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# Exploring the Role of Urban Green Spaces in Microclimate Modeling: Insights from ENVI-met Simulations in Augsburg, Germany

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Microclimate modeling serves as an indispensable tool for fostering sustainable urban development by quantifying the benefits of green and blue infrastructures. Urban green spaces (UGS) are integral to urban sustainability, acting as ecological refuges and providing essential regulating and cultural ecosystem services. This study presents a novel methodology for microclimate modeling by integrating an extensive tree database of 4,264 public and private urban trees in Augsburg, Germany, into ENVI-met simulations. The database allowed for unprecedented accuracy in representing tree species, heights, and distributions. The research, funded by the German Research Foundation under contract 471909988, focused on an urban park and a nearby residential district to evaluate microclimatic conditions and human thermal comfort under varying scenarios.

A total of sixteen ENVI-met simulation scenarios were developed, incorporating variations in vegetation modeling techniques, forcing methods, topography, spatial resolution, and seasonality. The baseline scenario was validated against in-situ measurements of air temperature (T) and relative humidity (RH) collected at nine representative locations. For a hot summer day in August 2024, scenario performance was analyzed through time series of T and mean radiant temperature (MRT) and spatial distributions of the Universal Thermal Climate Index (UTCI) at the pedestrian level.

The analysis revealed a consistent overestimation of T (Bias: from +0.66°C to +1.85°C) and underestimation of RH (Bias: from -0.89% to -4.73%), especially during daytime hours. Daytime T differences between residential and park sites averaged 1.88°C in the reference data but were underestimated by the baseline scenario (1.21°C) and almost entirely overlooked in the "Simple Plants" approach (0.05°C). Scenarios incorporating finer spatial resolution (1.37°C) and a digital elevation model (1.27°C) provided better approximations of these gradients. Greater variability was observed in MRT and UTCI results, with tree height, species, and vegetation models exerting considerable influence. At 14:00 UTC+1, the largest UTCI reductions (median: -1.51°C) were achieved in the L-tree scenario, which includes only one tree species (Acer platanoides), while the "Simple Plants" approach (+0.91°C) offered minimal thermal comfort improvement compared to the "No Trees" scenario (+1.40°C). Despite domain-wide neutral UTCI effects (-0.05°C) in the medium-high L-tree scenario, areas with the tallest trees experienced significant overestimations exceeding +7°C.

This study highlights the complexities and challenges in simulating urban green infrastructure impacts on microclimates and thermal comfort. It underscores the critical importance of detailed, accurate tree data – including species, heights, and leaf-area density profiles – to produce reliable and actionable microclimate modeling outputs. The findings provide valuable insights not only for climate modellers, but also for urban planners seeking to enhance climate resilience through evidence-based UGS design and management.