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Transferability of land-cover and urban-form effects on near-surface air temperature across European cities

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Exposure to urban heat stress and associated vulnerability vary with topography, climate, and socio-economic conditions, creating a need for both locally tailored and scalable heat-mitigation strategies. A key open question is which land-cover and urban-form drivers of near-surface air temperature are transferable across cities, and which are context-specific. Here, we assess the transferability of land-cover and urban-form effects on near-surface air temperature across four European cities spanning oceanic, temperate, and Mediterranean climates.

We combine quality-controlled citizen weather station air-temperature observations with standardized land-cover and urban-morphology datasets, and apply explainable machine-learning models to quantify the direction and magnitude of feature effects. Transferability is evaluated by testing models across cities and accounting for diurnal variability. Vegetation emerges as a robust and transferable cooling driver across all cities, confirming its role as a scalable urban heat-mitigation strategy. Impervious-surface metrics, including building height and footprint, act as broadly transferable warming drivers, with effect magnitudes modulated by urban geometry (e.g. sky-view characteristics) and city form. In contrast, water-related predictors show no consistent effect across cities, reflecting limited spatial coverage, configuration and scale effects, and variable proximity between monitoring sites and water bodies. Altitude-related cooling is transferable only where distinct elevation gradients and airflow patterns are present. Overall, transferability is higher at night, when feature–temperature relationships are more stable.

Our results demonstrate a systematic framework for cross-city comparison that integrates crowdsourced observations with explainable machine learning, and identifies which urban climate drivers can support generalizable planning guidance. The findings provide actionable insights for urban climate science and services, highlighting greening and reduced imperviousness as broadly effective strategies, while emphasizing that water- and geometry-based interventions require context-sensitive design.