Mapping Greenville's Trees Using Remote Sensing and GIS Techniques

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References & more

Background & Objectives

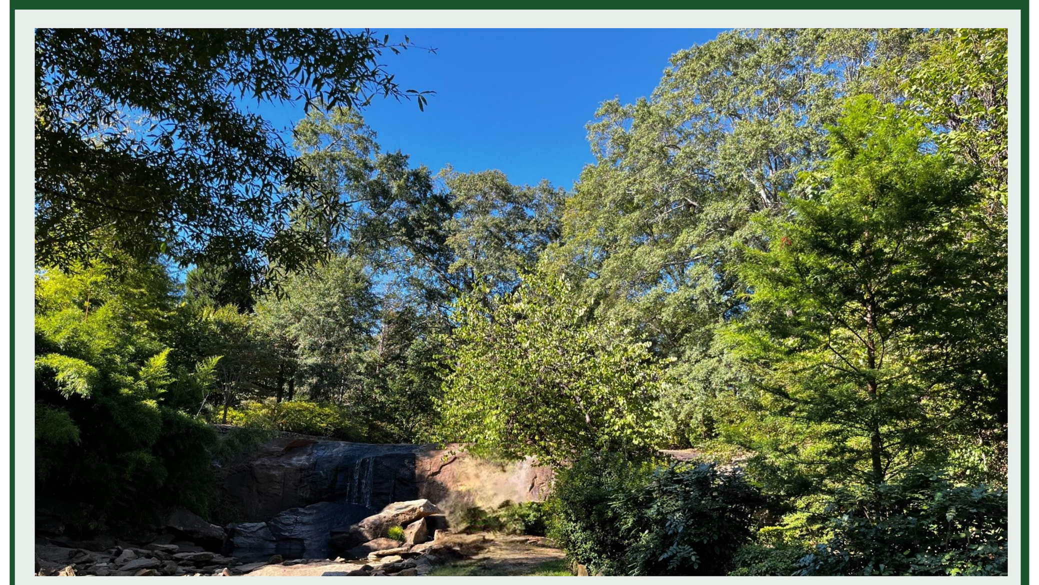
Trees provide numerous advantages in urban areas because of the multitude of benefits ("ecosystem services") they provide, including urban heat island mitigation, air and water pollution reduction, and runoff and flash flooding reduction.

- **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[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[10, 1, 5, 12].

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 the Heritage Trees ordinance.
- Examine tree distribution across the city with a focus on social and environmental equity.

Greenville Trees



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].

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, unvegetated 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.

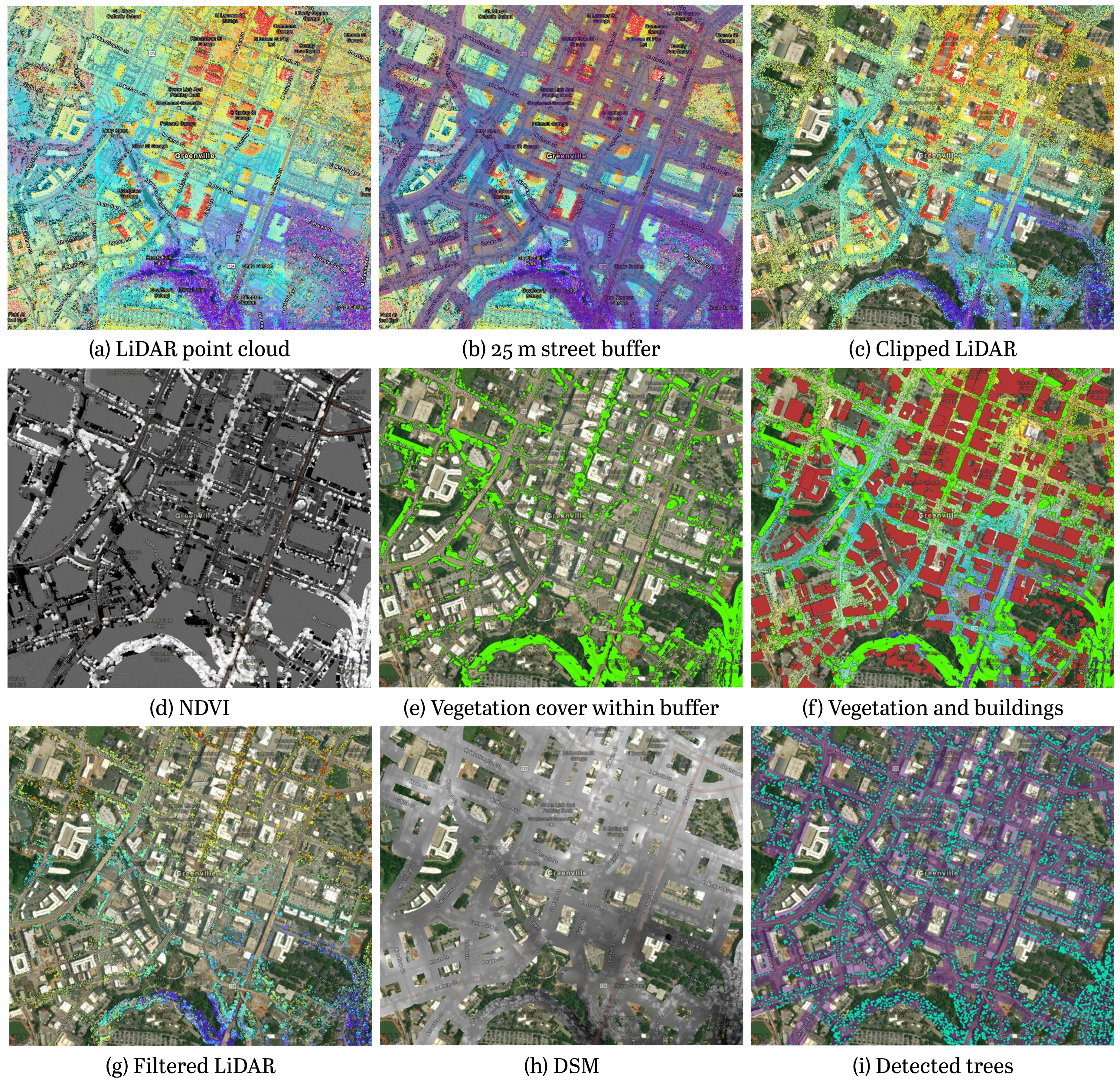


Figure 1 (left). A visual representation of the steps involved in each major stage of preprocessing and processing for the tree detection process, demonstrated in subfigures (a) – (i)

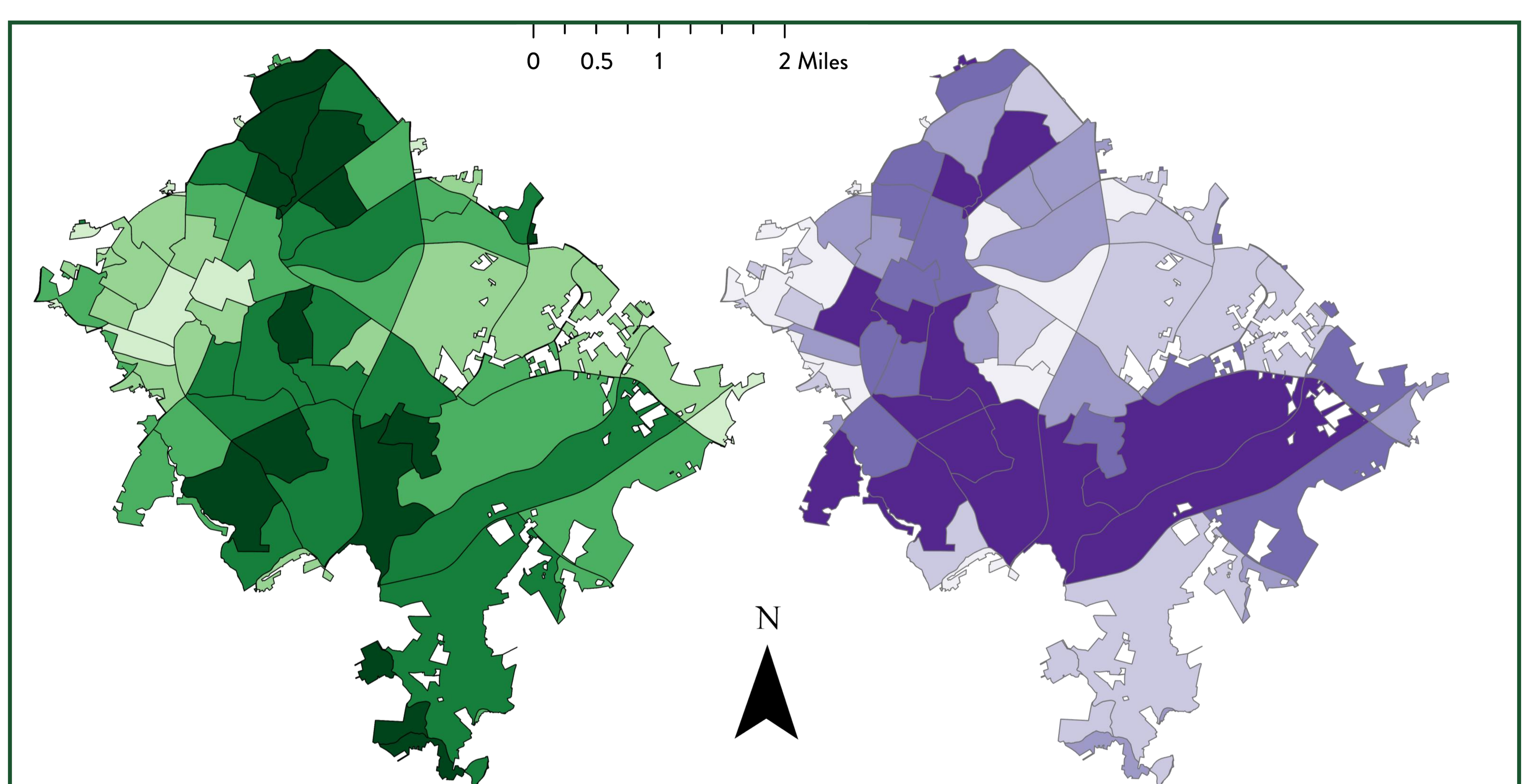
- A total of 42,074 trees were detected and mapped in the city
- Detected tree points are being verified using wintertime aerial imagery, multispectral imagery, Google Street View, and in-situ observation.
- Results are stored in an editable ArcGIS Online web map and field verification is being carried 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 2a (below left). Percent tree/vegetation coverage for each census block group. Darker shading indicates more coverage. Block groups were evenly divided into each classification range.

Legend: *0.0%-15.8%* *15.8%-23.5%* *23.5%-37.2%* *37.2%-46.4%* *46.4%-83.4%*

Figure 2b (below right). Aggregate household income for each census block group per household. Aggregate income for the entire census block group was divided by the number of households. Block groups were evenly divided into each classification range.

Legend: *$ 20k-48k* *$ 48k-61k* *$ 61k-81k* *$ 85k-140k* *$ 140k-360k*



Challenges

False tree detection: Field verification shows that the algorithm tended to overcount rather than undercount, with more of the errors being false positives. This likely occurred 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 high enough for accurate 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 pulses do not hit the exact top of the canopy. This results in fewer returns that represent higher-level branches of the tree.

Figure 3 (above). Selected examples of detection errors. Shades of red in the false-color base map indicate vegetation. Green points indicate true positives, purple points indicate false positives, and blue points indicate false negatives. Areas of interest are outlined.

Acknowledgements

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