

Use of homogenized data to determine the influence of air temperature on the spring phenology phase of oak

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INTRODUCTION

European oak species (Querus sp.) are one of the most economically and ecologically important deciduous forest tree species in Europe. Oak species have an important ecological role, as they support various insects and their fruit (acorns) provide a valuable food source for many birds and mammals. The canopy of oaks allows a fair amount of light to pass through, permitting a diverse and enriched understory. About 10.6 % of the forest area in Slovakia is covered by oak forests. Only 6 species of oaks are common in Slovakia (Q. petraea L., Q. robur L., Q. pubescens L., Q. dalechampii L., Q. rubra L., Q. polycarpa Schur). The ecological and physiological optimums for the oak forests are both located at the 1st and 3rd vegetation degrees. Between 1881 and 2021. Slovakia experienced a significant increase in annual mean air temperature of 0.15°C over 10 years. For annual atmospheric precipitation. we observed only a slight change of up to about 1%. However, there has been a change in the temporal distribution of atmospheric precipitation during the year. with an increase in the number of droughts. which are more intense and longer lasting, and an increase in the number of floods and flash floods (8NC SR, 2023). The main purpose of this study was to show on the importance of homogenization. Thanks to the homogenized data, we analysed the relationship between the selected phenological phase of oak (leaf unfolding) and air temperature (period of March and April) for the period of 26 years (1997-2022).

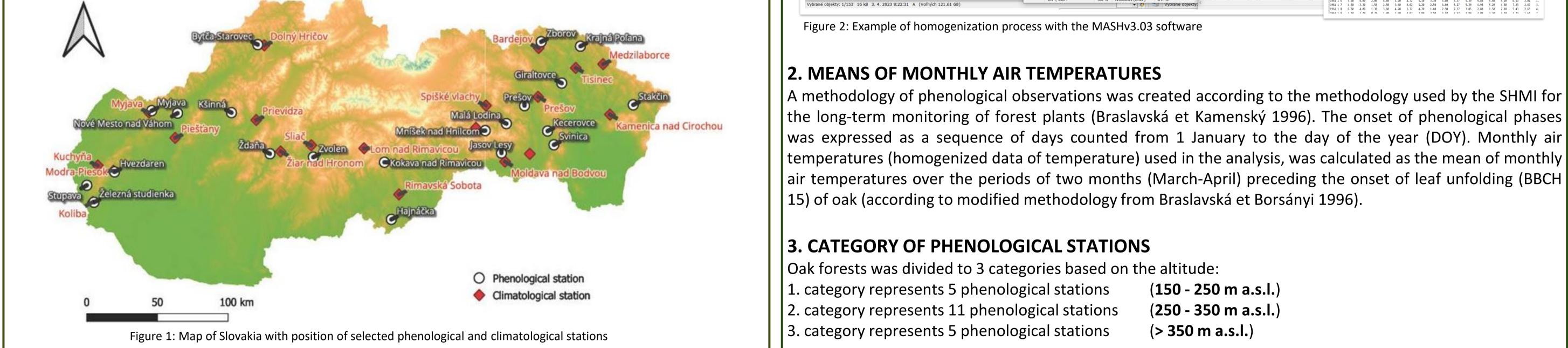
METHODS

1. HOMOGENIZATION

For the purposes of the study. we used the MASH (T.Szentimrey) program to homogenize the data of daily air temperature on 20 climatological stations in Slovakia. MASH software also includes quality control and missing

CLIMATOLOGICAL AND PHENOLOGICAL DATA

Climatological data (monthly air temperature means) and Phenological data (onset of leaf unfolding) for the period of 26 years (1997-2022) were obtained from 20 climatological stations, respectively 21 phenological stations which are situated in a direct neighborhood of climatological stations. Climatological and phenological stations are monitored by Slovak Hydrometeorological Institute (SHMI).



data implementation units. Depending on the climatic features. an additive or multiplicative model can be used. In our case. an additive model for air temperature was used. The used software version was MASHv3.03.

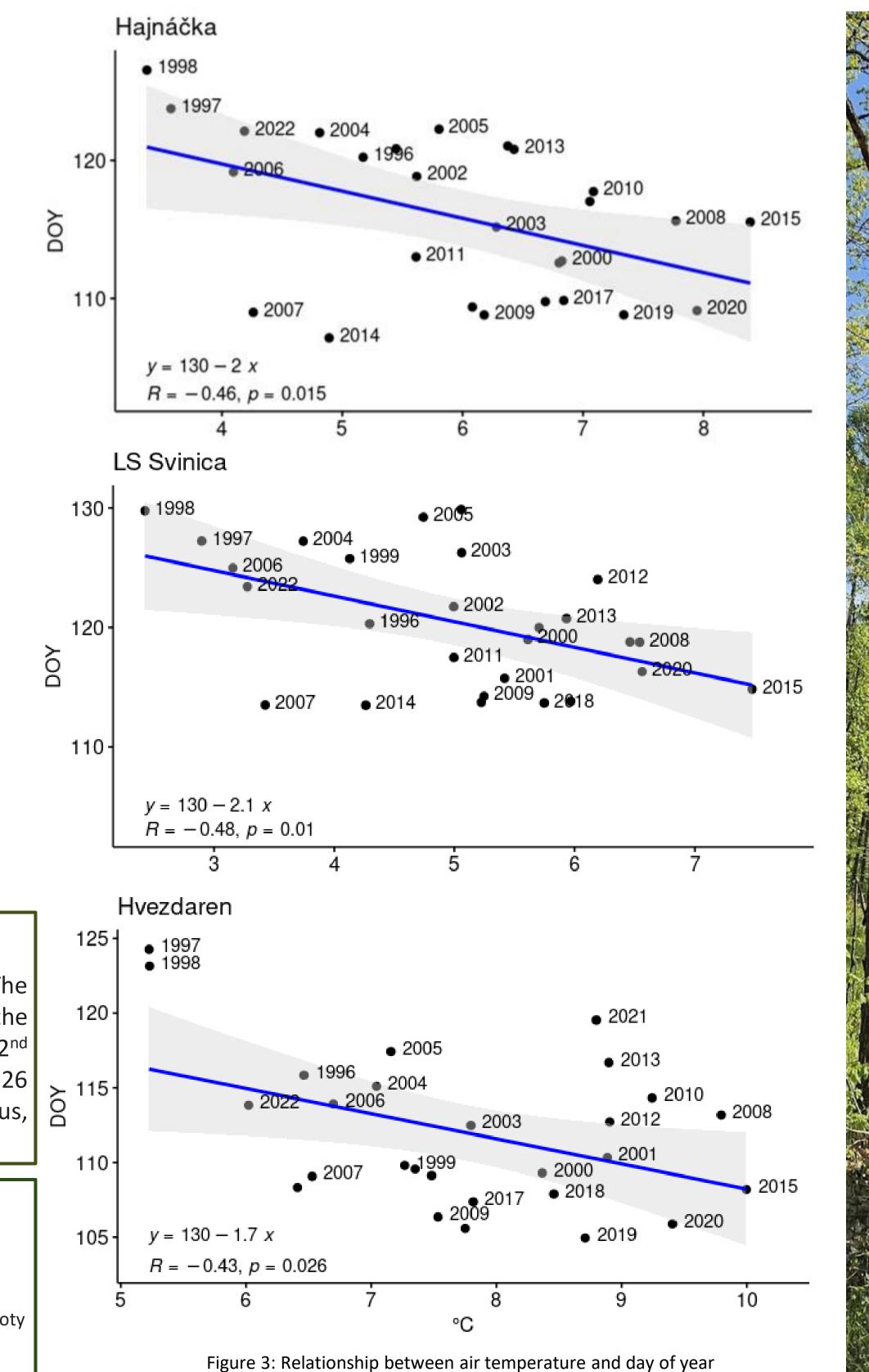
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|---|---|--|--|
| oor Úpravy Formát Zobraziť Pomocník | Súbor Úpravy Formát Zobraziť Pomocník | | |
| 2 5721.31a12.00 7.90 0.05 | Súbor Úpravy Formát Zobraziť Pomocník | | |
| odel: additive | VERIFICATION OF HOMOGENIZATION (Ordered Statistics) | | |
| umber of stations: 57 | 1 1/.14////9 48.40138891 206.0 11801 | | |
| ength of series: 62 | 2 18.04833334 48.87833338 303.0 11803 | | |
| ignificance level: 0.05 | 3 17.56166670 48.75388893 349.0 11806 I. TEST STATISTICS FOR SERIES INHOMOGENEITY | | |
| ritical value for break points: 21.31 | 4 17.11055556 48.16861112 286.0 11813 Null hypothesis: the examined series are homogeneous. | | |
| vitical value for correction: 12.00 | 5 1/.20000001 48.1/166668 133.0 11816 (citical value (significance level 0.05), 21.31 | | |
| vitical value for outliers: 7.90 | $6 \frac{1}{274}$ $\frac{1}{2224} \frac{48.20000001}{124.0} \frac{124.0}{1181}$ Test statistics (TS) can be compared to the critical value. | | |
| | 7.56611 47.89777 114.0 11818 The larger TS values are more suspicious! | | |
| KAMINED STATIONS AND INDEXES | 8 17.67083337 48.48666669 176.0 11819 | | |
| | 9 17.88194449 48.07027778 111.0 11820 10 17 83377733 48 (130555) 163 0 11830 1. Test Statistics After Homogenization | | |
| 11801: 1 11806: 2 11813: 3 11816: 4 11817: 5 11818: 6 | 10 17.83277782 48.61305559 163.0 11826 11 16.99416 48.58166 152.0 11835 Series Index TSA Series Index Series Index Series Index Series Index Se | | |
| 11819: 7 11820: 8 11826: 9 11835: 10 11847: 11 11850: 12 | 16.99416 48.58166 152.0 11835 11835 10 70.57 11901 23 67.63 11813 3 61.24 18.15472 48.56333 176.0 11847 11045 11901 23 67.63 11813 3 61.24 | | |
| 11858: 13 11862: 14 11865: 15 11866: 16 11867: 17 11868: 18 | 13 19 33016 49 1075 145 0 11850 11945 11945 | | |
| 11869: 19 11872: 20 11876: 21 11900: 22 11901: 23 11902: 24 | 14 18.13555556 48.28055557 135.0 11855 11944 Verification of | | |
| 11903: 25 11904: 26 11905: 27 11908: 28 11910: 29 11916: 30 | 15 10 101101 1817 5 28.34 | | |
| 11927: <u>31 11930: 32 11931: 33 11933: 34 11934: 35 11</u> 936: 36 | 11942 | | |
| 11938: 3 946: 42 | | | |
| 11947: 4 Indicatives of used stations 962: 48 | 10 | | |
| 11965: 4 979: 54 | | | |
| 11984: 55 11993: 56 11995: 57 | $_{20}$ (IIIUEXES, Idt., IUII., EIEV.) $_{11977}$ Statistics before all $_{1930}$ $_{37}$ $_{22.70}$ | | |
| ABLE OF REFERENCE SYSTEM (two rows belong to each examined station) | | | |
| by 1: index of candidate station(I3); number of reference stations(I3) | 22 19.34111 49.0725 500.0 11872 11966 11979 after homogenization) 1962 48 18.33 23 19.09889 49.13999 978.0 11872 11979 after homogenization) 1826 9 17.83 | | |
| w 2: indexes of reference stations(I3) | 23 19.90889 49.13999 978.0 11876 11979 11902 1819 7 16.90 | | |
| w z. indexes of felerence stations(15) | 24 18.85222227 48.58611114 275.0 11900 11933 34 16.84 11963 49 16.79 11908 28 16.74 | | |
| 19 | 25 18.89612 48.45944 622.0 11901 11978 53 16.59 11820 8 | | |
| 3 5 4 3 7 2 9 6 8 | 26 19.09388889 48.31916668 355.0 11902 11984 55 15 48 11976 51 | | |
| 2 9 | 27 19.14194445 48.64250003 313.0 11903 11931 33 14 79 11936 36 | | |
| 9 7 10 11 1 5 14 4 3 | 28 19.32194446 48.54416669 368.0 11904 11872 20 14.20 11847 11 195111 2.00 1.40 -0.40 -0.30 0.70 1.00 3.50 1.40 3.00 2.50 9999.99 195111 0.00 0.00 0 | | |
| 3 9 | 29 19.32 48.20666667 228.0 11905 11072 100 110777 11077 11077 < | | |
| 4 5 1 6 10 7 8 9 2 | AVERAGE: 24.68 195114 9.38 8.59 6.68 8.28 8.30 7.69 9.28 6.90 7.28 8.09 999.99 1 196114 8.68 8.09 999.99 1 196114 8.68 8.69 999.99 1 | | |
| 4 9 | 31 19.646666667 48.6444444 1015.0 11910 196.14 5.30 6.40 4.40 5.30 7.60 6.60 7.50 6.50 9999.99 1961.15 8.00 8 | | |
| 5 3 1 6 10 7 8 9 2 Coloction of | 32 19.64667 48.6444 1015.0 11916 2. Test Statistics Before Homogenization 1961 1 6 5.90 4.60 5.70 4.50 5.10 3.30 5.60 3.60 9999.99 1961 1 6 0.00 0.00 0.00 33 19.73638893 48.33888891 214.0 11927 1961 1 7 4.50 3.20 5.60 3.40 5.20 2.50 4.60 3.50 9999.99 1961 1 7 0.00 0.00 0.00 | | |
| Selection of | So 13.73636655 46.53666651 214.0 11527 Series Index TSB Series Index 1961 1 8 6.30 4.00 1.30 3.60 4.20 1.50 4.70 1.60 2.50 2.60 9999.99 1961 1 8 0.00 0.00 0 | | |
| 4 3 1 6 7 10 8 9 2 | 25 20 22417 40 19044 1762 0 11021 11835 10 436.97 11976 51 1961 10 20 20 10 10 10 10 10 10 10 10 10 10 10 10 10 | | |
| reference stations | 11977 52 107.14 11945 41 1961 111 4.40 3.80 | | |
| | | | |
| 7 9 | 29 20 12045 40 26299 1017 0 11026 11000 L 00110 11020 0 11010 0 | | |
| ² ² ¹¹ ¹ ⁵ ⁸ ⁴ ¹⁰ ³ to every | | | |
| | 40 20.09361112 48.59277781 311.0 11941 11956 36 57.57 11850 12 1961 117 0.40 0.60 OF HOTHOGENIZED AND | | |
| candidate station | 41 20.01055556 48.37388891 215.0 11942 11813 3 49.73 11961 47 1951 118 -1.59 -0.69 -1 | | |
| | | | |
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| 9 | 11862 14 33.93 11868 18 1961 122 -0.99 -3.59 -0 | | |
| 1 2 3 5 4 7 9 11 8 | 45 21 00166667 48 6044448 218 0 11047 111979 54 51.49 11995 57 | | |
| | A6 20 70445 49 055 399 0 11040 11938 37 27.43 11951 46 * Uniform Cast-rotanical violation | | |
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| 2 9 8 11 22 24 6 7 22 0 | 48 20,42249 49.38721 469.0 11951 11994 26 25.19 11876 21 196111 2.00 1.40 -0.40 -0.30 0.70 1.22 3.50 1.40 3.00 2.27 3.17 2.68 2.60 2.60 4.03 0 | | |
| 3 8 11 23 24 6 7 22 9 | AQ 20 84277782 AQ 26077770 AS A 11061 11941 38 22.06 11993 36 196112 1.88 1.40 -0.40 0.00 1.60 1.02 1.80 0.90 1.20 1.77 1.89 0.98 1.70 1.30 1.83 0.98 | | |
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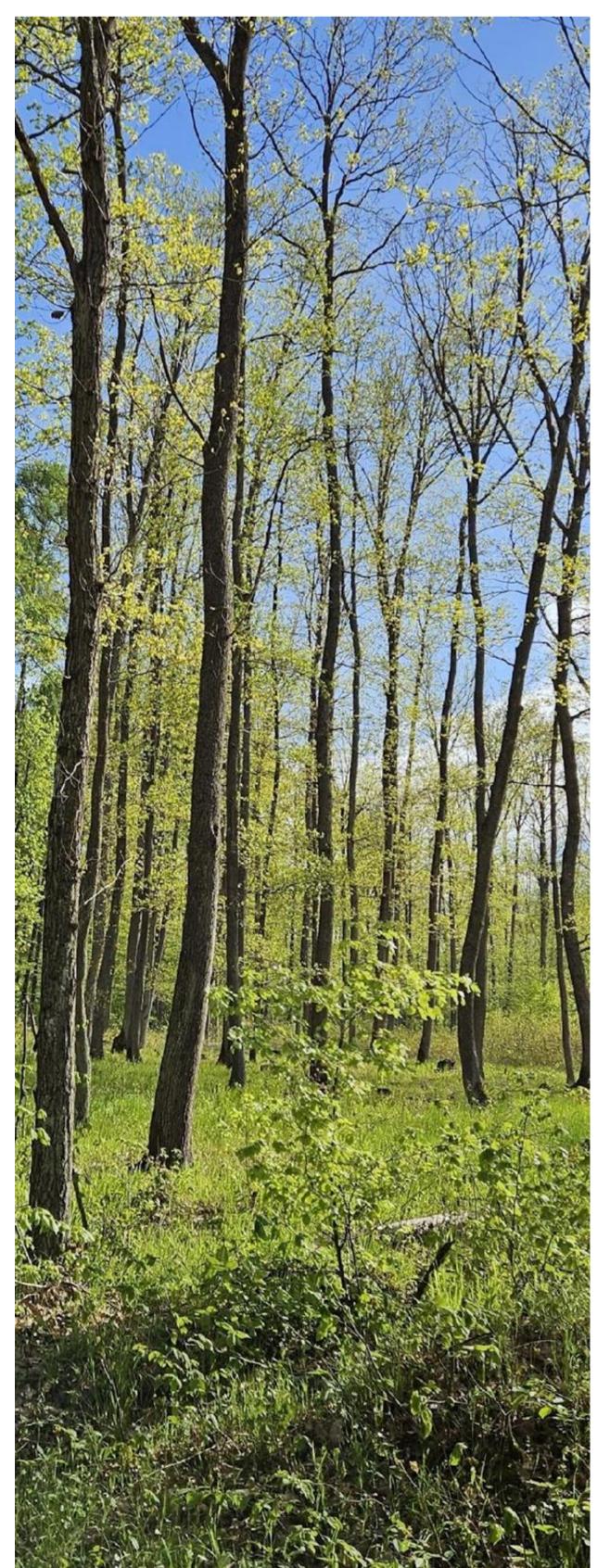
RESULTS

Table 1. List of phenological stations

Our analyses confirmed statistically significant trends (P<0.05) and a medium negative correlation between air temperature (period of March-April) and the onset of the spring phenophase (leaf unfolding) in the 1st category (expect Giraltovce stations) and 2nd category (expect Zvolen, Kecerovce, and Bytča-Starovec stations). However, non-significant trends, but a medium negative correlations was found in the 3rd category (expect Hvezdáreň, and Myjava stations). We also found that leaf unfolding of oak has shifted to an earlier start during the period of 26 years (1997-2022).

| Category | Fenological station | Altitude [m a.s.l. | R value | P value | Shift of phase/decade [day] |
|----------|----------------------|-----------------------|---------|---------|--------------------------------|
| 1 | Stupava | 177 | -0.42 | 0.030 | -3.7 |
| | Nové Mesto nad Váhom | 196 | -0.42 | 0.031 | -3.7 |
| | Železná studienka | 220 | -0.44 | 0.022 | -2.7 |
| | Hajnáčka | 220 | -0.46 | 0.015 | -3.1 |
| | Giraltovce | 240 | -0.36 | 0.067 | -2.1 |
| 2 | Stakčín | 256 | -0.37 | 0.055 | -2.1 |
| | Svinica | 272 | -0.48 | 0.010 | -2.6 |
| | Jasov Lesy | 280 | -0.41 | 0.032 | -3.0 |
| | Krajná Poľana | 295 | -0.4 | 0.040 | -2.1 |
| | Zvolen | 300 | -0.38 | 0.052 | -3.0 |
| | Ždaňa | 300 | -0.39 | 0.044 | -3.1 |
| | Bytča-Starovec | 305 | -0.38 | 0.051 | -2.8 |
| | Kšinná | 314 | -0.43 | 0.026 | -2.7 |
| | Kokava nad Rimavicou | 325 | -0.38 | 0.048 | -3.0 |
| | Zborov | 325 | -0.45 | 0.020 | -2.6 |
| 3 | Kecerovce | 328 | -0.36 | 0.067 | -2.9 |
| | Myjava | 383 | -0.47 | 0.013 | -3.2 |
| | Prešov | 388 | -0.36 | 0.068 | -3.0 |
| | Malá Lodina | 420 | -0.35 | 0.069 | -3.0 |
| | Mníšek nad Hnilcom | 471 | -0.34 | 0.078 | -3.0 |
| | Hvezdaren | 531 | -0.43 | 0.026 | -2.7 |





Conclusions

Our results indicate that temperature modified vegetative development of oak species. The analysis revealed a statistically significant, intermediate degree of correlation between the temperatures in spring (March–April) and the onset of leaf unfolding (in the 1st and the 2nd category). Trend analysis pointed to an earlier onset of leaf unfolding during the period of 26 years (1997-2022). This study shows the meaning and importance of homogenized data. Thus, we can analyse the long-term phenological events, like the leaf unfolding of oak.

REFERENCES

8NC SR. 2023. The eight National Communication of the Slovak Republic on Climate Change: under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Ministry of Environment of the Slovak Republic. Slovak Hydrometeorological Institute, Bratislava, 2023.

BRASLAVSKÁ, BORSÁNYI, ŠEVČOVIČOVÁ, 1996: Analýza nástupu fenologických fáz rastlín v Sučanoch v závislosti od zmien teploty vzduchu. In: Národný klimatický program SR, III, zv. 4, 77–89.

BRASLAVSKÁ, KAMENSKÝ, 1996: Fenologické pozorovanie lesných rastlín : Metodický predpis. SHMÚ. Bratislava. 22.