A GIS-based Automated Mapping of Greenville's Heritage Trees and Potential Applications

Jack Buehner* and Dr. Suresh Muthukrishnan

*Undergraduate Student, Department of Earth, Environmental, and Sustainability Sciences, Furman University, Greenville, SC 29613

References & more

Abstract

Trees play a vital role in carbon storage on a global scale, but they also contribute important benefits at the local scale. In urban areas, trees provide ecosystem services that benefit cities, including urban heat island mitigation, air and water pollution reduction, and runoff and flash flooding reduction. The City of Greenville in South Carolina recently passed an ordinance to protect trees on properties with newly permitted developments, including a special emphasis on protecting and encouraging larger, "heritage" trees, despite not having an existing database of protected trees throughout the city. The focus of this research is to use an automated tree detection algorithm to map trees along the streets of the entire city to help protect and monitor the trees and to more equitably enforce the ordinance. LiDAR data and GIS modeling approaches were used to detect individual tree locations and heights throughout the entire city to build an initial database. Multispectral imagery and building geometry data were also used in the process to minimize objects in unvegetated areas from being misclassified as trees. The results show that the automated tree detection algorithm worked well where trees were relatively smaller and separated at the canopy level, but deciduous trees with larger canopy structures were often classified as multiple trees. Field verification is necessary to correct some of these discrepancies. Results from this work can be used to understand the social and environmental inequalities related to green spaces and canopy cover and can drive more data-driven urban trees management strategies.

Background & Objectives

Trees provide numerous advantages in urban areas because of the multitude of benefits they provide, especially with respect to the management of stormwater runoff and catchments, urban heat islands, air pollution, water pollution, soil pollution, and carbon sequestration.

- **Stormwater runoff:** Urban trees retain an average of 18.3% of stormwater but can sometimes retain as much as 43.7%. Trees planted along bioswales can capture 46-72% of the runoff. [10, 5].
- **Water pollution:** Urban trees reduce water pollution by absorbing nitrate, phosphate, sulfate, carbon, and heavy metals from the water. Trees capture excess turf grass fertilizer [5, 3].
- **Heat & carbon:** Trees intercept 25-90% of short-wave radiation. Urban trees also provide cooling via evaporation. Temperatures can be up to 40°C cooler compared to unshaded, paved surroundings. Cities that prioritize trees with higher carbon sequestration can receive the benefits of reduced temperatures in addition to contributing towards carbon sequestration [10, 1, 5, 12].

The **City of Greenville in South Carolina** has established the TreesGVL program, through which it commits to:

- Plant 1000 trees each year in public parks and rights-of-way, funded by the City Tree Fund Foundation, and
- Conduct a multi-year public awareness campaign on the many benefits of trees to help inform people of the value of trees in an urban landscape outside of air quality and shade.

In addition, the City of Greenville recently passed a tree ordinance that adds restrictions for the removal of trees, including special restrictions and fines for the removal of large trees that are classified as "heritage trees" [10]. Greenville is currently working to incrementally create a database of trees using the TreePlotter software, which requires each tree to be manually added in the field. To assist in this process, we used airborne LiDAR and multispectral aerial imagery in a GIS system to detect and map points representing individual tree crowns based on the elevation of the returned LiDAR points [13, 8, 4, 9, 2].

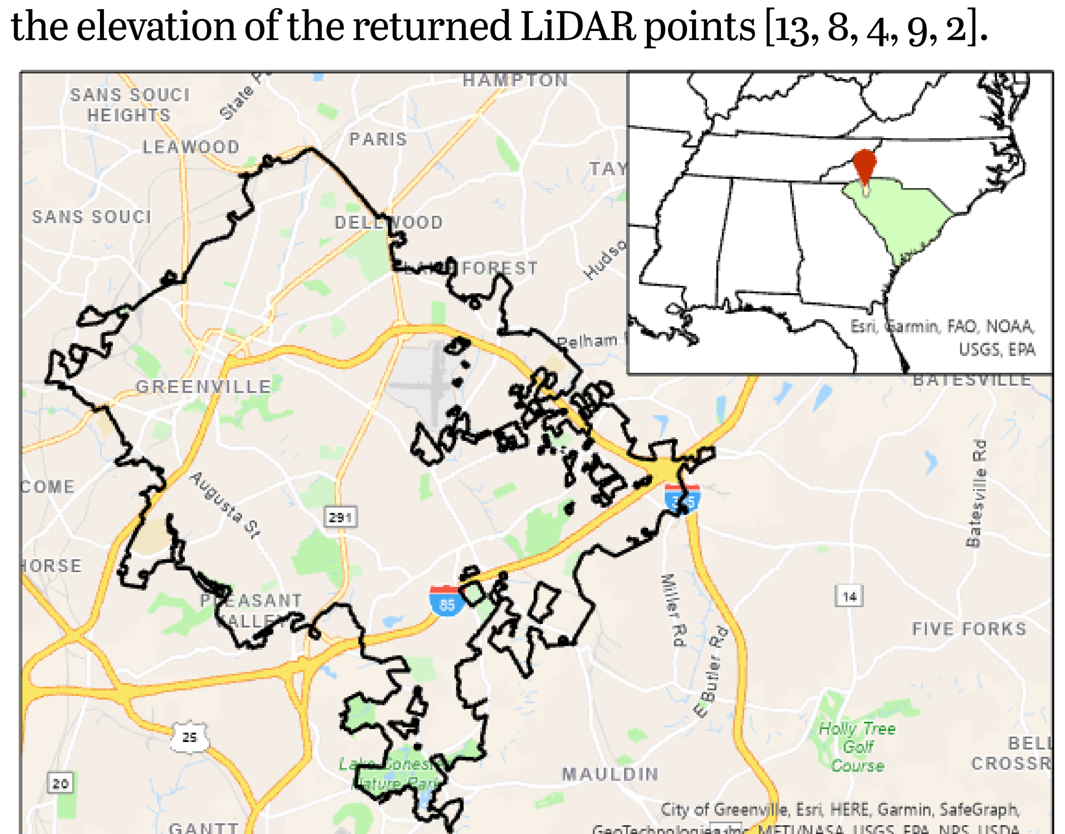


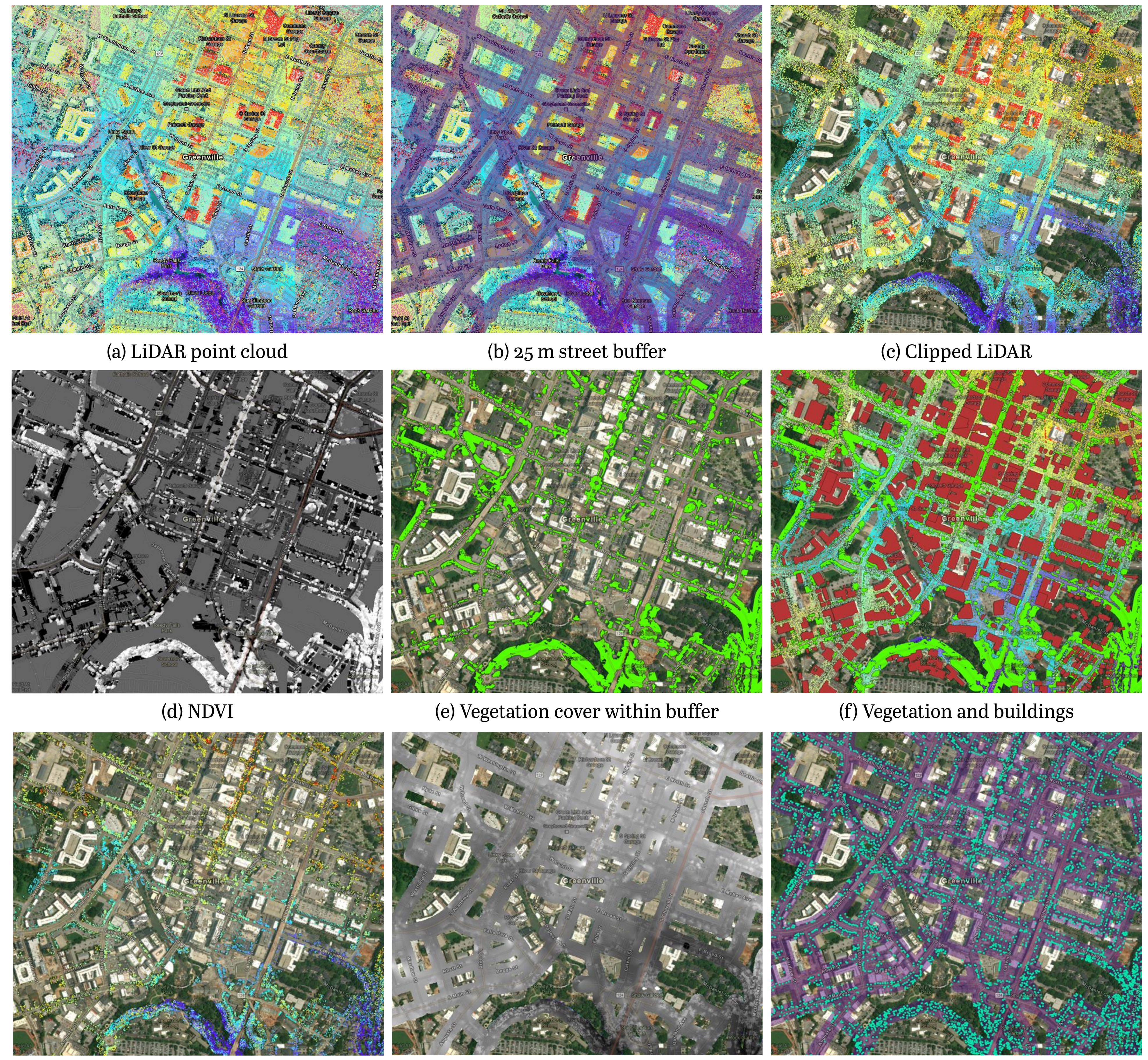
Figure 1 (left). Location of the City of Greenville in Greenville County, South Carolina.

The objectives of this project include:

- Create a city-wide database of tree locations and heights as a baseline dataset to help the city implement Heritage Trees ordinance.
- Examine tree distribution across the city with a focus on social and environmental equity.

Methods & Key Findings

The ForestTools R package [7] was used to detect the locations of trees using a digital surface model (DSM) generated from the LiDAR point cloud data. Before generating the DSM, the LidR R package [11] was used to remove buildings, non-vegetated areas, and planar points from the point cloud to improve detection accuracy. The Normalized Difference Vegetation Index (NDVI) calculated from high resolution multispectral imagery was used to separate vegetated areas from unvegetated areas. The details of methodology, including Python and R code and a set of ArcGIS Pro toolboxes, is publicly available at github.com/jackbuehner/treetools.



(a) LiDAR point cloud; (b) 25 m street buffer; (c) Clipped LiDAR; (d) NDVI; (e) Vegetation cover within buffer; (f) Vegetation and buildings; (g) Filtered LiDAR; (h) DSM; (i) Detected trees

Figure 2 (left). A visual representation of the steps involved in each major stage of preprocessing and processing for the tree detection process, demonstrated in subfigures (a) – (i)

- A total of 42,074 trees were detected and mapped in the city
- Detected tree points are being verified using wintertime aerial imagery, multispectral imagery, Google Street View, and in-situ observation.
- Results are stored in an editable ArcGIS Online web map and field verification is being carried out using ArcGIS Field Maps.
- Two major challenges were: (a) failure to detect smaller trees when they are completely underneath a larger tree, and (b) large trees with an unusual canopy shape were often misinterpreted as multiple trees.
- A public, non-editable web map and a trees dashboard will be made available in the future.

Figure 3 (above). Detected trees (42,074 in total for the whole city) in downtown Greenville at the intersection of Main Street and McBee Street. Shades of red in the false-color basemap indicate vegetation.

Challenges

False tree detection: Initial field verification shows that the algorithm tended to overcount rather than undercount, with more of the errors being false positives. This likely occurs due to the abundance of large deciduous trees in Greenville. Large deciduous trees have unpredictable, non-uniform canopy shapes that can cause individual large branches to be misinterpreted as distinct trees.

LiDAR limitations: The point density of the LiDAR data provided by Greenville County is not as high as it could be for improved tree detection. For Greenville's 2020 LiDAR data, the point spacing is 2.6 ft. In addition, the LiDAR data provided by Greenville County was collected in the winter, which means deciduous trees did not have leaves. Though this helps in cadastral applications, the ability to clearly delineate the top of the tree canopy and calculate height suffers since most laser points do not hitting the exact top of the canopy. This results in fewer returns that represent higher-level branches of the tree.

Next Steps

Accuracy assessment: The overall accuracy of tree detection is currently in progress. Randomly selected sample regions in city are currently being evaluated for accuracy.

Environmental and social justice: The total count and spatial distribution of trees in different census block groups will be evaluated to understand identify any inequity in tree cover and to produce recommendations for the city and the TreesUpstate organization to address the inequity.

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