Groundwater drought in Northeast Bulgaria and the SPI index

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Abstract
Groundwater is a valuable resource yet vulnerable to long-lasting droughts. One of the drought indices is the Standardized Precipitation Index (SPI) that allows monitoring of droughts at different time scales. For the study area from the Northeast Bulgaria (Dobrich region) the impact of drought on the groundwater system is investigated based on the SPI indices. The results show that the decline of the groundwater levels is in conformity with low values of the SPI especially for longer time scales. This fact indicates the importance of the drought monitoring. In general, the impact from the short-term wet and dry events is superposed on the long-term influence described by SPIs.

1. Introduction
According to many climatic scenarios, more frequent droughts for Southeastern Europe are expected with enhanced negative impact on the freshwater resources. Groundwater in Bulgaria is rather vulnerable to long-lasting droughts, based on the groundwater regime data (Benderev, et al., 2008).

The shortage of precipitation propagates trough different elements of the eco-hydrological system. Mishra & Singh (2010) introduce groundwater drought as an additional important type of drought in addition to the known types (meteorological, hydrological, agricultural and socio-economic). This type of drought generally occurs on the time scale of months to years and affects groundwater recharge, levels and discharge.

Drought in the northeastern part of Bulgaria is normal and a relatively common phenomenon (Nikolova, 2013). Long-lasting drought episodes affect groundwater systems. The aim of the study is to assess the impact of droughts on the groundwater regime in the Dobrich region (Northeast Bulgaria) based on the SPI indices.

2. Study area
The Dobrich region is located in Northeast Bulgaria, in the eastern part of the hilly Danubian Plain (Fig. 1). Low plateaus up to 150-200 m high are the typical relief of the area. The climate is temperate. The annual rainfall averages between 500-550 mm. Precipitation is characterized with maximum in June and minimum in February. The snow cover stays for up to 2.5 months. The main soil types in the area are: typical Chernozems and leached Chernozems. Agricultural landuse is widespread in the area.

The lithostratigraphical units of Sarmatian age (Neogene) that outcrop in the study area are: the Odarska Formation (detritus-shell and oolite limestones with sandy and clayey layers) with a thickness of about 20 m that overlays the Frangen formation (sands). Quaternary is represented by the Loess Formation with a thickness of 5÷15 m (Fig. 1).

Groundwater is accumulated in the Neogene limestone and sands. This Sarmatian aquifer, which is the most important source for water supply in the area, is vulnerable to pollution – mainly from the agricultural activity and settlements without wastewater treatment plants. Hydrogeological setting in the Dobrich region is described by Danchev et al. (1981) and Pulido-Bosch et al. (1997). Pavlova and Benderev (2014) identified several types of the groundwater regime for the region.

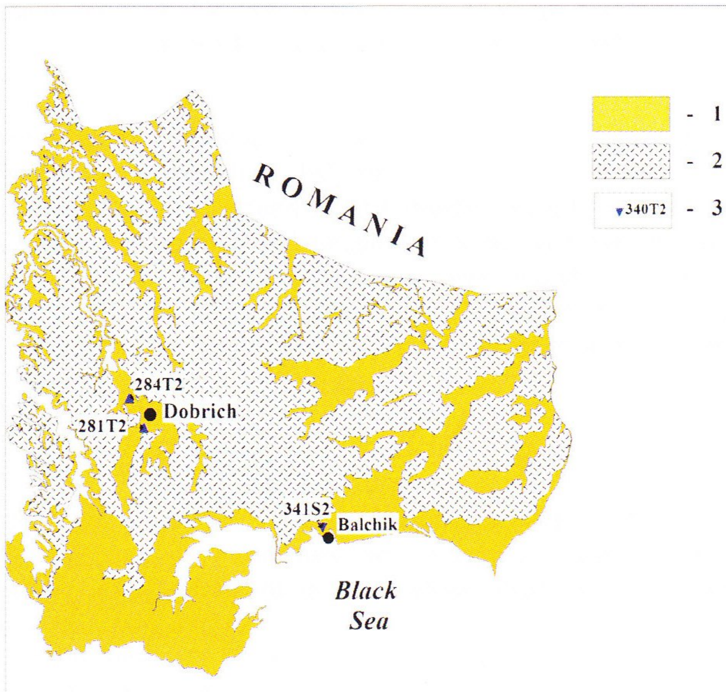

Fig. 1: Study area: 1- outcropping of the Sarmatian limestone; 2 – loess cover; 3 – well

Four observation wells are used in this study – two in the town of Dobrich and others – near the Black Sea coast (Fig. 1, Tab. 1). The individual number of each well includes symbols that mean as follows: "T" – borehole, "S" – dug well, and "2" – karst aquifer.

3. Method and data

The Standardized Precipitation Index (SPI) proposed by McKee et al. (1993) allows monitoring of droughts at different time scales – generally from 3-month to 24-month. The values of the SPI from -1.50 to -1.99 indicate severe drought, and SPI below minus 2 – extreme drought. The Standardized Precipitation Index (SPI-n) is a statistical indicator comparing the total precipitation received at a particular location during a period of n months with the long-term rainfall distribution for the same period of time at that location. SPI is calculated on a monthly SPI for a moving window of n months, where n indicates the rainfall accumulation period, which is typically 1, 3, 6, 9, 12, 24 or 48 months. The corresponding SPIs are denoted as SPI-1, SPI-3, SPI-6, etc. (SPI, 2012). A 3-month SPI reflects short- and medium-term moisture conditions and provides a seasonal estimation of precipitation. A 6-month SPI may be associated with anomalous streamflows and reservoir levels. SPIs of longer time scales are most probably tied to streamflows, reservoir levels and groundwater levels (according to http://drought.unl.edu/

MonitoringTools/ClimateDivisionSPI/Interpretation/6month.aspx). The Program to calculate the SPI value is downloadable from the National Drought Mitigation Center at the University of Nebraska - Lincoln (http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx, 19 Sep 2013).

Tab. 1: Average depth to the groundwater table (Hav) and standard deviation (s). Coefficient of correlation of the groundwater level with the SPI indices

Station	Location	Period	Hav, m	s, m	SPI-24	SPI-36	SPI-48
s341S2	Balchik	1987-2011	31.94	0.97	**0.62**	0.58	0.44
s332S2	Tsarichino	1986-2011	32.04	2.13	0.65	**0.77**	0.70
s281T2	Dobrich – park	2006-2011	18.32	0.56	0.57	-	-
s284T2	Dobrich	2006-2011	19.51	0.61	**0.74**	0.48	-

The time series used in this study are from the meteorological and hydrogeological networks at the National Institute of Meteorology and Hydrology at Bulgarian Academy of Sciences. To compute the indices SPI, a long-term time series of monthly precipitation sums are necessary. The monthly precipitation data is from the synoptic station at the town of Dobrich (period 1981-2011). The groundwater levels are from the four observational wells in the Dobrich area (Tab. 1). The wells are measured on monthly or daily basis.

4. Results

According to the annual precipitation sum in Dobrich, the identified dry years are as follows: 1983, 1986, 1990, 1992, and 2001, and the wet years are: 1995, 1997, 2002, 2005, and 2010. The SPI values are calculated based on monthly precipitation data for the synoptic station Dobrich. The results for SPI-24, SPI-36 and SPI-48 presented in Fig. 2 for the period 1989-2011 reveal the long-term wet and dry episodes.

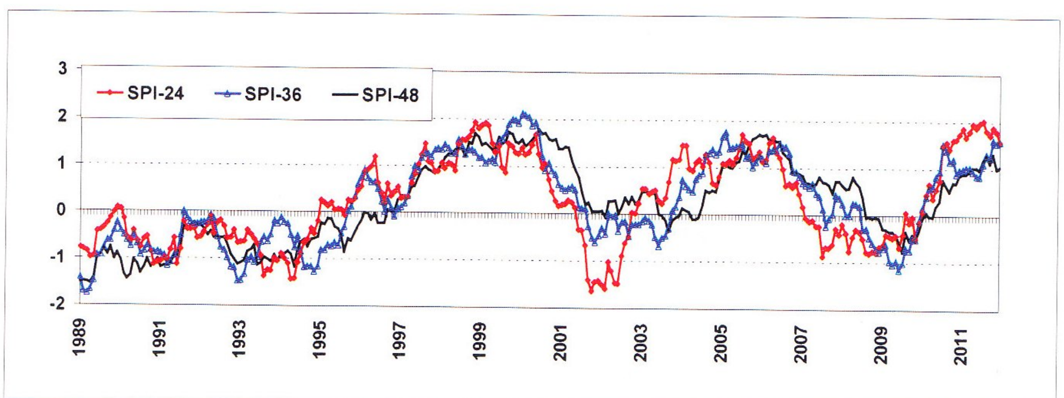

Fig. 2: Evolution of the 24, 36 and 48 months SPI for the study area

The groundwater regime for the wells is compared with the SPI indices. The highest correlation is observed for SPI-24 and SPI-36 (Tab. 1). The results give evidence that the groundwater levels are generally in conformity with the values of the SPI indices, especially for longer time scales (Fig. 3). Large precipitation amount in Dobrich in December 2009 and January 2010 that exceeded the respective monthly norms three to four times, contributed to the additional groundwater level rise in the beginning of the 2010 in addition to the long-term influence indicated by SPIs.

5. Conclusion

The groundwater regime in Northeast Bulgaria gives evidence to respond both to short-term and long-term fluctuations of the precipitation input. The succession of wet and dry years results in the respective variations of the groundwater levels. To assess the impact of the variable precipitation amount on the Sarmatian aquifer in Northeast Bulgaria, the groundwater regime in the Dobrich region is compared with the SPI indices. The results show that the fluctuation of the groundwater levels is in conformity with the SPI values mostly for longer time scales. Evidently, the Sarmatian aquifer is prone to droughts and is characterized with large temporal variation in groundwater recharge. Under the circumstances, its quantification on a regular basis is necessary along with monitoring of the groundwater drought. In general, wet and dry cycles of precipitation input alternate and further propagate into the groundwater system.

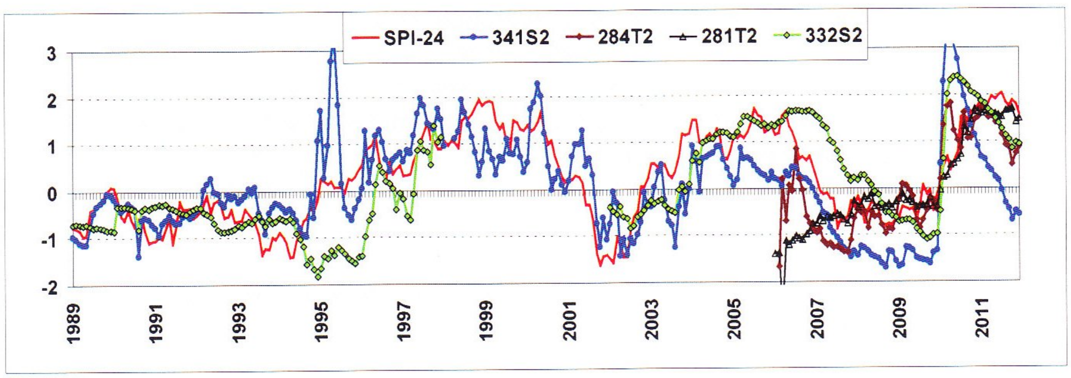

Fig. 3: Comparison of the groundwater levels in relative deviations (Hav-H)/s and the SPI-24

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