Enhancing Urban Climate Modeling through 3D Quantification of Greenspace using LiDAR and Generative AI

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Abstract

Urbanization has led to adverse microenvironment conditions, materialized through the Urban Heat Island (UHI) effect and the deterioration of air quality. This study explores the relationship between urban greenspace and these urban microclimate factors, focusing on the need to accurately quantify the three-dimensional (3D) aspects of urban greenspace to better comprehend its influence. We selected Prospect Park in Brooklyn, New York, for our investigation due to its extensive field-measured tree forestry data. Our goal was to construct a detailed 3D model of tree crowns in Prospect Park using LiDAR (Light Detection and Ranging) technology. To achieve this, geometric-based classification algorithms combined with tree segmentation algorithms were used to segment and delineate trees from the LiDAR capture. Generative A.I. was utilized to reconstruct tree canopies to estimate tree crown volume. This improvement enabled us to gain a more precise understanding of vegetation distribution and structure in Prospect Park. Importantly, the developed model can be extended to other urban parks, facilitating a comprehensive assessment of their ecological services. Our approach improved upon traditional satellite remote sensing, which lacks the necessary resolution to describe detailed tree crown structures. Additionally, while field surveys provide valuable data, they can be time-consuming and expensive. By leveraging LiDAR technology and advanced algorithms, our model enhanced the accuracy and efficiency of mapping tree crowns in urban green spaces. This approach provided us with a more precise understanding of the distribution and structure of vegetation within Prospect Park, and also generated a valuable new dataset that can be integrated into air purification and Urban Heat Island (UHI) models. This dataset can inform and improve decisions related to the preservation, management, and future design of urban greenspaces, ensuring their continued enhancement and the optimization.

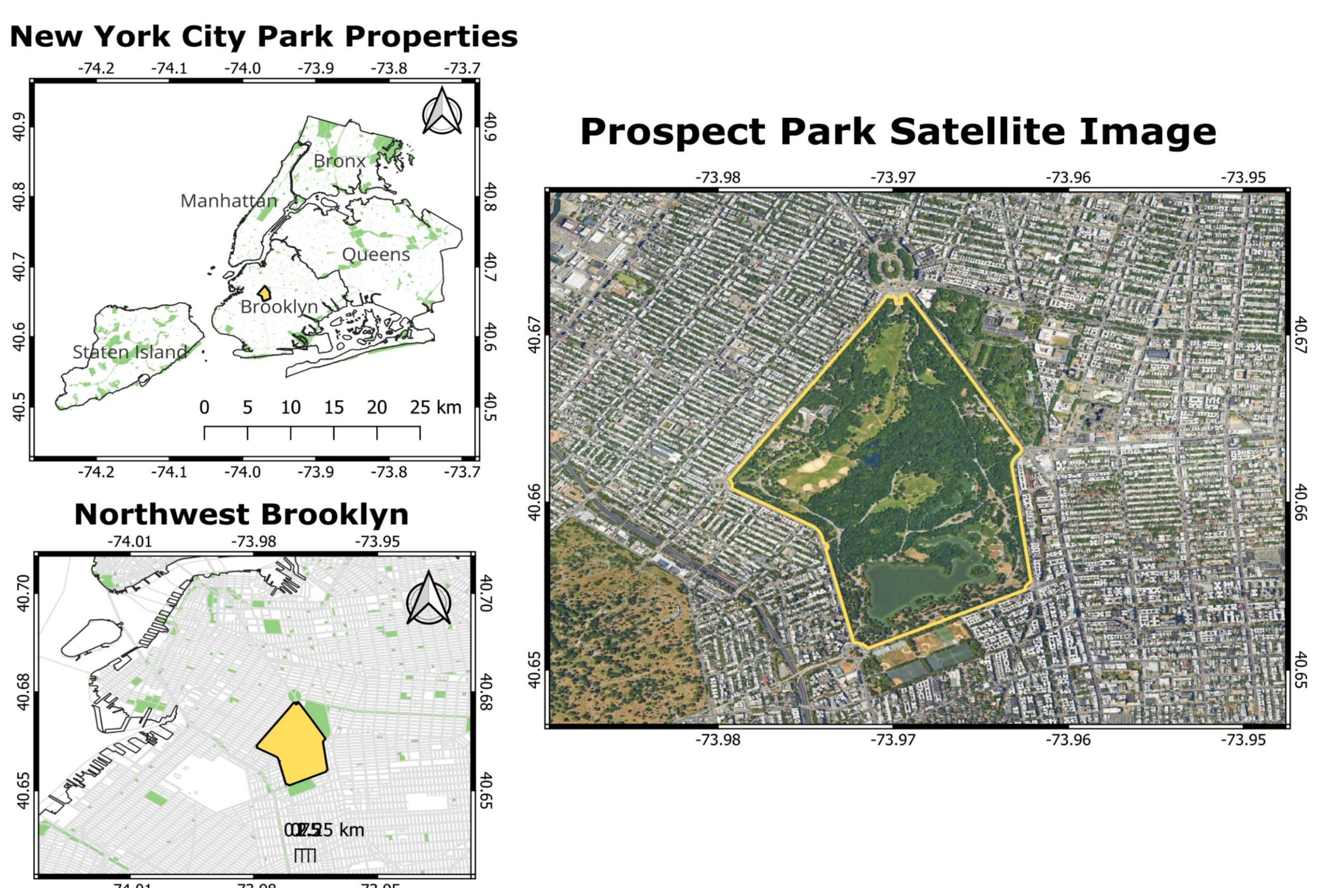

Figure 1 Study Area

Methods

Our study area was Prospect Park in Brooklyn, New York. Situated within a densely populated urban environment, the park's location holds significance as it provides an opportunity to assess the ecological benefits it offers to the surrounding community. Encompassing an expansive 585 acres, Prospect Park harbors a diverse collection of approximately 30,000 trees belonging to over 175 distinct species (Prospect Park Alliance 2022). This diverse tree population plays a crucial role not only in enhancing the park's aesthetic appeal but also in creating essential habitats for various wildlife. Furthermore, the Prospect Park Alliance's meticulous tree survey in 2018, covering around 12,000 trees, yields valuable data for this study.

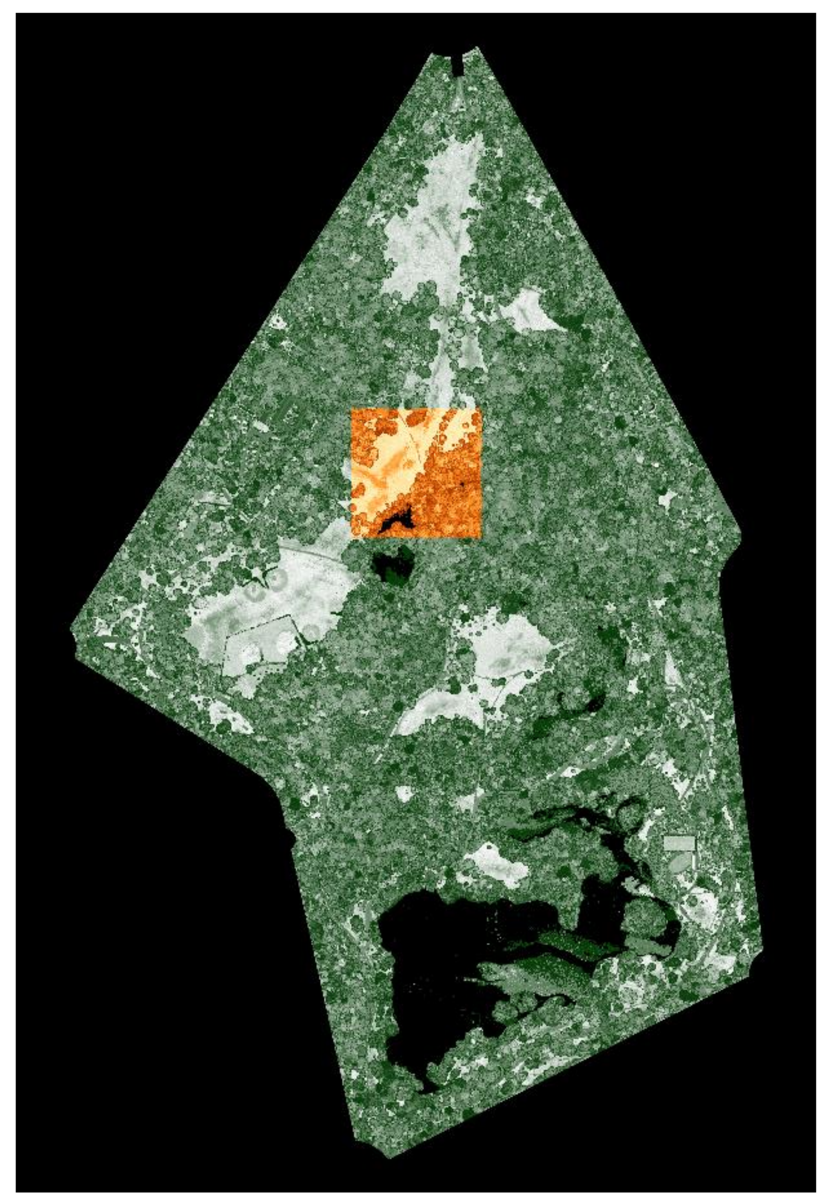

Figure 2. Prospect Park LiDAR Data Return Intensity with study sample highlighted

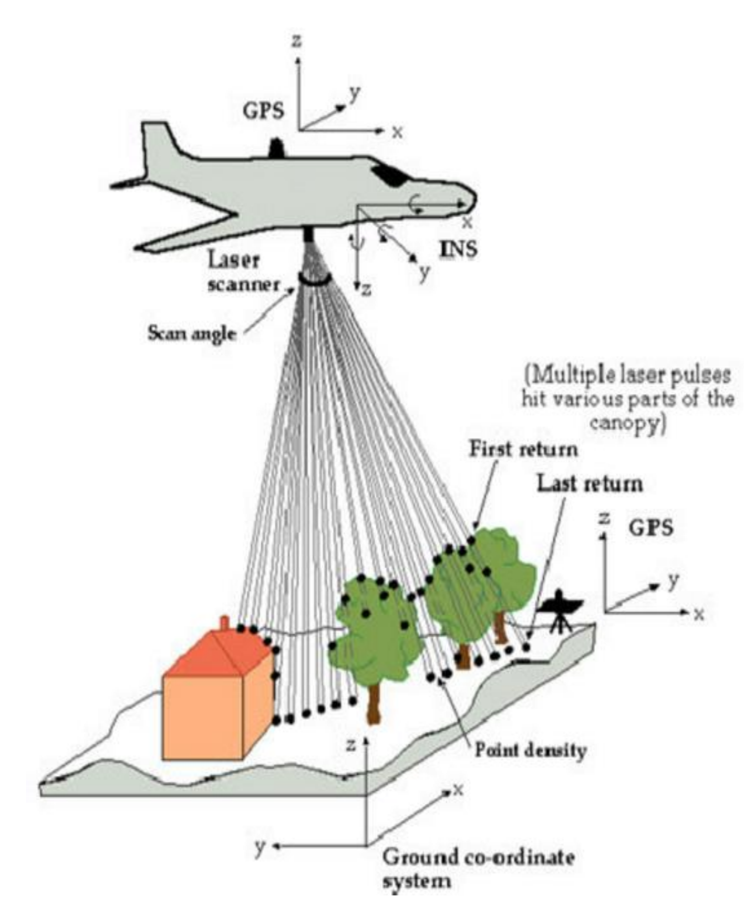

Figure 3. Diagram of Airborne Laser Scanning (Dowman, n.d.)

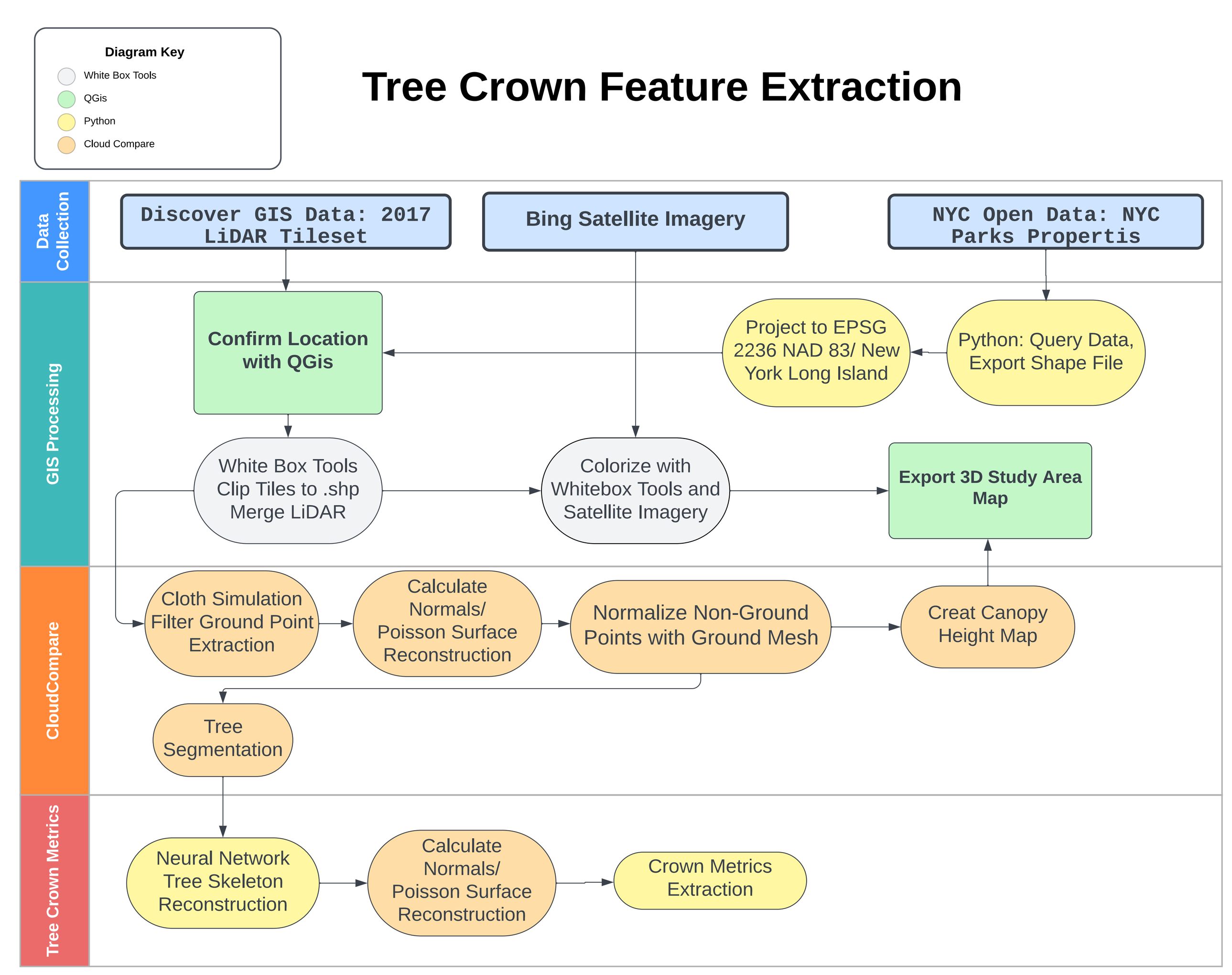

Figure 4. Data Analysis Flow Chart

Results

The Cloud Compare-generated model efficiently computes canopy height by filtering first returns within the point cloud and normalizing them to the ground mesh for relative height assessments. This process has enabled the creation of a crucial canopy height model that holds potential for diverse applications, such as tracking forest growth, simulating shade tree impacts on urban heat models, and aiding in biodiversity assessments. Furthermore, the digital terrain model (DTM) produced through this approach provides a valuable resource for comprehensive analysis of the study area. The integration of LiDAR technology and advanced algorithms has significantly improved the accuracy and efficiency of mapping tree crowns and canopy structures in urban green spaces.

Future Work

Segmentation of individual trees from the point cloud is still ongoing. This task is critical for obtaining precise information about tree distribution and density. Graph based segmentation algorithms are being explored and have shown potential in previous research (Strimbu & Strimbu, 2015; Jiang et al., 2023). As the implementation of neural networks for more advanced analysis progresses, the establishment of an appropriate and diverse training dataset required. Drawing inspiration from past studies, the investigation of synthetic datasets and the potential utilization of terrestrial laser scanning (TLS) point clouds hold promise in enhancing the training process (Bryson et al., 2023). The incorporation of fieldwork data into the training model is anticipated to contribute significantly to its refinement, further improving the accuracy and robustness of the developed techniques.

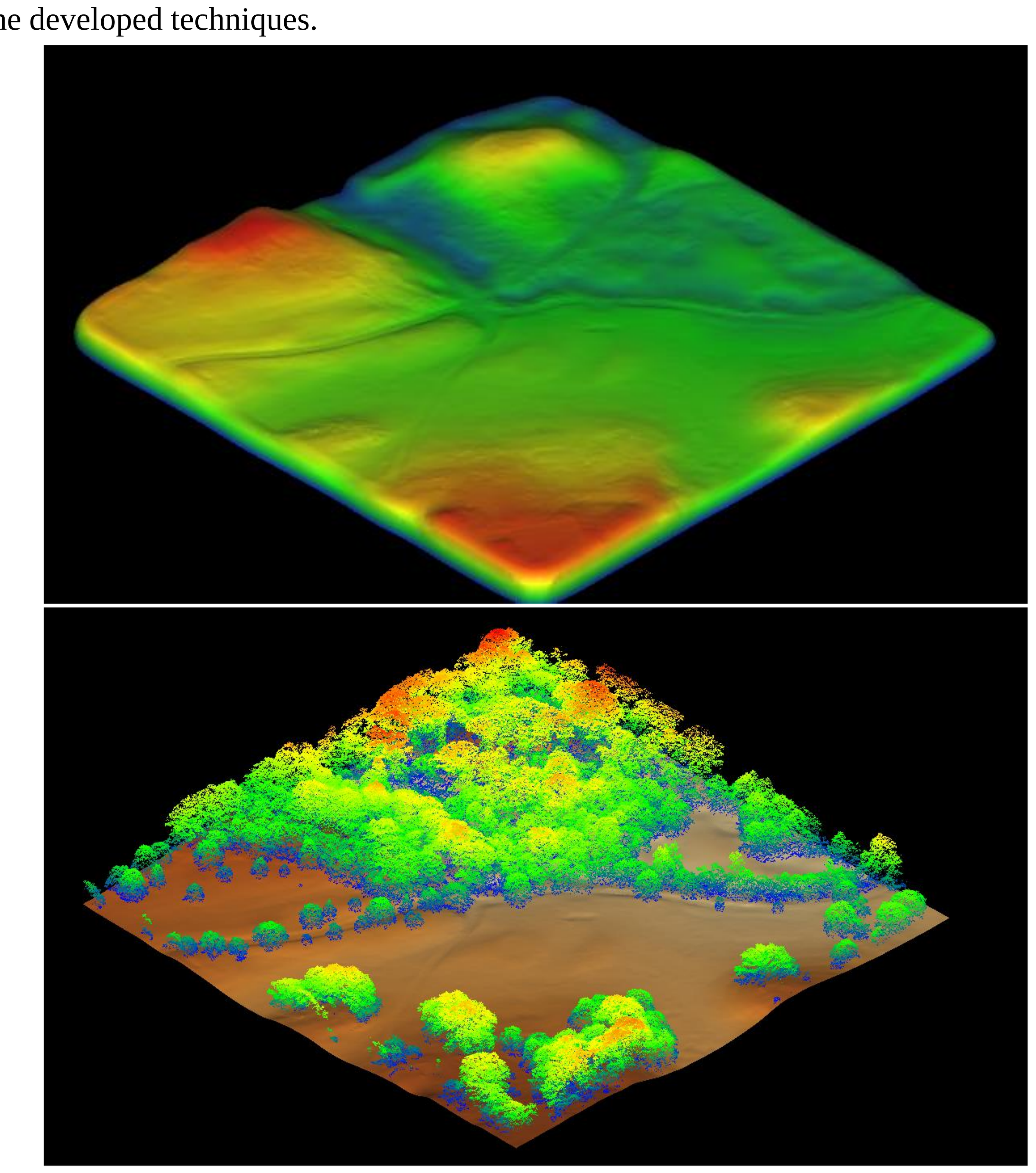

Figure 5. Poisson Surface Reconstruction and Normalized Canopy Height Map Prospect Park

Conclusion

The detailed 3D representation of urban trees is invaluable for modeling urban heat, hydrological processes, and air purification. This data integrates into models that simulate temperature changes, stormwater control, and pollutant spread. Additionally, machine learning can enhance tree crown features in ALS data, expanding forest analysis. Scaling individual tree metrics to whole forest systems enables a holistic view of ecological dynamics, biomass distribution, and canopy interactions. This synergy of LiDAR and machine learning can propel urban ecology analytics, empowering thorough environmental planning for sustainable urban growth.

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