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RESEARCH ARTICLE

The role of citizen science in demonstrating the local effects of climate change

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Abstract – Climate change is the greatest global challenge for present and future generations, destabilizing life-support systems with its diverse interrelationships and interactions. The real solutions to global problems at the local levels can only be expected through the widest possible social cohesion and the effective transmission of the results of science to all ages and social strata. One of the best ways to do this is by involving present or historical data from reliable sources of qualified and reliable amateur (citizen) scientists, which is an outstanding methodological opportunity to expand and increase the efficiency of scientific research. Therefore, citizen science has become more and more widespread within and between different disciplines in recent decades. One of the significant practical examples of this, with the persistent and accurate work of a late enthusiastic amateur data collector, Mr. László Cseh), who measured, collected and preserved main local climate data (that is, the average and maximum temperature and precipitation) over several decades in Csemő-Ereklyés region near Cegléd. The comparison of these data sets with the dynamics of the national middle-term data and the possibilities of their use in explaining plant phenology shifts are presented in this paper. According to our results, these local data sets fit well with the national trend and can increase the effectiveness of nature conservation by demonstrating the effects of climate change on plant phenology. Community science provides an opportunity for greater social recognition and acknowledgement of scientific results.

Keywords – citizen science, climate change, temperature, precipitation, plant phenology

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INTRODUCTION

Citizen science sounds special because of the inherently communal nature and goals of science, but, in fact, it has been playing an increasing role in expanding the opportunities and participants in scientific research in recent decades (Eleta et al., 2019; Vohland et al., 2021). It involves many interested volunteers in different phases of research, whose participation increases the efficiency of scientific research and utilization of the results (OpenScientist, 2011). In the Old Weather project, for example, hobby historians use data from ship logs from earlier historical periods to refine models of climate change (Vohland et al., 2021).

Social science offers numerous benefits but, on the other hand, has considerable risks (Goudeseune et al., 2020). Extensive, data-intensive research, in addition to their scientific knowledge-enhancing nature, can effectively contribute to better societal decision-making in various areas (CSA, 2021). This scientific research method allows collection of biological and ecological data on a large spatial and temporal scale, producing high-value data sets for basic and applied research (Baker et al., 2021). However, 'knowledge co-production, that is, extended thinking and ultimately the joint creation of shared knowledge, can be valuable and useful at the societal level with the full realization of the scientific requirements of accuracy and reliability as well as comparability and ethics (Rasmussen and Cooper, 2019) and may contribute to increasing climate awareness and sustainability goals (Rambonnet et al., 2019; Fraisl et al., 2020). The framework of community science also offers excellent opportunities to combine knowledge of traditional (folk) knowledge with the results of academic research (Panitsa et al., 2021), as well as to even influence environmental policy (Turbé et al., 2019).

Phenology is the scientific term for the temporal dynamics of production biological events recurring annually in the living world and the determination of the causes of their manifestation influenced by biotic and abiotic effects (Fenner, 1998). Climate change influences the seasonal activity of terrestrial ecosystems, while long-term phenological data sets are reliable indicators of a changing climate (Molnár V., 2014), so plant phenology indicates climate change and the effects of the environment on plants. Temperature is a major driver of many plant developmental processes; higher temperatures may accelerate plant development, and the next ontogenetic stage may occur earlier.

Plant responses to climate change are species- and site-specific due to genetic and environmental influences (Fitchett et al., 2015). Adaptability fundamentally determines the extent to which changes in temperature and precipitation affect plant development and performance. Good adaptability results in greater ecological and economic stability (competition, interactions, productivity). By understanding the responses of individual species to climate change, we can make the protection of biodiversity more effective.

One of the major successes of conservation applications in community science is the inter-disciplinary program of the English Botanical Society and the London Museum of Natural History called Orchid Observers, which combined field observations and online determinations of species with the participation of interested nature lovers and orchids experts. With nearly 2,000 participants, 50,948 online identifications of species were made, and the flowering times of 29 orchid species were examined in response to climate change. The summing study also included more than 200 new UK sites of orchid species, including habitats for rare and endangered taxa, which were identified in the program (Vohland et al., 2021).

Scientists recently used plant phenological data recorded in Concord, Massachusetts, by American naturalist *Henry David Thoreau* between 1852 and 1858 to demonstrate the effects of climate change. Primack and Miller-Rushing (2012) found an average 7-day difference–that is, earlier flowering–between the flowering dates of 43 plant species at that time and the period of 2004–2006. The publication of the Hungarian National Meteorological Service (OMSz) entitled “Guide to plant phenological observations” provides valuable help to participants in community research (OMSz, 2017).

In Hungary, most of the current citizen science projects have been focused on environmental education aimed at connecting people with nature and on engaging citizens in scientific monitoring and, ultimately, in conservation activities (Bela et al., 2016). One of the most active organizations in the field of citizen science in Hungary is the Environmental Social Science Research Group (ESSRG) – a non-profit research enterprise, a founder of the European Citizen Science Association, working on cross-boundary transdisciplinary research in natural and social sciences. This organization is a major contributor to the EU-Citizen Science project, a knowledge hub for citizen science in Europe and a platform for also providing various training modules (ESSRG, 2022).

MATERIALS AND METHODS

Late Mr. *László Cseh* (1909-1993) was a cooper living in Csemő-Ereklyés plain (47.074073; 19.392662) near Cegléd - close to the geographical center point of Hungary (47,168462 and 19,395633), who was carrying out meteorological observations for 40 years during the period from 1953 to 1992 in a meteorological observatory station established in his home. Thus, in a typical plain ecological environment in Hungary (Pannon Biogeographical Region), we have a reliable long-term data set recorded in the second half of the twentieth century, in which the daily average and maximum temperature values were recorded by Mr. Cseh measuring temperatures twice a day (7 and 12 AM) for 33 years continuously. This provides us with a unique opportunity to compare a local middle-term meteorological dataset recorded in the middle of the Carpathian Basin and to compare this to long-term national temperature and precipitation recordings.

The measurements were ordered/requested by the president of the local agricultural cooperative (AC), which was established in 1952, and his regularly observed meteorological data were utilized by the cooperative of Cegléd not only by the AC but also by the local state farm and forestry, as well as the surrounding individual small-scale farmers for their productions. This was especially important in the particular environment and production conditions, where large temperature fluctuations were characteristic of the weak sandy soils. László Cseh found that the temperature in Csemő-Ereklyés was always two or three degrees centigrade (°C) lower than in the nearby city of Cegléd, Hungary. To measure the air temperature, he used a certified and calibrated mercury thermometer with a Celsius scale, which measured in the range between (-30) and (+ 50) °C, and allowed readings in 0.1 °C increments. The thermometer was fixed in a measuring house located at the height of 2 meters from the ground.

Out of the eight handwritten weather diaries, six booklets were deposited by his daughter, *Borbála Cseh,* in the Library of the Georgikon Exhibition Center for Historical Farming of the Hungarian Agricultural Museum and Library in Keszthely, Hungary, ten years ago. In contrast, two booklets have been found just recently, completing the above climate data set, which was digitalized and analyzed in the present research program.

RESULTS

1. Temperature changes in the second half of the 20th century in the central part of Hungary

During the study period of thirty-three years, the annual average temperature increase was 0.7 °C in Csemő-Ereklyés, Hungary, according to the linear trend fitted to recorded data (Figure 1). The annual average temperature increase was observed as 1.2 °C (0.9 and 1.6 as the lower and upper limits of the 90% confidence interval, respectively) nationwide in Hungary in the 120-year period between 1901 and 2020 (OMSz, 2015). The time-span of 33 years in our study was included relatively in the middle of this time-period.

Hot days (when the daily average temperature was above 25 ºC) show a similar increasing trend in this study place and period (Figure 2) as that of the national data set between 1901 and 2014 (OMSz, 2015).

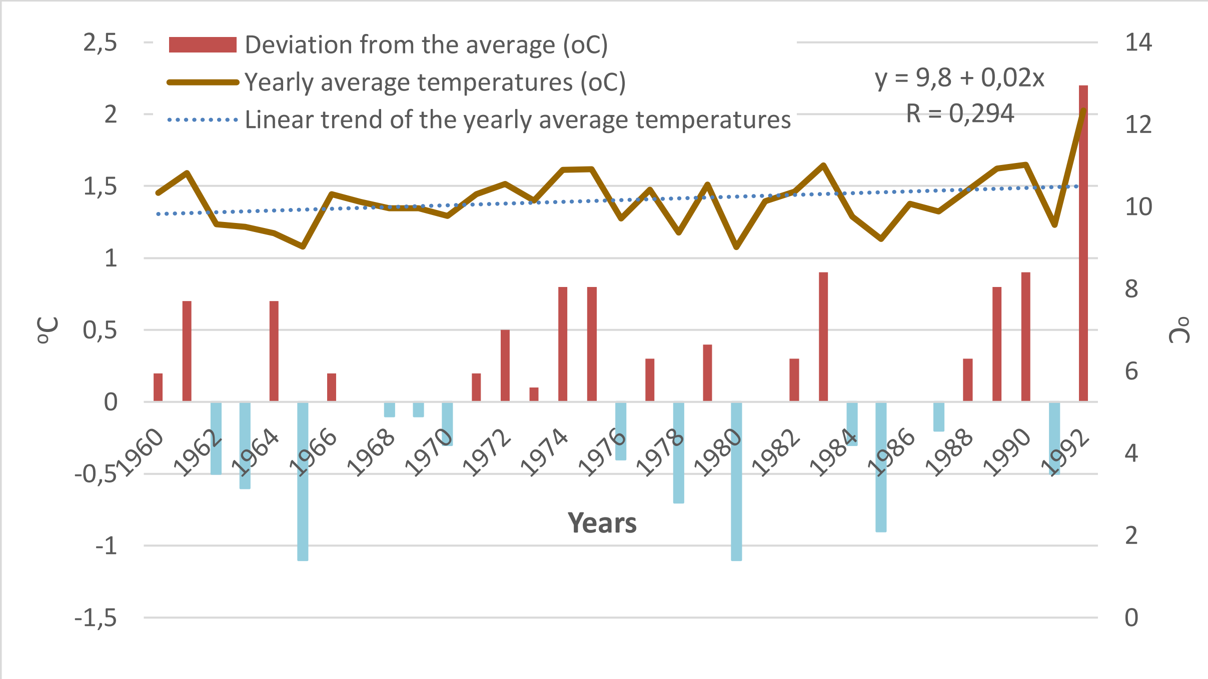

Figure 1. Mean temperatures and annual differences between 1960 and 1992 measured in this study (based on data from László Cseh, recorded in Csemő-Ereklyés, Hungary). The equation and the regression coefficient (R-value) of the linear curve fitted to the yearly average temperature data are shown in this figure.

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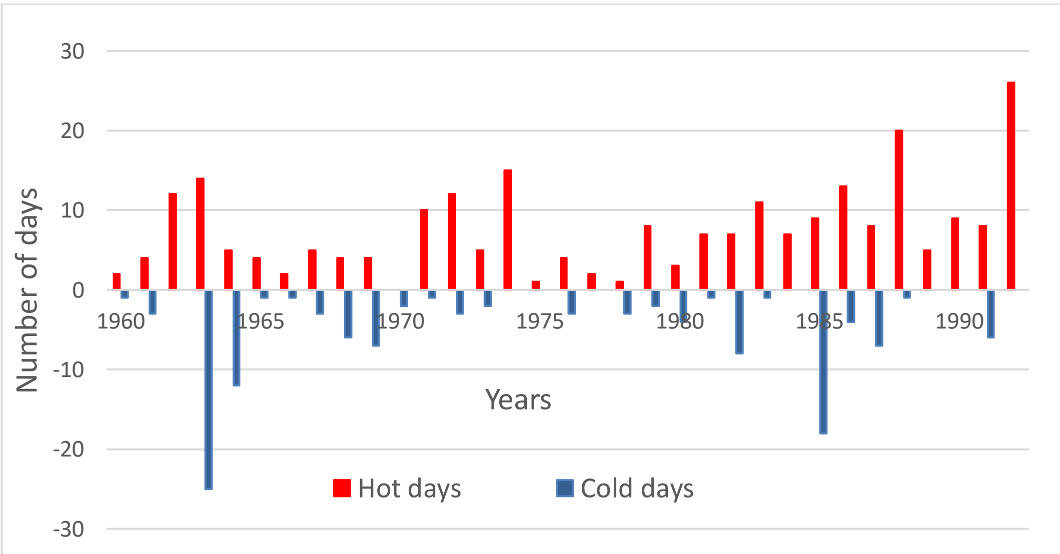

Figure 2. Numbers of hot (daily average temperature >25 ºC) and cold (daily average temperature <10 ºC) days between 1960 and 1992 (data recorded by László Cseh, Csemő-Ereklyés, Hungary).

The changes in the mean temperatures of the four seasons between 1960 and 1992 are shown in Figure 3. Based on the values of the linear trend line fitted to the measurement data, the average temperature of the seasons increased to different extents during the study period: the most significant increase (1.9 ºC) was observed in winter, while the lowest increase (0.24 ºC) was observed in spring, the same in summer and autumn increases (1.1 ºC and 1.0 ºC, respectively) were observed.

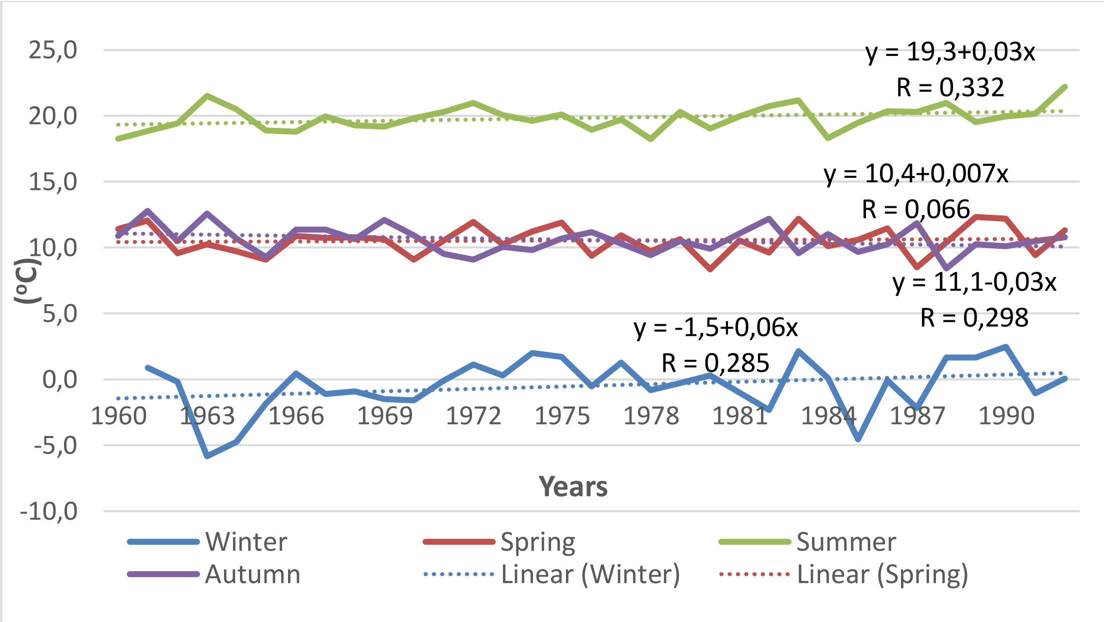

Figure 3. Changes in the average temperatures of different seasons between 1960 and 1992 (data recorded by László Cseh, Csemő-Ereklyés, Hungary).

Spring and autumn courses of the changes of the average temperatures during the time period investigated here show almost similar dynamics but resulted in different values for the fitted linear curves (Figure 3) and also for the seasonal mean temperature changes derived from these equations (Table 1).

We compared our results with the national data of OMSZ (2022), shown in Table 1. For the 120-year data series from 1901 to 2020, the highest increase was observed in summer (1.3 ºC), and for the last 40 years, the increase of 2.1 ºC also occurred in this season. However, the highest estimated seasonal mean temperature change (1.9 °C) was observed in winter for the 33-year period examined in this study at Csemő-Ereklyés, with the lowest increase of 0.2 ºC shown in spring (Table 1).

Table 1. Estimated annual and seasonal mean temperature changes in Hungary, with the lower and upper limits of the 90% confidence interval of the OMSZ (2022) data (*); and values from the equations of the fitted linear curves to the data of László Cseh, recorded in Csemő-Ereklyés, Hungary (**), presented in Figure 3.

Time-period	Year	Spring	Summer	Autumn	Winter
1901-2020*	1.2 (0.9-1.6)	1.2 (0.6-1.7)	1.3 (0.9-1.8)	1.0 (0.4-1.6)	1.2 (0.2-2.1)
1981-2020*	1.7 (1.2-2.2)	1.4 (0.6-2.2)	2.1 (1.4-2.8)	1.5 (0.7-2.2)	1.9 (0.4-3.4)
1960-1992**	0,7	0,2	1,1	1,0	1,9

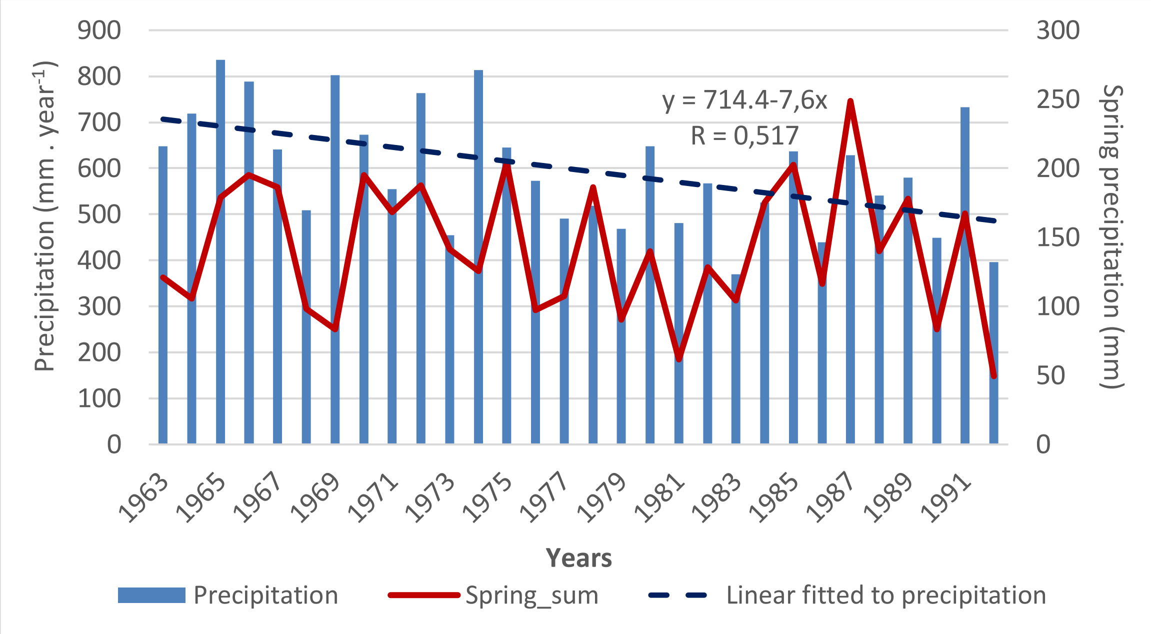

Figure 4. Changes in the annual and spring rainfall in the area of this study between 1963 and 1992 (data recorded by László Cseh, Csemő-Ereklyés, Hungary).

2. Applying plant phenology to detect the effects of climate change

Jacquemyn and Hutchings originally published their paper in 1992 and re-published it in 2015 to suggest the Early spider orchid (Ophrys sphegodes) species to demonstrate the plant phenological effects of climate change (Jacquemyn and Hutchings, 2015). The species is common in western, southern and central Europe; its development and time of flowering are greatly influenced by environmental influences, especially temperature and water supply, and the biological characteristics of flowering make it particularly suitable for detecting complex ecological effects. As an insect-pollinated species, climate change affects not only the phenological phases of the plant but also the appearance and pollination of bee species essential for reproduction, *Andrena nigroaenea* (Jacquemyn and Hutchings, 2015) in Central England, and their further ecological interactions and also biodiversity conservation. According to studies by Robbirt et al. (2011), between 1975 and 2006, one degree of Celsius increase in spring temperature resulted in flowering in spider orchid populations six days earlier.

The average middle day of Early spider orchid flowering in Hungary is May 13, leading to early and short (10-14 days) flowering in warm, dry weather conditions, while cold weather can cause a 30–40-day extension (Molnár V. et al., 2011). The largest domestic population of spider orchids occurs near Cegléd, where the effect of precipitation has been decisive in the formation of the plant population since the bed regulation of the Gerje stream. Based on the data measured by László Cseh just a few kilometers from the spider orchid population, the rainfall supply of the study area decreased significantly in the second half of the 20th century (Figure 4).

In the 30-year period (1963-1992) examined, based on the linear trend line fitted to the annual precipitations, the rate of decrease was -228.4 mm (-32%), falling from a value of greater than 700 mm (714.4 mm) to the level below 500 mm (486 mm) by the beginning of the 1990s. Over the same period, spring precipitation showed significant differences (Figure 4).

DISCUSSION

Interdisciplinary research programs using long-term meteorological observations and plant phenological data can be useful in revealing complex ecological relationships as the results of biotic and abiotic interactions and also allow the assessment and demonstration of the complex effects of climate change. The methodology of citizen science can be very helpful in detecting ecological processes. Local historical weather data sets – proving their reliability and preciseness – are of particular importance to provide the opportunity for investigating climatic changes at a smaller scale, and helping to better adaptation. Our results presented here are intended to give a good – and rather unique – example. During the study period of 33 years, the annual average temperature increase was 0.7 °C at Csemő-Ereklyés according to the linear trend fitted to measured data. The highest increase (1.9 °C) was observed in winter (in December, January, and February), while the lowest increase (0.2 °C) was observed in spring (in March, April and May), and increases of the same magnitude (1.1 °C and 1.0 °C) were observed in summer (in June, July and August) and autumn (in September, October and November), respectively. During the same period, annual precipitation decreased significantly (-32%). However, when observing the changes in precipitation in Hungary, the annual precipitation decreased slightly during the twentieth century, but an increase can be observed in recent decades (OMSZ, 2022).

To detect the complex ecological influence of climate change at the local scale, the use of the spider orchid species is also recommended in Hungarian environmental conditions, as it is a characteristic and strictly protected species in Hungary and sensitive to water shortage, especially in low soil moisture conditions.

CONCLUSION

In conclusion, we highlight the importance of citizen science for finding reliable historical datasets available or which can be found in libraries or in family repositories, as well as those plant phenology observations which can be used for the assessments of the local dynamics of climate change. These may serve a better understanding of intermediate- and short-term climatic and ecological processes and can be useful in designing more appropriate strategies for climate mitigation and plant conservation.

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