Park Cool Island Examinations in Debrecen, Hungary

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Absctract

Urban heat island (UHI) intensities are lower in urban green spaces than in their urbanized neighborhood. The phenomenon is called Park Cool Island (PCI). PCI intensities can be determined on the base of thermal differences between city centers and parks. Characteristics of the green spaces determine the degree and temporal dynamics of the thermal differences between the green areas and the built-up surfaces in the settlements.
Results of a one year long UHI and PCI measurement campaign are presented here. 32 measurements were carried out using mobile techniques under different synoptic conditions in the time of the maximal development of UHI and PCI in the town of Debrecen (population cca. 220 000) in East Hungary.
Beside the UHI, existence of the park cool island has been proved in Debrecen. Characteristic maximal UHI intensities have been determined for typical built-up types. The impacts of urban green spaces on the temporal and spatial dynamics of the development of the UHI and PCI were determined. Annual and seasonal mean maximal PCI intensities were calculated for Debrecen. Impacts of synoptic conditions on the development of PCI were taken into account as well. Cooling effects of the parks was traced in their urban environment.

Key words*:* urban heat island (UHI), Park Cool Island (PCI), mobile techniques, green spaces

1.Introduction

The main reason for the development of thermal differences between the settlements and their environment – the urban heat island (UHI) – is that built up areas have a different energy budget from that of natural surfaces. Settlement size and structure are important factors from the aspect of the development of the UHI [2,6]. The higher the ratio of artificial surface cover is the stronger heat island develops in the urbanized spaces [3]. However, UHI intensities are lower in urban green areas than in their urbanized neighborhood, since these areas are characterized by a close-to-natural surface cover that have an energy balance more similar to that of natural surfaces. The phenomenon is called Park Cool Island (PCI). PCI intensities can be determined on the base of the thermal difference between the city center and the park [4,1]. The features of the green spaces (height and spacing of plants, irrigation) determine the degree and temporal dynamics of the thermal differences between the green areas and the built-up surfaces. Beside parks, there are other types of green areas (cemeteries, agricultural areas, meadows, sport fields etc.) what behave more or less the same way from the aspect of the development of the UHI. In smaller settlements they are the dominant types of green areas in the urban environment.

2. Study area and methods

From the numerous methods developed for urban climate examinations mobile techniques were chosen in order to get abundant comparable data for Debrecen and the settlements involved in the research. A digital thermometer was mounted on a car with a thermal shield to eliminate radiant heat from the engine of the car. Data were recorded on a logit digital data logger; the sampling interval was set to 10 seconds.

The results of a one year long UHI measurement campaign are presented here.

The built-up inner area of Debrecen (over 25 km^2) was divided into grids of 500 by 500 meters and two routes were established in the Northern and Southern part of the city (Figure 1).

3. Results

On the base of the results of the measurement campaign spatial characteristics of the UHI in Debrecen were determined first.

The mean maximal Urban Heat Island intensity was 2.3˚C in the studied period. The spatial pattern of the UHI was determined by the structure of the city basically, while synoptic conditions had a strong impact on its intensities and air movements modified its shape (Figure 2).

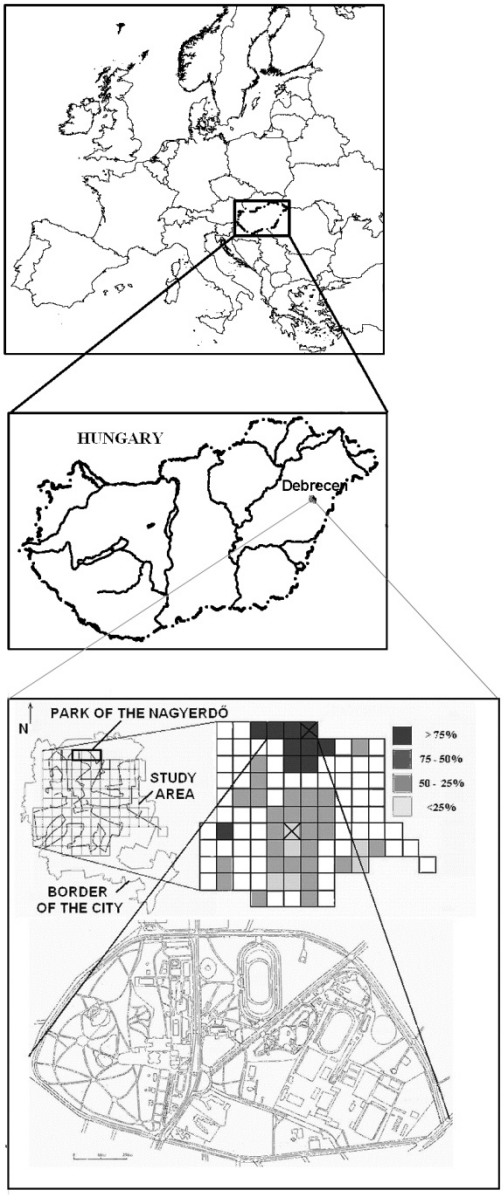

Fig 1. The grid network used during the observation campaign with the location of the park of the Nagyerdő of Debrecen, Hungary; the ratio of the green areas within the grid network (given in %). Grids in the city center and the park used for the calculation of park cool island intensities are marked with x

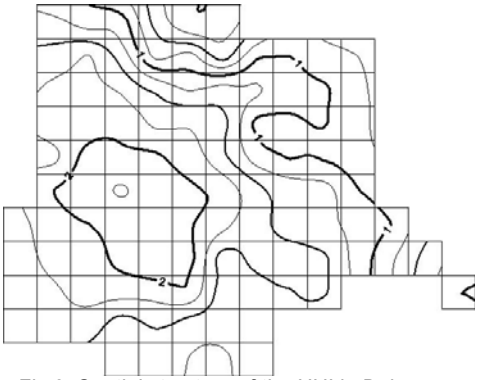

Fig 2. Spatial structure of the UHI in Debrecen. Intensities are given in °C. [5]

Highest UHI intensities should appear in the geometrical center of the city. Instead of that, its structure is drifted southwestward; due to the prevailing Northeastern wind directions and the special build up characteristics of Debrecen with the dominance of high raised blocks of flats in the Western districts. Beside the city center, housing estates and industrial areas, where the ratio of the vertical and horizontal active surfaces is high, are sub centers of the UHI. In the Eastern sector of the city intensities increase gradually towards the center because the built up density grows gradually as well. The steep horizontal temperature gradient called “cliff” is missing in that sector.

The park of the Nagyerdő in the North appears as a cool spot in the intensity maps (Figure 2, 3, 4). The annual mean maximal intensity was around 0°C. The park makes cooler its built-up environment by 1-1.3°C on the average. Highest horizontal gradients (0.5 °C/100 meters) were found there, what means that strongest “cliff” occurred there, within the city. PCI intensities reached 1,9°C for the whole studied period (Table 1).

In the heating season the mean maximal UHI intensity was 2.1°C, which is lower than the annual mean and the non-heating season mean values. The reason for it is that in the winter period (especially in November and December) the cyclonic activity is strong in the Carpathian basin. Northeastern winds are less dominant in that period what result in more regular UHI structures on the other hand. The city center is the center of the UHI, while housing estates and the industrial areas are sub centers of the heat island. The cool pole of the city is the forest of the Nagyerdő with intensities under 0°C on the annual average (Figure 3).

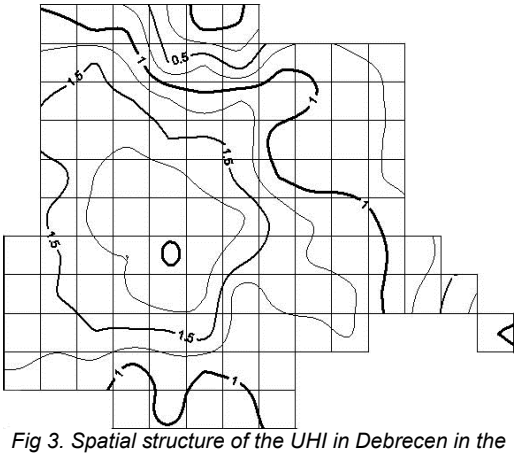

Fig 3. Spatial structure of the UHI in Debrecen in the heating season. Intensities are given in °C [5]

In the non-heating season the mean maximal UHI intensity reached 2.5°C, which is higher than that of the whole period. The reason for it is that favorable radiation conditions in the summer play more important role in the formation of the UHI than anthropogenic heat input in the heating season. The southwestward deformation of the UHI is stronger in the summer due to the prevailing 2-3 m/s Northeastern winds in the region of Debrecen (*Fig. 4*).

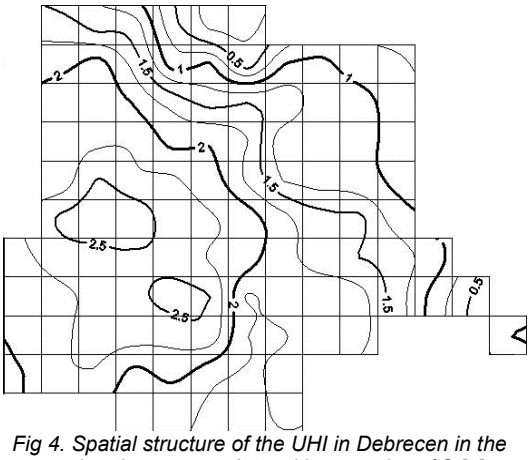

Fig 4. Spatial structure of the UHI in Debrecen in the non heating season. Intensities are given °C [5]

For the whole heating season the highest horizontal thermal gradients reached 0,2°C/100 m at the Nagyerdő (*Tab. 1*). The cold pole of the city was the park of the Nagyerdő with intensities around 0°C in the Northern grids. Weak PCI-s were found during the frequent weak UHI-s in the heating season: PCI intensities reached 1,8°C in that period. For instance, a PCI with an intensity of only 0,75°C was detected during a weak UHI with an intensity of 1°C (Tab. 1).

Table 1: Maximal and occasional maximal horizontal temperature gradients and park cool island intensities (given in °C) at the park of the Nagyerdő for the whole observation campaign, in the heating and non-heating season; under favorable and unfavorable conditions

	Horizontal temperature gradients (°C/100m)	PCI intensities (°C)
year	0,20	1,90
Non-heating season	0,20	2,00
Heating season	0,20	1,80
favorable conditions	0,50	3,50
unfavorable conditions	0,10	0,75

The coldest sector of the city was the park of the Nagyerdő again in the non-heating season, although it is less cold than the outer parts in that period. Diurnal course of temperatures is more even under the tree canopies (one active surface), since cooling rates in the night, what are responsible for the development of the UHI and PCI are much lower there than in the open outer spaces (plough lands/grasslands). Therefore, in the non-heating season the park behaved more like the built-up area, there were not any cases when intensities were under 0°C. In the coldest, northernmost grids what belong to the park of the Nagyerdő intensities under 0,3°C were observed. The maximal horizontal thermal gradient for the whole season was 0,1°C/100 m only, but it reached 0,5°C/100 m under favorable conditions (Table 1).

Spatial extent of the cooling effect of green spaces on the neighboring built-up areas was examined as well. For this, the position of the 1 °C UHI intensity isotherm was used for the whole studied period; the heating and the non-heating season (Figure 5), because it shows the strongest break at the park of the Nagyerdő. Connecting the first and the final points of the arc of the break of the isotherm we get the position of the line what the isotherm would take if there was not a green space. After that, the average distances between the two lines were measured on the three maps. The cooling effect could be traced within a distance of 300 meters.

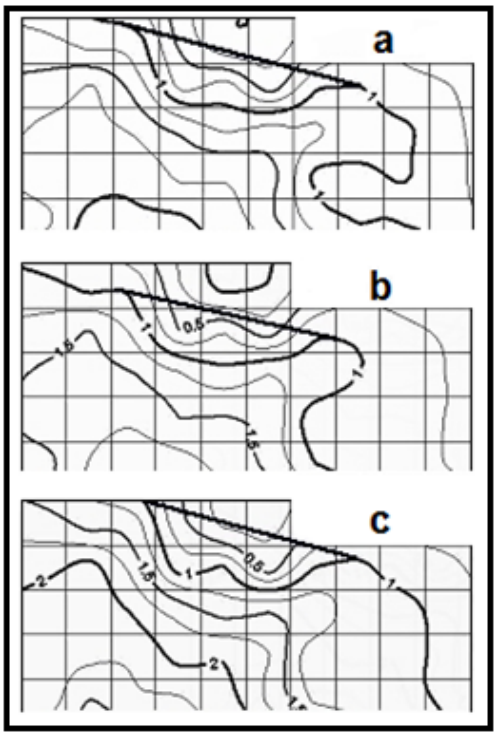

Fig 5. The real and the calculated position of the 1°C UHI intensity isotherm for the whole observation campaign (a), the heating (b) and the non-heating seasons (c)

Stronger UHI-s caused stronger PCI-s in the non-heating season; while weaker heat islands had weaker cooling effect in the heating season. Highest intensities reached 2,0°C (Table 1). There were not any significant differences in the absolute PCI intensity maxima for the whole year, the heating and the non-heating seasons similarly to UHI intensities. However in a case when an UHI of 4,5°C was measured, a PCI of 3,5°C was observed under favorable synoptic conditions.

4. Conclusions

The most important conclusions of the observations on the impact of the green spaces on the development of the UHI in Debrecen and the neighboring settlements can be summarized in the followings:

- Beside the UHI, existence of the park cool island (PCI) has been proved in Debrecen.
- Annual mean maximal PCI intensities reached 1.9°C, in other words, the park of the Nagyerdő was cooler than its urban environment by nearly 2°C on the average during the measurements.
- Mean maximal PCI intensities reached 1.8°C in the heating season and 2.0°C in the non-heating season, which are close to each other, but under favorable conditions PCI intensities reached 3.5°C.
- Mean maximal horizontal thermal gradients for the whole year, the heating and the non-heating seasons were 0.1°C/100 m, but they reached 0.5°C/100 m in the case of strong UHI-s.
- The cooling effect of the park could be traced within a distance of 300 meters in its urban environment.

5. Acknowledgements

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