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HUMAN BIOCLIMATOLOGICAL FEATURES OF CLUJ

BIOKLIMATYCZNA CHARAKTERYSTYKA MIASTA KLUŻ

This paper investigates some bioclimatical indicators (pulmonary, thermal comfort, thermohygrometrical, relative stress indices, number of beergarden days) given by a hundred year and shorter data series which are measured at the official station and another five set up in the characteristic part of Cluj (Romania).

INTRODUCTION

Today's world is an increasingly urbanised one where human settlements have grown into vast cities. The urban areas are characterised by a transformed climate which is being formed under the influence of built-up territories, effect of specific up warming and emission of pollutants. Cause and effect relations between the urban climate and human comfort can be analysed by the human bioclimatological indicators.

Results of the urban human bioclimatical analysis of different spaces are of interest because they can be used in the following fields:

– in urban planning concerning the investigations of impacts of constructional projects,
– giving advice regarding the building of residential and industrial areas,
– in tourism for selection leisure and recreational surfaces.

THE INVESTIGATED AREA

Cluj is situated in the middle north-west part of Romania, in the valley of the Somes River, between 300 and 700 m above the sea level (46°47′N, 23°35′E). From geographical point of view the city is situated at the junction of three topographically different areas: the east part of Apuseni Mountains,

the Transilvanian hillocks and the hills of Somes Plain. The city's territory reaches 4068 ha and its population is 340 000 in 1996. The surface of the city extends on three height levels, which are as follows:

- the tide land of Somes River and its affluent Nadas Rivulet,
- the river terraces,
- the neighbouring hills (e.g. Felek Hill).

In the city's territory there are six microclimatical sectors as follows:

- Inner city climate characterised by occurrence of heat islands,
- North slope climate,
- South slope climate,
- Tide land climate influenced by the Somes River,
- East industrial area climate with frequent occurrence of fog and thermical inversion,
- Citadel climate which is characterised by intense air motion (Fig. 1).

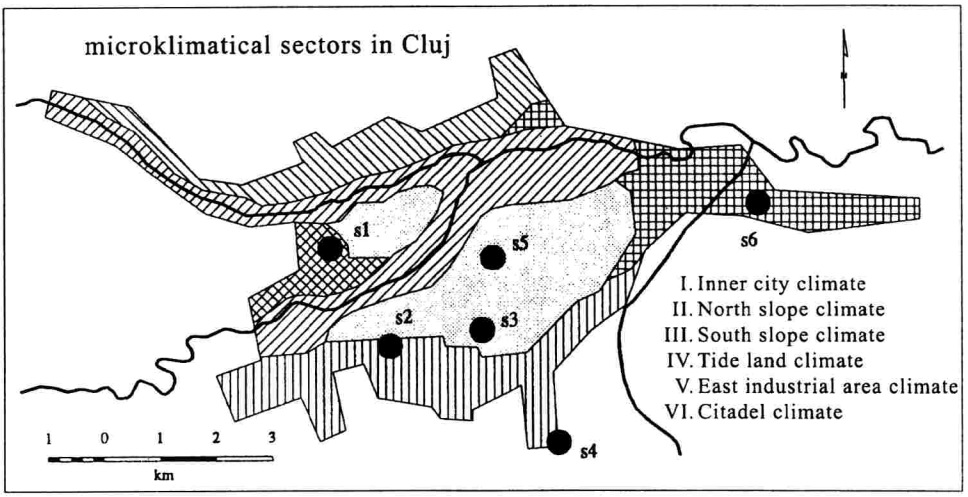

Fig. 1. Microclimatical sectors in Cluj

Rys. 1. Regiony mikroklimatyczne w Kluż

The climatological parameters which determine the comfort sensation of the human body are temperature, humidity, air movement and radiati n. In an investigated region the following measures could be accepted as simple bioclimatical indicators, for example: variation of average daily temperature, the number of summer, winter, heat days and the number of days with frost, the daily variation of relative humidity and the insolation.

However, the above enumerated indicators are not relevant enough, in the present study an attempt is made to analyse the joint effects of the climatological elements using complex bioclimatical indices like the pulmonary

stress index, number of the beergarden days, thermal comfort index, relative strain index and the thermohygrometrical index in the city centre and surroundings of Cluj.

We are using averages of data series concerning the main climatological parameters being at disposal like vapour pressure, relative humidity, wind velocity and temperature. These parameters were measured at the oficial station of Cluj, which changed its place during the time. In 1966 it has been placed on the Citadel Hill. Despite the moving of the observation site the series are homogeneous between 1880 and 1996. A part of our data was received from the microclimatological examinations made by Belozerov (1972) in the 1960's and 1970's. We have to emphasis that our results are preliminary ones because we did not take into consideration the urban development of the city during the last more than hundred years.

Concerning the sites of the observation stations, which are being in the represented areas of the city as follows:

– Station 1. is the official station of the city. It is laying on the Citadel Hill in a site with family houses and gardens,

– Station 2. is beside the 2 storey building of the Agricultural Institute with exposure to the north,

– Station 3. is near of the University in a sheltered place,

– Station 4. was set up on the north slope of Felek Hill. It is situated in an orchard area out of the city,

– Station 5. was placed on a square in the centre, in a very densely built-up area,

– Station 6. is located in the east part of the town at the airport (Fig. 1).

The study area has continental climate with a long warm season by Trewartha's classification.

The main average meteorological parameters of the city are as follows:

– mean annual temperature is 8.4°C,
– mean January and July temperature are –4.6 and 19.3°C,
– mean annual precipitation is 619 mm,
– mean annual sunshine duration is 1978 hours,
– mean annual relative humidity 74%,
– mean annual vapour pressure 9.6 hPa.

METHODS, RESULTS AND DISCUSSION

The pulmonary stress index represents the real quantity of moisture getting in touch with the pulmonary mucous of the human body. Normal water vapour content of blood plasma is 31.3 hPa. In reality normal lung function produces evaporation to a vapour pressure of 19.7 to 23.8 hPa so that

the true balance situation occurs at a vapour pressure of 7.5 to 11.6 hPa. For values above or below this it was deduced that the greater is the difference, the greater is the stress placed on the pulmonary interface. The pulmonary stress index values can be ranged in 7 class types between +2 (0–4 hPa) and –4 (26.6–31.2 hPa). The first value indicates the dehydrating state, the second one the hydrating state. The index gives the limit value for the normal function of the lung. Between the hydrating and dehydrating values, the balanced state (index 0) corresponds to the values of water vapour pressure from 7.5 hPa to 11.6 hPa. The value of 7.5 hPa represents the limit of tendency to dehydratation or blood condensation. Otherwise the value of 11.6 hPa represents the limit of tendency to hydratation or dilution of the plasma (Tab. 1).

Table 1

Pulmonary stress index classes

Klasy wskaźnika respiracji

Dehydrating		Balanced	Hydrating class			
+2	+1	0	–1	–2	–3	–4
0–4.0	4.1–7.4	7.5–11.6	11.7–16.5	16.6–21.5	21.6–26.5	26.6–31.2

Let us consider the monthly average index values of the Cluj Station during the period 1880–1996 (Fig. 2). It can be given by computing the vapour pressure data at 1 o'clock AM and PM (Géczi, Dormány, Unger 1996). The results show that the vapour pressure values are reduced in wintertime because dry masses of air occur in the investigated area at this time. Thus four months in winter half year are featured by dehydrating (+1) index values. February with a minimum of 3.9 hPa belongs to the dehydrating (+2) type. Three months are balanced (April, May and October) and the rest of the year, the summer months belong to the hydrating (–1) stage with a maximum of 15.7 hPa in July. The monthly means increase steeply from the beginning of the year till July and then decrease till February. So only four pulmonary stress index class type occur in this town (–1, 0, +1 and +2). The annual average index is balanced with a value of 9.6 hPa.

A different measure for comfort respectively for the sparetime value of the climate of an urban area or its surroundings is the number of the so called beergarden days (Bründl, Höppe 1984). It can be defined as the number of days on which the air temperature at 9.00 p.m. is still above 20.0°C. That represents gentle and mild evenings with possibility to stay outdoor without feeling cold. The highest value of this index can be measured in the inner city and at the airport, where the concrete surface of the runways still irradiates the warm received during the day (Fig. 3).

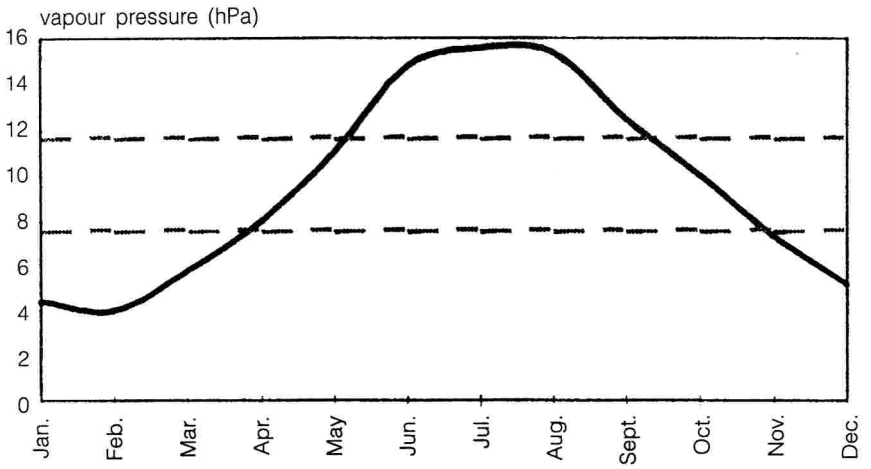

Fig. 2. The annual variation of the pulmonary stress index at Cluj station (1880–1996). Dotted lines are the thresholds for normal function of lung

Rys. 2. Roczna zmienność wskaźnika respiracji na stacji Kluż (1880–1996). Linią kropkowaną zaznaczono progi dla normalnej pracy płuc

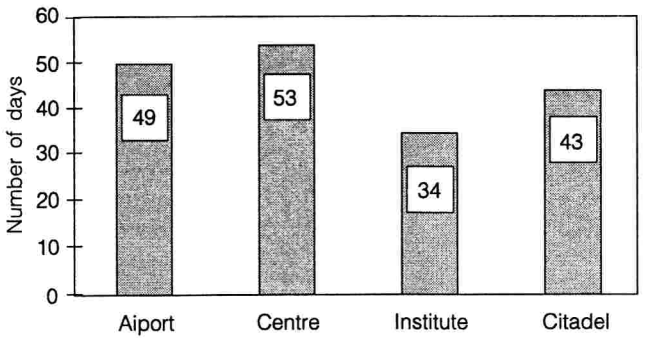

Fig. 3. Number of the beergarden days in 1996 at four stations

Rys. 3. Liczba dni z komfortem termicznym w 1996 r. na czterech stacjach

Another – bioclimatical indicator which was applied in our investigation, and estimates the effective temperature is the thermohygrometrical index. It is writing according to the Thom's empirical formula (Géczi, Dormány, Unger 1996):

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

where: t is the air temperature in °C, f is the relative humidity in % and THI is given in °C.

The optimal values of THI are between 15° and 19.9°. The THI was used originally to determine the discomfort due to heat stress, therefore it have to be evaluated over a much wider range of condition with 10 class types from hyperglacial (below –40°) to torrid (above +30°) (Tab. 2). Using the monthly means of temperature and relative humidity of the Cluj Station in the periods 1880–1996 the monthly average index values show that only the values in April and October belong to the narrow comfort type. The winter months belong to the cold interval between –1.7° and 12.9°, and the summer months to the hot class type (20–26.4°). Just in July the average THI value emerges into the very hot interval (between 26.6° and 29.9°) (Fig. 4).

Table 2

The class types of thermohygrometric index of Thom (1959)

Klasy wskaźnika termiczno-wilgotnościowego Thoma (1959)

THI types	Value (°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

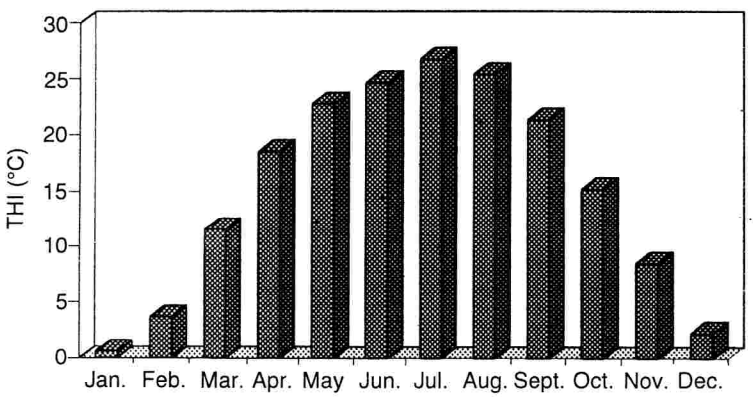

Fig. 4. Annual variation of THI values in Cluj station (1880–1996)

Rys. 4. Wieloletnie zmiany THI w Kluż (1880–1996)

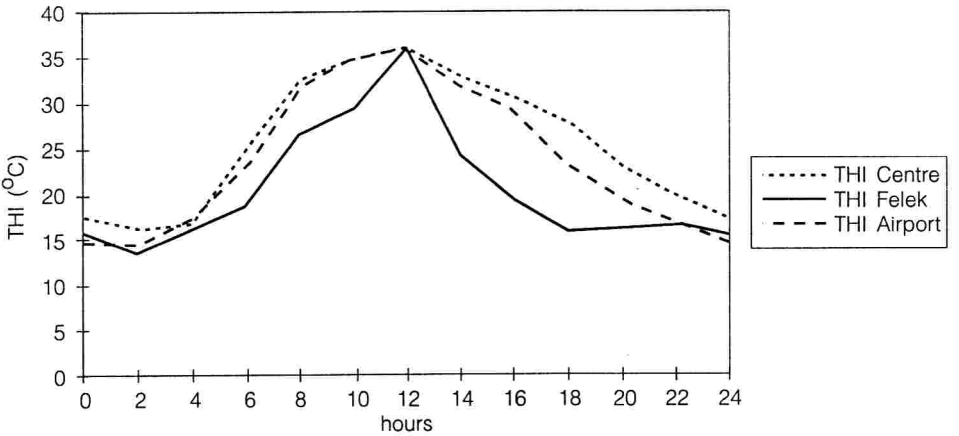

Fig. 5. The daily variation of the thermohygrometrical index in the centre, at the airport and on the Felek Hill in July 1964

Rys. 5. Dobowe zmiany wskaźnika termiczno-wilgotnościowego w centrum, na lotnisku i na stacji Felek Hill w lipcu 1964 r.

Considering the daily aristions of the THI values of the three stations in a hot summer month, in July 1964, the following general features emerge at three stations (Fig. 5). In the centre the most pleasant period occurs at night, between 10.00 p.m. and 6.00 a.m. (8 hours). During the day the THI values reach the hot and the very hot type and even the torrid one between 8.00 a.m. and 4.00 p.m. (max 36.2). Outside the centre on the Felek Hill the adequate period starts already at 4.00 p.m. and lasts till 6.00 a.m. It takes 12 hours because the THI value sinks under 15° at 2.00 a.m. (13.6° – cool type). In the daytime there is a steep increase and a steep decrease and the highest value occurs at 2.00 p.m. (35.7° – torrid type). At the airport station the situation is similar to the one in the centre but the comfortable period occurs a little bit earlier (from 8.00 p.m. till 6.00 a.m.).

A very complex bioclimatical indicator applied in this study is the so called thermal comfort index (ET) which is based on an approach of the effective temperature. The thermal comfort index represents the temperature effectively felt by the human body under different climatic conditions. According to the Missenard formula the thermal comfort index can be calculated using the temperature in °C (t) and relative humidity given in % (f) (Géczi, Dormány, Unger 1996):

$$ET = t - 0.4(t - 10)\left(\frac{1 - f}{100}\right)$$

The adequate temperature for the human body varies between 15° and 20° for a sedentary standard man with light clothes.

In this case the organism neither gains nor loses energy. If the temperature increases above the upper threshold or decreases under the lower one it would produce metabolic changes in order to maintain the body's internal temperature constant. Substituting the two-hourly means of temperature and relative humidity and comparing the numbers of thermal comfort hours at three stations in the summer months of 1964, we can find 12 hours at the centre, hours on the Felek Hill and 10 hours at the airport which belong to the narrow interval ot thermal comfort. The daily variation of this index is changing from one station to other (Fig. 6). Very pleasant afternoons can be exhibited in April with 6 comfort hours but this comfort period occurs four hours earlier than in July. In October there are only 4 hours which belong to the comfort type and they occur also in the afternoons. There are not comfortable hours mornings in the transition seasons.

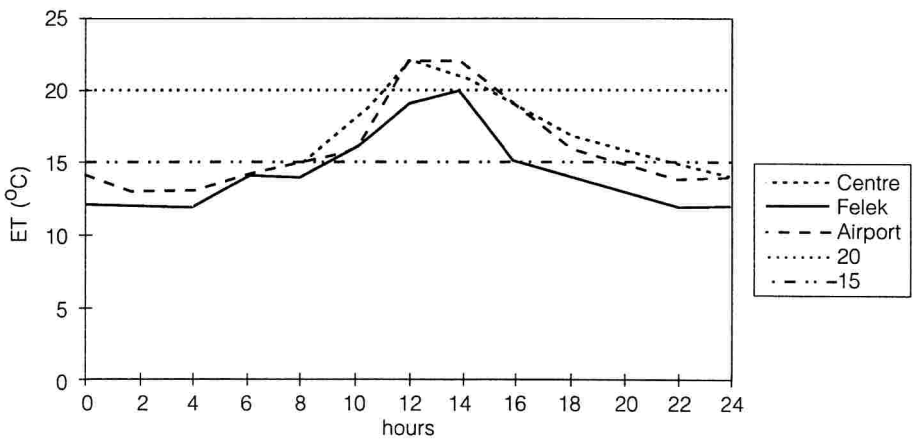

Fig. 6. Diurnal variation of thermal comfort index given by Missenard formula in the centre, at the airport and on the Felek Hill in summer 1964 (the lines are the thresholds for the adequate thermal comfort)

Rys. 6. Dobowy przebieg wskaźnika komfortu cieplnego wg wzoru Missenarda w centrı n, na lotnisku i na stacji Felek Hill w lecie 1964 r. (linie wskazują progi właściwych klas komfoı u)

Other index as a rational approach to the evaluation of heat stress is the relative strain index (RSI). It represents the capacity of the environment to accept the load imposed on a standard man and the physiological capacity of the man to meet the demands over a period of eight hour (K y l e 1992). According to the Kyle's formula it is expressed as:

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

where:

T is dry bulb temperature (°C) and e represents the vapour pressure (hPa).

This formula is valid for a sedentary standard 25–30 years old, healthy man. Table 3 lists the RSI classification. The RSI is used in general in the subtropics.

Table 3

The RSI classes (Kyle 1992)

Klasy RSI (Kyle 1992)

RSI	Percentage of persons unstressed/distressed
0.1	100 unstressed
0.2	75 unstressed
0.3	0 unstressed
0.4	75 distressed
0.5	100 distressed

The data on which the RSI calculation for Cluj is based are the mean hourly dry and wet bulb temperature data by days for a period of 33 year (1960–1992). Every 10–15 years during July and August occurs 4–7 days of distressed periods (0.4 stage) measured only at the airport, at the University and in the centre (e.g. in 1964, 1979, 1992).

CONCLUSIONS

According the annual courses of the pulmonary stress index values, the vapour pressure conditions in Cluj do not cause a very loading situation, but the period which really advantageous lists only three months and the rest of the year can be featured as slightly hydrating or slightly dehydrating ones. Only two months are comfortable by the annual courses of thermohygrometrical index, the rests are colder or warmer, which means a very disadvantageous effect during this long period. The most pleasant period occurs in April and October from all point of view.

The diurnal courses of bioclimatical indices shows spatial differences of the inside and outside urban climates. In the centre, an artificial inner-city climate prevails in opposition with the one in the surrounding area. On the Felek Hill and at the Institute the bioclimatic indices indicate a climate

with north exposure slope characters. There and on the Citadel Hill are the most likely territory of the area which is featured by stimulating bioclimate: the temperature are quite moderate with the longest thermal comfort period during the day in the summertime. The situations in the centre and at the airport are very similar. It can be explained with the huge amount of concrete at the airport, which thus has similar thermal properties as the densely built-up city centre.

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STRESZCZENIE

W pracy omówiono kilka wskaźników bioklimatycznych badanych na podstawie stuletniej i krótszych serii danych pomiarowych z pięciu stacji zlokalizowanych w charakterystycznych punktach miejscowości Kluż (Rumunia).