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Exploring active LiDAR and very high spatial resolution optical data in tree mapping

Simbarashe Jombo [a,*], Mohamed A.M. Abd Elbasit [b]

[a] *Department of Physical and Earth Sciences, School of Natural and Applied Sciences. Sol Plaatje University, Private Bag X5008, Kimberley, 8300, South Africa – simbarashejombo@gmail.com*

[b] *Risk and Vulnerability Science Centre, Sol Plaatje University, Private Bag X5008, Kimberley, 8300, South Africa – mohamed.ahmed@spu.ac.za*

* Corresponding author

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Abstract:

Urban green infrastructure offers various ecosystem services that are essential for the well-being of urban residents (Pu 2021). Trees in urban areas are particularly important as they reduce water and air pollution, provide shade and cooling, reduce energy consumption, and enhance the aesthetic value of the city (Jombo et al. 2022). However, the classification of tree species in urban environments is challenging due to the complexity and variability of urban features (Alonzo et al. 2014). The accurate mapping of urban tree species is necessary for understanding their distribution and extent, which is essential for managing urban tree species and creating sustainable urban environments (Pu and Landry 2020). Remote sensing technologies offer a more efficient and cost-effective alternative to traditional methods, such as field surveys and manual interpretation of aerial maps, which can be labour-intensive, time-consuming, and expensive (Wan et al. 2021). By using remote sensing technologies, such as LiDAR and optical data, urban tree canopy and species information can be obtained quickly, easily, and repeatedly (Michałowska and Rapiński 2021). This eliminates the need for extensive manual labour and reduces the overall cost of obtaining this vital information, making it a convenient option for researchers, cartographers, urban planners, and policymakers. Combining Light Detection and Ranging (LiDAR) data with optical data has been shown to significantly enhance the accuracy of mapping urban tree species (Hartling et al. 2019). This is due to the combination of textural and spectral information extracted from the optical data, along with the three-dimensional spatial information obtained from the LiDAR data (Wallace et al. 2021). LiDAR sensors utilize high-density pulses to scan objects on the ground and record the reflected light, enabling the generation of detailed and accurate three-dimensional representations of urban environments (Kelly and Di Tommaso 2015). In this study, we employed an extreme gradient boosting (XGBoost) algorithm to map urban tree species using LiDAR-derived normalized Digital Surface Model (nDSM), WorldView-2 (WV-2) imagery, and vegetation indices in the city of Johannesburg. The study aimed to determine the significance of nDSM, WV-2 bands, and vegetation indices in mapping urban tree species and to compare the accuracy of using WV-2 data alone and combining the three datasets. We selected a heterogeneous urban environment for our study to demonstrate the challenges of mapping urban trees in complex urban landscapes. We obtained a WV-2 image and LiDAR data for the study area and generated a normalized Digital Surface Model (nDSM) from the LiDAR data. In order to match the spatial resolution of the WV-2 image used in this study, a Digital Terrain Model (DTM) with a 2m spatial resolution was created by utilizing the ground points. The Inverse Distance Weighting (IDW) method, as described by Xiaoye (2008), was applied to produce the DTM. The Digital Surface Model (DSM) was transformed into a raster format utilizing first return data, with a 2m cell resolution. In this research, an nDSM was created by taking the difference between the DSM and DTM. It was assumed that each tree crown had an area of 3m², and the minimum height of a tree was 3m from the ground. To remove small features such as shrubs and grasslands from the urban tree species class, the study employed the values for crown size and height. The nDSM layer was utilized to display the highest points of reflective surfaces that were assumed to be tree canopies or building tops. Vegetation indices were used to differentiate tree canopies and building tops. We extracted vegetation indices from the WV-2 image and computed texture features from the nDSM. We then trained an XGBoost model to classify the tree species based on the input features. We evaluated the performance of the XGBoost model using a confusion matrix and calculated the overall accuracy, kappa coefficient, and F1 score. Our results highlight that the accuracy of mapping urban trees can be significantly improved by combining LiDAR and optical data. We achieved an overall accuracy of 89% using the WV-2 data alone and 95% on the combined dataset. The nDSM was the top-ranked variable with an F Score of 0.86, followed by the red edge vegetation index with an F Score of 0.70. The study provides valuable insights into the mapping of urban tree species using LiDAR and optical data. Our findings demonstrate that the combined dataset of LiDAR-derived nDSM, WV-2 imagery, and vegetation indices can significantly improve the accuracy of mapping urban trees in heterogeneous urban environments. The study highlights

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the importance of accurate tree species maps in managing urban tree species and creating sustainable urban environments. This knowledge is also relevant to tree planting initiatives, and it can motivate local governments to purchase high-point-cloud LiDAR data for urban tree management. Urban tree mapping is important to cartographers because it provides information about the distribution and extent of tree species in urban environments. This information can be used to create detailed maps that show the location, size, and species of trees in different areas of the study area. Cartographers can use this data to create thematic maps that show the spatial patterns of different tree species and help identify areas that require more green space or where trees are at risk due to urban development or other factors. By understanding the distribution and characteristics of urban tree species, cartographers and urban planners can make informed decisions about tree planting initiatives, green space development, and other urban planning activities that contribute to improving the quality of life in urban areas. This can include reducing urban heat island effects, mitigating air pollution, and providing other ecosystem services that support human health and well-being. Overall, urban tree mapping is an important tool for cartographers to create more accurate and detailed maps of urban environments, and to help guide sustainable urban development policies and initiatives.

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