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URBAN INFLUENCE ON HUMAN COMFORT SENSATION (ON THE EXAMPLE OF SZEGED)

WPŁYW MIASTA NA ODCZUCIE KOMFORTU (NA PRZYKŁADZIE SZEGEDU)

The study examines the influence of a medium-sized city on bioclimatic comfort sensation of individuals in Szeged, Hungary. The city is situated in the South-Eastern Hungary (46°N, 20°E). Its geographical situation is favourable to develop a relatively undisturbed urban climate. With the help of suitable indices such as the thermohygrometric index (THI) and the relative strain index (RSI), differences of the annual and diurnal variation of human bioclimatic characteristics between urban and rural environment are demonstrated. In urban and rural areas 6 and 1% of the year are in the "hot" THI type, 30 and 20% are in the "comfortable" type, 10 and 12% are in the "cool" type, while 54 and 66% are in the "cold" type, respectively. In the case of longer periods (weeks, months) RSI remains under the threshold value of heat stress. Consequently, the city modifies favourably the main climatological elements inside the general climate of its region therefore staying in the city is comfortable for longer period than in the nearby rural areas.

INTRODUCTION

The fact that our world is an increasingly urbanized one gives reason for the revelation of the special features of the local climate caused by cities. Several mechanisms contribute to the development of the urban climate: the natural radiation balance is disturbed by changes in the properties of the underlying surface and air pollution. Built-up areas are obstacles to the wind changing the natural flow and turbulence of the air. The water vapour balance is upset by the change from moist to dry surfaces. The combustion processes (heating, traffic, industry) emit artificial heat, water vapour and pollution to the atmosphere.

The atmospheric environment has several meteorological parameters which determine the comfort sensation of a human body (temperature, humidity, air movement and radiation). There are a lot of theoretical and empirical indices containing these parameters which more or less evaluate this comfort sensation. Some of the indices use only one of the above parameters while others use two or more (Clarke, Bach 1971). For example, to describe and characterize the Greek heatwaves of 1987 and 1988 hourly values of dry bulb temperature and relative humidity were used (Giles, Balafoutis 1990).

In the present study an attempt has been made to compare the differences of human comfort sensation between urban and rural environment in the case of a medium-sized Central-European city with the help of some appropriate bioclimatological measures.

STUDY AREA AND DATA

Szeged is a mid-latitude settlement, it is situated in the South-Eastern Hungary (46°N, 20°E) at 79 m above sea level. The city and its surroundings are plain (altitude differences inside and outside the city are only a few metres) and it is a long way from large water bodies except the River Tisza intersecting the settlement (Fig. 1).

Therefore its geographical situation is favourable to develop a relatively undisturbed urban climate. Szeged had 175.000 inhabitants in the investigated years (1978–1980) and its built-up area was approximately 46 km^2. The study area is in the climatic region Cf by Köppen's classification (temperate warm climate with relatively equal annual precipitation distribution) or in the climatic region D.1 by Trewartha's classification (continental climate with a long warm season) (Péczely 1979). Some average meteorological parameters of Szeged region are as follows:

- mean annual temperature is 11.2°C with mean annual range of 23.6°C,
- mean annual precipitation is 573 mm,
- mean annual relative humidity is 71%,
- mean annual cloudiness is 57%,
- mean annual windspeed is 3.2 ms^{-1} (Péczely 1979, 1984).

In the investigated years a station network was working in and around the city. The stations represented different built-up areas of the city. Station 1 (Aerological Observatory of Hungarian Meteorological Service) is situated at a distance of 4.4 km to the west of the city centre, so it is more or less free from urban climate modifying effects. It has been working till now continuously. The surrounding area is a cultivated land (wheat and maize fields) and it is considered to be a good example of the rural area. Station 2 was located in the city centre in a paved square bounded by multi-storey buildings and it is considered to be the representative urban station (Fig. 1).

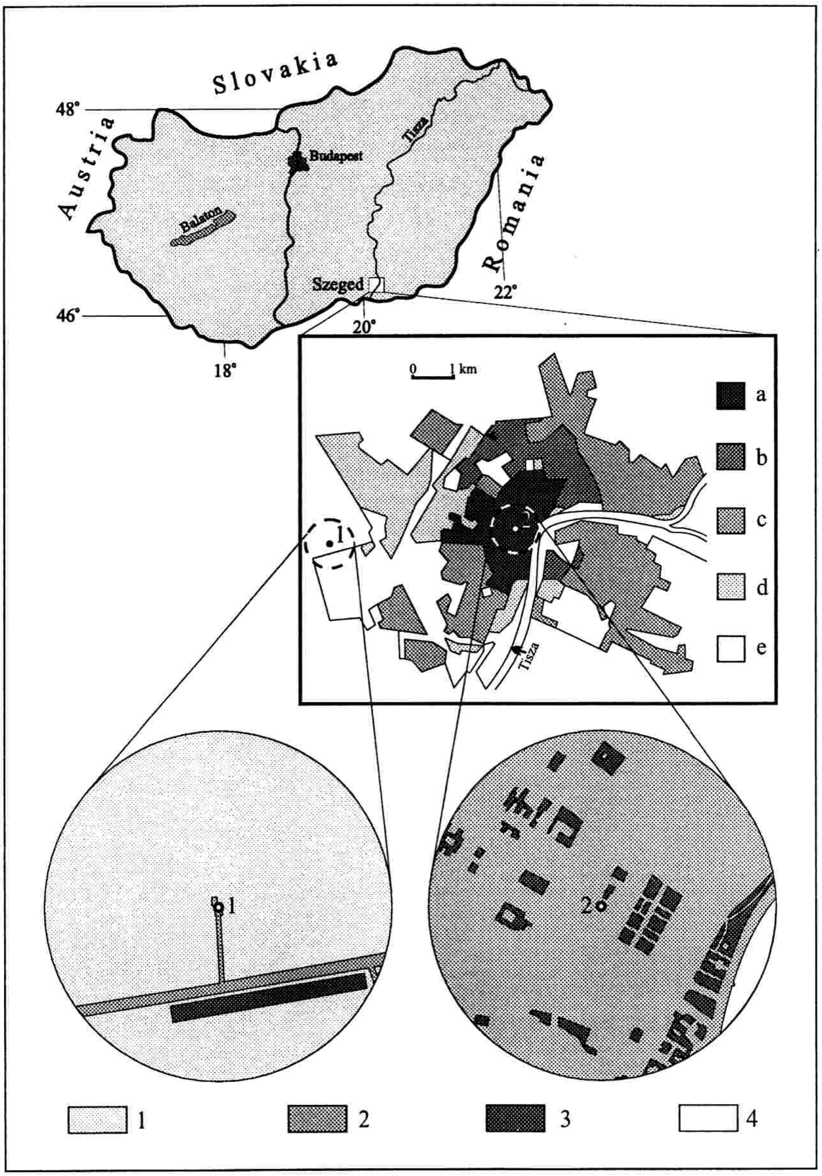

Fig. 1. Location of Szeged in Hungary, sites of the urban and rural stations with their immidiate surroundings (circles with 0.6 km radius) and built-up types of the city
a – downtown (2–4 storey old built buildings), b – housing estates with pre-fabricated concrete slabs (5–10 storey buildings), c – detached houses (1–2 storey buildings), d – industrial areas, e – green areas; 1 – ploughed land, 2 – covered surface (street, pavement, building), 3 – green surface, 4 – water surface

Rys. 1. Położenie Szegedu (Węgry), lokalizacja miejskich i pozamiejskich stacji w ich bliskim sąsiedztwie (w promieniu 0,6 km) i typy zabudowy
a – centrum (2–4-piętrowe stare budynki), b – dzielnice mieszkaniowe z blokami z prefabrykatów (budynki 5–10-piętrowe), c – budynki wolnostojące (1–2-piętrowe), d – obszary przemysłowe, e – obszary zielone; 1 – grunty orne, 2 – powierzchnie pokryte (ulice, chodniki, budynki), 3 – powierzchnie zielone, 4 – powierzchnie wód

METHODS

Methods mentioned below will be applied to compare the human bioclimatological features of the city centre and the rural area using monthly average values of temperature, relative humidity and vapour pressure of Station 1 and 2 between 1978 and 1980. The differences in the measures express the influence of the city on human comfort sensation, advantages and disadvantages of the altered physical environment of Szeged.

A useful thermal index is the effective temperature (ET) which is "the temperature of a still, saturated atmosphere which will lead to the same thermal sensation as that existing and thus exposing the body to the same difficulties of adaptation" (Kyle 1994). The effective temperature considers wet- and dry-bulb temperatures and thus it can be applied to the locations that are both shaded and protected from the wind. One of the best indices estimating the effective temperature was developed by Thom (1959). For most everyday applications, using commonly forecasted synoptic parameters, this traditional index suffices, which is supported by later works (e.g. Clarke, Bach 1971; Auclimens 1997). The Thom's thermohigrometric index (THI) uses air temperature (t) in Celsius terms and relative humidity (f) in its modified form:

$$THI = t - [(0.55 - 0.0055f)(t - 58) \ (°C)$$

The THI was used originally to determine the human discomfort due to heat stress, therefore Beancenot (1978) evaluated it over a much wider range of conditions. He concluded that the optimum occurs between 15 and 20°C and that is the basis for a comfortable class. Below a THI of 15°C evaporation, which constantly takes place at the skin surface even in the absence of apparent perspiration, takes away heat from the body thus requiring defence against cooling. Hence below a THI of 15°C there is a series of classes which require increasing thermogenetic mechanisms to combat increasing cold stress. Above a THI of 20°C the opposite process occurs because the perspiration system becomes effective as a cooling mechanism to prevent overheating. The higher the THI the more ineffective this mechanism becomes, giving rise to increasing heat stress, so a series of classes have been introduced above the comfortable zone, where the heat stress is increasing (Tab. 1).

Table 1

The class types of thermohygrometric index of Thom (THI) (modified from Beancenot – 1978)

Klasy wskaźnika termiczno-wilgotnościowego Thom'a (THI) (zmodyfikowane przez Beancenot'a – 1978)

THI types	°C
Hyperglacial	< –40.0
Glacial	–39.9 to –20.0
Extremely cold	–19.9 to –10.0
Very cold	–9.9 to –1.8
Cold	–1.7 to +12.9
Cool	+13.0 to +14.9
Comfortable	+15.0 to +19.9
Hot	+20.0 to +26.4
Very hot	+26.5 to +29.9
Torrid	> +30.0

In order to evaluate the heat stress for indoor condition and for sedentary standard man dressed in a business suit (25 years old, healthy and not acclimatized to heat) the relative strain index (RSI) was determined (Kyle 1992):

$$RSI = (t - 21)/(58 - e)$$

where t is air temperature (°C) and e is vapour pressure (hPa) and they are simultaneously recorded. 25% of the people will be uncomfortable at an RSI value of 0.2 and no one will be comfortable at an RSI of 0.3 (Tab. 2). For the elderly and men being ill the lower RSI of 0.2 means the treshold above they are subjects to heat stress.

Table 2

The relative strain index (RSI) classification (after Kyle, 1992)

Klasyfikacja wartości wskaźnika RSI (wg Kyle'a, 1992)

RSI	Percentage of persons unstressed or distressed
0.10	100 unstressed
0.20	75 unstressed
0.30	0 unstressed
0.40	75 distressed
0.50	100 distressed

RESULTS AND DISCUSSION

The average monthly THI values were counted for each observation times (1.00, 7.00, 13.00 and 19.00 hours) at Station 1 and 2 representing rural and urban areas, respectively. Drawing the isopleths from these values the daily and annual distribution of rural and urban THI can be seen

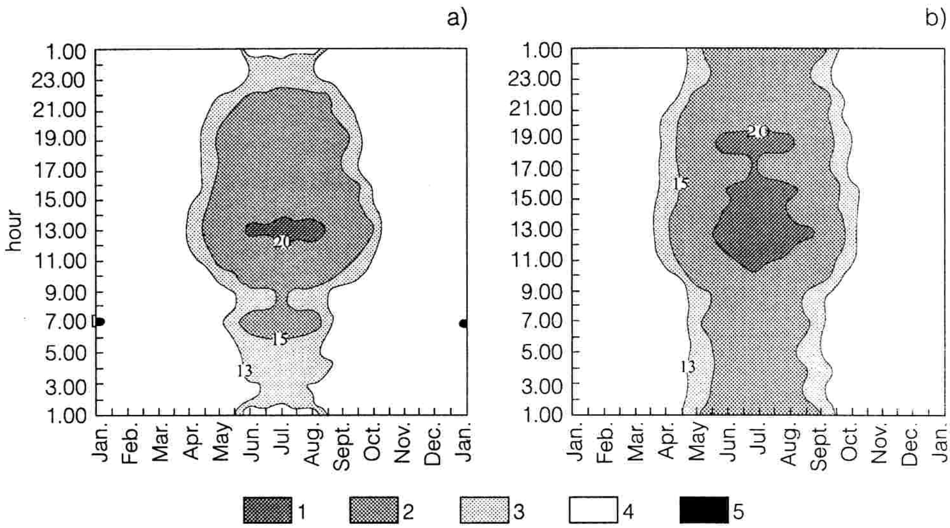

Fig. 2. Isopleths of mean rural (a) and urban (b) THI values (°C) (1978–1980)
Types: 1 – hot, 2 – comfortable, 3 – cool, 4 – cold, 5 – very cold

Rys. 2. Izoplety średnich wartości THI w mieście (a) i poza miastem (b) (°C) (1978–1980)
Typy: 1 – gorąco, 2 – komfortowo, 3 – chłodno, 4 – zimno, 5 – bardzo zimno

(Fig. 2). The figure shows that the year encompasses four THI types (hot, comfortable, cool and cold) in the city centre and five THI types (the previous ones and very cold) outside of the city. Comparing the isopleths the main features of the differences of human bioclimatological effects between the city centre and the surroundings are as follows:

Considering the length of a year as 100%, in the centre 6% of the time are in the "hot" THI type, which occurs in summer from about noon to evening hours with a maximum over 22°C, while in rural areas the most loading type is almost negligible (only 1% of the time), it appears only about noon in the summer months with a maximum of 21.6°C.

The most important "comfortable" type dominates in the city centre at nearly one third of the year (30%) mainly from May to September during the whole day except the afternoon hours in summer mentioned above ("hot" type). In rural areas it decreases to 20% and occurs also from May to September but only in the daytime and in the evening hours.

There is no significant difference in the durations of the "cool" type (10% in urban and 12% in rural), but while in the centre it appears only in April–May and September–October, in the surroundings it occurs even in summer in the nocturnal and morning hours. The relatively small part of the time of the "cool" type is easy to understand because of the relatively narrow range of possible THI values (only 2°C between 13 and 15°C).

In both locations the most dominant type is the "cold" one having a wide range of possible values (≈15°C). In the city centre it prevails from October to April during the whole day (54% of the year), while in the rural areas it appears even in June and August in the nocturnal hours (66% of the year). Here also the "very cold" type can be demonstrated in January at about 07h with a minimum of –2.47°C, but its importance is absolutely negligible (< 1%) because of its short duration.

It can be established that in Szeged the urban environment has more advantageous effects on the comfort sensation of men than disadvantageous ones because of the longer time of "comfortable" and the shorter times of "cold" and "cool" periods. Nevertheless the longer duration of "hot" period in the city centre means a disadvantageous effect.

The investigation of monthly means of RSI valuees at the four observation times revealed that in the climate region of Szeged we cannot reckon on strong heat stress even in the summer months. The index values reach their maximum in the city in June, July and August at 13.00 h (0.10) and in the rural areas in July and August (0.07 and 0.08) which do not mean any suffering from distress even for the elderly, either because the RSI values remain under the thresholds of heat stress mentioned above (0.2 for the elderly and 0.3 for the young). The results refer to the case of longer period (weeks, months). On certain days in summer it can exceed the threshold values but the heat stress periods do not last long.

Consequently, a mid-latitude and medium-sized city (Szeged) modifies the main climatological elements inside the general climate of its region every hour during the year. These modifications are mostly favourable from the human bioclimatological points of view that is the comfortable period within a year lasts longer for the individuals living in the city than for the ones living in the nearby rural areas.

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STRESZCZENIE

Badano wpływ miasta średniej wielkości na odczucie komfortu jego mieszkańców na przykładzie Szegedu (Węgry). Miasto jest położone w południowo-wschodniej części Węgier (46°N, 20°E). Jego położenie geograficzne jest korzystne dla rozwoju względnie niezakłóconego klimatu miejskiego. Za pomocą odpowiednich wskaźników (THI i RSI) zademonstrowano różnice rocznych i dobowych zmian charakterystyk bioklimatycznych między centrum miasta i terenami zamiejskimi. Na obszarach miejskich i zamiejskich odpowiednio 6 i 1% dni w roku to „gorący" typ THI, 30 i 20% odpowiada typowi „komfort", 10 i 12% – „chłodny", 54 i 66% – „zimny". W przypadku dłuższych okresów (tygodnie, miesiące) RSI pozostaje poniżej wartości progowej stresu cieplnego. W konsekwencji w ogólnym klimacie regionu miasto korzystnie zmienia główne elementy klimatologiczne, dlatego też przebywanie w mieście daje odczucie komfortu przez dłuższy czas niż na jego obrzeżach.