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Street-level greenery mapping and urban heat modelling using deep learning and street view imagery

In an urbanizing world, challenged by climate change and rising temperatures, street vegetation can help mitigate urban temperatures. However, scaling the understanding of street vegetation's cooling effects from local observations to the city level introduces challenges. While several studies have assessed the influence of street greenery on land surface temperature (LST) at the city scale using street view (SV) data, few have distinguished between different types of greenery. Additionally, the combined investigation of spatial non-stationarity and non-linear trends remains underexplored.

This study fine-tuned a semantic segmentation model for the city of Zurich using SV imagery. The model extracted urban features - trees, shrubs, grass, buildings, and sky - by calculating view factors (VFs). Street orientation and water presence were quantified using ancillary data. These urban characteristics served as inputs for a Geographically Weighted Random Forest (GWRF) model, complemented by SHAP analysis, to evaluate their impact on LST. Moreover, different approaches to quantifying the extracted features via VFs were assessed.

The fine-tuned deep learning model effectively captured different urban features from the SV data, achieving high Intersection over Union (IoU) scores across the extracted classes: tree (IoU = 0.91), shrub (IoU = 0.76), grass (IoU = 0.83), building (IoU = 0.92), and sky (IoU = 0.99). The GWRF model proved effective at predicting LST, with good evaluation metrics for both training ($R^2 = 0.89$, MAPE = 2.10%) and test data ($R^2 = 0.87$, MAPE = 2.26%). SHAP analysis revealed that buildings had the strongest positive effect on LST at moderate to high VFs, with a clear non-linear trend. Conversely, trees had the strongest cooling effect under similar VF ranges. Shrubs had a moderate, yet more spatially distributed cooling effect, suggesting their potential in areas where space for large canopy trees is limited.

The use of a modified, fine-tuned network proved effective in improving classification results of the street view images. In future research, this approach can be extended with additional classes to investigate the influence of specific urban characteristics. The applied method, integrating GWRF and SHAP analysis, showed potential for studying the relationship with LST while considering spatial non-stationarity and non-linear effects. By applying this method to other case studies, its wider applicability in analysing the dynamics of LST can be evaluated. Such studies could reveal spatial trends and support urban planners and policymakers in effectively mitigating LST in urban environments.

Keywords: Physical Geography and Ecosystem Analysis; Google Street View, Semantic Segmentation, Deep Learning, Street Greenery, Urban Heat Modelling, Geographically Weighted Random Forest., Zurich.

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