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DROUGHT CONDITIONS IN THE LAST TWO DECADES IN SZARVAS TOWN REGION, HUNGARY

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Abstract *Agriculture is a significant economic sector in Hungary. As a result of climate change, farmers can face extreme weather situations and their consequences (inland excess water, water shortage, drought, extremely high or low temperatures, yield loss) more often than before. Focusing on drought conditions in Szarvas town area (South-Eastern region of Hungary) we analysed temperature, precipitation and groundwater table level data of 4 monitoring wells between 2002 and 2021. In our study we used mainly the yearly average values. The Mann Kendall test was used to evaluate the data. Palfai Drought Index was calculated to quantify the level of drought. We found increasing trend in yearly average temperature, decreasing trend in groundwater level at most part of the area, no significant trend in yearly sum of precipitation and Palfai Drought Index. According to our data, the relative frequency of drought-free years in the Szarvas region is 30%, moderate and stronger droughts occurred in 50% of years, and the relative frequency of severe droughts was 10%. Severe droughts (PaDI 10-15) occurred twice in the 20 years studied, in 2003 and 2012. These data show the probability of a future drought or drought-free year. Our results hint to the importance of irrigation and irrigation development in the region.*

Key Words*: drought, Palfai Drought Index, precipitation, groundwater level*

INTRODUCTION

Climate change can have a negative effect on the agricultural production in Hungary. Currently, drought is the biggest risk in agricultural production. The formation of drought is affected mainly by precipitation and temperature in the growing season. The most typical period of drought formation is summer. The most severe drought occurs when there is little rainfall and high temperature throughout the growing season after a dry autumn and winter (PÁLFAI, 2002). In the Carpathian Basin droughts occur in approximately every two years, and the drought is severe or extremely severe once in ten years (PÁLFAI, 2010).

The yearly average temperature in Hungary is between 9 and 11 °C. Values above 10 °C are typical in the Great Plain. The temperature has an increasing trend, which can be observed in yearly and also in seasonal averages. The most intensive warming occurred in the last 40 years. The yearly number of heat wave days in the Southern Great Plain increased by 12-14 days (OMSZ, 2019A).

In Hungary, the average annual rainfall is 500-750 mm, but there are significant differences between the regions. There is no significant trend in the amount of annual precipitation for the period 1901-2020, only the spring period shows a significant decreasing trend (-17.2%). Annual precipitation amounts decrease in the western part of the country, while a slight increase can be observed in most of the Great Plain. On average, the number of rainy days decreased and the length of dry periods increased. In the last 40 years (1981-2020) the increase of precipitation is also significant on the national average (OMSZ, 2019B).

The soil has a significant effect on drought mitigation through rainfall storage (VÁRALLYAI, 2010). Groundwater levels are significantly dependent on topography, precipitation amount and distribution, evaporation, and different water extractions (YAN, ET AL., 2021; LI, ET AL., 2020). In Hungary, groundwater course is of continental type, so it is characterized by the spring maximum and the autumn minimum. Spatial variability and meteorological influencing factors have a significant effect (RÉTHÁTI, 1983).

The effect of precipitation on the rise of the groundwater level is shifted over time. According to the research of KOVÁCS (2014), depending on the depth of the groundwater, this shift can be up to a year. Examining the long-term changes in the groundwater level in Hungary, a decrease in the groundwater level can be detected in several places in the country, most notably in Nyírség and between the Danube and the Tisza.

The agricultural areas of Hungary have to face regularly with the damage caused by drought. The drought occurs most frequently in the central and southern parts of the Great Plain. According to the Pálfai Drought Index (PAI), the values of the greatest drought in the country are in the Central Tisza, Lower Tisza and Körös Regions, and in the central and southern part of the Trans-Tisza Region. The 1990s were years with serious droughts. This was followed by a shorter 2000-2003 period of heavy drought (PÁLFAI, 2010).

There are different indices which are used in practice to quantify drought level (PÁLFAI, 2002). The WMO-GWP (2016) publication describes a total of 40 international drought indices. The Pálfai Index (PAI) has been developed specifically for Hungarian conditions, expressing the strength of the drought with a single numerical value, primarily using the amount of precipitation and the monthly average temperature values. An improved version of the PAI index is PaDI, which calculates the necessary correction factors from monthly data, making it easier to calculate drought.

MATERIAL AND METHODS

Our study area is located in the Great Plain of Hungary in the Körös river basin (Figure 1).

Fig. 1. Map showing the Szarvas town area in Hungary

The elevation above sea level is typically between 82 m (near river, oxbow) and 86 m (at loess areas in the eastern part). The area is dominated by clayey loam soils. These soil types are less sensitive to drought compared to looser soils (e.g., sand). 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).

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

The groundwater level data of 4 monitoring wells between 2002 and 2021 were provided by Körös Region Water Directorate. In our study we used mainly the yearly average values.

In our research we examined the conditions for the development of drought in the Southern Great Plain over the past 20 years. Trends and seasonality of precipitation, temperature, and groundwater level data were analyzed. The Mann Kendall test was used to evaluate the data. 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 MAKESENSE Excel Macro developed by the Finnish Meteorological Institute were used in our research (SALMI ET AL., 2002). Based on the data, we calculated an annual type drought index. The Pálfai Drought Index (PaDI) was used to quantify the drought conditions. The drought index is essentially a fraction whose numerator is the average temperature of the months of April-August (multiplied by 100) and the denominator is the weighted sum of its monthly precipitation from October to September. The weight factor is 0.1 in October, 0.4 in November-December, 0.5 in January-April, 0.8 in May, 1.2 in June, 1.6 in July and 0.9 in September. The default value of the index is calculated by the following formula:

$$PaDI_0 = \frac{\left[\sum_{i=Apr}^{Aug} Ti\right]/5 * 100}{c + \sum_{i=Oct}^{Sept} \langle P_i * W_i \rangle}$$

PaDI₀ - the default value of the drought index °C/100 mm; T_i – monthly average temperature from April to August °C P_i – monthly precipitation from October to September; W_i - weight factors; c – constant value (10 mm).

The default value must be multiplied by three correction factors to get the PaDI value. The temperature correction factor (k_1), is the ratio of the average summer temperature of the current year to that of many years. The correction factor of precipitation (k_2) is the ratio of the precipitation of the driest month of many years and the summer month of the current year. The long-term effect of the precipitation is expressed by the correction factor k_3 (KOZÁK, ET AL., 2012).

$$PaDI = PaDI_0 * k_1 * k_2 * k_3$$

PaDI – the value of the Pálfai Drought Index °C/100 mm; k_1 – temperature correction factor, k_2 – precipitation correction factor; k_3 – correction factor for the previous 36 months of precipitation.

Table 2

A seven-point scale *is* used to evaluate PADI:

PaDI, 0C/100 mm	Qualifies
< 4	drought-free year
4 – 6	mild drought year

6 – 8	moderate drought year
8 – 10	medium drought year
10 – 15	severe drought year
15 – 30	very severe drought year
> 30	extreme drought year

RESULT AND DISCUSSIONS

Using Mann-Kendall test and Sen's estimator, we found a significant ($p=0.05$) increasing trend (1.25°C in 20 years). The warmest years (2014, 2015, 2018, 2019) show an average annual temperature above 12.5°C, and all of them are in the second half of the study period (Figure 2).

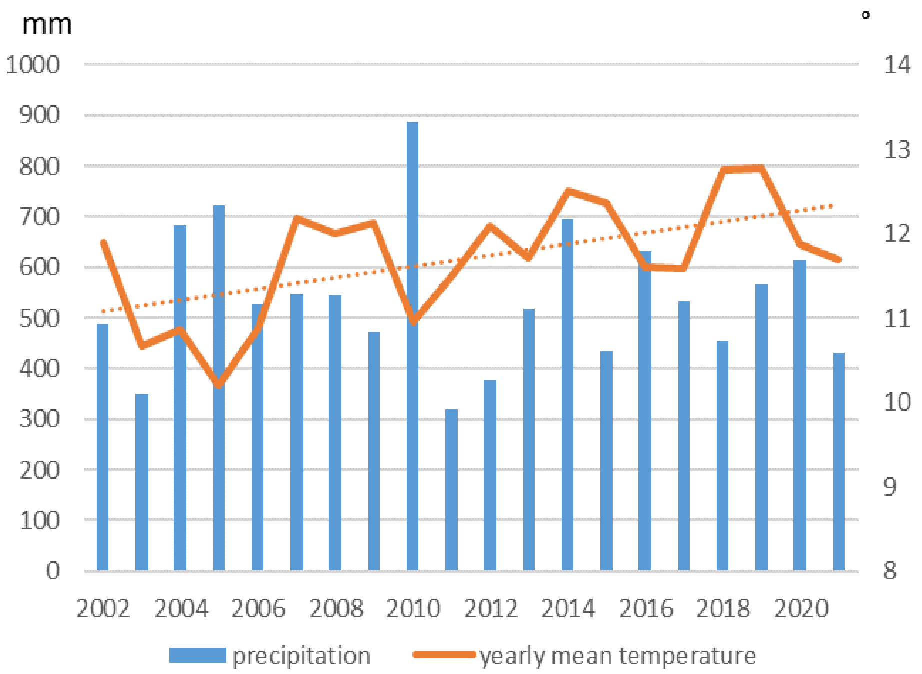

Fig. 2. Course of the yearly sum of precipitation (mm) and the yearly mean air temperature in Szarvas (2002-2021)

No significant trend can be detected in the precipitation data. During the years studied, 540 mm of precipitation fell on average, which is 25 mm more than in the 30-year period 1981-2010. The wettest year was 2010 with 888 mm of precipitation. Interestingly, the following year (2011) was the driest year, with 320 mm of rainfall. Precipitation below 400 mm was in 3 years, precipitation between 400 and 500 mm occurred in 5 years.

The precipitation in the winter half-year is 225 mm on average in the 20-year period and 313 mm in the summer half-year. Precipitation was 104 mm in the driest winter half-year and 407 mm in the wettest one. Precipitation was more variable in the summer half-year with values between 96 and 518 mm occurring over 20 years (Figure 3).

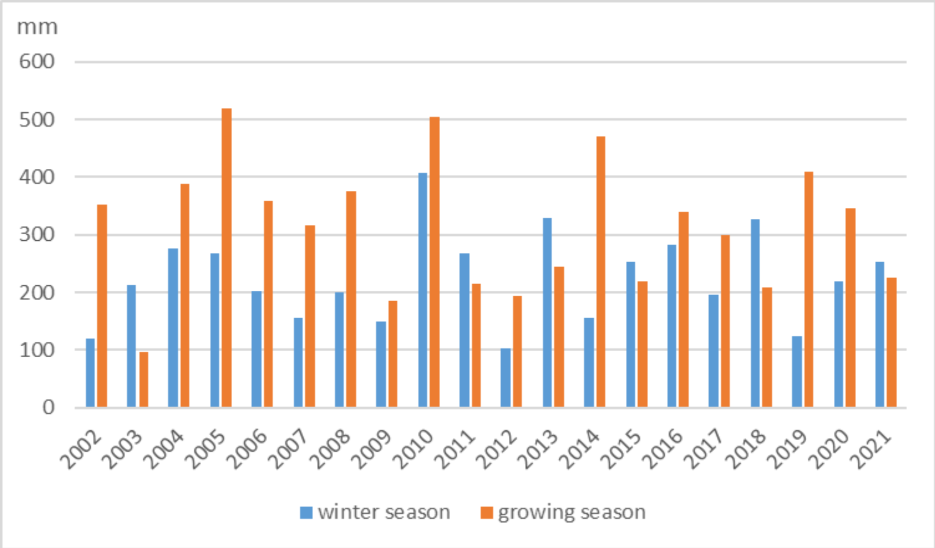

Fig. 3. Precipitation in the winter and summer half-years, Szarvas, Hungary (2002-2021)

The change of the groundwater level was examined by analyzing the data of four groundwater level monitoring wells in the area. The wells represent different parts of the area. Differences in groundwater levels result from different topographical, hydro-geomorphological, and soil conditions. The largest fluctuation (on an annual average) is shown by the Sz2778 well, and the smallest fluctuation is shown by the well Cs2779. The other two wells examined (Sz2835, B4035) also show large fluctuations. The highest groundwater levels were in 2005-2006 and 2010-2011, respectively. The groundwater level was at its deepest in 2019-2020. The groundwater level shows a significant decreasing trend in case of three wells (Sz2778, Sz2835, B4035). There was no significant trend in case of Cs2778 well (Figure 4).

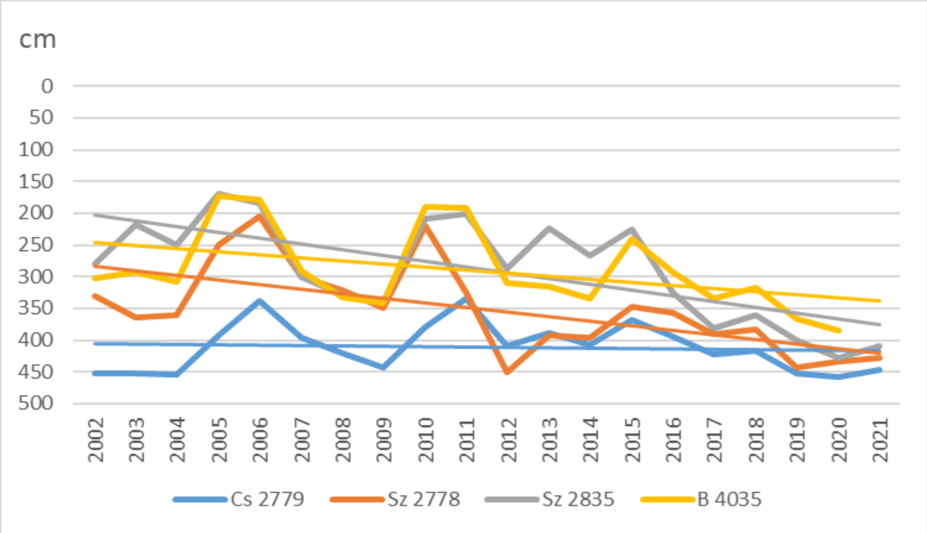

Fig. 4. Course of the yearly average groundwater level at 4 monitoring stations (2002-2021)

The value of the PaDI drought index in the Szarvas area has not shown a significant trend in the last 20 years. 6 years were drought-free during the study period. The mild drought category (PaDI 4 - 6) includes 4 years. The moderately drought category (PaDI 6 - 8) includes 6 years. These occur in equal numbers in the first and second half of the study period. The moderately drought category (PaDI 8 - 10) includes 2 years, which occurred in the second half of the study period. The category of severe drought (PaDI 10 - 15) was get in 2 years, one of it (2003) appeared in the first half of the study period and one (2012) in the second half (Figure 5).

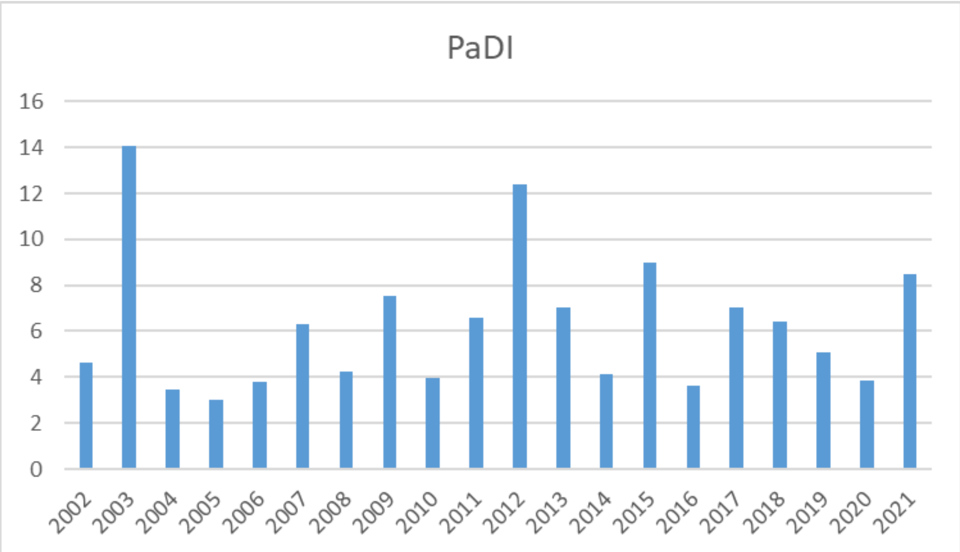

Fig. 5. Values of the Pálfai Drought Index between 2002 and 2021 in Szarvas, Hungary

The number of drought years is slightly higher in the last 10 years (2012-2021) compared to the previous 10 years (2002-2011). Primarily the number of moderately severe droughts has increased. A year with a severe drought may be followed by several drought-free years (e. g., after the drought in 2003), but the drought period may last for several years (e. g., after the drought in 2012) (Table 3).

Table 3

Occurrence of drought in Szarvas town region (2002-2021)

	2002- 2011		2012-2021		total number of occurrences 2002-2011
Drought category PaDI	occurrence	years	occurrence	years	
severe drought 10-15	1	2003	1	2012	2
medium drought 8-10	-		2	2015, 2021	2
moderate drought 6-8	3	2007, 2009, 2011	3	2013, 2017, 2018	6
mild drought 4-6	2	2002, 2008	2	2014, 2019	4
drought free <4	4	2004, 2005, 2006, 2010	2	2016, 2020	6

Based on the last 20 years, the relative frequency of severe and medium droughts is 10-10%. Moderately drought year can be expected with a 30% probability, and a mild drought with a 20% probability. Drought-free years occur in 30%, on average three times every 10 years. A very strong drought year did not occur, but the year with the highest drought index (14.1) was very close to this category. The second driest year in the study period was 2012, with a PaDI of 12.4.

The average temperature in 2003 was 10.7°C. That is a relatively low value, but this was mainly caused by the very cold winter period (January, February). The precipitation in the winter half-year was 212 mm, which is near to the average. After the cold and snowy winter the soils were filled with water up to their field capacity. In the summer half-year only 96 mm of precipitation fell. That is the lowest value during the 20 years studied. The groundwater level was in the medium range, no significant decrease in the groundwater level (in yearly average) can be observed, which is due to the favorable winter water supply.

The average temperature in 2012 was 12.1°C, which is by 0.4°C higher than the average temperature of the 20 years studied. 2012 and the months before were an extremely dry period. In particular, the winter semester of 2011 - 2012 was dry with only 104 mm of precipitation, which is the lowest value in the 20-year period studied. This was followed by a dry summer half-year with 194 mm of precipitation. There was a definite decrease in the groundwater level, but most of the wells have not yet reached extremely low groundwater levels.

CONCLUSIONS

Drought shows large spatial and temporal variability. Its formation has many environmental components, the most important ones are precipitation and temperature, especially these in the summer half year. In addition, soil properties and surface water resources also play a role in drought formation and effect on strength and durability. The risk of drought is partly related also to the precipitation of the given winter half-year and, to a smaller extent, the precipitation of previous years (this is reflected in the calculation of the PaDI value). Based on these, we can have some information about the risk of drought in a given year already at the beginning of the growing season. However, the development of drought highly depends on the weather in the vegetation period.

According to our data, the relative frequency of drought-free years in the Szarvas region (South-Eastern region of Hungary) is 30%, moderate or stronger droughts occurred in 50% of years, and the relative frequency of severe droughts was 10%. These data show the probability of a future drought or drought-free year. Our results hint to the importance of irrigation and irrigation development in the region. In case of dry farming (no irrigation), it is necessary to prepare for the drought and mitigate its negative effects with the appropriate choice of crop species, variaties/hybrids and agrotechnical solutions.

BIBLIOGRAPHY

KOZÁK, P., PÁLFAI, I., HERCEG, Á., 2012 - Palfai Drought Index (PaDI) – A Pálfai-féle aszályindex (PAI) alkalmazhatóságának kiterjesztése a délkelet-európai régióra. In: Délkelet-Európai Aszálykezelési Központ – DMCSEE projekt. Budapest: OMSZ, 21–26.

LI, H., LU, Y., ZHENG, C., ZHANG, X., ZHOU, B., WU, J., 2020 - Seasonal and Inter-Annual Variability of Groundwater and Their Responses to Climate Change and Human Activities in Arid and Desert Areas: A Case Study in Yaoba Oasis, Northwest China. Water, 12, 303.

OMSZ 2010 - Országos Meteorológiai szolgálat Klímamodellezési tevékenység, Eredmények (2010) Numerikus Modellező és Éghajlat –dinamikai Osztály https://met.hu/doc/tevekenyseg/klimamodellezes/Klimamodellezési_eredmelyek_2010.pdf

OMSZ 2019a - Magyarország hőmérsékleti viszonyai. https://www.met.hu/eghajlat/magyarorszag_eghajlata/altalanos_eghajlati_jellemzes/homerseklet/

OMSZ 2019b - Magyarország csapadék viszonyai. https://www.met.hu/eghajlat/magyarorszag_eghajlata/altalanos_eghajlati_jellemzes/csapadek/

PÁLFAI, I., 2011 - Aszályos évek az Alföldön 1931-2010 között. In: RAKONCZAI J. (szerk.) Környezeti változások és az Alföld: Nagyalföld Alapítvány Kötetei 7. Békéscsaba, 87–96.

PÁLFAI, I., 2002 - Magyarország aszályossági zónái. Vízügyi Közlemények. 84 (3): 323-357 .

PÁLFAI, I., 2010 - Az aszályok gyakorisága a Kárpát-medencében az utóbbi háromszáz évben „Klíma-21” füzetek Klímaváltozás-hatások-válaszok. AKAPRINT Kft, Budapest, 59: 42-45.

PIECZKA, I., 2012 - A Kárpát medence térségére vonatkozó éghajlati szcenáriók elemzése a PRECIS finom felbontású regionális klímamodell felhasználásával. Doktori értekezés ELTE, Budapest.

PONGRÁCZ, R., BARTHORY, J., PIECZKA I., SZABÓNÉ ANDRÉ, K., 2017 - RegCM szimulációkon alapuló éghajlati becslések eredményei http://nimbus.elte.hu/oktatas/metfuzet/EMF026/PDF/12-Pongracz-etal.pdf

RÉTHÁTI, L., 1983 - A talajvíz évi szélső vízállásainak időpontja. Hidrológiai Közlöny. 63. 525-572.

SALMI, T., MÄÄTTÄ, A., ANTTILA, P., RUOHO-AIROLA, T., AMNELL, T., 2002 - Detecting trends of annual values of atmospheric pollutants by the Mann-Kendall test and Sen's slope estimates –the Excel template application MAKESENS. Finnish Meteorologial Institut, Helsinki, Finland.

STELCZER, K., 2000 - A vízkészlet-gazdálkodás hidrológiai alapjai. ELTE Eötvös Kiadó. Budapest.

TORMA, CS., 2011 - Átlagos és szélsőségeshőmérsékleti és csapadékviszonyok modellezése a Kárpát-medencére a XXI. századra RegCM regionális klímamodell alkalmazásával. Doktori értekezés. ELTE, Budapest.

VIZITERV ENVIRON KFT., 2019 - Drought risk management and identification of measures to improve the capacity to adapt to the climate KEHOP-1.1.0-15-2016-00008 Nyíregyháza, 256.

WORLD METEOROLOGICAL ORGANIZATION (WMO) AND GLOBAL WATER PARTNERSHIP (GWP)., 2016 - Handbook of Drought Indicators and Indices (M. Svoboda and B.A. Fuchs). Integrated Drought Management Programme (IDMP), Integrated Drought Management Tools and Guidelines Series 2. Geneva.

YAN, B., LI, X., HOU, J; BI, P., SUN, F., 2021 - Study on the dynamic characteristics of shallow groundwater level under the influence of climate change and human activities in Cangzhou, China. Water supply. 21 (2) :797-814.