Comparison of the urban-rural comfort sensation in a city with warm continental climate

Ágnes Gulyás[1], Andreas Matzarakis[2], János Unger[1]

[1] University of Szeged, Department of Climatology and Landscape Ecology, Hungary
[2] Meteorological Institute, Albert-Ludwigs-University of Freiburg, Germany

Abstract

The aim of this study is to show the effect of the complex urban environment on the human bioclimatic conditions on local scale in a Central-European city with warm and relatively dry continental climate (Szeged, Southern Hungary). According to the practice in urban climate studies, the characteristics of two distinct locations were compared in bioclimatic aspects. The modifying effect of the city can be studied at the location situated in the built-up city center, while the effect of the city is negligible at a location on an arable land with open horizon. Hourly average values of each meteorological parameter (collected between 1999-2008) were used to calculate Physiologically Equivalent Temperature (PET) bioclimate index values. Based on these datasets the difference in physiological stress on urban and rural residents was described. Considering the average of the PET through the whole 10-year period between the urban and rural areas, it was 2.9 °C higher in the urban area. While the difference in the length of the *hot* and *very hot* period is 0,5% (compared to the full length of the studied term), this difference is 10% between the *cold* and *very cold* categories. According to our study the human bioclimatic modifying effect of the city is more pronounced in the physiologically more demanding cold periods.

1. Introduction

Characteristic climatic phenomena, occurring in cities (urban climate, urban heat island) generates special environments for their residents. The climatic effects of the cities can enhance the thermal stress of the residents (in summer, especially during heat waves), or attenuate it (in winter). The highest intensity of the urban heat island is formed several hours after sunset keeps the extent of the heat stress at high levels in addition to the strong heat stress during the daytime.

Table 1: Physiologically Equivalent Temperature (PET) for different grades of thermal sensation and physiological stress of human beings (internal heat production: 80 W, heat transfer resistance of the clothing: 0.9 clo) (Matzarakis and Mayer, 1996 modified)

PET (ºC)	**-4**	**4**	**8**	**13**	**18**	**23**	**29**	**35**	**41**
thermal sensation	extr. cold	very cold	Cold	cool	sligh. cool	comfortable	sligh. warm	warm	hot	extr. hot
Level of the physiology. stress	extreme		Strong	mod	slight	no stress	slight	mod.	strong	extr.
	cold stress						heat stress			

One of the most popular thermal index in the bioclimatic researches is the PET (Physiologically Equivalent Temperature). PET is defined as the air temperature at which the human energy budget for the assumed indoor conditions is balanced by the same skin

temperature and sweat rate as under the actual complex outdoor conditions to be assessed (e.g. Mayer and Höppe, 1987; Höppe, 1999). Ranges of the PET index are shown in Table 1. While the original scale does not contain, due to the homogeneity in winter we introduced a new category: below -4 °C PET it is named extreme cold thermal sensation.

The aim of this study is to compare the bioclimatic situation of a city and the surrounding rural area on the example of a Southern Hungarian city (Szeged) in a then-year period (1999-2008). Additionally, summer averages of 10 years were compared to the summer of 2003, when successive heat waves caused high heat load (Sch. Kriston and Schlanger, 2003). This comparison can provide data, how the bioclimatic stress is modified in extremely hot periods and how these changes are affected in urban and rural areas.

2. Study area and methods

Szeged is located in the southern part of Hungary (46ºN, 20ºE) at 79 m above sea level on a flat plain. The base of the street network is a circuit-avenue system, with several different land-use types from the densely built centre to the detached housing suburb region (Fig. 1 A, B). Szeged is in the climatic region *D.1* according to Trewartha's classification (continental climate with a long warm season). The annual mean temperature is 10.4 ºC and the amount of precipitation is 497 mm, the annual mean sunshine duration is 2100 hours.

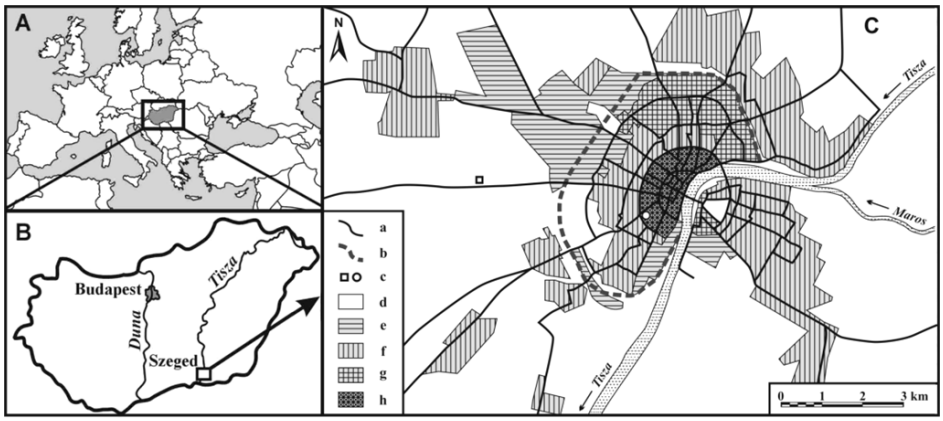

Fig. 1: Geographical location of Hungary in Europe (**A**), of Szeged in Hungary (**B**), characteristic land-use types and road network of Szeged (**C**) **a**: road **b**: circle dike **c**: measuring point in the city centre (○) and in the rural area (□) **d**: agricultural rural area **e**: industrial area **f**: 1-2 storey detached houses, **g**: 5-11 storey apartment buildings **h**: historical city core with 3-5 storey buildings

According to the widely used practice in urban climate studies, the characteristics of two distinct locations were compared from bioclimatic aspects. The modifying effect of the city can be studied at the location situated in the built-up city center (**h**), while the effect of the city is negligible at a location on an arable land with an open horizon (**h***) (Fig. 1C). Human biometeorological relevant data (air temperature (T_a), relative humidity (RH), wind velocity (v) and global radiation (G) were measured on these two different sites of the city with Vaisala meteorological stations. Wind speed data measured on the different height (station urban: 26 m, station rural: 10 m) were reduced to the 1.1 m

bioclimatologically standard height (Lee, 1979; Gál and Unger, 2009). Hourly average values of each meteorological parameter (collected between 1999 – 2008) were used to calculate PET values, using the RayMan model (Matzarakis et al., 2007). Based on these datasets the difference in physiological stress on urban and rural residents was described. PET categories were created according to the heat sensations levels (Table 1). Preliminary results show the results of the descriptive statistical analyses (e.g. absolute and relative frequency).

3. Results

Comparing the daily averages of PET index higher values can be observed in the city than in the surrounding rural area through the whole year (Fig 2).

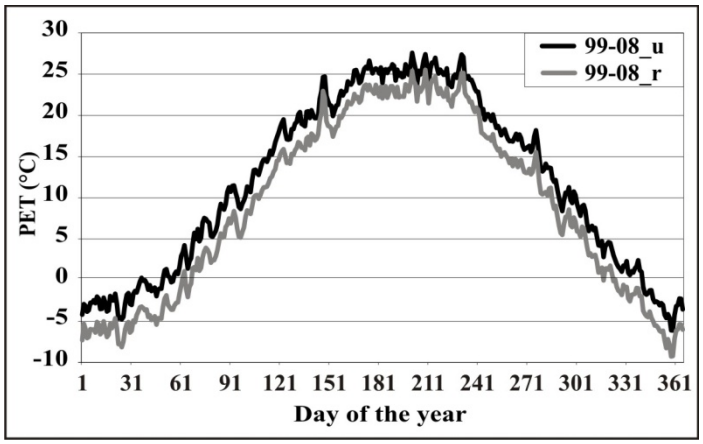

Fig. 2: Mean daily values of the PET index on the urban (u) and rural (r) area between 1999-2008 in Szeged

Considering the average of PET through the 10-year period, the difference is 2.9 ºC higher in the urban areas. While there is no considerable difference between highest PET values of the two examined areas (0.9 ºC), the difference between the minimum PET values is much higher (10.6 ºC) (Fig 3). Extremities have higher occurrence in the rural areas compared to the urban ones: frequency distribution of the strong or extreme heat stress (hot and very hot heat sensations categories) is 0.5 %, of the strong or extreme cold stress (between cold and extreme cold heat sensations) 9.5 % during the examined period. The occurrence of the periods without thermal stress is nearly two times higher in the city, than outside: 3.9 % compared to the full length of the studied term.

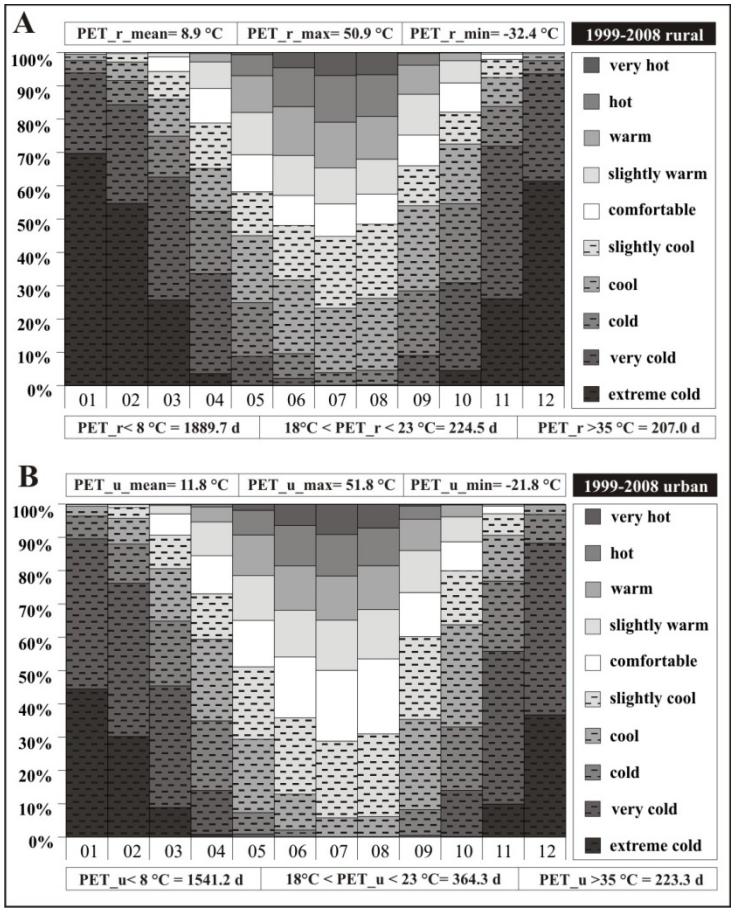

Fig. 3: Frequency of the PET (hourly averages) and the different grades of thermal sensation on the rural (**A**) and the urban (**B**) area between 1999-2008 in Szeged

It can be concluded from the averages that the city has equalizing effect on the thermal stress conditions. It reduces the extremities, furthermore this reduction is more pronounced on the cold extremities. Examining years what are significantly warmer than the average can predict the effect of global warming on bioclimatic situations, especially in case of the inhabitants of cities.

A very hot summer with several heat waves hit Europe and also Hungary in 2003. Very high daytime temperatures mostly in anticyclonic situation dominated between May and August with mainly low wind speed (Sch. Kriston and Schlanger, 2003). This period is compared to the averages of 10 years (Fig 4). During extreme hot periods, the frequency of the high heat stress periods is increased in both examined areas. Preliminary results show that in contrast to the average of the 10-year period, the increase is slightly higher in the rural areas compared to the city. Considerable increase of periods with comfort category was observed in the urban areas. This category remained unchanged outside the city, only the cold stress periods became shorter in the urban areas. The decrease of the cold stress periods was more pronounced in the city, the extent of the stress was also reduced to weak in the urban areas.

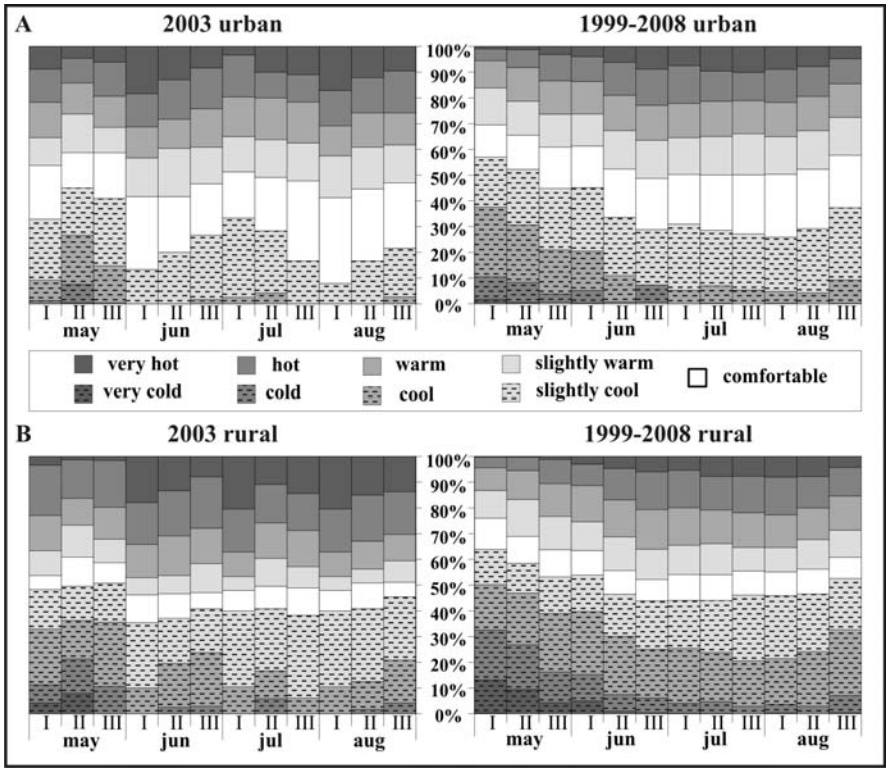

Fig. 4: Frequency of the PET (hourly averages) in then-day periods and the different grades of thermal sensation on the urban (**A**) and the rural (**B**) area between May and August in 2003 and 1999-2008 in Szeged

This phenomenon can be explained by the urban heat island (UHI) at night caused by reduced long wave radiation. These circumstances have physiologically disadvantageous effect in summer, because it can shorten the regeneration possibilities of urban inhabitants during the night.

4. Conclusions

The aim of this study was to compare the bioclimatic situation of a city with continental climate and the surrounding rural area.

(i) Using the PET index, we could detect significant difference between the two areas.

(ii) Examining data collected during long time periods, the reduction of the length of cold stress terms caused by urban effects is observed. In parallel the length of heat stress terms was slightly increased. This may increase the comfort of the residents of the city, especially in spring, autumn and winter, because cold stress is lower during the nights. Long term analysis shows that the city has a moderating and compensating effect on the human comfort conditions.

(iii) In heat waves however, this even heat load is not unequivocally positive phenomenon. Due to the lower direct radiation caused by smaller sky view factor values (obstacles of the city: buildings, trees), the occurrence of the extreme high heat stress is lower in the urban areas. During the night however the decrease of the heat load is significantly smaller (due to the UHI) in the city than in the surrounding rural areas. This effect reduces the regeneration chance of the human bodies before the heat stress of the

next day. Thus the occurrence of the comfort thermal sensation category is higher in the city apparently, but it does not mean better bioclimatic situation especially during the heat waves.

(iv) Our data predicts, that the extreme heat waves, occurring more frequently and higher intensity due to the global warming, will increase the heat stress more on the residents of the big cities, compared to their surrounding rural area.

Acknowledgements

This research was supported by the Hungarian Scientific Research Fund (OTKA K-67626).
Special thanks for Noémi Kántor for her help in preparing the figures.

References

Gál, T., J. Unger, 2009: Detection of ventilation paths using high-resolution roughness parameter mapping in a large urban area. Build. Environ. 44, 198-206.

Gulyás, Á., J. Unger, A. Matzarakis, 2006: Assessment of the microclimatic and human comfort conditions in a complex urban environment: modelling and measurements. Build. Environ. 41, 1713-1722.

Höppe, P., 1999: The physiological equivalent temperature – an universal index for the biometeorological assessment of the thermal environment. Int. J. Biometeorol. 43, 71-75.

Lee, D.O., 1979: The influence of atmospheric stability and the urban heat island on urban-rural wind speed differences. Atmos. Environ. 13, 1175-1180.

Matzarakis, A., F. Rutz, H. Mayer, 2007: Modeling radiation fluxes in simple and complex environments – Application of the RayMan model. Int. J. Biometeorol. 51, 323–334.

Mayer, H., P. Höppe, 1987: Thermal comfort of man in different urban environments. Theor. Appl. Climatol. 38, 43-49.

Sch. Kriston, I., Schlanger, V. 2003: 2003 nyarának időjárása. Légkör 48, 39-40. (in Hungarian)

Authors' address:

Ágnes Gulyás (agulyas@geo.u-szeged.hu)
János Unger (unger@ geo.u-szeged.hu)
Department of Climatology and Landscape Ecology, University of Szeged
Egyetem u. 2., H-6722 Szeged, Hungary

Andreas Matzarakis (andreas.matzarakis@meteo.uni-freiburg.de)
Meteorological Institute, Albert-Ludwigs-University of Freiburg
Werthmannstr. 10, D-79085 Freiburg, Germany