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Differential Cooling Efficacy of Fine-Grained Urban Green Spaces Across Diverse Functional Zones: A Case Study in the Beijing Metropolitan Area, China

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The urban heat island effect is a well-documented phenomenon in cities, particularly in metropolitan areas, with recognized environmental consequences. Mitigating this effect through urban green space planting strategies has been widely acknowledged. However, the extent of the spatial heterogeneity of the cooling effect across different urban functional zones remains insufficiently explored at a fine scale of urban green space.

In this study, we employed a robust semi-supervised deep learning method to precisely segment urban green spaces from high-resolution remote sensing images and developed a 0.5 m fine-scale urban green space product tailored for the Beijing metropolitan area. Leveraging the fine-grained urban green space segmentation results, we modeled cooling efficiency through a nonlinear relationship, quantified as the temperature reduction for a 1% urban green space cover increase. We also conducted a comprehensive assessment of differential cooling efficacy, considering both reference temperature and urban green space cover levels, across diverse urban functional zones at the scale of 300 m × 300 m urban grids.

The results revealed substantial disparities in cooling efficiency among different urban functional zones and different levels of urban green space coverage in Beijing. To be specific, with a 1% increase in urban green space, the commercial zone, residential zone, industrial zone, transportation zone, and public zone can achieve a cooling effect with a mean of 0.095 ± 0.075°C, 0.075 ±0.065°C, 0.075±0.065°C, 0.070±0.060°C and 0.055±0.045°C respectively. By uncovering spatial variations and heterogeneity in cooling effects, our study underscores the critical need for customized strategies in urban green space planning based on functional zone characteristics and offers valuable insights into urban planning and sustainable development practices.