Greener City Technical Report

RESILIENT CAMBRIDGE

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Greener City

1. Overview and Problem Statement

Cambridge (the City) is working to create a Greener City that supports resiliency and enhances the quality of life of its residents by cooling the environment on hot days, reducing stormwater pollution, and expanding the vegetated landscape. As extreme events defined by increased precipitation, sea level rise (SLR), coastal storm surges (SS), and extreme heat are projected to be more intense and frequent, plants will become increasingly important in helping to mitigate the negative impacts of climate change. The natural environment contributes to a better quality of life and a healthier built environment for Cambridge residents, while also providing the benefit of reducing temperatures and contributing to flood mitigation. There is an urgent need to preserve and grow the natural, vegetative environment in Cambridge. While these strategies will help mitigate climate impacts, vegetation is also vulnerable to increasing temperatures, changes in natural germination cycles, and the increased likelihood of drought and unstable growing conditions. Increased flooding threatens to damage planted areas through erosion and, in some cases, brackish inundation. Consequently, an enhanced "Greener City" will be one where improvements to open spaces, green infrastructure (GI) and urban trees will be implemented to both mitigate and adapt to climate change.

The challenge for Cambridge, which is densely populated and largely developed, will be to balance urbanization with the health of the City's vegetation. The density of development makes the implementation of new planting difficult due to a lack of available land area. Impervious surfaces exacerbate urban heat island (UHI) impacts and flooding. Natural loss of mature trees and the impact of human activity contributes to increasing tree canopy loss. If no action is taken, development pressures can contribute to an increasing amount of impervious area throughout the City.

The Greener City section of Resilient Cambridge aims to address existing and projected climate impacts by increasing the amount of vegetation citywide and increasing access to open spaces citywide, thereby also enhancing quality of life for Cambridge residents. The Greener City section of Resilient Cambridge assessed the following four indicators with the goal of recommending strategies that will result in measurable improvements to these indicators:

1. Pervious area
2. Tree canopy cover
3. Vegetation index
4. Access to open space

To better understand Cambridge's existing green spaces, a citywide baseline representing existing conditions was established for each of the four indicators. The baseline refers to a "snapshot" of existing conditions in the City. Having documentation of the current conditions, the baseline, allows for comparison to future conditions, as a measurement of progress. This baseline analysis was then used to determine "higher priority" neighborhoods for implementation of strategies that support a Greener City. This report summarizes the results of the baseline analysis and concludes with strategies and recommendations informed by these results. Recommendations were also informed by previous and ongoing analyses including The Port and Alewife Preparedness Plans and Handbooks, the Envision Alewife Gap Analysis, the Urban Forest Master Plan, the City's Open Space and Recreation Plan, and the Climate Resilience Zoning Task Force (CRZTF) Cool Factor. This report aims to synthesize findings and

recommendations from these previous and ongoing initiatives with findings from the baseline analysis to present holistic and comprehensive strategies for improving the Greener City.

While not the focus of this report, the interaction between green, vegetated areas and water is an important feature of the urban landscape that was considered. This interaction is explored further in the Stronger Infrastructure portion of the Resilient Cambridge plan and may be addressed further in future studies. Plants need water for growth and survival. However, flooding from increased precipitation and storm surge/sea level rise (SS/SLR) will adversely affect flood intolerant vegetation. Planted vegetation and green infrastructure (GI) can also help mitigate flooding impacts, decrease stormwater runoff, enhance groundwater recharge, and improve the water quality of surrounding surface water bodies. The City of Cambridge spans two watersheds shown in Figure 1, with the eastern side of the City draining to the Charles River and the western side of the City draining to the Alewife Brook and eventually to the Mystic River. About two-thirds of the City drains to the Charles River, and one-third to the Mystic River via Alewife Brook. While most of the City's land area is developed, the City does have some wetland areas in the vicinity of Alewife Brook and Fresh Pond.

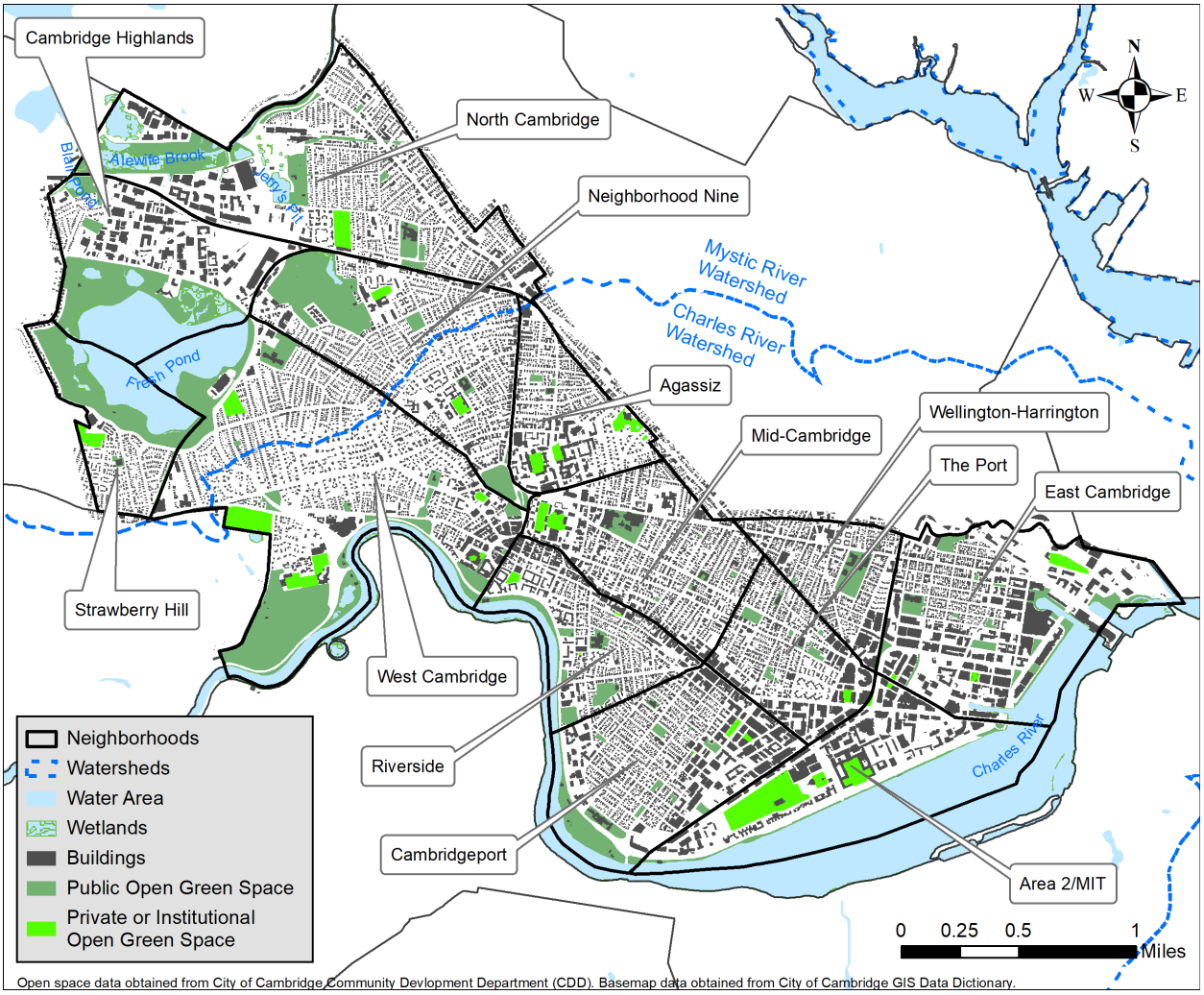


Figure 1 – *City water bodies, wetlands and open spaces. (Source: 2020 City GIS database)*

The City's water bodies and wetlands are significant components of the urban landscape with Fresh Pond Reservoir having the added importance of serving as the City's primary drinking water supply. Improvements to the City's green, vegetated spaces will help improve water quality in these downstream water bodies in addition to the other benefits these improvements will provide. The Alewife Stormwater Wetland is an example of a successfully implemented project in the City that highlights the interaction of vegetation with water to provide flood mitigation, enhanced water quality and wildlife habitat, and public access to a green space (Figure 2). This project is especially noteworthy as it was completed as part of a much larger sewer separation project and solved the need for new stormwater discharge and managed wetland impacts, flood plain impacts, and pre- and post- peak discharge requirements without violating wetland and flood plain regulations. The 3.4 acre constructed wetland simultaneously restores natural habitat creating parkland and public amenities.

Figure 2 – Alewife Stormwater Wetland

2. Analysis Methodology

The citywide baseline was established by mapping GIS layers that represent existing conditions of the Greener City. Percentages of **existing pervious area, tree canopy cover** and **total vegetated area** were determined for each neighborhood in the City to establish a baseline. A pedestrian network analysis was performed in GIS to determine the percentage of City parcels in each neighborhood that are within a 5-minute, 10-minute and 15-minute walking distance from a publicly accessible open space. Additionally, open space area per capita was determined for each neighborhood to better understand the amount of open space available relative to the population. This metric identifies neighborhoods where the amount of open space area is more critical and may need to be increased to provide a higher level of service to residents. These two metrics of walking distance and open space per capita were used to establish the

baseline for the **access to open space** indicator. There are some limitations to using the neighborhood boundary to define access, as these boundaries are arbitrary in terms of how open space is experienced by a resident; for example, one might be on the border of two neighborhoods. Refer to Section 3 for more detailed descriptions of the datasets used and analysis performed.

The baseline analysis was performed to summarize the current conditions of green, open spaces throughout Cambridge and provide recommendations where improvements should be prioritized and the level of improvement that can realistically be achieved. A simple prioritization system was developed to assign priority levels for the implementation of recommended strategies in each City neighborhood. A priority level of higher, medium or lower priority was assigned to each City neighborhood for each of the four indicators assessed based on thresholds outlined in Table 1. Thresholds were determined for each of the four indicators based on levels of vegetation and accessibility observed under existing baseline conditions including citywide average values, as well as reasonable levels that could be achieved through the implementation of recommended strategies. Previous analyses, including The Port and Alewife Preparedness Plans, the Envision Alewife Gap Analysis, and the Urban Forest Master Plan evaluated levels of pervious area and tree canopy that could be achieved under various implementation scenarios. These analyses informed the thresholds for the pervious area and tree canopy indicators. The thresholds for the access to open space indicator depend both on the percentage of City parcels within a 5-minute walking distance and open space area per capita. The numerical values for the thresholds were determined mainly by comparing to the existing baseline conditions and were informed generally by the City's Open Space and Recreation Plan

Table 1 – Higher, Medium and Lower Priority Thresholds for Each of the Four Indicators Describing the Greener City

Indicator	Higher Priority Neighborhood	Medium Priority Neighborhood	Lower Priority Neighborhood
1. Pervious area	Equal to or less than 30% of land area is pervious	Greater than 30% but equal to or less than 40% of land area is pervious	Greater than 40% of land area is pervious
2. Tree canopy	Equal to or less than 25% of land area has tree canopy cover	Greater than 25% but equal to or less than 30% of land area has tree canopy cover	Greater than 30% of land area has tree canopy cover
3. Vegetated index	Equal to or less than 30% of land area is vegetated	Greater than 30% but equal to or less than 40% of land area is vegetated	Greater than 40% of land area is vegetated
4. Access to Open Space	Less than 80% of parcels are within 5-minute walking distance or the open space area per capita is below the current citywide average	Less than 90% of parcels are within 5-minute walking distance or open space area per capita is below the current citywide average	Greater than 90% of parcels are within 5-minute walking distance and open space area per capita is above the current citywide average

The City is conducting further study on equitable access to open space through the 2020 Open Space Plan update.

3. Description of Data Used for Baseline Analysis

This section of the Greener City report describes the GIS data layers that were acquired to establish the baseline in addition to providing more specification for how the data were used in the analyses. ***Impervious, pervious, and tree canopy data*** were obtained from Applied Ecological Services (AES) and Reed Hildebrand; these layers were created for the City's Urban Forest Master Plan (UFMP)[1]. Data reflect 2018 conditions and were the most recent datasets available at the time of the analysis. The tree canopy data reflect 2018 "leaf-on" conditions. Existing tree canopy and impervious layers also serve as inputs to the baseline condition for land cover used in the UHI analysis. Areas identified as pervious are not necessarily vegetated including artificial turf fields, areas consisting of unvegetated soil or gravel, and areas with permeable pavers or porous asphalt.

Vegetated and unvegetated areas were estimated using 60-cm resolution aerial imagery data obtained from the United States Department of Agriculture (USDA) as part of the National Agriculture Imagery Program (NAIP). Aerial imagery data represents September 2018 "leaf-on" conditions, which generally matches the timeframe represented in the impervious area and tree canopy area layers and was the most recent dataset available at the time of the analysis. Raw aerial imagery data was processed by researchers at the University of Vermont to produce a GIS layer representing the ***normalized difference vegetation index (NDVI).*** NDVI is a quantitative measure that has been used extensively as a tool to indicate the presence and quality or density of vegetation. NDVI is calculated as a value from -1 to 1, with values greater than 0 representing vegetated areas and values less than 0 representing unvegetated areas. Using NDVI has its limitations when values are derived from aerial imagery data in urban areas. Shadow effects from urban buildings can result in vegetated areas appearing unvegetated with NDVI values less than 0. Additionally, the time of year when aerial imagery is captured greatly affects the values of NDVI as vegetation can change significantly throughout the year. Despite its limitations, NDVI is a useful metric for quantifying the amount of green vegetated area on a neighborhood scale as it captures both ground vegetation and overlying tree canopy vegetation in one composite metric. NDVI can also distinguish pervious areas that are vegetated and pervious areas that are unvegetated, such as artificial turf fields, areas consisting of unvegetated soil or gravel, and areas with permeable pavers or porous asphalt. Average NDVI was summarized at a 2-acre hexagon grid scale as recommended by UVM to account for limitations of aerial imagery data in urban areas and display NDVI values at a broad scale.

Open space layers for public open spaces, private and institutional open spaces that are publicly available were provided by the City's Community Development Department. These are the same open space designation and layers being used currently to update the City's Open Space and Recreation Plan. Population per neighborhood was obtained from the City's 2019 Neighborhood Statistical Profile and was used to assess open space area per capita. Neighborhood boundaries, water body and wetland layers were obtained from the City's GIS Data Dictionary.

In addition to quantifying and mapping the various components of the Greener City baseline, a network analysis was performed to determine resident access to public open space, or publicly accessible private or institutional open space. Using a ***pedestrian network dataset*** provided by the City's Community Development Department and the Network Analyst tool in ArcGIS, service areas were generated representing areas of the City within a quarter mile and within a half mile of an open space. Assuming an

[1] https://www.cambridgema.gov/Departments/publicworks/Initiatives/urbanforestmasterplan

average walking speed of about 3 miles per hour, a quarter mile distance corresponds approximately to a 5-minute walk and a half mile distance corresponds approximately to a 10-minute walk.

4. Results of Baseline and Network Analyses

This section of the report presents the results of the Greener City baseline and network analyses, and the identification of higher and lower priority neighborhoods for the implementation of recommended strategies. Results of the baseline analyses are presented spatially and quantitatively in citywide maps and bar charts.

The baseline for the ***pervious surface indicator*** is displayed in Figure 3. Figure 3 shows the divide between western and eastern Cambridge, with the six western neighborhoods generally being lower priority neighborhoods with pervious surface percentages greater than 30%, and the seven eastern Cambridge neighborhoods being higher priority implementation areas with pervious surface percentages less than or equal to 30%. This divide is expected considering the predominant land uses that exist on the two sides of the City, with the western side of Cambridge having more low-density residential, mid-density residential and open space land use, and the eastern side of Cambridge having more commercial, institutional and high-density residential land use. The Port neighborhood has the lowest percentage of existing pervious surfaces at 19%. Since 2009, overall citywide pervious area has remained relatively constant, only decreasing by approximately 42.3 acres or 1% of citywide land area. Figure 3 displays impervious areas as either building or non-building. This classification is important for determining the applicable strategies and level of implementation that is realistically feasible for different strategies.

While the western neighborhoods of Cambridge generally have high percentages of pervious surfaces, it is worth noting that some areas, particularly the Alewife Quadrangle and the area in West Cambridge around Harvard Square, have less pervious surface compared to the rest of West Cambridge and could be areas for implementing the Greener City strategies. Throughout the City, pervious surfaces generally contain some form of vegetation in the form of low-height grass, mid-height vegetation, or high-height tree canopy. However, it should be noted that surface areas consisting of bare soil, gravel, artificial turf, or permeable pavement are still classified as pervious despite having limited to no vegetation. Percentage of pervious surfaces is only one indicator for assessing the green vegetation in an urban environment and should be assessed in combination with the other indicators of Greener City.

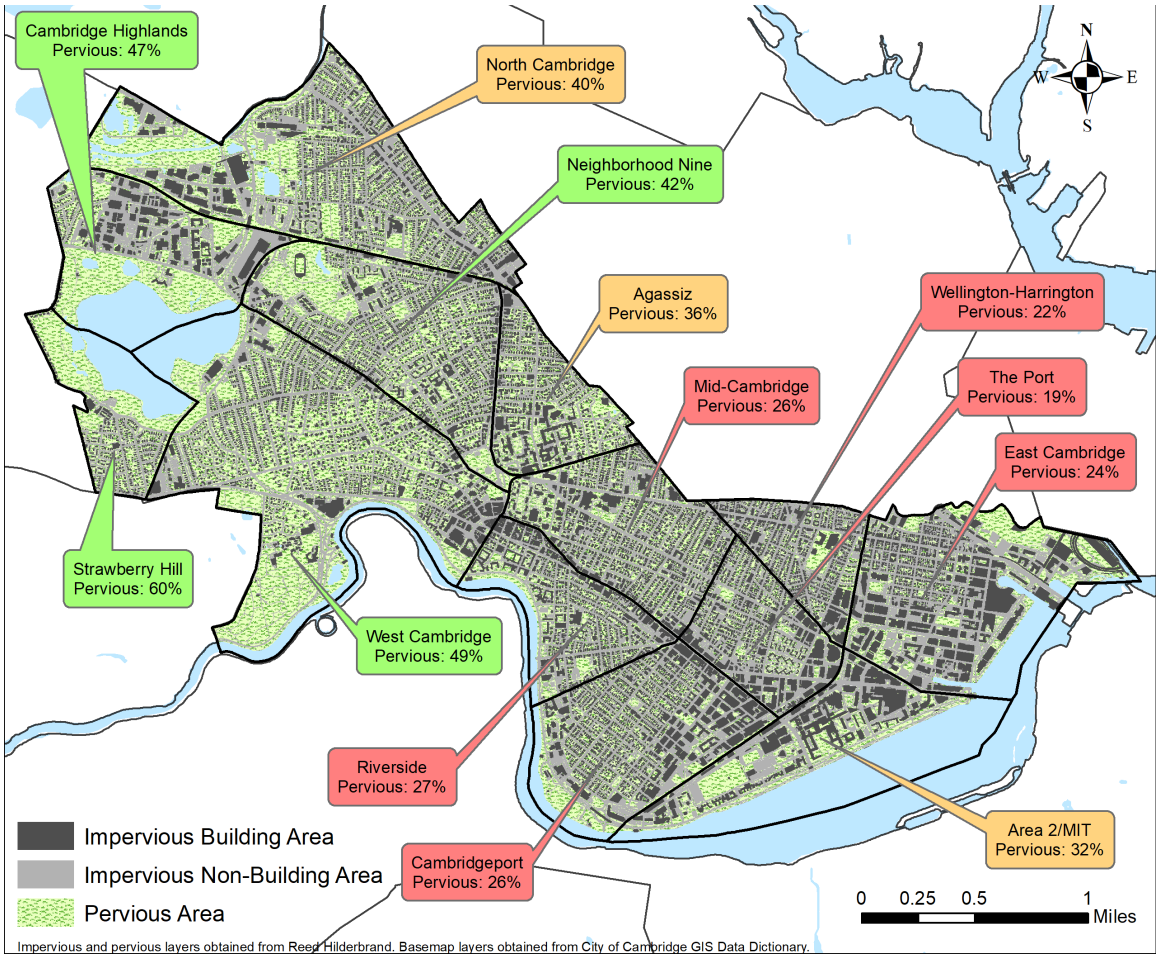


Figure 3 – Citywide Impervious and Pervious Surfaces.

The ***baseline for tree canopy*** is displayed in Figure 4. Like the baseline for pervious surfaces, neighborhoods in western Cambridge are generally lower priority for tree canopy with canopy percentages greater than 25%, and neighborhoods in eastern Cambridge are generally higher priority with tree canopy percentages less than 25%. However, the divide between western and eastern Cambridge is not as stark for pervious surfaces with two neighborhoods on the western side of the City (Cambridge Highlands and North Cambridge) having tree canopy percentages just above the 25% level recommended in the Urban Forest Master Plan (UFMP). These neighborhoods could soon fall below 25% tree canopy if current canopy loss trends continue and adequate tree maintenance and planting strategies are not implemented. Climate change may increase the loss of canopy. Since 2009, overall citywide tree canopy has decreased from 30% to 26% of citywide land area. The Urban Forest Master Plan notes that if this trend of 16.4 acres of canopy loss per year continues, citywide tree canopy will decrease to 21.6% by 2030.[2]

As expected, lower tree canopy percentages generally correlate with neighborhoods and areas containing less pervious surfaces and a higher density of development. The East Cambridge neighborhood has the lowest percentage of existing tree canopy cover at 13%.

[2] https://www.cambridgema.gov/-/media/Files/publicworksdepartment/urbanforestmasterplan/20191112cufmtechnicalreport.pdf

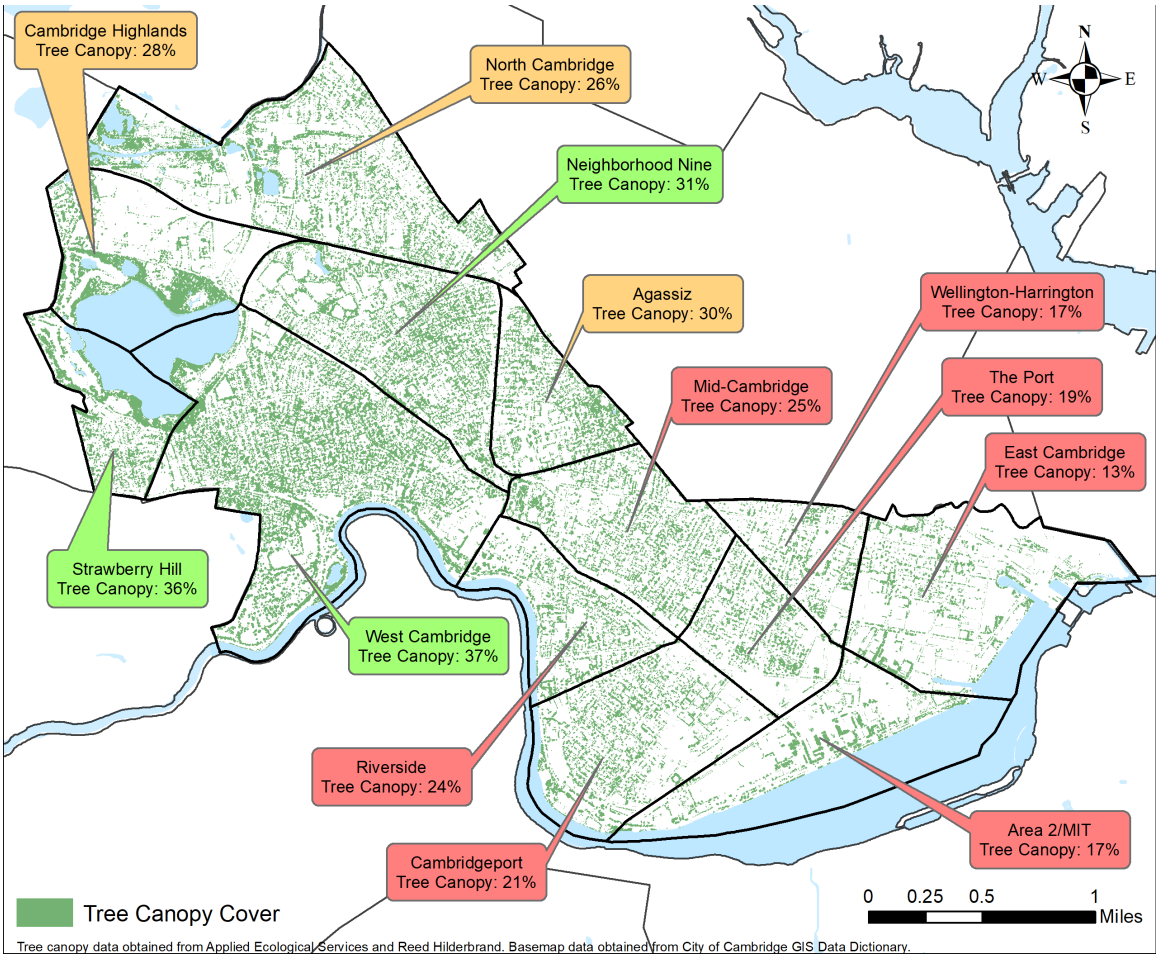


Figure 4 – Citywide Tree Canopy.

The ***baseline for NDVI*** is displayed in Figure 5. The three neighborhoods with the lowest percentages of vegetated area are Area 2/MIT, Wellington-Harrington, the Port and East Cambridge at 30%, 26%, 25% and 19%, respectively. Neighborhoods on the eastern side of Cambridge, Mid-Cambridge, Riverside, and Cambridgeport had lower percentages of vegetated area than the western neighborhoods. However, the percentage of vegetated area in these neighborhoods was still above 30% and was higher than the individual percentages of pervious area and tree canopy in these neighborhoods. This indicates that despite the low percentages of pervious area and tree canopy in these neighborhoods, a significant portion of the tree canopy is covering and providing shade to impervious areas and thus increasing the total neighborhood area with some form of vegetative cover. On the other hand, North Cambridge is 41% pervious but only 39% vegetated due to the presence of unvegetated pervious surfaces like the MBTA rail corridor and Russell Field with artificial turf.

While the use of NDVI as a measure of vegetation has its limitations in urban areas, the metric is useful in combination with the other indicators assessed in this analysis. Assessment of NDVI shows that the percentage of vegetated area does not always correspond directly to the percentages of tree canopy, and pervious area as tree canopy can cover both pervious and impervious surfaces, and pervious surfaces can be vegetated or unvegetated. Additionally, NDVI can provide a high-level overview of the quality and density of vegetation, indicated in Figure 5 by the four ranges of average NDVI values.

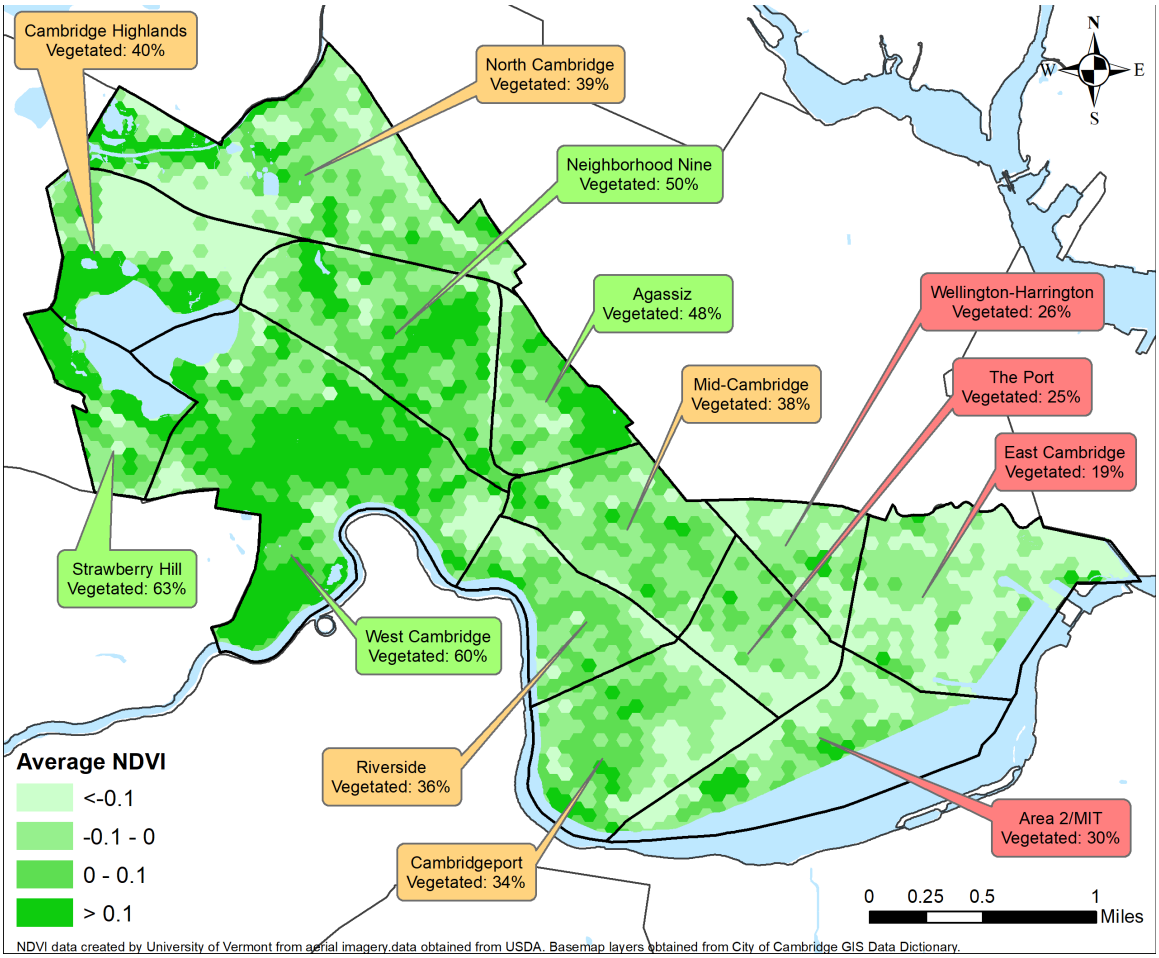


Figure 5 – Citywide Normalized Difference Vegetation Index (NDVI) summarized by 2-acre hexagon grid.

Figure 6 summarizes the citywide baseline for the pervious area, tree canopy and vegetation index indicators and allows for comparison of all neighborhoods to the citywide averages. As discussed previously, the western City neighborhoods are generally above the citywide averages for pervious area, tree canopy cover, and vegetated index area compared to the eastern neighborhoods that are generally below the citywide averages. Figure 6 also shows that while the vegetated index area is generally greater than the pervious area percentage, this is not the case for all neighborhoods. In Cambridge Highlands, North Cambridge, Area 2/MIT and East Cambridge, the vegetated index area percentage is less than the pervious area percentage. This demonstrates that the vegetated index area percentage per neighborhood depends on the distribution of tree canopy over impervious and pervious area and the vegetative quality of pervious area.

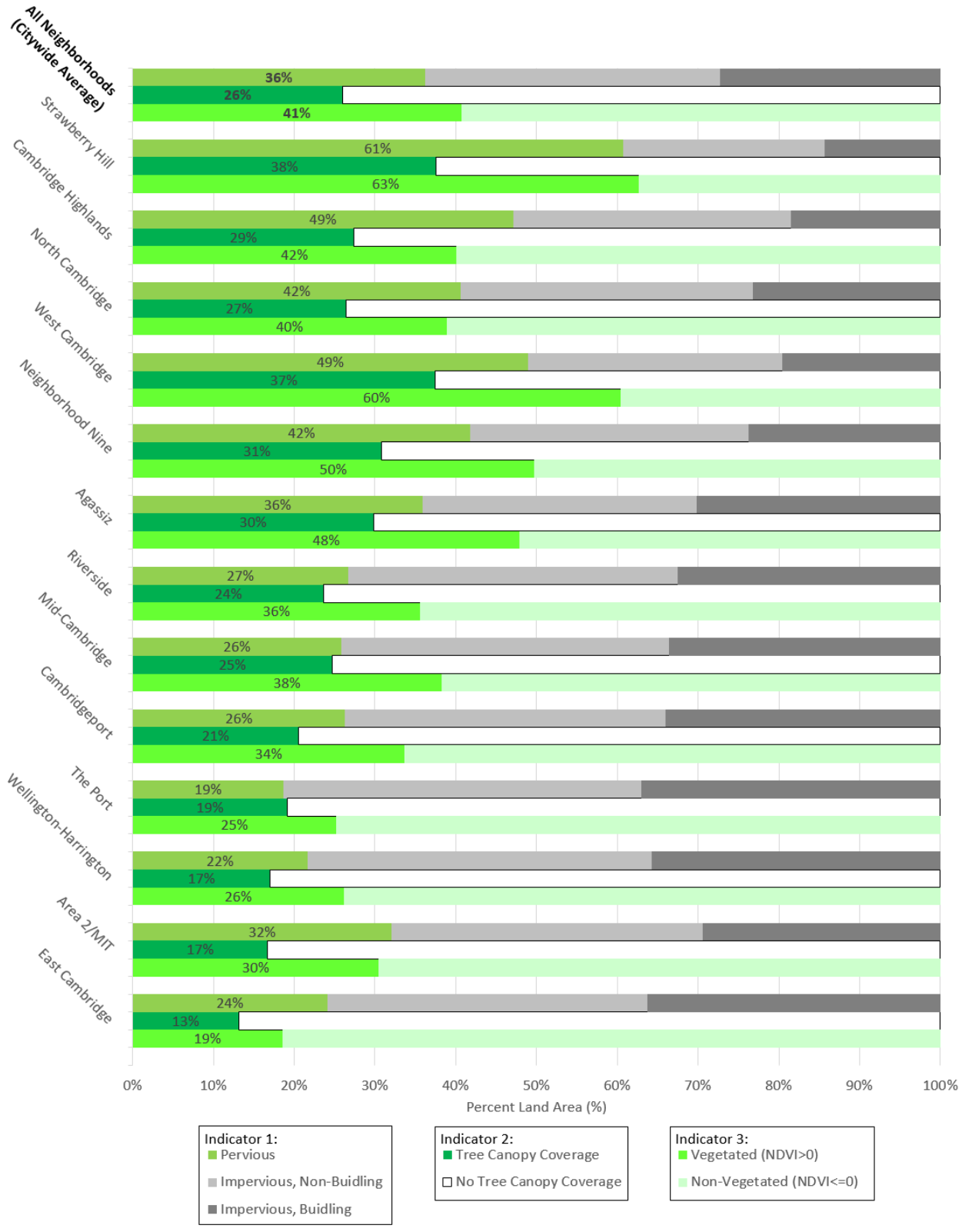


Figure 6 – Percent pervious area, tree canopy coverage and vegetated area for individual neighborhoods and for all neighborhoods (citywide average).

The baseline for ***open space accessibility*** is displayed in Figure 7. As shown in Figure 7, most of the City is within a 5-minute service area (quarter-mile walking distance) of an open space and essentially all people in the City are within a 10-minute service area (half-mile walking distance) of an open space. This indicates adequate accessibility and good spatial distribution of open spaces throughout the City. The two main areas shown to have longer walking distances to open spaces are the areas around Porter Square and between Huron Avenue and Brattle Street. However, these areas are still mostly within the 10-minute service area of an open space considered to be adequate.

The spatial network analysis of accessibility to open spaces did not consider open spaces in cities adjacent to Cambridge. All open spaces were treated equally in this analysis despite open spaces varying in size, recreational purpose (playgrounds, sports fields, walking paths, etc.), and amount and quality of vegetation. A more detailed spatial analysis could be conducted to incorporate and weight these aspects of open space accessibility, as well as determine areas with service to multiple open spaces or areas serviceable by multiple pedestrian paths, preferably with adequate tree canopy cover to remain cool on hot days.

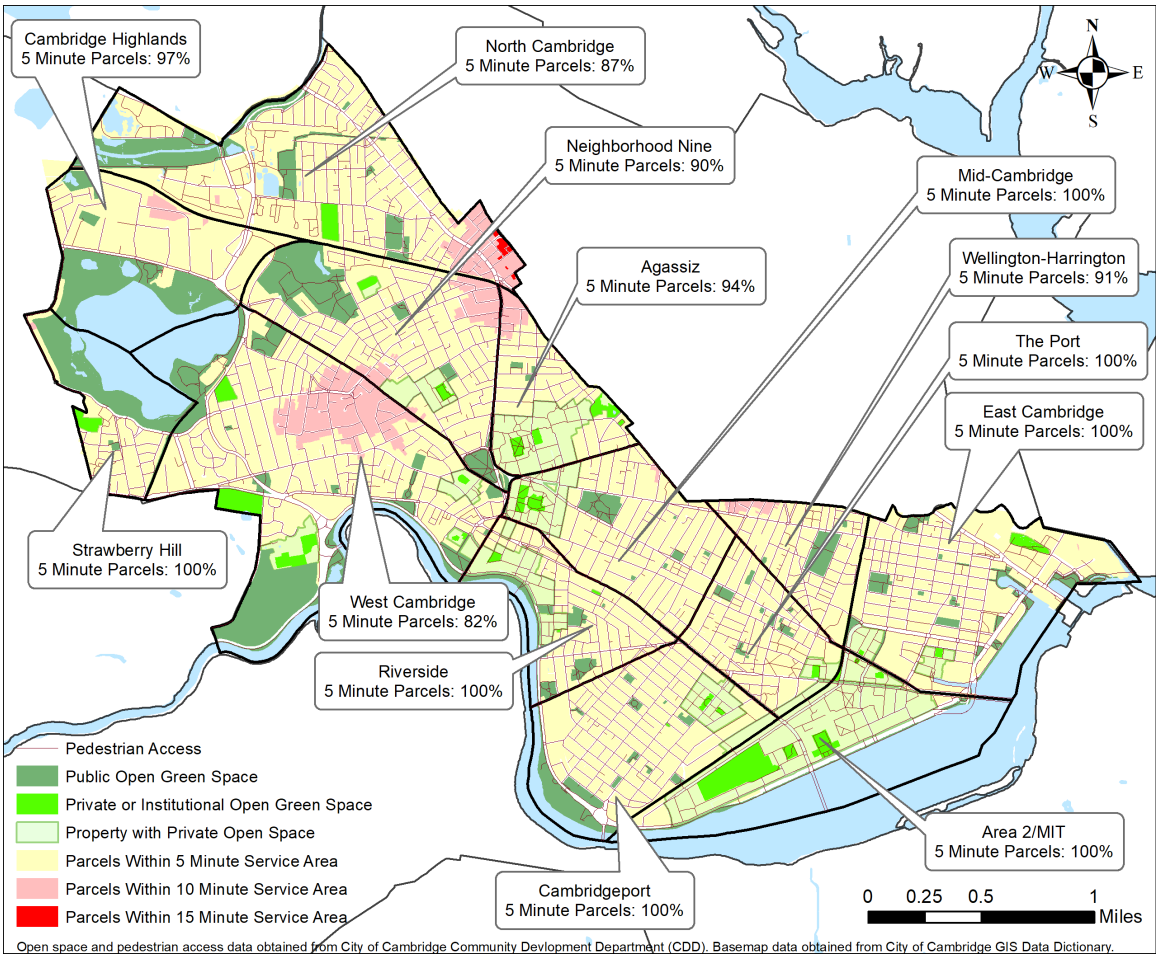


Figure 7 – Citywide open spaces and service areas.

The baseline for open space accessibility was also assessed in terms of open space area per capita for each City neighborhood and for all neighborhoods to represent the citywide average. Figure 8 summarizes square feet of open space per capita. This value can be thought of as representing how open spaces are shared by the neighborhood population. A lower value of open space per capita implies there is less open space allocated per person. As shown in Figure 8, the western City neighborhoods besides Agassiz are all above the citywide average. This indicates that there is adequate open space area relative to the neighborhood population, resulting in less instances of open spaces potentially becoming crowded or overstressed due to increased use. The eastern City neighborhoods besides Area 2/MIT are all below the citywide average. Even though access to open spaces in these neighborhoods may be adequate in terms of walking distance, assessment of the open spaces in terms of area per capita indicates that these areas are still underserved to some extent and could benefit from increasing open space area. The City is currently updating its existing Open Space and Recreation Plan, which outlines the shared community goals of the open space system including increasing the amount of open space area and improving and maintaining the quality of existing and new open spaces.[3] These baseline findings and recommendations can inform the update of the Open Space and Recreation Plan so that recommendations address the shared community goals of the plan, as well as enhance the Greener City.

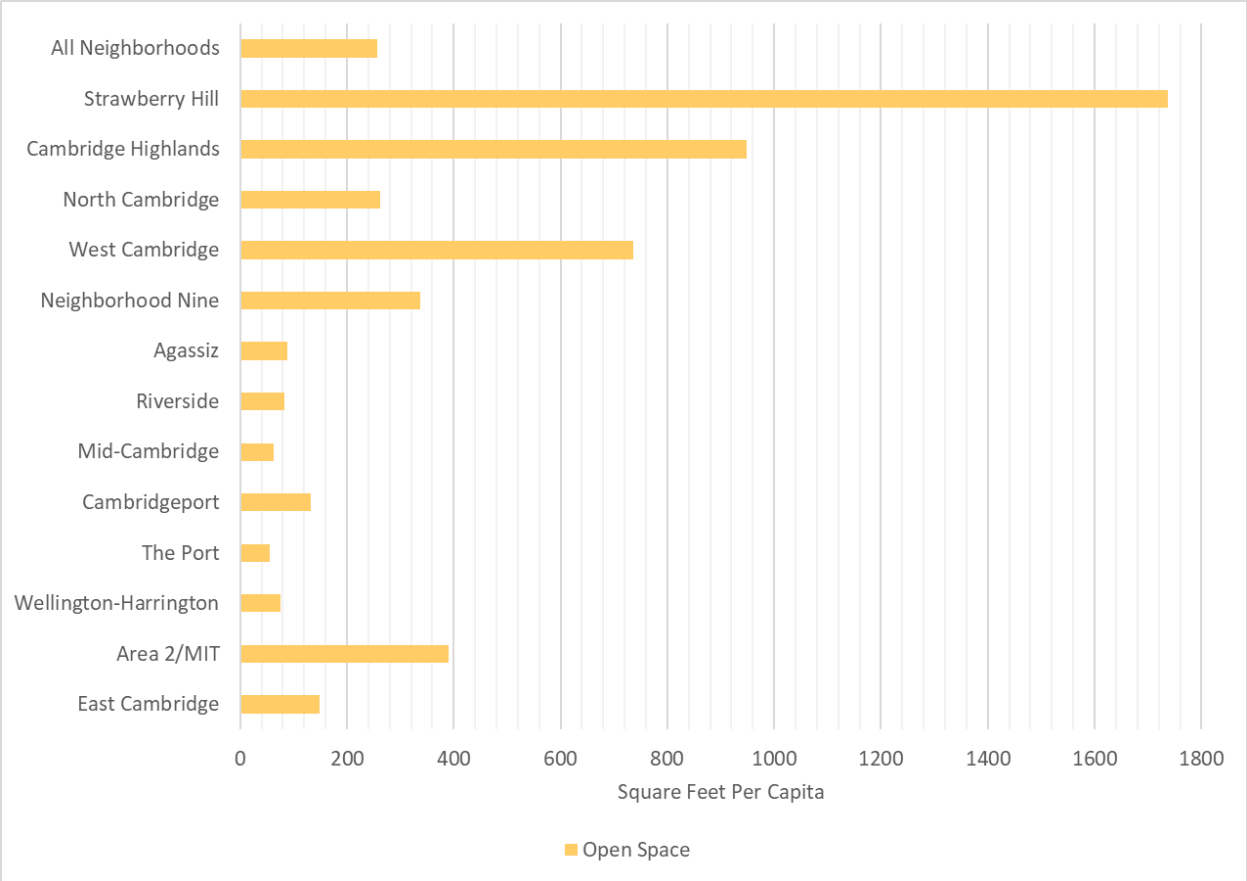


Figure 8 – Square feet of open space per capita for individual neighborhoods and for all neighborhoods (citywide average).

[3] https://www.cambridgema.gov/CDD/parks/osplanning/openspaceplan

Neighborhoods and areas of higher priority for the implementation of recommended strategies were determined from the results of the baseline analyses. Table 2 summarizes the priority level determinations for each neighborhood scale for each of the four indicators of Greener City.

Table 2 – Priority Levels for the Implementation of Strategies by Neighborhood and Indicator of the Greener City

Neighborhood	Pervious Area	Tree Canopy Cover	Vegetated Area (NDVI)	Access to Open Space
East Cambridge	Higher Priority	Higher Priority	Higher Priority	Medium Priority
Area 2/MIT	Medium Priority	Higher Priority	Higher Priority	Lower Priority
Wellington-Harrington	Higher Priority	Higher Priority	Higher Priority	Medium Priority
The Port	Higher Priority	Higher Priority	Higher Priority	Medium Priority
Cambridgeport	Higher Priority	Higher Priority	Medium Priority	Medium Priority
Mid-Cambridge	Higher Priority	Higher Priority	Medium Priority	Medium Priority
Riverside	Higher Priority	Higher Priority	Medium Priority	Medium Priority
Agassiz	Medium Priority	Medium Priority	Lower Priority	Medium Priority
Neighborhood Nine	Lower Priority	Lower Priority	Lower Priority	Medium Priority
West Cambridge	Lower Priority	Lower Priority	Lower Priority	Medium Priority
North Cambridge	Medium Priority	Medium Priority	Medium Priority	Medium Priority
Cambridge Highlands	Lower Priority	Medium Priority	Medium Priority	Lower Priority
Strawberry Hill	Lower Priority	Lower Priority	Lower Priority	Lower Priority

Thresholds were determined for each of the four indicators based on levels of vegetation and accessibility observed under existing baseline conditions including citywide average values, as well as reasonable levels that could be achieved through the implementation of recommended strategies. Refer to Table 1 for threshold values.

East Cambridge, Wellington-Harrington and The Port were identified as the highest priority neighborhoods for the implementation of planting strategies, with these neighborhoods assigned a high-priority level for three of the four indicators of the Greener City. Area 2/MIT, Cambridgeport, Mid-Cambridge and Riverside were identified as mid-level priority neighborhoods with these neighborhoods assigned a high-priority level for two of the four indicators of Greener City. Agassiz, North Cambridge, and Cambridge Highlands were identified as medium- to lower-priority neighborhoods with some opportunities for improvement in at least one of the four indicators of Greener City. Neighborhood Nine, West Cambridge and Strawberry Hill were identified as the lowest priority neighborhoods.

The assessment of Greener City on the neighborhood scale provides a general overview of the areas where planting strategies should be implemented. It should be noted that the neighborhood boundaries, while useful in prioritizing areas of implementation, are somewhat arbitrary; neighborhoods vary significantly in size, population, demographic, and predominant land-use types. Additionally, some priority areas, such as the Alewife Quadrangle and Harvard Square, span multiple neighborhoods and are not necessarily captured when assessing the Greener City at the neighborhood scale.

In the United States, people of color have historically been left out of planning practices, and discriminatory housing, education, and economic policies have hindered their ability to maintain secure housing, accumulate wealth, and seek equal opportunities. These types of policies have had lasting, multi-generational impacts on Black Americans and immigrants. The results of these policies vary, but can lead to less investment in park spaces, trees, and vegetation. Although Cambridge is proactively investing in all its neighborhoods, understanding potential overlaps in communities of color and areas with a deficit of quality open space, urban forest, and other vegetation can help identify where to prioritize public improvement projects and programs that support a healthy urban forest.

Race and ethnicity were evaluated per neighborhood using the CDD's demographic profile in the Closer Neighborhoods Technical Report. The neighborhoods with the highest percentages of people of color are MIT/Area 2, North Cambridge, Cambridge Highlands, and the Port. Of these neighborhoods, the Port was identified as a high priority neighborhood for increasing pervious area, tree canopy cover and vegetated area and a medium priority for improving access to open space. MIT/Area 2 was identified as a medium to high priority neighborhood for increasing pervious area, tree canopy cover and vegetated area and a low priority for improving access to open space.

The City should consider prioritizing open space improvements and additional vegetation, including maintenance of the urban forest, in the Port due to the low amount of open space in this neighborhood and low density of vegetation and tree canopy.

Resilient Cambridge strategies intend to support a more equitable Cambridge in terms of livability, wellness, and climate preparedness, particularly for communities of residents who have been marginalized in planning processes in the past.

5. Key Findings

The recommended strategies are targeted specifically at "higher priority neighborhoods," which are defined as having less than 30% pervious area, less than 25% tree canopy cover, less than 30% of the land that is vegetated, and less than 80% of parcels a 5-minute walk from a publicly accessible open space. The per capita area amount of open space also adds a new dimension to open space access. While neighborhoods might be highly walkable to publicly accessible open space, there may be a low amount per capita available to be enjoyed, particularly in the denser residential neighborhoods in southeastern Cambridge.

Within these neighborhoods, land ownership and development patterns are important factors in understanding implementation. There is a distinct trend between the northwestern part of the City and the southeastern part. For example, in dense-residential neighborhoods such as the Port, East Cambridge, Wellington-Harrington, Cambridgeport, Riverside, and Mid-Cambridge, there is less vegetated and pervious area and tree canopy cover due to the dense character of the built environment.

Because there is limited "open space" on private, residential parcels, strategies in these neighborhoods should be targeted at the scale of the urban, public realm, including public right-of-way (PROW) improvements, park retrofits, and land use changes (public projects) to facilitate the creation of new, publicly accessible open space. Strategies targeted at private parcels should acknowledge the space limitations in these "higher priority neighborhoods." Policies and programs intended to increase

vegetation should consider building-scale strategies such as intensive and extensive green roofs, vegetated facades, and improvements to small lawn areas through low-mid story planting. The Cambridge Cool Factor[4], performance-based zoning concept provided useful case studies for how small, residential parcels can realistically contribute to the Greener City. The Cool Factor requires a realistic target by calibrating the site based on its open space requirements by zoning and then best leveraging existing site and building area to provide better temperature reduction.

The neighborhoods of West Cambridge, North Cambridge, Neighborhood Nine, Cambridge Highlands, and Strawberry Hill have a less dense urban fabric and more open, private parcel area that can be improved through planting. At the same time, Neighborhood Nine, West and North Cambridge are less walkable to publicly accessible open spaces. Strategies in these neighborhoods might focus less on PROW improvements and park retrofits and more on regulations and incentives for private property owners and developers to increase the quality and density of their vegetation (private policies and programs).

6. Recommended Strategies Based on Baseline Analysis

This section presents strategies that respond directly to the four indicators of a Greener City: pervious area, vegetated area, tree canopy cover, and accessibility to public open space and publicly accessible private and institutional green spaces. The strategies also address the amount of "open space per capita" as an indicator of equitable access. The aim of implementation of these strategies is to not only create a Greener City through increased vegetation, but also to enhance the quality and density of vegetation. In doing so, more Cambridge residents will experience a Greener City that contributes to UHI reduction, water quality, and quality of life.

The strategies are organized by their goal or intent and include the actions needed to be taken to fulfill the goal. Each action is categorized as a project, policy or regulation, program, plan/study. If implemented, these recommendations would transform both the public and private realms to create resilient urban landscapes citywide. Together these public and private green spaces work as a connected system. The driving principle of these recommendations is that there is equitable access to quality green spaces for all residents, and that in particular populations at risk have ample access to these spaces. The following tables summarize the strategies based on which indicator of a Greener City they address, where implementation should happen, what the City is already doing to address the goal, and relevant case studies, research, or concurrent projects that support the aim of the strategy. The updated strategies inform the Resilient Cambridge Handbook:

- Provide for a Resilient Urban Forest (D1)
- Enhance Outdoor Thermal Comfort (D2)
- Reduce Impervious Area *(D3 - updated)*
- Seek Green Infrastructure Opportunities (D4)
- Expand and Improve Open Spaces (D5, new)

[4] https://www.cambridgema.gov/CDD/Projects/Zoning/climateresiliencezoning

The City is undertaking concurrent initiatives that are informing strategies for a Greener City:

The ***Urban Forest Master Plan*** (UFMP) was released by the City in November 2019 and will guide the development of the urban forest into the future. It includes a strategic plan to evaluate, maintain, and expand the urban forest canopy while being more resilient to climate change, reducing the UHI effect, mitigating stormwater runoff, reducing nutrient runoff, and contributing to community well-being. The plan addresses the health of the urban forest in both the public realm, on City property, and on private parcels. Resilient Cambridge strategies are informed by the UFMP to enhance the urban canopy in areas most exposed to UHI to help alleviate extreme temperatures.

Concurrently, the City is working with a ***Climate Resilience Zoning Task Force (CRZTF)***[5]***.*** This task force was created to build upon the City's 2017 Climate Change Vulnerability Assessment (CCVA) and ongoing Resilient Cambridge planning efforts, as well as a citizen's zoning petition, and to advise on development standards that can be incorporated into the Zoning Ordinance[6] that would result in new development that fosters a more climate-resilient city. The CRZTF has developed a ***Cool Factor*** concept with specific "targets" addressing the greening of the public realm and enhancement of ecosystems. These targets are informed by Greener City analyses and the draft CRTZF recommendations have been included in the strategies that follow.

The City of Cambridge is undertaking a citywide ***Open Space Plan*** update to enhance and strategize the planning of the City's open spaces. Specific actions have been identified to inform the Resilient Cambridge Plan to enhance the resiliency of the City's ecosystem as informed by gaps identified with the main indicators.

<table>
<tr><td colspan="3">Indicator that the strategy addresses: area with tree canopy cover</td></tr>
<tr><td colspan="3">Priority neighborhoods for implementation: East Cambridge, The Port, Wellington-Harrington, Riverside, Area 2/MIT</td></tr>
<tr><td rowspan="5">Provide For a Resilient Urban Forest (D1)

Reduce the UHI effect and improve water quality by increasing the urban forest canopy, developing a comprehensive urban forest management plan, and continuing</td><td>ACTION</td><td>TYPE OF ACTION</td></tr>
<tr><td>1. Increase trees along streets, in parking lots, and areas with a high percentage of impervious area</td><td>Project</td></tr>
<tr><td>2. Develop an urban forest management plan</td><td>Plan/program – (in progress undertaken by Urban Forest Masterplan (UFMP))</td></tr>
<tr><td>3. Continue urban forest maintenance (UFMP)</td><td>Project (in progress undertaken by UFMP)</td></tr>
<tr><td>4. Implement recommendations of the UFMP</td><td>Project, Policy/regulation, program (in progress undertaken by UFMP)</td></tr>
</table>

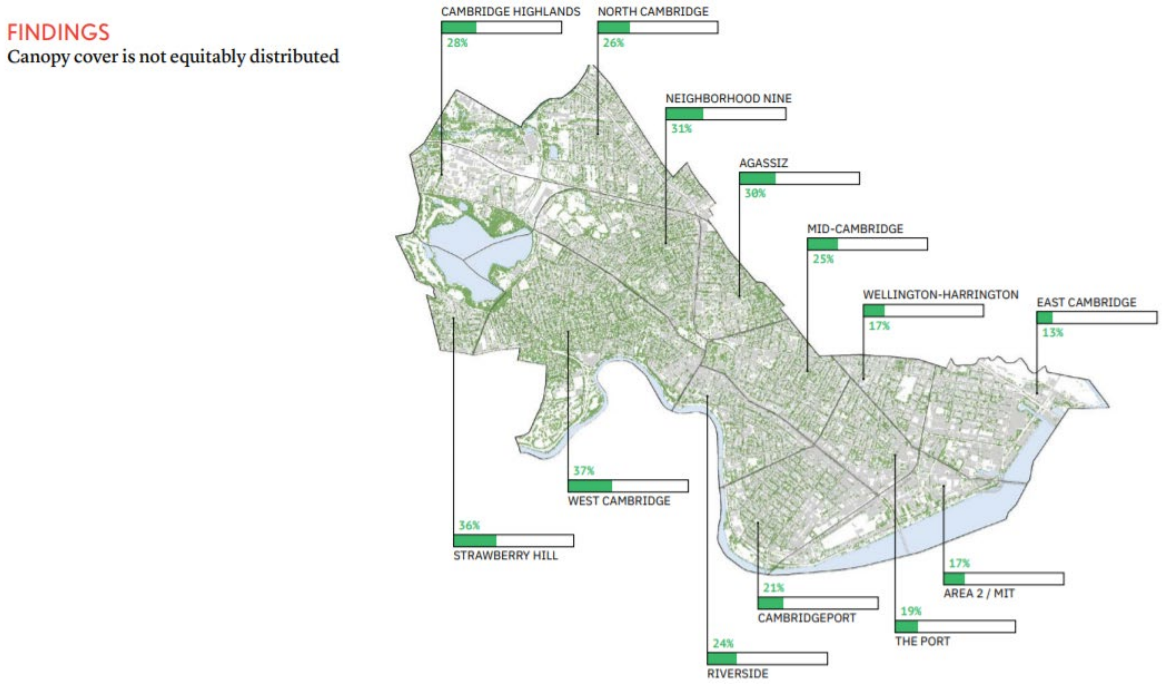
[5] https://www.cambridgema.gov/CDD/Projects/Zoning/climateresiliencezoning
[6] https://www.cambridgema.gov/CDD/zoninganddevelopment/Zoning/Ordinance

urban forest maintenance efforts	5. Enhance Tree Protection Ordinance	Regulation (in progress undertaken by UFMP)
	6. Proceed with the Cool Factor development and implementation of tree canopy strategies	Regulation (in progress being reviewing by CRZTF)
	7. Expand and conduct outreach for "Urban Forest Program"	Program
	8. Develop a program for tree planting parties	Outreach/Program (event)
	9. Study options for City parks retrofit projects to increase tree canopy	Project/Study to be included in the City Open Space Plan
	10. Initiate a Tree Trust to support the planting of trees on private property as recommended in the UFMP	Program
	11. Develop a partnership with educational institutions to increase their tree canopy	Program

What the City is already doing: UFMP, Tree Protection Ordinance, Cool Factor, Urban Forest Program

Case study/example of ongoing work/supporting research:

Policies, programs, and regulations such as the Tree Protection Ordinance, Cool Factor, and maintenance programs targeted at protecting trees on private properties are crucial, because the majority of the tree canopy is on private property, which is also where the most loss has occurred.

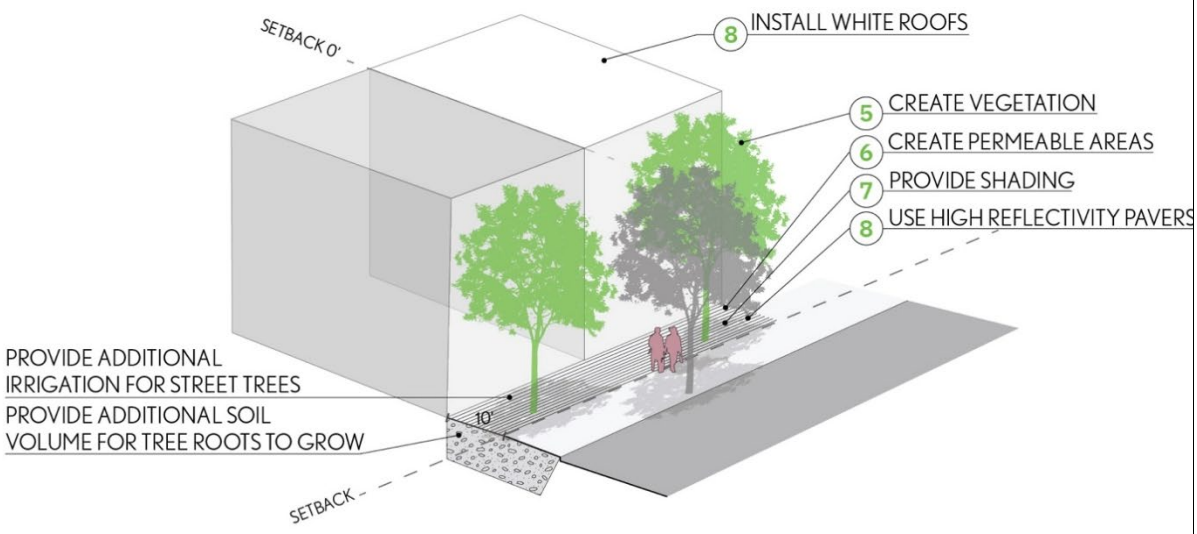


Source: Urban Forest Master Plan, 2019

<table>
<tr><td colspan="3">Indicator that the strategy addresses: pervious surface area, tree canopy cover area, equitable access, vegetated area</td></tr>
<tr><td colspan="3">Priority neighborhoods for implementation: Mid-Cambridge, Riverside, Area 2/MIT, Cambridgeport, East Cambridge, Wellington-Harrington, the Port</td></tr>
<tr><td rowspan="8">Enhance Outdoor Thermal Comfort (D2)

Develop “cool corridors” aligned with bike and pedestrian routes and MBTA bus stops to enhance outdoor thermal comfort for pedestrians, cyclists, and transit users.</td><td>ACTIONS</td><td>TYPE OF ACTION</td></tr>
<tr><td>1. Plant street streets and implement PROW planting along streets that are heavily trafficked by pedestrians to increase human comfort and contribute to UHI reduction</td><td>Project (Public/City and property owners)</td></tr>
<tr><td>2. Add additional permanent or flexible shaded structures at outdoor bus waiting area (cross-referenced strategy with Closer Neighborhoods)</td><td>Project</td></tr>
<tr><td>3. Increase accessibility to drinking water in public squares, parks, and at transit stops (cross-referenced strategy with Closer Neighborhoods)</td><td>Project</td></tr>
<tr><td>4. Conduct a feasibility analysis to better understand opportunities for replacing existing pavement with light-colored pervious or vegetated area.</td><td>Plan/study</td></tr>
<tr><td>5. Install spray pools in public parks</td><td>Project – approach to be further studied in the City Open Space Plan</td></tr>
<tr><td>6. Encourage planting on private property to enhance the contiguity of publicly accessible open spaces.</td><td>Policy/project</td></tr>
<tr><td>7. Partner with academic institutions to improve green open spaces and promote use by the public.</td><td>Program/Project</td></tr>
<tr><td colspan="3">What the City is already doing: Implementation of UFMP recommendations – Tree Protection Ordinance, park retrofit projects, Cool Factor, increased tree planting budget and targets for annual planting</td></tr>
<tr><td colspan="3">Case study/example of ongoing work/supporting research:
The primary goal of the Cambridge Cool Factor is to contribute UHI reduction and thermal comfort in the face of increasing temperatures. The Cool Factor presents a menu of strategies that property owners and developers can chose from to meet a target “cool score.” Scores are based on the relative</td></tr>
</table>

temperature reduction provided by each strategy and are given extra credit for cooling the public realm. Actions are complemented by the maximization of tree planting and GI in the PROW.



While the focus is to implement "green" or planting strategies for enhanced thermal comfort, it is assumed that in certain locations, planting options may be limited. Consequently, hardscape alternatives are also encouraged to reduce UHI and reduce outdoor temperature to benefit both people and ecosystems. As documented below, the impact of lower solar reflectance index (SRI) for hardscape is valuable:

- Paving with SRI of 39 or higher (aligned with LEED V4 requirements): Reflective "cool" materials contributed to at least 1 degree decrease in temperature, and in many cases an excess of 3 degrees. On a hot day, these materials contributed to a reduction of up to 6 degrees. *(Source: Louisville Urban Heat Management, Urban Climate Lab)*
- Shade structure with SRI of 39 or higher (aligned with LEED V4 requirements): Shaded surfaces, may be 20- to 45-degrees cooler than the peak temperatures of unshaded materials. *(Source: Environmental Protection Agency)*

Indicator that the strategy addresses: pervious surface area		
Priority neighborhoods for implementation: Mid-Cambridge, Riverside, Area 2/MIT, Cambridgeport, East Cambridge, Wellington-Harrington, The Port		
Reduce Impervious Area (D3 updated) Evaluate the implementation of GI to	ACTION	TYPE OF ACTION
	1. Evaluate revegetating paved areas and parking lots or implementing porous or high SRI paving.	Study, project

reduce UHI. *(In coordination with green and gray infrastructure stormwater strategies developed in Stronger Infrastructure.)* Adopt measures to increase the quality of the vegetated areas citywide.	2. Evaluate changing parking regulations to reduce minimum lot sizes.	Study, regulation
	3. Proceed with a comprehensive analysis of the vegetated area citywide to complement the NDVI analysis developed for Resilient Cambridge.	Study
	4. Implement the Cool Factor Zoning Ordinance requiring new developments and major retrofits to integrate strategies that contribute to reduction of impervious area and enhance the quality of the vegetated areas*.	Regulation
	5. Consider a small grant program for de-paving on private properties	study
	6. Update parking allowances through zoning to reduce minimum requirements	Regulation
	7. Reduce impervious surfaces on City properties	Project
What the City is already doing: Developing Cool Factor		
Case study/example of ongoing work/supporting research: Communities Responding to Extreme Weather host de-paving parties around Somerville and Cambridge.		

Source: Depave Hub

(*) The Cool Factor encourages the maximization of planted areas and encourages depth of soil, which supports enhanced vegetation.

Indicator that the strategy addresses: pervious surface area, tree canopy cover area, vegetated area, access to open space		
Priority neighborhoods for implementation: Mid-Cambridge, Riverside, Area 2/MIT, Cambridgeport, East Cambridge, Wellington-Harrington, the Port		
Seek Green Infrastructure Opportunities (D4) Implement GI to mitigate UHI. GI will also improve water quality and reduce flooding impacts from smaller rainfall events.	ACTION	TYPE OF ACTION
	1. Evaluate the potential for installation of raised planters in medium-density residential parcels in conjunction with streets improvement projects.	Projects
	2. Evaluate the potential to include bioretention basins in retrofitting medium-density residential parcels and in new high-density residential parcels, new light industrial development, public open space, and PROW.	Projects
	3. Evaluate using porous pavement and permeable pavers for residential driveways, new streets, and	Regulation (part of Cool Factor)

	parking lots of commercial parcels	
	4. Develop an education program for residents and public schools on local GI opportunities to benefit the local UHI.	Program

What the City is already doing: GI improvements to Western Avenue and Inman Square, new park projects and park retrofits, development of the Cool Factor

Case study/example of ongoing work/supporting research: Western Avenue improvements through GI as well as pedestrian and bike infrastructure provides a useful precedent for the "Cool Corridor" concept of increasing thermal comfort, stormwater management, and air quality through new plantings in the PROW.

Source: City of Cambridge

Indicator that the strategy addresses: access to open space		
Priority neighborhoods: North Cambridge, West Cambridge, East Cambridge, Wellington-Harrington		
Expand and Improve Open	ACTION	TYPE OF ACTION
	1. Develop a City Open Space Plan integrating retrofit projects to	Study

Spaces (D5, new)	increase tree canopy and the creation of new parks to provide cool, outdoor areas for public enjoyment	
	2. Easements on private property to enhance the contiguity of publicly accessible open spaces	Policy/project
	3. Study options for creation of new parks or publicly accessible open space in West Cambridge/Alewife and North Cambridge	City Open Space Plan
	4. Consider zoning change for a green roof ordinance or program to incentivize the creation of new green roofs that are ideally publicly accessible, or at least accessible to residents or workers.	Policy
	5. Partner with large property owners and institutions to improve green open spaces, and promote use by the public	Program/Project
	6. Increase access to waterplay areas and public pools	Program/Project

What the City is already doing: Updating the City open space plan, implementing the recommendations of Envision Cambridge, retrofitting the following park projects:

- **Binney Street Park**: The City will be constructing a new open space in eastern Cambridge located on Binney Street, between Galileo Galilei Way and the Grand Junction Railway Corridor.
- **Clarendon Avenue Playground:** The playground will undergo targeted repairs and equipment upgrades to improve play conditions for the safety of its users.
- **Graham and Parks School:** The playground will undergo repair and maintenance work to improve play conditions for the safety of its users.
- **Harvard Square Kiosk and Plaza Working Group:** In 2017, the City established a Harvard Square Kiosk and Plaza Working Group, comprising residents, business and property owners, representatives from local institutions, and urban design experts, to create a vision for the future use, operation, and governance of the Harvard Square Kiosk and Plaza.
- **Toomey Park**: The City is developing a new open space in eastern Cambridge located on Rogers Street between 2nd Street and 3rd Street.
- **Revised Design Approach for Triangle Park**: Building upon the work of the Urban Forest Master Plan process, the City is working with Stoss Landscape Urbanism to modify the proposed design of the new Triangle Park. The revised approach encourages greater tree canopy, in an area of the city

where increased planting has been identified as a priority. The new design increases the amount of planting area and number of new trees proposed for the park, while both fixed and movable seating continue to reflect the passive nature of the previous design.

Image Source: Stoss Landscape Urbanism

7. Projected Cooling Impact of Greener City Strategies

The Greening of the City will transform the built environment in ways that are projected to lower the impact of increase in temperature due to climate change. For the Climate Change Vulnerability Assessment (CCVA)[7] published in 2015, the City developed a model for reporting ambient air temperature[8]. The model was updated to 2018 conditions and was further developed to test projected impacts of implementing resiliency strategies including changes in tree canopy, pervious surface and implementation of cool roofs. Refer to the Better Buildings Technical Report for more information on cool roofs. Figure 9 below shows the modeled ambient air temperature for a 90°F day under existing conditions before implementation of resiliency strategies.

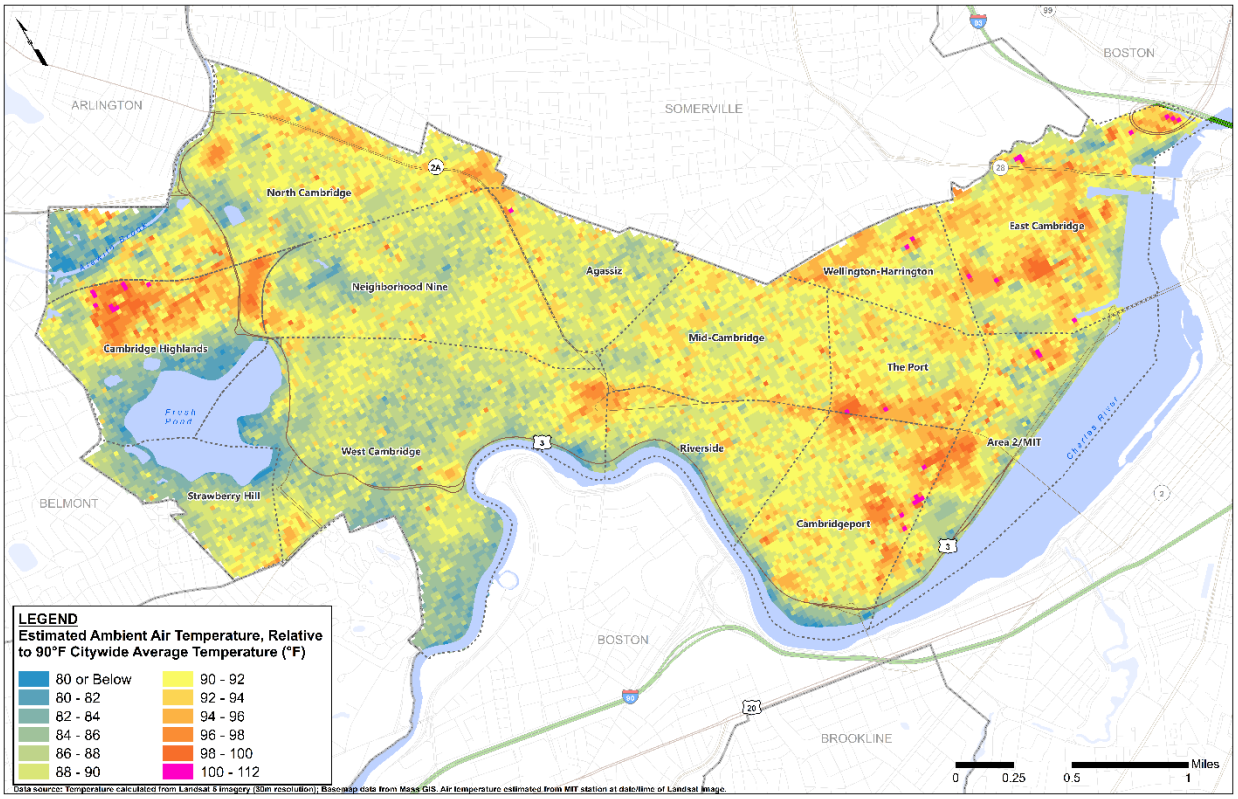


Figure 9. The map shows the modeled ambient air temperature adjusted for the 2018 tree canopy, impervious, and cool roof conditions.

The future ambient air temperature scenario for cool roof achieves a greatest decrease in average citywide temperature. While these results are tentatively promising, it should be noted that there are limitations and assumptions to the modeling approach for cool roofs that may overestimate the anticipated cooling benefit. The future impervious scenario results in the greatest percentage of citywide land area experiencing cooling, however all of this cooling is lower magnitude cooling less than

[7] https://www.cambridgema.gov/-/media/Files/CDD/Climate/vulnerabilityassessment/ccvareportpart1/cambridge_november2015_finalweb.pdf

[8] The methodology for developing the model is explained in a technical memo available at https://www.cambridgema.gov/-/media/Files/CDD/Climate/vulnerabilityassessment/ccvareportpart1/climateprojectionsandscenariodevelopment/appendixdurbanheatislandprotocolnovember20151.pdf

2.0°F. The level of cooling would ultimately depend on how the impervious area reduction would be distributed citywide. The future tree canopy scenario achieves the lowest level of cooling in terms of percent citywide land area experiecing cooling and citywide average temperature decrease. This was expected considering the assumed level of implementation for this scenario was less than for the impervious and cool roof scenarios in terms of acres of land cover change. If cooling is assumed to be simply additive, the three future cooling scenarios can be aggregated into a single combined scenario. Under this combined scenario the average citywide temeprature decrease would be the sum of the individual future scenarios which is approximately 2.9°F (Figure 10).

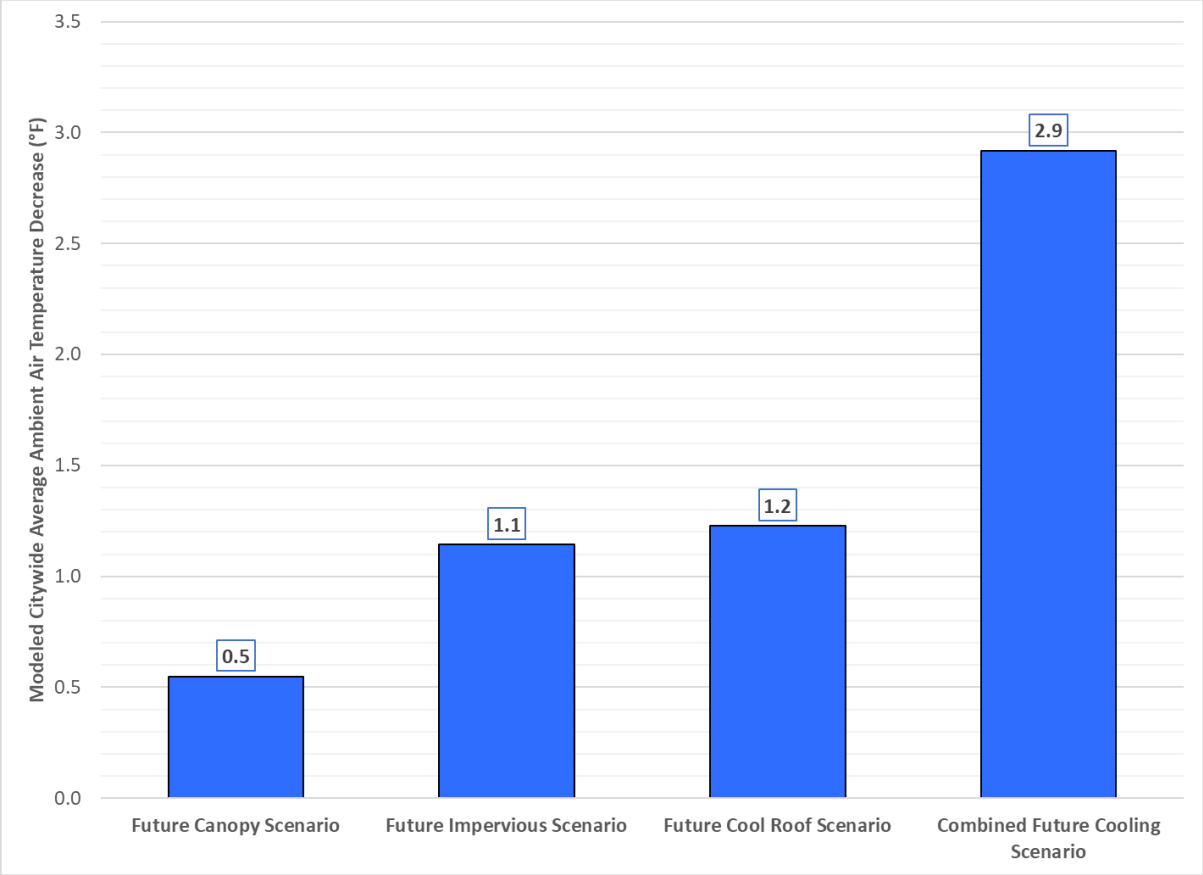


Figure 10 – *Modeled Citywide Average Ambient Air Temperature Decrease Under Future Scenarios.*

For more information on how the projected impacts were estimated, an Urban Heat Island Technical Report completed as part of Resilient Cambridge details the urban heat island (UHI) analysis. It describes the development of the UHI model as a part of the City's Climate Change Vulnerability Assessment (CCVA) and its use in various phases of the Resilient Cambridge planning process.

8. Priority Actions

1. **Complete the development and review of the Cool Factor to be adopted as part of climate resilience zoning amendments.** The Cool Factor zoning amendment will positively impact the indicators of a Greener City citywide, however, implementation is determinant on new development and significant retrofits. Cambridge Highlands (Alewife) and Area 2/MIT (Kendall) have a high rate of redevelopment, so it is possible that those areas will experience greater levels of implementation. East

Cambridge neighborhoods were identified as “higher priority” but have less available land area and development opportunities for implementation of the Cool Factor.

2. Complete a **financial feasibility study of a small grant or subsidy program** for property owners in East Cambridge, Wellington-Harrington, the Port, and Riverside neighborhoods to make improvements to their properties based on the menu of Cool Factor options. These neighborhoods were identified as higher priority neighborhoods in the Greener City analysis. This type of funding program would help take the financial burden off small property owners and homeowners willing to make vegetative improvements.

3. **Conduct a planning study for assessing vegetation density and “quality”/health to support the preliminary NDVI assessment.** Informed by the key findings, develop an implementation plan for improving the quality of planting in the City, focusing on the public realm, as defined by the City’s properties and abutting parcels. Cambridge’s residents would benefit directly from onsite improvements that increase the resiliency of the site and the quality of the natural environment, while also providing cooling benefits.

4. **Form a study committee focusing on GI improvements in PROW as an initial planning phase of a Cambridge Cool Corridors Initiative**. The committee would study best approaches for integration/prioritization of the UFMP recommendations to better understand feasibility of implementation. It would also study traffic and parking options to understand where “dieting” and conversion of parking spaces can occur to make space for new GI improvements aside from tree planting for enhanced vegetated areas and improved water quality.

5. **Integrate resiliency strategies and considerations into the City of Cambridge Open Space Plan update.** The recommendations of the Greener City analysis should be integrated into the City’s plan for improving, maintaining, and creating new open spaces.

6. **Focus on The Port for green strategies implementation:** The City should prioritize open space improvements and additional vegetation, including maintenance of the urban forest, in the Port due to the low amount of open space in this neighborhood and the low density of vegetation and tree canopy.