



Impact of urban form and antecedent weather on urban green space cooling deficits derived from multi-decadal Landsat LST

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Urban green spaces (UGS) are widely promoted as nature-based solutions to reduce heat risk in Urban Heat Islands. To quantify the cooling effects of UGS the use of remote sensing-based Land Surface Temperature (LST) indicators, such as the Park Cool Island Intensity (PCII) or Cooling Effect Intensity (CEI), has proven beneficial. However, these indicators heavily depend on the urban reference the UGS LST is compared with. This limits the comparability of the cooling performances of UGS across cities and urban forms and furthermore obscures the fact that UGS may themselves experience warming effects from adjacent urban areas in return, a mechanism which is still underrepresented in quantitative research.

In this study, we therefore develop and test a transferable approach for determining UGS cooling deficits (Δ LST) by consistently deriving UGS LST relative to a standardized rural baseline derived from Local Climate Zones (LCZ). Using a on a long-term (1984–2025) Landsat LST time series, we analyze several municipalities in Hesse, Germany, and compare summer patterns of Δ LST within and between municipalities.

UGS are characterized by size, tree cover, and vegetation state according to the Normalized Difference Vegetation Index. Surrounding urban structure is quantified using buffer-ring metrics and indicators of built form and land cover (e.g., imperviousness and building density) to capture how different urban contexts modulate Δ LST. This allows the evaluation of the warming effects of different urban areas on different UGS. To disentangle drivers of cooling deficits, we fit multivariate models that account for nested spatial structure (mixed-effects regression) and complement them with a nonlinear benchmark (e.g., random forest). Finally, we analyze to what degree antecedent weather conditions (air temperature, precipitation, and relative humidity) in different time periods (e.g., 7, 14, 21 days) prior to a Landsat acquisitions modulate Δ LST.

This approach provides a transferable, planning-relevant metric that allows UGS to be classified not only as "cool" or "warm," but also as more or less effective relative to a clearly defined rural reference state. This improves comparability across time, space, and different urban structures, and creates a robust basis for prioritized adaptation measures.