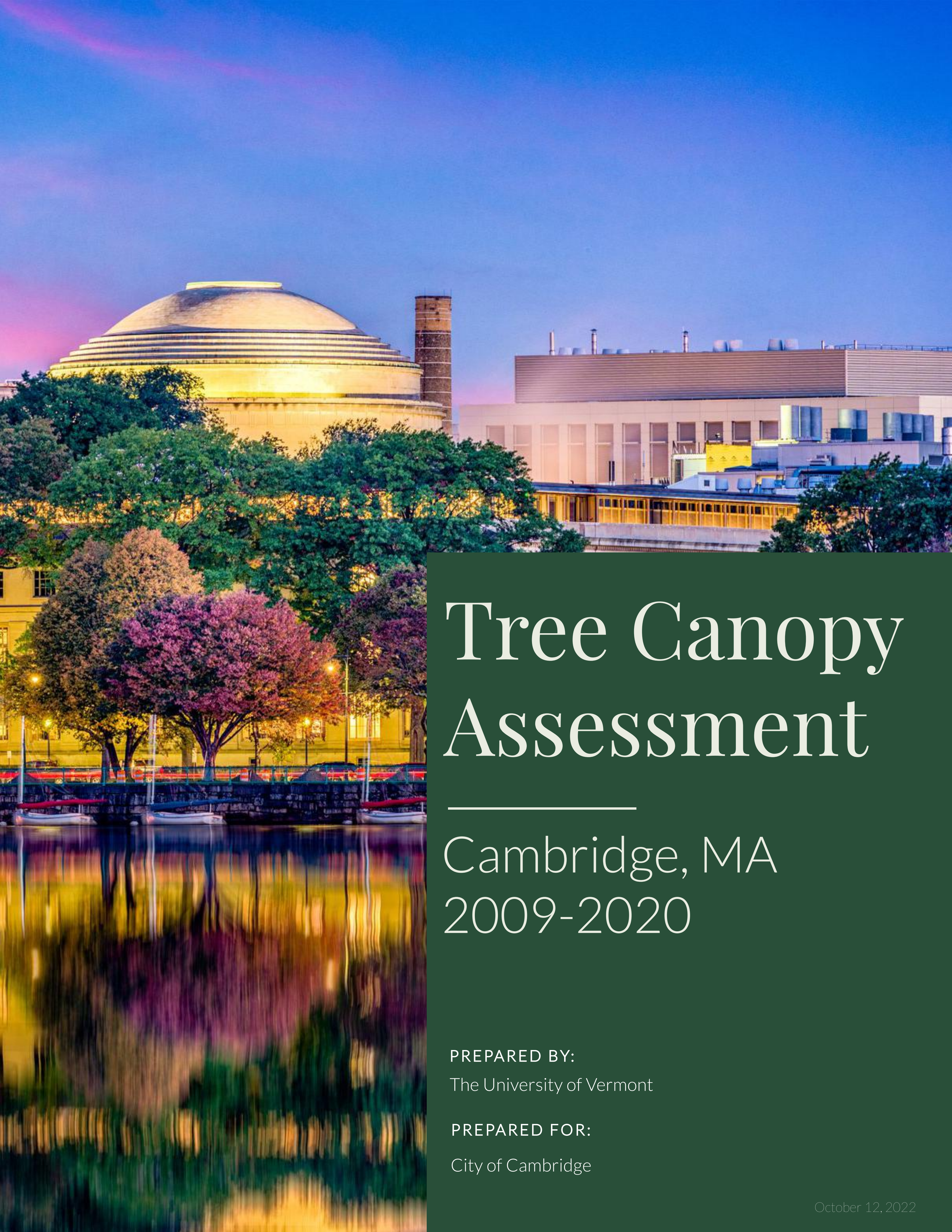


Tree Canopy Assessment

Cambridge, MA
2009-2020

PREPARED BY:
The University of Vermont

PREPARED FOR:
City of Cambridge

October 12, 2022

THE NEED FOR GREEN

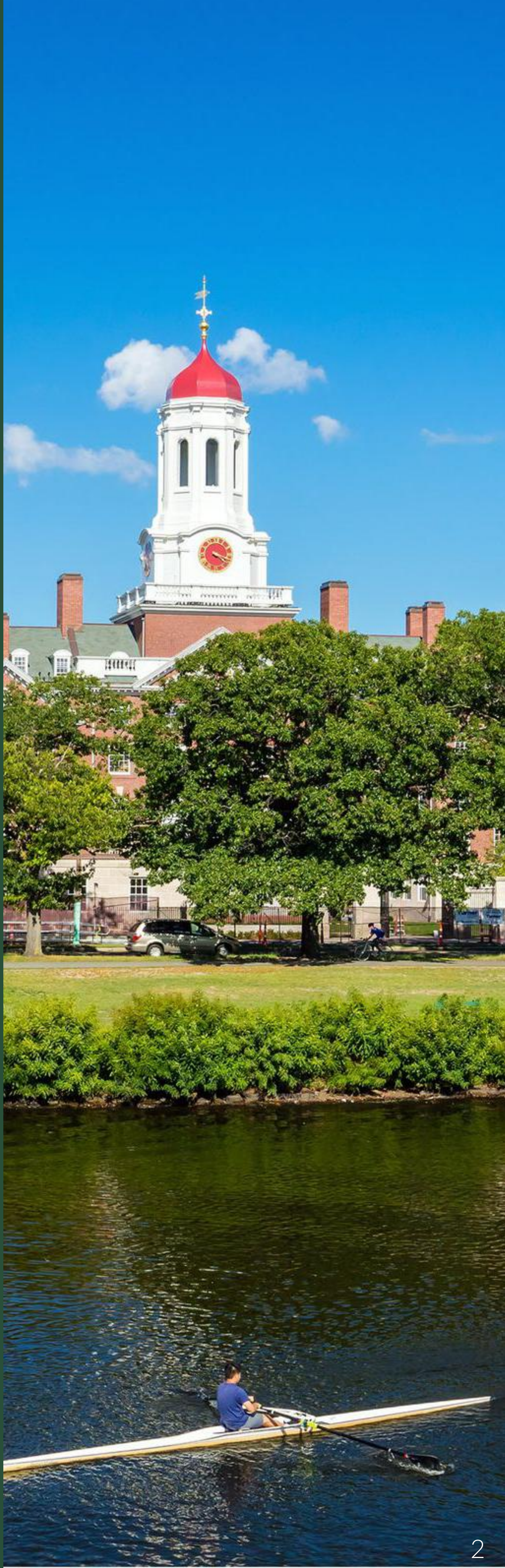
Trees provide essential ecosystem services in Cambridge, like reducing stormwater runoff, cooling the pavement in the summer and providing wildlife habitat. Trees are an indispensable part of the region's infrastructure. Research shows that these green assets can improve social cohesion, reduce crime, and raise property values. A healthy and robust tree canopy is crucial to building a more livable and prosperous town.

As with any community, Cambridge faces a host of environmental challenges while seeking to balance development and conservation. A healthy and robust tree canopy is crucial for maintaining this balance, providing Cambridge's residents with a resource that will impact the health and well-being of generations to come.

TREE CANOPY ASSESSMENT

For decades, governments have mapped and monitored their infrastructure to support effective management practices. Traditionally, that mapping has primarily focused on gray infrastructure, including features such as roads and buildings. Left out of this mapping has been an accounting of the green infrastructure.

The Tree Canopy Assessment protocols were developed by the USDA Forest Service to help communities better understand their green infrastructure through tree canopy mapping and analytics. Tree canopy is defined as the layer of leaves, branches, and stems that provide tree coverage of the ground when viewed from above. A Tree Canopy Assessment can provide vital information to help governments and residents chart a greener future by helping them understand the tree canopy they have, how it has changed, and where there is room to plant trees. Tree Canopy Assessments have been carried out for over 90 communities in North America. This study assessed tree canopy for Cambridge over the 2009-2020 period, using data from 2009, 2014, 2018, and 2020. This assessment had a particular focus on bringing into alignment past assessments, harmonizing the data to ensure gains and losses in tree canopy were accurately accounted for.



TREE CANOPY BY THE NUMBERS

Overall tree canopy change from 2009-2020

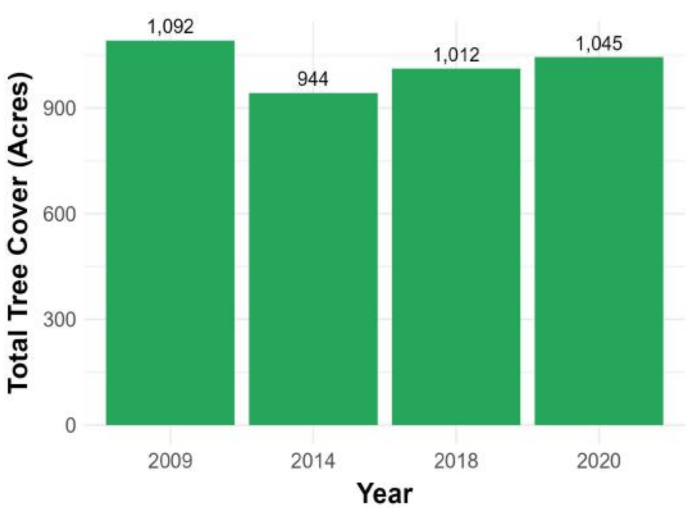
427
Acres of Gain

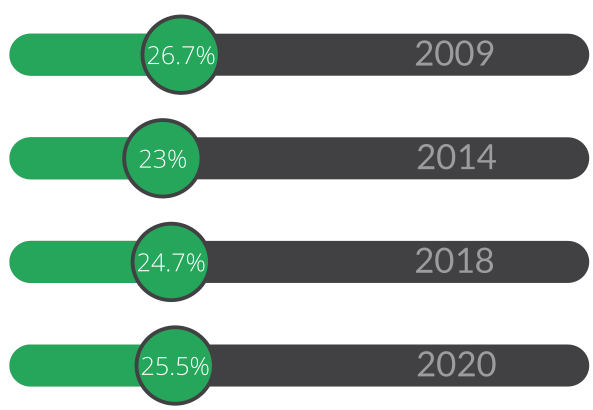
474
Acres of Loss

47
Acres net Loss

-1.2%
Absolute Change

Tree canopy by time period





Percent tree canopy coverage at each time period between 2009 and 2020

2009-2014
149
acres of net loss in tree canopy coverage.

2014-2018
69
acres of net gain tree canopy coverage.

2018-2020
33
acres of net gain tree canopy coverage.

FINDINGS

Cambridge's tree canopy decreased from 2009 to 2020, with an absolute loss of 1.2%.

There were 427 acres of tree canopy gained and 474 acres of tree canopy lost from 2009 to 2020.

Following a steep drop of -3.6% (148 acres) in tree canopy coverage between 2009 and 2014, the 2018 and 2020 time periods both saw net gains.

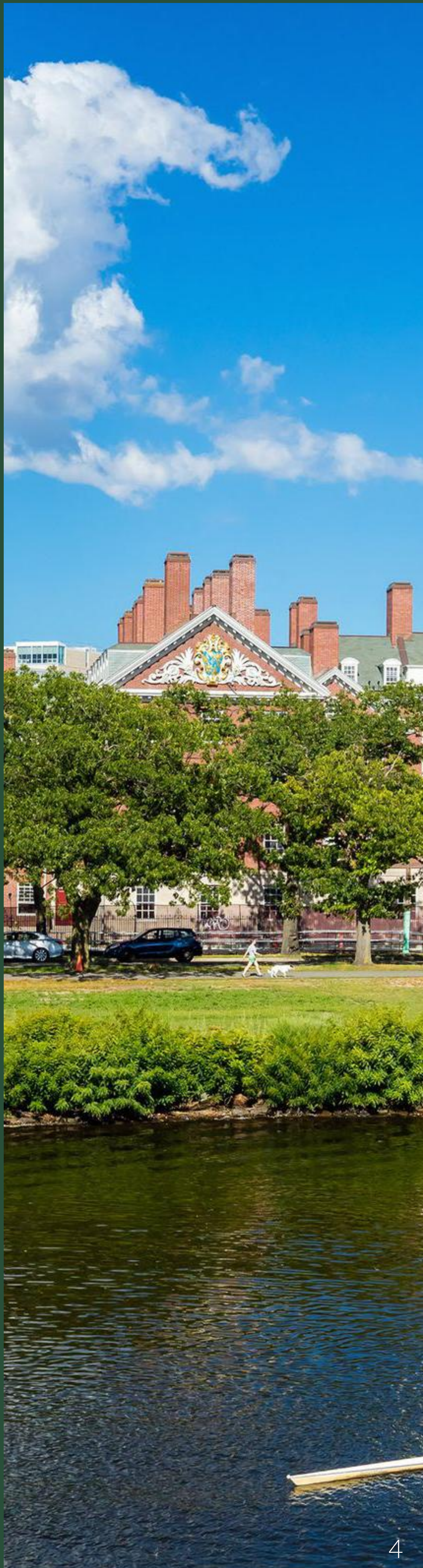
More tree canopy is on residential land than any other land use. Engaged residents who care for and enhance the tree canopy on their land is crucial.

The city's investments in tree plantings and maintenance combined with tree preservation initiatives are paying off, reversing the loss of tree canopy.

If Cambridge can maintain the progress made over the past years through planting and preservation efforts, the city can recover from previous losses and continue to increasing tree canopy.

Land use history, urban forestry initiatives, natural processes, and landowner decisions, all play a role in influencing the current state of tree canopy in the city.

Tree canopy loss is neither evenly distributed nor similar. It varies from removal of individual trees in backyards to clearing of patches of trees for new construction.



RECOMMENDATIONS

Preserving existing tree canopy is the most effective means for securing future tree canopy, as loss is an event but gain is a process.

Planting new trees in areas where tree canopy is low or in locations where there has been tree canopy removed will also help the city grow canopy.

Having trees with a broad age distribution and a variety of species will ensure that a robust and healthy tree canopy is possible over time.

Community education is crucial if tree canopy is to be maintained over time. Residents that are knowledgeable about the value of trees will help the city stay green for years to come.

Integrate the tree canopy change assessment data into planning decisions at all levels of government from individual park improvements, to comprehensive planning and zoning initiatives, to citywide ordinances.

Reassess the tree canopy at 2-5 year intervals to monitor change and make strategic management decisions.

Tree canopy assessments require high-quality, high-resolution data. Continue to invest in LiDAR and imagery to support these assessments and other mapping needs.

Field data collection efforts should be used to compliment this assessment as information on tree species, size, and health can only be obtained through on-the-ground inventories.

THE TREE CANOPY ASSESSMENT PROCESS

This project employed the USDA Forest Service's Urban Tree Canopy assessment protocols and made use of federal, state, and local investments in geospatial data. Tree canopy assessments should be completed at regular intervals, every 3-5 years.

Remotely sensed data forms the foundation of the tree canopy assessment. We use high-resolution aerial imagery and LiDAR to map tree canopy and other land cover features.

The land cover data consists of tree canopy, grass/shrub, bare soil, water, buildings, roads/railroads, and other impervious features.

The land cover data are summarized by various geographical units, ranging from the property parcel to the watershed to the municipal boundary.

These summaries, in the form of tree canopy metrics, are an exhaustive geospatial database that enable the Existing and Possible Tree Canopy to be analyzed.

The tree canopy metrics data analytics provide basic summary statistics in addition to inferences on the relationship between tree canopy and other variables.

The report (this document) summarizes the project methods, results, and findings.

The presentation, given to partners and stakeholders in the region, provides the opportunity to ask questions about the assessment.

The Importance of Good Data

This assessment would not have been possible without Cambridge's investment in high-quality geospatial data, particularly LiDAR. These investments pay dividends for a variety of uses, from stormwater management to solar potential mapping. This LiDAR will help the Cambridge advance their risk management plan by creating the tree centroids needed to run a risk analysis. Good data supports good governance.

MAPPING THE TREE CANOPY FROM ABOVE

Tree canopy assessments rely on remotely sensed data such as aerial imagery and light detection and ranging (LiDAR) data. These datasets are the foundational data for tree canopy mapping. Imagery provides information that enables features to be distinguished by their spectral (color) properties. As trees and shrubs can appear spectrally similar or obscured by shadow, LiDAR, which consists of 3D height information, enhances the accuracy of the mapping. LiDAR is more precise than imagery for mapping tree canopy and is the optimal dataset for tracking changes in tree canopy over time. This study benefitted from Cambridge's investment in LiDAR, employing data acquired in 2009, 2014, 2018, and 2020. Tree canopy mapping was carried out using a scientifically rigorous process that integrates cutting-edge automated feature extraction technologies with detailed manual reviews and editing. This combination of sensor and mapping technologies enabled the city's tree canopy to be mapped in greater detail and with better accuracy than ever before.

The high-resolution land cover that forms the foundation of this project was generated from the most recent LiDAR, which was acquired in 2020. Compared to national tree canopy datasets, which map at a resolution of 30-meters, this project generated maps that were over 1,000 times more detailed and better account for all of the city's tree canopy.

Tree Canopy Mapping

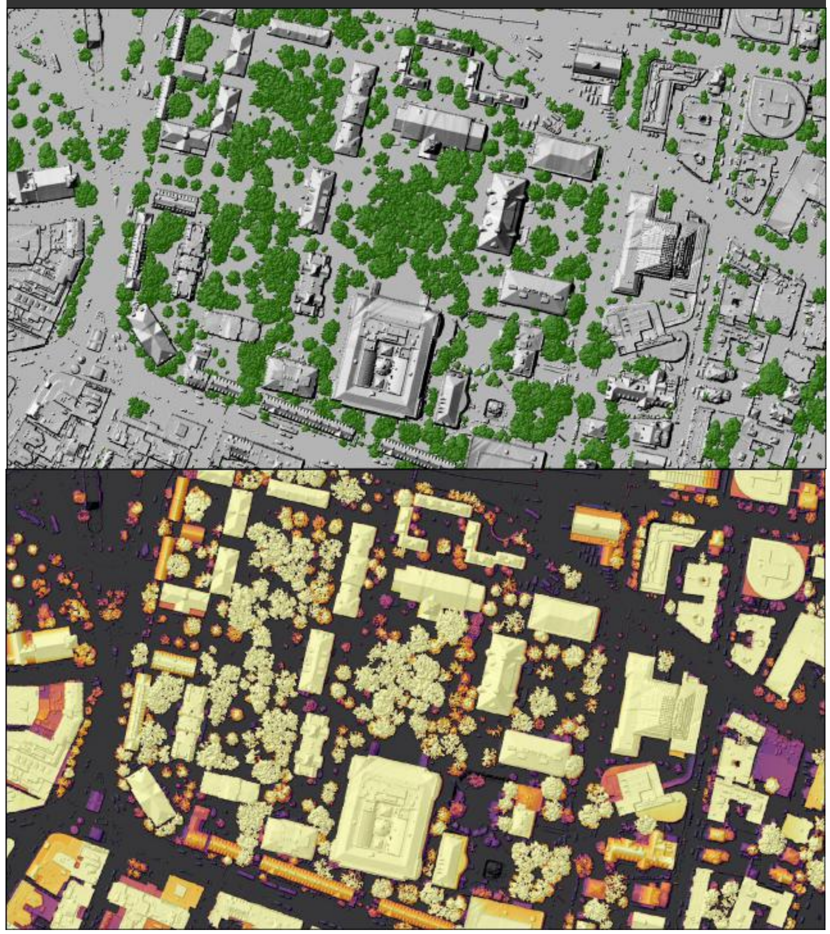


Figure 1. Mapped tree canopy overlaid on the 2020 LiDAR (top) along with a colorized LiDAR height model (bottom). Tall objects, such as trees and buildings, do not suffer from the lean associated with such objects in imagery, making it the ideal data source for mapping tree canopy change over time.

Land Cover Mapping

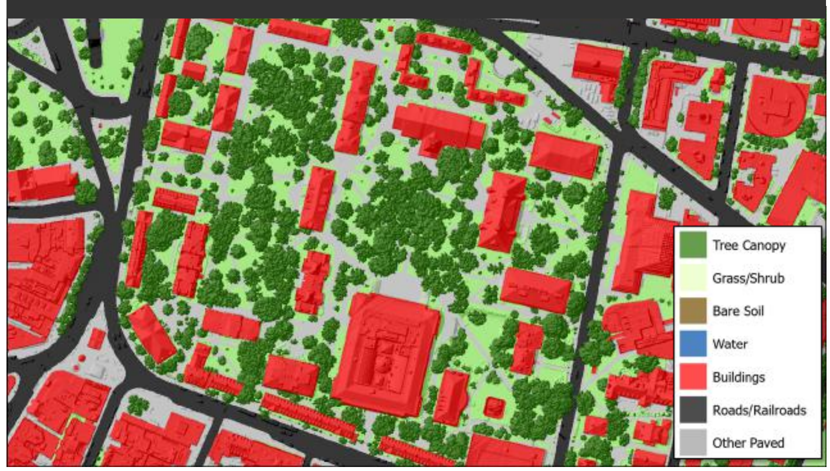


Figure 2. High-resolution land cover developed for this project.

LANDCOVER

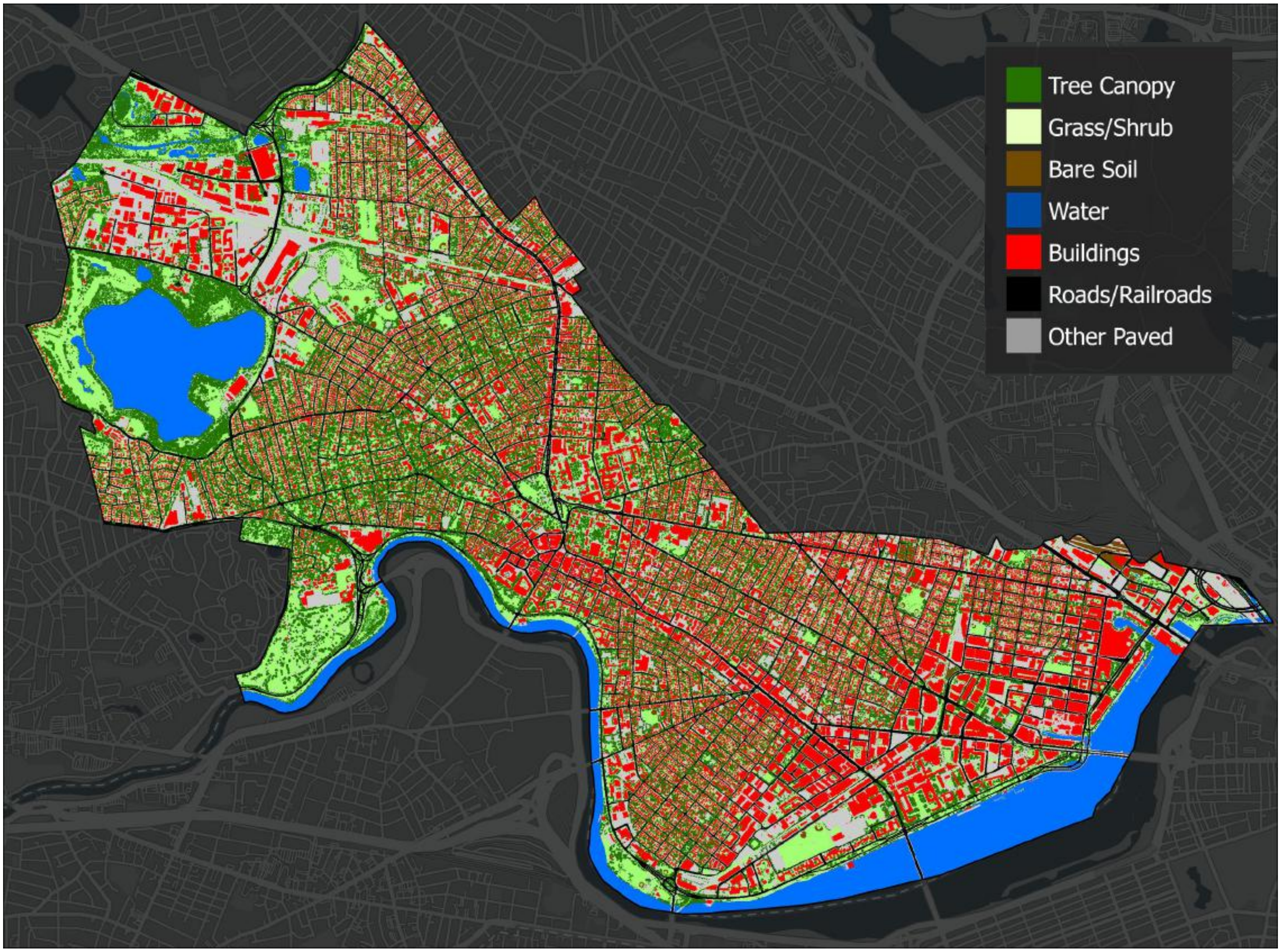


Figure 3. The new 2020 landcover was used in this assessment to quantify existing tree canopy, possible tree canopy - vegetated, possible tree canopy - impervious, and not suitable. The following terminology is used throughout this report.

Key Terms

Existing Tree Canopy: The amount of tree canopy present when viewed from above using aerial or satellite imagery.

Possible Tree Canopy - Vegetated: Grass or shrub area that is theoretically available for **the** establishment of tree canopy.

Possible Tree Canopy - Impervious: Asphalt, **concrete** or bare soil surfaces, excluding roads and buildings, that are theoretically available for the establishment of tree canopy

Not Suitable: Areas where it is highly unlikely that new tree canopy could be established (primarily buildings and roads).

Measuring Tree Canopy Change

Area Change - the change in the **area of** tree canopy between the two time **periods.**

Relative % Change -the magnitude of change in tree canopy based on the amount of tree canopy in 2011.

Absolute % Change - the percentage point change between the two time periods.

THE HARMONIZATION PROCESS

Tree canopy assessments were carried out for Cambridge for 2009, 2009-2014, and 2014-2018. This study sought to align these past assessments. This harmonization process was carried out to ensure the validity of the mapping classes across 2009, 2014, 2018, and 2020. Specifically, this assessment addressed the following issues:

Resolution. The tree canopy datasets were reprocessed to ensure a common pixel size, ensuring a consistent resolution across the four time periods.

Alignment. Detailed quality control procedures were carried out to ensure that errors in mapping from one time period did not carry over to the others.

Methods. Tree canopy change mapping was redone across all four time periods using the latest tree canopy mapping techniques developed in collaboration with the US Forest Service.

Gain. The new LiDAR in combination with advances in processing methodology enabled tree canopy gain to be mapped at a finer scale than prior assessments.

Accuracy Improvements

Due to improved accuracy achieved through the harmonization process, tree canopy numbers in this assessment may differ from previous analyses. Original tree canopy outputs for 2009 and 2014 were much coarser in resolution and required smoothing prior to harmonization.

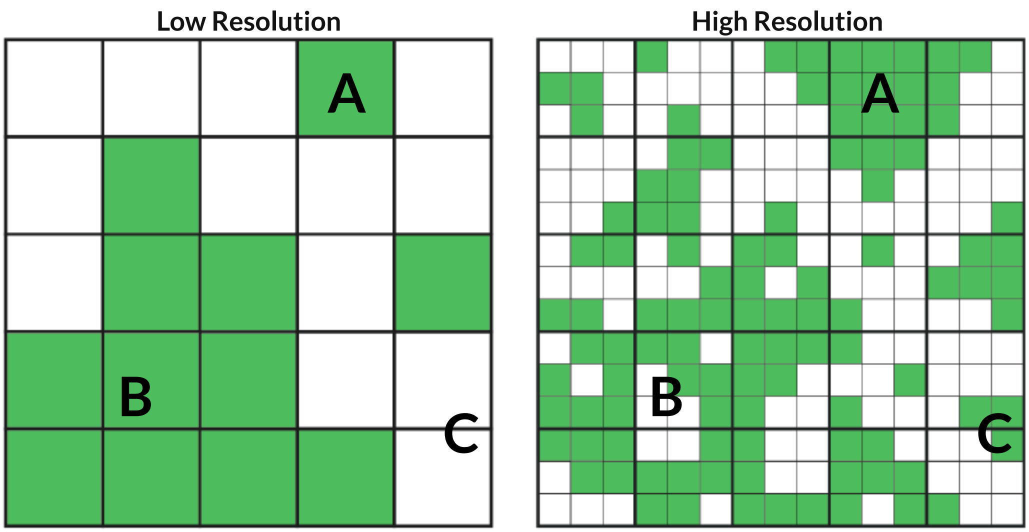


Figure 4. Illustration of how accuracy improvements can result in updates to tree canopy estimates. Both example maps represent the same 15m by 15m area, the left one has a resolution of 3m by 3m while the right has a resolution of 1m by 1m. The map on the right more accurately captures actual tree canopy area.

New techniques better capture:

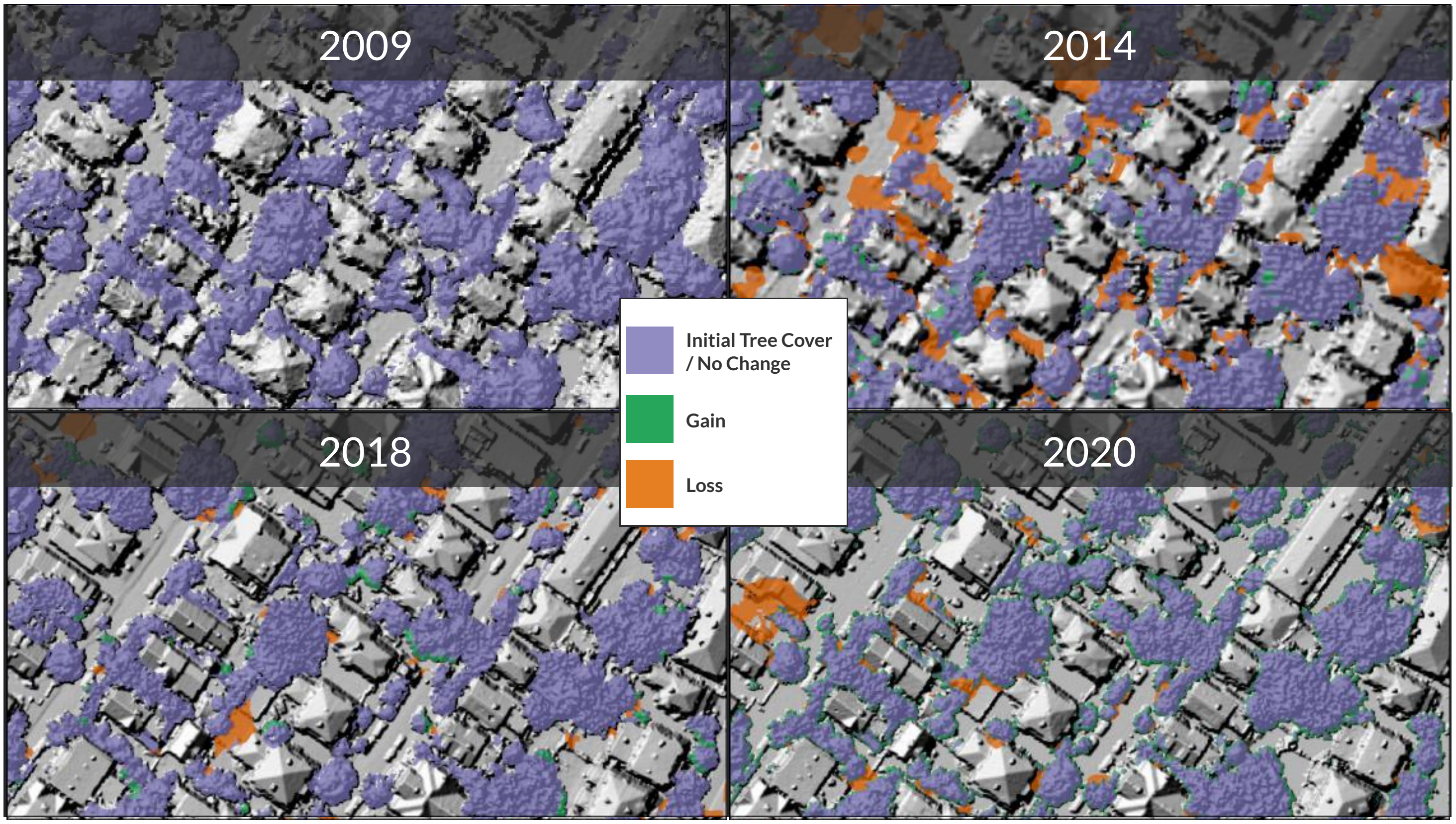
A Edge Growth. Better detection of edge growth may add tree cover that was not previously mapped.

B Forest Gaps. Previous assessments may include overestimates of tree cover where tree canopy gaps were not detected.

C Small Patches. Tree patches that were previously too small for detection can now be mapped.

PATTERNS OF CHANGE

The visual below shows the harmonized change mapped through the four years and three change periods overlaid on the 2020 LiDAR. From the initial tree cover in 2009 (purple), tree canopy that remained in the next time step is classified as No Change (purple), canopy that was present in the previous timestep but absent in the next is classified as Loss (orange), new canopy that was not present in the previous time step is Gain (green), and tree canopy that had been lost in a previous timestep is not shown in future timesteps.



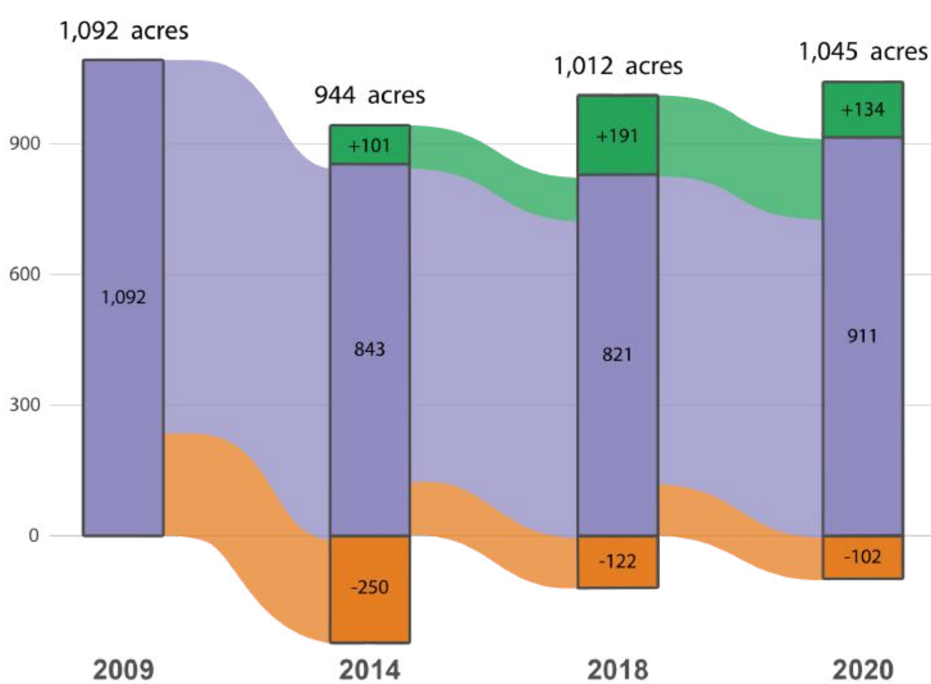


Figure 5. Total acres of tree canopy for each year are represented by the height of the bar above zero (No Change + Gain) Magnitude of gains and losses and are shown for each time period. City-wide, each time period saw both gains and losses. Gains tend to come from gradual processes: the growth of canopy edges of existing trees and natural succession. While losses tend to be more sudden: the removal of a patch of trees for construction, die off from disease or invasive pests, or damage from storms. Preserving existing tree canopy is the most effective means for securing future tree canopy, as loss is an event but gain is a process.

CHANGE EXAMPLES

Numerous factors contribute to the tree canopy change patterns in Cambridge, including zoning, land use history, urban density, and landowner decisions. Examining patterns and processes over the eleven years can provide insights into how the canopy may change in the future.

Residential Tree Canopy

Established trees continue to grow and contribute canopy but age, disease, invasive species, storms, and changing landowner preferences all contribute to removals. As a result, losses may outpace gains over time if replacement trees are not planted.

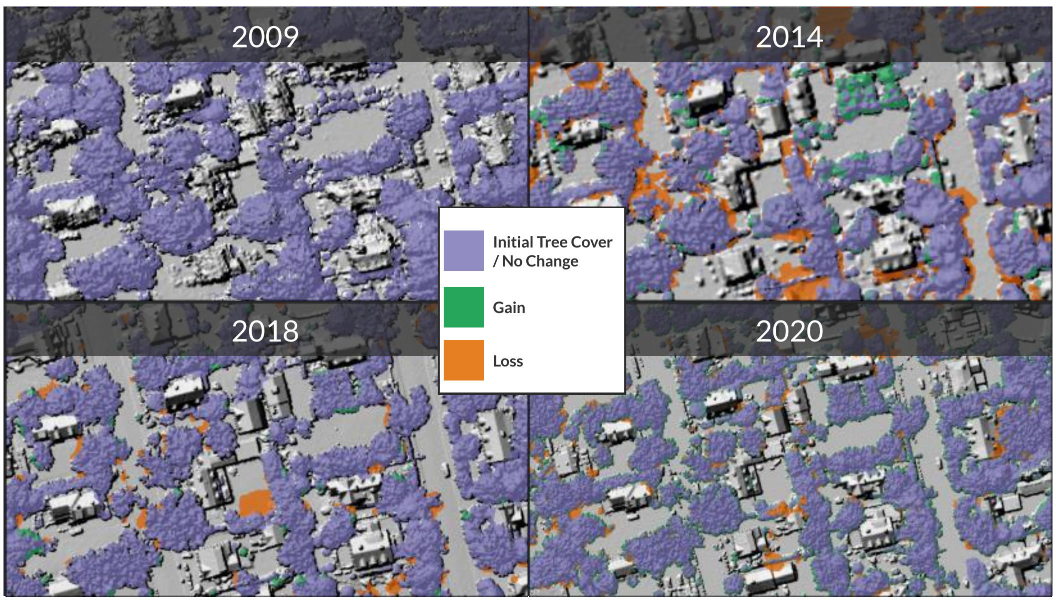


Figure 6. Tree cover patch losses and natural succession gains at canopy edges in the residential area near Lake View Ave and Fayerweather St. in the West Cambridge neighborhood.

Restoration Efforts

Tree planting and natural succession are slow but important processes for increasing urban tree canopy.

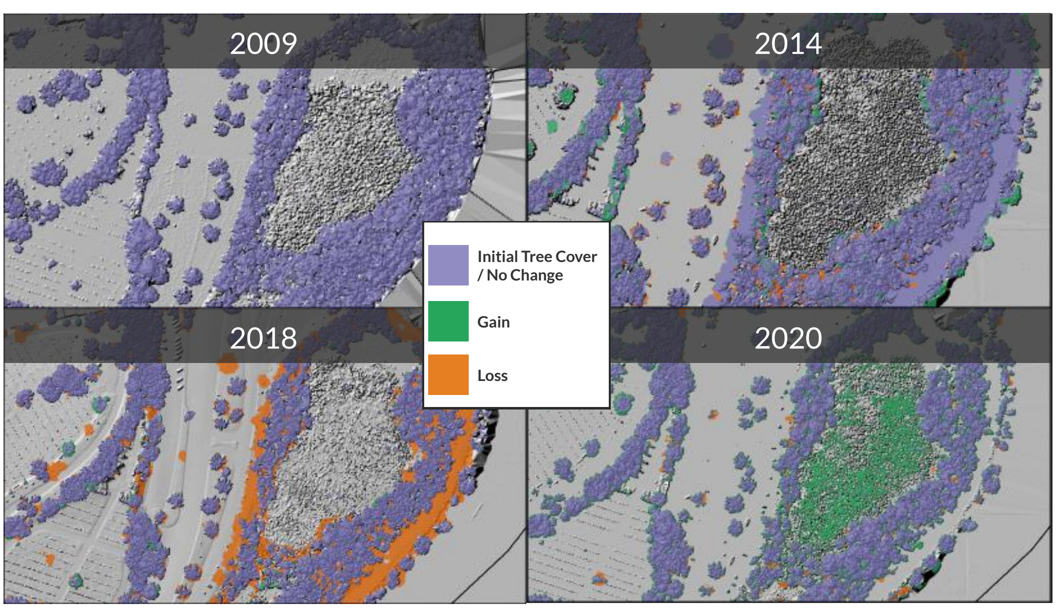
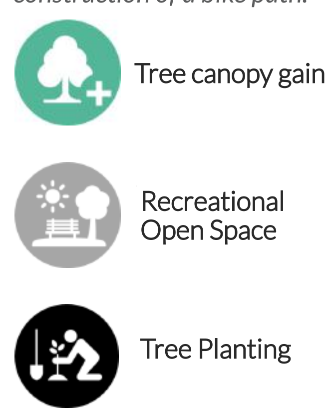
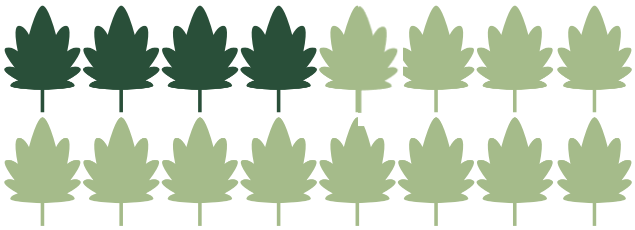


Figure 7. New plantings and natural growth in the area between the Charles River and Greenough Blvd help previous offset losses due to the earlier construction of a bike path.



TREE CANOPY METRICS

25.5% *of Cambridge's land is covered by tree canopy*



Tree canopy and tree canopy change were summarized at various geographical units of analysis, ranging from land use and property parcels to council district boundaries. These tree canopy metrics provide information on the area of Existing and Possible Tree Canopy for each geographical unit.

2020 Existing Tree Canopy

Cities commonly have uneven distribution of tree canopy, a pattern that applies to Cambridge. Some 10-acre hexagons have less than 10% tree canopy while others have nearly 100% tree canopy (Figure 8). This unequal distribution can be traced back to Cambridge's history of development patterns and open space planning. Residents who live and work in more treed areas benefit disproportionately from the ecosystem services that trees provide. Conversely, regions of the city have lower amounts of tree canopy receive fewer ecosystem services. Cambridge can enhance urban resilience and equity by prioritizing tree planting in neighborhoods that lack access to the numerous benefits trees provide.

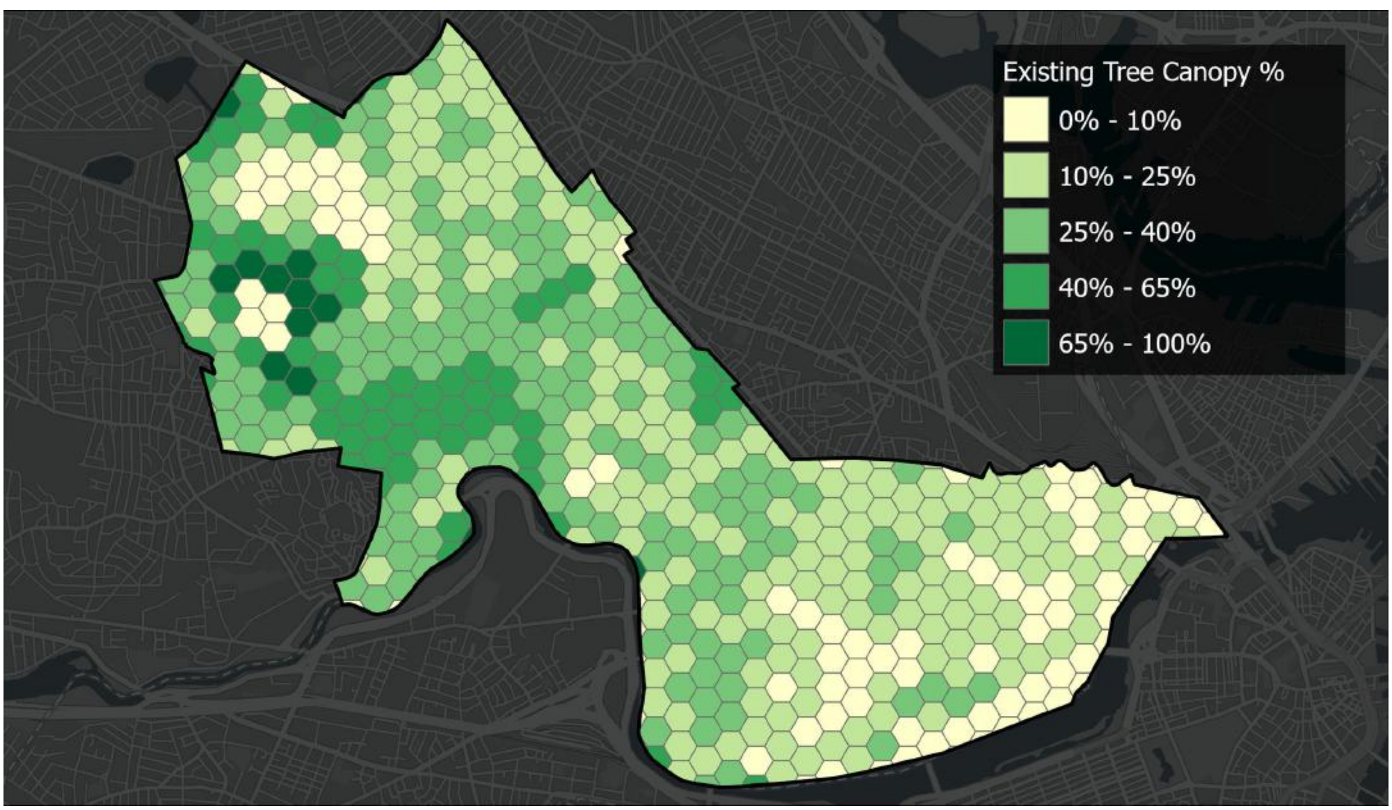


Figure 8. Existing tree canopy percentage for 2020 conditions summarized using 10-acre hexagons. For each of the hexagons, the percent tree canopy was calculated by dividing the amount of tree canopy by the land area, which excludes water. Darker green hexagons indicate more tree cover. Using hexagons as the unit of analysis provides a standard mechanism for visualizing the distribution of tree canopy without the constraints of other geographies that have unequal area (e.g., zip codes).

2020 Possible New Tree Canopy

There is available space in Cambridge to plant more trees. In this assessment, any areas with no trees, buildings, roads, or bodies of water are considered Possible-Vegetation and represent locations in which trees could theoretically be established without having to remove hard surfaces. Many factors go into deciding where a tree can be planted with the necessary conditions to flourish, including land use, landscape conditions, social attitudes towards trees, and financial considerations. Examples include golf courses and recreational fields. While there is open space to plant trees, there is a direct conflict in use; thus, the Possible-Vegetation category should serve as a guide for further field analysis, not a prescription of where to plant trees. With about 1,586 acres of land (comprising 38.7% of the city's land base) falling into the Possible-Vegetation category, there remain significant opportunities for planting trees and preserving canopy that will improve the city's total tree canopy in the long term.

In Cambridge's most densely urbanized areas, significantly increasing the tree canopy will be difficult; nevertheless, it remains vitally important to strive for canopy gains. Trees, when properly cared for, can mitigate environmental risks challenges relating to the urban environment such as flooding, air quality, and urban heat island. In the city's residential areas, healthy natural regeneration of the existing tree canopy and planting new trees will be important. There is often a "plant and forget" cycle in residential areas, where trees are generally planted when homes are built, without the follow-up to replace trees as they decline to establish the next generation of canopy.

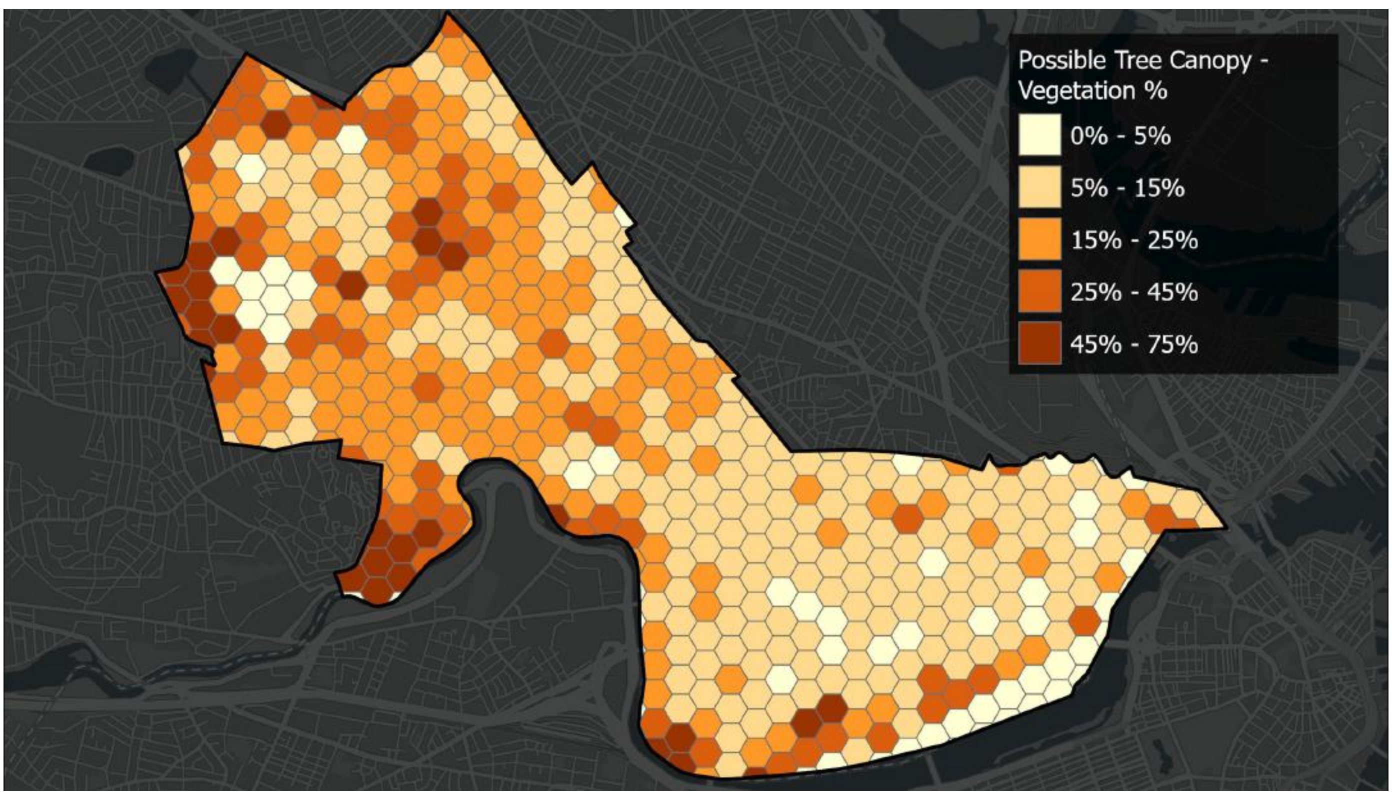


Figure 9. Possible Tree Canopy consisting of non-treed vegetated surfaces summarized by 10-acre hexagons. These vegetated surfaces that are not currently covered by tree canopy represent areas where it is biophysically feasible to establish new tree canopy. It may be financially challenging or socially undesirable to establish new tree canopy on much of this land. Examples include golf courses, recreational and agricultural fields. Maps of the Possible Tree Canopy can assist in strategic planning, but decisions on where to plant trees should be made based on field verification. Surface, underground, and above surface factors ranging from sidewalks to utilities can affect the suitability of a site for tree canopy planting.

2009 to 2020 Canopy Change Distribution

The magnitude of tree canopy change across Cambridge over the 2009-2020 time period can be measured by the relative tree canopy change. The relative change is calculated by taking the tree canopy area in 2020, subtracting the tree canopy area in 2009, then dividing this number by the area of tree canopy in 2009. Areas with the greatest change indicate that the canopy is markedly different in 2020 as compared to 2009. In some of the commercial and urbanized areas with little tree canopy in 2020, the growth of street trees resulted in a sizeable relative gain. Conversely, the removal of trees as a result of construction in sparsely treed areas resulted in substantial relative reductions in tree canopy.

Tree canopy gains from 2014 to 2020 helped offset steep losses during the 2009-2014 time period but looking at the magnitude of change over the whole study period shows that most areas of Cambridge still has less tree canopy in 2020 than they did in 2009. Recovery to pre-2009 tree canopy levels is possible but the trajectory of Cambridge's tree canopy in the future is uncertain. There are both environmental and anthropogenic risks facing canopy cover. Invasive species could pose a serious threat if not identified and controlled early. Natural events such as storms can have a mixed impact on the canopy. In conserved areas, tree canopy will return through natural growth, but in urbanized areas, trees lost to storms will need to be replanted. Climate change may cause trees to grow more quickly but could also result in inhospitable conditions for native species. Anthropogenic factors include preservation and conservation efforts and the strength of tree ordinances. Managing these risks will be key to maintaining growth and achieving Cambridge's tree canopy goals.

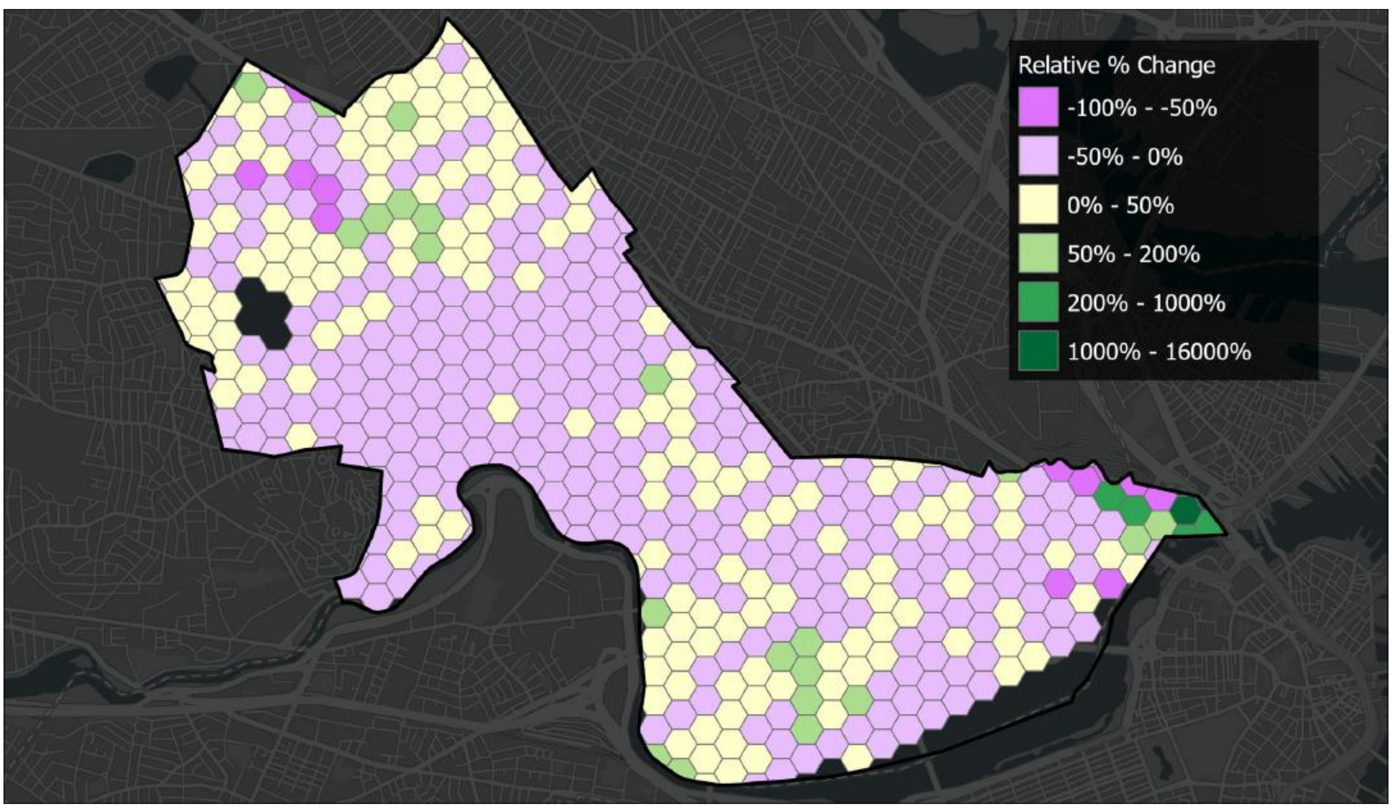
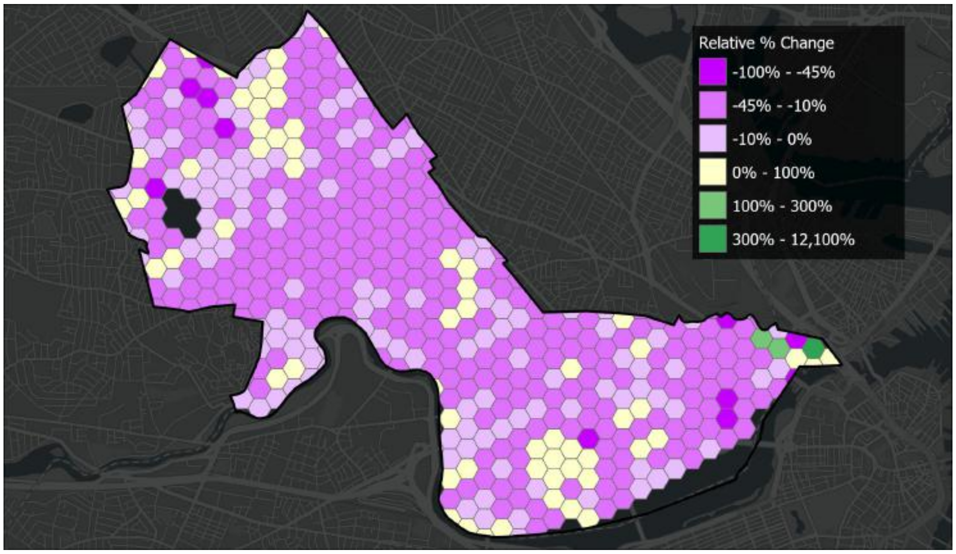


Figure 10: Tree canopy change metrics summarized by 10-acre hexagons. Relative tree canopy is calculated by using the formula (Tree Canopy Area 2020 - Tree Canopy Area 2009)/ Tree Canopy Area 2009. Colors are categorized by data quantiles. Darker greens indicate greater relative gain, while darker purple reflects a higher magnitude of loss.

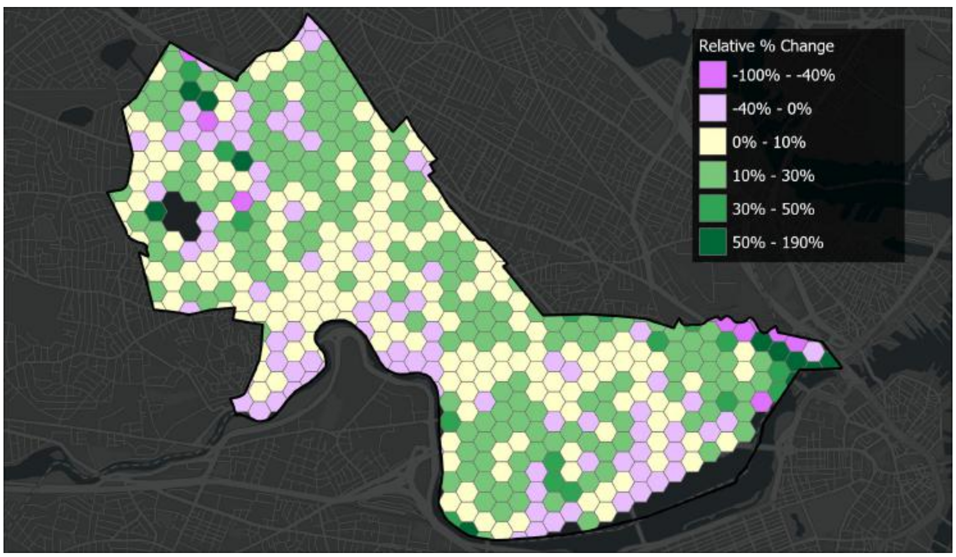
Canopy Change Distribution by Timestep

Relative percent change in tree canopy was calculated for each timestep to examine the magnitude of change within each time period. The formula, (Tree Canopy Area Year 2 - Tree Canopy Area Year 1) / Tree Canopy Area Year 1.



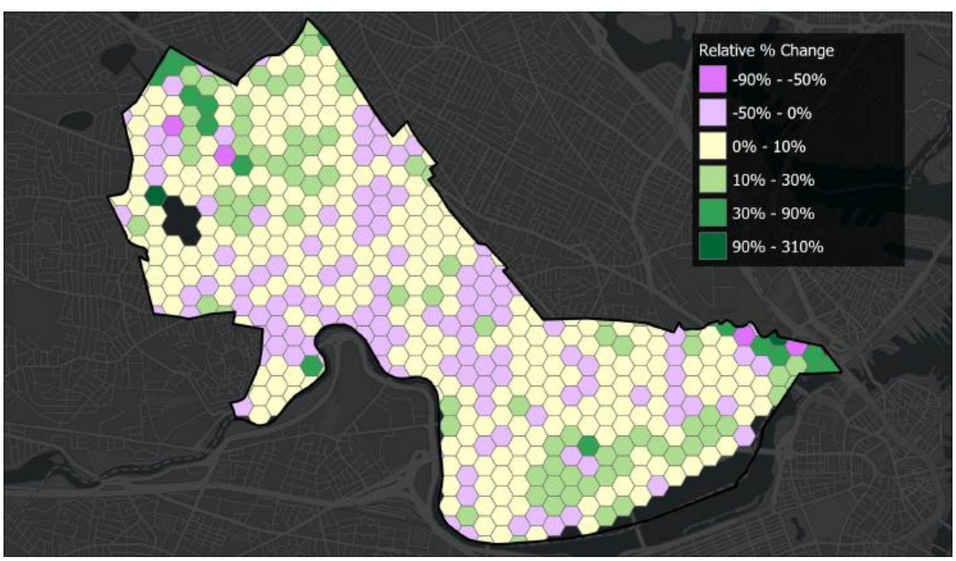
2009 to 2014

Figure 11: Relative tree canopy percent change 2009-2014. High magnitude tree canopy loss is widespread across Cambridge while limited pockets maintained or gained tree cover over this time period.



2014 to 2018

Figure 12: Relative tree canopy percent change 2014-2018. Relatively low magnitude but widespread gains in tree canopy were evident, outweighing patches of loss.



2018 to 2020

Figure 13: Relative tree canopy percent change 2018-2020. The trend of tree canopy gains continues from the previous time period, but at lower magnitudes. Patches of localized losses become more frequent in this time period.

Neighborhoods

In Cambridge, neighborhoods are areas that most residents can easily relate to, especially the neighborhoods in which they live, work or visit most often. The city's official neighborhood geographic boundaries are a useful way to summarize tree canopy and draw comparisons between neighborhoods.

In 2020, West Cambridge had the highest existing tree canopy overall (36.4%) as well as the largest area of existing tree canopy (about 256 acres). Though the Strawberry Hill neighborhood's tree canopy cover was small in area (48 acres), it had the second highest tree canopy percent (35%). East Cambridge had the lowest percent tree canopy (11.4%) followed by MIT/Area 2 (14.7%). All of Cambridge's neighborhoods saw net gains in tree canopy between 2018 and 2020. North Cambridge had the largest gains, both in terms of area (12 acres) and in terms of relative percent change (9.4%). Mid-Cambridge still saw increases in tree canopy but saw the smallest gains with a 0.69 increase in tree canopy acres, representing a relative percent increase of 0.9%. Strawberry Hill had similar growth in area to Mid-Cambridge with an increase of 0.7 acres, but because Strawberry Hill had a lower tree canopy area in 2018, it represented a larger magnitude of change, a relative percent increase of 1.4%.

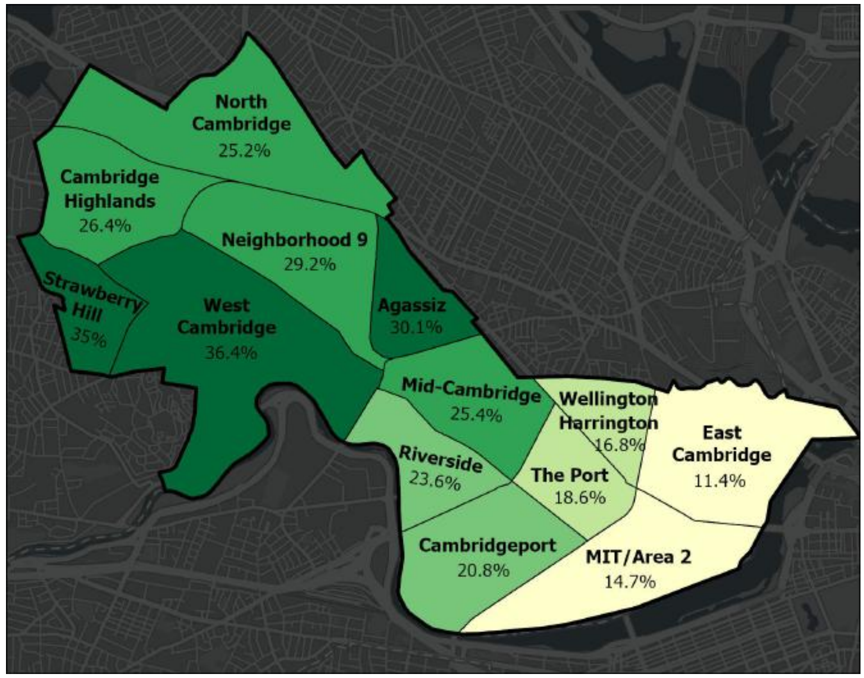


Figure 14: Existing tree canopy percentage for 2020 summarized by neighborhood.

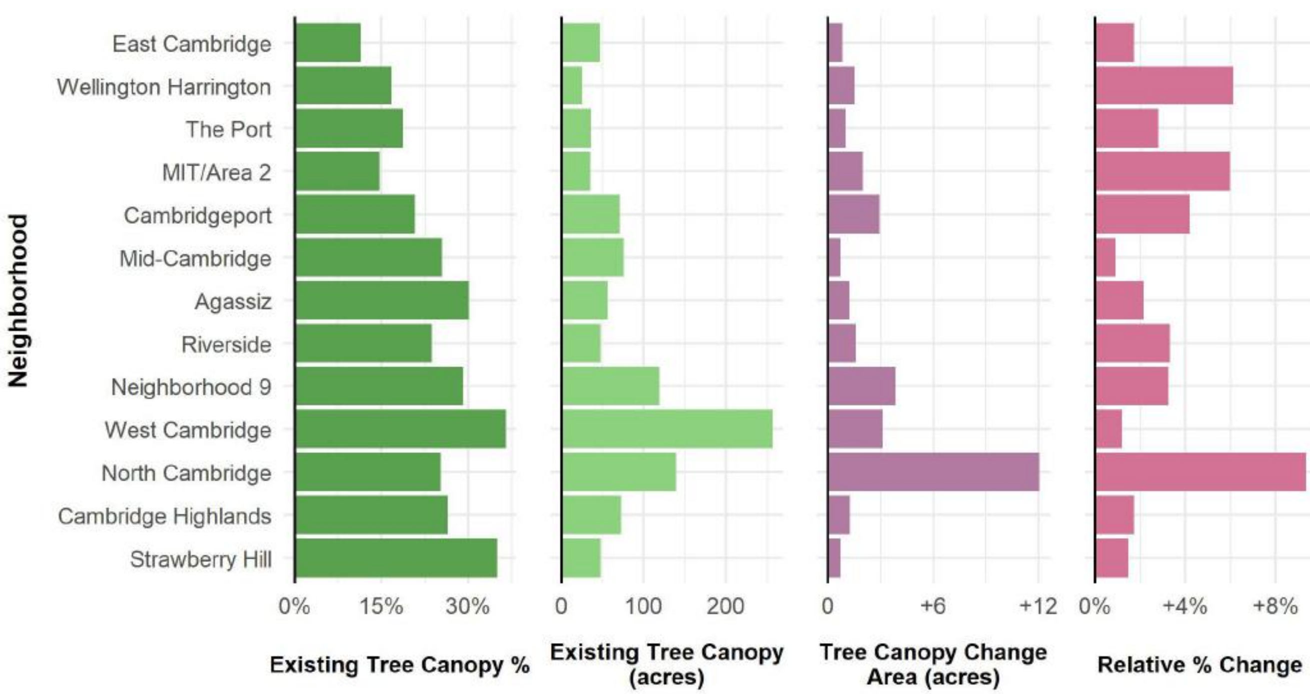
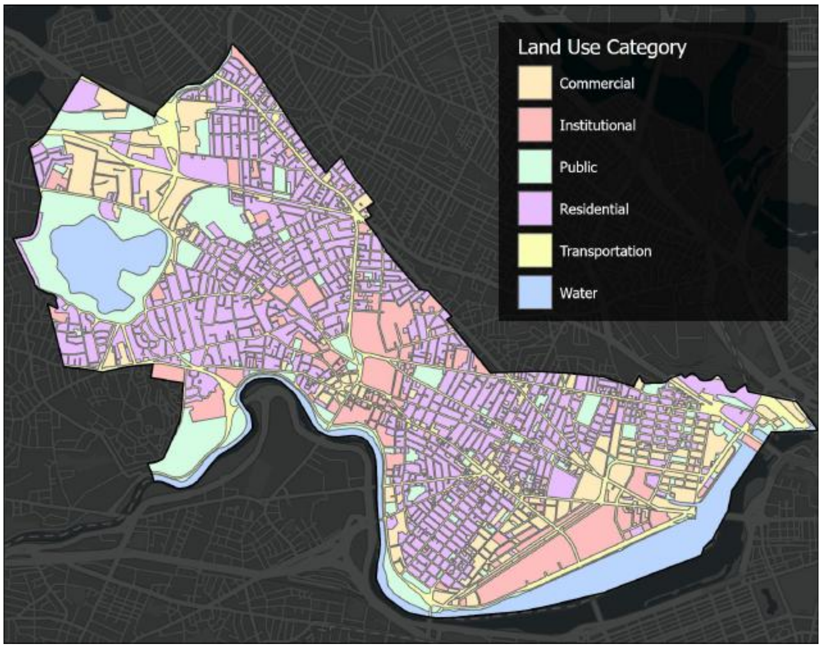


Figure 15: Tree canopy and 2018-2020 change metrics by neighborhood.

2020 Land Use Tree Canopy

Cambridge's urban forests span all land use types with varying coverage depending on the physical characteristics of each category. Understanding the location and land-use types that tree canopy falls into is important information for coordination and planning purposes. Tree canopy cover was calculated in terms of percent of the land area within land use category (Figure 11) to understand the proportion of each of each unit with canopy coverage, and as a percent of Cambridge's total existing tree canopy area (Figure 10) to determine contribution of each land use to the city's overall tree canopy cover.



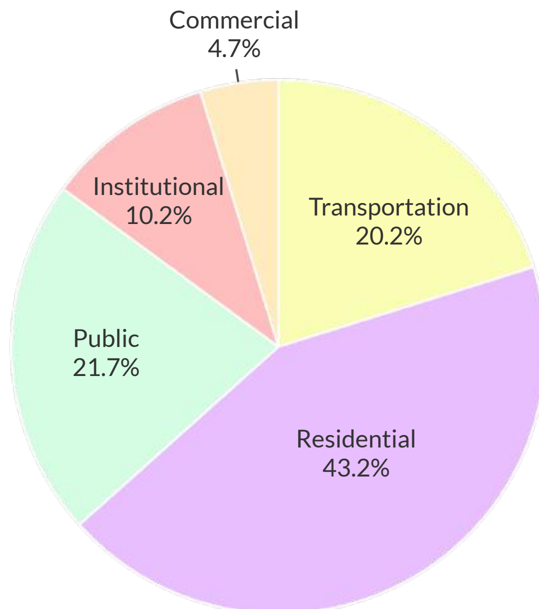


Figure 16: 2020 Cambridge simplified land use categories (left) and proportion of overall existing tree canopy found in each land use category (right).

The majority of Cambridge's tree canopy (43.2%) falls within residential land use areas. Despite being such a major contributor to overall tree canopy area, only 29% of residential land area is currently covered by tree canopy. This represents a major opportunity to create gains in Cambridge's tree canopy through plantings in residential areas. Public land use types make up the next largest portion (21.7%) of Cambridge's overall tree cover with about 222 acres of tree canopy. Though public areas make up a smaller number of tree canopy acres, they have the highest percentage of tree canopy coverage 37.8%. Commercial land use areas had the lowest tree canopy coverage in terms of percent tree canopy (8.5%), area of tree canopy (48 acres), and contribution to overall tree canopy (4.7%). increasing tree canopy in these areas would support ecosystem services in these areas and boost tree canopy cover overall.

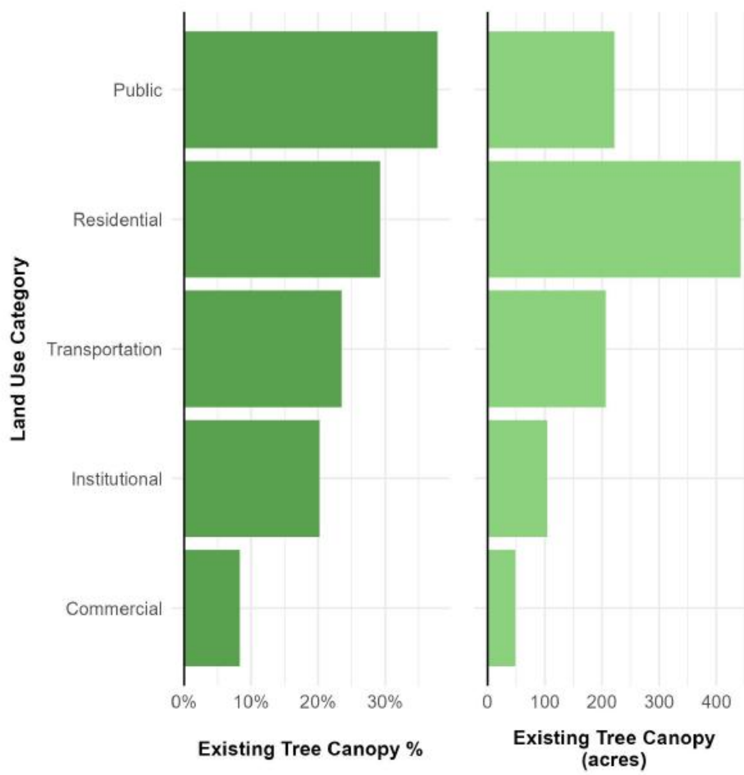


Figure 17: Tree canopy metrics in 2020 by Land Use.

2009 to 2020 Land Use Tree Canopy

One of the driving forces of differences in tree canopy distribution across Cambridge is how the land is used in each location. Some land use types are more conducive to suitable tree habitat than others but all areas can benefit from the ecosystem services a healthy tree canopy provides. All land use categories except, for public lands, followed a trend of having peak tree canopy in 2009, lowest in 2014, and increasing tree canopy in 2018 and 2020, though not reaching initial 2009 levels.

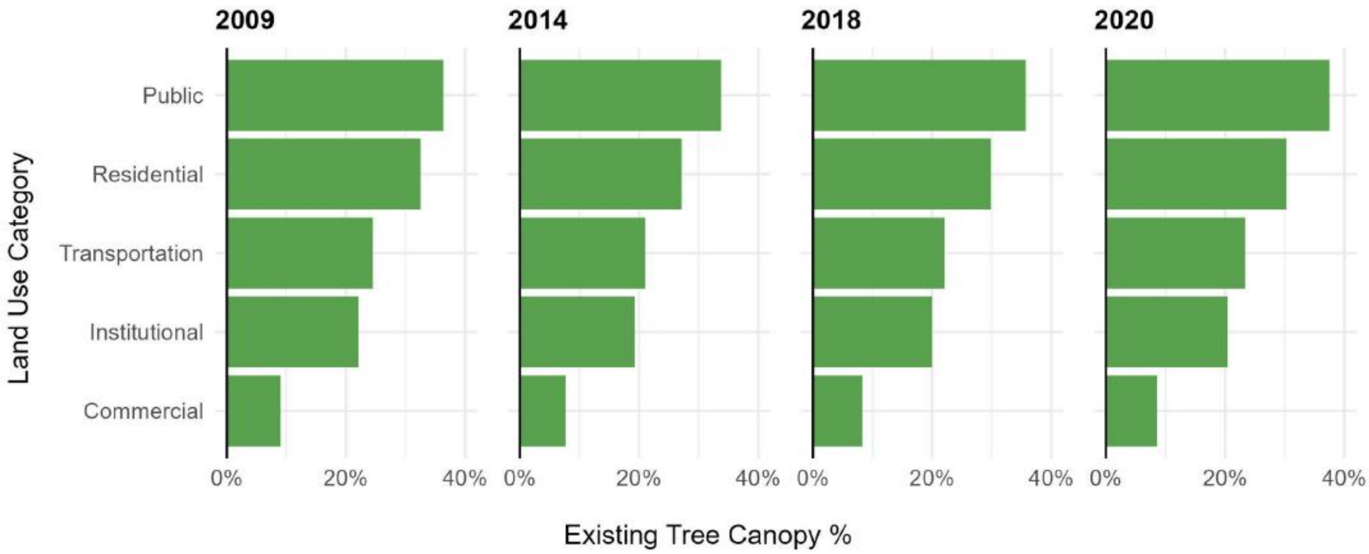


Figure 18: Existing tree canopy % each year (2009- 2020) summarized by land use type.

With a low of 33.8% tree canopy in 2014 to a high of 37.5% in 2020, public land was the only land use category that showed a net gain from over the entire study period. 2020 public land tree canopy surpassed 2009 levels by about 7 acres, resulting in a 1.2% net gain in tree canopy percent. Though public lands had the highest percent tree canopy each year, residential land use areas consistently represented the largest area in acres of tree canopy. However, residential areas saw the largest net loss of tree canopy over the entire time period. From 2009 to 2020, residential lands lost about 33 acres, a net loss of 2.22% tree canopy .

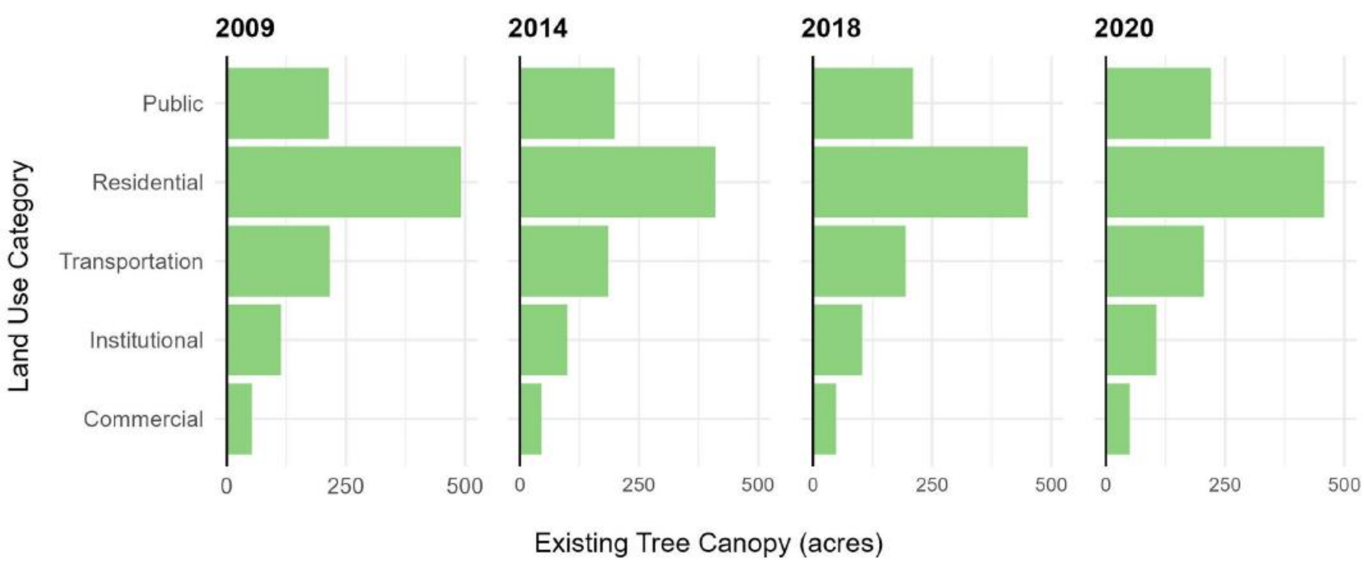


Figure 19: Existing tree canopy acres each year (2009 to 2020) summarized by land use type.

2009 to 2020 Land Use Tree Canopy Change

All of Cambridge's land use categories experienced both gain and loss of tree canopy within their boundaries, but overall loss outpaced gains across Cambridge, amounting to an overall decrease in canopy from 2009-2020. Planting and preservation efforts, natural succession, and growth of existing trees have helped to move towards recovery of tree canopy since the the steep decline between 2009 and 2014. Though losses currently still outpace gains, there is an opportunity for Cambridge to continue

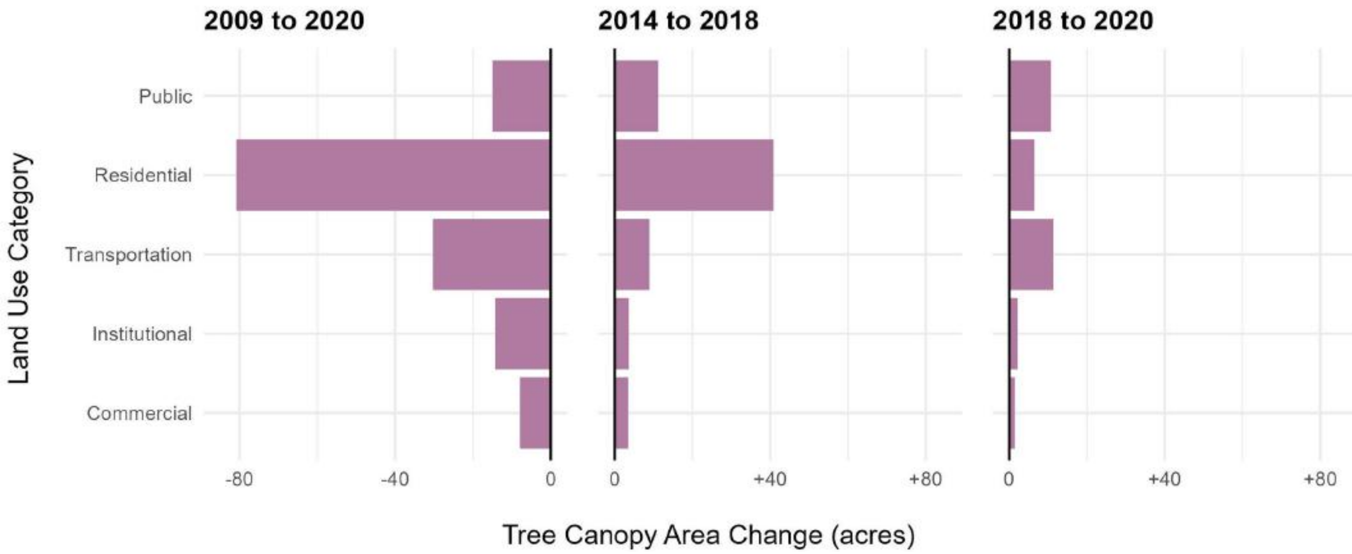


Figure 20: Tree canopy area change between time periods summarized by land use type.

With a total loss of 15 acres and a total gain of 22 acres, public land was the only category to see net gains in tree canopy by 2020. Transportation was the only category to see greater gains in the 2018 to 2020 period than the 2014 to 2018 time period. Residential areas saw an increase of 41 acres of tree canopy between 2014 and 2018 but only 6.5 additional acres between 2018 and 2020. It is important to keep up the trend of growth in order to meet tree canopy goals. In addition to area change, examining the relative percent change in tree canopy between time periods gives us insight into the magnitude of change in those areas. Though 2009 to 2014 losses by acre in commercial land use areas were relatively small, the sparse initial tree canopy coverage meant that these losses had an outsized impact on the area.

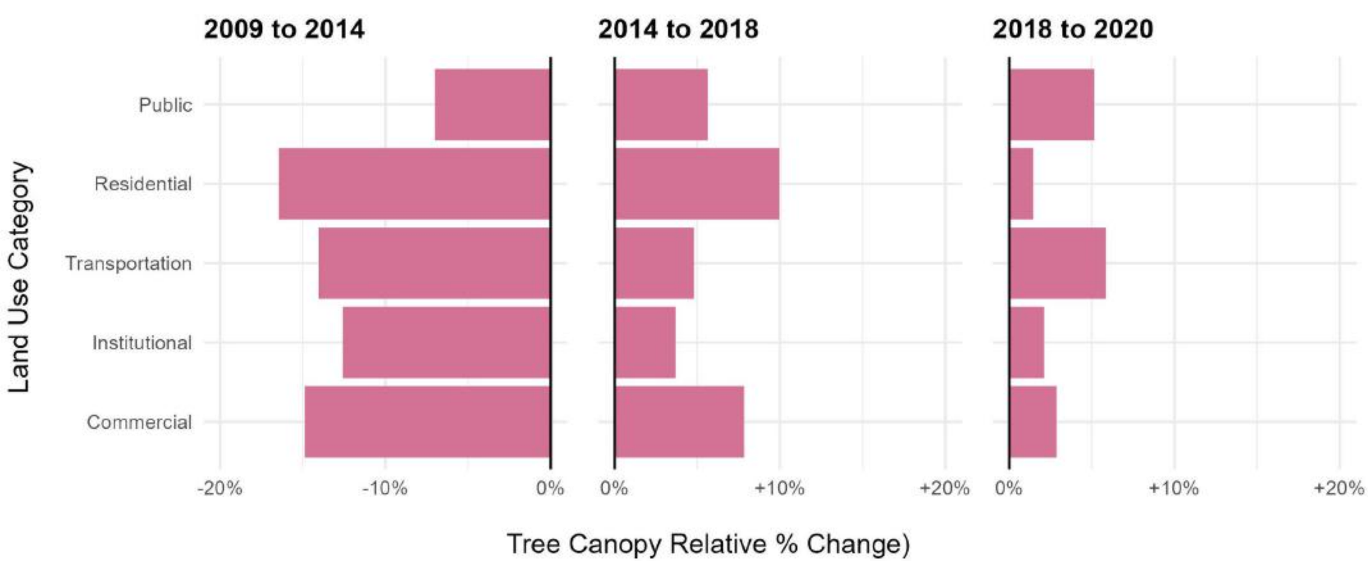


Figure 21: Relative percent change of tree canopy between time periods summarized by land use type.

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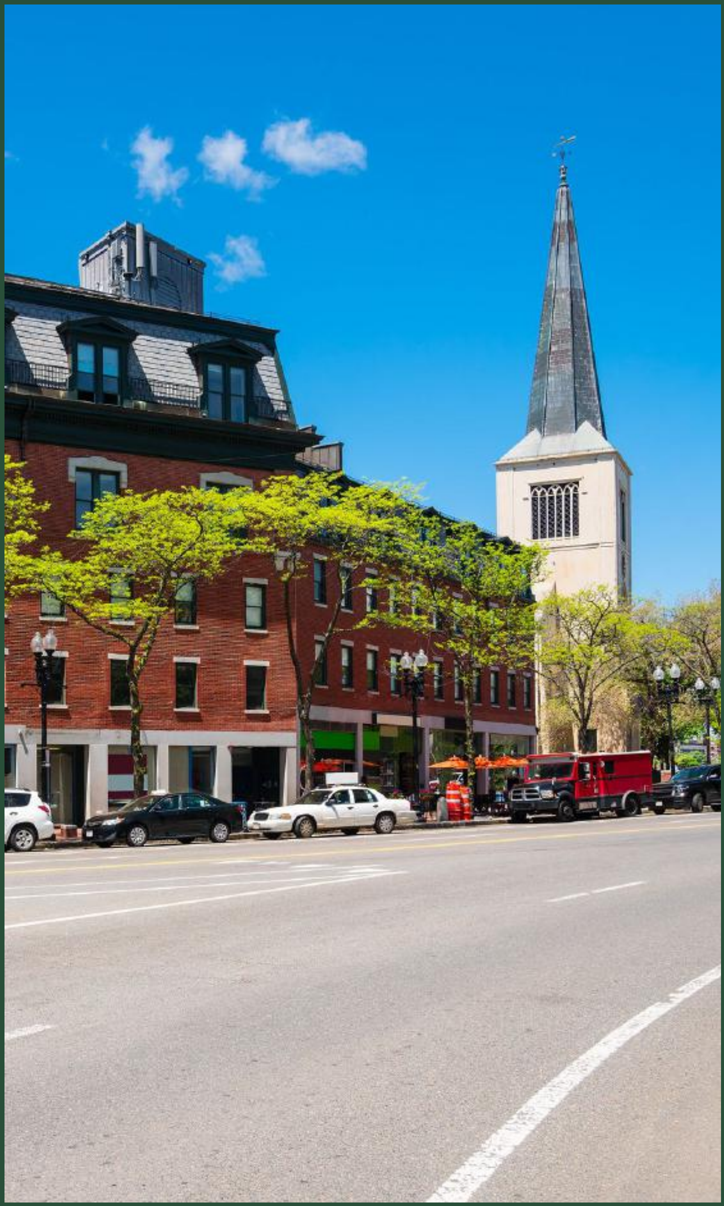

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