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Assessment of the microclimatic and human comfort conditions in a complex urban environment: Modelling and measurements

Ágnes Gulyás[a,*], János Unger[a], Andreas Matzarakis[b]

[a]Department of Climatology and Landscape Ecology, University of Szeged, P.O. Box 653, 6701 Szeged, Hungary
[b]Meteorological Institute, University of Freiburg, 79085 Freiburg im Breisgau, Germany

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Abstract

Several complex thermal indices (e.g. Predicted Mean Vote and Physiological Equivalent Temperature) were developed in the last decades to describe and quantify the thermal environment of humans and the energy fluxes between body and environment. Compared to open spaces/landscapes the complex surface structure of urban areas creates an environment with special microclimatic characteristics, which have a dominant effect on the energy balance of the human body. In this study, outdoor thermal comfort conditions are examined through two field-surveys in Szeged, a South-Hungarian city (population 160,000). The intensity of radiation fluxes is dependent on several factors, such as surface structure and housing density. Since our sample area is located in a heavily built-up city centre, radiation fluxes are mainly influenced by narrow streets and several 20–30-year-old (20–30 m tall) trees. Special emphasis is given to the human-biometeorological assessment of the microclimate of complex urban environments through the application of the thermal index PET. The analysis is carried out by the utilization of the RayMan model. Firstly, bioclimatic conditions of sites located close to each other but shaded differently by buildings and plants are compared. The results show that differences in the PET index amongst these places can be as high as 15–20 °C due to the different irradiation. Secondly, the investigation of different modelled environments by RayMan (only buildings, buildings + trees and only trees) shows significant alterations in the human comfort sensation between the situations.

Keywords: Urban environments; Thermal comfort; Physiological Equivalent Temperature; Szeged; Hungary

1. Introduction

Human beings are subjected to various kinds of stress in the urban environment. The most important ones are the meso- and microclimatic conditions, which differ significantly from that of rural areas. The main reason for this is the alteration of the surface structure (e.g. proportion of the built-up area, 3D geometry of the buildings and trees) triggering particular urban climate phenomena (e.g. urban heat island, changes in the radiation fluxes).

An important task of the bioclimatological research is to evaluate the thermal environment of human beings, since it determines the energy balance of the body and consequently its comfort sensation [1]. The physiologically relevant assessment of urban climate, and especially different urban microclimates, requires the use of methods and indices which combine meteorological parameters with thermo-physiological parameters [2,3]. Urban and regional planners are demanding easily understandable methods for the thermal component of climate in order to facilitate comfortable urban microclimates [1].

Human bioclimatological studies carried out in summer have a specific importance, because the urban heat island forming several hours after sunset keeps the

*Corresponding author. Tel.: +36 62 544000/3050; fax: +36 62 544624.
E-mail address: agulyas@geo.u-szeged.hu (Á. Gulyás).

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extent of the heat stress at high levels in addition to the strong heat stress during daytime. This shortens the regeneration possibilities of urban residents during the night. Based on the foregoing, the human thermal comfort issues and quantitative bioclimatological indices generate valuable information for urban planners and architects. The obtained data and suggestions can contribute to the planning process to achieve more suitable urban environment and healthy environment, e.g. to increase the well-being of the urban population by mitigating heat stress in summer.

This study is based on earlier bioclimatic and recent urban climate studies in the South-Hungarian city Szeged. According to these studies an urban heat island intensity of 2.7 °C on annual average can be measured in Szeged, which can increase to 6.8 °C during clear, anticyclonal weather conditions [4]. The results show a significant additional heat load to the human body, especially in summer. In former bioclimatic studies, with the aid of suitable indices for the available dataset, differences in the annual and diurnal variation of human bioclimatic characteristics between an urban and rural environment are evaluated over a 3-year period [5]. These indices were the thermohygrometric index (THI), defined by air temperature and relative humidity, the relative strain index (RSI), defined by air temperature and vapour pressure, and additionally the number of "beergarden days" defined by air temperature at 21:00 h. It was shown that, due to the increased heat stress, the modification effect of the city is rather negative in summer, while it improves the thermal sensation by shortening the unfavourable cold periods in winter.

The aim of this study is to demonstrate the importance and potentials of the quantitative evaluation of human comfort and heat stress. Findings are of use for city planning and architects, as shown for the city of Szeged, situated in the southern part of Hungary. The study applies a two-way approach while focussing on the same study area: (a) the modelling and alteration of the surface structure, and (b) an evaluation based on sophisticated microclimate measurements to reveal the human bioclimatological features of the study area.

2. Study area and methods

2.1. Study area

Szeged is located in the southern part of Hungary (46°N, 20°E) at 79 m above sea level on a flat plain (Fig. 1A–B). River Tisza passes through the city, otherwise, there are no large water bodies nearby. 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. 1C). The city's population of 160,000 lives within an administration district of 281 km^2, but the highly urbanized area is restricted to an area of about 30–35 km^2.

Szeged is located in the climatic region Cf according to Köppen's classification (temperate warm climate with uniform annual distribution of precipitation) or in the climatic region D.1 according to Trewartha's classification (continental climate with a long warm season) [6]. The annual mean temperature is 10.4 °C and the amount of precipitation is 497 mm.

The investigated sample area ($200 \times 200\,m^2$) in Szeged is situated in the heavily built-up city centre region with narrow streets and several 20–30-year-old (20–30 m tall) deciduous trees (Fig. 2). The area is crossed by a busy road (Petőfi av.) with a tram rail in a direction of NE–SW and by two narrow by-streets. One of the by-streets (Batthyány str.) has a NNW–SSW direction and the other (Egyetem str.) is parallel to the avenue. The

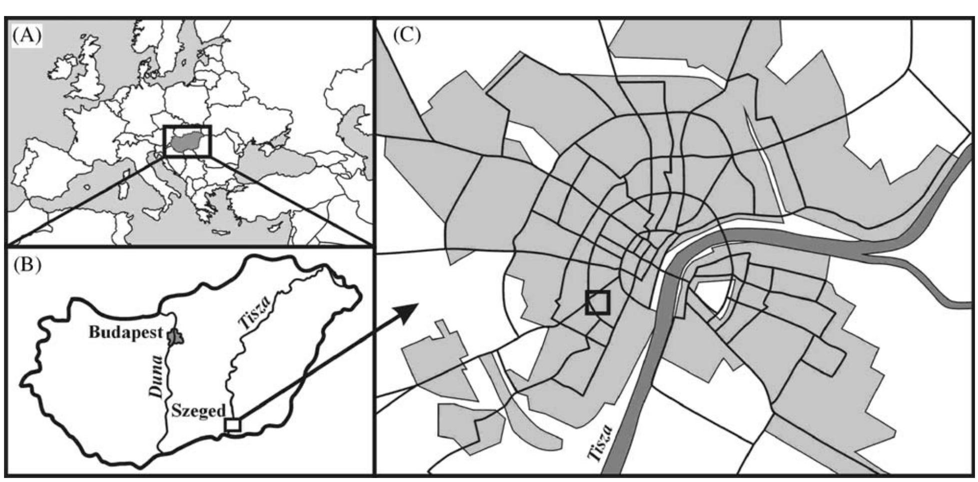
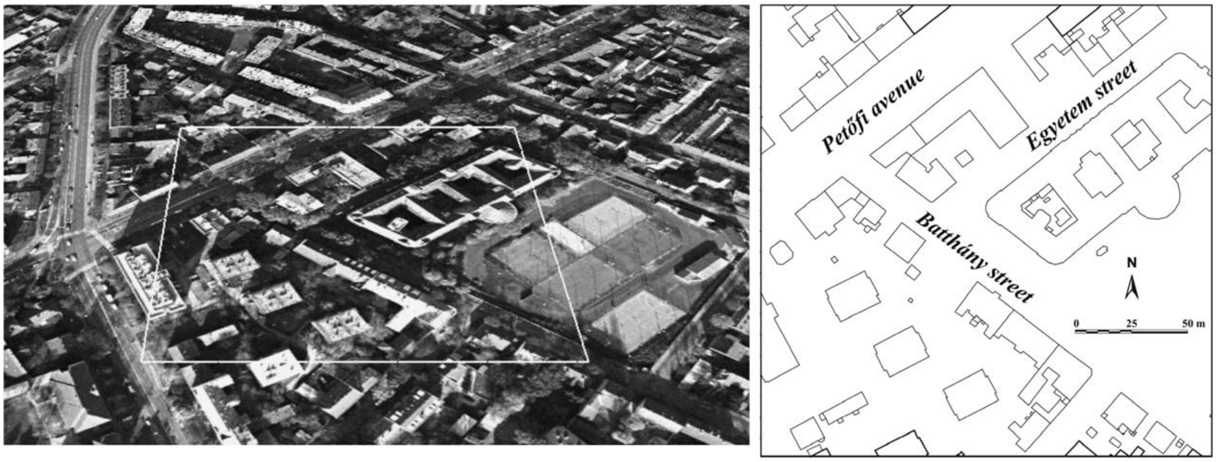


Fig. 1. Geographical location of Hungary in Europe (A), of Szeged in Hungary (B), built-up area and road network of the city (C) and the location of the 200 × 200 m sample area in the city.



(A) (B)

Fig. 2. 3D view created by ERDAS IMAGINE (A) and map (B) of the investigated area.

area is dominated by the five-storey building-complex of the University of Szeged.

2.2. Applied bioclimatic indices

In the last decades, several models were developed to estimate the energy balance of the human body in different environments. These models usually include various meteorological parameters, albedo of the surface and solid angle proportion [7–11]. The models utilize complex comfort indices—for example Predicted Mean Vote (PMV), Physiological Equivalent Temperature (PET) or OUT SET*—to evaluate the thermal stress affecting the body. Most of the indices include the mean radiant temperature (T_{mrt}), which is, especially during sunny weather, the most important input parameter for the energy balance [10]. T_{mrt} is defined as the uniform temperature of a surrounding surface giving of blackbody radiation (emission coefficient $\varepsilon = 1$) which results in the same energy gain of a human body as the prevailing radiation fluxes [12].

PET is a popular and useful bioclimatic index, because it has a widely known unit (°C) as an indicator of thermal stress. It makes results easy understandable and comprehensible for potential users who are not familiar with modern human-biometeorological terminology, including planners, decision-makers, and even the public. It evaluates the thermal conditions in a physiologically significant manner [12]. 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. This way PET enables various users to compare the integral effects of complex thermal conditions outside with their own experience indoors. In addition PET can be used all year around and in different climates (e.g. [9,13]).

Table 1
Examples of PET values at different weather conditions

Examples	T_a (°C)	T_{mrt} (°C)	WS (ms^{-1})	VP (hPa)	PET (°C)
Winter, sunny	−5	15	0.5	2	−1
Winter, shade	−5	−5	5.0	2	−13
Summer, sunny	30	60	1.0	21	43
Summer, shade	30	30	1.0	21	29

T_a, air temperature; T_{mrt}, mean radiant temperature; WS, wind speed; VP, vapour pressure (modified after [9]).

Meteorological parameters influencing the human energy balance include air temperature, air humidity, wind speed and short- and longwave radiation. It is necessary to determine these parameters at a human-biometeorologically significant height of 1.1 m above ground, corresponding to the average height of a standing adults' centre of gravity [12,14].

Large differences between air temperature and T_{mrt} (and PET) arise in winter days with high wind speed and in summer at calm and sunny conditions [9]. In these cases extreme cold or heat stress can be experienced. Examples of the resulting PET values at different seasonal, shading and wind conditions are illustrated in Table 1.

In this study, we use T_{mrt} and PET to characterize the radiation conditions and to evaluate the human bioclimatological comfort sensations, respectively, in nearby, but different urban environments.

Investigations based on the application of PET in urban environments and their results are concentrated primarily on Germany (e.g. [10,12,14–16]) and Sweden (e.g. [17–19]). Our work can contribute to this important research field and to the familiarization with the usefulness of PET.

2.3. RayMan model

One of the recently used radiation and bioclimate models is RayMan, developed in the Meteorological Institute, University of Freiburg. It is well-suited to calculate radiation fluxes (e.g. [14,15]), thus all our calculations for T_{mrt} and PET were performed with this model.

The RayMan model, developed according to guidelines of the German Engineering Society [3,20], calculates the radiation flux within urban structures on the basis of parameters such as air temperature, air humidity, degree of cloud cover, time of day and year, albedo of the surrounding surfaces and their solid-angle proportions.

The main advantage of the RayMan is that it facilitates the reliable determination of the microclimatological modifications of different urban environments, since the model considers the radiation modification effects of the complex surface structure (buildings, trees) very precisely. Beside the meteorological parameters the model requires input data on surface morphological conditions of the study area and on personal parameters.

2.3.1. Morphological–geometrical data

The co-ordinates of the building plan area were derived from a very detailed digital map of the Szeged Municipality, while the heights of the buildings were measured on digital orthophotos (compiled from aerial photographs) using the ERDAS IMAGINE software (Fig. 2).

Tree vegetation in the sample area was also mapped. Altogether, it includes 184 deciduous trees and the measuring points are shaded mainly by lime trees (*Tilia platyphyllos*). (The most effective and human-bioclimatologically significant radiation modification can be obtained by deciduous trees, because they can provide shade in summer, while in winter they hardly affect the irradiation, which can improve the comfort sensation at this time of the year.) The exact locations, heights, trunk heights, trunk diameters and canopy diameters of the trees are input data for the model.

2.3.2. Meteorological data

As input meteorological data for the model we use four measured parameters in both cases: air temperature T_a (°C), relative humidity RH (%), wind speed WS (ms^{-1}) and global radiation GR (Wm^{-2}).

In the first case, the data were logged by a VAISALA-MILOS 500 automatic weather station, which is located at the centre of the investigation area marked with (•) on Fig. 3.

In the second case, the detailed microclimatic monitoring was taken by a portable mini-weather station (type HWI) equipped with Campbell sensors according to the WMO standards and digital data logger. The measurements were taken at a height of 1.1 m above ground.

2.3.3. Personal data

Concerning thermo-physiology of the human body, the age, sex, height, weight, clothing insulation (in *clo* unit—e.g. [14,21]), physical activity and position (sitting or standing) of the investigated person have been

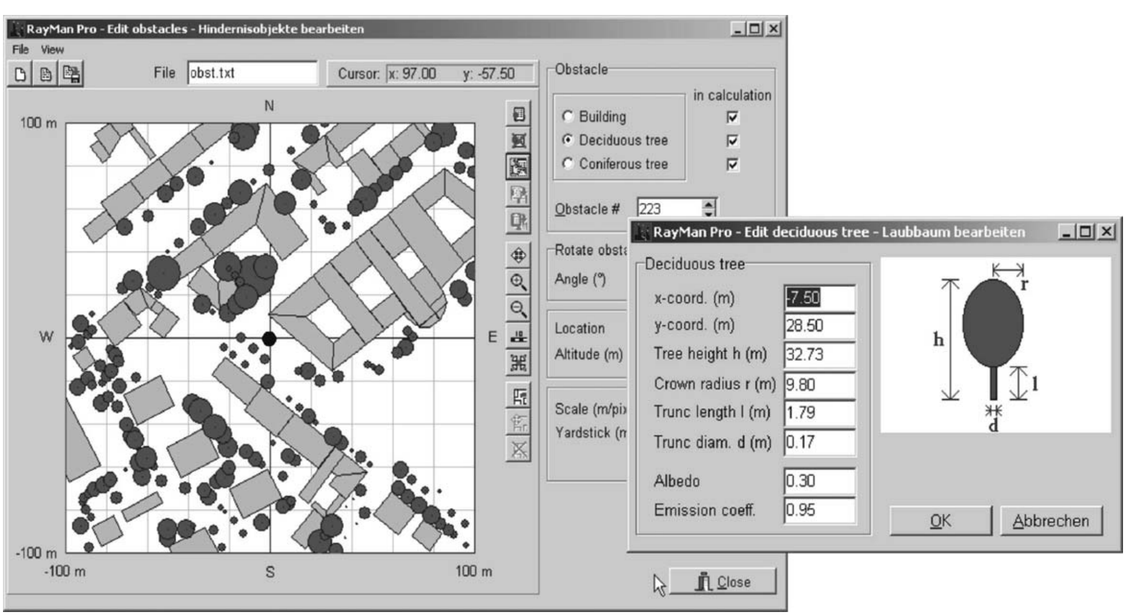


Fig. 3. The map created by the RayMan with the exact locations of the elements (A) and the parameters of trees (B) (buildings are marked by light grey and trees by dark grey).

considered. The comfort estimation in both cases is directed on a "typical European male" (35 years old, 1.75 m tall, weight 75 kg). His clothing index of 0.9 clo corresponds to a long sweeter and trousers as well as the heat produced by activity (metabolic heat) that is equivalent to 80 W [3]. It has to be mentioned that the reference person is sitting indoors.

Beside the calculated T_{mrt} and PET values, we also obtained graphical results as additional model outputs. Among others, the model compiles a picture from the 3D surface morphological data in polar co-ordinates of the area (similar to a fish-eye photo) including the visible part(s) of the sun path of the observation day at the place, with the contours of buildings, trees or other obstacles. It is helpful for the evaluation of the radiation conditions of the observational point. (Conversely, if we took a photo by fish-eye lens camera, it could be an input parameter.)

3. Results

3.1. Weather situations

On both investigated days (04 August, 2000 and 08 August, 2003) the weather was calm anticyclonal in the region of Szeged.

Fig. 4 shows 10-min average values recorded by the meteorological station located in the centre of the sample area during the first day. From the global radiation values it is clear that continuous sunshine (strong direct radiation) is experienced during the day. Consequently, temperature rises quickly in the morning and reaches its maximum (32.7 °C) at 14:00 h. According to this, the relative humidity has a mirror-like shape that is it decreases quickly from the value of 60% of the early morning hours to the lowest value of 32.2% at 14:00 h.

Since wind data are measured at a higher level (30 m, on the roof), the input data need to be recalculated. The wind speed is determined in the reference height of 1.1 m according to the next formula [22]

$$WS_{1.1} = WS_h(1.1/h)^{\alpha}, \quad \alpha = 0.12z_0 + 0.18,$$

where WS_h is the wind speed (ms^{-1}) at the height of h, α is an empirical exponent, depending on the surface roughness, z_0 is the roughness length. In our case $\alpha = 0.42$, because the sample area and its surroundings are a densely built-up inner city area with trees (see Fig. 2).

In the sample area six measurement points were positioned, which are adjacent to each other, but are characterised by very different exposure and radiation conditions (Fig. 5). We endeavoured to represent the varied microclimatic conditions in this small sample area. Measuring points 1 and 2 were located in the northern part of the NE–SW-positioned Egyetem street, where they were surrounded by high buildings. At site 1 the trees' foliage is nearly continuous, while at site 2 the

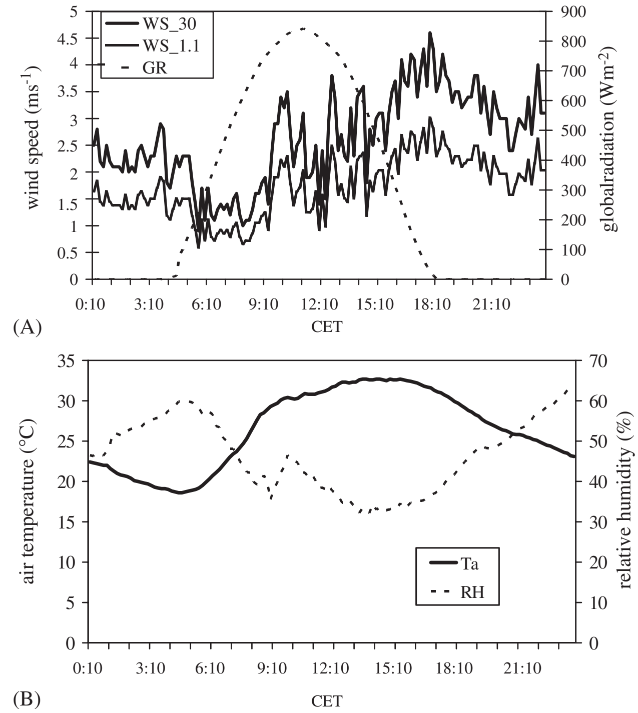


Fig. 4. Diurnal courses of meteorological parameters on 04 August, 2000 (WS_{30}, wind speed at a height of 30 m; $WS_{1.1}$, wind speed at a height of 1.1 m; GR, global radiation on the roof; T_a, air temperature; RH, relative humidity).

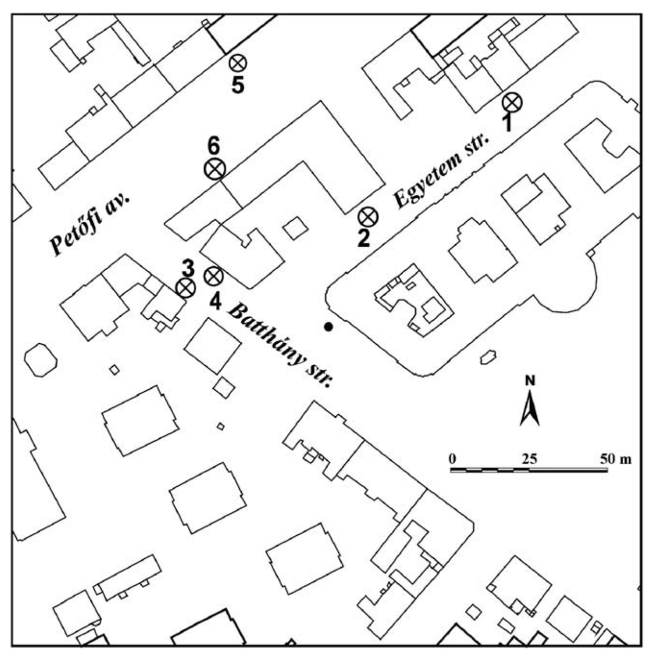


Fig. 5. The study area with the measurement points 1–6.

distances between trees are larger and trees do not provide complete shading. Sites 3 and 4 are situated in the two sides of the NW–SE-directed Batthyány street. The buildings are much lower and, therefore, the exposure to direct radiation is longer during the day.

The point 5 was on the northern side of the Petőfi avenue, on a relatively open area, while point 6 was on the southern side of the avenue. At site 6 the nearly completely closed canopy gives shade to the place nearly all day.

List of the expositions of the measuring points:

1. Street canyon with trees in NE–SW direction (abbreviated NE-scwt).
2. Street canyon without trees in NE–SW direction (abbr. NE-scwot).
3. Street canyon with trees in NW–SE direction (abbr. NW-scwt).
4. Street canyon without trees in NW–SE direction (abbr. NW-scwot).
5. Wide street without trees in NE–SW direction (abbr. NE-wswot).
6. Wide street with trees in NE–SW direction (abbr. NE-wswt).

The radiation characteristic of the second investigated day is also presented by the data measured on the roof (Fig. 6). The mobile measuring unit at the street level—derived from its low sensitivity—demonstrated almost windless conditions all day. Therefore, Fig. 6 shows wind data measured at a level of 30 m and the recalculated data for the height of 1.1 m.

One minute averages were recorded by using the mobile measuring unit from sunrise till sunset. Temperature and relative humidity data recorded at the six points describe the weather characteristics of the day (Fig. 7).

The temperature values are identical (23.3–23.5 °C) in every measurement points at sunrise and increase during the day due to the clear anticyclonal weather (Fig. 7A). The shape of the curves is similar during the day, the largest difference is observable in early afternoon, but the highest difference is only 1.7 °C between the sites 2 and 6. A short-time appearance of some clouds caused slight temperature decrease of a few tenth °C around 16:00 h. In the late afternoon until sunset the values converge. The relative humidity values are also identical in the six measurement points, the shape of the curves are the opposite compared to the temperature curves (Fig. 7B). Similarly to the temperature values, small differences between the sites can be seen; the slight increasing effect of the clouds in the afternoon is discernible. The small differences can be explained by the short distances between the measuring points.

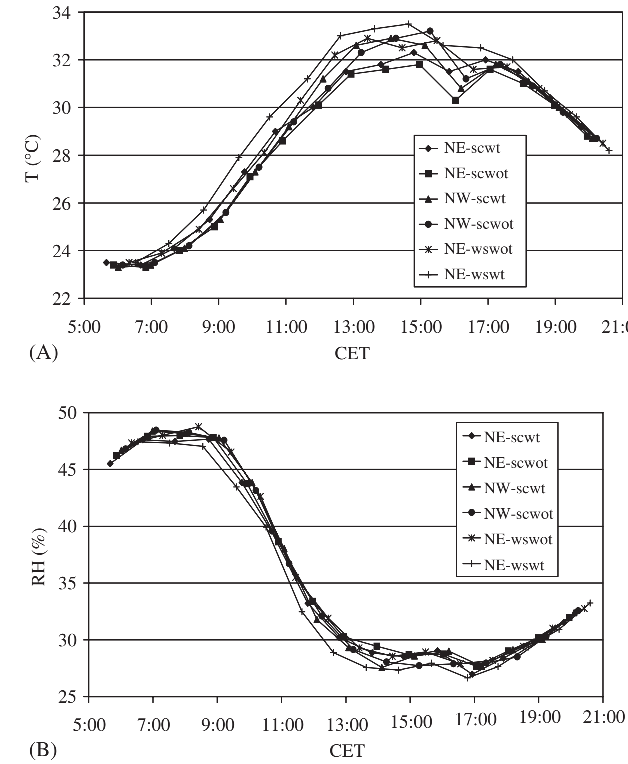


Fig. 7. Air temperature T (A) and relative humidity RH (B) at a height of 1.1 m above surface on 06 August, 2003.

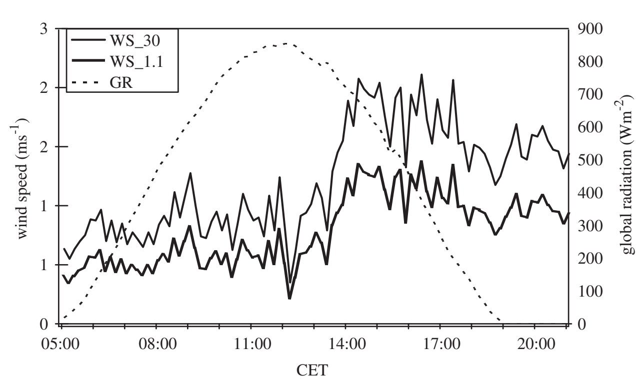


Fig. 6. Diurnal courses of meteorological parameters on 06 August, 2003 (WS_{30}, wind speed at a height of 30 m; $WS_{1.1}$, wind speed at a height of 1.1 m; GR, global radiation on the roof).

3.2. Thermal comfort

For the quantitative demonstration of the climatic effects of trees and buildings in a certain urban location, three bioclimatic index calculations were performed by the model considering the existing surface structure (Fig. 8A), omitting the tree vegetation (Fig. 8B) and omitting the surrounding buildings (Fig. 8C). Fish-eye diagrams generated by RayMan illustrate the shade-open situations.

As shown in Fig. 8, there are considerable differences in the calculated sky view factors (situation A: 0.278, situation B: 0.431, situation C: 0.560). The obtained T_{mrt} and PET values indicate significant changes in the bioclimatic properties caused by the different surface structures (Fig. 9). The figure shows these values during the day in the three situations and additionally the

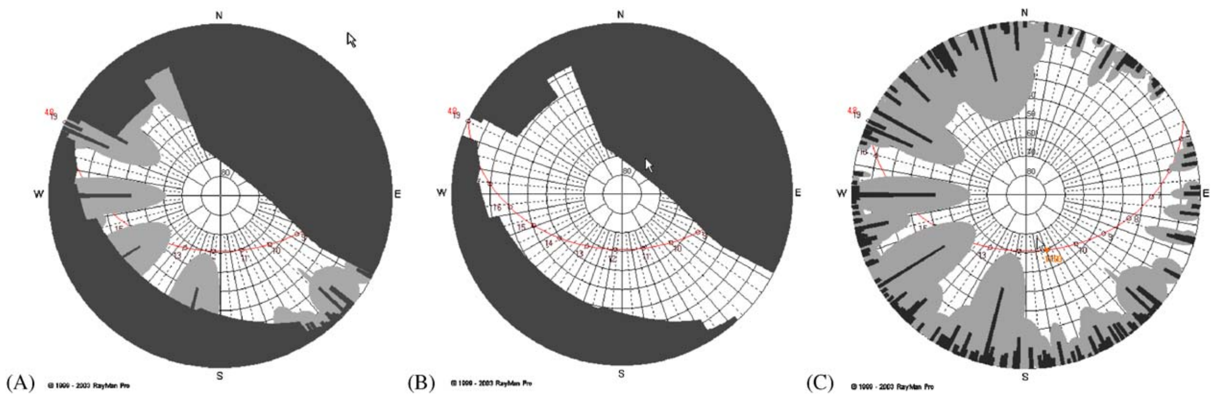


Fig. 8. Output fish-eye pictures in the centre point of the sample area with buildings and trees (A), with only buildings (B), with only trees (C) and the sun path on 04 August, 2000 generated by RayMan.

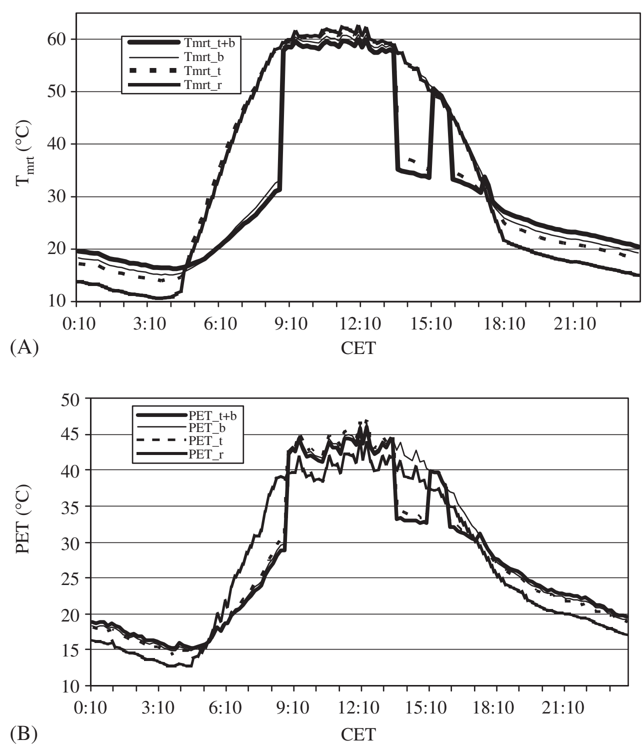


Fig. 9. Mean radiant temperature T_{mrt} and PET computed by RayMan in the three urban structures and on the roof on 04 August, 2000.

values measured on the roof at a height of 30 m, which has a sky view factor of 1.

T_{mrt} values have strong correlations with global radiation values during the day and the weather on the measurement day was sunny. Therefore, significant alterations in the shape of curves are caused mainly by the different shading situations (Fig. 9A). After sunrise, T_{mrt} values increased quickly on the roof (T_{mrt}_r) with a sky view factor of 1 and in the case of trees only (T_{mrt}_t). In the two other situations the increment starts only at 9.00, when the direct radiation hits the hypothetical body. The degree of the observed fast increment is around 30 °C. The shapes of the curves are similar at noon, because the direct radiation hit the body in all situations, but there is a difference in the maximum values observed. The maximum value of 62.3 °C is calculated on the roof (T_{mrt}_r), while at the same time this value reaches only 59.9 °C in the case of A (T_{mrt}_t + b), which means the existing surface structure. This difference is caused by the different projection factors of surrounding elements (walls, trees, etc.).

According to the calculated PET values heat stress is experienced on the examined day: the highest value of PET is 46.8 °C, which means a *very hot* thermal stress level (Fig. 9B). The shapes of the curves have almost the same form as T_{mrt}. This is not an unexpected result, because T_{mrt} is the primary factor of the thermal sensation. Due to the strong, undisturbed direct and diffuse radiation T_{mrt} values are the highest on the roof between 10:00 and 13:00 h. On the other hand, the PET is the lowest on the roof at this time, which is caused presumably by the higher wind speed at the elevated level of the roof compared to the street level (Fig. 6).

For our second case, the calculated T_{mrt} and PET values obtained from the mobile measurements are shown in Fig. 10. In contrast to the weather data, the values for the selected sites show significant differences (see Fig. 7). The results show a remarkable spatial variability in the values of T_{mrt} and PET.

T_{mrt} values are low during the day at the points NE-scwt and NE-wswt, because trees and buildings prevent the direct radiation (Fig. 10A). The widest range can be observed amongst the values obtained at the site NE-scwt. The value of global radiation (as well as the T_{mrt} value) increases immediately after sunrise and peakes at 13:00 h. In the afternoon, an adjacent tree shades the site so that the global radiation declines after 13 h. High global radiation values are also measured at site NE-scwot, but the high buildings in close proximity give shade to the site and cause shorter irradiation (between 11:00 and 14:00 h); therefore the radiation values quickly increase and then decrease there. At the site NW-scwt significant global radiation is measured only during a few hours in the afternoon.

The calculated PET index shows that the heat stress exceeds the *comfortable* (18 °C < PET < 23 °C) level of human comfort (according to [23]) sensation during the whole day, even a slight stress can be experienced after sunrise. The heat stress is increasing until about 14:00 h at every site, but local differences occur between the stations. The highest heat load is calculated for the site NE-wswot (PET = 47.7 °C). This means an extreme physiological heat stress for the human body. The calculated maximum PET value reaches 45 °C at the more open site NE-scwot, but the duration of the harmful effect of heat stress is shorter that at the site NE-wswot, due to the above-mentioned fast decrease of T_{mrt}.

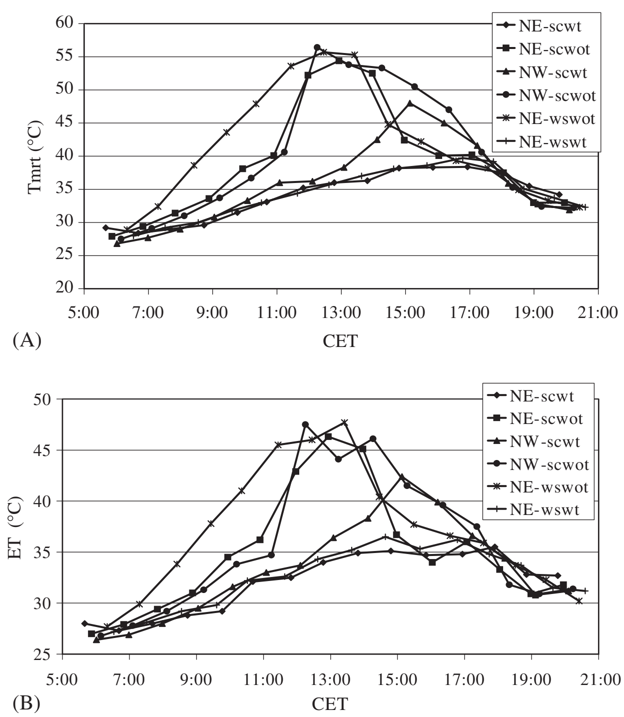


Fig. 10. Mean radiation temperature T_{mrt} (A) and Physiological Equivalent Temperature PET (B) computed by RayMan at the six measurement sites on 06 August, 2003.

The heat stress values are much lower on the sites (NE-scwt and NE-wswt) where no or only small amounts of direct radiation reach our model body. To present this, data from two measuring points NE-wswot and NE-wswt, which are close to each other (25 m) on the opposite sides of the same street (see Fig. 5), are compared. The fish-eye views at these sites, generated by RayMan, show the path of the sun on the measurement day and the shading effect of the adjacent natural and artificial objects (trees, buildings) (Fig. 11 A and B).

The measuring point NE-wswot is surrounded by buildings from NW, causing shade in the late afternoon (Fig. 11A). There is no coverage by buildings from other directions. In the first-half of the day, only the tree canopies can provide some protection against the direct radiation. The opened SE exposure explains the extremely high direct radiation values and, as a result, the calculated very high heat stress. The point 6 is in shade almost during the whole day (Fig. 11B).

Fig. 12 compares the T_{a}, T_{mrt} and PET values obtained from sites NE-wswot and NE-wswt. The differences between the pairs are negligible at sunrise. The temperature values show small differences during the day, but between the T_{mrt} values the difference is increasing rather fast until early afternoon hours. As a result, the difference in the PET index at this time is very

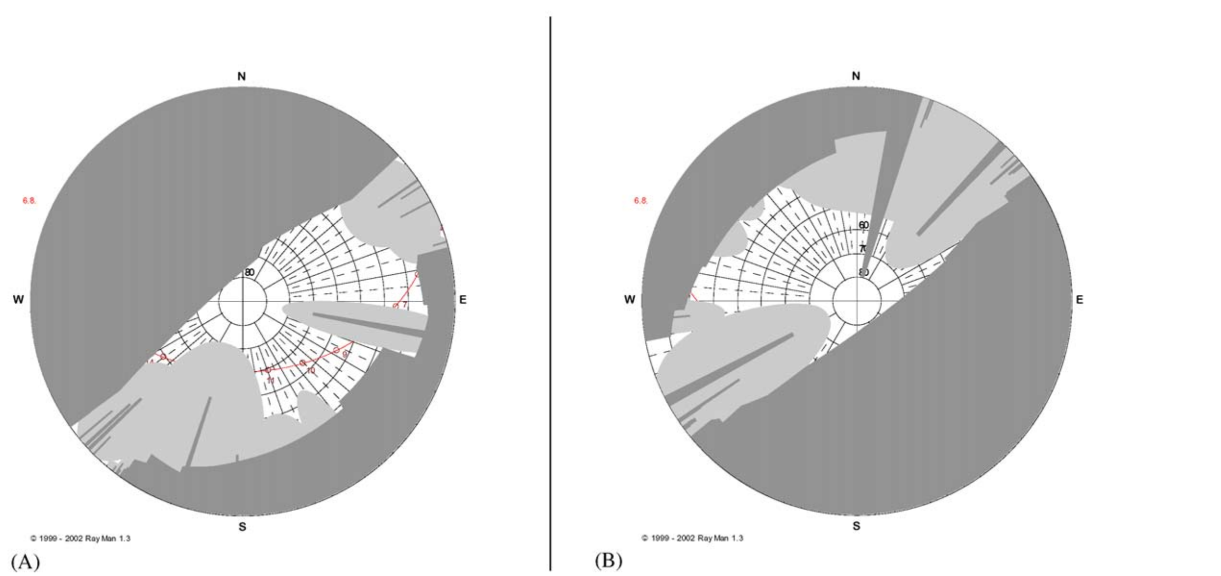


Fig. 11. Fish-eye views at the measuring points NE-wswot (A) and NE-wswt (B) with the sun path on 06 August, 2003 created by RayMan.

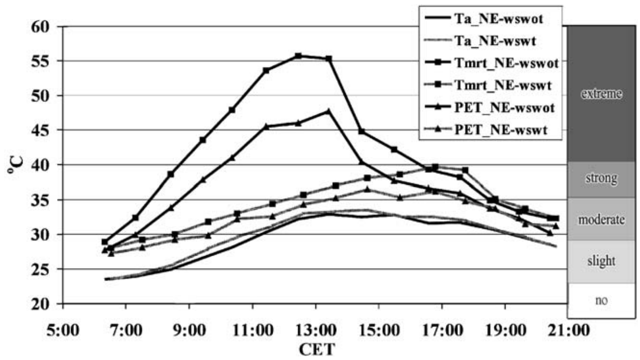


Fig. 12. Air temperature (T_a), mean radiation temperature (T_{mrt}) and Physiological Equivalent Temperature (PET) with the Grade of Physiological Stress at the points NE-wswot and NE-wswt on 06 August, 2003.

high (18–20 °C), indicating a 2 step-stronger heat stress at the site NE-wswot than at the site NE-wswt.

4. Discussion

Both studies suggest that the value of the bioclimatic index PET—expressing the heat-load of the body—shows a strong relationship (as expected by the applied method) with the T_{mrt} value (the irradiation) in summer. This relationship is stronger than the relationship with the air temperature on PET. This statement is supported by the differences observed between T_a, T_{mrt} and PET values of the two selected points (NE-wswot and NE-wswt) in the second case. Despite the slightly higher temperature values at point NE-wswt, due to the irradiation conditions, the heat-load is significantly lower than at point NE-wswot (Table 2).

It is difficult for urban planners to design comfortable urban environments in cities or districts similar to our study area, because the parameters of the local climate are modified predominantly by the radiation modification effect of the 3D geometry of the existing built-up area. This phenomenon is more pronounced during summer when, after the high radiation load during daytime, the blocking or hampering of the outgoing long-wave radiation causes the heat island phenomenon, which often does not allow to decrease the heat stress to the *comfortable* level even during the night. Our results prove the beneficial effect of the vegetation, especially of trees.

Similarly to earlier studies in Germany, our results show a strong correlation between radiation modifications and changes in the thermal stress, focussing on the role of tree vegetation in these processes [14,24].

The first case shows that (the cutting of trees) logging causes significant raise of the heat stress level, while the second case proves this statement by comparing two points with different exposure and shade conditions.

Table 2
Mean and maximum differences between the points NE-wswot and NE-wswt in the air temperature (T_a), mean radiant temperature (T_{mrt}) and Physiological Equivalent Temperature (PET) on 06 August, 2003

	Point NE-wswot–point NE-wswt	
	Mean	Max
T_a	−0.5	−0.6
T_{mrt}	7.0	16.0
PET	4.6	11.2

An excellent prevention of summer heat-load is to plant deciduous trees. In our case the large canopy gives some protections against the direct radiation and, as a consequence, against the extreme heat stress in the midday hours. During the winter season the ideal situation is just the opposite [19]. Leafless trees reduce the extreme cold stress, since the incoming radiation with low angle can reach the surface unhampered.

The latest results of human bioclimatology and urban climatology should be considered when designing or reconstructing urban areas. Bioclimatic research can provide important data for planning and constructing urban surface structures and their environment, which is relevant not only for human comfort aspects.

5. Conclusions

The following conclusions are derived from the analysis presented:

(i) The presence of natural and artificial obstacles around the human body has an impact on the radiation fluxes and, consequently, on the energy balance of the human body; therefore changes in the radiation situation cause changes in the thermal comfort sensation.
(ii) Complex urban environments can result in very different and often extreme comfort sensations even within short distances.
(iii) Consequences of changed thermal environment, caused by different planning variations, can be quantified through the use of the PET index or a similar thermal index based on the full human energy balance.
(iv) Disadvantageous human bioclimatic conditions can be improved (e.g. by planting trees) even in the case of an old ''inherited'' city structure.
(v) In the course of the planning of new districts or single buildings in a city, alterations in human bioclimatic conditions should be taken into consideration.
(vi) The results obtained by RayMan can be a valuable source of information for planners, decision-makers

and practitioners when planning and constructing new urban areas. The outputs are also of interest to the broader public, as they affect daily life.

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