PhD DISSERTATION

THESES

EVALUATION AND MAPPING OF SPATIAL AND TEMPORAL DISTRIBUTION OF THE URBAN HEAT ISLAND IN SZEGED

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1. Precedents and objectives

Since more and more people live in towns, urbanization accelerated and reached enormous magnitude from the second half of the twentieth century. Compared to their surroundings, not only large cities, but also smaller settlements can significantly modify several characteristics of the urban atmospheric environment. The artificial factors create a local climate (the so-called urban climate), whose most obvious modification occurs in temperature. Generally, this modification is an excess, which is called as urban heat island (UHI). The strength (intensity) of the heat island shows a typical diurnal variation and spatial distribution inside the settlement. These theoretical backgrounds (*Stummer*, 1939; *Duckworth – Sandberg*, 1954; *Kratzer*, 1956; *Steinhauser et al.*, 1957-59; *Changnon*, 1962, 1976; *Oke – Hannell*, 1970; *Oke – Fuggle*, 1972; *Oke*, 1974, 1976, 1979, 1981, 1982, 1987, 1988a, 1988b, 1997; *Probáld*, 1974, 1975, 1980; *Oke – Maxwell*, 1975; *Yoshino*, 1975; *Rubinshtein*, 1979; *Peterson – Stoffel*, 1980; *Landsberg*, 1981; *Park*, 1987; *Kuttler*, 1990; *Grimmond – Oke*, 1991; *Eliasson*, 1996; *Comrie*, 2000; *Unger – Sümeghy*, 2002b) are summarized in Chapter 2.

In Chapter 3 a short overview about the foreign (*Kratzer*, 1956; *Neumann*, 1979; *Landsberg*, 1981; *Fezer*, 1995) and Hungarian (*Réthly*, 1947; *Bacsó*, 1958; *Probáld*, 1974; *Miklósi*, 1981; *Roncz*, 1985; *Justyák – Tar*, 1994; *Molnár*, 1998; *Bartholy et al.*, 2003) precedents of urban climate research is given, – with special emphasis on Szeged (*Jantos*, 1967; *Sindely*, 1978; *Péczely*, 1979; *Pelle*, 1983; *Zsiga*, 1983, 1988; *Unger*, 1992a, 1992b, 1993, 1995a, 1995b, 1996a, 1996b, 1997a, 1997b, 1997c, 1997d, 1998, 1999a, 1999b). These studies are also precedents of this work from several viewpoints. Being one of the most important aims in local climate research, earlier investigations turned the attention to a direction which studied the temperature increasing effect of settlements. Altough the investigation of phenomena is rather worldwide, relatively less attention turned to the strongest development of the heat island and to its features, probably caused by the fact that it is not an easy task to 'catch' the maximum UHI in the diurnal temperature course. Having an almost four-decade history and partly due to its favourable geographic conditions, Szeged has an outstanding position in the urban climate research activity of Hungary.

Chapter 4 deals with some of the fundamental methodological questions of the urban climate research (*Lowry*, 1977; *Landsberg*, 1981; *Oke*, 1984, 1997; *Fezer*, 1995). This part provides us wit some help to select the appropriate method(s) and instrument(s) depending on the size of the planned study area as well as climatological parameters.

In the development of urban climate and of a heat island we have to take into consideration the fact that settlements only modify the (background) climate which is formed as a result of meteorological processes at different scales. Naturally, physical geographical conditions of the city's environment (e.g. topography, distance from large water bodies) also affects the climate. Preceding of the presentation of results, in Chapter 5 it is necessary to discuss the environmental conditions of Szeged (*Frisnyák et al.*, 1978; *Péczely*, 1979, 1984; *Mezősi*, 1983; *Keveiné Bárány*, 1988). We have to emphasize that among the cities of Hungary the cities located in flat areas (e.g. Debrecen and Szeged) are the most advantageous position from the point of view of urban climate development. The investigation of cities located in valleys (e.g. Eger and Veszprém) or cities situated between mountains and a plain (e.g. Budapest and Szombathely) are more complex, because it is difficult to separate artificial and topographical effects. As for the settlements on a plain (like Szeged), detailed climatological measurements can provide a basis for the general deductions on urban climate.

Based on earlier studies, a long research project started in Szeged in 1999. Its main objective was to map and investigate the spatial distribution of the UHI at its maximum development in the diurnal course. Two one-year-long measurement campaigns were carried out: the first one, which can be considered as a thorough pre-study, took place between March 1999 and February 2000, while the second one between April 2002 and March 2003. The latter provided the greatest part of the data set used for the presentation of the spatial structure of the maximum UHI. Due their importance, therefore, methods and results of the areal investigation of the UHI are summarised in Chapter 6.

Beside the investigation of spatial structure of the UHI development, data sets provided by the measuring campaigns of 1999/2000 and 2002/2003 give us a possibility for the examination along an urban cross section, which is suitable to conclude general deductions. These observed values refer to the time of maximum UHI development; thus, the temporal dinamics of the UHI cannot be examined on the basis these values, although this examination is also very important to understand the UHI phenomena in details. Therefore, the measurement campaign of 2002/2003 was completed by a measurement series along a cross-section with monthly frequency, which provided information on the building and rebuilding of the heat island. Chapter 7 exhibits these measurements; later, with the application of te above-mentioned data, it reveals seasonal similarities and differences in the spatial and temporal distribution of the UHI intensity along a typical urban half cross-section. Furthermore, it explains the role of the typical urban surface parameters and climatological variables as well as their counteractions.

In the interpretation of results related to the structure of the urban heat island the best way is the application of thematical (primarily isoline and cartogram) maps. In the course of the construction and utilization of the latter ones arose a demand for the re-thinking and re-interpretation of the cartogram-method, as a category of thematical mapping. Related results of theoretical cartography, induced by the UHI research, are discussed in Chapter 8.

The investigation of the urban heat island is an important task from several viewpoints, because the UHI influences the comfort sensation of the citizens (at the middle latitudes with different signs according to the seasons), the energy demand of heating and cooling as well as the length of vegetation period and phenological phases. Thus, several studies both in Hungary and abroad deal with the topic, but mainly at a level of case studies. Less investigations were carried out which are based on regular measurements during longer periods. Therefore, they are appropriate in drawing general conclusions. On one hand, this fact motivated the recent UHI investigations in Szeged. On the other hand, only a large data set could constitute the basis of our further objective (not discussed in this dissertation); namely the mathematical-statistical modelling and the prediction of the urban heat island.

2. Study area

Szeged is an important urban centre in Hungary. The city's population of 168 000 (2001) lives within an administration district of 281 km^2. Real urban and suburban areas occupy only 25-30 km^2 and are located mainly inside of the circular dike on the right bank of the Tisza River.

As for the city structure, its basis is a boulevard-avenue road system. Number of different land-use types is present including a densely built centre with medium wide streets and large housing estates of tall concrete blocks of flats set in wide green spaces. Szeged also contains areas used for industry and warehousing, zones occupied by detached houses as well as considerable open spaces along the banks of the river in parks and around the city's outskirts.

The river is relatively narrow and, according to our earlier investigation, its influence is negligible (e.g. *Unger et al.*, 1999). These environmental conditions make Szeged a suitable place for studying an almost undisturbed urban climate.

Recent investigations in Szeged, more detailed than the earlier ones, are focused on the urbanized part of the administration district. A grid was established by quartering the 1 km x 1 km square network of 1:10,000 scale maps of the Unified National Mapping System developed for the topographical maps of Hungary. The same grid size was employed earlier in several studies of urban climate (e.g. *Jendritzky – Nübler*, 1981; *Park*, 1986), but it is applied in recent projects, too (e.g. *Lindberg et al.*, 2003; *Long et al.*, 2003).

3. Methods, measurements and evaluation

3.1. Temperature

The study area for the examination of the spatial structure of UHI consists of 107 cells covering the urban and suburban parts of Szeged. The outlying parts, characterized by mostly rural features, are not included in the network except for four cells on the western side of the area necessary to determine the temperature contrast between urban and rural areas.

The examination of the maximum UHI intensity, based on mobile measurements, took place in the period of April 2002 - March 2000. In case of near-surface air UHI measurements, vehicle-based observation is a common process in urban climate research (e.g. *Oke – Fuggle*, 1972; *Moreno-Garcia*, 1994; *Eliasson*, 1996; *Yamashita*, 1996; *Voogt – Oke*, 1997; *Klysik – Fortuniak*, 1999; *Comrie*, 2000; *Santos et al.*, 2003).

A division of the study area into two sectors was necessary because of the large number of cells. The northern and southern sectors consisted of 54 (13.5 km^2) and 53 grid cells (13.25 km^2), respectively. Since measurements took about 3 hours, the 68 km- and 66 km-long return routes in the northern and southern sectors were needed to make time-based corrections.

Altogether 35 measurements were taken. The frequency of car traverses (one measurement per 10 days) provided sufficient information on the maximum development of the UHI in the whole study area under different weather conditions, except for rain.

Based on the literature (e.g. *Oke*, 1987) and on the experience of our earlier investigations (*Boruzs – Nagy*, 1999; *Unger – Sümeghy*, 2000), measurements along the given routes were taken between 2.5 and 5.5 hours after sunset. This was caused by the fact that the possible time of the maximum UHI (reference time) was 4 hours after sunset.

Temperature readings were obtained using radiation-shielded LogIT HiTemp resistance sensors (resolution of 0.01°C) connected to LogIT DataMeter 1000 data loggers (DCP Microdevelopments and SCC Research) for digital sampling. Data were collected every 10 sec, so at an average car speed of 20-30 kmh^{-1}, the average distance between measuring points was 55-83 m. In order to avoid the influence of engine and exhaust heat, the sensor was mounted 0.60 m in front of the car at 1.45 m above the ground (e.g. *Ripley et al.*, 1996).

Having averaged the temperature values by cells, adjustments to a reference time (4 hours after sunset) were applied. The maximum UHI values, namely maximum temperature difference between the city and its surroundings (ΔT – ºC), can be determined by cells as follows:

$$\Delta T = T_{cell} - T_{cell(W)}$$

where T_{cell} and $T_{cell(W)}$ are the temperatures of a given urban cell and the westernmost cell regarded as rural.

Studying the UHI patterns by shapes, beside the investigation of the absolute intensity (ºC), the application of the so called normalized intensity (ΔT_{norm} – dimensionless value between 0 and 1) proved to be useful (*Sümeghy – Unger*, 2003c, 2004a). It is defined as:

$$\Delta T_{norm} = (T_{cell} - T_{cell(W)}) / (T_{cell(max)} - T_{cell(W)})$$

where $T_{cell(max)}$ – the absolute value of the cell which had the maximum intensity at the given night.

As it was mentioned earlier, the investigation of the maximum UHI intensity using mobile measurements in Szeged started already in 1999, whereas the first measurement campaign was carried out between March 1999 and February 2000. The study area and the method were almost the same as the previously mentioned second one. One difference between them was that in 1999/2000 the measurements were taken with weekly frequency: altogether 48 measurements took place. It means more information only at first sight. Nevertheless, since one car was used at that time, thus at one occasion we measured only in one of the two sectors. The areal extent of the sectors and the lenght of routes were a bit different from the ones in 2002/2003: the northern and southern sectors consist of 59 (14,75 km^2) and 60 (15 km^2) cells, with an overlapping area of 12 cells (3 km^2). This area thought to be needed for laying the foundation of cross-section measurements. The lengths of the routes in the northern and southern sectors were 75 and 68 km, respectively. At this measurement campaign the less modern data logger collected the data more infrequently (every 16 s), so at an average car speed of 20-30 km h^{-1} the average distance between measuring points was 89-133 m.

A significant part (87%) of the temperature values in the investigation of the maximum UHI along a half cross-section originated from the two areal measurement campaigns (48 occasions in 1999/2000, 35 occasions in 2002/2003). Merely with the application of data observed at 4 hours after sunset, the rest (12 occasions, 13%) of the occassions originated from the monthly frequency cross-section measurements in 2002/2003.

In order to reveal the temporal dinamics of the heat island along the whole cross-section, measurements started at sunset and finished at sunrise or 10 hours after sunset at short summer and long winter nights. Instruments and methods of observation and evaluation were the same as in case of areal measuments in 2002/2003. The length of the route was 10.5 km in one direction, so it took only about 50 minutes to traverse along the return route, but this measurements had several reference times (at every hours after sunset) (*Sümeghy – Unger*, 2003c). This means 10 and 7 measurements in winter and summer, respectively.

3.2. Built-up ratio

Parameters of general land use for grid cells were determined by GIS methods combined with remote sensing analysis of SPOT XS images The digital satellite image was rectified to the Unified National Mapping System using 1:10,000 scale maps. The geometric resolution of the image was 20 m x 20 m; thus, small urban units could be assessed. Normalized Difference Vegetation Index (NDVI) was calculated from the pixel values (*Gallo – Owen*, 1999):

$$\mathrm{NDVI} = (\mathrm{IR} - \mathrm{R}) / (\mathrm{IR} + \mathrm{R})$$

wherel IR – pixel value in the visible (0.58-0.68 μm) and R – pixel value in the near infrared (0.72-1.1 μm) bands. They are between -1 to +1 indicating the effect of green space in the given spatial unit. Using these values, built-up, water, and vegetated surfaces were distinguished and their ratios (to total cell area) were determined for each grid square.

Ratio of the built-up (covered surface – building, street, pavement, parking lot, etc.) areas is one of the most important factors of climate modification effects in cities. The employed satellite images were taken in 1992. Since that time, significant construction activity has has taken place in certain parts of Szeged. Therefore, in order to get more exact built-up values (in percent), the earlier values were refreshed using orthophotos taken in 2003.

3.3. Sky view factor

The built-up ratio does not describe completely the characteristics of an artificial urban surface. Streets and buildings create canyons. This 3D geometry plays an important role in the development of the UHI. Namely, heat transport and outgoing long wave radiation decrease because of the moderated turbulence and increased obstruction of the sky. To the quantitative estimation of the openness of cell surfaces, we applied the sky view factor (SVF), which measures the degree of sky covered by objects in the surroundings of a given point (naturally, it is also influenced by trees in the vegetation period).

Commonly, the SVF is determined by using either analytical or photographic methods (*Szakály*, 1962; *Oke*, 1981; *Bärring*, 1985; *Park*, 1987; *Holmer et al.*, 1992; *Grimmond et al.*, 2001). In our analytical method, along the measurement route by about 100 meters, we have measured two elevation angles to the top of the buildings (α_1 and α_2) perpendicularly to the axis of streets in both directions, using an 1.5 m high theodolite. From these data, wall view factors can be calculated to the left (WVF_1) and right (WVF_2) sides. The calculation of SVF is based on *Oke's* (1988) results:

$$\mathrm{WVF}_1 = (1 - \cos\alpha_1) / 2 \qquad \text{where } \alpha_1 = \tan^{-1}(\mathrm{H}_1/\mathrm{W}_1)$$

$$\mathrm{WVF}_2 = (1 - \cos\alpha_2) / 2 \qquad \text{where } \alpha_2 = \tan^{-1}(\mathrm{H}_2/\mathrm{W}_2)$$

$$\mathrm{SVF} = 1 - (\mathrm{WVF}_1 + \mathrm{WVF}_2)$$

4. Results

4.1. Maximum absolute heat island intensity

1. Two equations are available in the literature on calculation of the maximum temperature difference between the European cities and their surroundings, where the difference is expressed as a function of the size of population (P):

$$\Delta T_{max} = 2{,}01 \cdot \lg P - 4{,}06 \quad (^{\circ}C) \quad (\textit{Oke}, 1973)$$

$$\Delta T_{max} = 1{,}92 \cdot \lg P - 3{,}46 \quad (^{\circ}C) \quad (\textit{Park}, 1987)$$

   Consequently, the calculated theoretical maximum heat island intensities for Szeged (P = 168.000) are 6,44ºC and 6,57ºC based on the first and the second equations, respectively. However, as our measurement experience shows, larger values than these estimated ones (even almost 8ºC) can occur in reality. Therefore, a very careful interpretation is needed while estimating the value of the maximum UHI intensity based on population, because the phenomena is developed as a result of complex counteract of several factors which are not always in connection with the population (number of settlements).

4.2. Relationship between urban parameters and urban heat island

2. There is a positive relationship between the built-up ratio and the average maximum UHI intensity, that is with the growing value of the built-up ratio the temperature difference between the city and its surroundings also increases. The strength of the linear connection is supported by the high value of the correlation coefficient (r = 0,7787). Namely, at our number of elements (107) the relationship is real at 1% significance level already at r = 0.25 (*Péczely*, 1979). Thus, the null-hipothesis, that there is no connection between the two parameters, unambiguously can be rejected.
3. The relationship between the SVF and the average maximum UHI intensity is converse, that is with the growing value of the SVF the temperature difference decreases. The strength of the linear connection is proved by the high value of the correlation coefficient (r = -0,6889). In this way, similarly to the built-up ratio, the relationship is real.

4.3. Spatial structure of the mean maximum urban heat island

4. The annual average pattern of the maximum UHI, based on the investigated one-year period of 2002/2003, is almost concentric and the temperature values are increasing from the outskirts towards the inner areas. Large deviations from this shape occur in the north-eastern and in the north-western parts of the city, where

the isotherms stretch towards the suburbs. This fact can be explained by the effect of large housing estates. A mean maximum intensity of higher than 2°C indicates significant thermal modification. The extension of this area is rather large, it covers 8-9 km^2, which is about one third of the total investigated area (*Sümeghy et al.*, 2003). The largest values (1.5-2.5ºCkm^{-1}) of the temperature gradient occur in the northern, south-eastern and western parts, because here the different land-use types of Szeged change very quickly in narrow belts. Along the Tisza River the isotherms a bit withdraw to the central areas, but this effect is not very strong. The irregularities in the isotherms follow very well the changes of land use, and are in accordance with the distribution of the built-up ratio and the SVF. This picture is supported by data of the campaign in 1999/2000 (*Sümeghy et al.*, 2000).

5. It is important to establish that the distributions in the heating (16 October – 15 April) and in the non-heating (16 April – 15 October) seasons are similar, but their intensities are a bit different. During the non-heating season, in the development of the UHI the role of appropriate weather conditions (stronger solar radiation income, more frequently clear sky and weak wind) is more pronounced than the heating in urban areas. The climate conditions in winter, conducive to the formation of the UHI, are less common. In this way, the significance of artifical heating in the development of the UHI is rather limited. Seasonal differences form rather as a consequence of different weather characteristics than as a consequence of heating or non-heating of inhabitants (*Sümeghy – Unger*, 2003a, 2003c).

4.4. Normalized heat island intensity

6. Presenting examples, it is proved that the form of the average normalized structures can be very different depending on the different construction methods. Normalizing the absolute mean, the largest values will dominate in the case of significant intensity differences combined with small number of elements. Therefore, the result of this process does not show the 'real' picture. Instead of this process, we propose first the normalization of the individual patterns and then calculating the average from them. With this method, the roles of different cases are balanced, that is the weights of cases in the average are the same. This process eliminates the alterations caused by the differences in the UHI magnitude (*Sümeghy et al.*, 2004).
7. According to the Section 6, the average pattern of the normalized heat island based on the investigated one-year period (April 2002 – March 2003) was calculated from the 35 normalized individual patterns. Using normalized values

contrary to absolute ones has an advantage that the weights of the 35 patterns in the average are the same. The calculated heat island intensity increases from the outskirts towards the inner areas. The shape of the pattern is almost concentric in accordance with the main built-up characteristics of Szeged. Large deviations from this shape occur along the north-east – south-east and north-east – south-west axes. This can be explained by the shape of urban areas and by built-up features (*Sümeghy – Unger*, 2004a; *Sümeghy et al.*, 2004).

8. After studying the 35 UHI patterns, mentioned in Section 7, it is emerged that some patterns repeated which raise a possibility of the classification (*Sümeghy – Unger*, 2003a, 2004a). Taking absolute values into account, *Klysik* and *Fortuniak* already in 1999 made a trial with a simple grouping. According to the running of isotherms they distinguished only two types: the so-called ’ordinary’ heat island and the heat archipelago with several local maximum values. This latter type often occurs in Szeged: there are heat archipelagos in one third of the patterns of 2002/2003. The most characteristic common feature of the cases with two or more local maxima is when one of the local ’peaks’ occurs in the areas of large housing estates. This explains the observation of *Péczely* (1979), who stated that the largest intensities can be found in those particular areas. According to our results, this is not valid for the averages based on measurements of longer periods – e.g. season (*Unger et al.*, 1999), half year (*Sümeghy et al.*, 2000) and year (*Sümeghy – Unger*, 2003a).
9. In order to make a more exact classification than the one presented in Section 8, a cross-correlation was applied for the normalized temperature patterns (107 values by patterns) of the 35 measuring nights (*Sümeghy et al.*, 2003). The classification is based on the simple idea that the cases, being in significant correlation with each other, are collected in one class. According to the classification of the individual UHI patterns, using correlation coefficients, 6 types can be distinguished. In comparison with the relatively regular, centralized pattern, at the other 5 types shifts in the shapes can be observed. These shifts can be, presumably, explained by the actual meteorological conditions: investigation of the prevailing wind directions and mean wind speed in a 6-hour-period (3 hours before and 3 hours during the measurements) explains satisfactorily the shifts occured in the normalized UHI patterns. Among the meteorological parameters not only the wind formed the UHI structure, but its role was crucial: thus, the separation of the statistical groups was caused by the alteration of the wind direction and speed (*Sümeghy – Unger*, 2004a).

4.5. Average cross-section profiles

10. In order to get general deductions in Szeged, the selected half cross-section is the most appropriate, because an outstanding temperature data set is at disposal (altogether 95 measurements: 23 in spring, 26 in summer, 23 in autumn, 23 in winter). The profiles in every season show a marked increase at the edge of built-up areas, reaching the largest values in the city centre. Here the largest and smallest values occur in summer (3,13ºC) and in winter (2,27ºC), respectively. The profile of the annual average is not only between the summer and winter ones, but it is also between the profiles in spring and autumn. The largest difference between the latter ones and the annual profile is only 0,31ºC (in spring, in the central cell). This seasonal magnitude variation of the urban temperature anomaly is attributed mainly to differences in the weather conditions (*Sümeghy*, 2001; *Unger – Sümeghy*, 2001, 2002a). The highest wind speed and cloudiness can be found in the winter months; at that time the UHI intensity is the weakest. In summer, when the above mentioned parameters have the smallest values, the extent of the UHI is the largest in every point along the half cross-section. Concerning wind speed and cloudiness, spring and autumn have a medium position. This fact suggests that the effects of these climatological parameters on the development of the UHI are of fundamental importance.
11. Investigation of the normalized profiles of the absolute averages as well as the seasonal and annual means of the normalized profiles of the 95 measurements shows that seasonal differences almost disappear (*Sümeghy – Unger*, 2002). These patterns follow remarkably well the general cross-section of the typical UHI described by *Oke* (1982), who separated three typical parts of the profile ('cliff', 'plateau' and 'peak') independently from the seasonal weather conditions. In this case, we suggest the modification of the model equation M = C + L + U (*Lowry*, 1977) describing the metropolitan temperature variable (*M*) for cities situated in special geographical conditions (L = 0): *M* is equal to the sum of components *C* (background climate of the region) and *U* (production of urbanization in surface), where U = c · u (multiplication of weather and urban surface factors) (*Sümeghy*, 2001; *Sümeghy – Unger*, 2001; *Unger et al.*, 2001b). This theoretical consideration means an important basis for the firmament of the mathematical-statistical modelling and prediction of the urban heat island (*Sümeghy – Unger*, 2003c).

4.6. Building and rebuilding of the heat island

12. Regarding the temporal dinamics of the UHI in Szeged, general conclusons can be drawn from the absolute and normalized means of the 12 observation of the cross-section measurement campaign in 2002/2003. The profiles of every hour

show a steep gradient at the edge of the built-up areas ('cliff'), but the typical 'plateau' does not develop. A well-developed 'peak' region formed instead, with a further temperature growth, which reaches the largest values in the city centre 5-6 hours after sunset. Towards the other edge of the city, throughout the area of detached houses and housing estates, the intensity values decrease moderately. The streched shape of profiles can be explained mainly by the biases in the built-up and the SVF values. The strength of the UHI after sunset increased regularly in every cell along the cross-section, the building of the heat island lasted to 5-6 hours after sunset. At that time the UHI reached its maximum development and, in accordance with the general features, from the seventh hours the heat island intensity started to moderate.

13. As a result of the continuously varying weather effects, the dinamics of the UHI can be modified from measurement to measurement. Thus, individual features different from the general picture can emerge. In my dissertation these special cases, illustrating alterations caused by climatic parameters, are presented by four (one by seasons) case studies. Accordingly, for example a douple peak could develop as a result of a coming front and changing wind direction (*Sümeghy*, 2001), or simply by the effect of the decreasing wind speed (*Sümeghy – Unger*, 2003b). The changing wind direction can cause the streching out as well as other alterations of the UHI structure (*Sümeghy – Unger*, 2003c). Under undisturbed weather conditions and continuous snow cover the different surfaces in the material and the color of urban and rural areas can significantly intensify the heat island (*Sümeghy – Unger*, 2003b).

4.7. Reconsideration of thematic mapping theory – a new interpretation of the cartogram-method

14. According to the prevailing definition in Hungary, a cartogram is — an adequate tool of the spatially correct demonstration of quantitative data referring to an area without exact parameters. The reference area can be a statistical, geometrical or geographical area. According to the traditional approach, if the quantity is an absolute value, we use symbol-cartogram that is figurative drawing or geometrical forms (in the course of the demonstration). If the quantity is relative value, we use areal-cartogram that is graduated areal symbols or colors. Nevertheless, recently the building and application of GIS and GIS-softwares support both the symbol- and areal-cartograms independent on the type of the quantitative attribute-data of construction. Thus, by now it became widespread, also among those without any significant cartographical training, to work with all the contsruction processes and demonstration methods provided by the GIS-softwares. As a result, many of such (apt, useful and good) thematical maps

appeared, which do not belong to any type of cartogram according to the traditional definition. In the course of the dissertation, a problem is presented which is related to the investigation of the urban heat island. Namely, a symbol-cartogram of relative, and an areal-cartogram of absolute values are adequate demonstrations since none of them distort reality. In this way, we suggest that, independent on relative or absolute features of data, the spatially correct demonstration of quantitative data – referred to an area but an exact place – should be named by symbol-cartogram if it uses figurative drawing or geometrical forms or it should be named by areal-cartogram if it uses graduated areal symbols or colors (*Sümeghy – Unger*, 2004b).

Thematic articles published by the author

Articles, not applied in the dissertation are marked with *

Sümeghy, Z., 2001: *A keresztmetszeti hőmérsékleti profil jellege városi környezetben.* 2. díjas pályamunka, mely az MTA Szegedi Akadémiai Bizottságának felhívására készült (manuscript), Szeged.

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