



18th „Building Services, Mechanical and Building Industry days”
International Conference, 11-12 October 2012, Debrecen, Hungary



Paper code: ENR-12-05

EVALUATION AND MODELLING THE MICRO-BIOCLIMATOLOGICAL CONDITIONS OF A POPULAR PLAYGROUND IN SZEGED, HUNGARY

Lilla Andrea ÉGERHÁZI; Noémi KÁNTOR, PhD; Tamás GÁL, PhD

*Department of Climatology and Landscape Ecology, University of Szeged, Szeged, Hungary
egerhazil@geo.u-szeged.hu*

Key words: *thermal effect, urban playground, land cover, numerical simulation*

Abstract:

This paper presents a thermal comfort study of a popular playground in Szeged (Hungary) in order to find its optimal land cover and vegetation options. For this assessment simulated micro- and bioclimatological conditions recorded on a typical summer day (12th July 2011) were analysed. The thermal and radiation features of the study area were quantified by two biometeorological indices, Predicted Mean Vote (PMV) and Mean Radiant Temperature (T_{mrt}). For the simulation of the meteorological parameters and the bioclimate indices, ENVI-met microclimate model was used. The results confirmed that the modelled areas with different land cover provide a variety of thermal conditions for the visitors; moreover, human thermal sensation was significantly affected by the change of the radiation environment.

1. Introduction

In urban areas the climatological and bioclimatological conditions are modified compared to the rural areas (Unger, 1999), and even inside a city in micro scale these conditions are changing rapidly following the urban surface characteristics. The setup of the urban surface characteristics is related with the work of planners, architects and urban planners therefore they have an influence on the local and micro scale climate conditions. The urban planning and planning of urban green spaces is a very complex process and it has several climatological aspects. The final shape of an urban park is designed by the aspects of the architecture but this final setup determines the microclimate of that area and finally the thermal comfort of the visitors. As a result of the thermal comfort conditions the visitors or users of the urban park may alter their opinion about it. If the park is perfect in architecture aspect, but there is heat stress in most of the time, than the visitors will avoid this area.

Fortunately in the last decades there were numerous researches in the topic of microclimate and thermal comfort, therefore now several methods and software are available to predict the microclimate conditions of an urban park when it is existing only in plans, or before the construction begin (e.g. Lehme and Bruse, 2003; Gulyás et al., 2006; Chow et al., 2011; Frölich and Matzarakis, 2012). This study is an example for this micro scale modeling methods, which can give useful information for the architects to make sure that the finally constructed open space or park has the optimal or best setup in several aspects.



2. Study area and applied methods

2.1 Study area

Our thermal comfort examinations took place in the centre of Szeged, located in the south-eastern part of a Central-European state, Hungary (46°N, 20°E). The investigated approximately 3300 m² large area is one of the most modern and well-attended playground in the city. In this open space children can choose among several toys, jungle gyms as well as swings, and 20 benches offer seating place for the visitors. In the western part of the playground, a cottage is situated where the visitors can play even in bad weather.

The surface of the area is primarily covered by light-coloured paving stone that protects the playing children from greater injuries. Different land cover can only be found on two parts of the playground: the children's sand pits are filled with sand, and the immediate vicinity of the cottage and the southwest corner of the playground is paved. The vegetation is considerable (primarily deciduous trees), however, they are mainly located in the border regions of the study area. Therefore during forenoon and in the early afternoon hours, a large part of the playground is exposed to the sunlight (Figure 1).

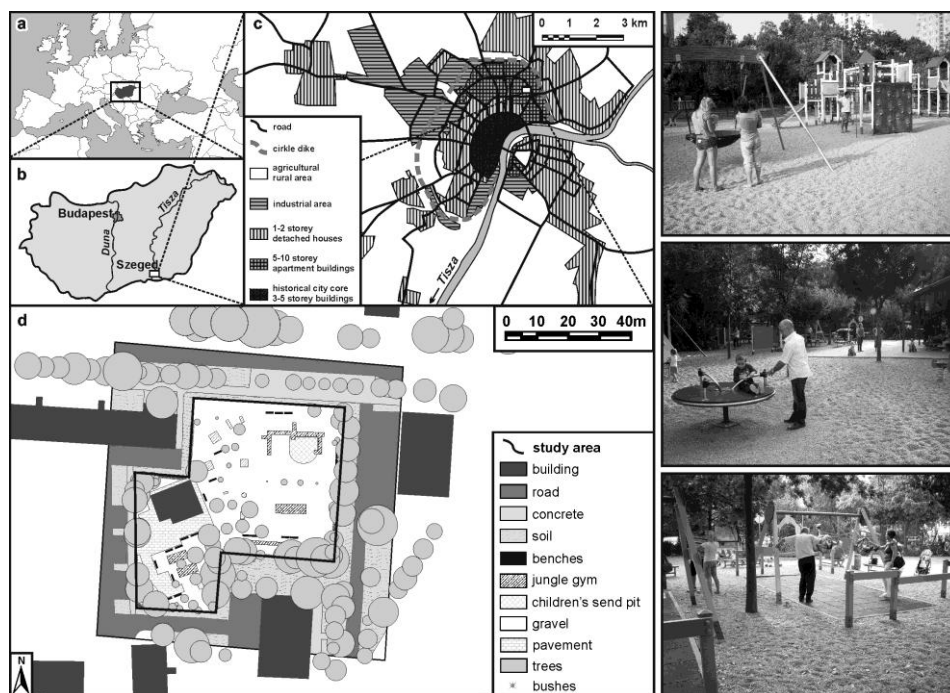


Figure 1: Geographical location of the study area and some photographs from the investigated playground

2.2 Methods – simulation with ENVI-met

ENVI-met is a three-dimensional non-hydrostatic climate model which is able to model the interactions in the surfaces-atmosphere-vegetation system with relatively high temporal (10 min) and spatial (0.5-10 m) resolution (Bruse and Fler, 1998). The simulation required two groups of



input data: the configuration file (.cf) contains the basic settings and the necessary meteorological parameters of the simulation while the area input file (.in) includes the morphological elements (buildings, plants, land covers etc.) of the investigated area.

The present study introduces the use of ENVI-met in the comparison of the effects of different land covers and designs on the micro- and bioclimatological conditions. This latter was quantified by two thermal indices beside air temperature: Mean Radiant Temperature (T_{mrt}) describes the radiation environment of an area, while Predicted Mean Vote (PMV) quantifies the thermal sensation of the people.

The simulation was run on a typical hot, cloudless summer day (12.07.2011), because at this period the differences in the thermal and microclimatic environment can clearly be observed. As parameters of the modelling procedure, 18 hours (00:00 - 18:00) of total simulation time and a spatial resolution of 1.5 m was adjusted in ENVI-met. The simulation results regarded to the bioclimatological references height of 1.1m. Table 1 shows the basic settings of the simulation and the necessary meteorological data obtained from the meteorological station of the Hungarian Meteorological Service situated in the city centre of Szeged (Unger and Gál, 2011).

Table 1: The basic settings of the simulation

Wind speed in 10m (m/s)	3.4	Spec. Humidity in 2500m (g/kg)	7
Wind direction (°)	325	Roughness	0.1
Temperature (K)	296	Total simulation time (h)	18
Relative Humidity in 2m (%)	58	Start simulation	00:00:00

Four simulation scenarios were created in ENVI-met to find the optimal land covers and design for the studied playground. *Scenario 1* contains the base area without any modification (Figure 2a). In *scenario 2*, grassy land cover was employed instead of gravel (Figure 2b). In case of the *scenario 3*, a little fountain (lake) was virtually built in the north-eastern part of the playground, but the original land covers were retained (Figure 2c). Finally in *scenario 4*, a part of the vegetation was removed (Figure 2d). This paper demonstrates the results of these modifications at a typical time (11 a.m.) on the investigated simulation day.



Figure 2: The schematic pictures of the four simulation scenarios



3. Results

3.1 Thermal and radiation features of the playground

In the first part of the analysis, the results of scenario 1 were examined. Figure 3a shows that the spatial patterns of the simulated air temperature was relatively homogenous, differences were not larger than a few tenths of degree Celsius all over the area. Warmer air temperature values (about 24°C) occurred in the northern areas. In the eastern and southern parts, where the vegetation is significant, the temperature was slightly cooler (about 23.4 - 23.6°C).

However, the maps of T_{mrt} and PMV (Figure 3b and 3c) representing the spatial distribution of the radiation environment and the thermal sensation were much diverse, proving the complexity of these bioclimatological indices compared to air temperature. At the same time, these above mentioned maps illustrate the effects of the different land covers and vegetation types in micro- and bioclimatological sense. The spatial distributions of T_{mrt} and PMV values were analogous, which supported the fact that the radiation factor plays an important role in human thermal sensation.

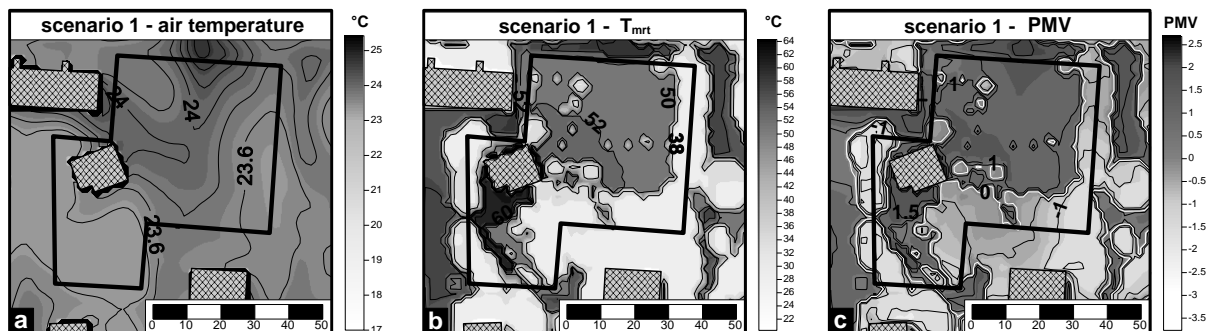


Figure 3: The thermal features of the study area without modification (scenario 1)

Duo to the strong direct radiation in this period as well as the significant reflected radiation from the surface of the pavement, the highest T_{mrt} values (60°C) occurred in the vicinity of the cottage. In the middle parts of the area, T_{mrt} values were slightly decreased (50 - 52°C), however significant drop in the values can only be found in the shadow of the trees (38°C). The heat stress map (PMV map) illustrates that the most unpleasant part (PMV=1.5, slightly warm – warm thermal sensation) of the playground is situated on the pavement due to the above mentioned increased radiation. However under the trees, where the incoming and reflected radiation fluxes were both minimal in this period, the thermal conditions were more comfortable and the values approached to PMV=0 (neutral thermal sensation) and the PMV=-1 (slightly cool thermal sensation).

3.2 The effects of area modification on the thermal conditions

In order to compare the scenarios, difference maps were created. In these maps the modeled values of the base area without modification (Figure 3) were subtracted from the appropriate values of the given scenario (scenarios 2-4), thereby the effects of the modification can easier be observed.

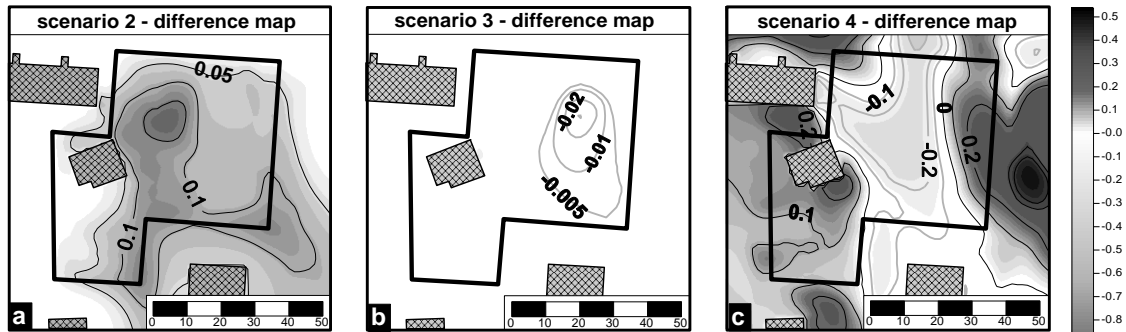


Figure 4: Differences maps of the modeled air temperature in case of the scenarios (black isolines mark the positive, grey isolines the negative changes)

According to Figure 4a, the air temperature slightly increased in scenario 2 (grassy surface instead of gravel), which can be explained by the different water-holding capacity of the gravel and the grass. However, this difference did not exceed 0.15°C anywhere, consequently the influence of the modifications in scenario 2 were practically negligible. Similar tendency can be observed in case of the scenario 3 (simulation with fountain): although the air temperature decreased in the vicinity of the fountain, its cooling effect was negligible (Figure 4b). This can be caused by the fact that the simulation applies simplifications: the fountain was visualized as a small water surface causing reduced cooling effect as that of a sprayed mass of water. Beside this fact the present version of ENVI-met may not be able to render such fine adjustments employed in scenarios 2 and 3. On the map of scenario 4 (simulation with reduced vegetation), differential air temperature values varied between -0.2 and 0.2°C (Figure 4c). Positive differences, i.e. increase of air temperature mainly occurs in the border regions of the study area, where a part of the vegetation was ignored. In the northwestern part of the simulation area, a large group of trees was removed (Figure 2d), which gave way to the prevailing, northwesterly winds (Table 1). The incoming wind cooled down the environment, therefore the temperature in the middle part of the area slightly decreased.

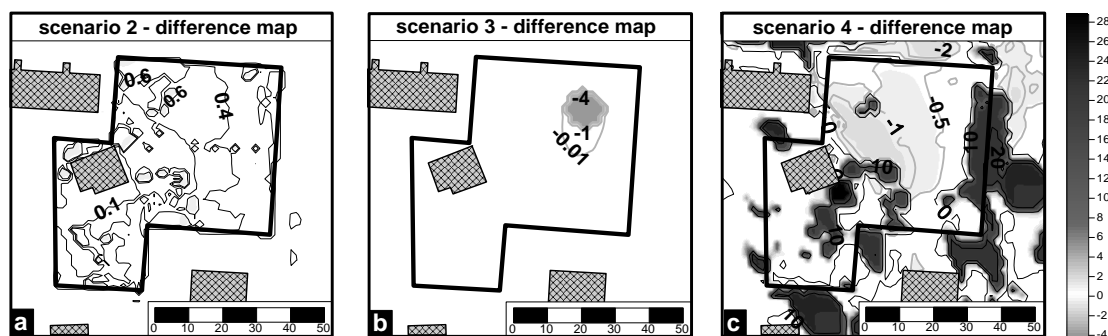


Figure 5: Differences maps of the modeled T_{mrt} in case of the scenarios

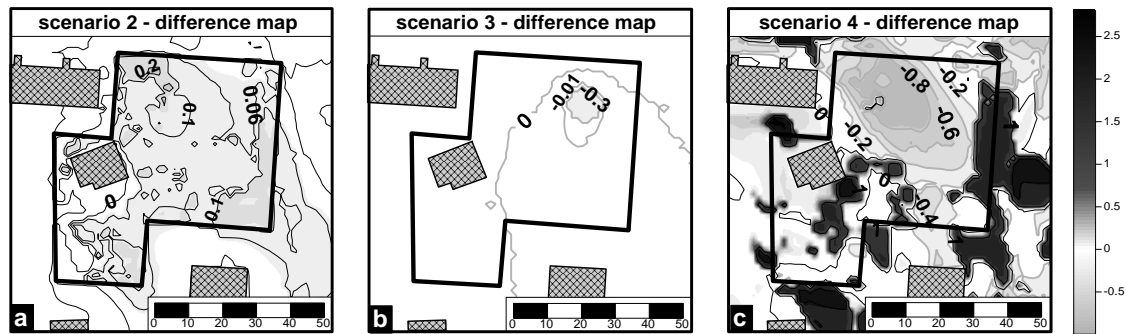


Figure 6: Differences maps of the modeled PMV in case of the scenarios

As illustrated in Figure 5, the variation in the thermal radiation conditions was hardly significant on the first two difference maps (scenario 2 and 3). In case of scenario 2, the deviations of the T_{mrt} values not even achieved 1°C (Figure 5a). In scenario 3, the effect of the fountain was limited and extended only the area of the water surface (Figure 5b).

However, map of scenario 4 highlighted that the modification of the vegetation caused significant changes in the radiation environment (Figure 5c). The dark blots in the map indicated places of removed vegetation, where the increase of T_{mrt} values exceeded even 20°C due to the strong incoming radiation.

Although the air temperature and T_{mrt} values are important indicators of thermal comfort, PMV can predict and quantify how people sense the thermal conditions of a given area. Therefore the analysis of the spatial patterns of the PMV values was explicitly pronounced in of the investigated scenarios. Figure 6 shows the difference maps of the modeled PMV values. According to our simulation results, scenarios 2 and 3 caused negligible changes in the thermal environment (Figure 6a and 6b). The slight increase of PMV values (0.06 - 0.2 PMV) in scenario 2 and the reduction of that (-0.01 - -0.3 PMV) in the vicinity of the fountain (scenario 3) were almost imperceptible to human organism. However the difference map of scenario 4 shed light on the important role of vegetation in thermal comfort investigation (Figure 6c). Namely, the removal of trees from certain parts of the playground caused an increase of as much as 1 PMV, so these areas shifted into another, warmer thermal sensation category (slightly warm instead of neutral). In the middle part of the playground, slightly cooler PMV values (-0.2 - -0.8) can be found due to the above mentioned incoming northwestern wind. Consequently, in some cases the position of the trees may contribute to the ventilation of the area providing more comfortable environment.

4. Conclusions

Some introductory results of a thermal comfort investigation based on the simulation of micro- and bioclimatological conditions were presented discussing the effect of different land covers on the thermal comfort sensation. Four simulation scenarios were carried out by the model ENVI-met, where the thermal environment was characterized by bioclimatic indices T_{mrt} and PMV beside air temperature.

The obtained results show that a grassy land cover (scenario 2) and a virtual fountain (scenario 3) caused only slight variations in the thermal condition. Contrary to the expected results, the influence of these two scenarios was not significant according to the simulation. This can probably be explained by the fact that it is difficult to treat these minor changes in the model area by the present



18th „Building Services, Mechanical and Building Industry days”
International Conference, 11-12 October 2012, Debrecen, Hungary



Paper code: ENR-12-05

version of the simulation. However, the outcome of scenario 4 revealed the importance of the vegetation in the thermal sensation. The reduction of the number of trees increased the thermal load in the playground. At the same time an increased ventilation on the area occurred by the prevailing wind.

The aim of this study to emphasize the importance of modeling procedure in the process of urban planning and to give a hand in the development of a comfortable urban environment.

References

- Bruse M., Fleer H. (1998). Simulating Surface-Plant-Air Interaction Inside Urban Environments with a Three Dimensional Numerical Model. *Environmental Software and Modelling* 13. p.373-384.
- Chow W.T.L., Pope R.L., Martin C.A., Brazel A.J. (2011). Observing and modeling the nocturnal park cool island of an arid city: horizontal and vertical impacts. *Theor Appl Climatol* 103 p.197-211.
- Fröhlic, D., Matzarakis, A. (2012). Modeling of changes in thermal bioclimate: examples based on urban spaces in Freiburg, Germany. *Theor Appl Climatol* DOI 10.1007/s00704-012-0678-y
- Gulyás Á., Unger J., Matzarakis A. (2006). Assessment of the microclimatic and human comfort conditions in a complex urban environment: Modelling and measurements. *Building and Environment* 41, p.1713-1722.
- Lahme E., Bruse M. (2003). Microclimatic effects of a small urban park in densely built-up areas: Measurements and model simulations. ICUC5, Lodz 1-5 September 2003, p.4.
- Unger J. (1999). Comparisons of urban and rural bioclimatological conditions in the case of a Central-European city, *International Journal of Biometeorology* 43, p.139-144.
- Unger J., Gál T. (2011). Automata állomáspár Szegeden - A városi klímamódosító hatás online megjelenítése [Automatic station pairs in Szeged – The online visualization of the climate modification effect of the city (in Hungarian)], *Légekör* 56, p.93-96.