

SPATIAL DISTRIBUTION OF THE PHENOLOGICAL PHASES AND URBAN HEAT ISLAND IN THE CASES OF TWO HUNGARIAN CITIES

Agnes Gulyas^{*1}, Laszlo Lakatos², Zoltan Sumeghy¹, Tamas Gal¹

¹University of Szeged, Szeged, Hungary

²University of Debrecen, Debrecen, Hungary

Abstract

Our previous results showed that a local climate with special spatial structure (e.g. heat island) is formed within the settlement compared to outside open spaces. We presume that these climatic modifications affect the phenological and phenometrical properties of the urban vegetation. For this study we have chosen two medium-sized Hungarian cities (Szeged and Debrecen), with areas over 300 km² and with population between 160 and 220 thousand. The phenological and temperature observations have been taken in grid networks in spring of 2003.

As a good observable plant, forsythia (*Forsythia suspensa*) was the object of our examination because this species occurs in the 60-70% of the areas of both cities. The time of the different phenological phases were monitored in a daily fashion. According to the results there is significant correlation between the spatial distributions of the timing of these phenological phases and of the intensity of the urban heat island.

Key-words: phenology, urban heat island, *Forsythia suspensa*, Debrecen, Szeged, Hungary

1. INTRODUCTION

Phenological observations were used as a bioindicative method by ecological research and the applied agricultural practice for a long time (Schwartz, 1999). Impact of global climatic change on vegetation was widely investigated using long-term data and remote sensing (Defila and Clot, 2001; Valentini et al., 2001). Other researches studied the small scale modifying effect of urban climate on urban vegetation (e.g. Roetzer et al., 2000). The city itself represents a modified ecological environment for plants in many aspects (urban heat island phenomenon, high building density, air pollution, soil sealing and pollution, water balance) so pattern of phenological data represents mainly an ecological-microclimatical structures of urban area (Karsten, 1986). The results of these researches indicate that flowering of different plant species happened earlier in urbanised than in rural areas (Roetzer et al, 2000). So shift of phenological phases is a result of a complex mechanism but can be linked to the urban heat island (UHI) intensity. The objective of this study is to analyse eco-climatic effects in two Hungarian middle-sized cities, Debrecen and Szeged.

2. STUDY AREA AND METHODS

The investigated areas, Debrecen (47,5°N, 21,5°E) is located in the north-eastern and Szeged (46°N, 20°E) in the south-eastern part of Hungary; at 120 m and 79 m above sea level respectively on a flat plain. Administration districts of Debrecen (220 000 inhabitants) and Szeged (160 000 inhabitants) are about 300 km² (Fig. 1). Debrecen does not have any larger river while River Tisza passes through Szeged. Szeged has a boulevard-avenue road system structure with a heavily built up centre region and housing estate zone in north-eastern part of the city. Debrecen has a less centre region at about the geometrical centre of the city than Szeged but there is a huge housing estate zone in the western part of the city. We used for the observation a 500 x 500 m grid-network which was applied earlier for urban climate researches (Sumeghy et al., 2003). Having averaged these phenological data the received means refer to the centre of each cell.

The investigated species was forsythia (*Forsythia suspensa*), because its distribution is well extended (60-70%) over both cities. The times of four selected phenological phases (beginning of the flowering, 25%, 50% and 100% blooming) of the plants (4-8 in one grid) were recorded. Blooming maps show the days starting from the 1st of January 2003. In order to assess the extent of the relationships between the mean maximum UHI intensity and blooming events, in the statistical data processing correlation and regression analyses were applied. The maps were drawn with Surfer 7.0 software.

* Corresponding author address: Agnes Gulyas, Department of Climatology and Landscape Ecology, University of Szeged, POBox 653, 6701 Szeged, Hungary; e-mail: agulyas@geo.u-szeged.hu

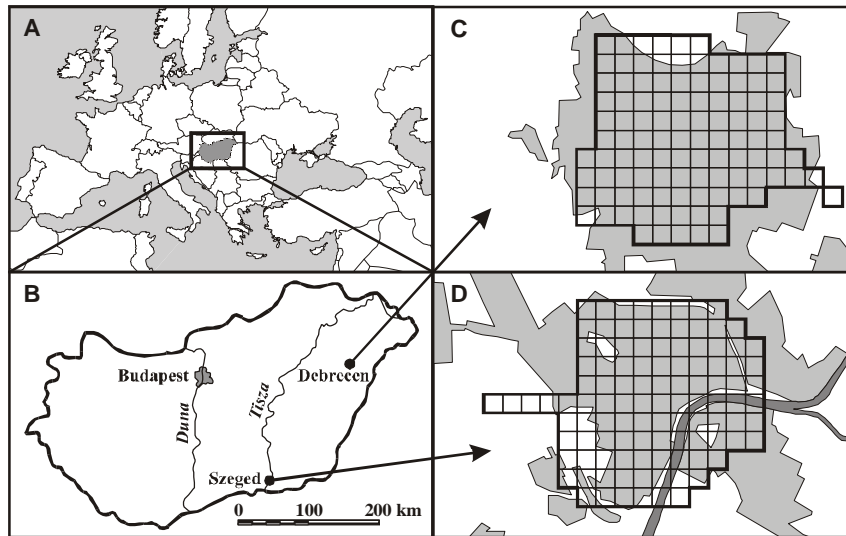


Fig. 1. Geographical location of Hungary in Europe (A), of Debrecen and Szeged in Hungary (B), measurement grid-network in Debrecen (C) and in Szeged (D)

3. RESULTS AND DISCUSSION

The urban climatological investigations in Szeged (UHI, humidity, human comfort) have a tradition of a couple of decades (e.g. Unger, 1996, 1999a, 1999b). Recent urban climate studies show a maximum urban heat island intensity of 2.3°C as annual average in Debrecen (Fig. 2A), and 2.7°C in Szeged (Fig. 2B) between April 2002 and March 2003. These values can extend up to 5.8°C/6.8°C at clear, anticyclonic weather conditions (Sumeghy et al., 2003; Szegedi and Kircsi, 2003). The maximum UHI in our case the urban-rural temperature difference a few hours after sunset, when the UHI effect is most pronounced.

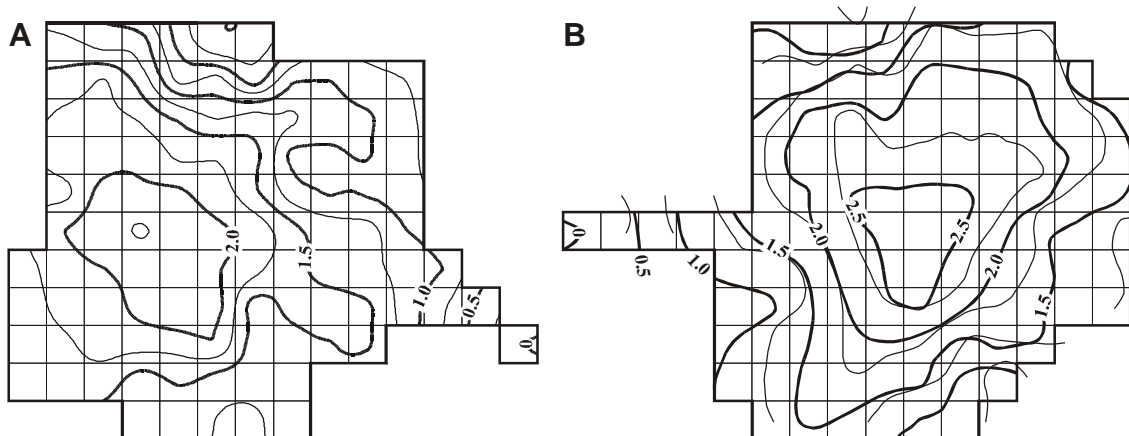


Fig. 2. Spatial distribution of the mean maximum heat island (UHI) intensity (April 2002 – March 2003) in the cases Debrecen (A) and Szeged (B)

Based on the received data isochrone maps about spatial distribution of different flowering dates in both cities were created. The results show a significant connection between the phenological data and the location of the heat island intensity. Two examples are presented to support this statement: Fig. 3. shows spatial distribution of time of the beginning of flowering and Fig. 4 shows the full-flowering phenophase (A - Debrecen, B - Szeged). (Observation covered more clusters in Debrecen, hence maps refer to Debrecen have higher resolution than those which regard to Szeged). According to the results the investigated plants reached the given phase earliest in the heavily built-up centre and housing estate region. (These regions represent the highest UHI intensity, too.) Shapes of isolines are stretching out towards W in Debrecen and towards N-NE in Szeged due to the urban structure.

On account of macrosynoptical conditions and geographical location flowering began in Debrecen 2-4 days after Szeged, and the blooming process was drawing. Full-flowering phase occurred 10 days later than in Szeged.

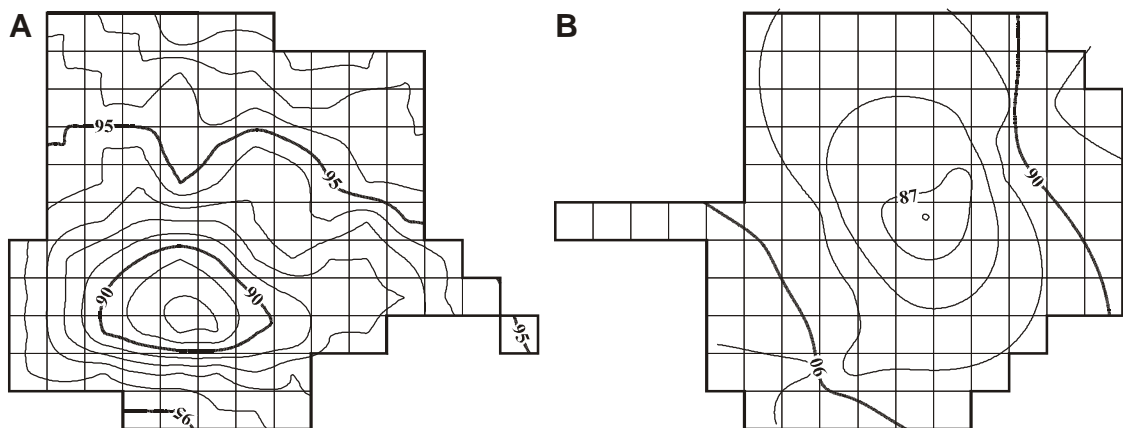


Fig. 3. Spatial distribution of the beginning of the blooming *Forsythia suspensa* in Debrecen (A) and Szeged (B) in spring 2003

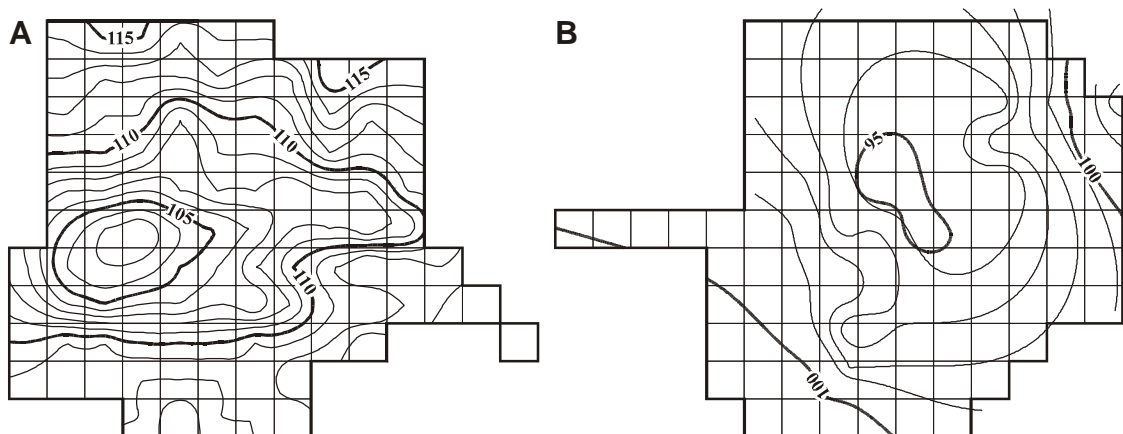


Fig. 4. Spatial distribution of the full-flowering phenophase of *Forsythia suspensa* in the case of Debrecen (A) and Szeged (B) in spring of 2003

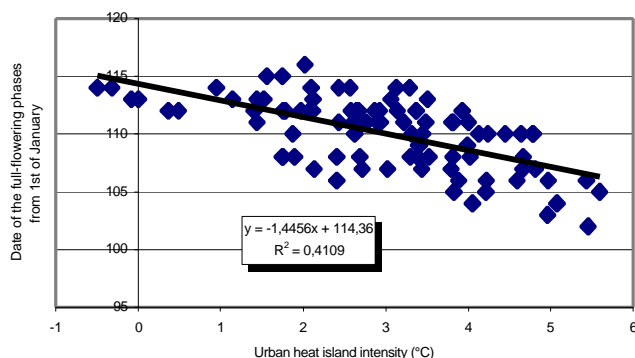


Fig. 5. Correlation between the urban heat island intensity and the date of the full-flowering phenological phases in Debrecen in spring 2003

Fig. 5 shows the correlation between UHI intensity and date of 100% flowering in Debrecen in spring of 2003 by cells. The correlation coefficient is $r = -0.6473$ ($r^2 = 0.4109$) with a standard deviation of 2-3 days. It means in such a complex modified process like blooming a strong relationship at a significance level of 0.1%. As the regression line presents the relationship between the two variables is negative, as it was expected.

4. CONCLUSIONS

The following conclusions are reached from the analysis presented:

- (i) Significant differences were experienced between city centres and suburbs in both cities.
- (ii) Pattern of phenological phases shows good correlation with microclimatological data.

- (iii) Phenological phases can be shifted earlier by several days even one week (in our investigation 4-8 days) in heavily built city centre region and blocks-of-flat areas with high intensity heat island.
- (iv) Time shifting of phenological phases can be attributed partly to the effect of urban heat island.

Acknowledgements: This research was supported by the grant of the Hungarian Scientific Research Fund (OTKA T/034161).

References

- Defila, C., Clot, B., 2001, Phytophenological trends in Switzerland. *Int. J. Biometeorol.*, **45**, 203-207.
- Karsten, M., 1986, Eine Analyse der phäenologischen Methode in der Stadtklimatologie am Beispiel der Kartierung Mannheims. *Im Selbstverlag des Geographischen Institutes der Universität Heidelberg, Heft 84*, Heidelberg.
- Roetzer, T., Wittenzeller, M., Haeckel, H., Nekovar, J., 2000, Phenology in central Europe- differences and trends of spring phenophases in urban and rural areas. *Int. J. Biometeorol.*, **44**, 60-66.
- Schwartz, M.D., 1999, Advancing to full bloom: planning phenological research for the 21st century. *Int. J. Biometeorol.*, **42**, 113-118.
- Sumeghy, Z., Unger, J., Balazs, B., Zboray, Z., 2003, Seasonal patterns of the urban heat island. *Proceedings of ICUC-5, Lodz, Poland*.
- Szegedi, S., Kircsi, A., 2003, The development of the urban heat island under various weather conditions in Debrecen, Hungary. *Proceedings of ICUC-5, Lodz, Poland*.
- Unger, J., 1996, Heat island intensity with different meteorological conditions in a medium-sized town: Szeged, Hungary. *Theor. Appl. Climatol.*, **54**, 147-151.
- Unger, J., 1999a, Comparisons of urban and rural bioclimatological conditions in the case of a Central-European city. *Int. J. Biometeorol.*, **43**, 139-144.
- Unger, J., 1999b: Urban-rural air humidity differences in Szeged, Hungary. *Int. J. Climatol.* **19**, 1509-1515.
- Valentini, N., Me, G., Ferrero, R., Spanna, F., 2001, Use of bioclimatic indices to characterize phenological phases of apple varieties in Northern Italy. *Int. J. Biometeorol.*, **45**, 191-195.