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Unveiling urbanisation effects on trees outside forests dynamics along the urban-rural gradient in Bengaluru, India

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Abstract

Rapid urbanisation transforms urban-rural gradients, particularly in larger cities, shaping diverse landscapes through human activities. This dynamic affects the distribution and characteristics of urban trees, a subset of "Trees Outside Forests" (TOF), crucial for informed decision-making in urban planning, conservation, and sustainable land management. High-resolution satellite imagery is essential for comprehensive TOF monitoring, but accurately identifying individual trees remains challenging due to crown heterogeneity and spectral similarities with other vegetation. Deep learning, such as detection transformer models (DETR), offers new avenues for efficient and accurate TOF image analysis. In this study, we propose an end-to-end object detection approach for large-area tree detection based on a DETR architecture called DINO. we employed this tree detection approach and identified 1.3 million trees in a study area that covers the urban-rural gradient of Bengaluru, a megacity in India. Additionally, we developed an allometric equation to estimate DBH from the tree crown diameter as derived from the detected bounding boxes. Our study focused on analysing variations in tree density and tree size along this gradient. Comparative analyses highlight DINO's superior detection performance with a SWIN transformer backbone, achieving an F1 score of 74 % and an AP of 76 %, surpassing other models like Faster RCNN, YOLO, and other DETR variants. Further validation in Delhi and Shanghai demonstrated consistent performance of proposed tree detection approach, yielding F1 scores of 87 % and 73 %, respectively. The findings revealed distinct patterns: urban domains displayed larger tree crown diameters (mean CD: 8.87 m) and diameters at breast height (mean DBH: 43.78 cm) despite having the lowest tree density (32 tree per hectare). Furthermore, as distance from city centre increased, tree density showed an upwards trend, while the mean tree crown diameter and mean tree basal area decreased: there are clear differences of urban tree density and size between urban and rural domains in Bengaluru. This study offers a methodology that helps generating instructive insights into the dynamics of urban trees along the urban-rural gradient. This may inform urban planning and management strategies for enhancing green infrastructure and biodiversity conservation in rapidly urbanizing cities like Bengaluru.

Keywords: Deep learning, high resolution satellite imagery, trees outside forests, urbanisation

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