Moldavian Plateau

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1 Introduction

Regional and global scale effect of climate changes on temperatures and precipitation can trigger significant changes in river runoff and groundwater level, which later reflect in the evolution of water resources and social development at a regional level (de Moura et al., 2020). In these conditions, it is important to identify methods to analyze the impact of climate changes on hydro-climatic and hydrogeological parameters that are relevant in the medium and long term (Koster et al., 2017). In the last decades, the scientific research on the impact of climate change on the various hydro-climatic parameters has been multiplied, most of the analyzes focusing on the identification of trends in the extreme seasonal and annual values of precipitations, temperatures, or rivers flow (Croitoru et al., 2018). Two main directions were identified in the analysis of trends. The first one was based on Mann-Kendall test (MK) and associated estimating trends by the Sen method (Bürger, 2017). The results obtained by applying to different climatic or hydrological parameters highlighted statistically significant trends of increasing average or maximum annual temperatures (Shrestha et al., 2017), rainfall (Zelenekova et al., 2017) or river runoff (Asraf et al., 2020). To verify the results, the method was compared with Spearman's rho trend statistic test (Hamed, 2016) and Monte Carlo simulations method (Wang et al., 2020). The second direction proposed to highlight the trends through graphical methods is innovative analysis method (ITA) (Șen, 2012). For eastern part of Romania, where Moldavian Plateau is expanding over more than 20.000 km^2, previous researches based on MK and ITA have estimated significant changes in climatic (Croitoru et al., 2016), hydrological (Dumitriu, 2020) and hydrogeological parameters (Minea, Croitoru, 2017) as a result of regional climate changes. Climatic scenarios evolution on short, medium and long term shows a tendency of increasing temperatures and decreasing water input from precipitation over entire region. For that the trend evaluation of the groundwater level becomes obligatory in the water resources management projects in a region with high dependency on groundwater resources availability (Minea, 2020).

2 Data base and methodology

In this paper, seasonal and annual data from the 147 hydrogeological wells from eastern Romania were used to identify changes that occurred in groundwater level. The analysis for groundwater level was performed based on four seasonal and one annual data set (with no gaps in the data sets) over a period between 1983 to 2020. All the hydrogeological data sets were computed from monthly values. The data were provided by the Prut-Bârlad Basins Branch of Romanian Waters Administration. Three methods were used to analyze trends of groundwater level: Non-parametric Mann-Kendall test (MK), Innovative Trend Analysis Method (ITA) and Spearman's Rho Test (SR). MK test has the advantage of not taking into account the outliers that can bring some deviation in statistical analysis and also, to be applied to data sets that do not fit into a statistical distribution (Tabari et al., 2011). ITA can be computed on data series which do not need statistical assumptions and from this point of view different hydroclimatic parameters were used in the analysis (Dabanli et al. 2016). SR test is non-parametric rank-based method used to analyze the variations of hydroclimatic parameters in order to compare the results with other statistical methods (like MK or ITA). All hydrogeological wells were classified according to the water depth in 8 clusters (from 0 to 2 m considered cluster 1 water depth to over 15 meters depth considered cluster 8). Taking into account that in the case of groundwater level the actual measurements relate to the surface of the terrain, the interpretation of the trends is performed inversely to the interpretation of the trends in the hydro-climatic parameters from the surface (Minea et al., 2020).

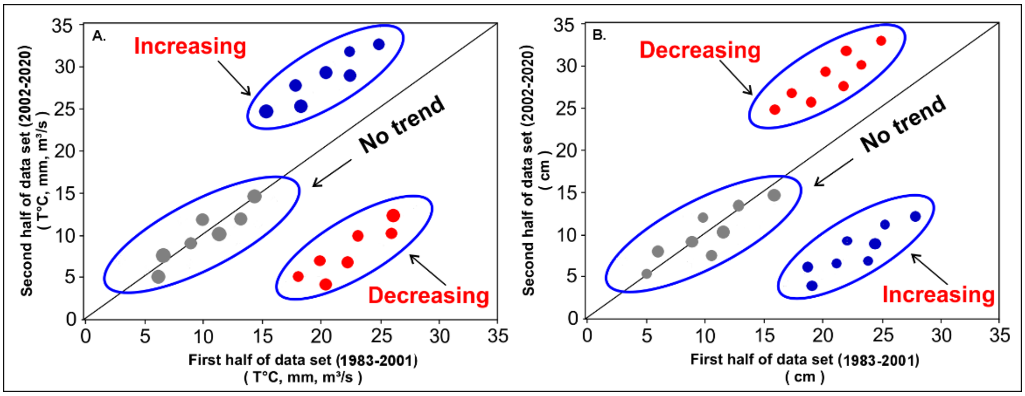

Figure 1 Graphical interpretation for hydroclimatic (A) parameters and groundwater level (B) trends.

3 Results

The applicability of the innovative trend analysis (ITA) method was investigated by comparing its results with the one obtained by MK and SR methods which are computed at monthly, seasonal and annual temporal scales. At monthly time scale, a total of 1764 timeseries were tested by using MK and SR methods, out of which 78% and 75% of timeseries exhibited significant trends, respectively whereas, 92% timeseries manifested significant trends by using the ITA method. A mixture of significant increasing and decreasing trends was found for annual groundwater level data set for each method used (Figure 2). For instance, statistically significant decreasing trends (more than 65%) were observed for data obtained by ITA method for the groundwater level from well with water depth under 2 meters (Cluster 1) (Figure 3). The same trends were observed using MK test and SR test, but with less statistical significance (56%, respectively, 52%). These changes in the groundwater level can have a negative impact on the environment. In winter and spring seasons, the decrease in groundwater level, identified for depths of 0 and 2 m, can have a significant impact on surface water and underground water changes. Decreasing levels for groundwater may lead to lower groundwater quality through faster infiltration of surface water directly or through the hydrographic network.

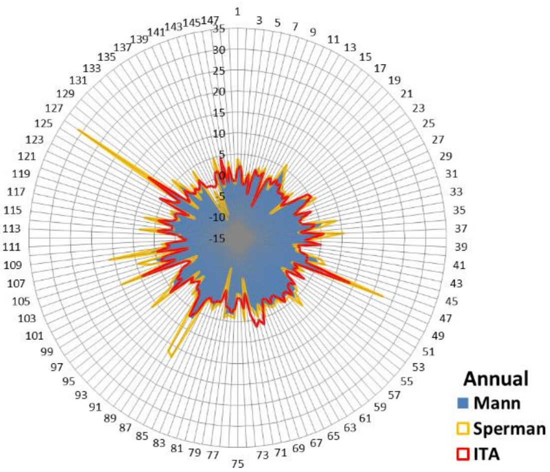

Figure 2 MK, SR and ITA comparison of trend results in annual dataset.

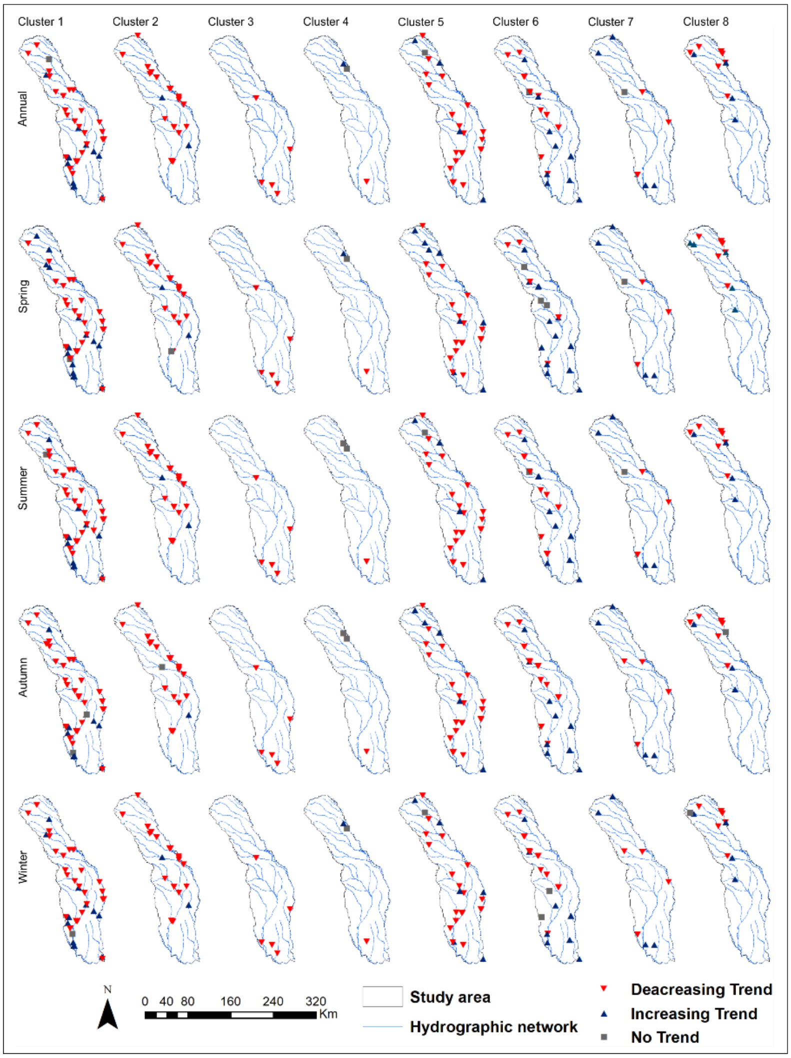

Figure 3 Spatial distribution of seasonal and annual groundwater level trends by using ITA method.

As the depth of the piezometric level increases, the decreasing tendencies fade, reaching even an increasing tendency at depths of groundwater level of over 10 m (Cluster 5 to 8). This situation can be explained by reducing the influence of atmospheric water intake in groundwater supply and increasing the role of local geological conditions in the variation of groundwater level. In the spring and summer seasons due to the variations of the monthly average values of the groundwater level under the impulse of the hydric water supply from the surface (from precipitations or hydrographic network) the slopes of the trends have the lowest significance.

Following the analysis, a series of conclusions can be drawn that can be helpful in groundwater resources management projects at local and regional level. In the first place, all methods can be applied to highlight the trends of groundwater level variations, the results obtained, in terms of the trend being identical in over 84% of cases. The values obtained using the ITA method have a higher statistical significance (in 92% of cases in the analysis of data on summer and autumn seasons and 95% in the case of data on annual values of groundwater level). These results are supported by the high values of statistical significance of the trends obtained by MK test and RN test for groundwater depths. The obtained results can be correlated with the trends obtained for seasonal and annual hydro-climatic parameters from this region (precipitation, air temperature, medium and maximum river runoff, etc.) analyzed by using MK test and ITA methods.

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