Tree Canopy in Cambridge, MA: 2009-2014

Summary

The University of Vermont Spatial Analysis Lab includes some of the world's foremost experts in urban tree canopy mapping. The lab has carried out a number of high-resolution tree canopy projects throughout North America. Tree canopy in Cambridge is a vital asset that provides ecosystem services such as reduced stormwater runoff, improved air quality, habitat for wildlife, and enhanced quality of life. Although tree canopy for Cambridge has been mapped before, the 2009 to 2014 tree canopy change dataset represents the most accurate accounting of tree canopy ever done for this location. For Cambridge to effectively manage its tree canopy, and to enact policies and initiatives to ensure that a robust urban forest exists for generations to come, a comprehensive understanding of its tree canopy is vital. Through high resolution imagery and LiDAR it was determined that a 2% decrease in tree canopy cover has occurred between 2009 and 2014.

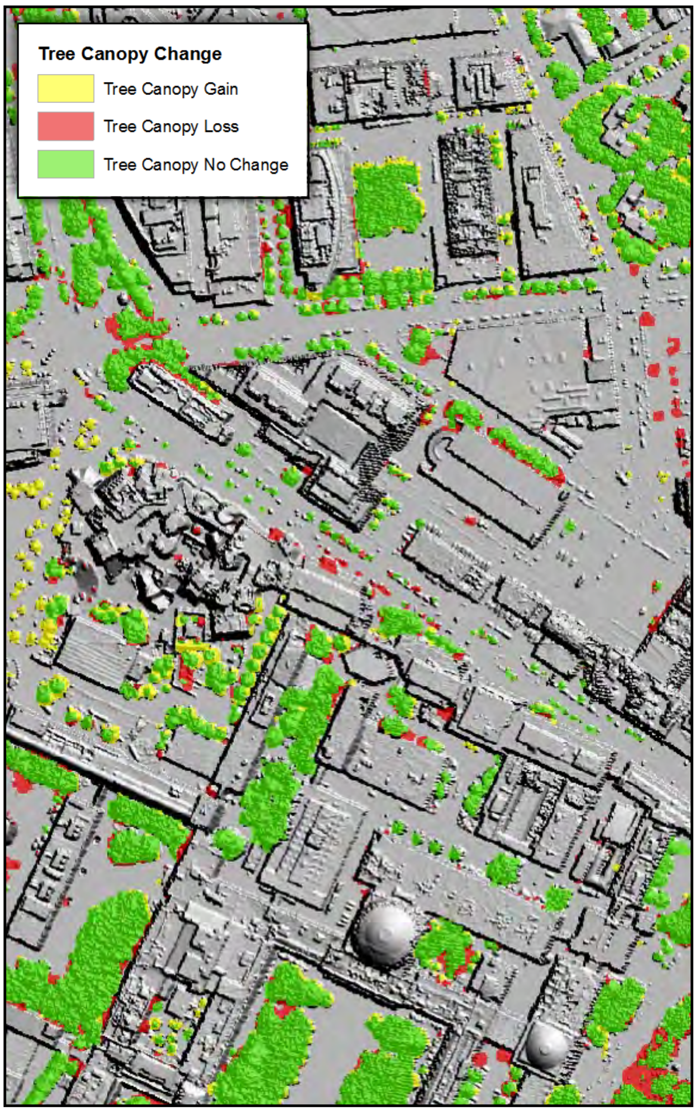

Figure 1: Example of the tree canopy change derived from LiDAR for this project.

Why is Tree Canopy Important?

Trees provide many benefits to communities, such as improving water quality, reducing stormwater runoff, lowering summer temperatures, reducing energy use in buildings, reducing air pollution, enhancing property values, improving human health, and providing wildlife habitat and aesthetic benefits. Many of the benefits that trees provide are correlated with the size and structure of the tree canopy which is the layer of branches, stems, and leaves of trees that cover the ground when viewed from above. Therefore, understanding tree canopy is an important step in urban forest planning. A tree canopy assessment provides an estimate of the amount of tree canopy currently present as well as the amount of tree canopy that could theoretically be established. The tree canopy products can be used by a broad range of stakeholders to help communities plan a greener future.

Project Partners

This project applied the USDA Forest Service's Tree Canopy Assessment protocols to Cambridge. The analysis was conducted using LiDAR data that was acquired in 2009 and 2014. The Spatial Analysis Laboratory (SAL) at the University of Vermont's Rubenstein School of the Environment and Natural Resources carried out the assessment in collaboration with the USDA Forest Service and the

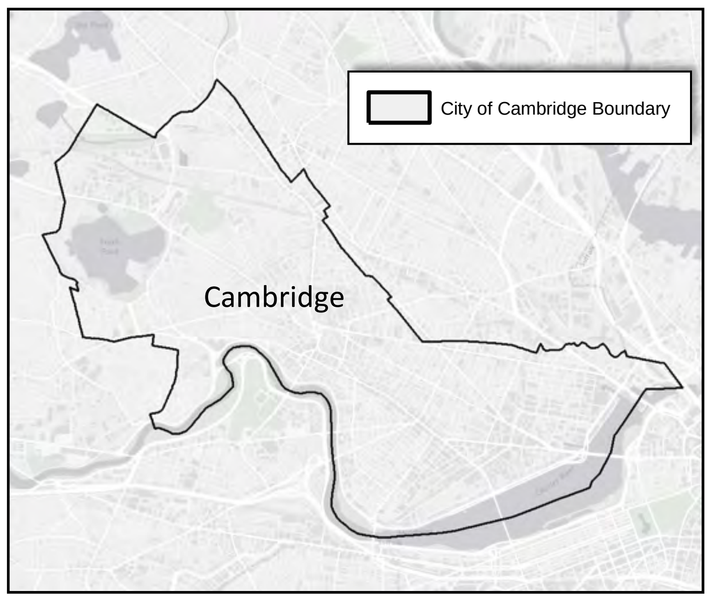

Figure 2: Study area for this project, which is the full city of Cambridge

Key Terms

Tree Canopy: Tree canopy (TC) is the layer of branches, stems, and leaves of trees that cover the ground when viewed from above.
Gain: New tree canopy added over the 2009-2014 time period.
Loss: Tree canopy that was lost/removed in the 2009-2014 time period.
No change: Tree canopy that has remained unchanged from 2009-2014.

How much did Tree Canopy Change Between 2009 and 2014?

Cambridge had an overall decrease in tree canopy cover of about 2% (as a percentage of land cover). Tree canopy losses totaled approximately 200 acres, which was offset to a limited degree by the addition of half as much new tree canopy. Losses resulted primarily from an incremental, citywide erosion of tree canopy. These broadly distributed tree canopy losses were greatest in East Cambridge and in northern, central areas of the city. A few larger removals were an exception to this pattern, most noticeably in the North Point area of East Cambridge, where there were also tree canopy gains, and in the riparian area west of Alewife Station in North Cambridge.

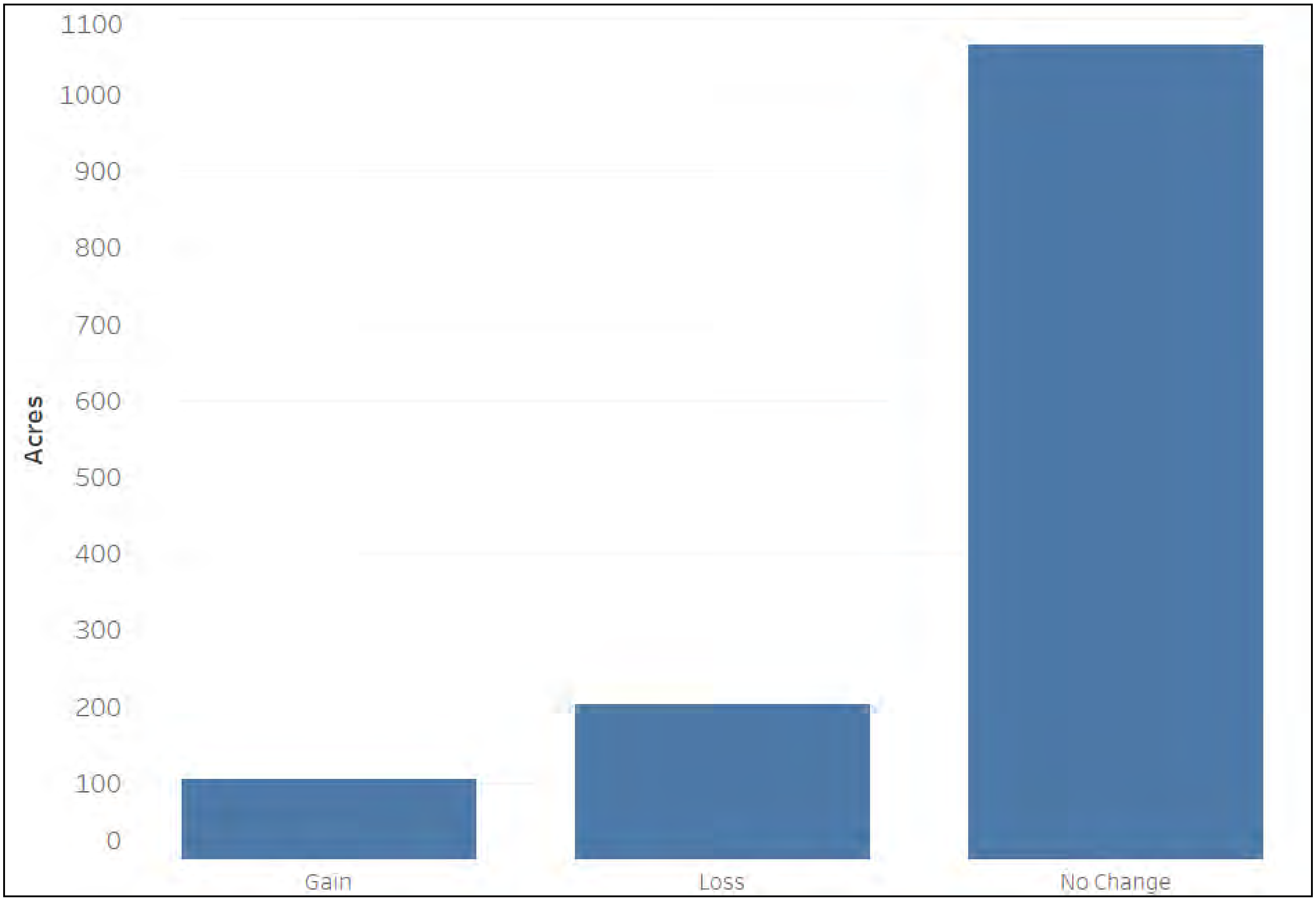

Figure 3: Area (acres) of Tree Canopy gain, loss, and no change in Cambridge.

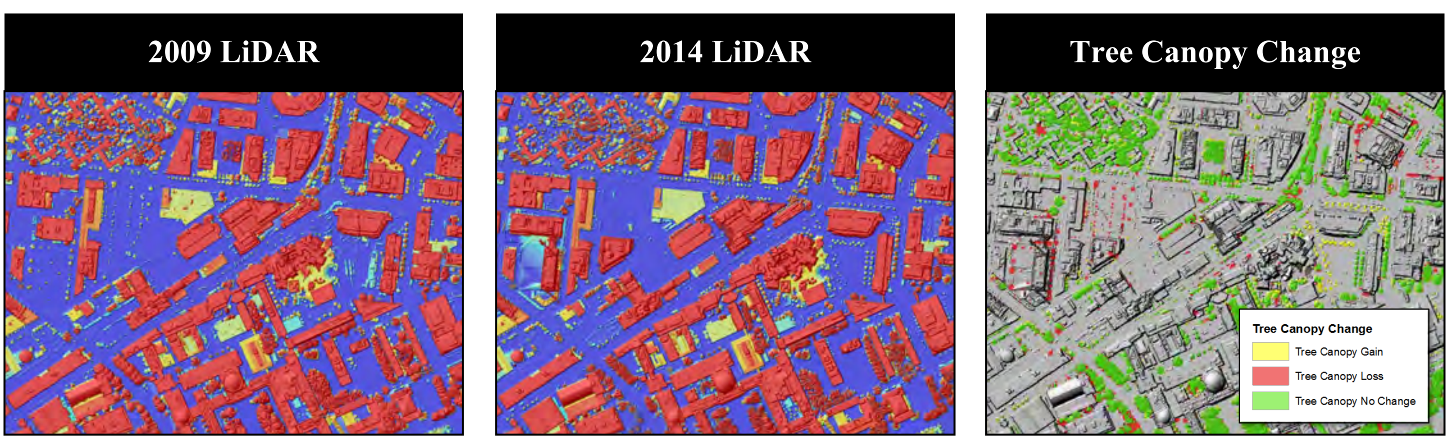

Figure 4: Tree canopy change in Cambridge showing tree canopy loss in red, tree canopy gain in yellow, and no change in green.

How was the Tree Canopy Change Mapped?

Methods

Two distinct but complementary remotely sensed datasets were the primary sources for tree canopy mapping. LiDAR (light detection and ranging) data acquired under leaf-off conditions in 2009 and 2014 was provided by City of Cambridge (Figure 4A). LiDAR has the advantage that it is extremely accurate and provides 3D measurements, which are particularly useful in separating tree canopy from shrubs. Leaf-on imagery acquired in 2016 was obtained through the USDA National Agricultural Imagery Program (NAIP; Figures 4B and 4C). While slightly less accurate than the LiDAR, this imagery has the benefit of providing spectral information that is useful in separating vegetated from non-vegetated surfaces. LiDAR was the primary source of tree canopy change, with NAIP imagery serving as a supplementary dataset to provide contextual awareness.

Tree canopy was mapped via a semi-automated approach. In the first phase, tree canopy was automatically extracted from the LiDAR and imagery datasets using artificial intelligence. This involved using segmentation algorithms to create objects (polygons) from LiDAR and imagery, assigning the objects to the appropriate land cover class (e.g. tree canopy) using properties from LiDAR and imagery, then refining the objects to improve the cartographic appearance.

Following the automated extraction, a team of highly trained image analysts reviewed the tree canopy at the scale of 1:2000. Any observable errors were corrected and incorporated into the final tree canopy output. Manual corrections consisted of both a detailed review by an individual analyst and then a secondary review by a supervisor.

Results

This five year tree canopy change dataset represents the most accurate accounting of tree canopy change ever done for Cambridge, with trees as small as eight feet in height mapped (Figure 3D). Datasets are suitable for summarizing the area and percent area of tree canopy down to the individual property parcel level. Previous projects have mapped tree canopy within Cambridge, but as this project benefitted from a combination of superior source data and methodologies, any comparisons between the various tree canopy datasets are not valid. Of particular note is the fact that prior estimates of tree canopy should not be used to draw conclusions with respect to changes in tree canopy over time. This dataset will serve as the foundation for tracking tree canopy changes over time for the City of Cambridge.

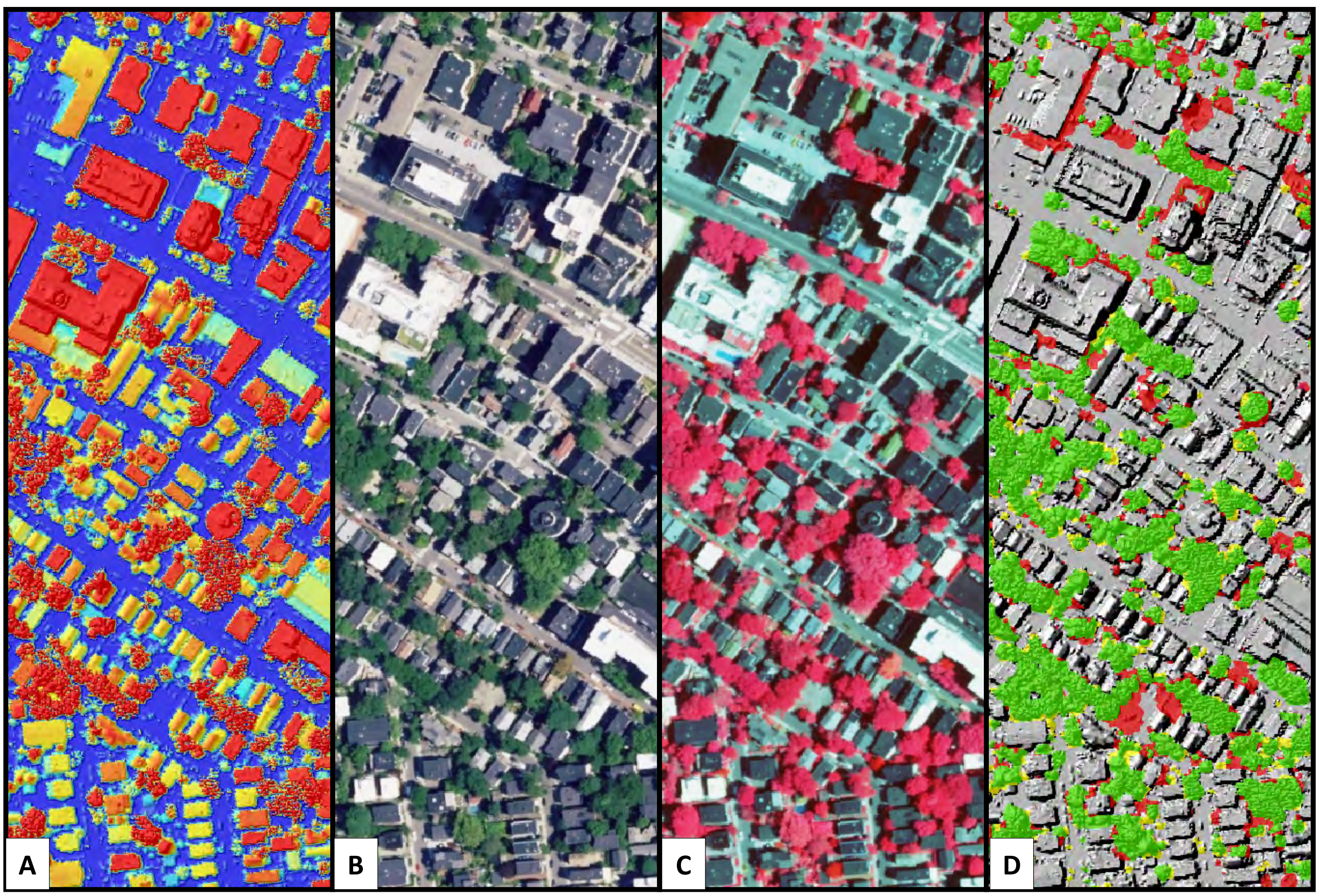

Figure 4: Example of the input data used to extract tree canopy change data. LiDAR is on the left, then true color imagery, Color Infrared Imagery, and then the tree canopy change data on the right.

How are Tree Canopy Change Metrics Calculated?

Methods

Tree canopy metrics are generated using the USDA Forest Service's tree canopy metrics tool (Figure 5). This GIS operation takes input geographies, or polygons, such as property parcels and Census tracts and computes the amount of relative percent change, absolute percent change, and change in area for each geography.

Relative percent change is the difference in tree canopy over two periods while taking into account the original percent cover of a geography. The absolute change is simply the difference in tree canopy over two periods in time. Absolute change shows where in the city tree canopy has changed the most, while relative change shows how tree canopy is affected within a geography.

Results

Figure 6 shows an example of the Tree Canopy change metrics computed at the 250 feet x 250 feet grid level. The grid boundaries (top, black lines) represent the geographical units. The relative change percent (middle) is the relative percentage of tree canopy change in each grid. This was computed at the grid level by subtracting current tree canopy cover by the original tree canopy and then dividing by the original tree canopy. The absolute change (bottom) indicates the difference in tree canopy between 2009 and 2014. Summarizing the information by various units of aggregation, from the grid level to the Census tract level, enables the data to be used for everything from targeted tree planting to exploring issues of environmental equity.

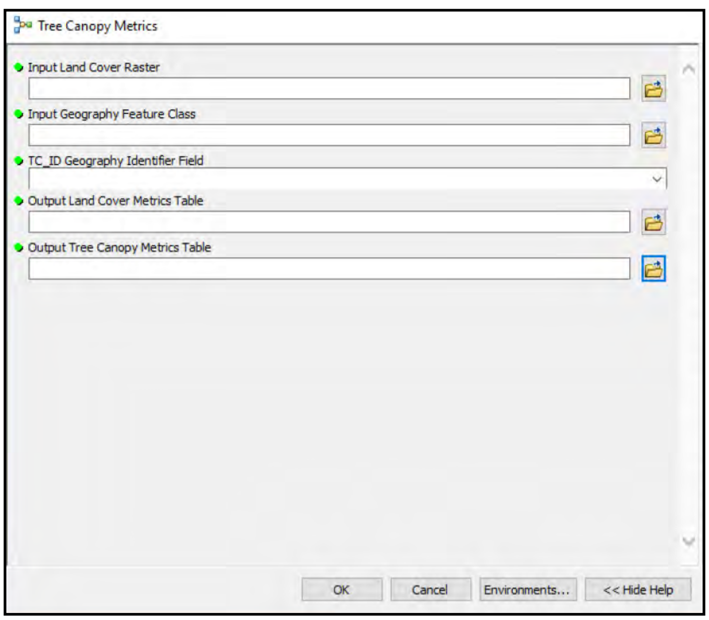

Figure 5: Graphical user interface for the tree canopy metrics tool. The tree canopy metrics tool is an ArcGIS-based geoprocessing model that summarizes tree canopy information based on the input polygon boundaries

Figure 6: 250 feet (ft) x 250 ft grid-based tree canopy change metrics.

How has Tree Canopy Changed in Each Census Block Group?

Tree canopy relative percent change and absolute percent change were summarized for each Census Block Group in Cambridge (Figure 7 and Figure 8).

Of 88 groups, only 8 had relative tree canopy gain. Of these groups where tree canopy increased, only one group increased tree canopy by more than 6%. An East Cambridge group at North Point Park experienced the largest gain of tree canopy at 47%.

80 groups experienced relative tree canopy loss. A group behind the MBTA Maintenance Facility in Somerville had the most tree canopy loss at 34%. 46 groups experienced less than 10% tree canopy loss.

80 Census Block Groups also experienced absolute tree canopy loss, although every group had less then 8% loss.

Eight groups also had absolute tree canopy gain, although all gains were less than 2%.

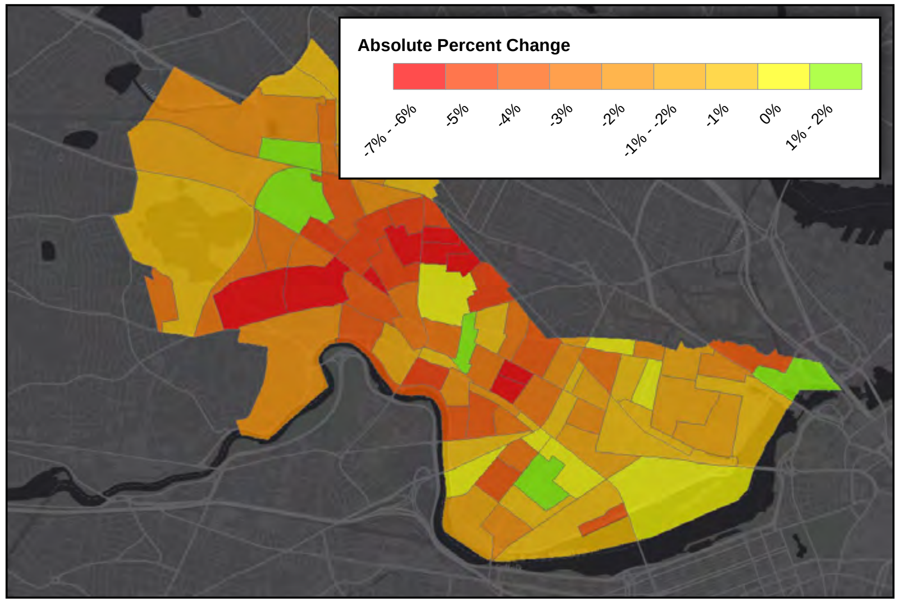

Figure 7: Absolute percent of tree canopy change per census block group between 2009 and 2014.

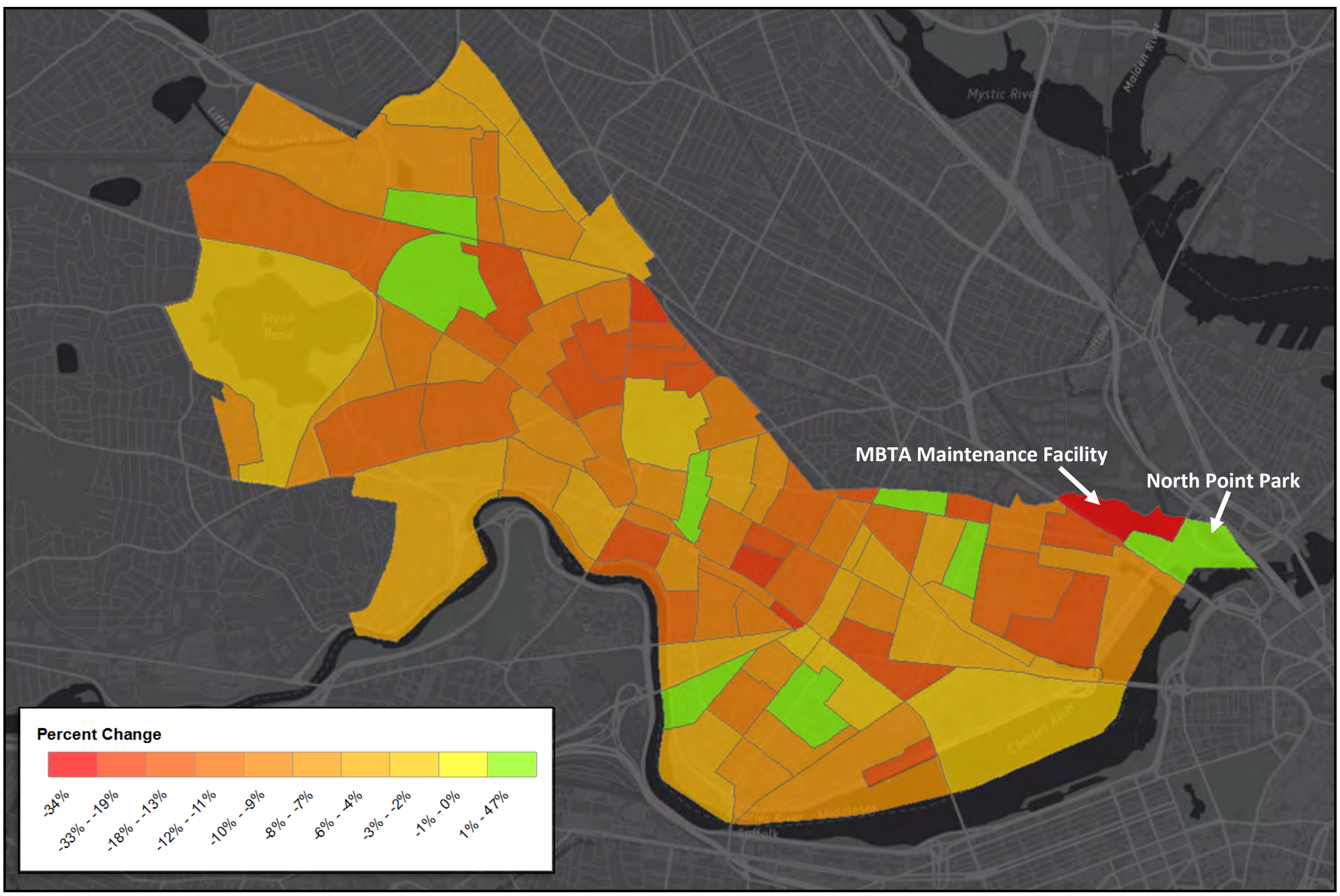

Figure 8: Relative percent of tree canopy change per census block group between 2009 and 2014.

How has Tree Canopy Changed within Each Neighborhood?

Tree canopy relative percent change and absolute percent change were summarized for each neighborhood in Cambridge (Figure 9 and Figure 10).

Every neighborhood in Cambridge experienced relative tree canopy loss between 2009 and 2014. Agassiz and East Cambridge neighborhoods experienced 10% relative tree canopy loss in 5 years. Strawberry Hill, Cambridgeport, and Area IV experienced 5% relative tree canopy loss, which is the least relative tree canopy loss among all neighborhoods.

All neighborhoods experienced absolute tree canopy loss as well. Agassiz had the most tree canopy loss at nearly 4%. Cambridgeport experienced the least absolute tree canopy loss at just over 1% tree canopy loss.

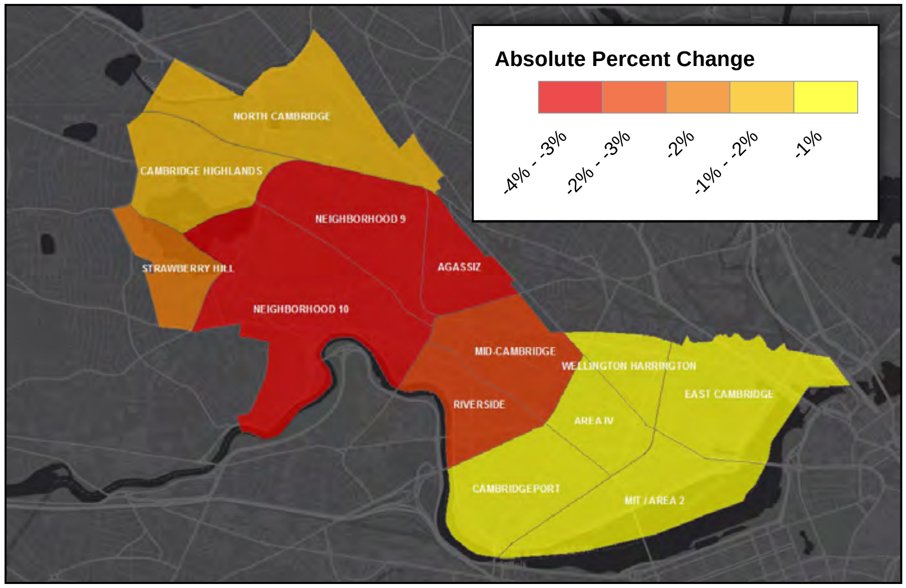

Figure 9: Absolute percent of tree canopy change for each neighborhood between 2009 and 2014.

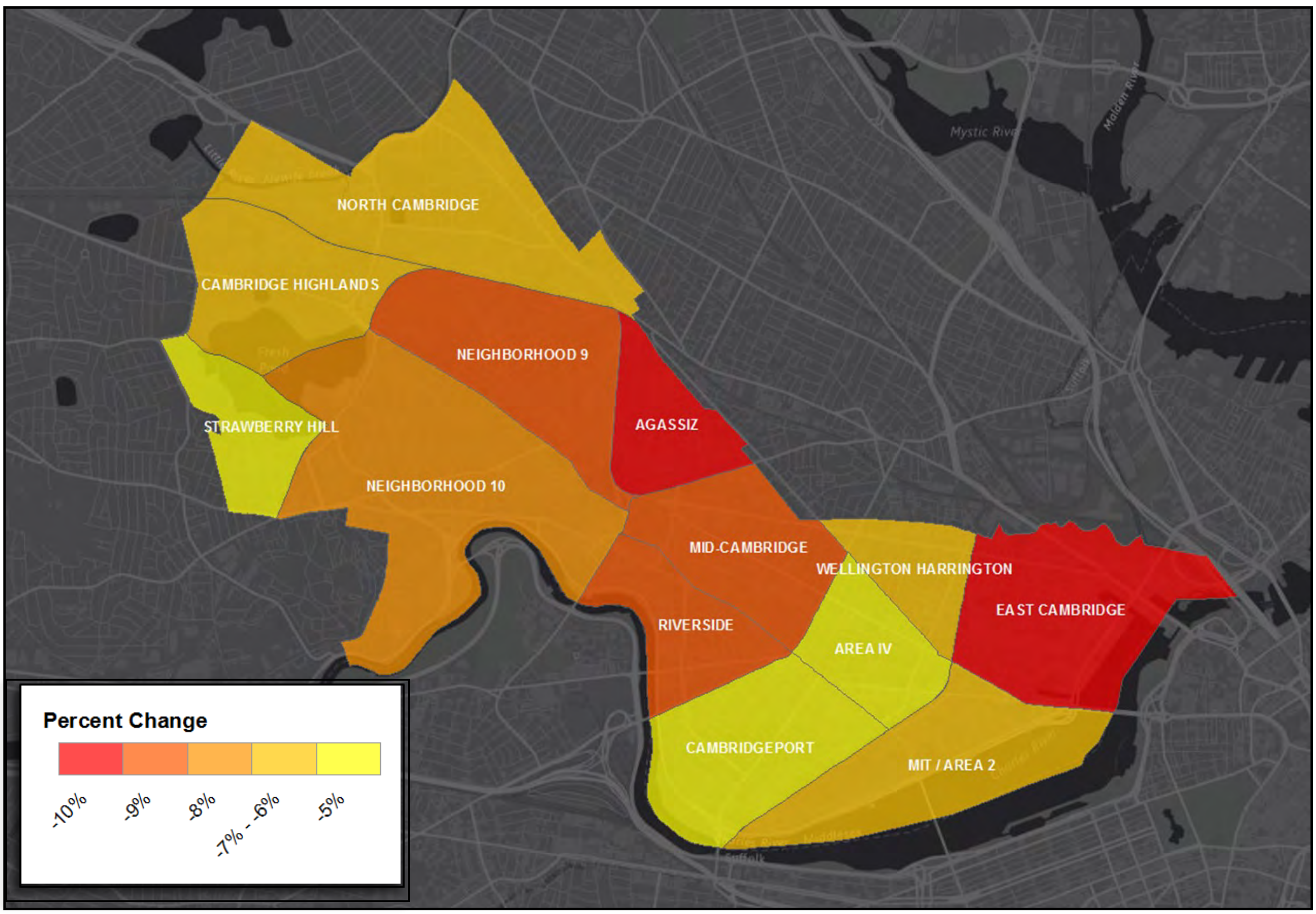

Figure 10: Relative percent of tree canopy change for each neighborhood between 2009 and 2014.

How has Tree Canopy Changed in Each Land Use Type?

Tree canopy relative percent change and absolute percent change were summarized for each general land use type in Cambridge (Figure 11 and Figure 12).

All land use types had relative tree canopy losses between 2009 and 2014. Residential had the most tree canopy loss at 11%. Commercial, Institutional, and Transportation also experienced relative tree canopy losses of 7-8%. Public and Water each lost 3%.

Residential land use also had the largest, absolute tree canopy loss for the 5-year period, declining from 37% to 34% area in tree canopy. Transportation and Institutional declined by 2%, and the other land use types lost 1%.

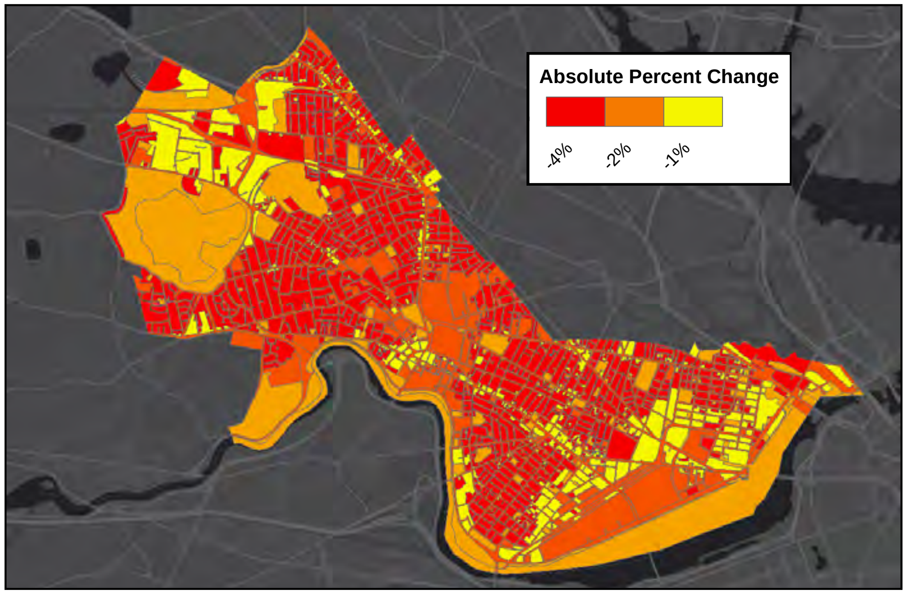

Figure 11: Absolute percent of tree canopy change for each commercial district between 2009 and 2014.

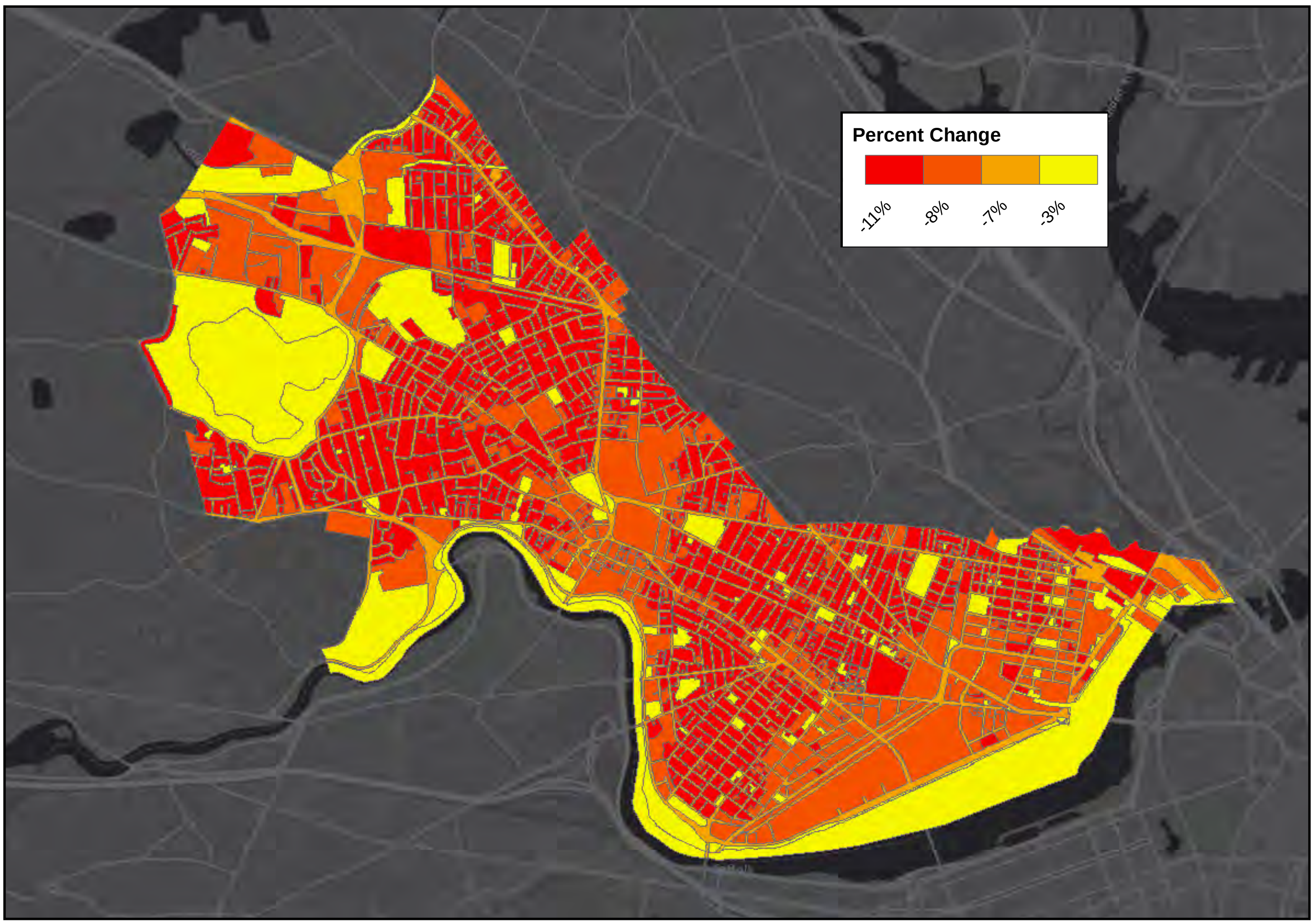

Figure 12: Relative percent of tree canopy change for each commercial district between 2009 and 2014.

How has Tree Canopy Changed Within Each Recreation Open Space?

Tree canopy relative percent change and absolute percent change were summarized for each recreation open space in Cambridge (Figure 13 and Figure 14).

Eleven open spaces had 100% relative tree canopy loss, although those spaces are generally small polygons that had only one or two trees in 2009 that had been removed by 2014. 142 open spaces experienced relative tree canopy loss.

118 open spaces had relative tree canopy gain, with 56 of those spaces experiencing a relative gain of over 10%.

142 open spaces experienced absolute tree canopy loss between 2009 and 2014. Of the spaces that experienced loss, 116 of them had less than 10% absolute tree canopy loss.

127 open spaces had absolute tree canopy gain with 43 of those experiencing tree canopy gain of over 5%.

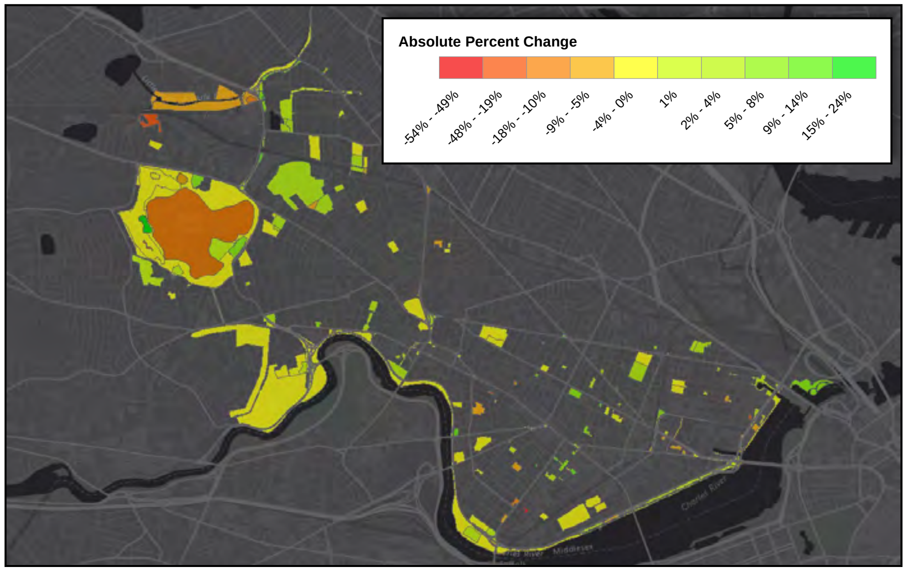

Figure 13: Absolute percent of tree canopy change for each recreation open space between 2009 and 2014.

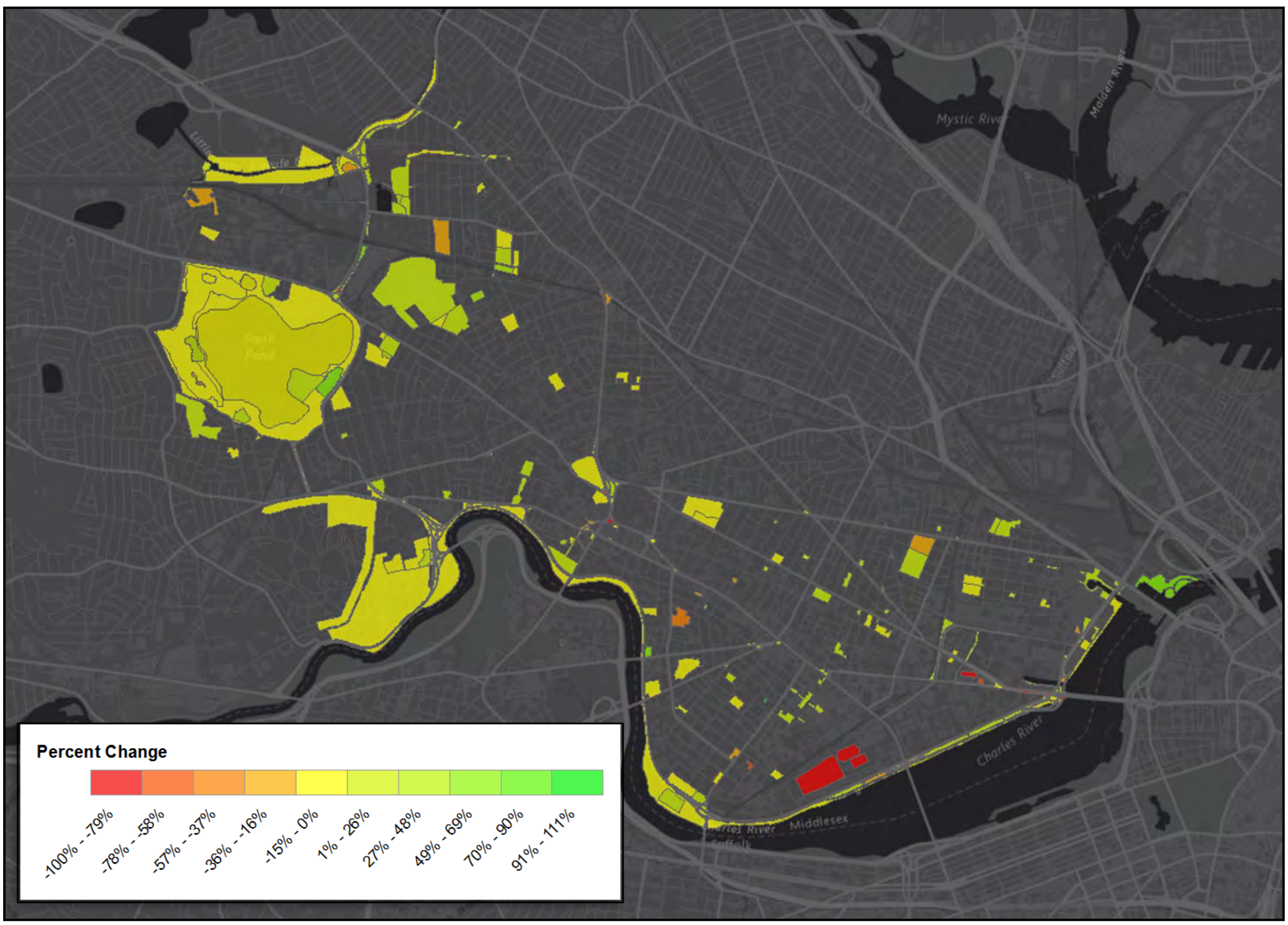

Figure 14: Relative percent of tree canopy change for each recreation open space between 2009 and 2014.

Conclusions

- This study provides the foundation for understanding the quantity, distribution, and configuration of tree canopy within the City of Cambridge as well as how tree canopy has changed between 2009 and 2014. The true value of the study will be realized when the analyses are used to drive and specify goals to conserve existing tree canopy in addition to establishing new tree canopy. Tree canopy in Cambridge is a vital asset that provides a multitude of ecosystem services: stormwater runoff reduction, improved air quality, decreased carbon footprint, enhanced quality of life, savings on energy bills, and habitat for wildlife.
- Overall there has been little net change in tree canopy within Cambridge. The low amount of net change in tree canopy masks the dynamics that have occurred during the 2009-2014 time period. Over 200 acres of tree canopy were lost. Fortunately, this loss has been largely offset by new growth and tree plantings.
- The distribution of ecosystem services varies with the trees producing those services. The data from this study can be used to establish localized canopy goals and targeted plantings and conservation efforts to maximize limited resources. Selecting a specific ecosystem benefit to build an engagement campaign can increase the success in tree planting action, particularly when such an audience is already galvanized around a particular issue (e.g. engaging residents concerned about a specific neighborhood's stormwater in tree planting efforts).
- Although tree canopy change in the city of Cambridge has been relatively slow, it is important to note that significant changes in tree canopy do occur. The best way for a community to increase tree canopy is to maintain what it currently has. Existing tree canopy helps to support both natural growth and natural regeneration. Removals of tree canopy, particularly in large quantities, pose a threat to Cambridge's green infrastructure.
- This dataset can be used to help determine some of the drivers of tree canopy change within Cambridge. New construction is one driver of change, and this dataset could be integrated with recently approved permitting to explore the relationship between development and tree canopy. Tree canopy also changes as trees are lost to old age, or during storm events. Clusters of tree canopy removal may by indicative of a change in attitude by residents towards tree canopy. These changes in attitudes can be caused by recent storms in which tree blowdowns have caused property damage, resulting in residents taking preemptive action to remove other trees that might be a risk for adjacent structures.
- Preserving tree canopy is just as important as new planting initiatives. Efforts to maintain larger forested areas will facilitate natural regeneration in addition to ensuring the preservation of unique ecosystem services provided by these areas.
- Future tree canopy assessments should be planned to assess changes to the tree canopy in Cambridge. Such assessments can provide crucial information on how effective tree planting and preservation efforts are, in addition to understanding how other factors (e.g. development) may be impacting tree canopy. Future assessments will only be possible if continued investments are mode in high-resolution, remotely-sensed imagery and LiDAR. We suggest that the future assessments are conducted at least every 5 years.

Figure 15: Tree Canopy change dataset overlaid 2014 LiDAR. Tree canopy loss is red, tree canopy gain is yellow, and no change is green.

Prepared by:

Jarlath O'Neil-Dunne
University of Vermont
Spatial Analysis Laboratory
joneildu@uvm.edu
802.656.3324

Additional Information

For more info on the Urban Tree Canopy Assessment please visit **http://nrs.fs.fed.us/urban/UTC/**

University of Vermont
Spatial Analysis Lab

Tree Canopy Assessment Team: Noah Ahles, Jarrett Barbuto, Paige Brochu, Ernie Buford, Tayler Engel, Emma Estabrook, Sean MacFaden, Jarlath O'Neil-Dunne,, Anna Royar, Kelly Schulze