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Heat mitigation with shade trees: the role of landscape design and tree parameters in ameliorating summertime heat stress in a Central-European square

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Climate change projections for Central Europe indicate a significant rise in summertime temperatures and an increase in the frequency and severity of extreme heat events. Combined with the peculiar climate of cities–characterized by the Urban Heat Island effect and reduced ventilation due to high building density–climate change is expected to have more pronounced effects in urban environments. Shade trees are demonstrated to be one of the most effective means to mitigate heat stress in cities. However, very few studies have evaluated systematically the impact of different landscape design and tree parameters (e.g. the species selection or the spatial distribution) on the heat mitigation effectiveness of shade trees. This study aims to assess the role of vegetation transmissivity, canopy size and tree distribution in a medium-sized Central-European square.

The rectangular Bartók Square, located in the inner city of Szeged (Hungary), was selected as a study area. The numerical simulations were carried out with the radiation model SOLWEIG (v.2015a). The necessary meteorological data, collected on clear and warm summer day, was obtained from a nearby weather station run by the Hungarian Weather Service. The default model was built on the basis of available GIS data and utilized tree related parameters from detailed field measurements (tree location, canopy size and shape, etc.). Crown transmissivity data originated from a preliminary, long-term radiation measurement survey covering the vegetation period. Alternative scenarios were constructed with the following characteristics:
1) keeping the original tree layout of the square, the initial tree crown transmissivity of 0.0678 was changed to small (0.0243) and high (0.1328) values;
2) keeping the original canopy volume, two additional scenarios were introduced with evenly distributed trees of different crown sizes: that of several small trees and of fewer large ones;
3) keeping the original canopy volume and using the same number and size of trees, we assessed the role of tree distribution by introducing a scenario were the trees were arranged along the bounding facades of the square—this scenario was compared to the evenly distributed configuration.

In order to evaluate the impact of vegetation, all scenarios are reported in reference to a theoretical, non-vegetated square. Since several studies revealed that mean radiant temperature (Tmrt) plays a key role in summertime heat stress in the European context, this parameter was selected as performance indicator. Tmrt combines the heat effect of all short-and long-wave radiation fluxes reaching the human body.

Our results indicate that when shade is provided for the facades only, the nighttime Tmrt surplus nearly disappears. However, while horizontal long-wave radiation fluxes have a greater impact on human thermal comfort due to the different absorption coefficients of the human body (0.7 vs. 0.95 for short and long-wave radiation, respectively), providing shade for the facades only is not a successful daytime heat mitigation strategy in open urban places. Comparing the influence of vegetation transmissivity revealed that low transmissivity species were able to reduce Tmrt by only 2°C on average during the day. According to our case study, when transmissivity and canopy volume is kept constant, considerable mean radiant temperature reduction can be achieved by evenly distributed mature trees.