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Characteristics of Groundwater Level in the Szarvas-Békésszentandrás Oxbow Subbasin

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Abstract: The shallow groundwater has a direct and indirect effect on natural vegetation and agricultural production. The decline in groundwater level (GWL) can have negative impacts. In many areas in Hungary decreasing GWL trends in the last decades were found by earlier studies. In our research we studied the characteristics of groundwater level focusing on our study area, the subbasin of Szarvas-Békésszentandrás Oxbow. We analysed 20 years daily data of groundwater level of eight monitoring wells. Annual course and long term tendencies of groundwater level were examined. In average of 16 years the GWL reaches its maximum in April and its deepest level in autumn (September, October and November depending on the station). Four typical groups of groundwater level courses could be distinguished based on the average depth and seasonal variations of GWL. The year to year GWL variability is larger in January and April compared to July and especially to October. The trends of the middle months of the seasons are almost the same in significance and slope compared to the trends based on yearly mean time series. The differences in trends can be found between stations rather than between the months used for calculations. The larger part of the subbasin can be characterised by decreasing trend in groundwater levels (2002-2020). The change exceeds 1 m at station Szarvas 2832 (144 cm) and Szarvas 2778 (122 cm). However, there is a station with no significant trend, GWL at Csabacsűd 2779 station shows relative stability in yearly average, which is valid for some areas in the eastern part of the subbasin.

Keywords: groundwater level, trend, long-term, annual course

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Introduction

The shallow groundwater has a direct and indirect effect on natural vegetation and agricultural production. High levels of groundwater increases the risk of inland excess water. In case of optimal level the groundwater can significantly contribute to the water supply of plants. This optimal level depends on the crop species, soil type and meteorological conditions. The decline in the groundwater level can result in loss of this positive effects. Such a phenomenon can be observed in many regions caused by the climate change. In our study we focus on these questions related to our research area, Szarvas-Békésszentandrás Oxbow Subbasin.

In the lysimeter groundwater experiments, the optimum level was at 1 m depth for field crops (wheat, maize, sugar beet, alfalfa) and higher (0.5 m) for grasses, where the average yield reached values of irrigated treatments. In deeper-rooted plants, the effect of decreasing groundwater level occurs more slowly, as they are able to absorb water from deeper groundwater (Szalóki, 1994). From the groundwater, the water enters the upper layers of the soil mainly through capillary water lifting (Pálfai, 1996).

High groundwater levels can help or cause the formation of inland excess water (Rétháti, 1983). Rising groundwater levels can bring harmful salts to the soil surface, which can cause secondary salinization. If the upward water movement can be changed to a downward one by some technical solution (e.g. drainage), then the salinity in the given place can be kept at the leaching stage or in equilibrium even at a higher than critical groundwater level (Molnár & Winter, 1983).

The change of groundwater level is influenced by meteorological factors (precipitation, temperature, evaporation) and human activity (water extraction, irrigation, sewerage) ((Li et al., 2020; Yan et al., 2021)). Near watercourses, groundwater level follows the water level of the surface water (river) ((Stelczer, 2000)). An increase in groundwater levels may occur as a result of irrigation and leakage from irrigation channels (Molnár & Winter, 1983).

Groundwater levels change periodically throughout the year. Annual and daily fluctuations in the vertical movement of the groundwater level are observed (Li et al., 2020). The general seasonal course in water level in Hungary has a spring maximum and an autumn minimum (Rétháti, 1983). Nyizsalovszki and Szabó (2003) showed two minimum in the groundwater level in Tokaj-Hegyalja during the year, a smaller minimum at the end of summer (August-September) due to lack of precipitation, evaporation loss, water uptake by plants, and then as an organic continuation, a stronger minimum late autumn-early winter minimum, that occurred during November-December. It was caused by low rainfall during the measurement period. The maximum values occurred in the spring (March-April). There was a strong correlation between the amount of precipitation and the fluctuation of the groundwater.

In the studies of Kovács and Turai (2004) the result for the Mátra-Bükkalja area the groundwater level basically depends on precipitation conditions. It was also found that the extraction of mining water and the changes of confined aquifers have no influence on the groundwater level. However, according to other Hungarian studies the intensive water withdrawals from the confined aquafer reduces the amount of shallow groundwater (Pálfai, 2010). In another study of Mátraalja-Bükkalja area the groundwater level reached its maximum values in April-May during the year (Kovács, 2014). There was no direct correlation between the monthly precipitation and the groundwater level depth in the given month. The maximum groundwater level of each well occurred only 0.6–1.2 years after the occurrence of precipitation maxima, depending on the depth of the average groundwater level in the wells. The time shift is longer if the groundwater level is deeper (1.5-3 m water depth: 0.7-0.9 years, 3-4 m water depth: 1.0-1.4 years).

In areas with different climatic conditions Abliz et al. (2016) also found seasonal fluctuations in groundwater level in Northwest China, with the shallowest groundwater levels in spring, sinking during summer and autumn, due to evapotranspiration and extensive agricultural water consumption. Hao et al. (2017) observed a continuous decline in groundwater levels in China as a result of long-term water extraction.

In Hungary between the Danube and the Tisza rivers, in the north-western observation wells (Ócsa, Ladánybene), the groundwater level decreased significantly between 1940 and 2008. The measurements showed a decrease in the groundwater level in the southern part of the Danube-Tisza area (around Rém) and in the area of Ásotthalom, too, regarding the long-term series data. Annual fluctuations can be detected in the water regime of the Öregcsertó observation well in the floodplain of the Danube, but it does not

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Table 1: Average air temperature (T, °C) and precipitation (P, mm) in Szarvas, 1981-2010

	1	2	3	4	5	6	7	8	9	10	11	12	year
T	-1.0	0.5	5.6	11.5	16.8	19.8	21.9	21.4	16.6	11.2	5.0	0.3	10.8
P	29	30	28	42	51	61	58	51	48	32	41	45	515

Table 2: Groundwater monitoring stations metadata

Monitoring well	soil surface elevation	first data	daily data from	data for every 4 hours from	last data for the study
Békésszentandrás (4035)	82.82 m	2002.01.	2014.11.	2014.11.	2021.01.
Csabacsűd (2779)	84.79 m	2002.01.	2004.01.	2006.01.	2021.08.
Kardos ((4602)	85.43 m	2004.11.	2004.12.	2010.06.	2021.11.
Öcsöd (3858)	84.21 m	2002.01.	2004.11.	2005.11.	2021.12.
Szarvas (2778)	83.19 m	2002.01.	2003.12.	2005.12.	2021.12.
Szarvas (2832)	82.02 m	2002.01.	2017.11.	2017.11.	2021.06.
Szarvas (2833)	81.87 m	2003.07.	2010.05.	2010.05.	2021.12.
Szarvas (2835)	84.00 m	2002.01.	2004.01.	2004.03.	2021.12.

show a trend-like change (Szalai, 2011).

In our research the characteristics of the groundwater level (especially the average seasonal course and long term tendencies) was examined in the subbasin area of the Szarvas-Békésszentandrás Oxbow using time series of 8 monitoring wells (2002-2021).

Materials and Methods

The study area of our research, the Szarvas-Békésszentandrás Oxbow Subbasin is located in the middle part of the Hungarian Great Plain. The area is almost totally flat. The elevation above sea level is typically between 82 m (near river, oxbow) and 86 m (at loess areas in the eastern part). The 8 groundwater monitoring wells which data were used in the research are located within a distance of 15 km from town Szarvas (Figure 1).

The climate is continental with average air temperature of 10.8°C and yearly average precipitation of 515 mm. Annual course of precipitation shows a slight maximum from May to July and minimum from January to March (Table 1).

The groundwater level data of 8 monitoring wells were provided by Körös Region Water Directorate. Most data series start in year 2002 and finish in 2020 or 2021. There were changes in the frequency of measurements during this time period. In the first years manual measurements of the groundwater level were carried out weekly. After automatization data were get daily, later in every 4 hours (six times a day). The monitoring stations represent different types of topography and location related to the oxbow (Table 2.).

Before the statistical examination the monthly average groundwater levels were calculated for each well for the whole period using software Excel. Parallel, the check of missing data was performed.

The average annual groundwater level course of each wells was calculated. It was important to do it based on the same time interval for all of the 8 wells (2005-2020) not to get misleading results. Using the data and graphs it was possible to describe the main char-

Figure 1: Location of the monitoring wells in the study area

Table 3: Average groundwater depth and its annual amplitude (using monthly average data, 2005-2020)

well groups	average (cm)	amplitude (cm)
A	257	62
B	288	72
C	360	100
D	400	51

acteristics of groundwater level in the study area and identify groups of wells with distinguishable patterns.

The main aim was to find long term trends of groundwater level. The trend analysis was based on 5 time series data set (annual, and middle months of the seasons: January, April, July and October) for groundwater level of 4 monitoring wells. The criteria for choosing this 4 wells were: they represent different groundwater characteristics, their data sets have no interruptions over the period 2002-2020.

The analysis was based on the nonparametric Mann-Kendall test for the significance of trend and the nonparametric Sen's method for the magnitude of the trend. These methods are commonly used in analysing climate time series and groundwater level time series, too. Practically, the MAKESENS Excel Macro developed by the Finnish Meteorological Institute was used in our research (Salmi et al., 2002).

Results and discussion

In average of 16 years the groundwater level (GWL) reaches its maximum in April. It is in accordance with the results of previous studies made in Hungary. The groundwater reaches its deepest level in autumn, but there are differences in months. Both September, October and November can be the month when the GWL reaches its minimum. That is in average, but there were years with maxi-

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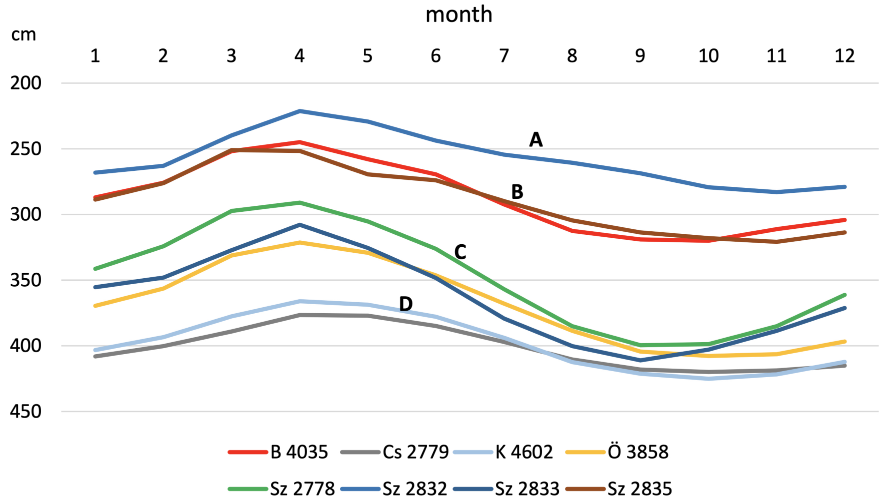

Figure 2: Average annual course (2005-2020) of groundwater level of the monitoring wells. A, B, C, D: groups of groundwater level course

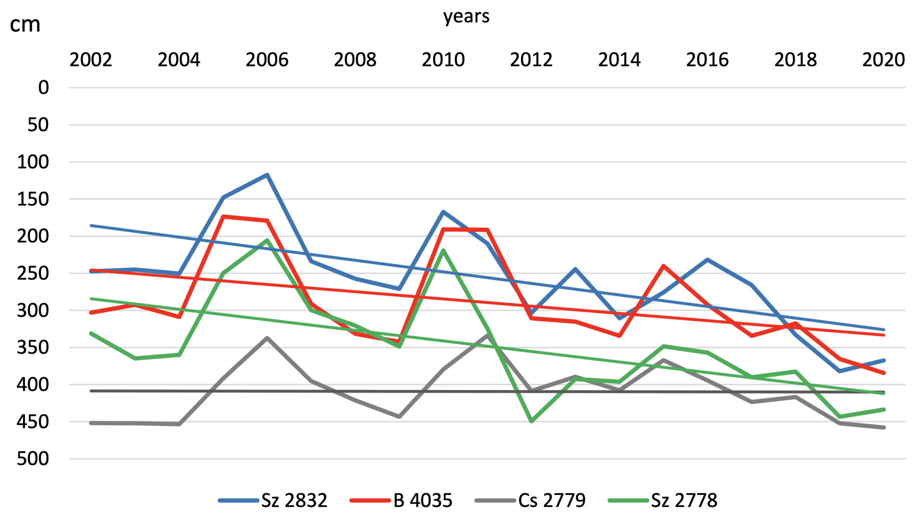

Figure 3: Course of the yearly average groundwater level at 4 monitoring stations (2002-2020)

mal GWL in January, February, March, April or in December, and with minimal GWL in any month from July to February (Figure 2). According to the graphs showing 16-year-average, 4 typical groups of groundwater level courses can be distinguished:

A Highest groundwater level, small annual variation. Szarvas 2832 (Sz 2832) is the only well with this characteristics. It can be clearly explained by the effect of the nearby oxbow (70 m distance).

B Relatively high groundwater level in winter and spring, medium annual variation. Békésszentandrás 4035 (B 4035) is located at a low terrain (only stations near to the oxbow have

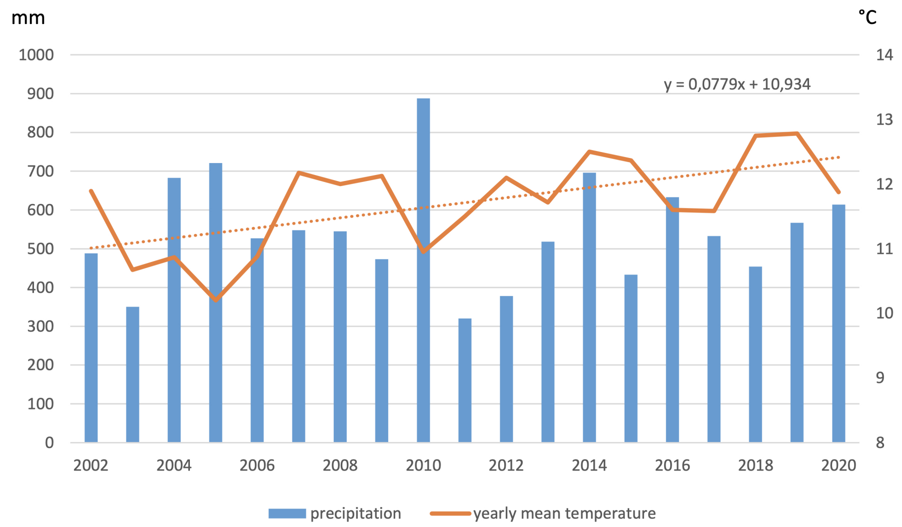

Figure 4: Course of the yearly sum of precipitation (mm) and the yearly mean air temperature in Szarvas (2002-2020)

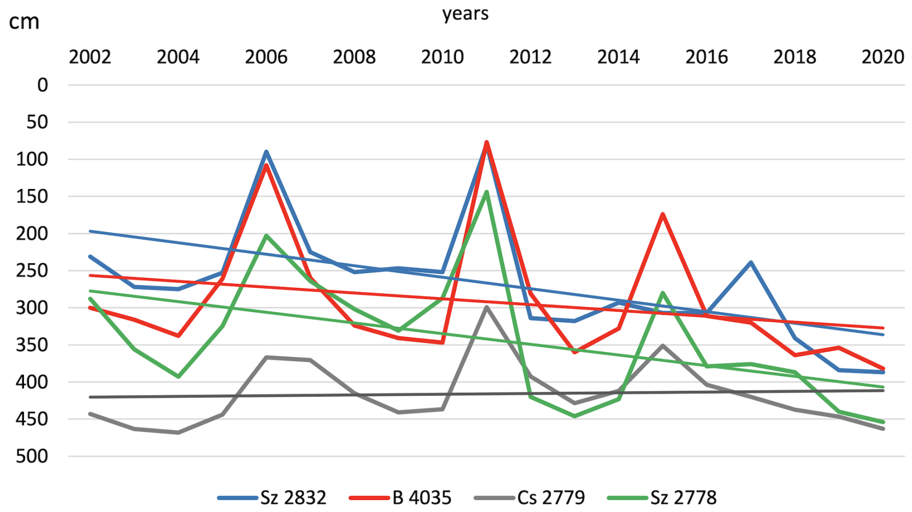

Figure 5: Course of the January mean groundwater level at 4 monitoring stations (2002-2020)

lower elevation above sea level), while Szarvas 2835 (Sz 2835) has a higher elevation, but with a local depression in the topography (about 1 m compared to the surrounding).

C Medium groundwater level, large annual variation. Monitoring stations Öcsöd 3858 (Ö 3858), Szarvas 2778 (Sz 2778) represent the medium level terrains in our study area.

D Deepest groundwater level, small annual variation. Csabacsűd 2779 (Cs 2779) and Kardos 4602 (K 4602) represent the loess areas in the eastern part of the study area with elevation about 85-86 m above sea level.

The expressions such as low, medium, high GWL and others describing seasonal varia-

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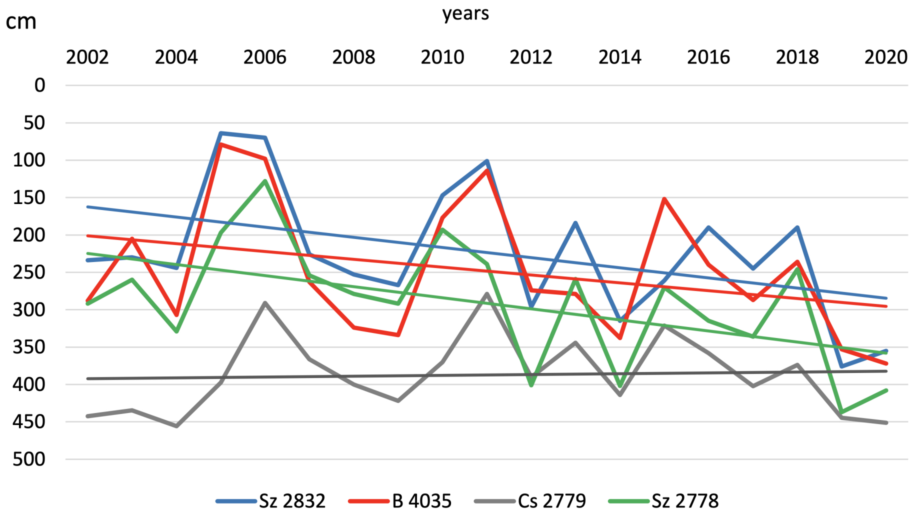

Figure 6: Course of the April mean groundwater level at 4 monitoring stations (2002-2020)

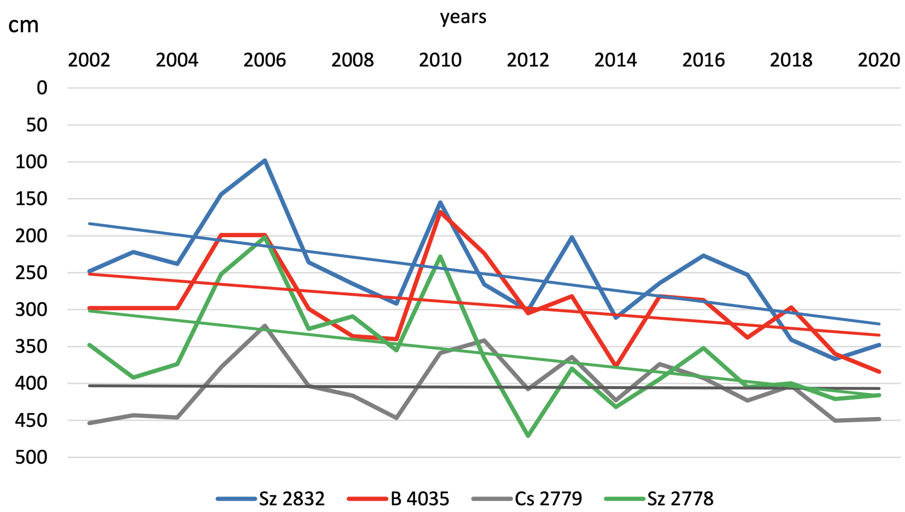

Figure 7: Course of the July mean groundwater level at 4 monitoring stations (2002-2020)

tion are only valid in the context of our research. Near to the oxbow the average GWL is about 2.5 m, while at higher elevated areas it is 4.0 m. The annual amplitude calculated from the average monthly values is small near the oxbow (0.6 m) and at the higher elevated loess areas (0.5 m) with the deepest GWL. It has to be noted that a larger average amplitude is get in case the yearly amplitudes are calculated first and just averaging after that (Table 3).

The long term trends of GWL were studied based on time series of yearly average GWL and the GWL values of January, April, July and October. The trends of yearly average values show the decrease of groundwater level in case of Szarvas 2832, Szarvas 2778 and Békésszentandrás 4035 monitoring wells (Figure 3). These decreasing trends are significant at p= 5% or 1% level (Table 4), with the largest rate of 7.6 cm/year (Q, the Sen's estimator, the groundwater level

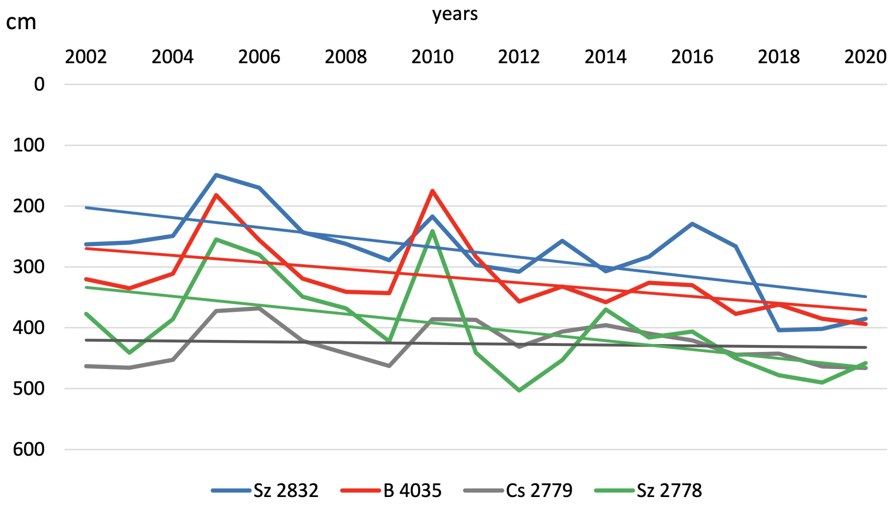

Figure 8: Course of the October mean groundwater level at 4 monitoring stations (2002-2020)

Table 4: Parameters of the linear trend analysis based on data sets (yearly average, January, April, July and October) for groundwater level at 4 monitoring stations (2002-2020)

	Sz 2832			B 4035			Cs 2779			Sz 2778		
	R^2	Q	sign.	R^2	Q	sign.	R^2	Q	sign.	R^2	Q	sign.
year	0.42	-7.6	**	0.18	-4.4	*	0.00	-0.3	-	0.34	-6.4	*
Jan	0.30	-7.3	**	0.07	-4.0	*	0.00	+0.4	-	0.23	-6.9	*
Apr	0.20	-6.8	*	0.11	-5.0	-	0.00	+1.0	-	0.27	-7.2	*
July	0.37	-7.5	**	0.19	-4.2	*	0.00	-0.3	-	0.26	-6.2	*
Oct	0.46	-7.5	*	0.28	-4.3	**	0.01	-1.9	-	0.29	-6.9	*

Mann-Kendall test ** trend at $\alpha = 0.01$ level of significance, * trend at $\alpha = 0.05$ level of significance, – no significant trend, Q, the Sen's estimator, R^2: coefficient of determination calculated by Excel to linear trend.

change per year) in case of the well near the oxbow (Sz 2832). The GWL at Station Cs 2779 (deepest groundwater level, small annual variation) shows no significant trend in groundwater level during the 2002-2020 period.

The decreasing GWL at 3 stations can not be explained by the changes in yearly precipitation sums. The precipitation has no decreasing trend during this period (Figure 4). However, the yearly average air temperature is increasing (significant, 0.78°C/10 years increase). This can be a cause of the groundwater level sink through the indirect effect of temperature on evapotranspiration.

The year to year GWL variability is larger in January and April compared to July and especially to October. The trends of the middle months of the seasons (January, April, July, October) are almost the same in significance and slope compared to the trends based on yearly mean time series (Figures 5-8.). The differences in trends can be found between stations rather than between the months used for calculations.

It can be concluded that in the study period

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(2002-2020) there was a decline in groundwater levels in the Szarvas-Békésszentandrás Oxbow Subbasin in most monitoring wells. The change exceeds 1 m at station Szarvas 2832 (144 cm) and Szarvas 2778 (122 cm). That has an agricultural importance because the recent level of groundwater can much less contribute to the water supply of arable crops than the earlier values. However, there is a station with no significant trend, GWL at Csabacsűd 2779 station shows relative stability at around 4 meter depth in yearly average, which is valid for some areas in the eastern part of the subbasin.

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