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ANALYSIS OF AIR TEMPERATURE AND PRECIPITATION IN NITRA, SLOVAKIA IN 2005–2019

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High air temperatures and low amount of precipitation occur more and more frequently in Slovakia. The aim of this work is to evaluate the temperature conditions and total precipitation during the period 2005–2019 and to compare it with the 50-year climatic normal 1951–2000. Also, there was calculated the probability of summer days, tropical days, super-tropical days, frost days and ice days occurrence. Annual temperature is higher by 0.9 °C (1.1 °C during vegetation period) than normal. Rainfall, especially in the last 5 years, has a decreasing character (-75 mm.year^{-1}) with frequent fluctuations. New phenomena – super-tropical days has occurrence of up to 20% between July and August. This study provides information based on which adaptation measures to the climate change need to be taken.

Keywords: precipitation, air temperature, drought, probability of occurrence

The average temperature of the Earth's surface has increased by almost 0.9 °C since the beginning of the 20th century, whereas since 1951, it has warmed by 0.72 °C. The annual air temperature trend for the period 1960–2012 reached 0.2 °C per decade in south-eastern Europe and up to 0.4 °C in northern and north-eastern Europe. Precipitation in some parts of southern Europe dropped by 70 mm in a decade (Horák, 2017). Agroclimatic analyses of the last decades confirm the increasing impact of weather on various areas of human activity. There will be a change in temperature and humidity security, a change in phenological conditions, a change in agroclimatic production potential, etc. (Čimo et al., 2014). The occurrence of very hot days and the duration of very low rainfall events are projected to increase by the end of the 21st century. The predicted higher incidence of extreme weather events will have an increasing influence on agricultural productivity (Al Jbawi, 2020). Droughts can arise from a range of hydrometeorological processes that supress precipitation or limit surface water or groundwater availability, creating conditions that are significantly drier than normal or limiting moisture availability to a potentially damaging extent (WMO and GWP, 2016).

Material and method

The aim of the work is to evaluate the air temperature and precipitation conditions for the Nitra locality during period 2005–2019 and to compare it with the climatic normal in 1951–2000. Agrometeorological Station of the Department of Biometeorology and Hydrology is at an altitude of 172.6 m a.s.l. (18° 07' longitude and 48° 19' latitude). The climate area according to Konček (1955) is warm, very dry with mild winter (Bochníček, Hrušková, 2015).

For the evaluation there were used mean monthly temperatures, total monthly precipitation and comparison according to 50-year climate normal and calculation of the Standardized Precipitation Index (SPI) and probability of occurrence of the phenomenon.

The SPI measures precipitation anomalies at a given location, based on a comparison of the observed total precipitation amounts for an accumulation period of interest, with the long-term historic rainfall record for that period. The average SPI value for the study area and the specific reference period is zero, leading to a straightforward identification of wet (positive values) and dry (negative values) periods (Tigkas, Vangelis, Tsakiris, 2018). For SPI calculation there was used the software SPI Generator by the National Drought Mitigation Centre, University of Nebraska (NDMC, 2018).

The determination of the period with the onset of characteristic days (mean daily temperatures ≤0 °C, ≥5 °C, ≥10 °C and ≥15 °C) according to the formulas (Čimo et al., 2012):

- onset of temperatures (days):

$$r_v = R\frac{T_n - T_2}{T_1 - T_2} \quad (1)$$

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- termination of temperatures (days)

$$r_p = R\frac{T_1 - T_u}{T_1 - T_2} \quad (2)$$

where:

T_n – onset temperature (°C)
T_u – termination temperature (°C)
T_1 – the nearest average monthly temperature above the onset or termination of temp. (°C)
T_2 – the nearest average monthly temperature below the onset or termination of temp. (°C)
R – the difference in days between the middle of the months with the average temperature T_2 and the average temperature T_1, can be expressed as an average number $R = 30$
r_v – difference in days between the middle of the month with temperature T_2 and the date of onset of temperature T_n
r_p – difference in days between the middle of the month with temperature T_2 and the date of termination of temperature T_u

The probability of occurrence of the phenomenon was calculated by the formula (SHMÚ, 2020):

$$p(A) = \frac{m}{n} \cdot 100 \quad (\%) \quad (3)$$

where:

$p(A)$ – probability of the phenomenon
m – the total frequency of the observed event over a period
n – length of observation period in years

Results and discussion

The monthly mean temperature (Figure 1) in most cases exceeds the values of the climatic normal. Especially in 2007, the mean temperature reached 4.4 °C in January and 5.0 °C in February, which is by 5.8 °C and 4.5 °C higher than normal, respectively. Negative extremes are also seen in the observed period. In January 2017, the temperature reached -9.1 °C (7.7 °C below normal), and in May 2019, it reached 9.3 °C (5.9 °C below normal).

The monthly total precipitation (Figure 2) exceeded the values of the climatic normal in certain months. Extreme values occurred in 2010 (April – June), 2011 (July – September) and 2013 (January – March). A significant decrease is visible in 2015–2019, when from April to August there occur dry, very dry and extremely dry months. The lack of precipitation was not compensated by extremely wet months (February, July 2016; September 2017; May 2019).

Monthly values should follow the trend of the long-term climate normal. This is the case in monthly temperatures, except in the winter months, where fluctuations are visible. Precipitation in recent years has shown a frequent occurrence of extremely wet and extremely dry months compared to normal.

The annual total precipitation (Figure 3), in 2010 reached 869 mm (321 mm more than the normal – very wet year). In the vegetation period (VP) precipitation reached by 322 mm more. Extremely wet were the months April, May and June. The year 2011 was also extreme – the total rainfall was by 198 mm more than the normal (extremely wet July, August and September). In recent years, however, the opposite trend is observed with a lack of precipitation. The biggest decline is in 2018 – the total amount was by 180 mm less than the normal (July and August – extremely dry, April, October and November – very dry, and May and June – dry). Over the past 5 years, rainfall decreased by an average of 75 mm.year^{-1} and by 62 mm per VP^{-1} compared to the normal.

We used the values of 3-month and 12-month SPI for the period 2005–2019. The SPI time scales between 3 and 6 months may be relevant for agricultural users. Hydrologists may be more interested in values between 12 and 24 months (Portela et al., 2015; Wu et al., 2005; Tigkas, Vangelis, Tsakiris, 2018). SPI-3 (Figure 4) shows the alternation of dry and wet periods. Extremely humid months occurred in 2010, 2011 and 2013. Nowadays, there are more frequent occurrences of dry months. SPI-12 (Figure 5) shows this trend when very dry and extremely dry periods have been observed in the last 5 years.

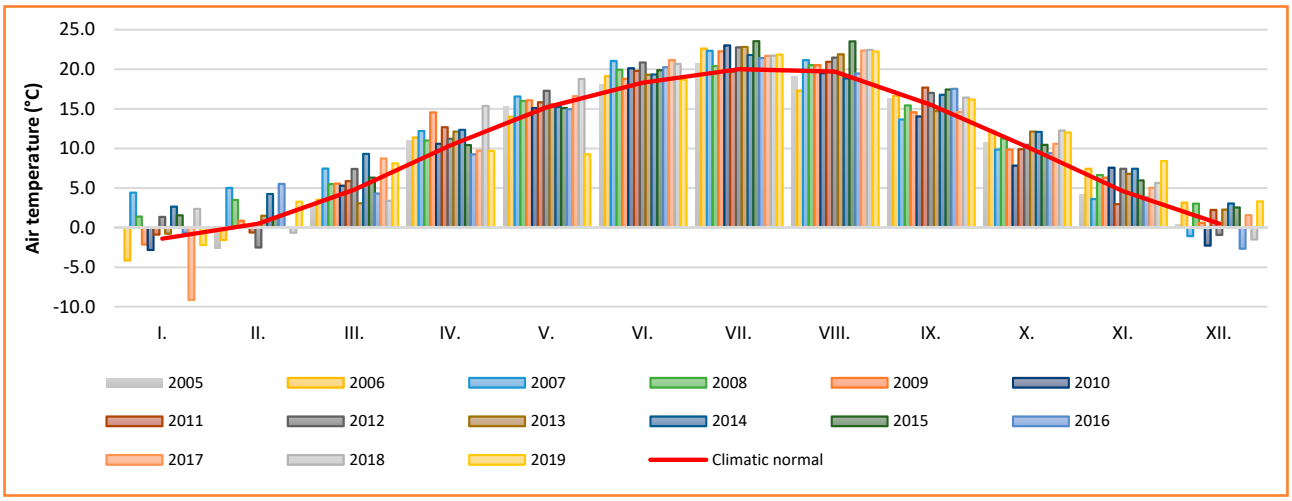


Figure 1 Mean monthly temperatures (2005–2019) compared to the climatic normal 1951–2000

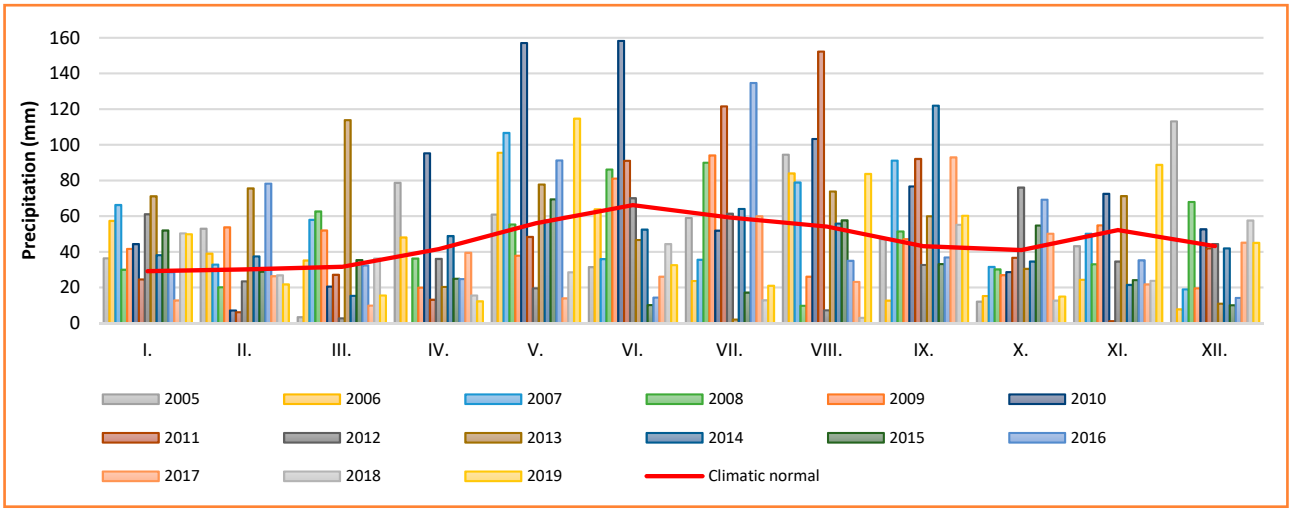


Figure 2 Total monthly precipitation (2005–2019) compared to the climatic normal (1951–2000)

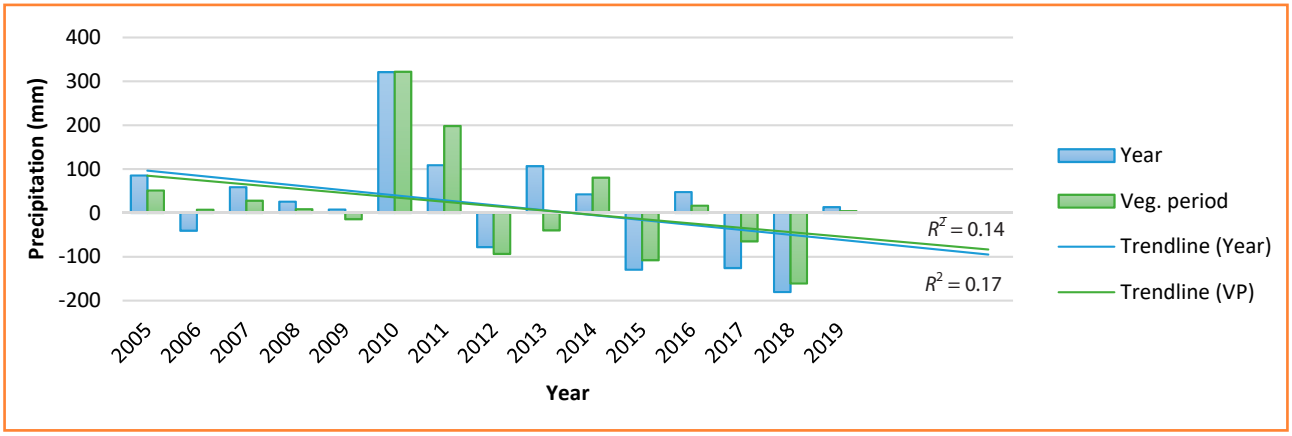


Figure 3 Evaluation of precipitation in 2005–2019 compared to the climatic normal 1951–2000

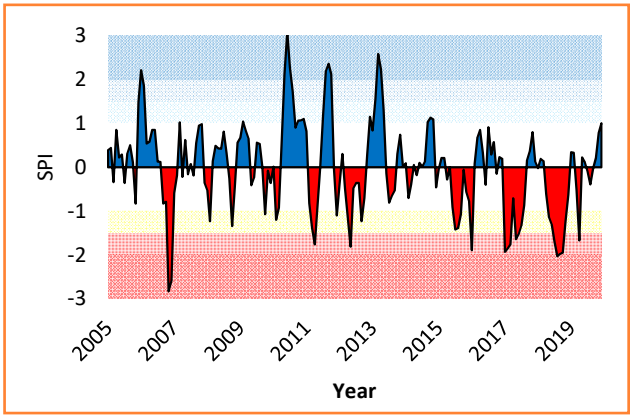


Figure 4 SPI-3 in 2005–2019

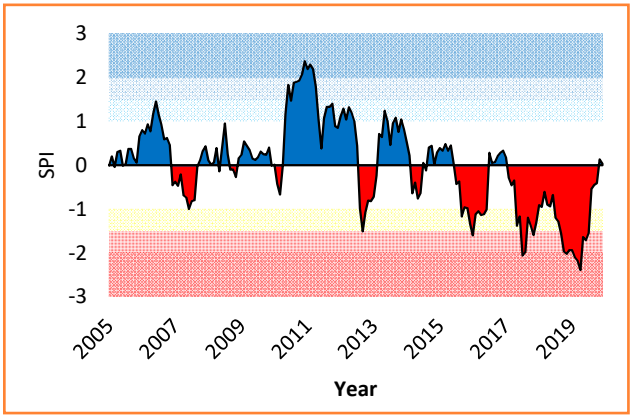


Figure 5 SPI-12 in 2005–2019

Figure 6 shows the probability of occurrence of atmospheric precipitation ≥0.1 mm and ≥10 mm during the year for the reference period from 2005 to 2019. On average, the annual probability is 40% and 4% respectively. During the growing season, this represents 37% and 6%, respectively.

The evaluation of mean temperatures (annual and VP) in comparison with the normal showed an increase in annual temperatures (Figure 7). The warmest year was 2014, when the mean temperature reached 11.9 °C (2.0 °C higher than the normal). The highest temperature during the VP was reached in 2018, when it exceeded the normal by 2.7 °C (April and May – extremely warm, June and August – very warm, and July and October – warm). However, 2019 is different during the VP, which caused cold weather in April and May (temperature was 9.7 °C and 9.3 °C, respectively). During the study period (2005–2019), there is an increase in the mean annual air temperature by 0.9 °C and in the growing season by 1.1 °C.

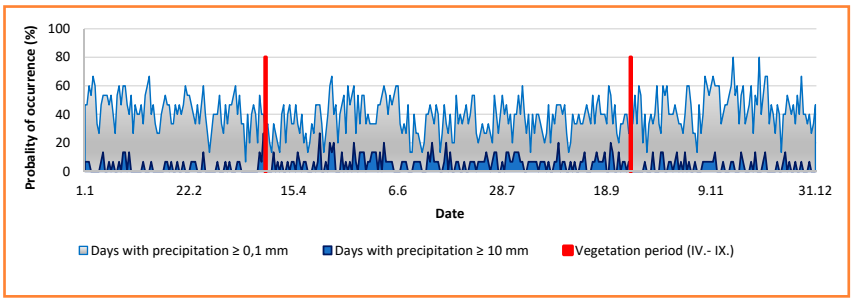


Figure 6 Probability of occurrence the precipitation during year

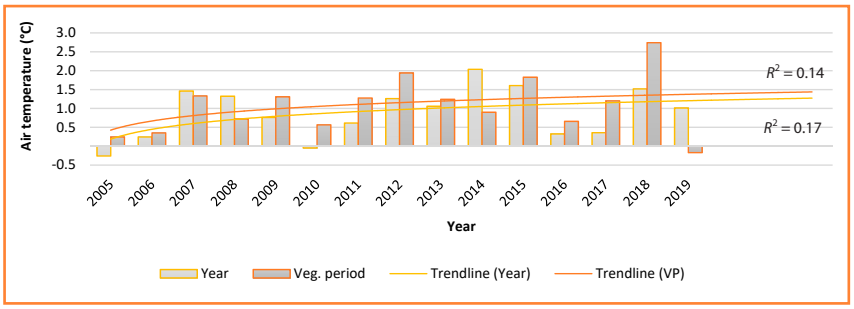


Figure 7 Evaluation of air temperature in 2005–2019 compared to climatic normal

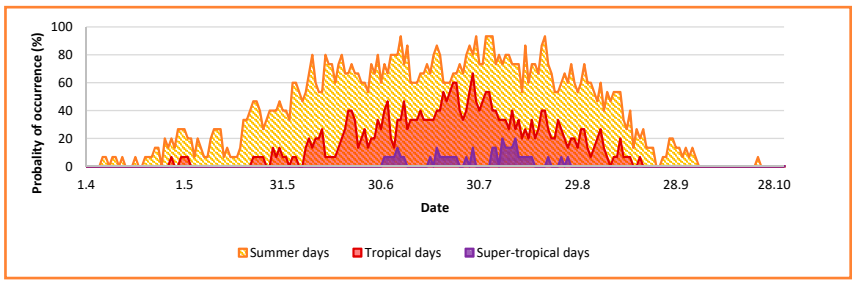


Figure 8 Probability of occurrence of summer days, tropical days and super-tropical days

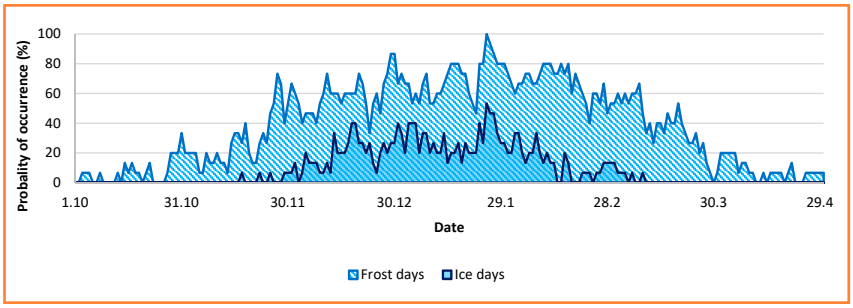


Figure 9 Probability of occurrence of frost days and ice days

We calculated the probability of occurrence of characteristic days of the summer period (Figure 8) – summer days (T_{max} ≥25 °C), tropical days (T_{max} ≥30 °C) and super-tropical days (T_{max} ≥35 ° C). Based on the reference period 2005–2019, the probability of occurrence of summer days from the beginning of June to the end of August is 60–80%, on some days up to 93%. The highest occurrence of tropical days (60%) is between July and August. In this time there also occur super-tropical days with the probability of up to 20%.

We also determined the probability of occurrence of frost days with Tmin <0 °C (Figure 9), which is above 40% and lasts from the end of November to the middle of March, except on 23.12., when it falls to 33%. Ice days with T_{max} <0 °C follow the trend of frost days, but their probability of occurrence from November 15 to March 15 is on average 17%. The highest probability of occurrence of a frost day (100%) and an ice day (53%) is on January 25.

The calculation of the onset, duration and termination of certain temperatures is related to physiological and biological processes. The onset and termination of T ≥5.0 °C limits the great vegetation period (GVP) – this temperature activates the physiological processes in the organs in the spring and ends in the autumn. The onset and termination of T ≥10.0 °C delimits the main vegetation period (MVP) and the onset and termination of T ≥15.0 °C delimits the vegetation summer (VS) (Čimo et al., 2012). During the years 2005–2019, the number of days of individual periods (GVP, MVP, VS) in comparison with the period 1951–2000 increased by 15 days (T ≥5 °C), by 9 days (T ≥10 °C) and by 6 days (T ≥15 °C) (Figure 10). These changes also affected the dates of onset and end of individual phenophases. The great vegetation

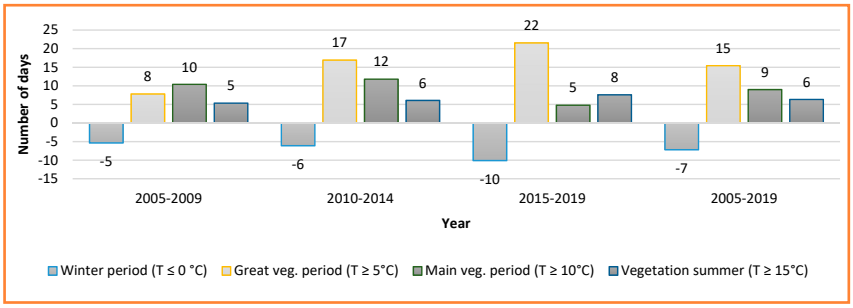


Figure 10 Evaluation of the number of days with temperature $T \leq 0$ °C, $T \geq 5$ °C, $T \geq 10$ °C and $T \geq 15$ °C compared to the climatic normal

period compared to the period 1951–2000 (March 17 – November 13) has a postponed date from March 9 to November 20, the main growing season April 8 – October 21 (normal April 13 – October 17) and vegetation summer May 10 – September 21 (normal May 13 – September 19). The opposite phenomena is the number of days with $T \leq 0$ °C, which decreased on average by 7 days.

Nowadays, scientific papers are focused on researching the impact of the climate change. Changes in the number of days with the occurrence of characteristic temperatures (Čimo, Malenčíkova and Szomorová, 2015), extreme precipitation values (Repel et al., 2020), alternating wet and dry extremities (Zeleňáková et al., 2018) as well as analysis of long-term air temperatures and precipitation (Faško, Lapin and Pecho, 2008; Labudová, Faško and Ivaňáková, 2015; Hlavatá, Tomková, 2015) confirm the change in climatic conditions in Slovakia, which we claim in this study. In this study we focused on the period 2005–2019, which can be the base for future prediction of temperature in agricultural areas in Slovakia.

Conclusion

The aim of this work was to evaluate the air temperature and precipitation conditions in the locality of Nitra, Slovakia for the period 2005–2019. The measured data show an increased mean monthly and annual temperatures. Also, the temperature during the VP is higher by 1.1 °C compared to the normal. Summer, tropical and subtropical days occur in late July and early August. The probability of their occurrence is up to 80% (SD), 60% (TD) and up to 20% (STD). The total precipitation is uneven and alternates extremely humid months with extremely dry ones. In the last 5 years, the total precipitation has decreased by an average of 75 mm compared to the long-term normal. This review study provides information, which can be the base for prediction and with additional information (relative humidity, wind direction, soil moisture, etc.) can help agronomists to prepare for the ongoing climate change in Slovakia.

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