Cambridge Urban Forest Master Plan Technical Report

November 2019

GENESIS OF THIS PROJECT

This study builds upon the findings of the Cambridge Climate Change Vulnerability Assessment (CCVA) and attempts to deepen the City's understanding of the risks to the urban forest in the years ahead. The strategies developed in this study were conceived to support the goals of the Climate Change Preparedness and Resilience (CCPR) study, specifically building infrastructural, economic, and social resilience that integrates the built and natural environments. Even more broadly, this study recognizes the capacity of urban forest to play a key role in realizing the Core Values articulated in Envision Cambridge—Livability, Diversity and Equity, Economic Opportunity, Sustainability and Resilience, Community Health and Wellbeing, and Learning.

STRUCTURE OF THIS REPORT

This document is not intended to be a Master Plan report with specific and detailed directives. This technical “White Paper” documents the findings of 12 months of study, provides a synthetic analysis of the data, sets broad goals and targets, and proposes a range of possible responses.

It is organized into chapters that document “The State of the Urban Forest” today, evaluate the “Risks to the Urban Forest” in the future, delineate a series of potential “Response Strategies,” provide “Scenario Models” which evaluate opportunities and strategies for change, and lay out "Targets, Prioritization, and Next Steps."

Initial goals, targets, and metrics are proposed for review and discussion and are subject to revision. Additional study and refinement will follow after the content of this report has been distributed and reviewed by the City, Task Force and the public.

FURTHER STUDY AND ENGAGEMENT

Following distribution of this technical report, the City will organize additional opportunities for review, feedback, and discussion. Working with the consultant team, a series of conversations will be organized within City agencies, with potential partner organizations, and with allied task forces and initiatives. Feedback will be gathered from the Cambridge Urban Forest Master Plan Task Force and from the public through a public meeting forum in the Fall 2019. During this time additional research and analysis related to specific response strategies will be undertaken by the consultant team.

A final report with recommended actions is expected winter/spring 2020. The final report may recommend additional efforts to develop implementation plans or specific guidelines associated with proposed strategies.

PUBLIC MEETINGS

In October 2018, a presentation and open house was held at the Peabody School on Rindge Ave in order to introduce the project to the community and solicit feedback from individuals on their concerns about the future of the urban forest and to assess what components of the forest they most valued. In March 2019, a second meeting was held at the Morse School in Cambridgeport. The consultant team presented the preliminary findings followed by a discussion of potential response strategies. In an open house format that followed, the community was able to engage in deeper one-on-one conversations with members of the consultant team about specific proposals. A third public meeting is expected in the fall of 2019.

TASK FORCE

A task force of 18 private citizens representing residents of Cambridge, subject experts, local institutions, and business groups met 11 times during 2018 and 2019 to review progress, pose questions, and provide advice to the consultant team. These monthly meetings included presentations on specific subject matter and evolving findings, and the interaction with the Task Force has significantly shaped the content of this report, the approach to the subject, and the components of the response strategies.

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1.
Executive Summary

1.1 The State of the Urban Forest

Trees enhance our quality of life, cool our environment, and provide a variety of ecosystem services from managing stormwater to improving our air quality. Fewer trees provide less shade, which means the city feels hotter in the summer. The presence of urban trees can reduce air temperatures on summer days by 2 – 4°F,[1] preventing heat-related illness and fatality. Trees also provide scale, character, and qualities of place that encourage people to gather and interact as a community — all of which supports the economic and social sustainability of the city as a desirable place to live/work/study.

Today, Cambridge's urban forest is shrinking. In 2009 more than 30% of the city was shaded by trees — trees growing on city property, but also those growing in front yards and back yards, on campuses, in parking lots and within commercial developments. By 2018 only 26% of the city was shaded by canopy (*Figure 1.1*).

Between 2009 and 2018, Cambridge's canopy declined at an average rate of 16.4 acres per year. At this rate, canopy cover could be reduced to 21.6% in 2030. With the increasing impacts of climate change on the vitality of the forest and without further action to reverse this trend, canopy cover could potentially further decline to 17.6% by 2030.

Cambridge is not an anomaly. Nationally, cities are facing persistent canopy decline. And, canopy loss is not simply an abstract statistic; it has real and immediate physical and psychological impacts for people and habitat.

Continued canopy loss will impact the livability of the city, including its social and economic vitality.

The City of Cambridge has already taken action to combat canopy loss. The City is ahead of many of its peers in understanding the link between the urban forest and climate resiliency and has begun forecasting the investments necessary to support trees in the city. Cambridge spends a comparatively robust $21.34 per capita on tree-related efforts city-wide (see 2017 Tree City USA). In 2018 the City hired a full-time Superintendent of Urban Forestry and Landscapes. It employs a full-time staff of 10 in its urban forestry department, and held contracts with local landscape firms to plant 600 trees in 2019. Cambridge has a unique program to water newly planted city trees and is undertaking a pilot project to apply liquid biological amendments (sometimes called "compost tea") to improve the survival of newly planted trees.

In the face of continued loss, the City of Cambridge is committed to further action, and this report identifies key opportunities to curb the current rate of canopy loss and presents strategies to grow the canopy again.

Forests are dynamic ecosystems. Loss and growth are part of their natural processes. Likewise, the overall urban forest will always cycle between periods of growth and periods of loss. We will never be able to stop all canopy loss. At this moment of persistent loss, however, the critical question is whether this persistent trend — the rate of loss exceeding the rate of canopy gain — can be reversed over the long term through mortality reduction, enhanced growth of existing trees, and replanting efforts.

Finding response strategies is no simple task. There is no single cause of canopy loss to fight. Many conditions — some historical, some economic, some horticultural, others directly linked to the physical patterns of the city — have contributed to the current trend. Analysis at the city-wide scale indicates that trees are being removed throughout the city for various reasons, but the largest percentage of loss has been on private residential properties. On-the-ground review of specific areas of loss indicates that no single precipitating event can be identified as a primary cause of tree removal. Loss is associated with new building construction, increased paving, landscape renewal projects, lack of adequate tree care and protection, and natural decline.

Analysis has also revealed that loss is frequently paired with replanting. Although relatively small as a percentage of canopy cover, many construction projects have planted canopy trees which will over time create significant shade. Others have installed green roofs or other forms of green infrastructure that support some functional components of the forest, such as cooling and stormwater mitigation. But these can not replicate the spatial experience or human comfort of a mature canopy.

By area, residential use covers the largest land area in the city (37%), and canopy cover is lowest in areas with large commercial and industrial development (*Figure 1.3*). Thus, any approach to growing canopy must be multi-faceted and must engage all constituents in the city.

If this current trend of loss continues, the future of the urban forest is most certainly at risk. Nevertheless, there are strategies that can reduce losses and regrow canopy for future generations. It will not happen immediately, and it can only be accomplished by collective action around multiple initiatives at a range of scales and costs. This study assesses strategies focused around changes in policy, planning and design initiatives, enhanced and improved horticultural practices, and education, strategic partnerships, and outreach — all vectors for changing the way citizens understand and cultivate the urban forest of the future.

Supporting the long-term vitality of the urban forest is critical to realizing the City's goal to be an equitable, vibrant, and progressive place to live, work, and learn. This study is a first step in ensuring that vitality — analyzing the state of the forest, examining the causes of loss, articulating a series of canopy-specific goals, and defining a range of possible interventions to reorient current trends toward a brighter but more shaded future.

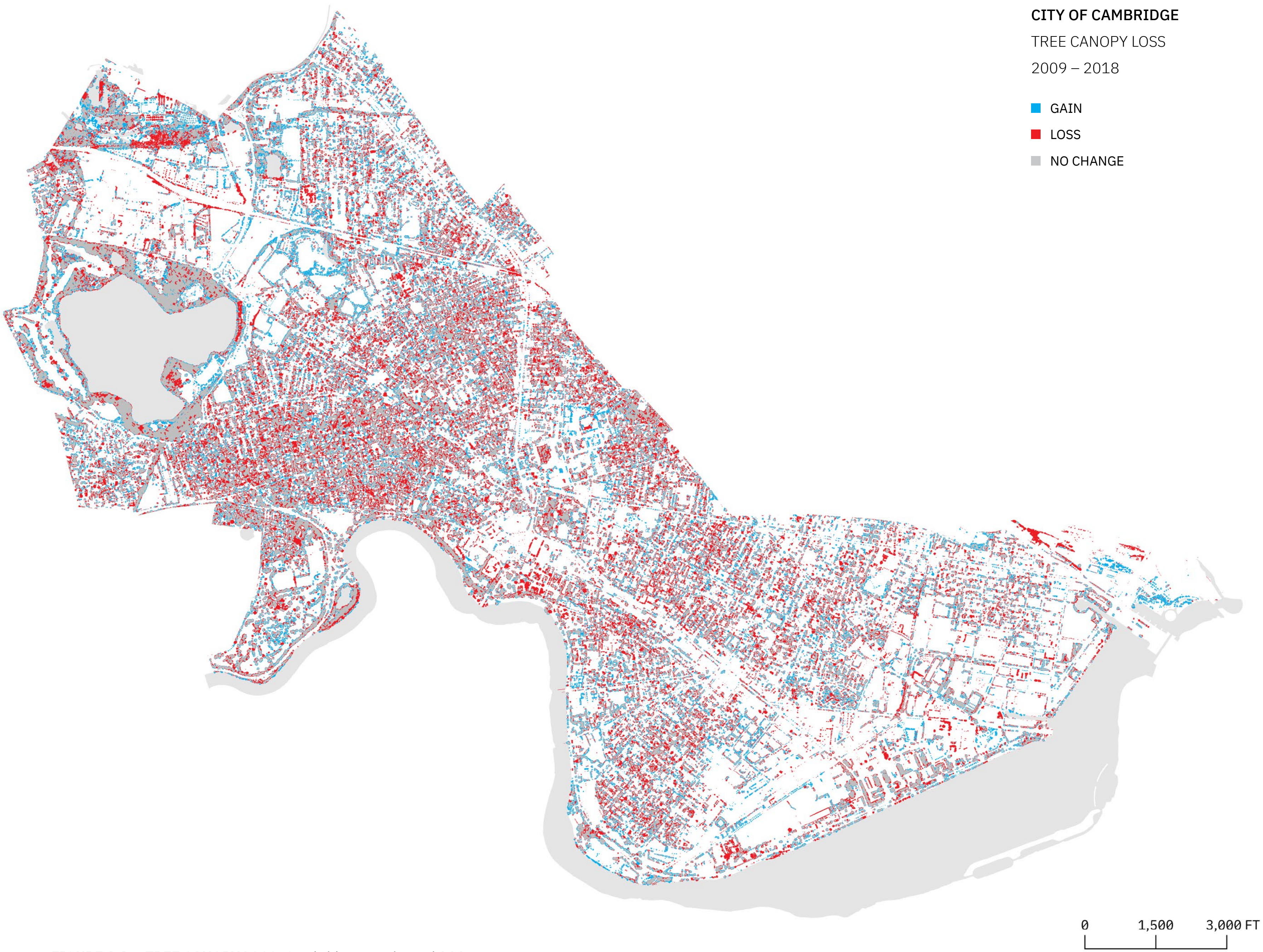


FIGURE 1.1 — TREE CANOPY LOSS. Cambridge experienced 164 acres of loss between 2009 and 2018.

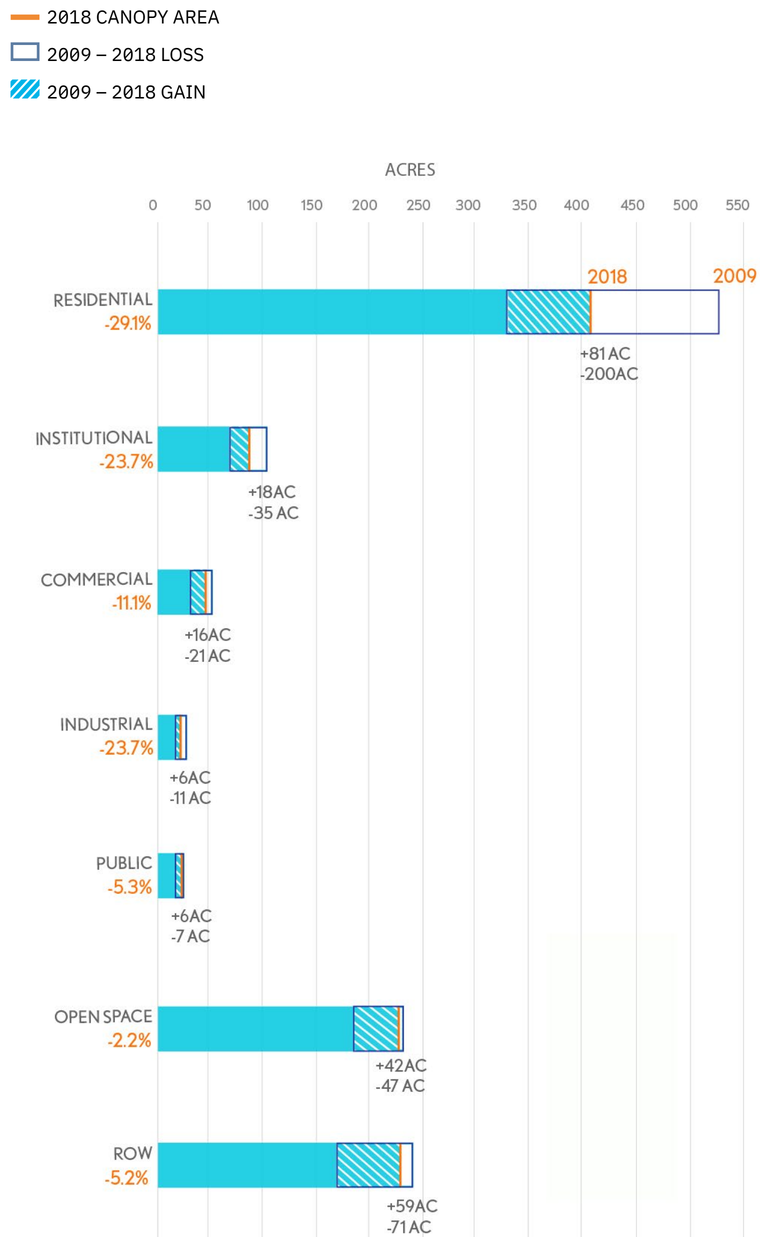


FIGURE 1.2 — CITYWIDE CANOPY LOSS (164 ACRES OF CANOPY LOST BETWEEN 2009-2018). Largest loss, both acres and percentage wise, occured on residential land use.

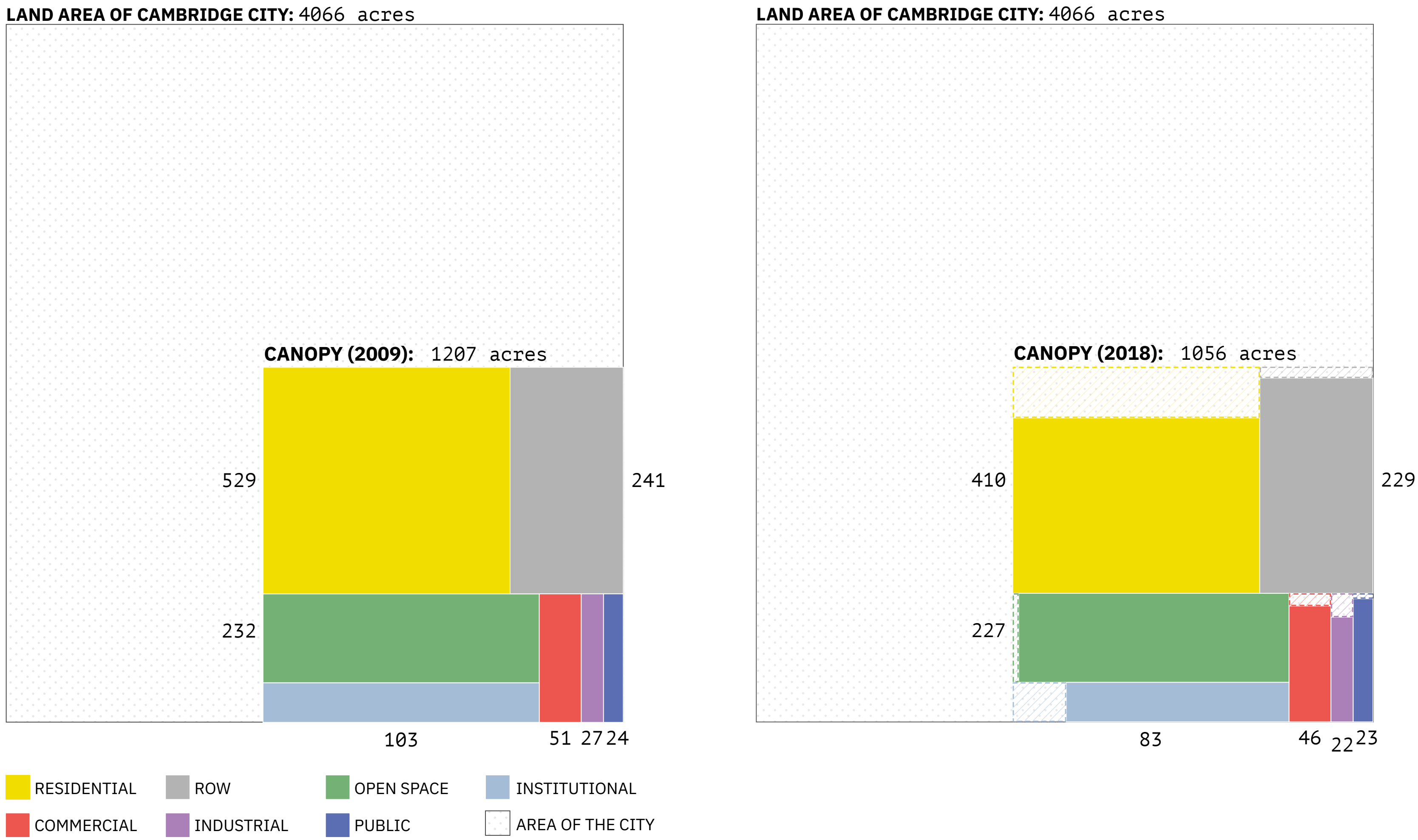


FIGURE 1.3 — TREE CANOPY LOSS ACRES COMPARED TO AREA OF CAMBRIDGE CITY.
Visual description of canopy loss between 2009 and 2018 by land use type, and totalcanopy in omparison to the land area of Cambridge.

WHAT IS AN URBAN FOREST?

We describe the canopy of the city as an "urban forest," a term that spans trees on both public and private property and recognizes that, like in a forest, trees are only part of a living system that includes the soils and natural systems of the ground, the range of vegetation that grows in and among the trees, and the habitat that these complex plant communities support.

However, a city is not a forest. It is a dense, largely paved, heavily built designed landscape. Cambridge is over 65% impervious surface (building or paving). The space for trees and the mutually supportive community of plants, animals, and living soils that support those trees is in short supply.

In fact, the community of vegetation in the city might more appropriately be compared with a savanna. Savannas have between 5% and 50% canopy cover (Cambridge is 26%) whereas forests have 50% to 100% coverage. Forests have layers of vegetation including rich understories, whereas a savanna usually has only two layers: trees and a grassy groundcover.

Some parts of the city might be forest-like (parks, natural areas, created wildlands) but most of the city is essentially like a savanna where trees function as islands within a matrix of open spaces. We can still seek to create forest like conditions and increasing tree to tree interactions by planting trees more closely, sharing soil volume, and varying vegetative structure.

	FOREST	SAVANNA
Canopy Cover	50 – 100%	5 – 50%
Vegetation structures	4 Layers herbaceous, shrub, subcanopy, canopy Vertical branching architecture + 60 trees / acre	2 Layers Herbaceous Canopy Largely horizontal branching 4 – 60 trees / acre
Plant communities	Trees support each other through significant tree-to-tree interaction – root grafting and exchanges of nutrients, perhaps water Many fungal associations due to large numbers of fungi in forests	Limited tree-to-tree interaction More tree-to-herbaceous species interactions Fungal associations exist, but fewer due to few species of fungi in savannas
Nutrient cycling	Carbon content variable, but higher than cropland May retain nutrients due to leaf fall dynamics and herbaceous layer uptake	Usually high carbon content due to accumulation of herbaceous plant roots Nutrients tend to become bound in leaf litter of herbaceous plants
Succession	Continuous recruitment of trees into the canopy, with "advanced regeneration" of saplings in subcanopy waiting for light gaps	Cohorts of canopy trees become established at intervals based on life-spans

SAVANNA

FOREST

HYBRID

SENNOTT PARK


MEMORIAL DRIVE

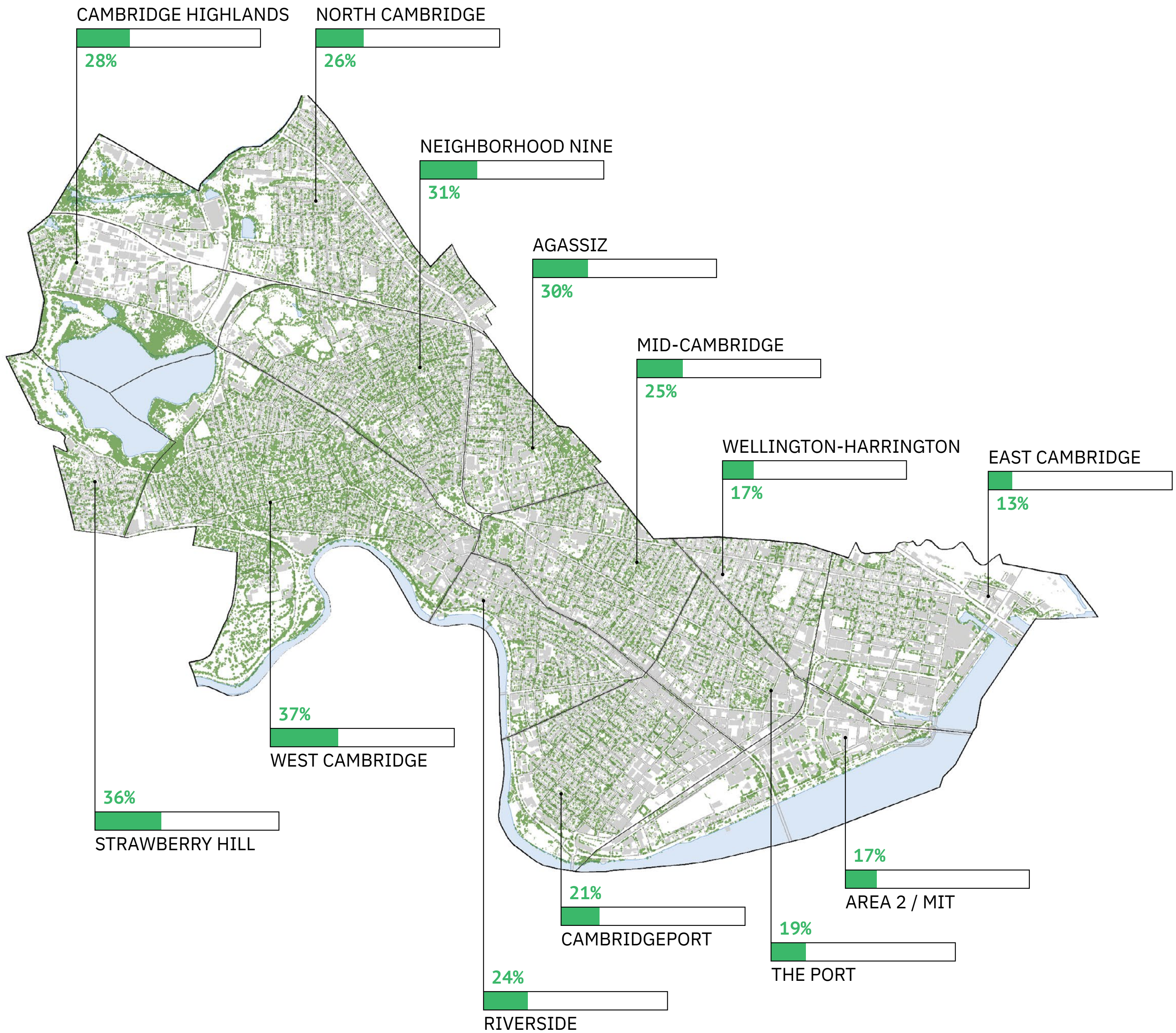


FIGURE 1.4 — 2018 CANOPY COVER PERCENTAGES BY NEIGHBORHOOD.
Canopy cover by neighborhood varies from 13% to 37%.

1.2 A Path Forward

FIRST, UNDERSTAND THE PATTERNS WITHIN THE URBAN FOREST

The urban forest is the matrix of treed landscapes that span public, private, and institutional properties across the city. And, it is more than just large canopy trees — including understory trees, shrubs, groundcover plantings, and even the soils that support broader ecological communities. But the urban forest is most profoundly experienced in the shade and enclosure of mature canopy trees. It is those trees that are most at risk today and that take the longest to regrow in the future.

CANOPY DISTRIBUTION IS NOT EVENLY DISTRIBUTED

The canopy in Cambridge is not evenly distributed and the benefits of the urban forest are not felt equally across the population (*Figure 1.4*). In 2018, areas of the city with lower than average canopy cover were more frequently correlated with populations at risk[2] (*Figure 1.5*). With fewer trees, these neighborhoods are more likely to suffer from urban heat island impacts at the same time that they have populations generally less able to respond or adapt to the threats of heat extremes.

URBAN FORM INFLUENCES PLANTABLE AREA

Canopy distribution correlates with underlying urban patterns and areas of open space, with higher canopy cover rates in neighborhoods with detached single family homes with setbacks and yards like West Cambridge and lower coverage in neighborhoods with denser multi-family housing and large commercial or industrial buildings like East Cambridge or the Port (*Figure 1.6*).

In areas of the city undergoing significant change (Alewife and Kendall Square), zoning and urban design guidance with respect to the scale and character of open space and with defined green infrastructure goals can have significant impacts. In denser areas that are already built out, and where existing urban fabric is often not compliant with underlying zoning, overcoming canopy deficit will require more significant efforts and will rely primarily on a broad transformation of the public realm to accommodate more and larger planting areas. In addition, the application of complementary strategies like white roofs and other green infrastructure will be required to meet cooling goals.

LIFE-CYCLES SHAPE TRENDS

The forest is a living system. It is dynamic and responsive to changing environmental conditions, and it is significantly influenced by human action. In order to maintain a robust and resilient forest, it is critical to understand the forest as constantly in flux, a product of cycles of planting, growth, decline, and renewal. As an example, the character of the tree cover in West Cambridge today is at least in part the product of plantings which took place as part of a housing boom eighty to one hundred years ago. Those same trees — now majestic canopy trees providing pervasive shade to these residential neighborhoods — are reaching the end of their life span, and their gradual but inevitable loss is having a disproportionate impact on the city's overall canopy (*Figure 1.7*).

This study suggests taking action to improve viability at all stages of a tree's life cycle, improving chances of establishment, enhancing vitality through maturity, and extending lifespans as much as safe and practical. But we cannot lose focus by believing we can stop the cycle of growth and decline. It is essential to work to reduce the rate of loss, but equally important is to remain vigilant in order to plan ahead for renewal in the face of loss, always considering the urban forest as a whole and dynamic system.

MULTIPLE INTERESTS COMPETE FOR ATTENTION AND FOR SPACE

The physical space of the city is limited, and efforts to preserve the existing canopy or to plant more trees often seem to be in competition with other critical needs. Constructing new and more densely spaced buildings provides critical housing, but can impact existing open space; building safer bike accommodations may take plantable area from the public realm; or increasing budgets for tree planting and care may reduce the available funds for other valuable initiatives. This report recognizes the necessity of situating the needs of the urban forest in a broader context and that the final prioritization of efforts must be part of a larger process of discussion and engagement.

SECOND, ADVOCATE FOR THE SIGNIFICANCE OF THE URBAN FOREST, UNDERSTAND THE RISKS, AND GROUND STRATEGIES IN A SIMPLE FRAMEWORK

If the community is to change its approach to the stewardship of the urban forest, we must transform and broaden the way it is understood. The complexity, interconnectedness, and sheer value of the urban forest is largely invisible and is

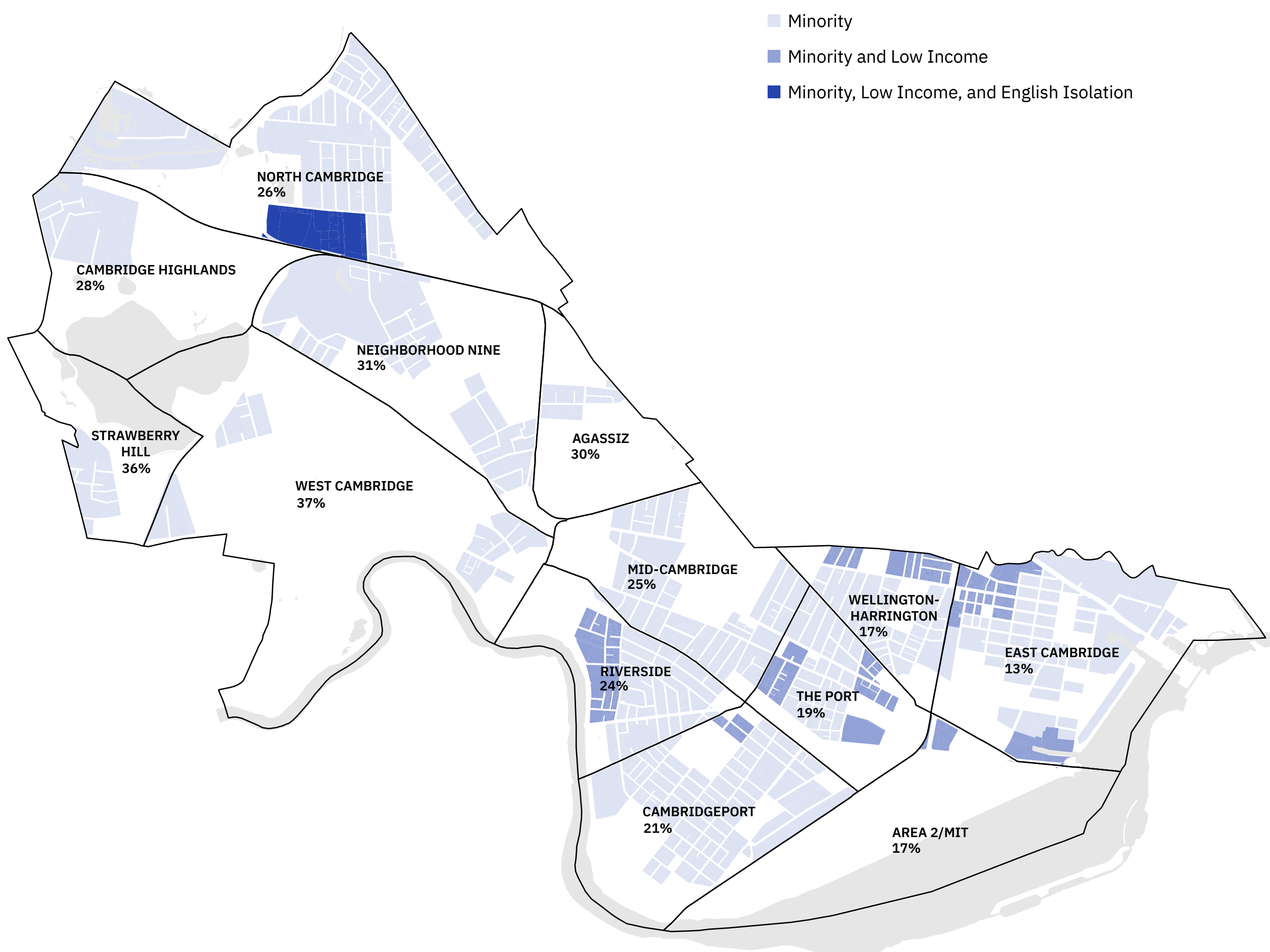


FIGURE 1.5 — POPULATIONS AT RISK. Canopy cover is generally lower in areas with populations at risk.

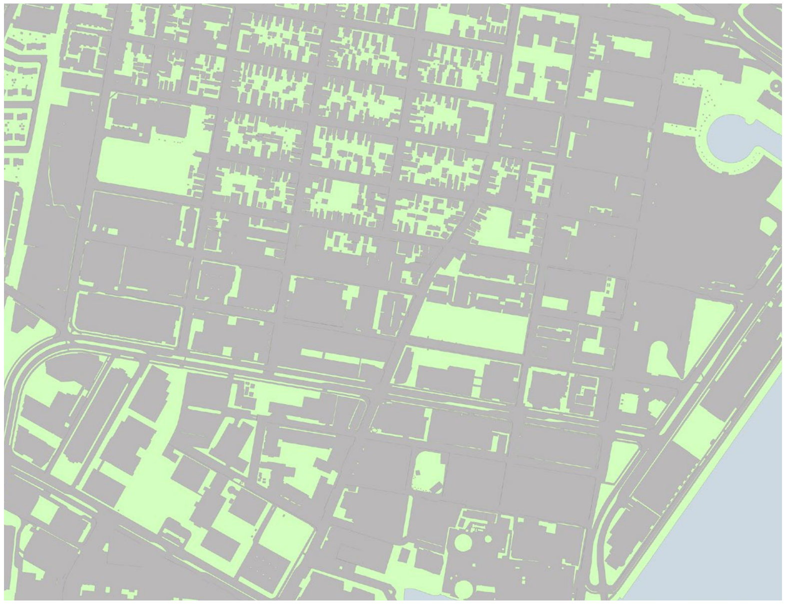


FIGURE 1.6 — PLANTABLE AREAS (SHOWN IN GREEN) IN EAST CAMBRIDGE (ABOVE) AND WEST CAMBRIDGE (BELOW). Some areas of the city have more plantable area.

certainly hard to quantify. Yet, framing the intangible and practical value of the forest in common terms and providing the public with tools to contextualize investment will enable more strategic, long-term, collective and visionary approaches to the future.

One of the key findings of this study is that 89% of the canopy loss over the last decade has taken place on privately owned property, and that the City alone can not make up the difference to expand the canopy. It is therefore incumbent on the City and its organizations to educate the public and bring them along as partners in this effort. The following themes begin to set forth a shared narrative to engage and activate the public around a renewed sense of stewardship of the urban forest.

UNDERSTAND THE RISKS

If the current trajectory of Cambridge's urban forest continues, canopy cover will decline from 26% in 2018 to 21% by 2030 and 15% by 2050. Climate change will likely increase tree mortality, and under certain climate scenarios, Cambridge's forest cover could drop as low as 18% by 2030 or 10% by 2050.

Species that are susceptible to climate risks, particularly pests and diseases and drought, will likely not fare as well as others. Currently, 29% percent of the forest is highly susceptible to pests, drought and/or flood factors. This risk is spread evenly across neighborhoods. Drought, which is predicted to be increasingly frequent, will potentially have a moderate impact on existing tree canopy. Projecting out to year 2030, increased flooding due to large storms was found to have a only a minimal impact on canopy mortality, because its footprint and duration of inundation is limited. (see *Section 3*).

VIEW THE FOREST AS A DYNAMIC SYSTEM

The shade and cooling impacts of trees don't stop at property lines. Habitat value is a product of the scale and connectivity of plants as communities not as individuals. The stormwater benefits of trees and healthy soils accrue collectively to add resiliency across watersheds and communities. And trees themselves are living and dynamic organisms that share resources and support each other's growth and vitality. Risks and challenges are also systemic, with pests and diseases spreading easily between public and private trees and across regions.

For these reasons, it is important to reframe our understanding of the urban canopy from a collection of trees to a living system that functions on a regional scale. The forest is much more than the sum of the value of each individual tree.

By viewing the canopy as a forest, we can see that disturbance and change have far-reaching impacts. But we also recognize that they are a natural part of succession and renewal. Translated to an urban condition, we are reminded that while each tree has value, in order to balance the complex needs of a changing city we should focus on the performance and resilience of the forest as a whole. Undue attention on individual trees may distract from larger shared goals.

VALUE THE FOREST AS A PUBLIC RESOURCE

The urban forest is a public resource that has measurable value and impacts everyone. It provides shade to cool our environment, gives scale and character to our streets, provides habitat for

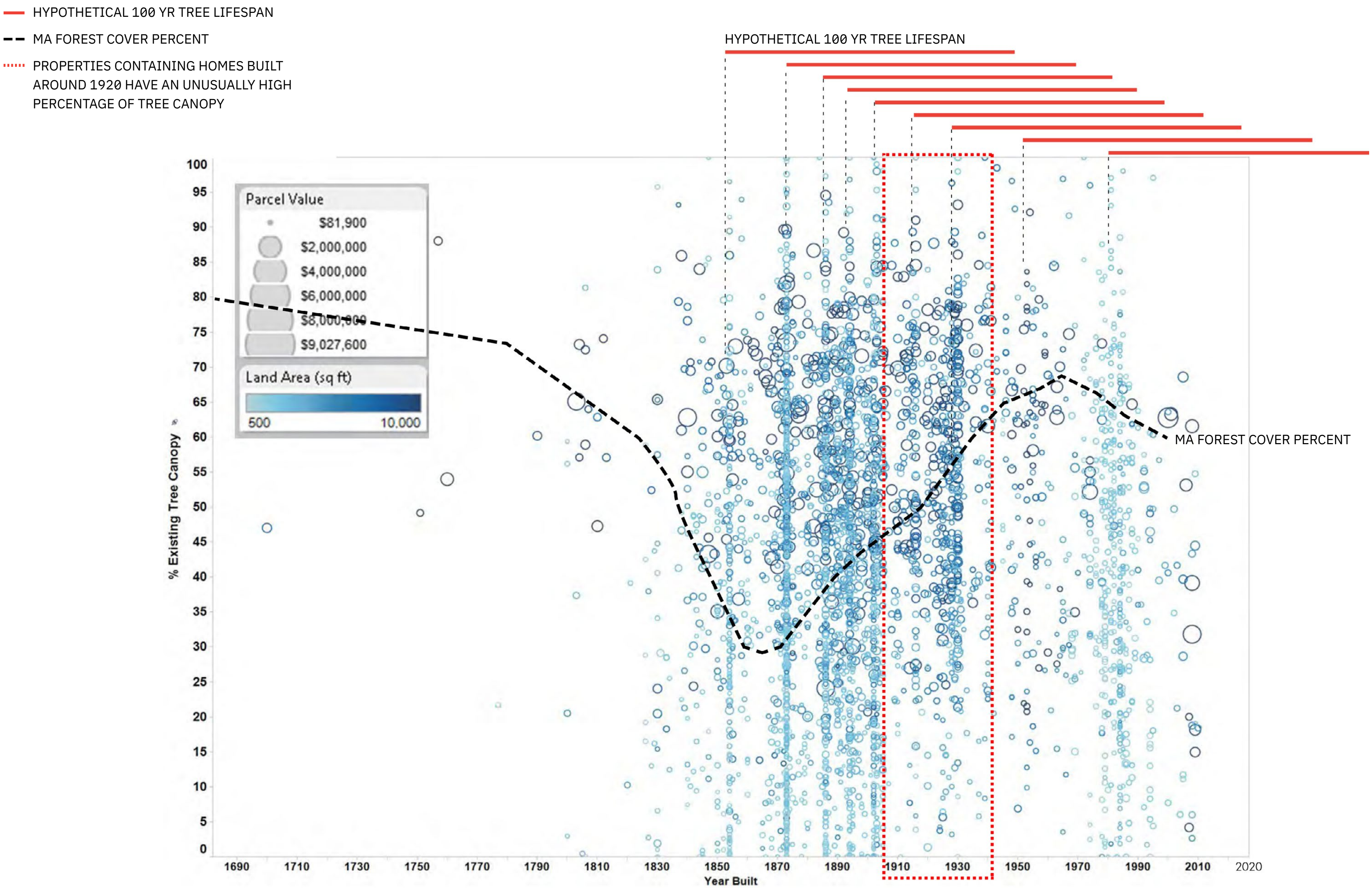


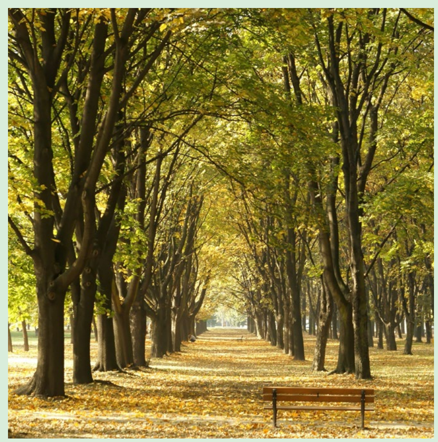
FIGURE 1.7 — PERCENT EXISTING TREE CANOPY IN RELATION TO YEAR BUILT, PARCEL VALUE, AND LAND AREA FOR SINGLE FAMILY RESIDENTIAL PARCELS. Adapted from: UVM, "A report on the City of Cambridge's Existing and Possible Tree Canopy", 6/1/12











WHAT DO TREES MEAN TO US?

Trees have an unquantifiable cultural value, giving context to our daily lives and standing witness to significant events. We gather together under their shade. We plant them to commemorate people and events. Their scale and longevity span across property lines and generations. Trees inspire us to paint and write and sing. They are entirely common, mysterious and magical. Trees, individually, are sculptures to be seen. As a forest they are territories to be explored and experienced.

Trees in cities mark our common spaces, places where we gather, debate, celebrate and mourn. They shape the great parks of European cities, the Mall in Washington, Boston's Emerald Necklace, and many great streets and boulevards. They create a sense of individual well-being, and yet they also build our social networks and bolster our communities by creating public spaces that give communal life deeper meaning.

This Master Plan assesses the value of trees to contextualize and build arguments for investment alongside other competing needs. But it also proceeds with the recognition that not all qualities can be quantified and valued. And some of the most important and evanescent values cannot be found outside of the space of our treasured trees.

diverse species, improves our air quality, manages and reduces stormwater impacts, and improves our health and well-being. Using the industry standard USDA iTree Eco calculator, the value of Cambridge's urban forest — from carbon storage, property value, air quality, stormwater mitigation, energy reduction, and heat island benefits — is $581.5 million. This estimate does not include numerous social, mental well-being and ecosystem benefits. Other cities have estimated the average value of a canopy tree over its lifetime to be $57,000[3]. At this value, the Cambridge urban forest would be worth $3.1 billion.

To reflect this shared value, the urban forest should be understood and managed as urban infrastructure, a common utility (like water or sewer). The community — both public and private entitites — should commit to a significant up-front investment in plantings to improve resilience and reduce life-cycle costs, to managing the forest as an integrated system not as individual trees, and to planning for the inevitable replacement at the end of their service life.

INVEST IN THE PUBLIC REALM

The urban forest is felt most strongly in our public realm and common spaces (sidewalks, front yards, parks, schoolyards, and commercial and institutional campuses). In a survey conducted as part of this study, public sidewalks and streets were identified by the majority of respondents as the most important location for tree planting.

Enhancing the canopy within the public realm, where the impact of loss is felt most strongly and the significance of gain is most equitably distributed, deserves the comminity's primary attention and investment. The Right of Way (R.O.W.), which consists of the public streets and sidewalks, makes up 20% of the land area of the city. Current canopy cover in the R.O.W. is 28%, but it is not equally distributed across the city, and many of our most traveled commercial streets are also the most exposed and vulnerable to urban heat island. There are ample opportunities to bolster connectivity and fill in coverage gaps.

This study proposes to prioritize investing in:

Canopy Corridors

— A resilient ecosystem of shading and cooling along highly traveled networks will connect and enhance commercial and cultural centers, residential neighborhoods and green spaces across the city. A robust and connected canopy in the public realm relies on more than just thriving street trees within the public R.O.W. It requires canopy within front yards and private lands that front on the public realm as well as within publicly accessible open spaces owned by private entities.

Areas of Canopy Deficit and Inequity

— A more evenly distributed forest reduces the disproportionate impacts of urban heat island and increases the resilience and well-being of populations at risk. The varied urban form and density of Cambridge may never allow equal distribution of canopy across the city; however, in areas of canopy deficiency and in centers of cultural activity like public open spaces and commercial hubs, significant effort should be applied to meeting a minimum canopy cover. The complexity and cost of creating conditions for a thriving canopy may be higher in these areas, but investing disproportionately to meet equity goals is justifiable.

GALVANIZE COLLECTIVE ACTION

A thriving urban forest requires the mutual care of many parties, including city government, homeowners, businesses, developers, local organizations, institutions and state agencies. The City of Cambridge has direct control over approximately 30% of the land area (not including water bodies) and thus is limited in how much impact its own practices can have. The current trend of loss cannot be reversed without care, action, and investment from all sectors of our community. It is in our mutual interest to do so.

As a largely residential community, 39% of the city's canopy is on private residential lots. And over the last ten years 72% of the net canopy loss has been associated with residential parcels. As such, it is clear that private landowners have a disproportionate responsibility to the stewardship of the urban forest.

To enhance the canopy on private property, the City will need to develop strategies to encourage tree preservation, planting of new trees, and effective maintenance by private owners. But it should be balanced and fair, linking the interests of all parties around smart solutions and should be wary of the potential unintended consequences of over-regulation that may disincentivize tree planting.

Alongside, potentially in advance of regulatory action, The City should undertake broad education efforts on the benefits of the urban forest and act as a catalyst for partnerships between interest groups to encourage its stewardship. But it must do so within the context of building trust with


JFK PARK

CENTRAL SQUARE

its communities so that they embrace these efforts and see them as supporting their local interests.

Ultimately, the urban forest is a not just a shared resource, it is a driver of our shared experience. The shaded spaces of our parks, the walkability of our streets, and the cooled centers of commerce and culture create a city of human scale and humane qualities where people are encouraged to gather and engage and where the fabric of our community is built and reinforced. The responsibility to protect and extend this powerful component of our civic space falls on everyone (*Figure 1.8*).

THIRD, ORGANIZE A RESPONSE AROUND SHARED VALUES

See *Section 4 for an more detailed discussion of these values.*

DEFINE SHARED VALUES

The three core values of equity, resilience and shared responsibility will help guide decision making when prioritizing where and how to act (*Figure 1.10*). We aim for an equitable, resilient urban forest where all city constituents are invested in and participate in its care.

Equity

A healthy urban forest provides benefits for all people in the city. Currently, low canopy cover corresponds to neighborhoods where populations at risk reside. This means these populations are subject to more urban heat island impacts, exposed to fewer air quality benefits, obtain fewer energy savings, and experience fewer social and mental well-being benefits from trees. The community should first focus on growing canopy in these areas of existing deficit (*Figure 1.12*). More trees can mitigate some of the urban heat island impacts for those populations generally less able to respond or adapt to the threats of heat extremes.

Resilience

A resilient city requires an urban forest that benefits human health and well being. Trees can reduce the spread and intensity of heat island hotspots and create shaded corridors for pedestrians, bicyclists, transit, scooter and vehicular users. Trees can structure a network of parks with dense canopy cover that provides cooling benefits and returns value to the entire city.

A resilient urban forest is also able to recover quickly from disturbances and catastrophic pest and disease outbreaks. Building toward an urban forest that is more diverse and does not contain an overabundance of a single species, genus, or family will enable the canopy to better withstand the increasing pressures of climate change.

Shared responsibility

An equitable, resilient urban forest relies on the collective choices of many actors in the city. As there is not one single cause of canopy decline, there is no single solution and we must take an all-of-the-above approach. Within city government, choices about policy, enforcement, planning, and practice are also dispersed and shared. There is no single department or individual who speaks for the urban forest. In order to be accountable and to ensure advancement, this study recommends developing clear mandates that are adopted across

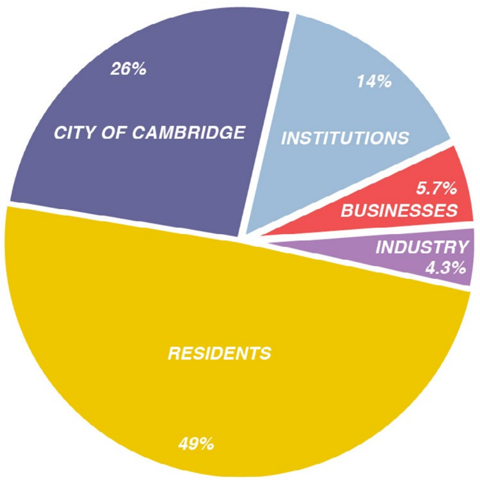


FIGURE 1.8 — PLANTABLE AREAS BY STAKEHOLDERS

Cambridge Urban Forest and Strategy Matrix

STRATEGIES

		Policy					Design			Practices			Outreach		Other	
		Enhance and Expand the Tree Protection Ordinance	Formalize Practices for Planting and Inspection	Leverage Land Use Requirements	Leverage Public-Private Partnerships	Institutionalize Tree Priorities	Plant Resilient Species	Street Tree Planting Strategies	Site New Parks and Open Space Strategically	Improve Monitoring	Expand Maintenance	Expand Planting Practices	Invest in Educational Programs	Build Community Partnerships	Seek Alternative Green Strategies	Integrate UFMP into Complementary Planning Studies
	in response to …	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Curb loss	Mature canopy decline	•					•							•		
	Land conversion	•		•										•		•
	Tree removals	•		•		•							•	•		
	Poor tree condition	•	•	•			•				•	•	•	•		
	Planting conditions			•								•			•	
	Understanding the value of trees				•	•							•	•		
Grow canopy	Equity in distribution of canopy cover	•	•	•	•	•		•	•	•	•	•	•	•		•
	Shading and cooling / pedestrian thermal comfort	•	•	•	•	•		•	•	•	•	•		•		•
	Environmental quality / wellbeing and public health	•	•	•	•	•	•	•	•	•	•	•		•	•	•
	Ecological connectivity	•		•		•	•	•	•	•	•	•			•	•
	Diversity of forest composition					•	•	•		•	•					

FIGURE 1.9 — STRATEGY MATRIX

departments. These can be linked to other city priorities and efforts, like climate resiliency and social equity.

CURB LOSS AND GROW CANOPY

This study organizes potential response strategies into two buckets — **curb loss** and **grow canopy** — the two primary vectors by which the community can change the future of the urban forest (*Figure 1.9*). Within these buckets, this document further organizes the range of response options into the following categories: **Policy** — the legal and procedural frameworks developed by city government that can reduce removals or encourage planting. **Design** — innovative approaches to the design of landscapes to enhance the growth and vitality of trees. **Practice** — the day-to-day care of our trees, public and private, including soil vitality, watering, pruning, and pest and disease management. And **Outreach and Education** — the communications and strategies, including partnerships with existing institutions and groups that advance the goals of the study.

Curb Loss

It takes decades to regrow the canopy that is lost when one mature tree dies. For this reason, reducing the rate of loss has the most powerful impact on the future projections for overall city-wide canopy cover. Reducing the annual rate of canopy loss by just 25% raises the 2030 canopy cover projection from 21.6% to 22.6% — preserving almost 43 acres of canopy. Efforts to curb direct tree removal considered in this plan include:

- educating residents on the value of their canopy as an important ecological/health resource for themselves and their community
- Encouraging City departments and agencies to take action around the goals of this study, encouraging them to create policies and undertake practices that reduce removals and protect existing trees
- enhancing the city permitting and review process to track and seek alternatives to tree removals
- protecting exceptional trees of unique age and size
- strengthening policies that discourage removals and increasing mitigation costs (when retention is not possible) while not adversely impacting residents at risk

The average lifespan of an urban street tree is between 19 and 28 years[4]. The cost of planting amortized at 19 years is significantly more than over the natural 75+ year lifespan of a canopy tree, and a tree with a shortened lifespan will never provide the character, shade, and ecosystem services that a mature tree can. For this reason, efforts to establish and sustain the forest are essential and more cost effective than increasing the pace of replanting. Efforts to curb loss by maintaining the forest and improving tree vitality and longevity include:

- enhancing soil specifications and planting details to improve establishment and long-term success
- modifying and diversifying recommended tree species to respond to a changing climate and increased risks of pests and diseases
- enhancing City tree management practices and tracking of individual tree health and city-wide tree health
- developing crisis management plans for drought, storms, or pests and diseases
- providing knowledge to private landowners for how to maintain their trees, especially in front yards
- educating the community to take care of their trees, especially stemming counterproductive but common cultural practices such as tree boxes
- managing and coordinating utility work above and below grade
- ensuring compliance with tree protection during construction activities
- encouraging pest management across land ownership types and partnering and investigating cost-sharing for catastrophic pests like Emerald Ash Borer

Grow Canopy

The loss of individual trees can be delayed, but it cannot be avoided. It is the natural cycle of the forest to decline and to regrow. Planting new trees now is an investment in growing the next generation of urban canopy. While replanting is most powerfully felt in the public realm, it must be distributed across the city and must be the responsibility of many actors. Replanting efforts, which should be undertaken intentionally with the long-view in mind, include:

- significantly increasing the rate of planting within the public realm
- implementing alternative approaches to public realm design that increase opportunities, expand plantable areas, and enhance viability
- partnering with local institutions and landowners to make commitments, set internal targets, and support community-wide goals
- implementing comprehensive zoning guidelines that provide credit for planting new trees and specify canopy targets
- educating the public about the resources that are available to encourage private planting and increase trust within the community
- modifying the definition of open space to include permeability requirements
- looking at long term changes to how we live in the city, such as the changing role of cars, to assess whether vehicular infrastructure could over time be transformed into planting spaces, weighed against other transportation needs

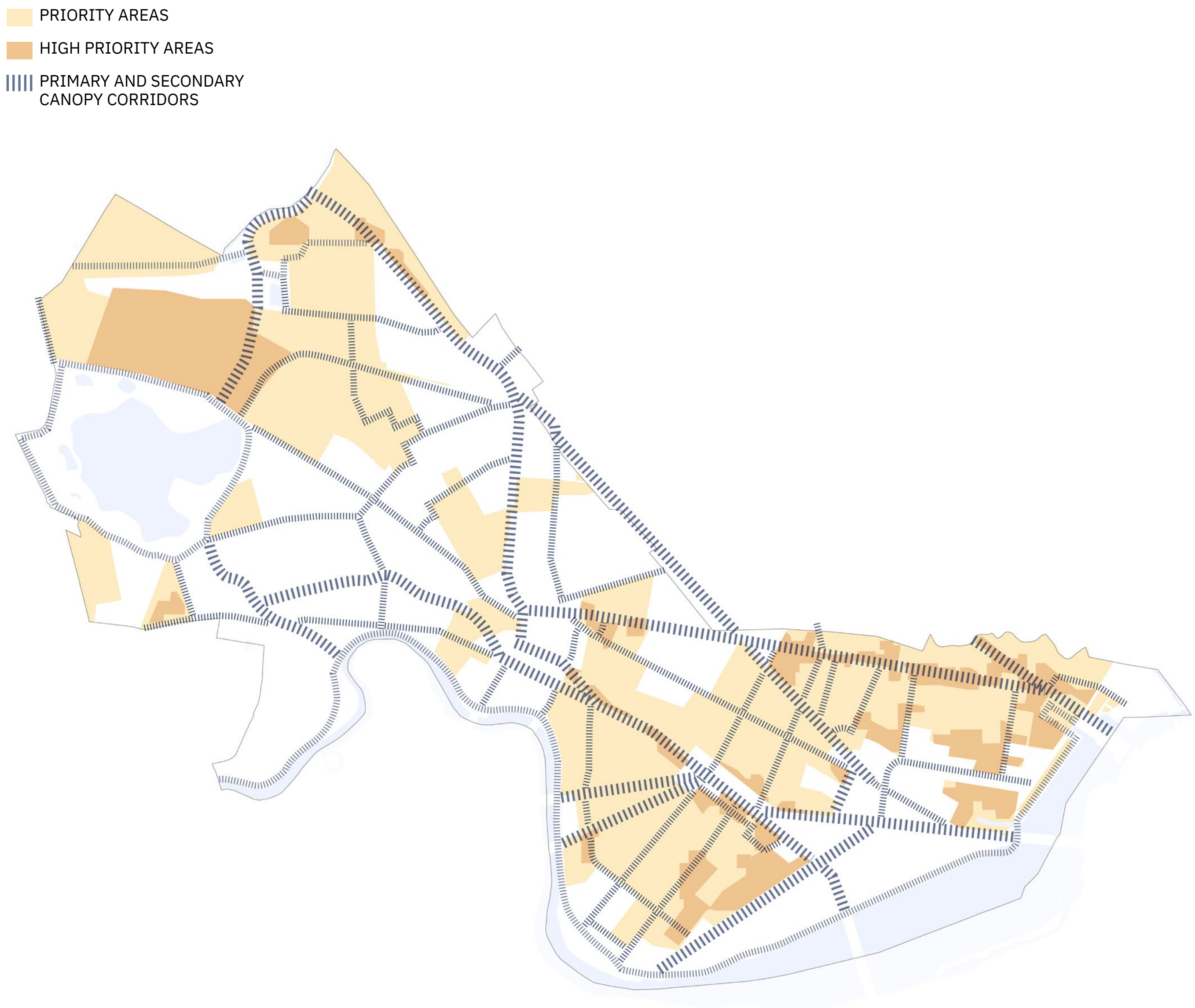


FIGURE 1.10 — PLANTING PRIORITY AREAS MAP. Priority areas are defined by overlaying areas of existing canopy deficiency as organized by the following priorities: canopy corridors, at risk populations, heat island hotspots, and community infrastructure. These overlaid criteria produce a spatial plan of priority areas (one criteria is met) and high priority areas (two or more of these criteria intersect).

BROADWAY STREET

ENCOURAGE COMPLEMENTARY APPROACHES

Trees are unique in that they provide a multitude of benefits all in one package. However, trees are but one of many essential ingredients to a resilient city. Many other allied actions must be taken to respond to a changing climate and build a vibrant and healthy city. It is also true that in a city like Cambridge, there will be places where it is not feasible to plant trees. In areas where soils are limited, where infrastructure conflicts, and where trees can not be adequately protected or maintained such that they can thrive, complementary approaches to meeting the City's resilience goals — as in Envision and CCPR — should be undertaken. Investing in depaving and alternative planting strategies, integrated stormwater systems, building green roofs, green walls, or other shade structures are recommended over expending limited funds to plant trees in conditions where they can never thrive and succeed.

FOURTH, SET GOALS AND TARGETS, GALVANIZE COMMUNITY AND MEASURE SUCCESS

This study sets forth broad objectives that position the urban forest as a critical factor in achieving the City's ambition of increased resilience and social equity. To meet these ambitious goals, it will take the efforts of many parties. And to keep these efforts directed effectively, this study proposes a series of clear and measurable targets at which to aim. These goals, described in the sidebar "Draft Goals and Targets" in this section and further articulated in *Section 6* are simple to understand, but nuanced enough to respond to the diversity of the City and the need for flexibility over time.

To ensure that adequate progress is being made toward these goals, the City should institutionalize a framework for frequent evaluation of progress against a series of increasingly ambitious and detailed metrics. (See *Section 1*).

SET GOALS AND TARGETS

Broad goals (increased canopy cover) must be paired with specific quantifiable targets by which to measure progress. The City should set ambitious but realistic goals for canopy cover over different time scales. Specific tree planting targets should be set in the short, medium and long term, and should be articulated both city-wide and at a finer grain — by urban typology like R.O.W., residential, and institutional landholdings, and by neighborhood, setting priority areas based on equity and areas of greatest need. It also may be valuable to set goals related to soils and infrastructure upgrades, or other measurable ecosystem services.

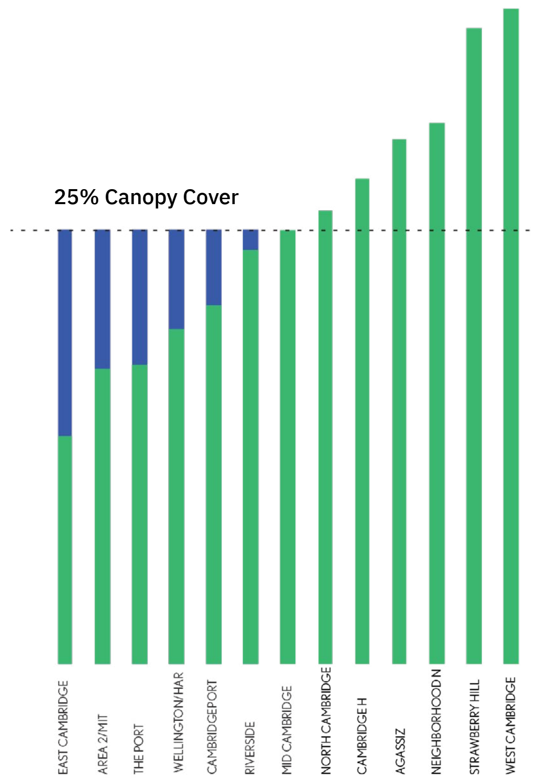


FIGURE 1.11 — EQUITY. To provide for equitable access to the benefits of tree canopy, the City should target 25% canopy cover in all neighborhoods. The 25% minimum is based on an idealized study of tree planting of East Cambridge.

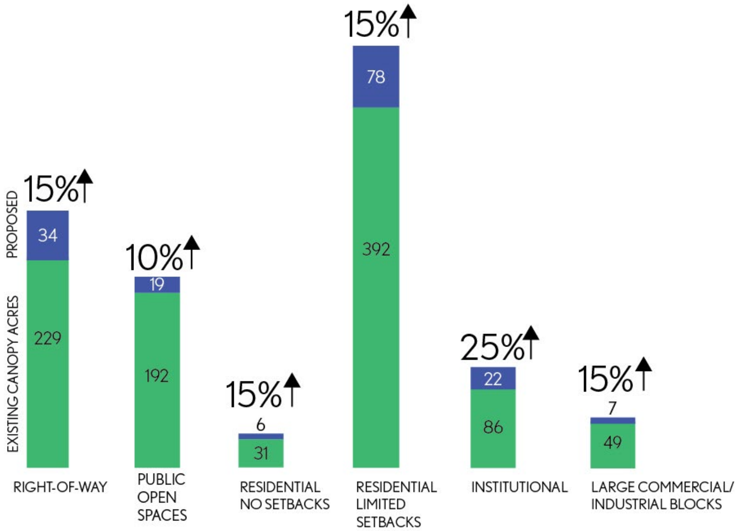


FIGURE 1.12 — SHARED RESPONSIBILITY. The urban forest is a shared resource but individual trees are managed and cared for by many different parties in the City. It is the responsibility of all parties to protect and extend the urban forest.

Cities frequently set canopy cover targets between 30 and 35%. But every city is unique. The analysis undertaken in this study suggests that even with the optimal planting of the public realm and increased planting on private and institutional properties, it is unlikely that the City could achieve significantly more than 30% canopy cover within 30 years. The systemic causes of canopy loss and the reality that trees need time to grow before they develop large canopies means that it will take significant effort and time to first, reverse the trend, and then, to grow canopy.

With this in mind, and believing that necessarily limited resources should be deployed wisely toward where they have most impact and benefit, and not just to try to meet abstract targets or citywide goals, this study proposes a series of more specific targets based on the values previously articulated. If achieved, the collective result will return the Cambridge to a canopy cover of around 30%. Below, draft goals and targets are summarized (see *Section 1* for full explanation).

Equity Goal: Every neighborhood should have at least 25% canopy cover (*Figure 1.11*). Many neighborhoods that currently have well below 20% cover will require significant change and investment to meet these goals. For example, when streets are rebuilt, they should be designed and constructed to support mature canopy trees, something that will increase capital costs and require disruption and change to the public realm. Setting a minimum of 25% canopy cover as a goal for each neighborhood would go a long way in creating a more evenly distributed canopy and would have a measurable impact on the urban heat island effect, which is most strongly felt by populations at risk who often reside in these same neighborhoods. Currently, the six neighborhoods of East Cambridge, The Port, Area 2/MIT, Wellington/Harrington, Cambridgeport and Riverside have overall canopy cover below 25%. Tree planting efforts should be concentrated in these neighborhoods and in neighborhoods that exceed the minimum, efforts should be made to protect the existing canopy.

Human Resilience — Connectivity Goal: Sidewalks should have 60% canopy cover. To expand the connectivity and impact of cool corridors (continuous linked areas that are below average ambient air temperature citywide), the percentage of canopy cover directly over sidewalks citywide should increase. Current canopy cover over sidewalks citywide is 38% and in the Citywide Canopy Corridor Study (see *Section 5.1*) an additional 12,000 street trees planted in the R.O.W. could increase sidewalk canopy cover to 60%.

Human Resilience — Hotspot Reduction Goal: Hotspots (area of 2 degrees over city average or 92 degrees on a 90 degree day) within the R.O.W. should be reduced by 50%. Critical to the function of cool corridors is continuity of shade along important transportation routes, as large gaps create heat islands that act as barriers to use. One indicator of discontinuity is hotspots along proposed cool corridors. Traditional street tree planting at 20 to 30' spacing may not be enough to significantly reduce corridor hotspots and other design strategies such as subcanopy planting, staggered tree plantings, and repurposing roadway or parking spaces to create additional space for tree plantings may be necessary. Additionally, the City should apply other complementary strategies (permeable pavement, green/white roofs, reflective pavement) in conjunction with tree planting to target heat island hotspots.

Forest Resilience Goal: The urban forest should be diversified to better withstand disturbance due to climate change and catastrophic pest and disease outbreaks. Planting practices should aim for a forest that is no more than 10% of any one species, 20% of any one genus, and 30% of any one family.[5] Not only should the City diversify the species palette, but species that have a higher climate resiliency score (see *Section 3.6*) should be prioritized in the next generation of planting.

Shared Responsibility Goal: Each stakeholder group within the community (private property owners, institutions, commercial/industrial landowners, and municipal/state entities) should increase its relative canopy cover by 10 to 25% (*Figure 1.12*). Recognizing that some urban typologies are more conducive to planting and that some uses already have high levels of canopy cover, a range from low to high canopy increase is targeted.

Overall Citywide Goal: Careful selection of where trees are planted and planting wisely to ensure success, is more important than planting trees at a greater quantity just to meet a target. Thus, the equity, resilience, and shared responsibility goals are considered the primary goals of this study.

However, it is still important to have an overall city-wide canopy goal as a metric to measure progress. This study proposes setting a secondary goal of overall city-wide canopy cover fluctuating around 30% (*Figure 1.16*) Aiming for 30% as a first step means setting a trajectory for an urban forest that can continue to grow significantly in the decades that follow.

Reaching this target appears achievable over the next 30-40 years under potential scenarios tested in this study. For example, if the community increases canopy cover by 10 to 25% on each land use category (residential, industrial, institutional, etc), 30% canopy cover could be realized. While it is not realistic to expect that all plantable areas of the city (51% of the total land area) become canopy covered, given the type of land uses and the current build-out of Cambridge, the city could realize a city-wide canopy of up to 34% . Setting a canopy cover range acknowledges that the urban forest cycles through periods of development and growth, of removal and planting, and of growth and decline.

The following specific targets will aid the community in applying the necessary efforts to meet these broad strategic goals and in evaluating progress in reaching them.

Tree Planting and Curbing Loss Targets

Curb Loss Target: Curb Loss by 35% to 50% citywide. Increasing canopy cover citywide will require curbing the current rate of loss of canopy, whether through reducing the intentional removal of trees or providing better maintenance and care so trees live longer. Because the existing rate of loss is so high for residential land use, this plan asks residential land owners to work towards reducing the current loss rate by 50%. For other landowners, the target is to curb loss by a minimum of 35%. Thus, the target is to curb loss by a minimum of 35% citywide from the existing rate of 1.6% per year to 1% per year.

Tree Planting Target: Trees take time to mature and newly planted trees will take many years to replace the cover of removed canopy.

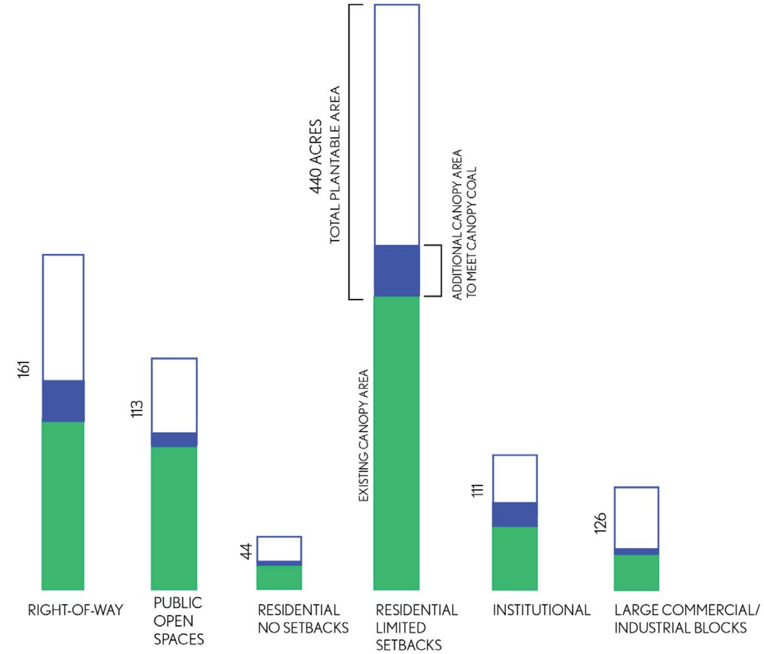


FIGURE 1.13 — FEASIBILITY. Within each urban typology, there exists enough plantable space to arrive at targeted canopy goals citywide.

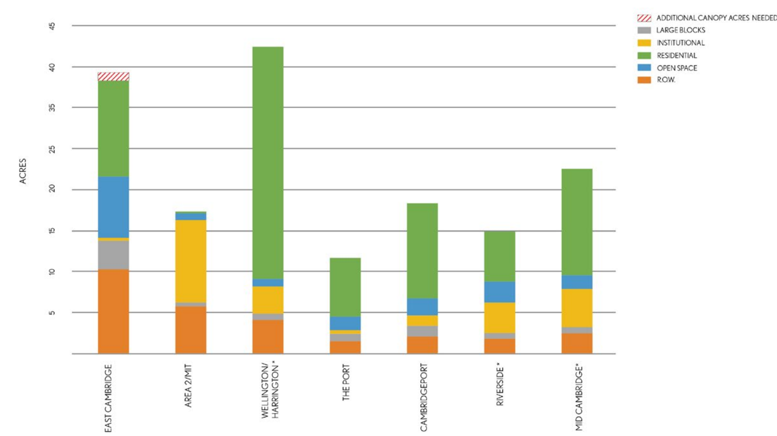


FIGURE 1.14 — FEASIBILITY. Within low canopied neighborhoods, there exists enough plantable space to arrive at 25% canopy cover. This will be harder to achieve in East Cambridge and Area 2/MIT.

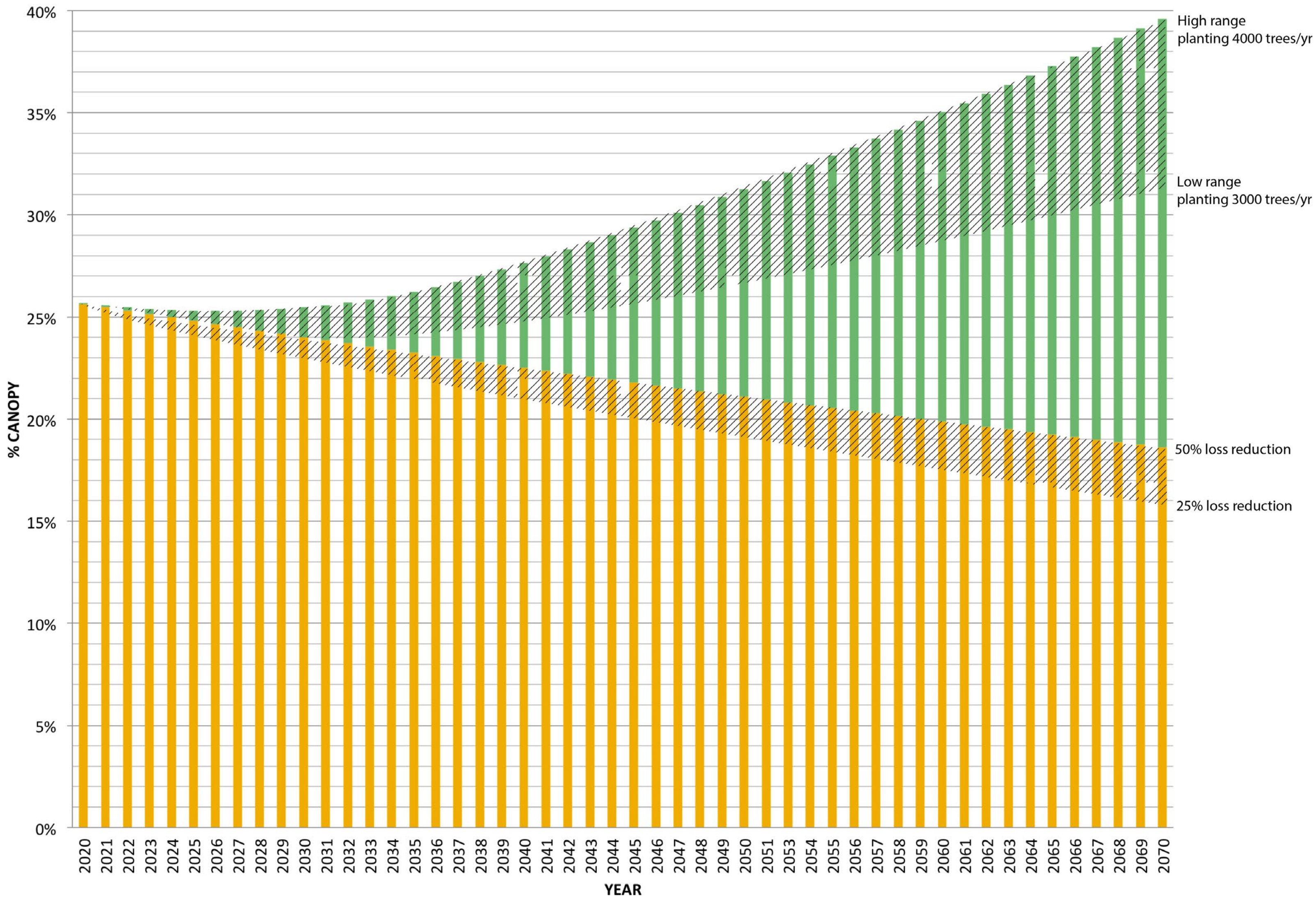


FIGURE 1.15 — CANOPY PROJECTIONS TO 2070 WITH A RANGE OF CURBING LOSS RATES (25 TO 50%) AND A RANGE OF ANNUAL TREE PLANTING TARGETS (3000 TO 4000 TREES PER YEAR)

Thus, to grow canopy in the near term, it is necessary not only to replace trees that are removed or die, but to plant substantially more trees, making up for years of net loss in the recent past. Assuming a reduction in loss rate of 35% to 50% can be achieved, 3,000 to 4,000 trees would need to be planted annually citywide to begin to expand canopy cover again in the coming years (*Figure 1.15*).

Aiming for this ambitious tree planting target would set the trajectory for a forest that will continue to grow significantly. One significant caveat is that these projections are based on the historic rate of canopy loss by land use type experienced from 2009 to 2018. Loss rates will likely vary in the future and there is no way to predict how this will fluctuate. If loss rates fall drastically, planting rates could also decrease significantly. But if loss rates do not improve, planting rates would need to be even higher to shift the curve from loss to gain in canopy. The City will need to monitor and react to changing canopy loss trends, adjusting annual planting targets accordingly in response to new information. This could occur every 3 to 5 years as the City updates its canopy survey.

Because planting trees requires permission from the land owner, it makes most sense to set tree planting targets by urban typology. Yearly planting targets by urban typology are proposed below and are based on growing canopy cover by 10 to 25% for each urban typology (*Figure 1.15*). Refer to *Section 6.3* for further discussion of the planting opportunities and strategies within each urban typology.

Feasibility of Goals and Targets: The goals and targets were tested to confirm there is enough remaining plantable area in the city to accommodate all the new trees that need to be planted. Plantable area is defined as the total area of the city minus the area currently occupied by streets, buildings, water, and athletic fields. Plantable area includes impermeable areas such as parking lots, driveways, and sidewalks, and all other permeable areas. As illustrated in *Figure 1.13*, there exists enough plantable area in each land use type to achieve the canopy cover target.

If each urban land use typology were to be planted out at the rate recommended by Policy Strategy 3A — Establish canopy cover requirements by parcel through Zoning Ordinance, there would be enough plantable area in almost all neighborhoods to reach the 25% minimum canopy target with the exception of East Cambridge and Area 2/MIT (*Figure 1.14*). East Cambridge would still have 16 acres of deficit and Area 2/MIT 2 acres of deficit. To reach 25% canopy cover, these two neighborhoods must further increase planting density for some urban typologies, or create new plantable area, such as creating parks out of private parcels or reducing street width and creating more plantable areas in the right of way.

With the additional tree planting in the R.O.W. comes additional investment in the maintenance and care of the trees. The City historically has planted around 400 trees per year and will be planting 600 trees in 2019. It will take time for the City to ramp up to the level of effort and increased labor to reach the target of 1,000 new street trees per year. If the City is able to plant 100 more trees every year, by 2023 the City will reach the target 1,000 trees per year.

Reaching targets in private property may be more challenging because the City has limited ability to plant and incentivize planting on private property. Partnerships with institutions, business owners, and residents will be essential for tracking and reaching the target planting rates. Based on an analysis of LIDAR data between 2009 to 2018, thus study estimates at least 650 trees per year were planted citywide (Appendix P). The City has historically planted 400 trees per year, which means at least 250 trees a year are being planted on private property. This Master Plan is asking private property owners to dramatically increase planting rates to approximately 2,000 to 3,000 trees per year.

GALVANIZE THE COMMUNITY

It will take intensive efforts of outreach and education to encourage residents to value their forest as a resource, to maintain and preserve mature trees, and to plant the next generation of the urban forest. Only 26% of plantable area is on public property. The majority, 49% of plantable area, is on the land of private residences. Blending public art and engagement, direct education, and strong communication from the City, an organized

Other city canopy cover targets[6]

Boston[7]	35% (2030)
Baltimore	40% (2036)
Hartford	35% (Ongoing)
New York City	36% (2036)
Philadelphia	30% (2025)

communications effort should be developed and implemented upon completion of this study. Long term efforts should be initiated, but those should be paired with immediate, highly visible initiatives that communicate the City's commitment to this work. (see *Section 4.5*)

LEVERAGE PARTNERSHIPS

The city has a strong network of non-governmental organizations and private institutions. The City should investigate and encourage partnerships with private institutions, who control 11% of the city by area and 14% of the plantable area. With robust landscape management resources and significant flexibility, institutions may prototype innovative approaches to planting design and forest stewardship that could be evaluated and potentially rolled out city-wide based on performance. The institutions should also set and annually report internal canopy cover targets which support overall city goals.

Private residences contain up to 49% of the plantable area in the city, yet state law appears to limit the City's ability to directly aid homeowners in planting trees. Through a public private partnership, a trust fund for planting and potentially caring for trees on private property, especially residential properties, could be innitiated.

The City's many neighborhood groups, cultural organizations, religious communities, and advocacy groups are ideal links between the City and the people. Partnering with existing groups in education efforts, volunteer tree planting, and maintenance and tree care efforts will have diffuse but meaningful impact, especially in communities where the tradition of tree planting and care may not be as established.

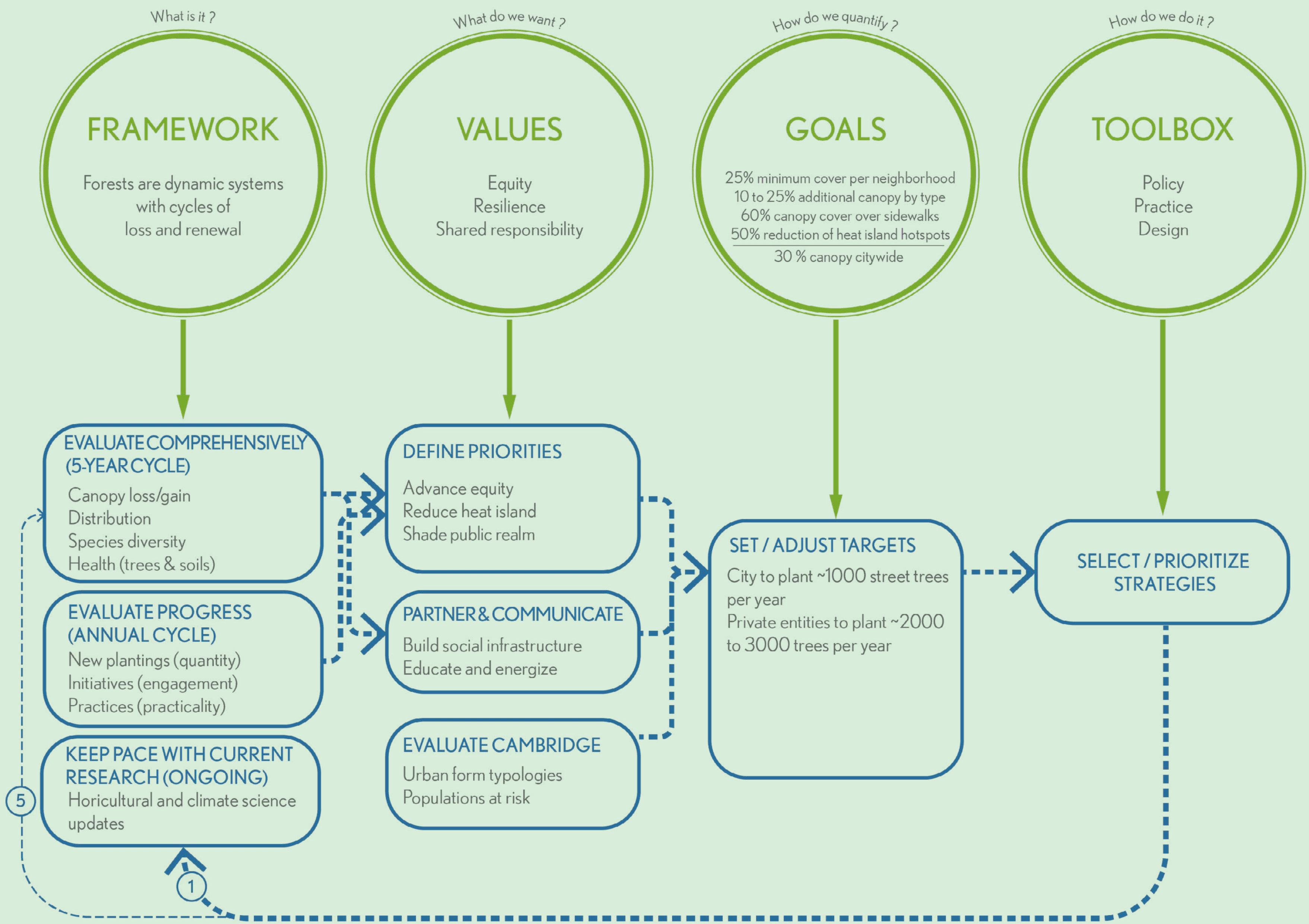
MEASURE SUCCESS

Regular evaluation of progress toward the community's goals will enable strategies to be adjusted as needed to ensure success. A yearly summary report of initiatives, efforts, and impacts should be published to keep the public informed and encourage participation. Every five years, a thorough evaluation of progress should be structured using the tools for canopy evaluation developed for this study. Building upon aerial surveying, on-the-ground sampling, and the City's own growing database of public tree health, an independent objective evaluation against performance metrics should be undertaken. The outcome of this process should be revised interim targets and specific adjustments to the recommended strategies within the categories of planning, policy, practice, and outreach.

MANAGE THE FOREST DYNAMICALLY

As the science of urban forestry changes in the coming years, as climate change impacts become more clear, and as technology advances, the management of trees in Cambridge must always keep pace. This requires constant vigilance and regular review. Working with the Committee on Public Planting and on-call outside consultants, the City should regularly update outlooks, responses, and best practices. These parties should be supplemented by subject experts, scientists, and people from allied disciplines, who comment on yearly evaluations and provide advice and peer review of important strategic decisions.

A PROCESS FOR EVALUATION AND PRIORITIZATION



EQUITY

Goal
Minimum 25% cover per neighborhood

Target
Each year, plant X* trees in neighborhoods deficient in canopy

Feasibility Analaysis
Six neighborhoods do not currently meet the target. Will be difficult to achieve in East Cambridge.

SHARED RESPONSIBILITY

Goal
City, residents, universities, developers all to increase their canopy cover by 10 to 25% by 2050

Target
Each year, each constituent plants X* number of trees

Feasibility Analysis
There is enough plantable area to achieve this goal.

RESILIENCE

Human resilience goal
1. 60% of sidewalks canopy covered.
2. 50% reduction in the number of hotspots (92 degrees when 90 degree average) in the R.O.W.

Target

Each year, plant X* trees in the R.O.W.

Forest Resilience Goal
No more than 10% of a single species, 20% of a genus and 30% of a family.

Target
Each year, plant more of X* species on recommended list, fewer of X* species

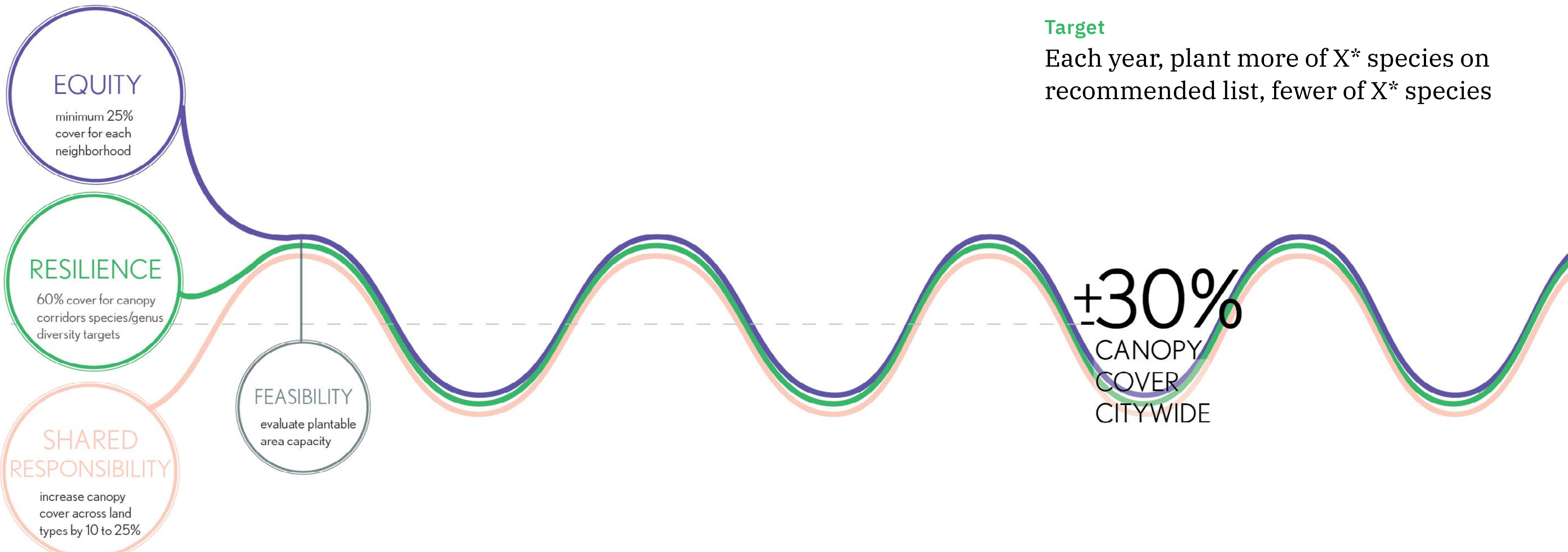


FIGURE 1.16 — VALUES AND GOALS. *Planting target numbers will fluctuate depending on a number of factors such as neighborhood, constituent type, and most recent data on loss rates.

MEMORIAL DRIVE

1.3 PROJECT BACKGROUND

This study was initiated by the City in 2017 to develop responses to a series of questions underlying the realization of canopy loss — Why is it happening? Where is it happening? What are the impacts of canopy loss? What can be done to reverse the trend? And what are the costs and benefits of increasing canopy cover?

During the year-long process of the first phase of the Cambridge Urban Forest Master Plan a series of well-publicized tree removals in the City brought concern over canopy loss to the larger community's attention and galvanized citizens behind action. And in February 2019 the City Council passed a one-year moratorium on tree removals in response.

These events and the passions of the Task Force assembled to inform, assist, and respond to the consultant team during the planning process illustrate the deeply felt nature of these issues and the dedication of the City and its many communities to taking action. This study and report attempt to respond to these concerns and the desire to see action through careful evidence-based analysis and the development of ambitious but realistic goals.

A MULTI-DISCIPLINARY TEAM

A diverse team of consultants contributed to this study and report. Lead by Reed Hilderbrand, a Cambridge-based landscape architecture firm, the study approaches the urban forest as spatial, horticultural, ecological and social infrastructure needing design, cultivation and stewardship.

The lead consultant has been supported by the Conservation Law Foundation (policy and law), Kleinfelder (engineering and climate resilience), Applied Ecological Services (remote sensing data analysis and ecology), Bartlett (arboriculture), F^2 Environmental (soils), Ellana (cost estimating), and OverUnder (communication and graphic design).

This multidisciplinary team has brought a breadth of knowledge and depth of experience to the problems, working collaboratively and collectively to understand the issues holistically and across disciplines.

ACTION GROUNDED IN EVIDENCE

This study is based in the review and evaluation of evidence based in peer-reviewed research and the quantitative analysis of city-wide data. Baseline data has been compiled from the City's records, from representative surveys of trees and soils, and from aerial mapping and surveying. All referenced journal articles are footnoted throughout this document and all data sets are available for independent review.

Proposed response strategies derive from these findings and will be evaluated and prioritized based on their respective impact on canopy health, resiliency, and coverage. In a time of heated rhetoric and complex agendas, this study brings science and rigorous analysis to the subject, aiming to create consensus around decisions through a shared understanding of the evidence.

A LONG-RANGE VIEW

While the risks facing the urban forest appear immediate and pressing, this study takes a long-range view of the problem and the potential solutions. The current state of the forest has been years in the making and represents many small influences. Likewise, efforts to shift rates of loss into appreciable gains in canopy cover will take years to realize. We must recognize that the urban forest, like any ecosystem, is a living, dynamic system. There is a cycle of germination, growth, maturity, decline, and death. In order for the urban forest to thrive and expand, that cycle has to be understood and respected and we must work with and within those cycles.

A TELESCOPIC APPROACH

Trees, people, forest — three lenses to understand the issues we face — structure the analysis and the response strategies. The urban forest is an ecological matrix made up of individual trees, and the health and resilience of each tree does impact the future of the forest. That health is influenced by the underlying soils, water and nutrient availability, and patterns of care and stewardship. As humans, we experience the impact of trees in physical, psychological and social ways and that cultural significance is critical to how we galvanize action. And, at the scale of the city, this study approaches questions at the scale of the forest, an ecological network that includes fungi, insects and other fauna and that functions as a living infrastructure that is regional in nature.


MID CAMBRIDGE

A MULTI-PRONGED APPROACH

Planning, Policy, Practice, and Advocacy — Our analysis shows that there is no single reason for persistent canopy loss. Likewise, there is no single solution. Integrated approaches to Planning, Policy, Practice, and Advocacy structure our analysis and response strategies.

Planning is the understanding of the spatial implications of trees in the city, and solutions focused on where and how trees may be planted.

Policy is made up of governance systems, regulation, and incentives that the City puts in place to organize and guide the treatment of the forest by its citizens and itself.

Practice considers the practical measures that support the life of urban trees, from planting and soil details to moisture delivery and establishment strategies and from pest and disease control to what species the City recommends for planting.

Finally, **Advocacy** is a process of communication and engagement, galvanizing collective action toward shared goals, whether that be through partnerships with existing institutions and groups or modes of education and engagement of the public at large. These categories assist in understanding the range of responses, but success ultimately relies on an all-of-the-above approach.

1.4 A Process of Engagement

PUBLIC OPINION SURVEY

A public opinion survey was conducted to collect information about Cambridge residents' opinions on the urban forest to help inform the development of the Urban Forest Master Plan. The survey was completed by 1,643 respondents between the dates of September 5, 2018 to December 6, 2018. The survey results are based on a self-selected sample, not a random sample. Therefore, the results may not be representative of all Cambridge residents, but can help shape approaches to continued outreach, education, and engagement strategies.

HEALTH AND QUANTITY OF EXISTING TREES

Respondents were split on the perception of the health of trees in their neighborhood. 53 percent said the health of trees was "fair" or "poor" and 42 percent of respondents said the health of trees was "very good" or "excellent". Respondents had a similar perception of the amount of trees in their neighborhood. 57 percent of respondents said the amount of trees is "too few" and 39 percent said the amount of trees is "enough." For both health and quantity of trees, the results were generally consistent across neighborhoods with a few notable differences. About the quantity of trees, most neighborhoods with low canopy coverage such as East Cambridge (13%), Wellington-Harrington (17%) and The Port (19%), respondents generally answered as there are too few trees. However, Area2/MIT, which has a low (17%) canopy cover, a high percentage of respondents (42%) perceived that there are enough trees. About the health of trees, while 70 percent of the trees in Riverside are in good health, only 35 percent of the respondents perceived the trees in excellent or very good health.

BENEFITS OF TREES

Respondents were asked about seven benefits of trees including shade/cooling, flood management, property value, quality of life, energy cost reduction, pollution reduction, and beauty. Results indicate that the majority of respondents agree that trees provide each of these benefits; however, there was more uncertainty about the benefits of flooding and energy cost reduction than the other categories.

AWARENESS OF EXISTING PROGRAMS AND POLICIES

Most respondents were not aware of the city's existing tree planting programs. In cases where respondents were aware of a city program, very few indicated they had ever used the program. However, 59 percent of respondents indicated they were "somewhat aware" or "very aware" that the city has opportunities for residents to volunteer to take care of public trees. Of those who indicated they were aware, only 27 percent said they had ever volunteered their time to take care of public trees.

ATTITUDES TOWARD TREE PRESERVATION AND GROWTH

The majority of respondents said that the City of Cambridge should have laws about removing and replacing trees. About 66 percent of all respondents indicated that these laws should apply to all types of property including public property, new development and private residences, businesses, and institutions. The overwhelming majority of respondents agreed that the city should have laws that protect trees on public property; however, the majority also indicated that the city should incentivize, not require, tree planting and maintenance on private property. Despite this preference for incentives over requirements on private property, 50 percent of respondents disagreed that private property owners should make decisions about trees on their property without input from the city.

There was also a strong preference for the city to prioritize both planting new trees and preserving existing trees to protect and grow the urban forest. Public sidewalks and streets were identified by the majority of respondents as the most important location for tree planting followed by new development sites and parks and green spaces.

DEMOGRAPHICS

Survey respondents were given the option to provide demographic information.

Of those that opted to provide this information, the majority were 45 years or older (63 percent), female (69 percent), non-Hispanic (93 percent), and white (84 percent). The income range of the majority of respondents was $75,000 or more (57 percent).

References
1 McDonald, R.I., et al., Planting Healthy Air: A global analysis of the role of urban trees in addressing particulate matter pollution and extreme heat (Arlington, VA: The Nature Conservancy, 2016).
2 Minority, Low Income, and English Isolation populations as defined in Climate Change Vulnerability Assessment: Vulnerable Population Ranking Memorandum. Report (Boston, MA: Kleinfelder), Nov. 2015.
3 http://bcrp.baltimorecity.gov/forestry/treebaltimore/value
4 Roman and Scatena, Street tree survival rates: Meta-analysis of previous studies and application to a field survey in Philadelphia (Pennsylvania, USA: Urban Forestry & Urban Greening. Volume 10, Issue 4, 2011).
5 Santamour, Frank S., "Trees for Urban Planting: Diversity, Uniformity, and Common Sense." Proceedings of the Seventh Conference of The Metropolitan Tree Improvement Alliance (Washington D.C.: U.S. National Arboretum, 2002)
6 Leff, Michael, The Sustainable Urban Forest Guide (Kent, Ohio: Davey Institute, 2016).
7 https://climate-xchange.org/2018/06/21/lack-trees-boston-leaves-city-lagging-climate-goals/

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2.
State of the Urban Forest

Cambridge's canopy cover was 26% in 2018, down from 30% in 2009.

Cambridge's current trend of decline in canopy cover is part of a larger cyclical statewide and nationwide decline. Factors driving canopy loss include new construction, renovations and site improvements, mortality, and a broad category of miscellaneous decisions by individual owners.

Canopy is not evenly distributed throughout the city's neighborhoods and populations at risk tend to reside in areas of less canopy cover.

Residential land use contains the highest portion of canopy citywide, 39%, while 22% of the total City canopy falls on public Right of Ways (R.O.W.). Open space, R.O.W., and Residential land use types have the greatest canopy cover.

The forest is in relatively good health as a majority of the trees in the city are in good (62%) or fair condition (28%). Ten species make up the bulk of the urban forest and three species comprise 30% of the Cambridge forest.

The annual value of ecosystem services from Cambridge's urban forest is estimated at $6.8 million. The total value of the urban forest in 2018, including carbon storage and compensatory value, is estimated to be $581.5million or $550k per acre. This number does not include many social, economic, environmental benefits that urban trees provide because there currently does not exist valuation methods for those benefits.

The City of Cambridge is ahead of many of its peers in understanding the link between the urban forest and climate resiliency and the investments necessary to support trees in an urban environment.

Trees in Cambridge are subject to both state and local protections. At the local level, the City has a Tree Protection Ordinance that governs the removal of trees associated with development through special permits and certain building permits.

Public sidewalks and streets were identified by the majority of public survey respondents as the most important location for tree planting followed by new development sites and parks and green spaces.

2.1 Current Condition

CURRENT CANOPY COVER

Currently, Cambridge's citywide canopy cover is 26%. This percentage accounts for all trees in the city — trees that grow on city property, in front yards and backyards, on campuses, in parking lots and on commercial and industrial properties. In 2009 more than 30% of the city was shaded by trees. Between 2009 and 2018, Cambridge's canopy declined at an average annual rate of 16.4 acres. See *Section 2.2* for further discussion of this trend.

Looking at 2018 canopy coverage by neighborhood, those with the highest canopy cover – West Cambridge, Strawberry Hill, and North Cambridge – tend to have more residential land uses, while neighborhoods with the lower canopy cover – East Cambridge, Area2/MIT, and the Port – tend to have more commercial and industrial developments. For neighborhood canopy maps associated with land use, refer to Appendix J.

The largest proportion of the city's canopy falls on private residential property (39%) while 22% falls on public R.O.W. Open space, R.O.W., and Residential land use types have the greatest canopy cover.

Land Use Type	2018 Acres of Land Use Overall	Total Canopy Acres (2018)	% canopy cover within that land use type	% of total canopy	% of land use as % of total area
Residential	1501	409.4	27%	39%	37%
R.O.W.	812	229.3	28.2%	22%	20%
Open Space	521	227.14	44%	22%	13%
Commercial	452	46	10%	4%	11%
Institutional	436	86.3	20%	8%	11%
Industrial	216	21.5	10%	2%	5%
Public	128	22.6	18%	2%	3%
Over water (mostly open space)	–	13.76			
TOTAL	4,066	1,056			

TABLE 2.1 — CANOPY BY LAND USE TYPE EXCLUDING WATER BODIES

Cambridge	29.0% (2014)	26.0% (2018)
Boston	27.0% (2017)	22.3% (2019)
Baltimore	28.5% (2013)	21.0% (2019)
Hartford	25.0% (2013)	25.9% (2019)
New York City	20.9% (2013)	21.0% (2019)
Philadelphia	20.3% (2013)	15.7% (2019)

TABLE 2.2 — CANOPY COVER COMPARISON OF CAMBRIDGE WITH OTHER CITIES[1,2]

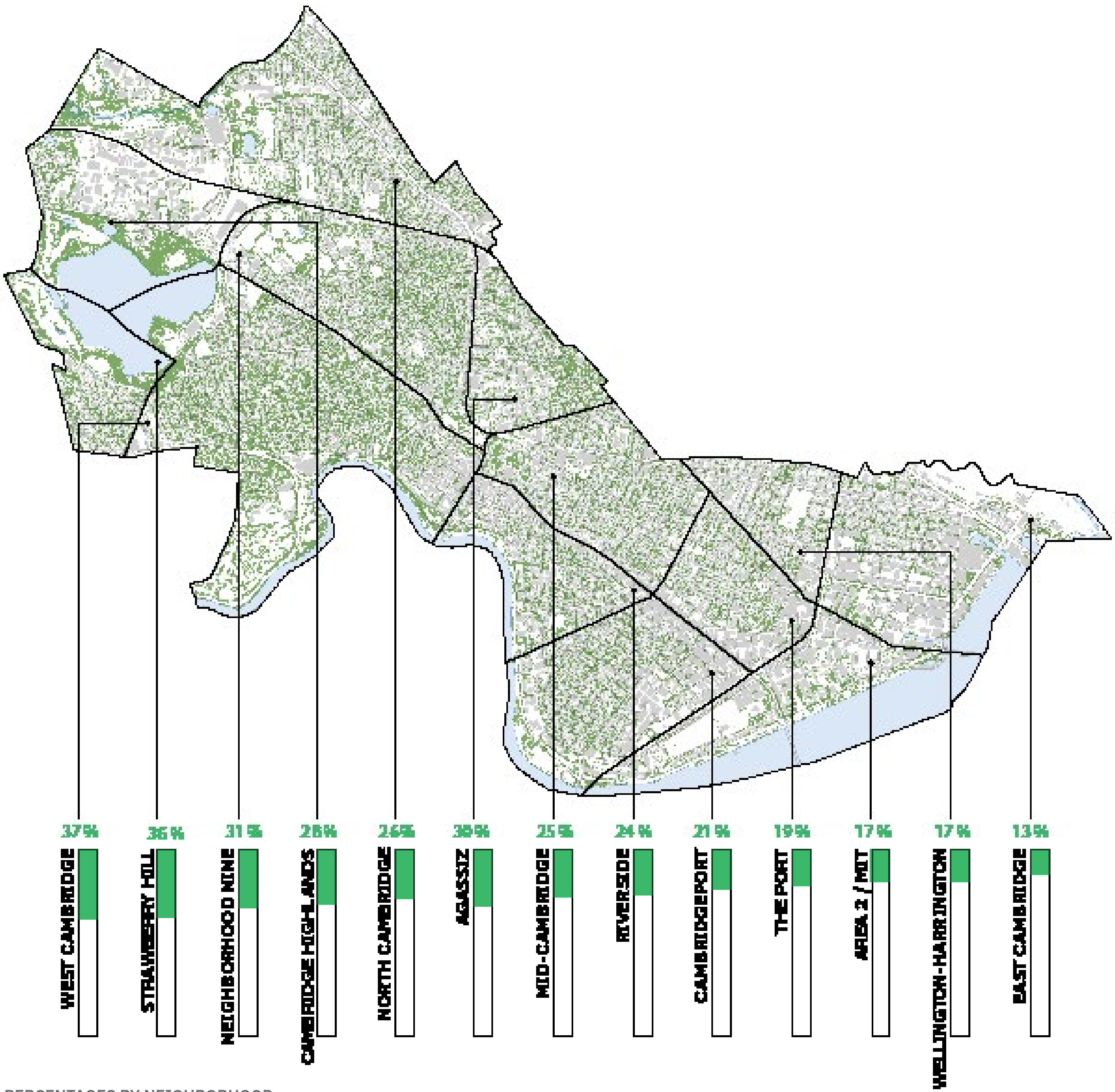


FIGURE 2.1 — CANOPY COVER PERCENTAGES BY NEIGHBORHOOD

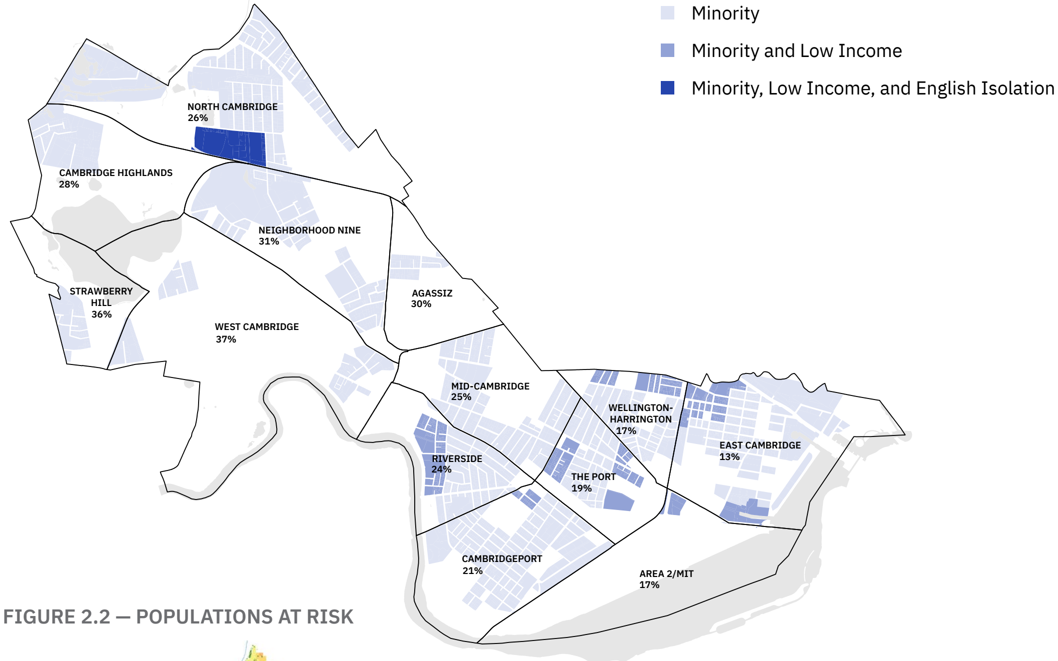


FIGURE 2.2 — POPULATIONS AT RISK

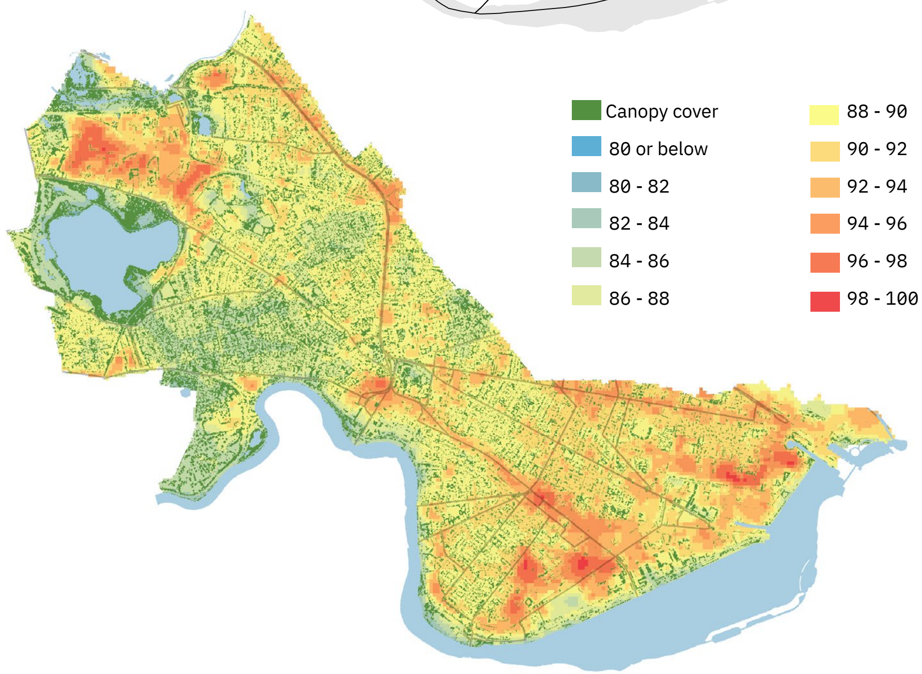


FIGURE 2.3 — COMPARISON BETWEEN HEAT ISLAND AND CANOPY COVERAGE.
Estimated ambient air temperature of a 90° F day.

CURRENT CANOPY DISTRIBUTION

As the canopy cover of Cambridge is not equally distributed, the benefits of the urban forest are therefore not equitably distributed across the city's population. In 2018, areas of the city with lower than average canopy cover were more frequently correlated with populations at risk[3]. With denser urban fabric and more impervious surface cover, these neighborhoods are more likely to suffer from urban heat island impacts and have populations generally less able to respond or adapt to the threats of heat extremes. See Response Strategies section for discussion of prioritizing canopy equity.

CURRENT FOREST COMPOSITION AND CONDITION

Our understanding of the composition and health of the citywide tree canopy cover is derived from two sources: a 5% inventory of 200 randomly selected one acre plots throughout the city conducted by certified arborists and a canopy classification dataset derived from analysis of satellite imagery and LiDAR (see Appendix D, A for technical descriptions). The classification dataset identifies trees in the city down to genus and/or species, classified through 2018 LiDAR data and aerial imagery and verified against the 5% inventory. See Appendix D for 5% inventory data and Appendix B for tree classification data.

4,118 total trees fell within the 5% inventory plots. Categories of assessment were: species, genus, diameter at breast height (DBH), condition class, age class, pest/diseases, location information, material, size of planting bed/tree pit. 80 trees were observed to be affected by pests or disease. Pests/diseases identified include: anthracnose, aphids, bark beetles, borers, emerald ash borer, gall insects, leaf beetle, leaf spot, powdery mildew, rust, scab, scale, slime flux and tip blight.

The 5% inventory identified 140 species with the 200 plots. 62% of the 4,118 trees are in good condition with 25% in fair condition, 8% in poor condition and 4% standing dead trees. 57% trees are on City property, 30% are on private, 8% are on Commercial and 5% are on university property. Overall there is an even distribution across desirable age classes: 1% new plantings, 32% young trees, 33% semi-mature, 33% mature, and 1% over-mature (over-mature being trees that are at the end of their life-expectancy). See following graphs for further analysis of the inventory and classification datasets.

Ten species make up roughly 64% of the urban forest. Norway Maple, Pin Oak and Honey locust are the highest in number.

SOIL CONDITION

Trees are dependent on soils for their health. Soil sampling was conducted at 20 City or State owned sites to form a generalized picture of city soils to better understand existing tree health. At each site the top 12” of soil was sampled for biological, textural, and chemical analysis, the 12 to 24” horizon was sampled for textural and chemical analysis, and the 24 to 36” horizon was sampled for textural and chemical analysis.

Textural observations revealed a general inconsistency of soils materials, meaning the soils vary within the tree pit. Of the 20 sites sampled, 16 had severe compaction, 12 sites had little or no available nitrogen, and 7 sites showed poor drainage 2’ to 3’ below the surface.

The test results indicate that soil health for street trees is fair to poor, with high compaction, low nutrient cycling, and characteristics of poor drainage, all of which is typical of urban soils that are not managed. The conclusion from soil testing is that soils have degraded post-planting as evidenced by the compaction and low nutrient cycling results, and the City can do more to manage soils to provide healthier growing conditions for its trees. See Appendix H for photographs and testing data for the 20 sites, and see *Section 2.3* for discussion of Management Practices.

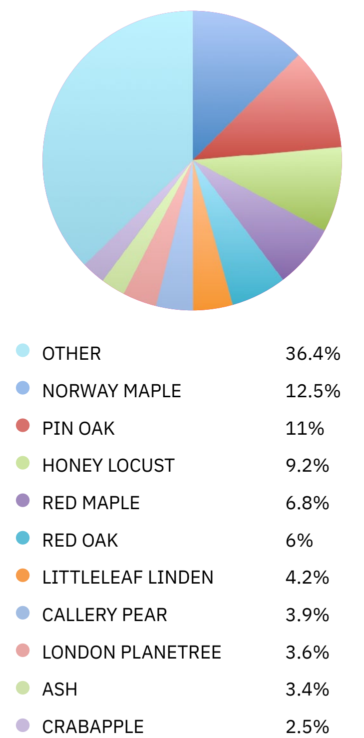


FIGURE 2.4 — CURRENT FOREST COMPOSITION

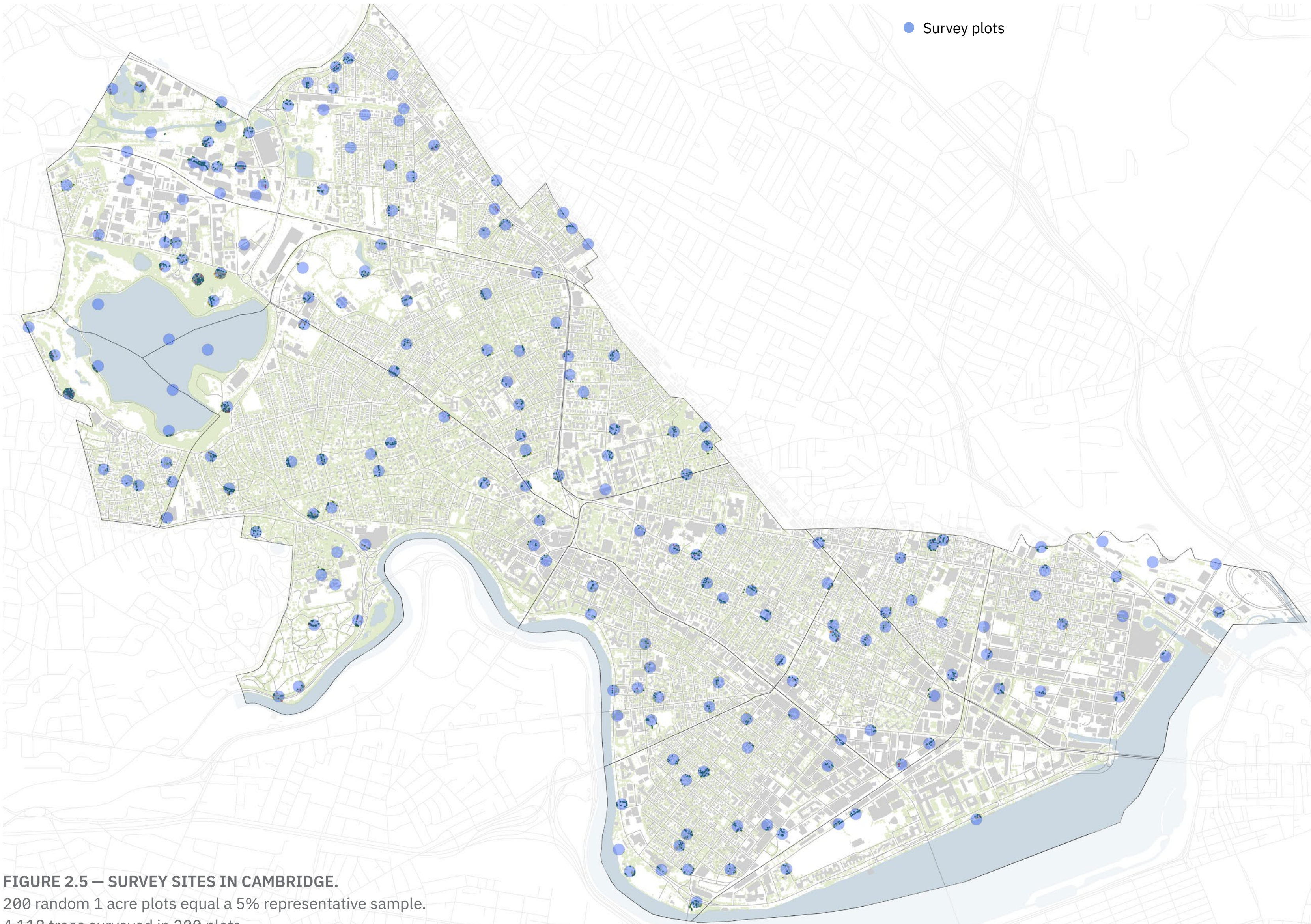
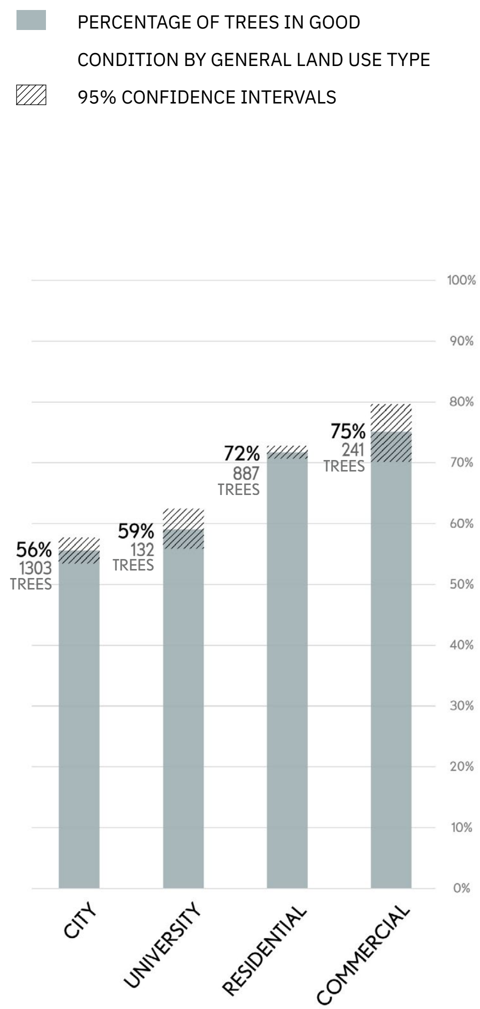
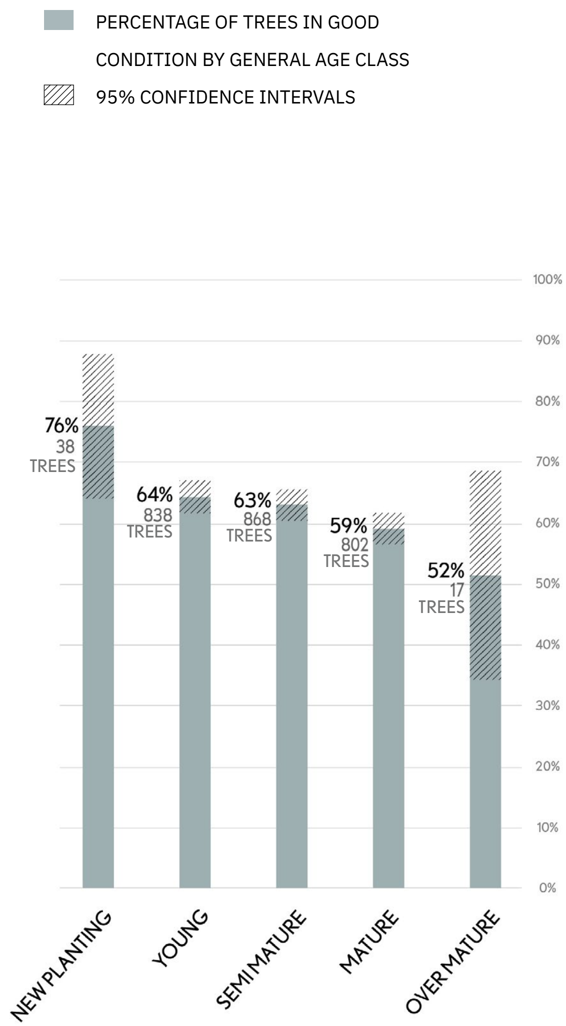


FIGURE 2.5 — SURVEY SITES IN CAMBRIDGE.
200 random 1 acre plots equal a 5% representative sample.
4,118 trees surveyed in 200 plots.





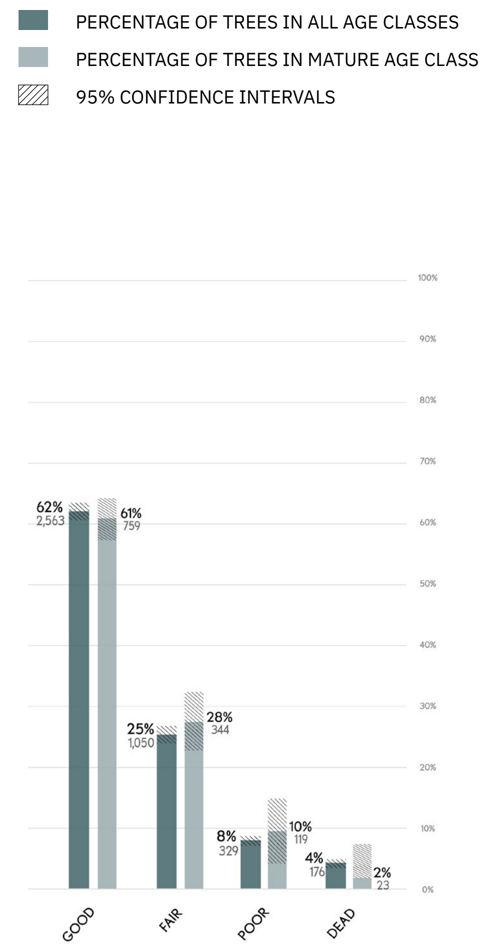


FIGURE 2.6 — TREES ON COMMERCIAL AND PRIVATE PROPERTIES HAVE THE HIGHEST PERCENTAGE IN GOOD CONDITION. Trees on the city property have the lowest percentage in good condition.

FIGURE 2.7 — THE PERCENTAGE OF NEW PLANTINGS AND YOUNG TREES IN GOOD CONDITION ARE THE HIGHEST. Only half of over-mature plantings are in good condition.

FIGURE 2.8 — CONDITION OF MATURE TREES. A large portion of mature trees are not in good condition.

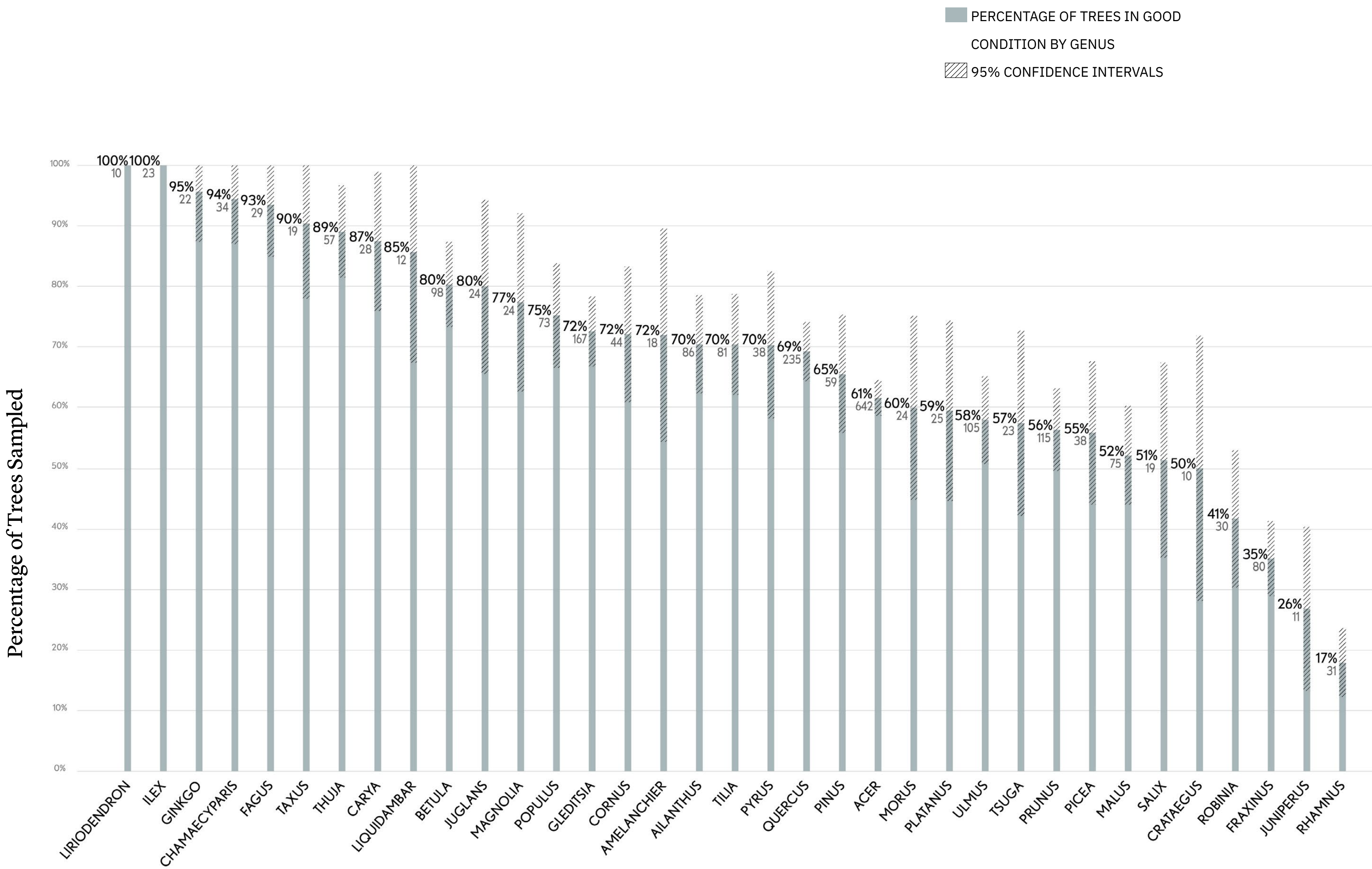
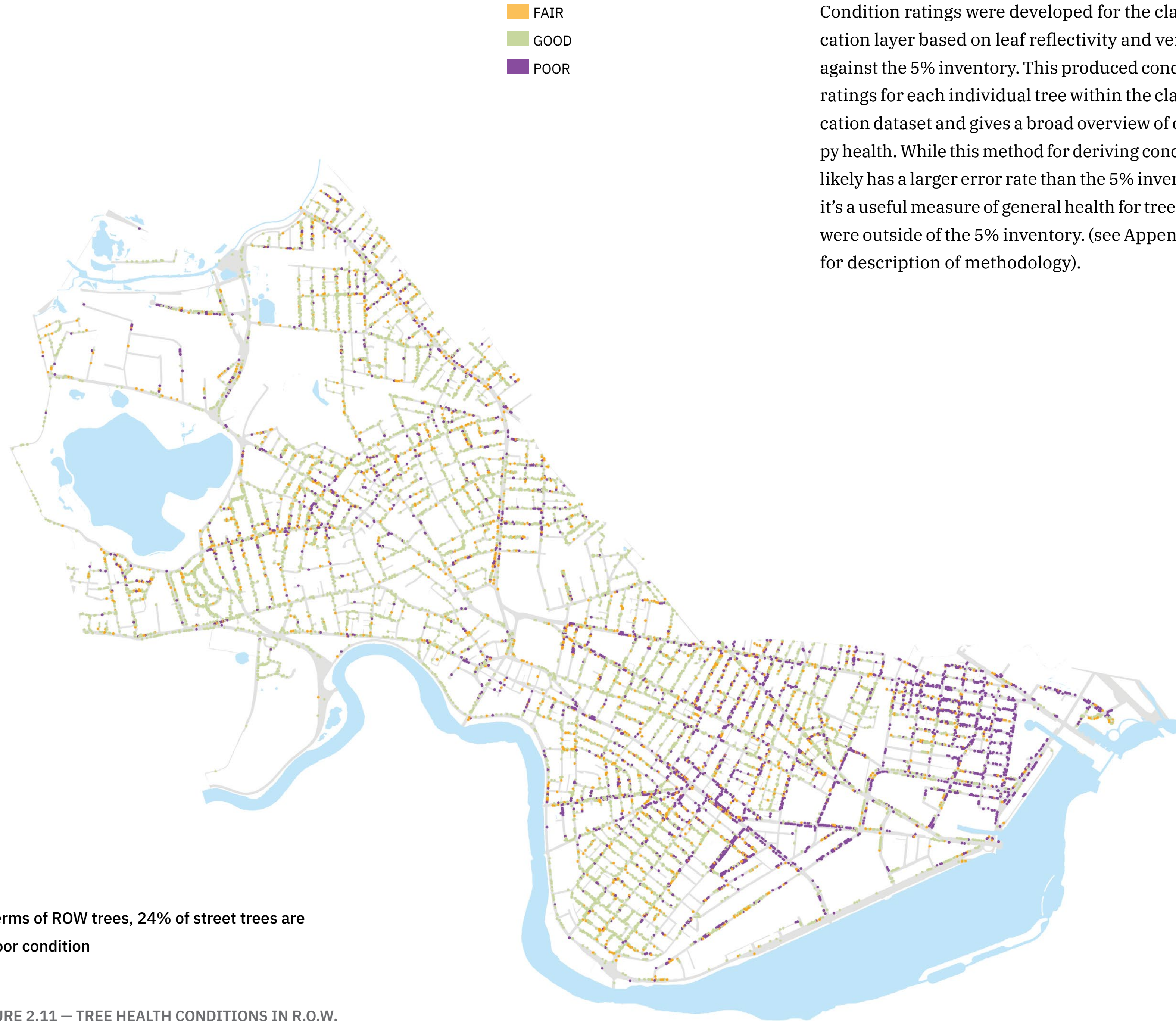


FIGURE 2.9 — PERCENTAGE OF TREES IN GOOD CONDITION BY GENUS. Genus with 20 or more occurrences are shown

Ash trees currently make up roughly 5% of the city's canopy, half of which is on private property.

FIGURE 2.10 — INSTANCES OF SUSPECTED EAB + TREE CONDITION. Percentage of trees in good condition by genus. Genus with 20 or more occurrences are shown.



Condition ratings were developed for the classification layer based on leaf reflectivity and verified against the 5% inventory. This produced condition ratings for each individual tree within the classification dataset and gives a broad overview of canopy health. While this method for deriving condition likely has a larger error rate than the 5% inventory, it's a useful measure of general health for trees that were outside of the 5% inventory. (see Appendix D for description of methodology).

In terms of ROW trees, 24% of street trees are in poor condition

FIGURE 2.11 — TREE HEALTH CONDITIONS IN R.O.W.

39% of trees in sidewalks greater than 8' wide are in poor condition, frequently these areas have no front yard setbacks. The data shows that street trees with setbacks are in better condition than those in wider sidewalks but with no setback.

FIGURE 2.12 — TREE HEALTH CONDITION. 39% of trees in sidewalks greater than 8' are in poor condition. Frequently these areas have no front yard setbacks.

FIGURE 2.13 — STREET TREE CONDITIONS IN EAST CAMBRIDGE AND WEST CAMBRIDGE. Areas with front yard setbacks have street trees in better condition

FIGURE 2.14 — STREET TREE CONDITION VERSUS FRONT SETBACK DIMENSION. Trees in 0 front setback zones are in poorer condition compared with other setback conditions and with city avaerage

2.2 Canopy Loss Analysis

CITYWIDE CANOPY LOSS FROM 2009 TO 2018

The Cambridge urban forest is shrinking. In 2009, more than 30% of the city was shaded by trees. By 2018, only 26% of the city was shaded by canopy. Between 2009 and 2018, Cambridge's canopy declined on average by 16.4 acres every year.

While analysis at the city-wide scale indicates that trees are being removed throughout the city, the largest percentage of loss by land use has been on residential properties with a net loss of 119 acres between 2009–2018.

Canopy loss is not simply an abstract statistic; it has real, immediate impacts, both physical and psychological, for people and wildlife. Fewer trees provide less shade, which results in a warmer city. The presence of urban trees can reduce air temperatures on summer days by 2–4°F. Trees also improve our quality of life and mental well-being, and provide a variety of ecosystem services from managing stormwater to improving our air quality. Trees create a sense of place, character, and scale that make a city aesthetically pleasing and encourages people to linger in treed spaces, all of which support the economic and social sustainability of the city as a desirable place to live/work/study.

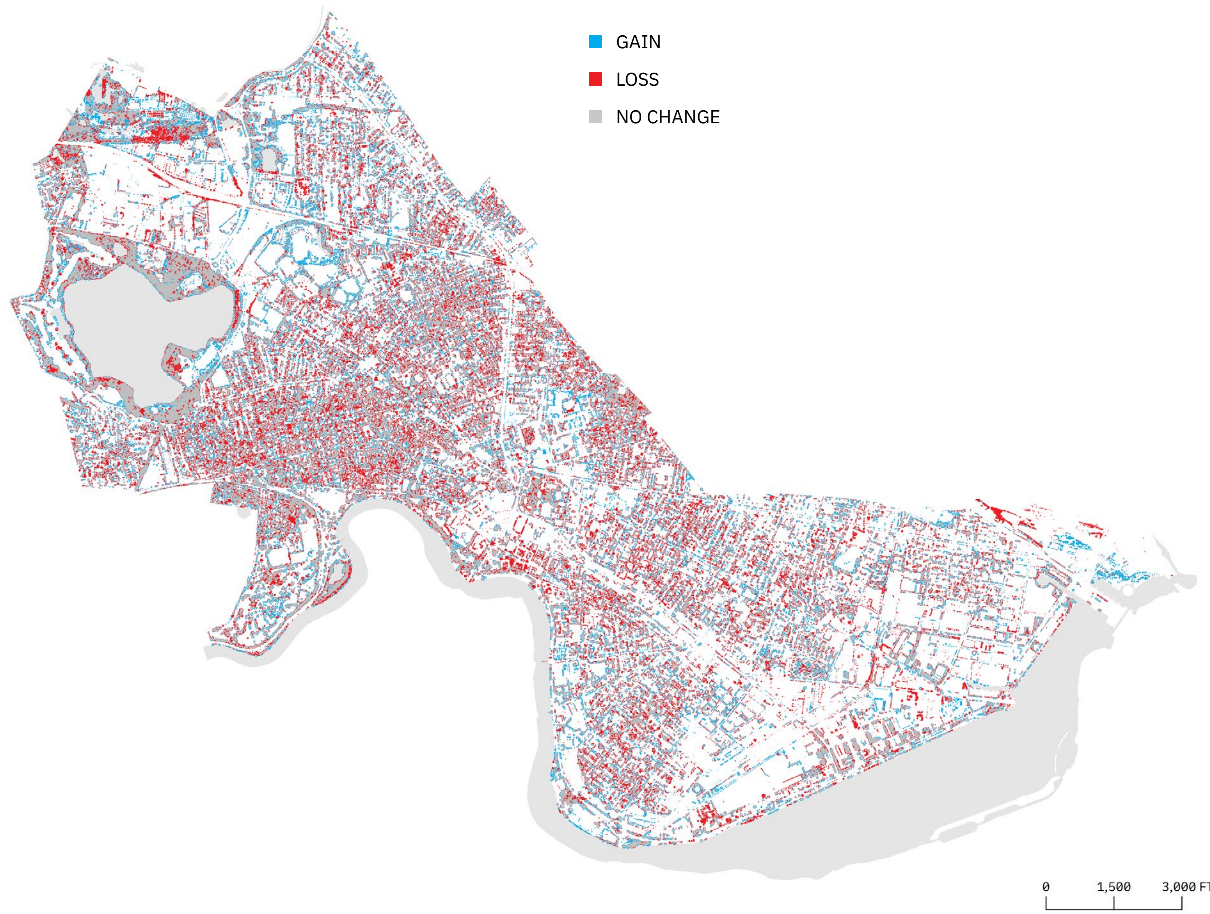


FIGURE 2.15 — TREE CANOPY LOSS BETWEEN 2009–2018

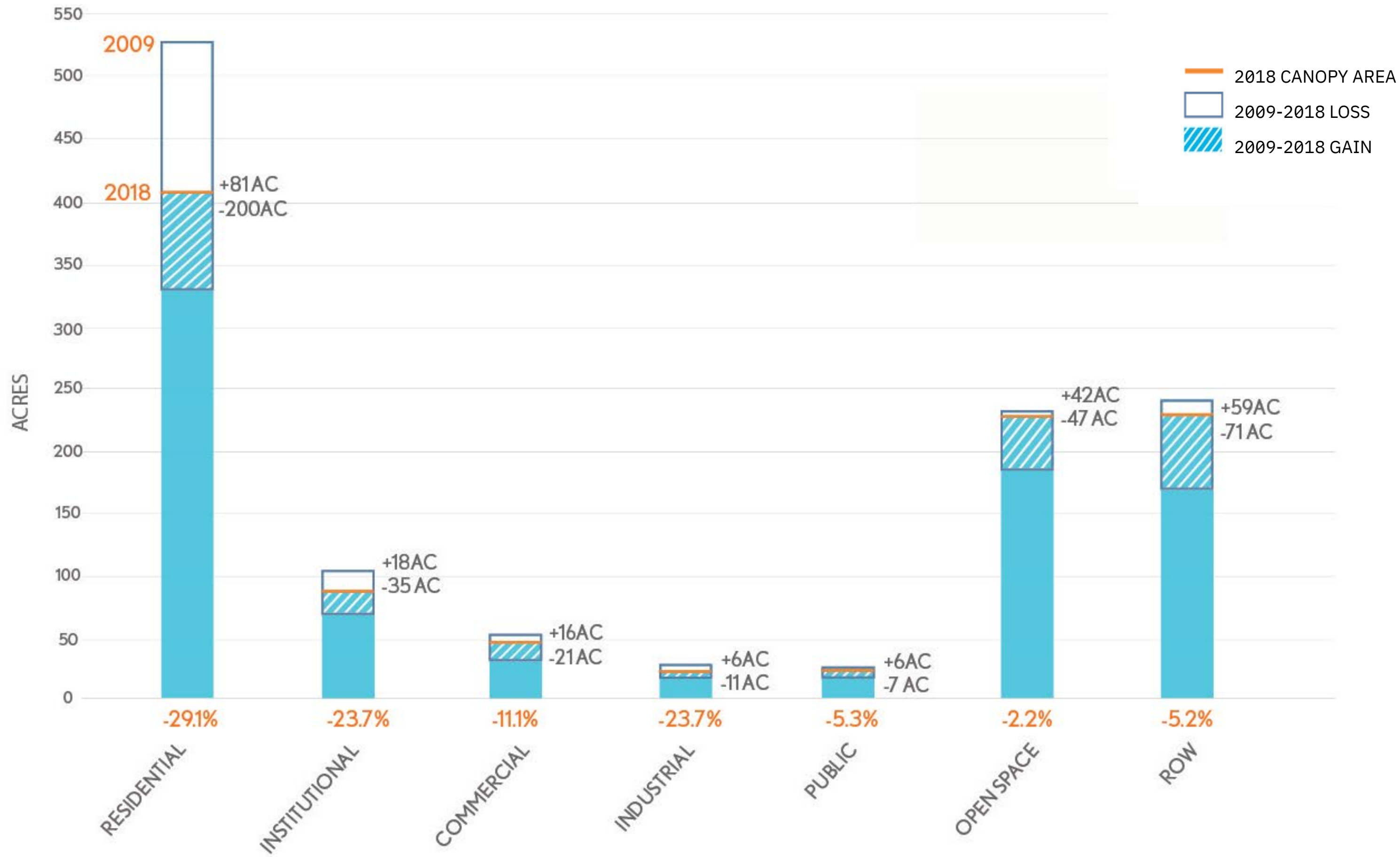


FIGURE 2.16 — TREE CANOPY LOSS BY LAND USE TYPE

CANOPY LOSS WITHIN LARGER CONTEXT

Canopy loss in the City of Cambridge is not an anomaly. Nationally, cities are facing persistent canopy decline.[4] Tree cover in urban areas dropped 1% over a 5 year period between 2009 to 2014 with an increase in impervious cover coinciding with the loss of tree cover.

From 1600 to 1860, forest cover in Massachusetts declined as more and more trees were felled for farmland (*Figure 2.17*). After about 1860, forests rebounded as agriculture dwindled in the state and farms returned to forest. After 1950, the trend reversed as the expansion of suburban housing caused a rapid decline in forest cover.

Shifts in human patterns of activity have also had a significant local impact on Cambridge's urban forest. *Figure 2.18* shows that single family homes built before 1930 represent a high proportion of residential tree canopy. Development tapered off after this period so we can surmise that the residential canopy would also decline as those trees reach the end of their lives, shown by the red bars along the top of the diagram representing a generic tree's 100 year lifespan. As those trees are removed there is no comparably sized cohort of younger trees to take their place. It could be argued that this is a significant cause of canopy decline on residential property which in turn comprises the largest portion of canopy loss by land use. In summary, canopy growth and decline are cycles influenced by human activity, and the decline of Cambridge's residential canopy cover is speculated to be correlated with the end of this period of residential construction.

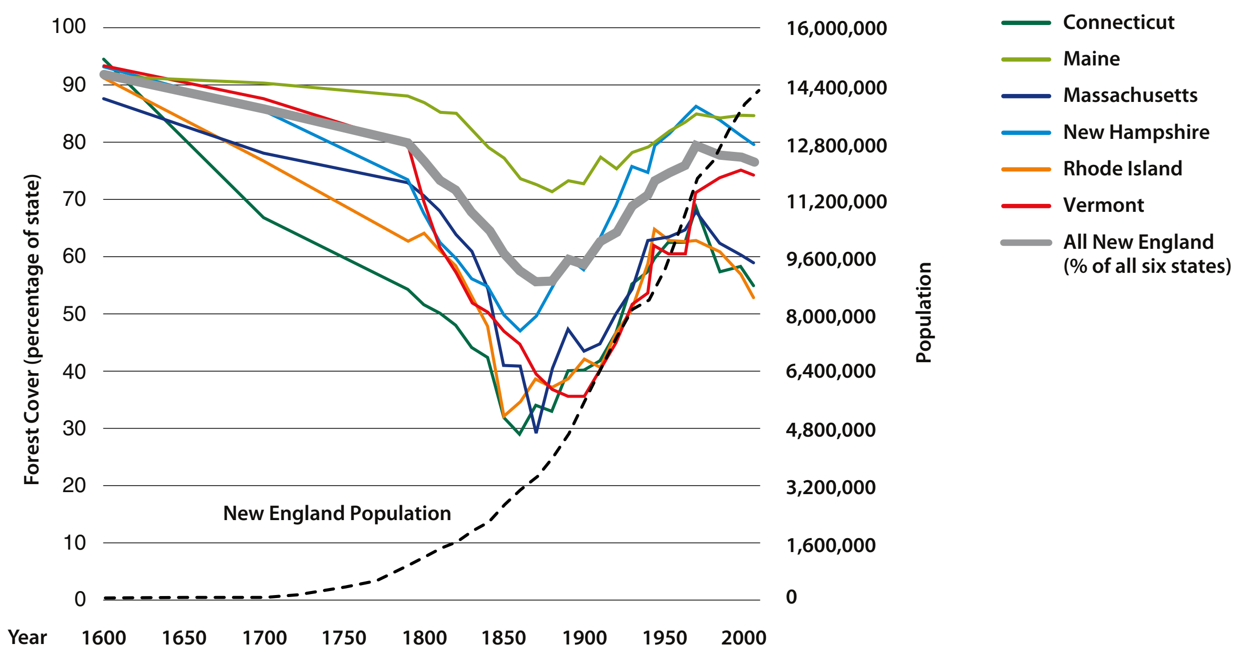


FIGURE 2.17 — FOREST COVER AND POPULATION CHANGE IN NEW ENGLAND. (Source: Thompson, Jonathon, Lambert, Kathy F., and Foster, David, Changes to the Land: Four Scenarios for the Future of the Massachusetts Landscape (Harvard Forest and Smithsonian Institution, Dec. 2013).

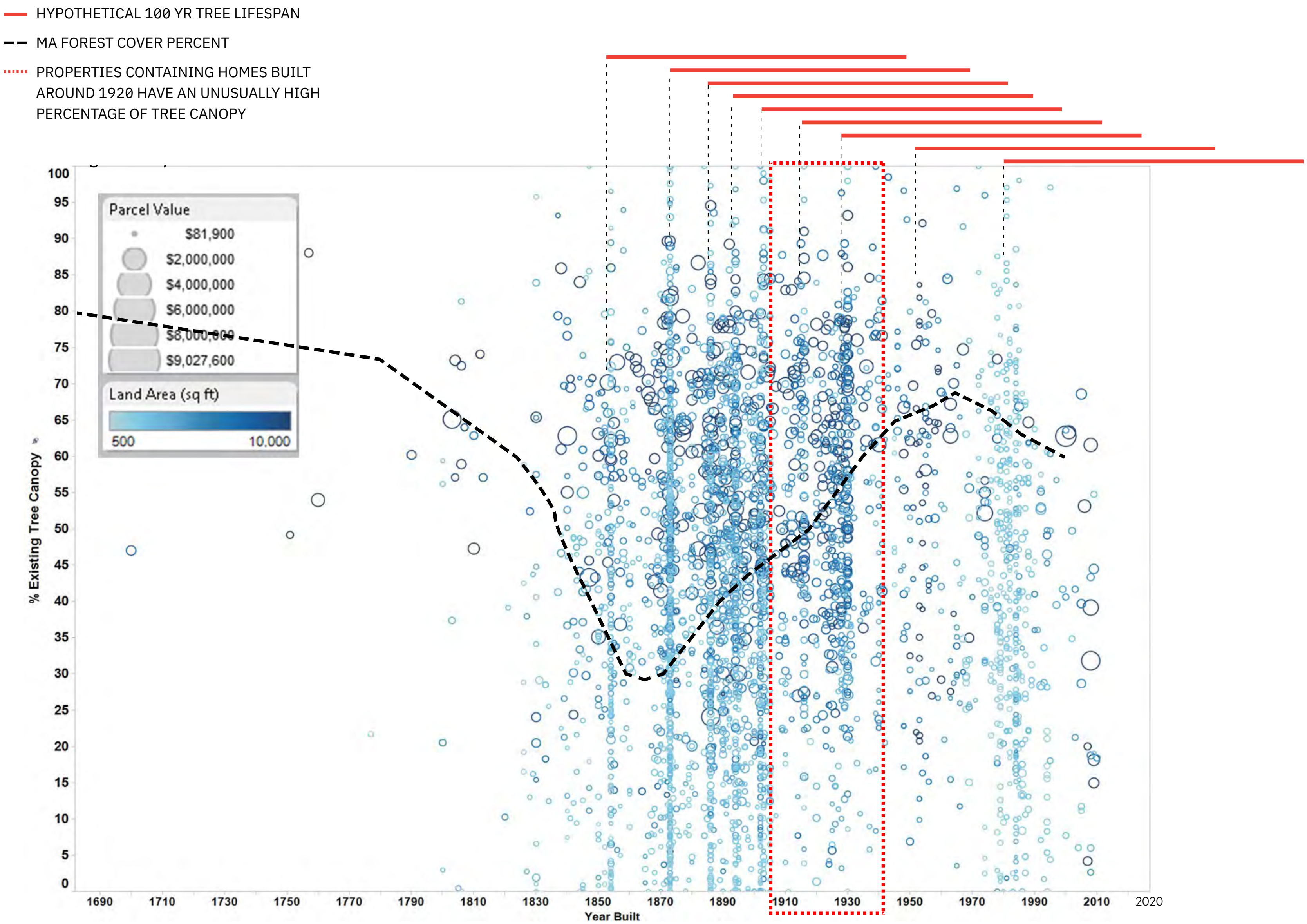


FIGURE 2.18 — EXISTING TREE CANOPY IN RELATION TO YEAR OF CONSTRUCTION, PARCEL VALUE, AND LAND AREA FOR SINGLE FAMILY RESIDENTIAL PARCELS. (Source: Modified from: O'Neil-Dunne, Jarlath, Report on the City of Cambridge's Existing and Possible Tree Canopy, (Burlington, VT: Spatial Analysis Laboratory, University of Vermont, Jun. 2012).

LOCALIZED CAUSES OF CANOPY LOSS

A series of studies were conducted to test whether losses could be tied to home sales, changes in impervious surface, or other identifiable causes. The sites were distributed across the city and cover different typologies and neighborhoods.*Figure 2.19* depicts the locations of study sites that were used to examine:

1 Loss associated with increased impervious area
2 Loss associated with property sales
3 Other causes for canopy loss

1. Impervious area change

The study of impervious area change relative to canopy loss was driven by the concern that renovations, whether increases in building footprints or increases in paved area, could be a significant cause of canopy loss. While impervious cover in Cambridge increased approximately 1.6 percent from 2010 to 2018, and the city-wide tree canopy cover fell by 13.4 percent, findings show that increased impervious surface is not clearly correlated with canopy loss in the city. However the opposite correlation did appear to be significant, as canopy increased 24% more where impervious cover did not increase. This suggests that preserving previous areas creates beneficial conditions for increasing tree canopy. Data from aerial mapping, overlaying change in impervious cover between 2010-2018 and change in canopy cover between 2009-2018 was used to assess correlation.

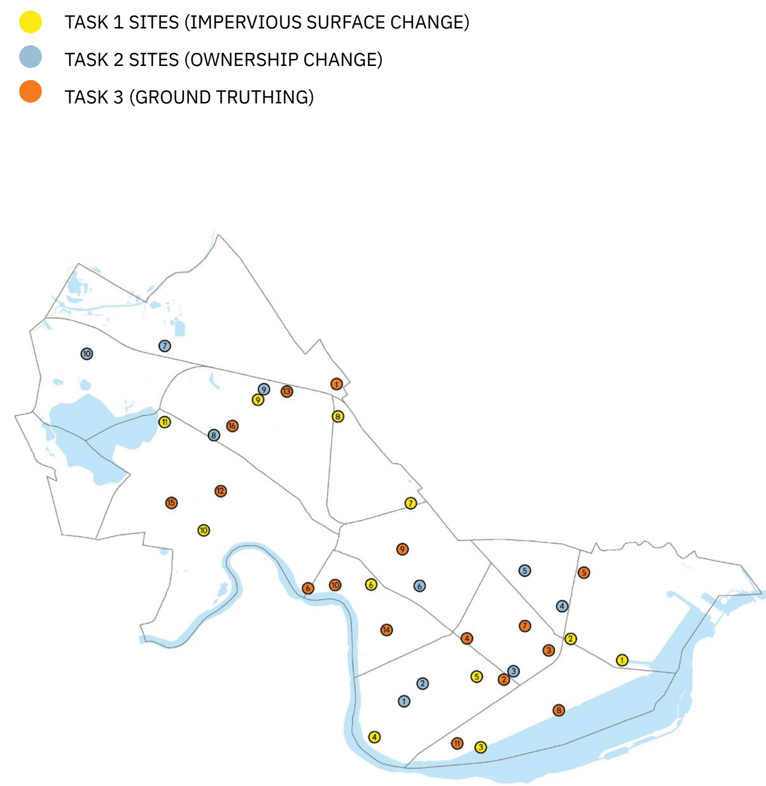


FIGURE 2.19 — CANOPY LOSS INVESTIGATION SITES IN CAMBRIDGE

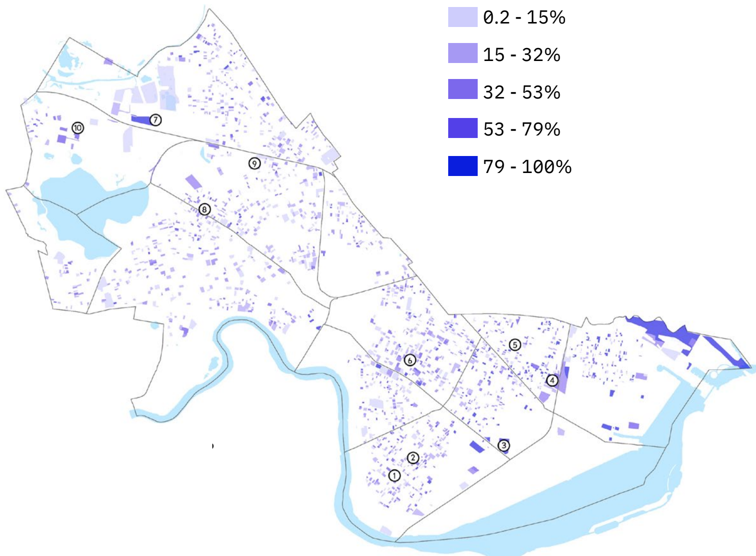


FIGURE 2.20 — PERCENT CANOPY LOSS WITHIN PARCELS THAT CHANGED OWNERSHIP AND SHOW LOSSES

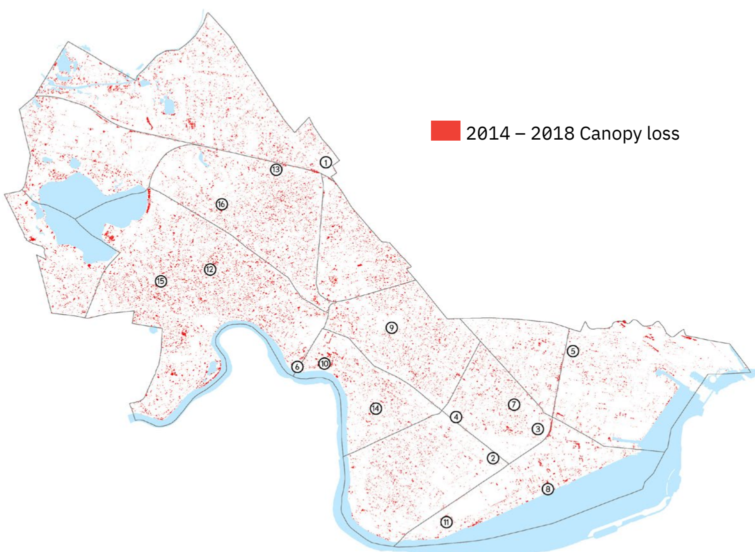


FIGURE 2.21 — TREE CANOPY LOSS 2014 - 2018 AND INVESTIGATION SITES

2. Property sales

Using the aerial mapping and city records, property sales from 2015-2017 (only years available through the City's Open Data portal at the time of inquiry) were overlaid with change in canopy cover between 2014 and 2018 to assess whether new development associated with property sales was a significant cause of canopy loss.

Findings from this include:

- 2,945 parcel sales took place from January 1, 2015 to December 31, 2017 out of 13,006 total parcels in Cambridge

LOSS:

- 22.3 acres of canopy loss (of 330 total gross canopy loss) was on land sold during that time.
- 10.5 acres (almost half) of 22.3 acre loss was associated with just 179 parcels. 10.5 acres represents 8.5% of the canopy loss from 2014 to 2018
- 1,100 parcels showed only minor losses.

GAIN:

- 29 parcels contributed 2.9 acres of new canopy.
- 313 parcels contributed 4.1 acres of new canopy.

The majority of the loss associated with property sales occurred on a small number of parcels. The most important finding was that small amounts of canopy loss occurred on over a thousand parcels that were sold. 82% of canopy loss during this period occurred on parcels where there was no ownership change. This suggests that stemming canopy loss in the city requires outreach to residents on a large scale regarding maintenance of existing tree canopy.

3. Other Causes

A third study attempted to ascertain from aerial imagery and ground truthing whether canopy loss could be attributed to other reasons beyond the two discussed above.

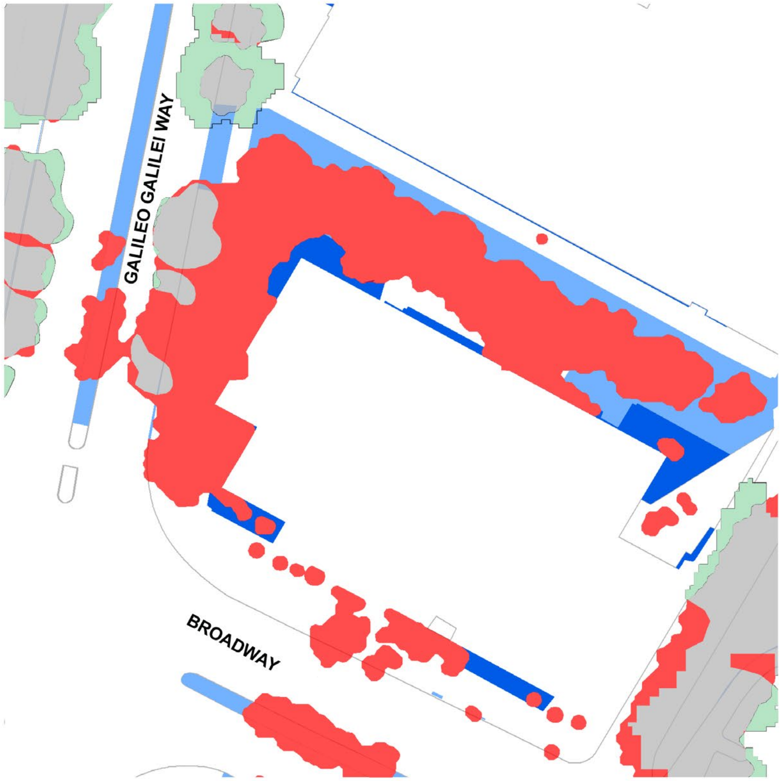
This study suggest an association between four drivers of new construction, renovation and site improvements, mortality, and miscellaneous decisions with canopy loss.

On the ground investigations have also revealed that frequently loss is paired with replanting. Although relatively small as a percentage of canopy cover, many new projects have planted canopy trees which will over time create significant shade. Others have installed green roofs or other forms of green infrastructure.

DRIVERS OF CANOPY LOSS

The analysis of the canopy loss studies showed that there are many different decisions driving canopy loss, but there is no one cause of canopy loss. Many factors have contributed to the current trend of loss including historical uses, horticultural conditions, and urban form. GIS analysis and on-the-ground review of specific areas of loss indicate that loss is generally associated with new building construction, increased paving, landscape renewal projects, utility infrastructure projects, lack of adequate tree care and protection, and natural decline, but there was no overwhelming factor to point to.

NEW CONSTRUCTION

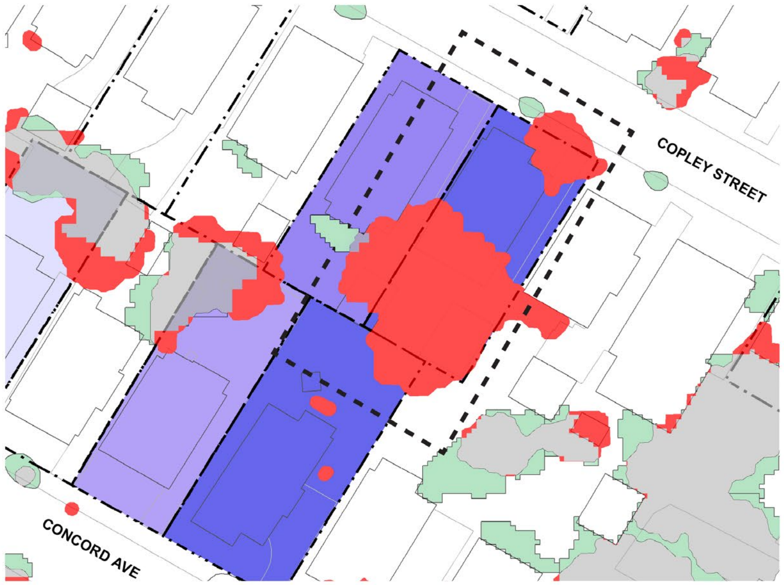


- 2009-2018 CANOPY LOSS
- NEW STRUCTURE
- NEW PAVEMENT
- CANOPY GAIN
- NO CANOPY CHANGE

PROJECT TYPE: COMMERCIAL

FIGURE 2.22 — TREE REMOVAL IS ASSOCIATED WITH CONSTRUCTION OF A NEW COMMERCIAL BUILDING ON BROADWAY. Street design to change also impacted trees in median

RENOVATION & SITE IMPROVEMENTS



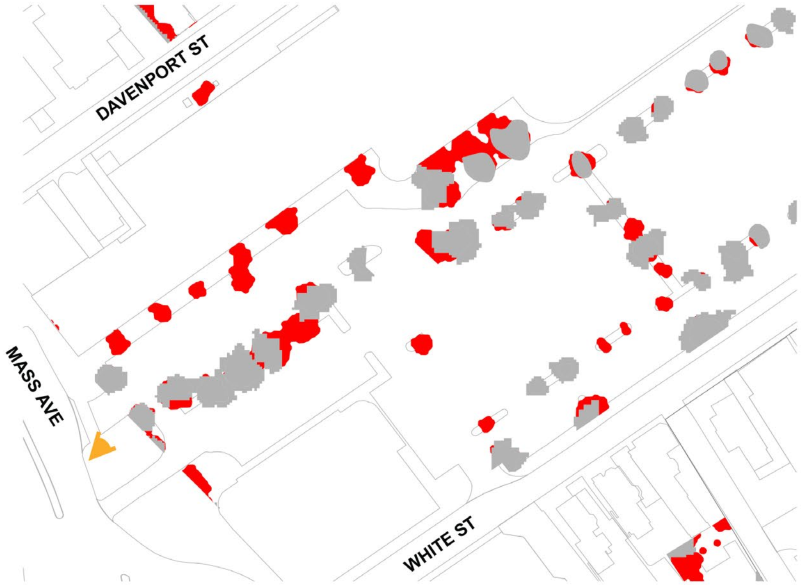
2014-2018 CANOPY LOSS	0.02 - 15%
CANOPY GAIN	15 - 32%
NO CANOPY CHANGE	32 - 53%
STUDY AREA	53 - 79%
PROPERTY LINE OF SOLD PARCELS	79 - 100%

Percent canopy loss within parcels that changed ownership and show losses

PROJECT TYPE: RESIDENTIAL

FIGURE 2.23 — TREE REMOVAL IS ASSOCIATED WITH A BACKYARD RENOVATION ON COPLEY STREET AFTER OWNERSHIP CHANGE

MORTALITY (DECLINING HEALTH)



2014-2018 CANOPY LOSS

NO CANOPY CHANGE

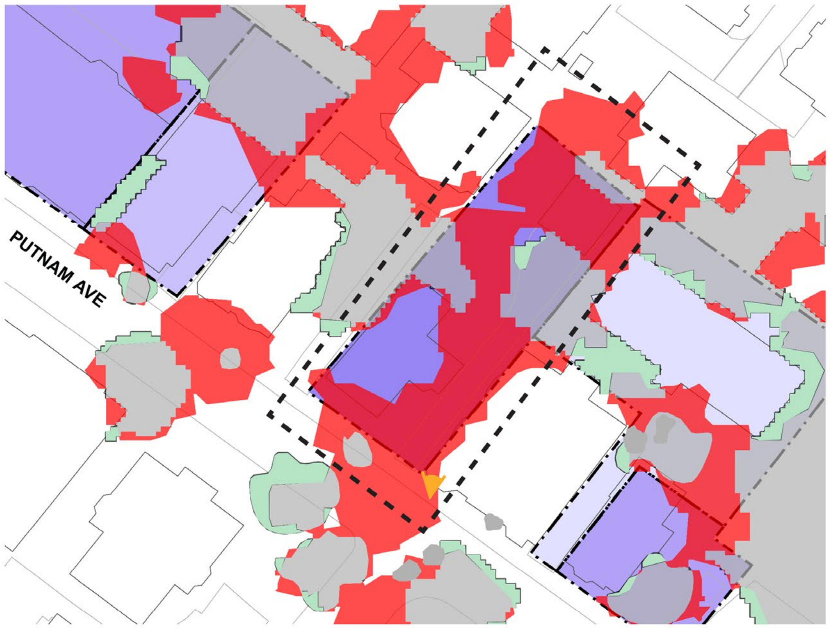
2013

2016

PROJECT TYPE: COMMERCIAL

FIGURE 2.24 — TREES AT PORTER SQUARE PARKING LOT WERE REPLACED BY NEW SMALL TREES

MISCELLANEOUS DECISIONS BY INDIVIDUAL OWNERS



2011

2015

2014-2018 CANOPY LOSS	0.02 - 15%	Percent canopy loss within parcels that changed ownership and show losses
CANOPY GAIN	15 - 32%	
NO CANOPY CHANGE	32 - 53%	
--- STUDY AREA	53 - 79%	
-·- PROPERTY LINE OF SOLD PARCELS	79 - 100%	

PROJECT TYPE: RESIDENTIAL

FIGURE 2.25 — TWO LARGE TREES ON PUTNAM AVENUE WERE REMOVED AFTER OWNERSHIP CHANGE

2.3 Canopy Management Practices

The City of Cambridge is ahead of many of its peers in understanding the link between the urban forest and climate resiliency and in understanding the investments necessary to support trees in the city. Cambridge spends $21.34 per capita on tree-related efforts city-wide (see 2017 Tree City USA budget data). The average municipal expenditure on tree planting in the U.S. is $5.83 per capita[5]. The Urban Forestry division manages all park and street trees, 19,000 in total. The Water Department is responsible for managing all trees on Fresh Pond Reservation. In 2018 the City hired a full-time Superintendent of Urban Forestry and Landscapes, and Urban Forestry currently has a full-time staff of ten in the department. Five of their personnel are Certified Arborists. The City provides some training in-house such as Electric Hazard Awareness program (EHAP) and staff also have the opportunity to attend trainings to maintain continuing education units (CEUs).

Trees in urban environments face a range of challenges that create stress and can shorten a tree's life:

- Restricted soil volume
- Utility conflicts which can also limit a tree's access to soil
- Soil compaction/poor drainage
- Lack of nutrients
- Gas leaks which push oxygen out of the soil and suffocate the roots
- Raised planter boxes around the base of a tree which will slowly kill a tree
- Deicing salts/contaminants
- Construction practices which can damage or kill

TREE PLANTING

Street tree plantings are executed by outside contractors, and this year's contract (2019) is for 600 balled & burlapped trees. The contractor is responsible for cutting the tree pit if one does not exist, disposal of excess existing soils, supplying new planting soils and tree, staking the tree, and watering the tree for two years after installation. The tree planting details accompanying the planting contract follow industry standards. More attention could be paid to ensuring the new tree pits are free-draining. The City has also recently begun using sand based structural soils in select plantings where the soils extend under the concrete sidewalk to provide a larger soil volume for the tree. Property owners have ability to refuse street tree plantings in front of their property. The City maintains a list of recommended ornamental and shade tree species for new plantings.[6] Ornamentals are recommended when overhead wires are present. 26 total species and 40 total genus are covered in the list, which provides for a reasonably diverse planting palette given the constraints of planting in an urban environment.

MAINTENANCE

Home-owner requests for planting and maintenance come into the City's work management system either through SeeClickFix, phone calls, or emails. In-house staff work is primarily reactive, responding to maintenance requests. The proactive work is contracted out: street tree pruning (six year cycle), park and cemetery tree pruning (eight year cycle), Emerald Ash Borer (EAB) treatments for City-owned ash trees now that EAB has been found in Cambridge, and the previously

OPEN PIT PLANTING BED MULCH TREE GRATE FLEXIPAVE

FIGURE 2.26 — ABOVE GRADE STREET TREE CONDITIONS

MASS AVE BETWEEN HUDSON ST AND SHEPARD ST

MASS AVE BETWEEN MARTIN ST AND SHEPARD ST

EXETER PARK TREE WELL

FIGURE 2.27 — BELOW GRADE CONDITIONS THAT LIMIT TREE HEALTH AND INCREASE TREE MORTALITY

mentioned street tree planting contract (300-600 trees per year).

PRUNING & REMOVALS

The regular street tree pruning contract follows the American National Standard for Tree Care Operations. The pruning contractor is required to record each tree pruned in Cartegraph. When trees are damaged from storm events or hazards are posed, the City relies on the public to report these hazards and will respond reactively. In-house pruning is conducted only in response to resident requests, and staff will conduct pruning, removal of dead trees, and stump grinding. Eversource performs pruning around utility lines on a four year cycle. State law requires that an annual plan be provided to the City for upcoming work, and the City Arborist has a good working relationship with Eversource to review the plans and minimize the tree clearance around utility wires to the extent possible.

PESTS AND DISEASES

City manages existing threats proactively. The Water Department treats for the Hemlock Woody Adelgid and the Winter Moth at Fresh Pond. The City Arborist, David Lefcourt, has extensive experience developing EAB monitoring and response plans. Emerald Ash Borer is an invasive boring insect from Asia that feeds on ash trees. Without treatment, an infected ash will die within five years. Urban Forestry has been setting out traps in multiple locations to monitor for EAB, and positively identified the beetle in a trap in fall of 2018. The City immediately contracted with an outside company to begin a program of inoculation for City-owned ash trees.

In the near future the City Arborist expects spotted lanternfly, an invasive insect from Asia, will move into the area. The spotted lanternfly has been found in Pennsylvania and feeds on more than 70 types of plants, including crops such as grapes, apples, hops, walnuts and other hardwood trees. Sudden Oak Death, caused by the pathogen *Phytophthora ramorum*, causes rapid decline in oaks and other species and has been detected in New York.

INVENTORY MANAGEMENT

The Department of Public Works has been using Cartegraph for two years now to track tree inventory and maintenance tasks. The maintenance tasks tracked are: SeeClickFix requests from residents, pruning contract work, in-house tasks (pruning and removals), EAB treatments, and contractor watering (two years of water required for each tree planted). Cartegraph tracks the following tree attributes: species, condition, DBH, and completed or pending maintenance tasks. Removals are not currently recorded, but the City will start tracking removals starting this year (2019). Pruning contractors are required to update the Cartegraph records with species and DBH information. Summer interns do updating also when they water or mulch a tree. In the summer of 2019 two interns will be hired to conduct a tree inventory. The stated goals for tracking individual trees are: to gain insight into improving site specific planting by trying to identify sites where they are having difficulty getting trees to establish and to improve the watering regime by tracking health post-watering. Maintenance costs could be tracked but currently this feature is not in use.

WATERING

At a minimum, newly planted trees are watered for the first five years: contractors are required to water the trees they plant for the first three years and the City takes over watering those trees for two additional years. Cambridge runs a Tree Ambassador program to water contractor-planted city trees. The program consists of a full-time supervisor and six to eight interns each summer from May to August. The interns use hydrants to fill gator bags on trees and will also water existing trees adjacent to the hydrant. The interns record the trees watered in Cartegraph through handheld tablets.

MULCHING

Soils maintenance is important to tree health, and mulching is an important component of overall tree maintenance. Mulch typically is an organic material spread on the soil surface to reduce weed growth, protect roots from heat, cold, and drought, and to provide nutrients to plants as it decomposes. Due to staffing constraints the Urban Forestry division only mulches and weeds new trees and this is done through the Tree Ambassador program. Park trees are mulched by the Parks division's contractor.

SIDEWALK DEICING

The City is working to minimize the amount of deicers used while keeping safety in mind. Mechanical application of deicer can sometimes lead to overspray into tree pits and should be carefully monitored.

Private property owners are responsible for keeping the sidewalks adjacent to their properties free of snow and ice, and the City recommends avoiding the use of rock salt (sodium chloride) and using more environmentally friendly Calcium, Potassium or Magnesium Chloride or Calcium Magnesium Acetate.

SOILS MANAGEMENT

The City is implementing a new pilot project in spring of 2019 to brew liquid biological amendments (compost tea) and apply it to all newly planted trees to improve their survival. Liquid biological amendments promote healthy soils by introducing beneficial microorganisms that are important for a balancing biological activity in the soils and improving nutrient cycling.

The City has also installed Flexipave over tree pits in high pedestrian traffic areas to reduce soil compaction. It is still too early to tell how successful this method will be at promoting tree health, but if successful, the City intends to install this material in other tree pits.

2.4 Existing Statutory/Regulatory Framework

Trees in Cambridge are subject to both state and local protections. At the state level, the Public Shade Tree Law, M.G.L. c.87 ("Chapter 87") provides protection for all trees within the public R.O.W. Chapter 87 is the main statutory authority that provides guidance to Massachusetts cities and towns for the administration, maintenance, protection and care of street trees. Chapter 87 outlines the powers of the municipal Tree Warden, procedures for removing and planting public shade trees, penalties, and violations. The Tree Warden is responsible for the care, control, protection, and maintenance of all public shade trees within the municipal boundary except those along state highways and those in public parks under the jurisdiction of the park commissioners (unless the park commissioner grants the Tree Warden control in writing).

At the local level, a Tree Protection Ordinance (Title 8, Chapter 8.66 of the Cambridge Municipal Code) governs the removal of "Significant Trees" defined as trees larger than 8-inch DHB. Any removal of a significant tree requires a permit. Prior to February 2019, this ordinance was only associated with development through special permits and certain building permits. In February 2019, the Tree Protection Ordinance was amended to extend to all properties. Furthermore, a moratorium was imposed for one year following the amendment for properties outside of the special permit process on any issuance of tree removal permits except for the following circumstances: the tree is dead or dangerous; an emergency exists relative to public health, safety or welfare; removing the tree may result in a healthier tree canopy; or the tree poses a significant risk to an adjacent existing structure.

The Tree Protection Ordinance does not supersede the protections of Chapter 87 but is an additive layer of protection. Those applications for a special permit or building permit must include a Tree Study that has been reviewed and approved by the City Arborist. The Tree Study must include a Tree Survey, a Tree Protection Plan and a Mitigation Plan for trees that cannot be preserved onsite. If any Significant Trees are proposed to be removed, their location and the location, height and size of Replacement Trees proposed to be planted on the lot must be described. If Replacement Trees are not proposed, an equivalent value, as identified in the Mitigation Plan, will be paid to the City and deposited in the City's Tree Replacement Fund. Money generated from the Tree Replacement Fund must be used for the purpose of buying, planting, and maintaining trees in the city. Annual appropriations are made through the budget approval process.

The City also has various requirements for the protection of existing trees and the promotion of new trees throughout the City's zoning ordinance. The zoning ordinance includes requirements for trees associated with off-street and on grade parking facilities as well as various building and land use types including certain business and residential zones. There are also specific requirements for two of the City's zoning overlay districts: the Parkway Overlay and Prospect Street Overlay Districts. The zoning ordinance focuses primarily on minimum requirements for the number and size of trees for certain land uses and the placement of trees for street frontage and setbacks.

2.5 The Shared Value of the Forest

The urban forest is a public resource that has significant value. Though over 50% trees are on private property, the economic, ecological and social benefits they provide are enjoyed community-wide. They provide shade to cool our environment, give scale and character to our streets, provides habitat for diverse species, improve our air quality, reduce stormwater impacts, improve our health and well-being, and provide many other benefits as well (Table 2.3). Some of these benefits can be monetarily quantified but there is not a standardized method for evaluating the many other ecological, economic and social benefits. New York City has estimated that their street trees currently return $5.60 to the community for every $1 spent on management.[7]

The US Forest Service (USFS) has conducted extensive research to determine a monetary value for various ecosystem services provided by trees. Based on the current (2019) version of the USFS program i-Tree Eco and an assessment of Cambridge's 2018 forest, Cambridge's current annual benefit from ecosystem services of the urban forest is estimated at $6.8 million. The total value of the urban forest in 2018, including carbon storage and replacement value, is estimated to be $581.5 million or $550k per acre. This estimate does not include numerous social, mental well-being and ecosystem benefits. Other cities have estimated the average value of a canopy tree over its lifetime to be $57,0003. At this value, the Cambridge urban forest would be worth $3.1 billion.

BENEFITS	BENEFIT ESTIMATE	VALUE ESTIMATE
Pollutants ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, PM 2.5 microns*	Hourly tree-canopy resistances for O3, SO2 and NO2 based on canopy deposition models Removal of CO and PM2.5 based on average measured values from literature, adjusted Depending on leaf phenology and leaf area	Local change in pollution concentration with health effects (US EPA Benefits Mapping and Analysis Program)
Avoided runoff*	Based on rainfall interception by vegetation Only precipitation by leaves is accounted for in this analysis	$0.07 per cubic foot
Heat Island/ Energy**	avoided mortality, morbidity, and electricity consumption	$21–49 annually per capita.
Carbon Sequestration*	Estimated by average diameter growth for the appropriate genera, diameter class and tree condition	varies by species from $0.04 to $6.80
Carbon Storage*	Benefit estimate: estimates above-ground and below-ground parts of woody vegetation. Biomass for each tree calculated using literature/measured tree data	$171 per ton
Structural value***	value of the physical resource itself/replacement cost of a similar tree	International Society of Arboriculture's Trunk Formula Method and current City tree replacement costs ($1700 for a 2 dbh tree)

TABLE 2.3 — TREE BENEFIT AND VALUE ESTIMATES. * i-Tree Canopy. i-Tree Software Suite v6.0. (n.d.). Web. Accessed 22, Jan 2019. http://www.itreetools.org **per McDonald, R.I. et al. The Value of US Urban Tree Cover for Reducing Heat-Related Health Impacts and Electricity Consumption. (Ecosystems, 2019). *** per International Society of Arboriculture's Trunk Formula Method and current City tree replacement costs

Scientifically demonstrated tree benefits include (quantifiable economic benefit through iTree are *):

Economic benefits

- Increased property value*
- Reduced expenditure on air pollution removal
- Reduced expenditure on stormwater infrastructure*
- Saved investment in new power supplies
- Reduced heating and cooling costs*
- Reduced time on housing market

Ecosystem services

- Carbon storage and sequestration*
- Air quality improvement*
- Stormwater attenuation (reducing rate and volume of stormwater runoff, improving water quality, recharging groundwater, minimizing flooding damage)
- Energy conservation

- Habitat preservation
- Noise reduction
- Microclimate amelioration (reducing heat island, glare and reflection)

Quantifying tree benefits is a three step process. First, one defines the area of analysis and measures the number of trees or the amount of canopy. Bottom up ground based assessments are typically individual tree, GIS based where one records tree species, condition, and other attributes. Top down aerial based approaches include remote sensing and aerial photography. Then, the benefit itself must be quantified, whether it is reduction of air pollutants, the amount of carbon sequestered, or a decrease in ambient temperature. Lastly, there is a conversion of that benefit to economic value. For reduction of air pollutants, it may be the decrease in asthma cases or hospital visits, and for carbon sequestered,

There exists tree valuation programs that run aerial imagery or GIS data through a model to estimate monetary benefits. A peer reviewed and highly regarded program is the USDA Forest Service's iTree programs. iTree Eco takes user provided GIS data, and uses local preprocessed hourly weather and air pollution concentration data in the calculations. While there is substantial research forming the basis for many of the calculations, assumptions underlie much of the calculations, and much of the research was conducted in other geographic regions of the country.

iTree Eco, was selected to analyze Cambridge's urban forest and data from the 5% inventory was entered into the program. The inputs into the program included tree species, condition, DBH, public/private tree, street tree/non-street tree, and land use type. The results from the 5% survey was then extrapolated to obtain an estimate for the entire City.

iTree Eco classifies benefits into two buckets: annual values, which describes the benefits that are constantly accruing over time (air pollution removal, avoided runoff, carbon sequestration, and energy savings) and one time values (carbon storage and structural value), which are benefits that do not accrue over time. The majority of that benefit is derived from structural value, which is the cost to replace all of the trees if they were to die, and was calculated using the International Society of Arboriculture's Trunk Formula Method and current City tree replacement costs. iTree Eco does not yet include benefits of mitigation of the heat island effect. A recent study of 97 cities found that avoided mortality, morbidity and electricity consumption from tree cover is estimated at $21 to $49 per capita annually[8]. This means the City of Cambridge obtains a value of $2.4 million to $5.6 million annually just from heat related benefits from trees. This benefit was added to the iTree Eco output.

Thus, the overall value of Cambridge's urban forest in 2018 is **$581.5** million or $544k per acre. $6.8 million or $6440 per acre reflects the ecosystem services benefit just in 2018 from the urban forest.

Refer to Appendix C for a summary of survey methodology, Appendix D for results and Appendix E for iTree ECO output, and assumptions for extrapolation to entire canopy.

What do these numbers mean individually? The carbon storage of the urban forest is equivalent to:

- amount of carbon emitted in Cambridge in 10 days (estimated 1.4 mil tons/yr)
- annual CO2 emissions from 20,400 cars
- emissions from 8,360 single-family homes

The nitrogen dioxide removal equivalent is equivalent to:

- annual NO2 removal from 500 cars
- 220 single family houses
- The sulfur dioxide removal equivalent to:
- annual SO2 emissions from 2,060 cars

While we recognize that this valuation does not by any means capture the full range of benefits that trees provide, it is one way to evaluate the urban forest. Ecosystem service benefits not monetarily captured include providing habitat and food for wildlife, stormwater attenuation (reducing rate and volume of stormwater runoff, improving water quality, recharging groundwater, minimizing flooding damage), and noise mitigation. Numerous studies have looked at quantifying social and mental wellbeing benefits from trees (Table 2.4). One study found that the more parks there are within 500m of a home, the lower the children's BMI at age 18[9]. Being surrounded by green space in childhood may improve mental health of adults. Researchers from Aarhus University in Denmark found that children growing up around vegetation had a 55 percent lower risk of developing mental health disorders in adulthood[10]. Trees are proven to reduce stress and to increase physical activity. A method for conversion to monetary benefit does not yet exist for social and physical/mental benefits beyond heat related health benefits.

Urban tree benefits reported in the 115 research papers on urban trees examined in this study.

Benefits	Discussed	Demonstrated
Social benefits	7	5
Making urban environment more pleasant to live, work and spend leisure time	3	2
Providing significant outdoor leisure/recreation opportunities	3	2
Providing nature in the city	1	1
Enhancing quality of urban life	5	3
Promoting environmental responsibility and ethics	1	–
Building stronger sense of community	1	–
Enhancing community's sense of social identity and self esteem	1	–
Providing settings for significant emotional and spiritual experiences	1	–
Providing opportunities for inner city children to experience nature	1	–
Economic benefits	28	27
Saving substantially on fuel expenditure	1	–
Increasing land value	3	3
Increasing property value	13	12
Increasing rental price	1	1
Increasing neighbouring property value	2	1
Reducing 'time on market' for selling property	1	1
Increasing property taxes	1	–
Increasing tourism revenue	1	–
Increasing business activity	1	–
Contributing to the economic vitality of the city	1	–
Providing annual returns on municipal investments	2	1
Alleviating the hardships of inner city living for low – income groups	1	–
Reducing expenditure on air pollution removal	7	6
Reducing expenditure on storm water infrastructure	4	3
Saving annual heating and cooling costs	2	2
Savings on electricity costs	1	1
Avoiding investment in new power supplies	3	2
Providing potential for future carbon offsetting trade	2	2

Ecosystem services	Discussed	Demonstrated
Carbon related ecosystem services	30	27
Storing/sequestering carbon	30	27
Air quality related ecosystem services	38	34
Producing oxygen	2	2
Filtering air	11	9
Removing ozone	18	16
Removing carbon monoxide	12	10
Removing sulphur dioxide	17	15
Removing nitrogen dioxide	15	14
Removing airborne particle matters/suspended particles	22	20
Removing dust	1	1
Reducing smog	3	3
Reducing carbon dioxide emissions	9	8
Storm water related ecosystem services	10	9
Reducing rate of storm water runoff	10	9
Reducing volume of storm water runoff	8	7
Reducing flooding damage	4	3
Reducing water quality problems	3	2
Recharging ground water	1	1
Energy related ecosystem services	20	18
Reducing annual energy use	14	11
Reducing summer time energy use	5	5
Reducing seasonal cooling energy	4	4
Reducing carbon dioxide emission from power plants	3	2
Habitat related ecosystem services	7	5
Providing habitat for wildlife	7	5
Enhancing biodiversity	1	–
Providing stability to urban ecosystems	1	–
Noise related ecosystem services	8	5
Reducing noise	8	5
Reducing apparent loudness	2	1
Micro climate related ecosystem services	25	25
Providing shade	16	16
Reducing solar radiation	4	4
Modifying microclimate	9	
Reducing relative humidity	1	1
Reducing air temperature	15	15
Reducing heat island effect	10	10
Reduction of glare/reflection	3	3
Controlling wind	6	6

Benefits	Discussed	Demonstrated
Health benefits	5	2
Fewer complications and faster recovery at hospital having windows with tree view	2	–
Reducing stress	3	–
Improving physical health	2	–
Creating relaxed psychological states	3	1
Averting premature death	1	1
Averting respiratory hospital admissions	1	1
Visual and aesthetic benefits	6	5
Providing a sense of place & identity	2	1
Creating seasonal interest by highlighting seasonal changes	1	1
Improving scenic quality	6	5
Providing privacy	2	2

Roy et al A systematic quantatitive review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. Urban Forestry & Urban Greening 11 (202 p. 351-0363).

TABLE 2.4 — A COMPREHENSIVE LIST OF URBAN TREE BENEFITS INCLUDE SOCIAL, ECONOMIC, CARBON, AIR QUALITY, STORMWATER, ENERGY, HABITAT, MICROCLIMATE, HEALTH, AND VISUAL BENEFITS

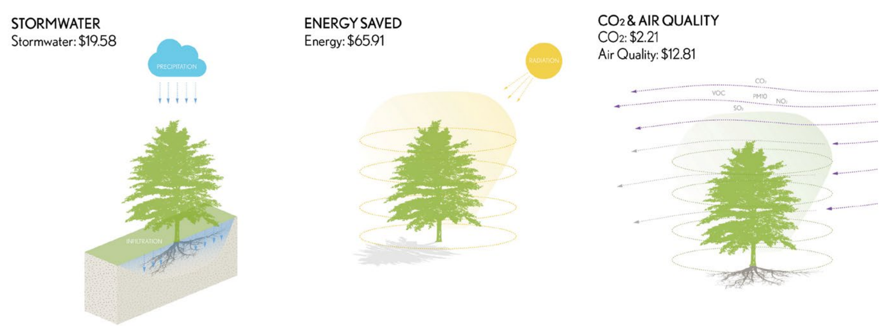


FIGURE 2.28 — ECOSYSTEM SERVICES FOR AN AVERAGE PIN OAK IN CAMBRIDGE.
(Source: iTree Streets)

ANNUAL VALUE	x20	x34.65**		
POLLUTION REMOVAL*	$704 K	$1.22 M	$962 K	36,500 LB/YR
CARBON SEQUESTRATION*	$133 K	$230 K	$181.2 K	1050 TONS/YR
AVOIDED RUNOFF*	$60K	$104 K	$83 K	1.22 MILLION CU FT/YR
ENERGY*	$413 K	$413 K	$413 K	
HEAT ISLAND***	N/A	N/A	$5.6M	$21 TO $49 PER CAPITA
TOTAL BENEFIT	$1.3 M	$1.97 M	$6.8 M	
BENEFIT PER ACRE			$6440	

ONE TIME VALUE	x20	x34.65**		
CARBON STORAGE*	$4.9 M	$8.5M	$6.7M	
REPLACEMENT VALUE***	N/A	N/A	$568 M	
TOTAL BENEFIT	$98.3 M	$170.3 M	$574.7 M	
BENEFIT PER ACRE			$544 K	
OVERALL VALUE			$581.5 M	

TABLE 2.5 — TREE VALUATION CALCULATION FOR CAMBRIDGE. *per i-Tree ECO for air quality, stormwater, energy and sequestration **Based on canopy areas: Bartlett's 5% survey stated that canopy covered 30.47, which when extrapolated to 100% underestimates current canopy cover. This is likely because private trees were not all visible or surveyable. If we were to scale the 5% survey to the actual canopy area, we would multiply the iTree results by 34.66 to come to the 1056 acres that makes up the 2018 canopy. ***per McDonald, R.I. et al. The Value of US Urban Tree Cover for Reducing Heat-Related Health Impacts and Electricity Consumption. (Ecosystems, 2019). *** per International Society of Arboriculture's Trunk Formula Method and current City tree replacement costs

Scientifically demonstrated (but not quantified) social and physical/mental benefits include:

Social benefits

- Increased quality of life (stress relief-survey study)
- Health benefit – averting respiratory hospital admissions and premature death
- Improved scenic quality
- Providing a sense of place and identity
- Creating seasonal interest
- Providing privacy

Physical health and mental wellbeing:

- Lower risk of diseases and mortality rate
- Lower stress levels
- Better cognitive function in students
- Improved attention among children
- Enhanced performance in the workplace
- Lower risk of mental health disorders

2.6 Public Opinion on the State of the Forest

A public opinion survey was conducted to collect information about Cambridge residents' opinions on the urban forest to help inform the development of the Urban Forest Master Plan. The survey was completed by 1,643 respondents between the dates of September 5, 2018 to December 6, 2018. The survey results are based on a self-selected sample, not a random sample. Therefore, the results may not be representative of all Cambridge residents.

HEALTH AND QUANTITY OF EXISTING TREES

Respondents were split on the perception of the health of trees in their neighborhood. 42 percent of respondents said the health of trees was "very good" or "excellent" and 53 percent said the health of trees was "fair" or "poor." Respondents had a similar perception of the amount of trees in their neighborhood. 57 percent of respondents said the amount of trees is "too few" and 39 percent said the amount of trees is "enough." For both health and quantity of trees, the results were generally consistent across neighborhoods with a few notable differences.

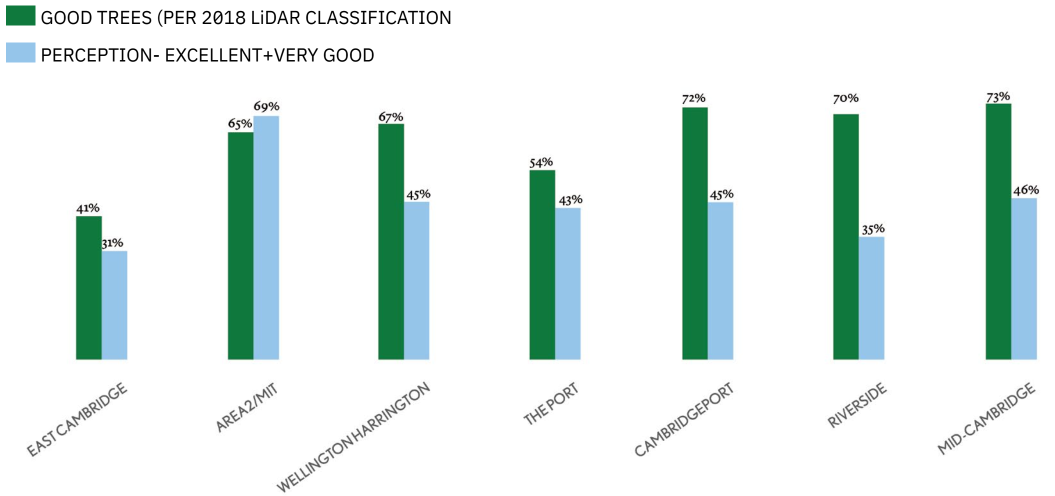


FIGURE 2.29 — PERCENT OF GOOD TREES BY NEIGHBORHOOD AND PERCENT OF SURVEY RESPONDENTS THAT THINK TREES IN THEIR NEIGHBORHOOD ARE IN EXCELLENT AND VERY GOOD CONDITION

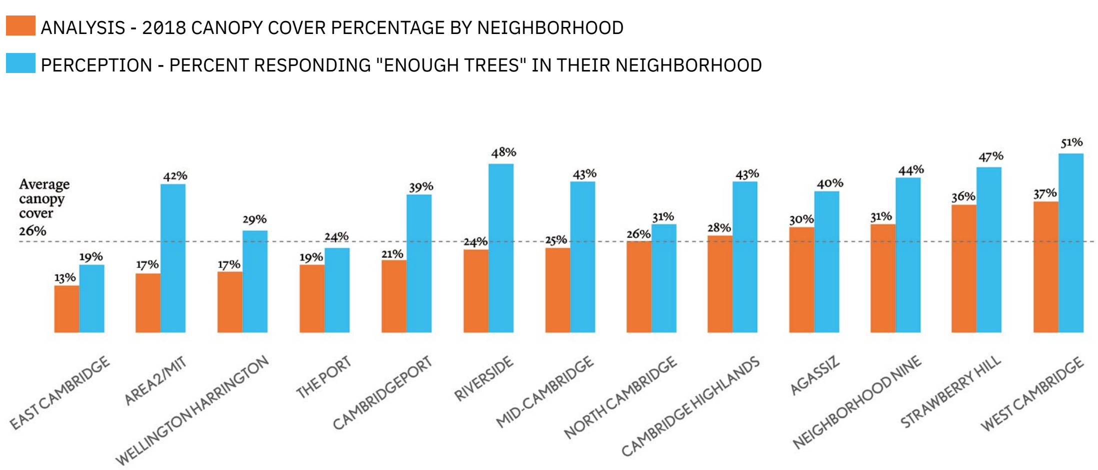


FIGURE 2.30 — 2018 CANOPY COVER PERCENTAGE BY NEIGHBORHOOD AND PERCENT RESPONDING THERE ARE ENOUGH TREES IN THEIR NEIGHBORHOODS

BENEFITS OF TREES

Respondents were asked about seven benefits of trees including shade/cooling, flood management, property value, quality of life, energy cost reduction, pollution reduction, and beauty. Results indicate that the majority of respondents agree that trees provide each of these benefits; however, there was more uncertainty about the benefits of flooding and energy cost reduction than the other categories.

AWARENESS OF EXISTING PROGRAMS AND POLICIES

Most respondents were not aware of the city's existing tree planting programs. In cases where respondents were aware of a city program, very few indicated they had ever used the program. However, 59 percent of respondents indicated they were "somewhat aware" or "very aware" that the city has opportunities for residents to volunteer to take care of public trees. Of those who indicated they were aware, only 27 percent said they had ever volunteered their time to take care of public trees.

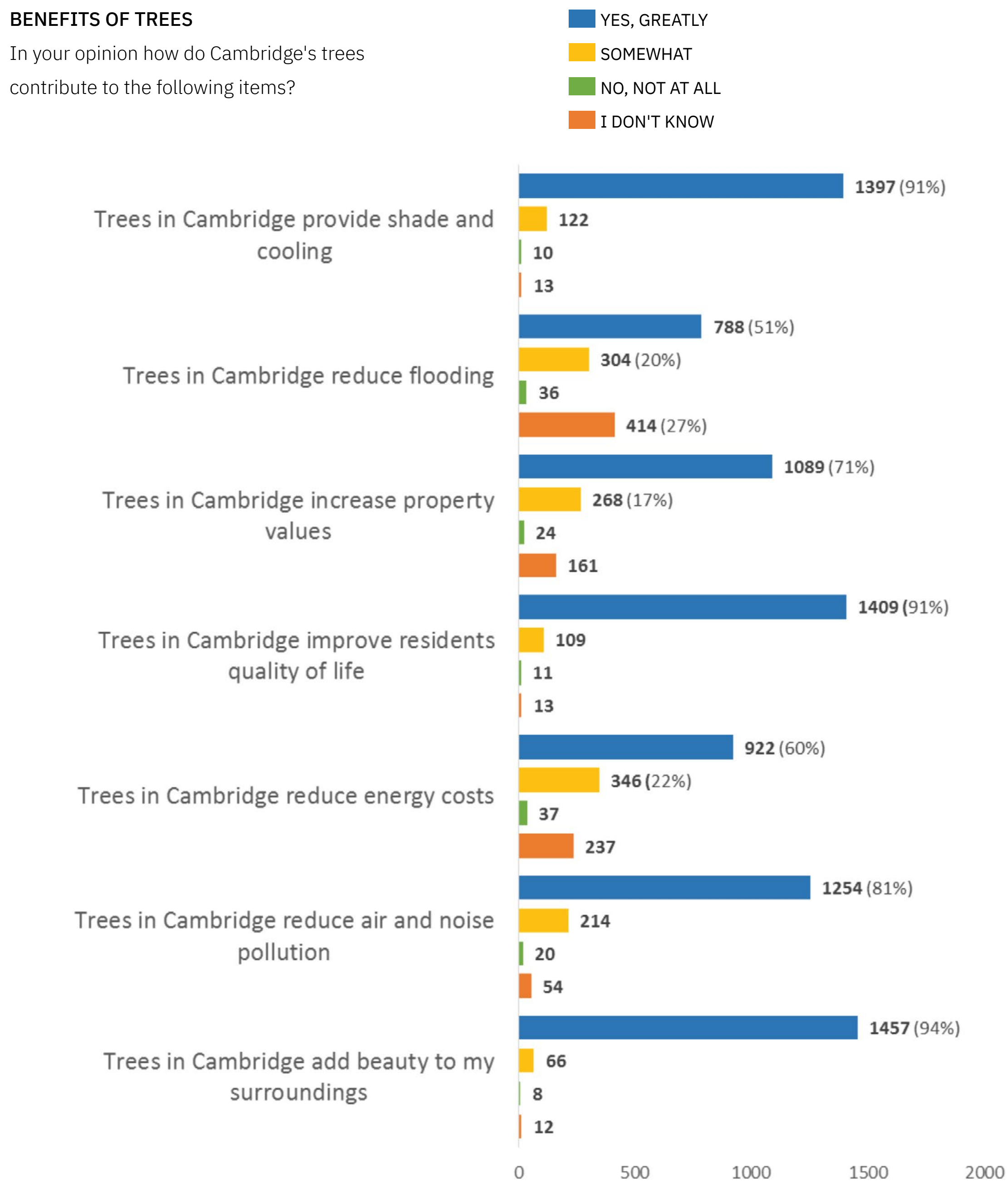


FIGURE 2.31 — SURVEY RESPONSES RELATED TO BENEFITS OF TREES

ATTITUDES TOWARD TREE PRESERVATION AND GROWTH

The majority of respondents said that the City of Cambridge should have laws about removing and replacing trees. About 66 percent of all respondents indicated that these laws should apply to all types of property including public property, new development and private residences, businesses, and institutions. The overwhelming majority of respondents agreed that the city should have laws that protect trees on public property; however, the majority also indicated that the city should incentivize, not require, tree planting and maintenance on private property. Despite this preference for incentives over requirements on private property, 50 percent of respondents disagreed that private property owners should make decisions about trees on their property without input from the City.

There was also a strong preference for the city to prioritize both planting new trees and preserving existing trees to protect and grow the urban forest. Public sidewalks and streets were identified by the majority of respondents as the most important location for tree planting followed by new development sites and parks and green spaces.

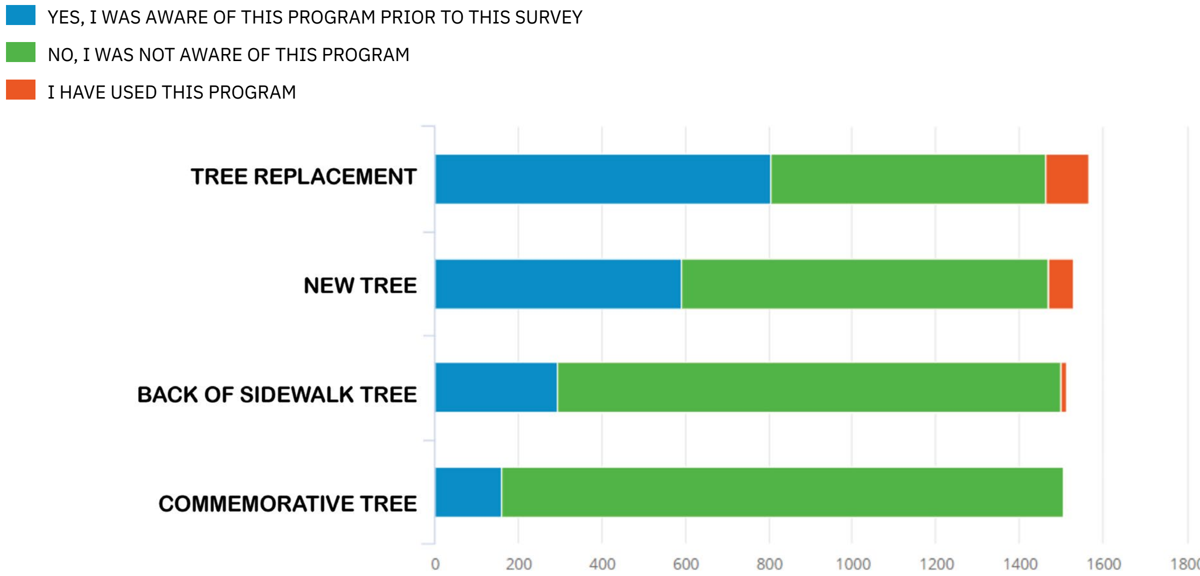


FIGURE 2.32 — SURVEY RESPONSES ABOUT THE AWARENESS OF EXISTING CITY PROGRAMS AND POLICIES

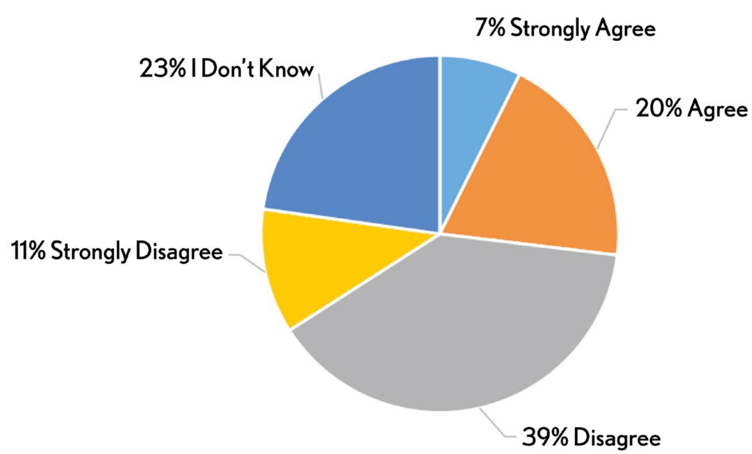


FIGURE 2.33 — SURVEY RESPONSES RELATED TO BENEFITS OF TREES
50% DISAGREE (11% STRONGLY DISAGREE, 39% DISAGREE) WITH THIS STATEMENT:
"Private property owners should make decisions about trees on their property without input from the city"

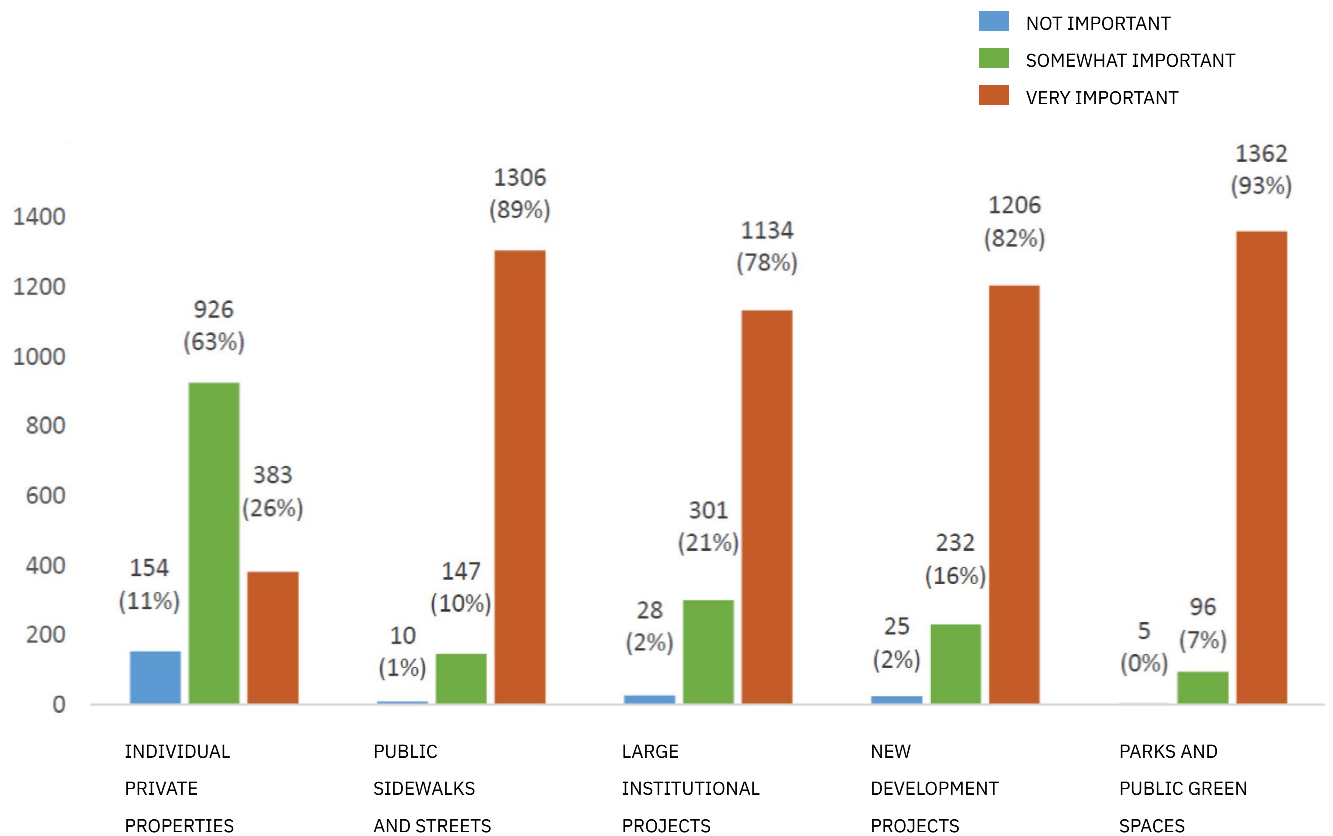


FIGURE 2.34 — SURVEY RESPONSES ABOUT TREE LOCATIONS
A MAJORITY (55%) STATED THAT PUBLIC SIDEWALKS AND STREETS WERE THE SINGLE MOST IMPORTANT LOCATION TO PLANT NEW TREES WHEN ASKED A FOLLOW UP QUESTION ABOUT THE SINGLE MOST IMPORTANT LOCATION TO PLANT NEW TREES

DEMOGRAPHICS

Survey respondents were given the option to provide demographic information.

Of those that opted to provide this information, the majority were 45 years or older (63 percent), female (69 percent), non-Hispanic (93 percent), and white (84 percent). The income range of the majority of respondents was $75,000 or more (57 percent).

Refer to Appendix G for survey results by neighborhood.

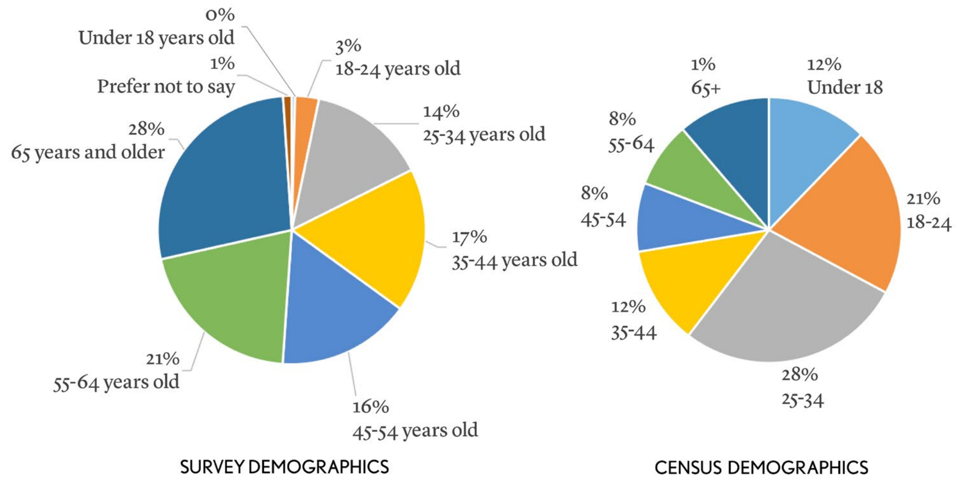


FIGURE 2.35 — SURVEY DEMOGRAPHICS BY AGE

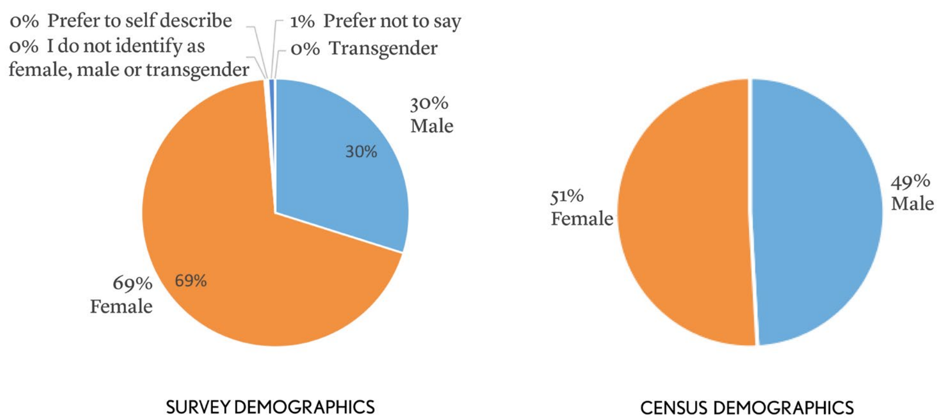


FIGURE 2.36 — SURVEY DEMOGRAPHICS BY GENDER

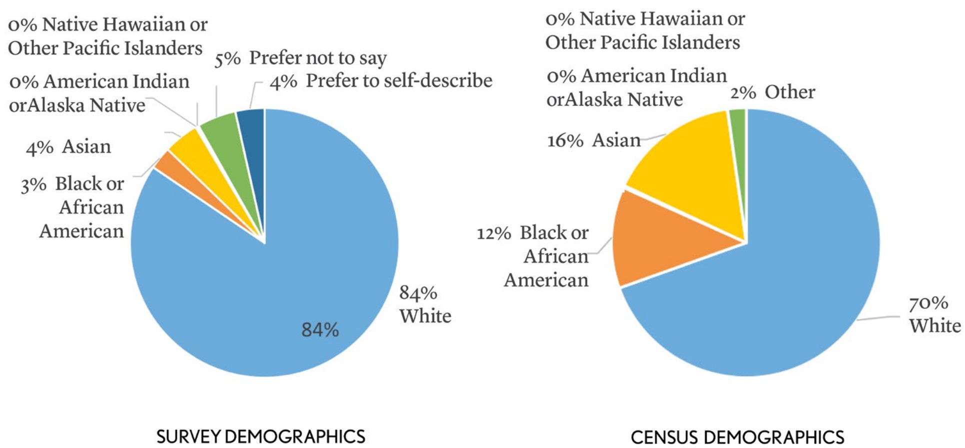


FIGURE 2.37 — SURVEY DEMOGRAPHICS BY ETHNICITY

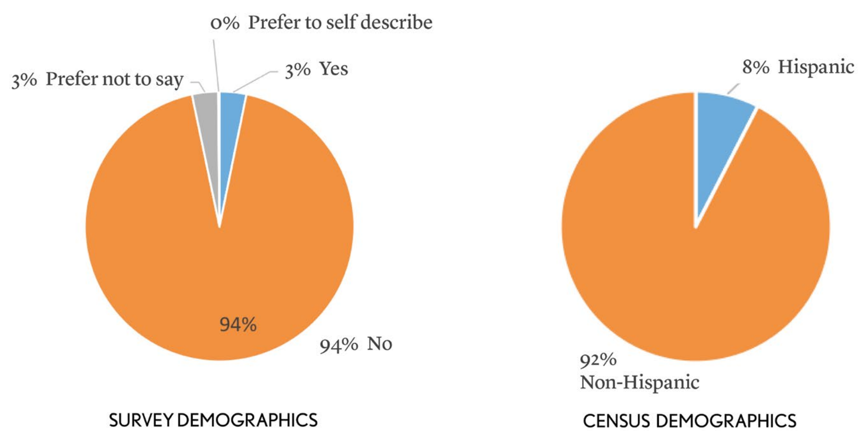
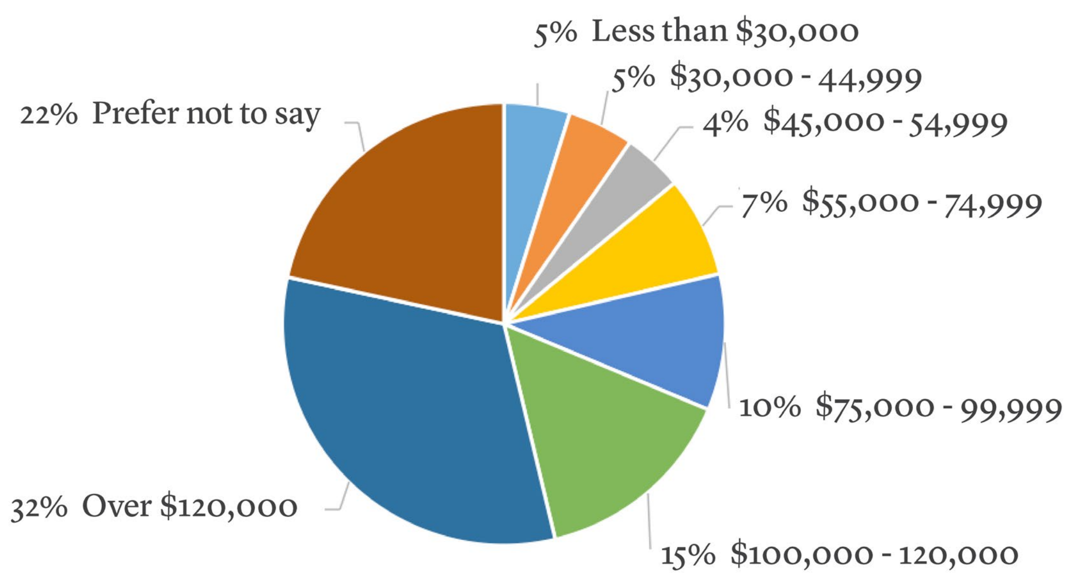


FIGURE 2.38 — SURVEY DEMOGRAPHICS, HISPANIC VS NON-HISPANIC



47% of respondents earn more than $100,000.

Median household income is $83,122.

FIGURE 2.39 — SURVEY DEMOGRAPHICS BY INCOME

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3 (Minority, Low Income, and English Isolation populations as defined in Climate Change Vulnerability Assessment: Vulnerable Population Ranking Memorandum. Report (Boston, MA: Kleinfelder), Nov. 2015.)

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5 McDonald, Rob, Lida Aljabar, Craig Aubuchon, Howard G. Birnbaum, Chris Chandler, Bill Toomey, Jad Daley, et al. Funding Trees for Health An Analysis of Finance and Policy Actions to Enable Tree Planting for Public Health, (Arlington, VA: The Nature Conversancy, 2017)

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7 Peper et al. New York City, New York Municipal Forest Resource Analysis. Center for Urban Forest Research, USDA **Forest Service, Pacific Southwest Research Station, 2007.**

8 **Mcdonald, Robert & Kroeger, Timm & Zhang, Ping & Hamel, Perrine. "The Value of US Urban Tree Cover for Reducing Heat-Related Health Impacts and Electricity Consumption." Ecosystems. (2019).**

9 **Nowak, David J., Eric J. Greenfield, "Declining urban and community tree cov**er in the United States," Urban Forestry & Urban Greening 32 (2018): 32-55.

10 Wolch, J., et al., Childhood obesity and proximity to urban parks and recreational resources: A longitudinal cohort study. (Health & Place. 17: p. 207-214), 2011.

1 Engemann, et al., Residential green space in childhood is

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3. Risks to the Urban Forest

If the current trajectory of Cambridge's urban forest continues, canopy cover will decline from 26% in 2018 to 21% by 2030 or 15% by 2050. Climate change will likely increase tree mortality, and Cambridge's forest cover could drop as low as 18% by 2030 or 10% by 2050.

Currently, 29% percent of the Cambridge forest is highly susceptible to pests, drought and/or flood factors that will be exacerbated by climate change. Drought was found to have a potentially moderate impact on existing tree canopy through 2030, flooding from large storms was found to have a minimal impact on canopy. Susceptible trees are currently spread evenly across neighborhoods. As trees die, the species composition of the future forest will be composed of more resilient, adaptive species. The climate resiliency of tree species should inform city-wide tree planting recommendations.

A simulation of the future Cambridge canopy suggests the following:

↳ Plant flood tolerant species in flood-prone areas and drought tolerant species especially near impervious surfaces.

↳ Plant more climate resilient species, particularly drought tolerant species where surfaces are impervious.

Manage adaptively — what works today may not work twenty years hence. The recommended species list (discussed in *Section 4.0* Strategies) should be revised to incorporate new information about pests and diseases and climate predictions as it becomes available.

3.1 Challenges

Increasing tree canopy is one of many strategies to make our community more resilient and adaptable to climate change impacts. But the current trend of canopy loss means that every year the City derives fewer benefits from the urban forest. With climate change, the urban forest will face stresses beyond the already challenging conditions for growing trees in an urban setting. Cambridge will become increasingly warm, tripling the number of days each year above 90 degrees by 2030[1] and moving from hardiness zone 6b to 7a by 2070[2].

Additionally, research suggests that Cambridge may continue to see extreme cold weather snaps due to Arctic warming[3]. As a result, in the near-term the number of tree species able to thrive in these temperature extremes may be reduced, with warming summer temperatures eliminating northern species but continued cold outbreaks preventing southern species from surviving through winter. Over time, the warmer temperatures are also predicted to bring new pests and diseases to the area and possibly increase the virulence of those agents. Some of these effects may be small, both others may be catastrophic, like the loss of the Elms in the last century.

By 2050, flooding from extreme rainstorm events is likely to become more frequent and intense. Large rain events can result in standing water in low-lying areas and where stormwater infrastructure backs up. Tree species have different tolerances to flooding conditions, and for some, even a few hours of standing water can greatly threaten them.

Trees planted in and near pavement already face heat stress from the urban heat island effect — the conversion of light hitting the pavement to heat energy and the heat given off by that pavement during at night when normally the air would cool. Increased occurrence of drought associated with climate change intensifies heat stress, making it even harder for urban trees to survive.

Individually and cumulatively, these challenges will change the character and composition of the Cambridge forest in the coming decades. (*Figure 3.1*[4])

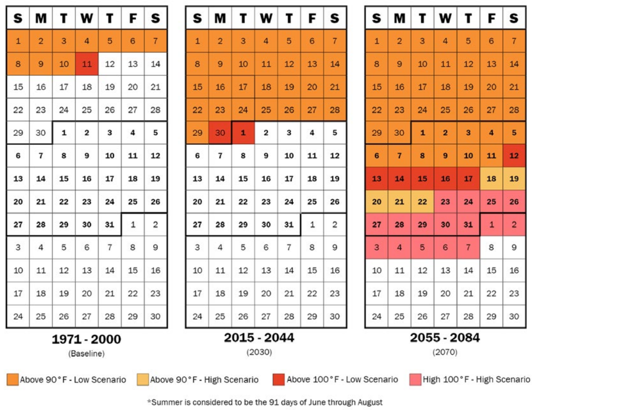


FIGURE 3.1 — THE NUMBER OF DAYS EXCEEDING 90 DEGREE DAYS ARE EXPECTED TO INCREASE SIGNIFICANTLY IN THE COMING DECADES.

3.2 Projected Canopy Cover in 2030, 2050 and 2070

To understand the relative and specific impacts of these risks, the study developed a computer model to simulate the composition of the Cambridge urban forest in 2030, 2050 & 2070 given both current trends and the predicted threats of climate change.

This canopy change model took the 2009-2018 average yearly canopy loss rate and projected it into the future. It adjusted the loss rate for each tree species based on its susceptibility to climate factors and predicted future pests and diseases. The model also tested the impacts of doubling the annual rate of loss — a conservative "worst case" scenario, assuming actual climate change effects from 2018 to 2070 would be greater than in the 2009-2018 period. Of several catastrophic climate events that are possible in New England, specific flood and drought events were added to the base models, resulting in 16 total future scenarios modeled out to 2070 (Appendix K). The model results for each scenario are shown in the tables below and in associated maps representing possible future conditions of the Cambridge tree canopy.

The results of the model also provide specific feedback including an evaluation of how vulnerable the current forest and specific species are to climate change, and which species might be planted in the future to mitigate the effects of climate change. (Refer to Appendix K for description of methodology of the Canopy Change model and for detailed results.)

If the current trajectory of Cambridge's canopy loss continues, canopy cover will decline from 26% in 2018 to 21% in 2030 (*Figure 3.2*). This conservative loss scenario also accounts for species that will fall out of their hardiness zone and the loss of ash trees on private property due to the Emerald Ash Borer *(EAB)*.

With changing climate patterns, past performance alone can no longer serve as a predictor of what may happen in the future. While any model of future canopy change is speculative, given the known factors, an accelerated loss rate is entirely feasible. As a sensitivity test, the study considers what would happen to canopy cover if the mortality rate for each species was doubled based on how they are affected by pest and disease. In this scenario, canopy cover would decline to 17.6% in 2030 (*Figure 3.4*).

Note: Figures depict a representative scenario of tree canopy in 2030.

Based on these same assumptions, by 2050, the projected canopy cover could range from 10% to 15% and in 2070 from 5% to 11%. These numbers assume the city continues to plant trees in the public realm at the current rate of 400 trees per year.

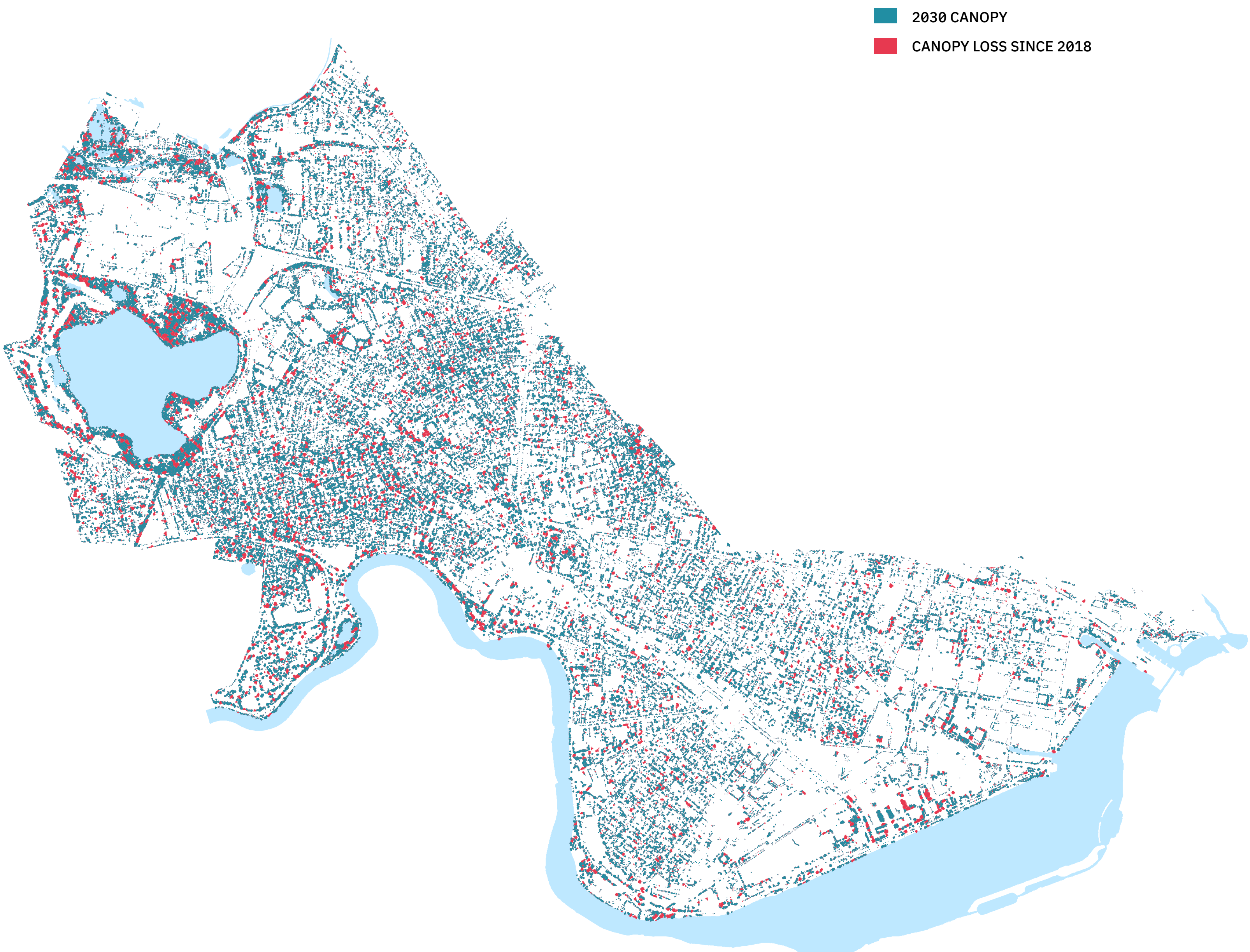


FIGURE 3.2 — CANOPY LOSS BETWEEN 2018 AND 2030 IN A CONSERVATIVE LOSS SCENARIO. Considering temperature shifts and EAB threat, the loss rate of 1.55% increases to 1.8%, resulting in 21.0% total canopy cover.

Given the likely impacts of climate change, the composition of Cambridge's urban forest will evolve over time, culling many species on the edges of their climate zones or susceptible to pests and diseases and trending towards more resilient, adaptive species. By 2030, honey locust could replace the Norway maple as the most abundant species represented in the canopy. Per the simulations, Norway maple, red maple, northern red oak, sugar maple, and callery pear all decline in abundance by 2030. Species that performed the best with the lowest mortality rate include the dawn redwood, northern catalpa, black locust, Kentucky coffeetree, Amur maackia, and zelkova (*Table 3.1*).

Most Common Species Cambridge 2018	Most Common Species Cambridge 2030	Best Performers Cambridge 2030
Norway maple	Common thornless honeylocust	Dawn redwood
Pin oak	Norway maple	Northern catalpa
Honey locust	Pin oak	Black locust
Red maple	Red maple	Kentucky coffeetree
Red oak	Northern red oak	Amur maackia
Littleleaf linden	London planetree	Serviceberry
Callery pear	Littleleaf linden	Amur corktree
London planetree	Sycamore	Magnolia
Ash	Sugar maple	Japanese snowbell
Crabapple	Callery pear	Ginkgo
		Japanese lilac tree
		Zelkova

TABLE 3.1 — BASELINE SCENARIO IMPACT ON SPECIES

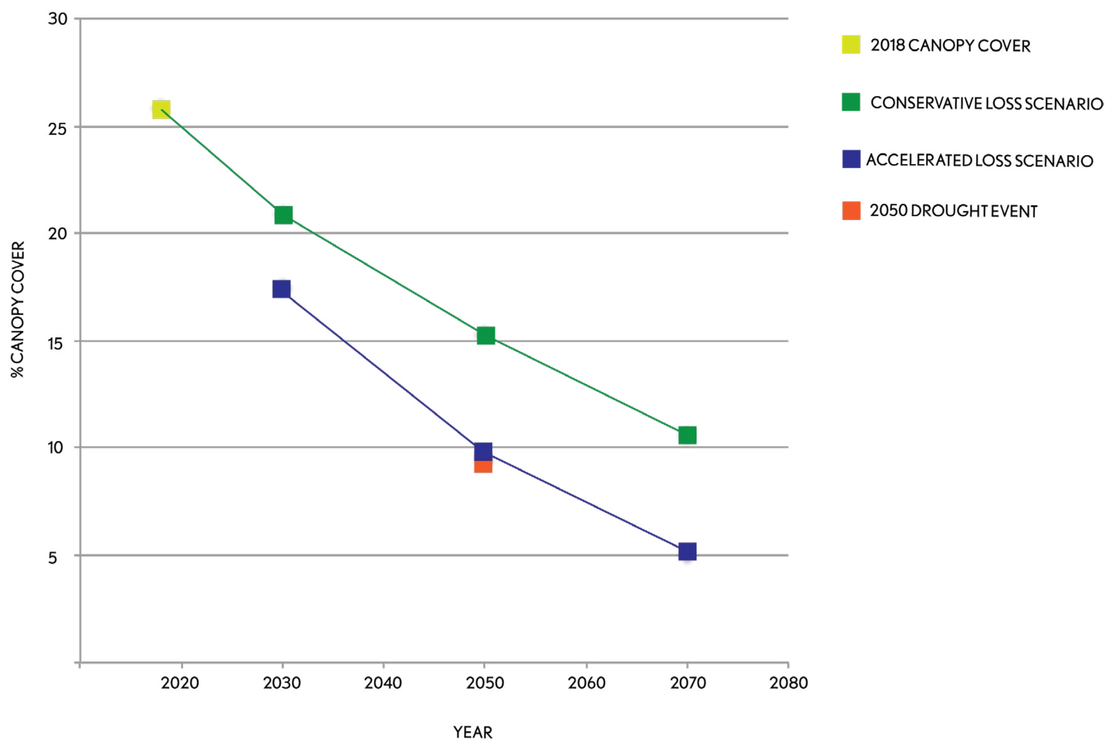


FIGURE 3.3 — CLIMATE MODELING PROJECTIONS FOR CONSERVATIVE LOSS AND ACCELERATED LOSS SCENARIOS FOR 2030, 2050 AND 2070 AND THE 2050 DROUGHT EVENT. (the 2030 flood event does not have enough change to depict on this figure).

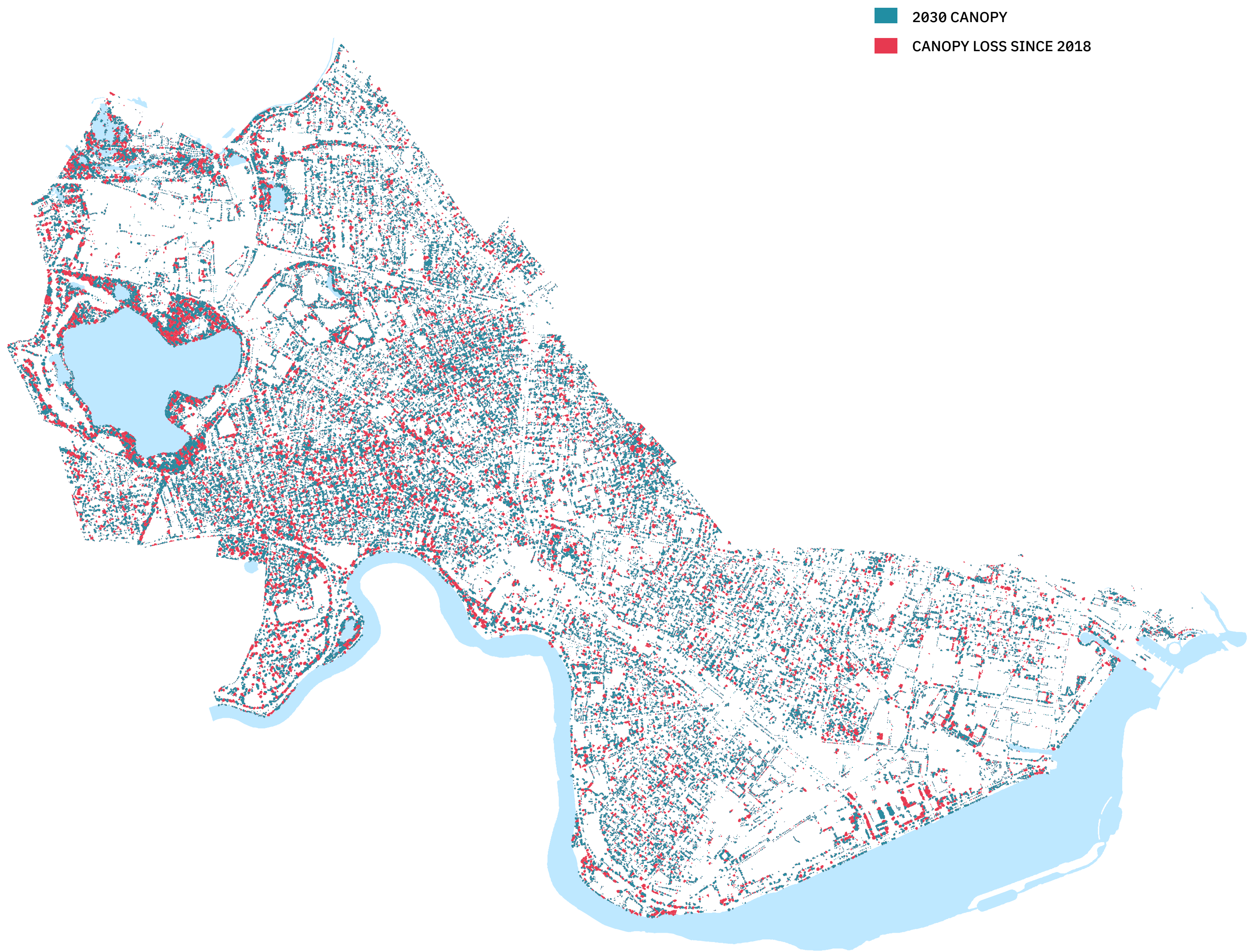


FIGURE 3.4 — CANOPY LOSS BETWEEN 2018 AND 2030 FOR AN ACCELERATED LOSS SCENARIO. By doubling the impact of pests and diseases on each species, the total annual canopy loss rate increases to 3.2%, resulting in 17.6% total canopy cover.

3.3 Projected Impact of Extreme Climate Events

In addition to gradually increasing temperatures that will bring new tree pests and diseases to Cambridge, climate change is forecasted to also increase the frequency of droughts, floods, windstorm events, and perhaps outbreaks of extreme cold. For that reason, the study also examines the effects of an extreme climate event on tree canopy so that the City can plan an appropriate response.

To determine what type of climate event to model, several questions were asked of each: what is the frequency/likelihood of the event, what would be the spatial impact of that event, and how would the event affect different tree species? The team evaluated several possible extreme climate events against these questions. Flooding and moderate drought events were selected to model because sufficient data existed to predicted frequency, extent, and intensity for these two events.

Cambridge will be more vulnerable to rising temperatures and precipitation-driven flooding in the near future than to sea level rise and coastal storm surges[5]. Building on the work of Cambridge Climate Change Vulnerability Assessment (CCVA)[6], the study models two extreme climate events: a medium-term drought scenario and an inland flooding scenario. Tree condition plays an important role in whether an individual tree will survive a climate event. Trees that are already in stressed conditions would have a lower chance of surviving a drought or flood event. Thus, using a sample of actual tree condition undertaken[7], the model categorizes all trees in the city as good, fair or poor for use in this analysis (see Appendix K for description).

FLOODING SCENARIO

A precipitation-driven flooding event, a 100-year 24-hour storm as predicted for 2030, was selected to model the canopy loss in the near-future. This type of rainstorm has a 1% annual probability of occurring, and is associated with a total rainfall depth of 10.2 inches over 24 hours, and a peak rainfall intensity of 2.5 in/hr[8]. The area of the city that is projected to be flooded by the 100-year storm is likely to increase from 13% under present conditions to approximately 18% under 2030 climate conditions.

Under this scenario, the projected flooding in northern Cambridge is primarily from Alewife Brook overflowing its banks and from stormwater backup in street drains. The flooding projected for eastern Cambridge is due to insufficient capacity in the combined stormwater and sewer systems. The pipe infrastructure cannot convey the storm water quickly enough, causing water to back up and pond around manholes and catch basins.

The extent of flooding will become more extreme in the further future. In addition to precipitation-driven flooding, by 2070 Cambridge is likely to experience flooding from sea level rise and storm surge, with higher probabilities of this type of flooding in northern and western Cambridge. The Amelia Earhart Dam on the Mystic River and the Charles River Dam on the Charles River will likely protect Cambridge from storm surge flooding until at least 2030. It is projected that the Amelia Earhart Dam will likely be bypassed by a “100 year” (1% annual probability) coastal storm surge in 2045 and the Charles River Dam around 2055[9]. The City’s Alewife-Fresh Pond area will be the most impacted area by flooding from sea level rise and storm surge. This more extreme flooding from storm surge was not modeled.

The impacts on trees are subject to standing water on roadways, parks and private properties is primarily related to the duration of flooding. Many species can endure short-term inundation, but for many tree species, being in standing water for more than a few hours can significantly weaken or even kill them. The pumps at each of the dams play a critical role in reducing the duration of flooding, during and after a rainfall event, as they release the stormwater that flows into the rivers into the ocean when the water level becomes high[10]. The model event assumes that the pumps function properly and the duration of flooding used in this study was estimated from running the City’s hydrological/hydraulic model of its piped infrastructure.

The predicted 2030 100-year storm was selected as the basis of the flooding scenario for three reasons:

- Precipitation-driven flooding is a more representative type of flooding that all parts of the City have already experienced.
- 2030 represents a near-term planning horizon and it was deemed to be important

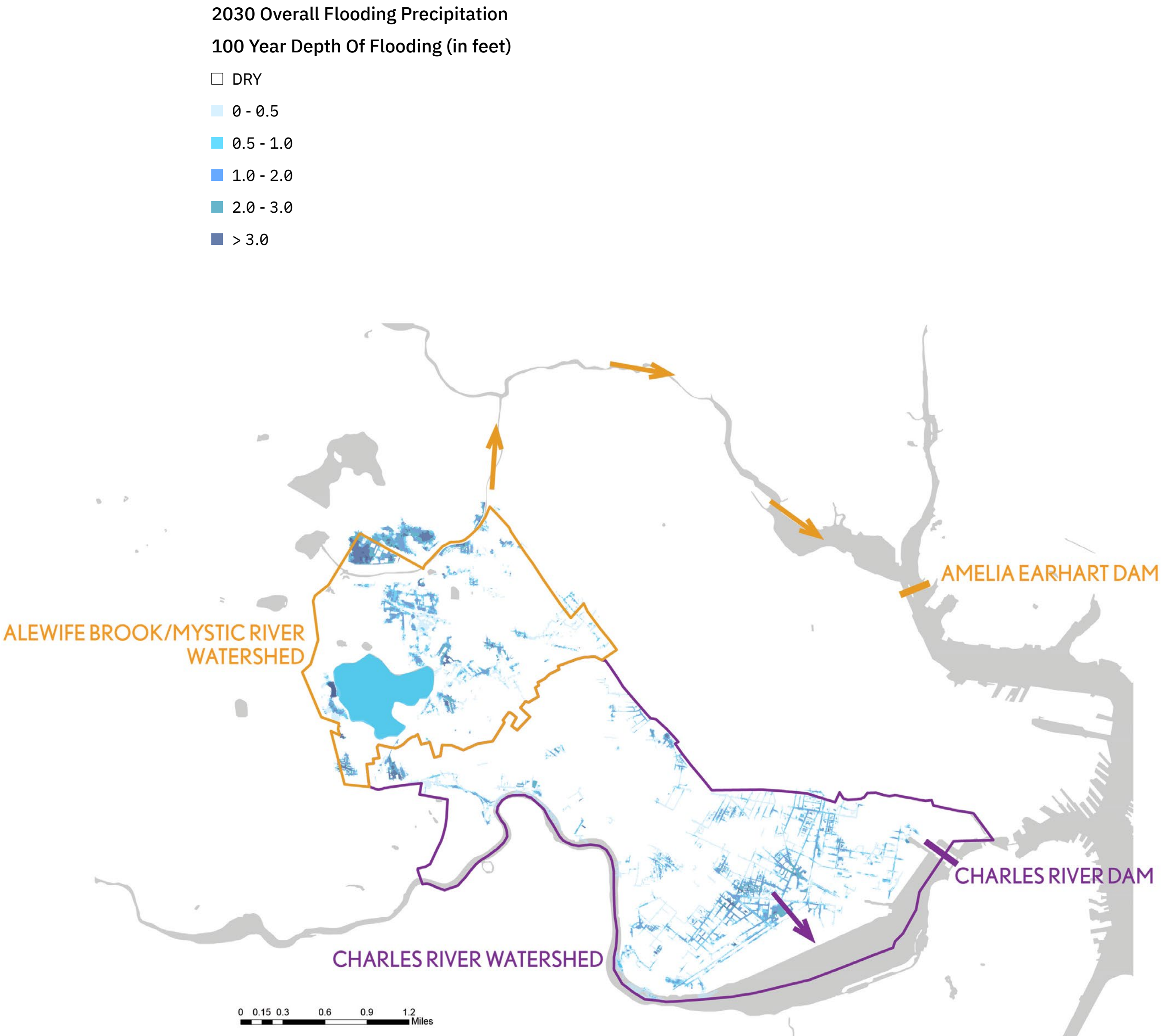


FIGURE 3.5 — MYSTIC RIVER AND CHARLES RIVER WATERSHEDS IN A FLOODING EVENT IN 2030. (One-third of Cambridge is with the Alewife Brook watershed and discharges through the Amelia Earhart Dam)

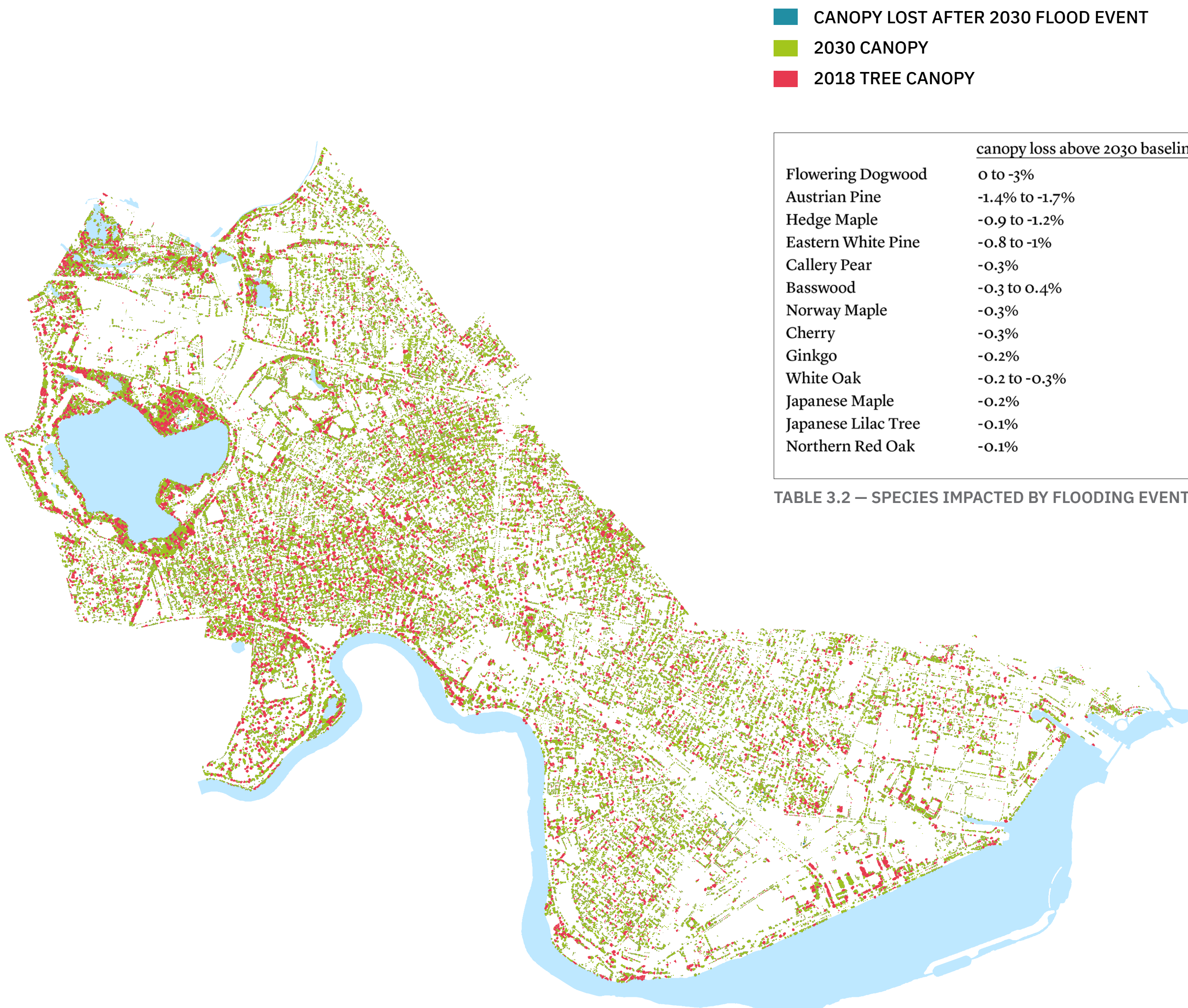
to understand how existing canopy can be affected by an extreme event in the near future.

- Although the 100-year storm by 2030 is a low probability event (1% annual chance of occurring), if one of the pumps at the dams is not functional, such that the basin water level rises beyond the normal range, this type of flooding can be experienced even today with multiple small storms in succession.

Results: As modeled, the flooding event increased tree canopy mortality citywide by 0.2% (from the 2030 baseline scenario — resulting in minimal reduction of canopy in 2030 (~0.7 acres of additional loss). The model assumed that water intolerant trees standing in water for more than 24 hours in poor condition would not survive. Species that experienced the highest mortality due to flooding were the flowering dogwood, Austrian pine, hedge maple, and eastern white pine. It is probable that tree mortality in an extreme flood event was not higher due to the distribution of existing tree canopy — relatively few trees are growing in the flood hazard areas.

This study represents just one modeled storm event and while flooding may not appear to pose a significant threat to the urban forest in the near future, the frequency, extent and duration of flooding will most likely continue to increase over time and repeated events may have a more significant cumulative impact on a larger population of trees.

The 100-year storm predicted for 2070 represents a total rainfall depth of 11.7 inches over 24 hours, and a peak rainfall intensity of 2.9 in/hr. The area of the city that is projected to be flooded by the 2070 100-year storm is likely



	canopy loss above 2030 baseline*
Flowering Dogwood	0 to -3%
Austrian Pine	-1.4% to -1.7%
Hedge Maple	-0.9 to -1.2%
Eastern White Pine	-0.8 to -1%
Callery Pear	-0.3%
Basswood	-0.3 to 0.4%
Norway Maple	-0.3%
Cherry	-0.3%
Ginkgo	-0.2%
White Oak	-0.2 to -0.3%
Japanese Maple	-0.2%
Japanese Lilac Tree	-0.1%
Northern Red Oak	-0.1%

TABLE 3.2 — SPECIES IMPACTED BY FLOODING EVENT IN 2030

FIGURE 3.6 — THE FLOODING EVENT RESULTED IN 0.2% ADDITIONAL MORTALITY (~0.7 ACRES OF LOSS) FROM THE 2030 BASELINE SCENARIO, RESULTING IN MINIMAL REDUCTION OF CANOPY. Because the 2030 flood event is hard to see in this figure, Table 3.2 is included here showing the species impacted.

to increase from 13% under the present climate to 23% by 2070. Although this study did not simulate a 2070 event, this more intense flooding should be assumed to cause deeper and more extensive standing water and therefore impact a much larger number of trees.

DROUGHT SCENARIO

This study defines drought as occurring when soil moisture is within the lowest 10% of all soil moisture values analyzed over a 50-year period[11]. This definition relates directly to the availability of water for agriculture and drinking water supply.

To model canopy loss under an extreme drought event in the future, this study assumes that a medium-term duration of drought of three to six months will occur once every 30 years by the 2050 planning horizon, which includes the years 2035 - 2064[12].

A medium-term drought by 2050 was selected primarily for the following reasons:

- The frequency of late summer and fall droughts is expected to increase in the Northeast.
- Year 2050 represents a far-term planning horizon and it was important to understand how existing canopy can be affected under an extreme event in the future.

Results. Drought was found to have a potentially moderate effect on the existing tree canopy. The medium-term drought event resulted in 3.2% additional canopy loss, or a loss of 14 to 20 acres of canopy above the 2050 baseline scenario. The model assumed that drought-intolerant species in poor or fair condition would not survive a medium-term drought (Fig 3.7). Species that were affected the most are Canadian hemlock, red maple, eastern white pine, and American hornbeam. Drought intolerant species in poor condition, and therefore most susceptible to drought are clustered in East Cambridge but are also scattered throughout the rest of the city.

	canopy loss above 2050 baseline*
Canadian Hemlock	92.4%
Red Maple	26.2%
Eastern White Pine	24.0%
American Hornbeam	23.1%
White Ash	22.6%
Basswood	22.3%
Downy Serviceberry	20.7%
Hornbeam	20.6%
Magnolia	15.0%
Serviceberry	9.5%
Sugar Maple	9.2%
Tree of Heaven	9.0%
Eastern Black Oak	8.9%
Eastern Arborvitae	8.4%
Flowering Dogwood	7.8%
Northern Red Oak	5.0%
White Oak	2.7%

TABLE 3.3 — SPECIES IMPACTED BY 2050 BASELINE + MODERATE DROUGHT. Refer to Appendix C for assumptions for event parameters and detailed results from the model runs and Appendix D for results.

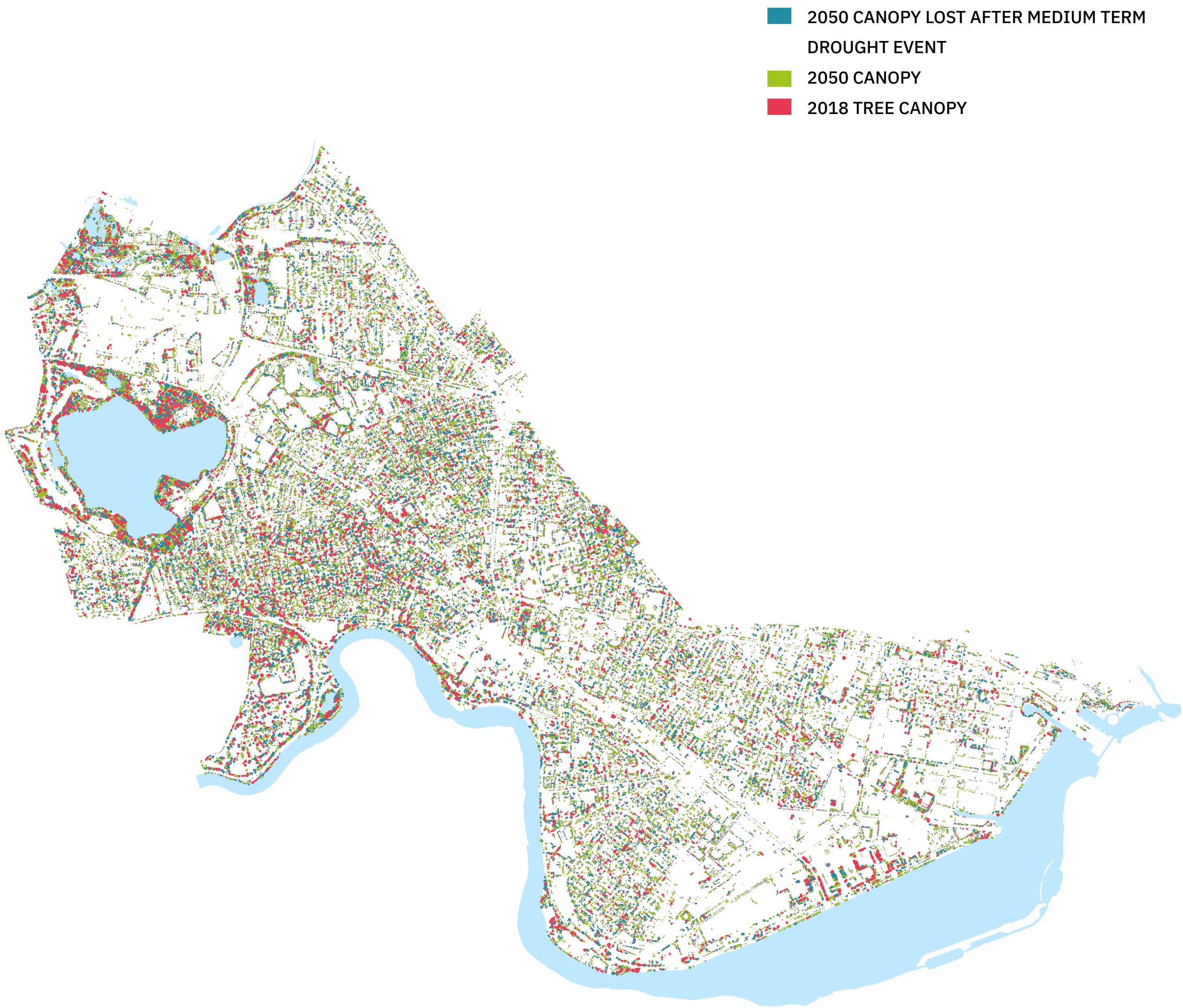


FIGURE 3.7 — THE MEDIUM-TERM DROUGHT EVENT RESULTED IN AN ADDITIONAL 3.2% OF CANOPY LOSS ABOVE THE 2050 BASELINE, OR A LOSS OF 14 TO 20 ACRES.

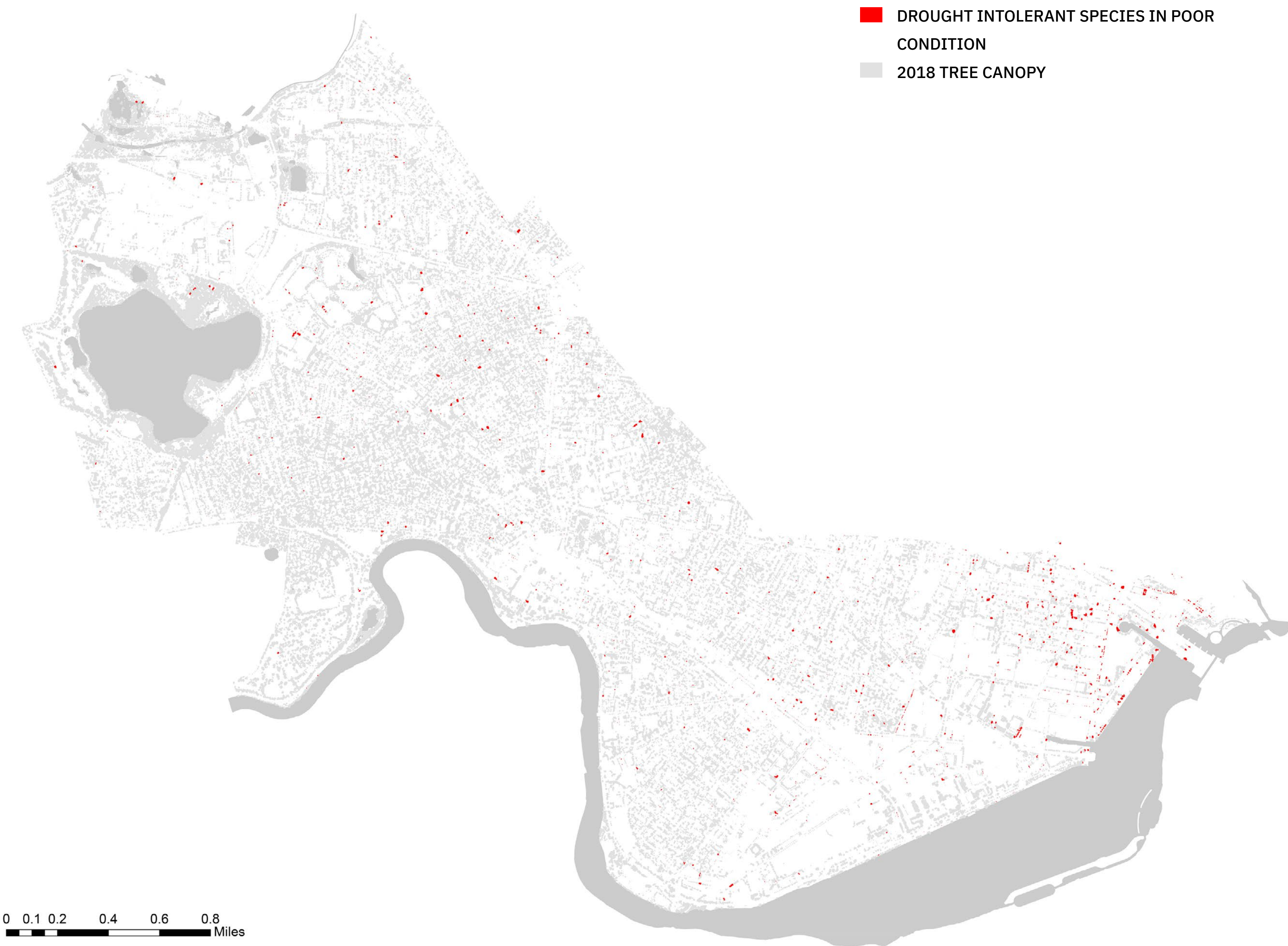


FIGURE 3.8 — MODERATE DROUGHT. The lower bound of the moderate drought event resulted in 1.9% additional mortality from the 2030 baseline scenario. resulting in 10.3% total canopy cover in 2030

OTHER CLIMATE EVENTS

Several other extreme climate events were considered: heat waves, severe winds, extreme cold, and sudden saltwater intrusion due to storm surge. Unfortunately, scientists have less confidence in their predictions about the frequency and intensity of these events; moreover, their effect on the urban forest and individual trees is quite general. Other unusual climate events are not only challenging to predict, their effects are difficult to describe in a canopy change model. To cite a few examples, lack of snow cover in early winter can lower growth rates of trees the following summer[13], possibly reducing their competitiveness and survivorship over time. Additionally, growing seasons are shifting unpredictably as the climate warms, and this will affect the timing of plant and animal life cycle events. Different species have different environment cues, resulting in potential misalignments between species that rely on one another. Lastly, research suggests that Arctic warming is linked to episodes of extreme cold in eastern North America which, if this trend verifies and continues, would limit our planting palette by preventing southern tree species from surviving in Cambridge at the same time that northern species would be pushed north by overall annual warming[14]. However, researchers are unable to project how far into the future these cold outbreaks may continue to occur before winter minimum temperatures become warmer overall, so there is no reliable way to model future extreme cold events.

This study focused on events for which scientists have greater confidence in predicting frequency and intensity—rainstorms and droughts—and which affected a specific location or individual trees in the city. The modeling of these two extreme climate events is useful because they indicate the canopy loss that is likely to occur in addition to the year-by-year canopy loss already occurring or accelerating with climate change.

On the other hand, it is certain that a hurricane or Nor'easter will strike the region again, as it has in the past. The 1938 hurricane that destroyed millions of trees across New England will probably be repeated sometime in the future. What should the City do in this situation, when a significant percentage of the urban forest canopy is destroyed and damaged in a brief time?

The aftermath of a massively destructive climate event would be weathered better by having an emergency action plan in place. An emergency action plan for Cambridge would describe the level of loss being addressed and the overarching strategy to deal with it. It would lay out an inventory and prioritization scheme based on city neighborhoods. The climate-adapted tree species to plant, other needed materials (mulch, etc.), labor required, and cost to replace an acre of urban forest would guide the replanting effort. An emergency response manager would be designated to lead the replanting effort, with the added responsibility of updating the plan each decade. All would not be lost, however. A massive loss of canopy, though a terrible thing, presents an opportunity to replace trees that were at the end of their lifespan, were not adapted to the new climate conditions, or had traits that were undesirable.

While there are preliminary indications of the extent and range of potential climate events that Cambridge will face, the outcomes are all dependent on many variables that will likely change. As the City continues to monitor climate conditions, the City can revisit and adjust recommendations with the most recent projections. Being able to respond and adjust to new information is an integral aspect of building a more resilient forest.

3.4 Projected Urban Heat Island Expansion

The term “urban heat island” is used to describe the phenomenon by which cities are hotter than the surrounding suburban and rural areas, both in the day and evening hours. The danger of urban heat island is the warming of the ambient air, which in a city with 1 million people or more, can be 1.8–5.4°F warmer than its rural surroundings[15]. During the day building and pavement surfaces are heated by the sun, and in the evening these surfaces radiate stored heat, preventing natural cooling once the sun goes down. Higher air temperature exacerbates pressures on those with existing health conditions. Populations with fewer resources for air conditioning may be disproportionately impacted and put at increasing risk for health issues. Additionally, spikes in temperature cause electricity demand to rise and stresses the city’s electrical grid. Tree canopy is one effective way to reduce heat related injury and death and to reduce the load on the electric grid.

Urban trees can reduce air temperatures on summer days by 2- 4°F and this effect can extend beyond the immediate shade the tree generates[16]. Trees and their canopy of foliage are also considered highly effective at reducing particulate matter (PM10), which has been found to have a meaningful health benefit[17]. A recent study of 97 cities found that avoided mortality, morbidity and electricity consumption from tree cover is estimated at $21 to $49 per capita annually[18]. This means the City of Cambridge realizes a value of $2,386,230 to $5,567,870 annually just from the heat and health-related benefits from trees.

The impact of increasing temperature on public health has also been quantified in the Public Health Assessment completed as a part of CCVA. The Assessment reports excess heat-related deaths for two different climate projection models, with temperature changes from the two climate projections ranging from 0.59-1.32 °C (1.06-2.38 °F) and 2.17-2.33 °C (3.91-4.19 °F), respectively. Even for the more conservative temperature change scenario (1.06-2.38 °F) a significant increase in excess heat-related mortality was reported.

A University of Massachusetts study compared building energy use during the summer months (mid-June to mid-September) before and after a significant removal of trees in a Worcester neighborhood due to the Asian longhorned beetle infestation. The study reported that an average 1% decrease in canopy cover resulted in an average 1.2% increase in building energy use (reported in kWh per cooling degree day)[19].

Results: To assess the impact of canopy change on summer-time temperatures in Cambridge, the linear temperature change relationship of 0.12 °F of temperature change per 1 percent change of tree canopy was used to evaluate the temperature impacts of different tree canopy scenarios (see Appendix L for explanation). A threshold of 0.5 °F or more temperature increase was chosen to represent a significant temperature change. While 0.5 °F change may not seem significant, it is important to note that the temperature change is averaged over a 100 foot by 100 foot grid, so the temperature difference directly under a tree will more substantial.

Applying this temperature correlation to the tree canopy change citywide from 2009 to 2018, the model projects that 39% of the city experienced an increase in temperature greater than 0.5°F, and 19% experienced cooling greater than 0.5°F. While some areas have experienced cooling since 2009 from tree canopy growth and additional tree planting, the overall trend citywide has been towards loss of canopy leading to significant areas of the city experiencing an increase in temperature.

Under the accelerated loss scenario, in 2030 38% of the city is projected to experience a further increase in temperature greater than 0.5°F, with 27% of the city projected to experience an increase in temperature greater than 1.0°F. With this temperature increase comes higher energy costs to cool buildings, additional strain on the energy grid, and potentially more heat related medical emergencies and mortality.

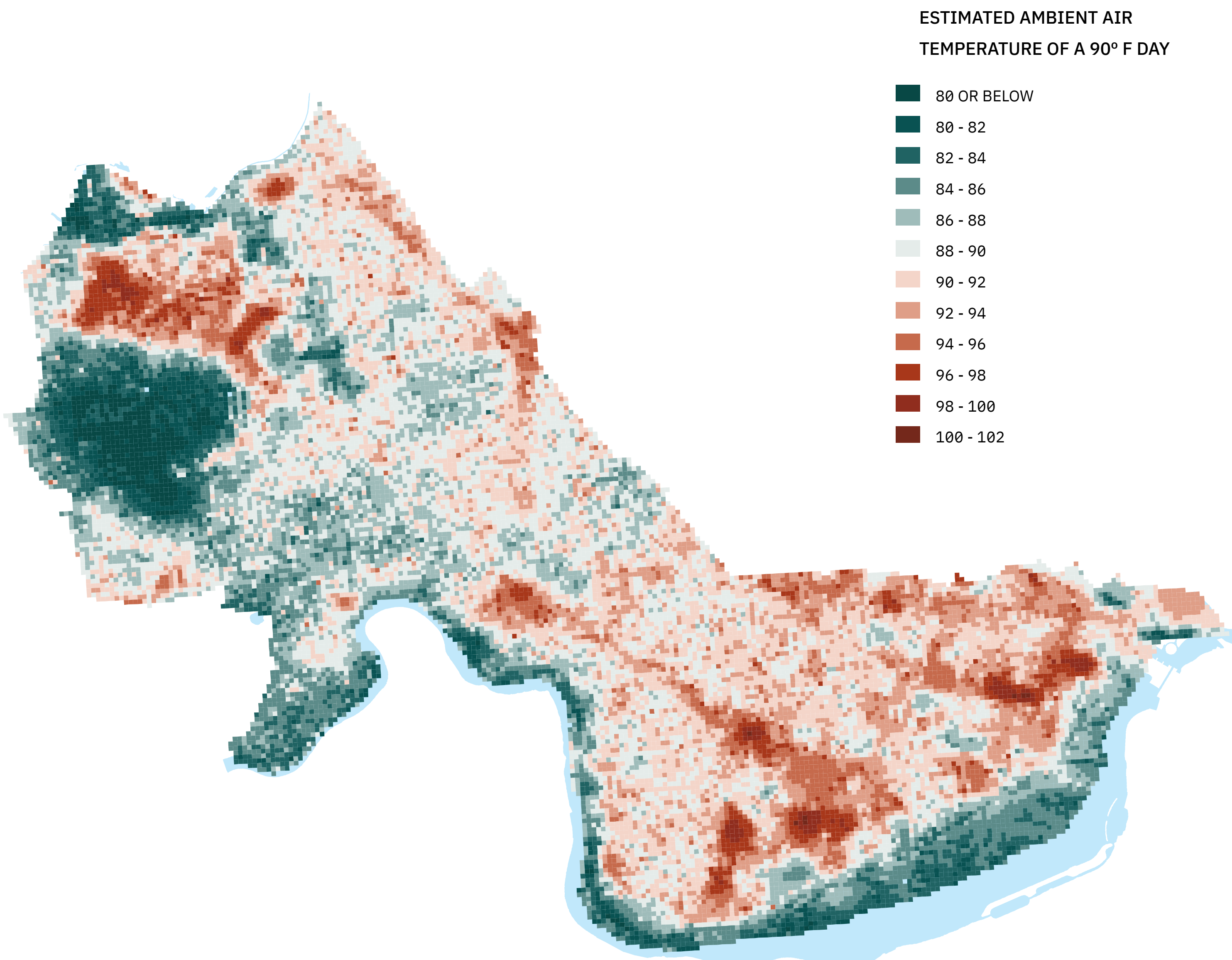


FIGURE 3.9 — HEAT ISLAND MODEL OF THE 2018 CANOPY

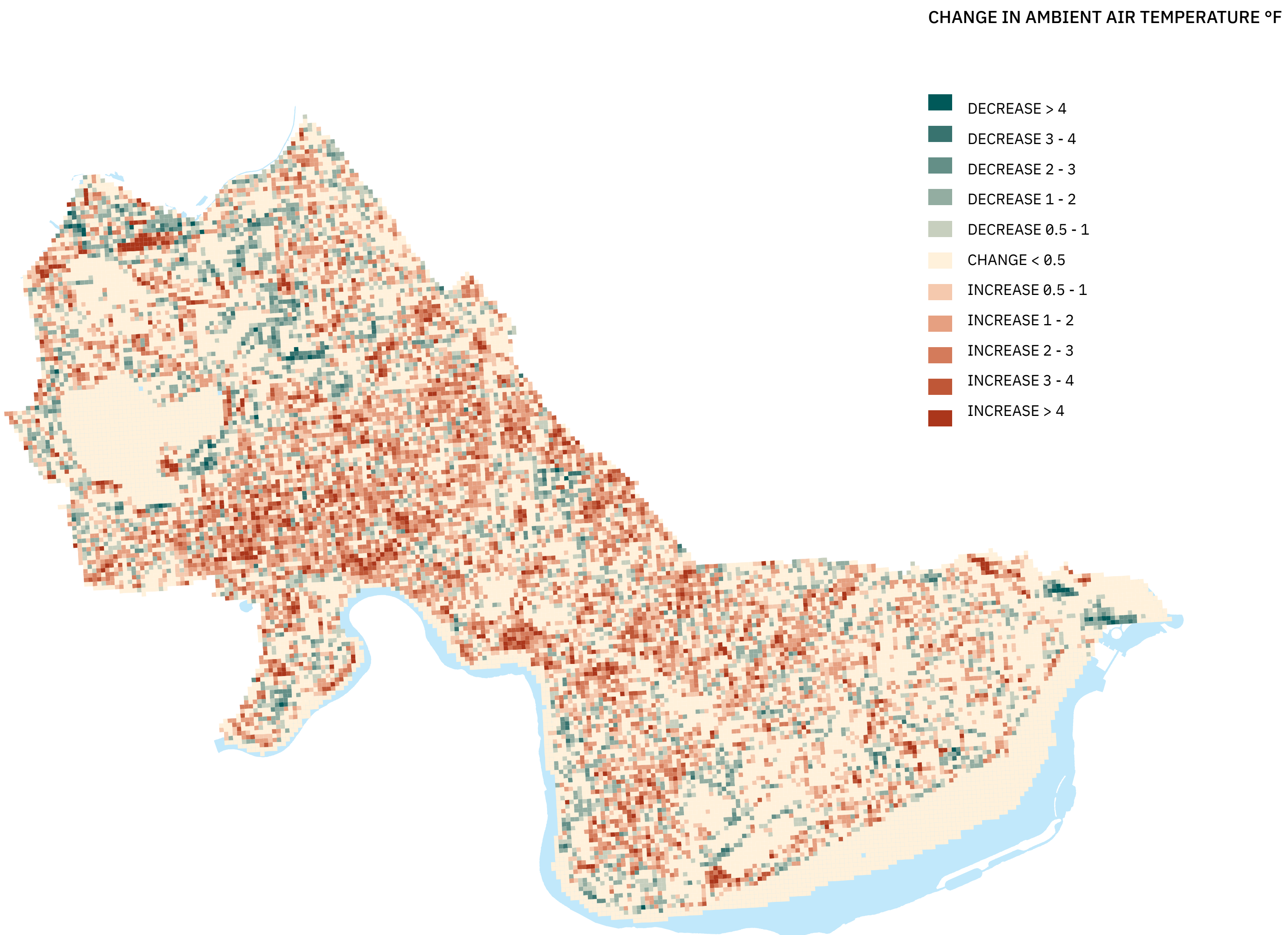


FIGURE 3.10 — AS A RESULT OF CANOPY CHANGE BETWEEN 2009 AND 2018, 39% OF THE CITY EXPERIENCED AN INCREASE IN TEMPERATURE (> 0.5%0°F) AND 19% EXPERIENCED COOLING (> 0.5%°F).

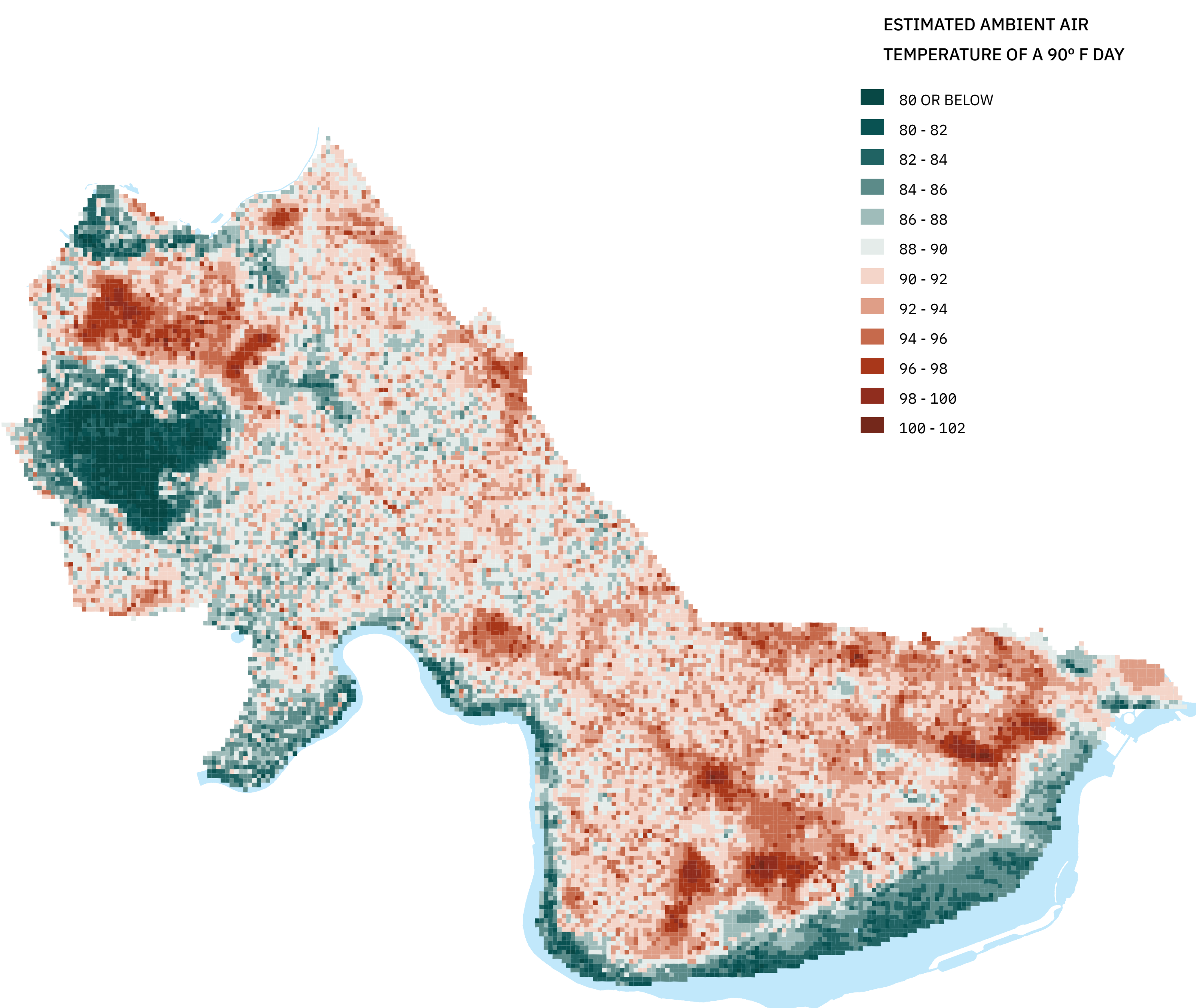


FIGURE 3.11 — 2030 ACCELERATED LOSS SCENARIO (17.8% CANOPY COVER)

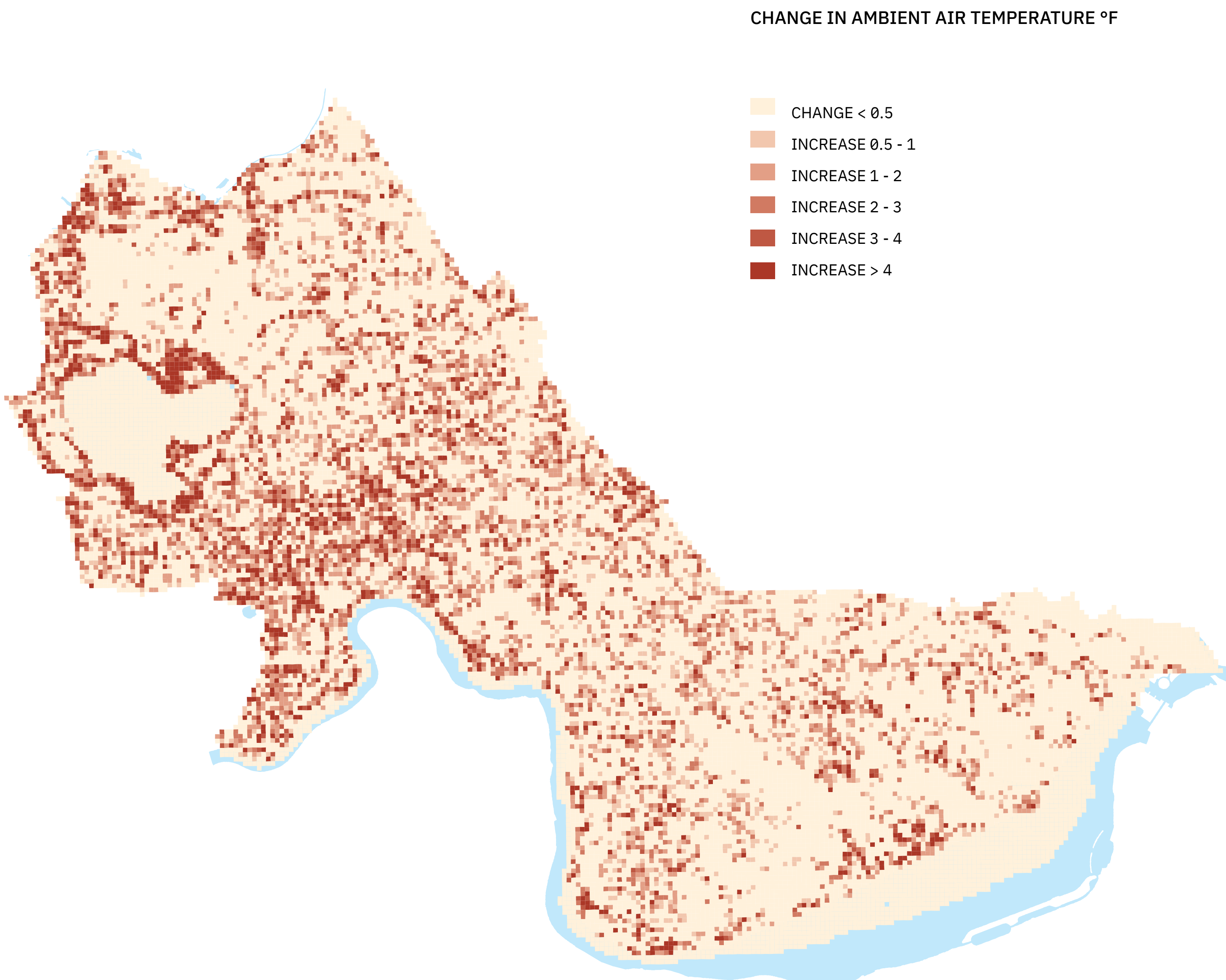


FIGURE 3.12 — 38% OF THE CITY EXPERIENCED AN INCREASE IN TEMPERATURE (> 0.5%°F) UNDER A 2030 ACCELERATED LOSS SCENARIO OF 17.8% CANOPY COVER.

3.5 Potential Canopy Value Loss

As described in *Section 2*, State of the Urban Forest, the total value of the urban forest in 2018 can be estimated at $581.5 million. This represents some of the ecosystem services benefits of the urban forest such as air quality, stormwater and heat island mitigation, carbon storage, and the aesthetic value of trees. Given that Cambridge is experiencing canopy loss, every year the City derives fewer benefits from the urban forest. Under the current trajectory of decline, the cumulative value of the forest in 2070 would be $427 million. If climate change were to double the rate of mortality per tree species, the cumulative value of the forest would be $208 million, or less than a third of the benefits we see today.

3.6 Projected Species Resilience

To anticipate which tree species may fare better with the climate change, this UFMP created a climate resiliency score for each tree species. This is a tool that can be used to assess long-term predicted performance. Data was collected on the pest susceptibility, drought tolerance and flood tolerance for each species into a large database (Appendix N). This score is limited to the data that was collected for this study, so as new climate and species information becomes available, the scores should be updated.

EVALUATING TREE SPECIES FOR RESILIENCY

Each tree species was assigned a score based on drought (intolerant, moderately tolerant, tolerant), flood (intolerant, moderately tolerant, tolerant), and pest susceptibility (low, medium, high). The existing species/genus makeup of the urban forest is susceptible to climate risks, with 29% percent of the forest having high susceptibility to pests, drought and/or flood factors.

High risk species are generally spread evenly throughout Cambridge. East Cambridge, Strawberry Hill, Cambridge Highlands, and West Cambridge have higher than average susceptibility. The latter three neighborhoods contain significant portions of Fresh Pond/Alewife Reservation and the high concentration of oaks, pine species, sugar maple, etc. in these areas drive up the neighborhoods' overall susceptibility. However, because these trees exists in naturalized conditions, they will actually be less susceptible to some climate factors such as drought.

We have no way of knowing which pest/diseases may appear in the future so the climate score is partially speculative. In the model, pests and diseases currently present and within 250 miles of Cambridge are assumed to potentially impact Cambridge's urban forest in the next 50 years. While this is a large assumption, we believe it is a prudent strategy for the City to plan ahead, to be projective about which species may do better with the current information we have on hand. The City should revisit and adjust this score as additional information about likely pests and diseases appear. Recommended species for Cambridge are discussed in further detail in *Section 4.4* Design Strategies.

Latin Name	Common Name	Climate Score	% species	% genus
Juniperus virginiana	Eastern redcedar	7	less than 1%	
Carpinus betulus	European hornbeam	7		
Cotinus coggygria	Common smoketree	7		
Sophora japonica	Japanese pagodatree	7		
Sassafras albidum	Sassafrass	6.5		
Eucommia ulmoides	Hardy rubber tree	6.5		
Parrotia persica	Persian parrotia	6.5		
Ptelea trifoliata	Wafer ash	6.5		
Ginkgo biloba	Ginko	6.5	1%	1%

TABLE 3.4 — EXISTING SPECIES MAKEUP OF THE URBAN FOREST IS SUSCEPTIBLE TO CLIMATE RISKS OF INCREASED PESTS/DISEASES, DROUGHT AND FLOODING. 10% is the diversity threshold for a single species abundance.

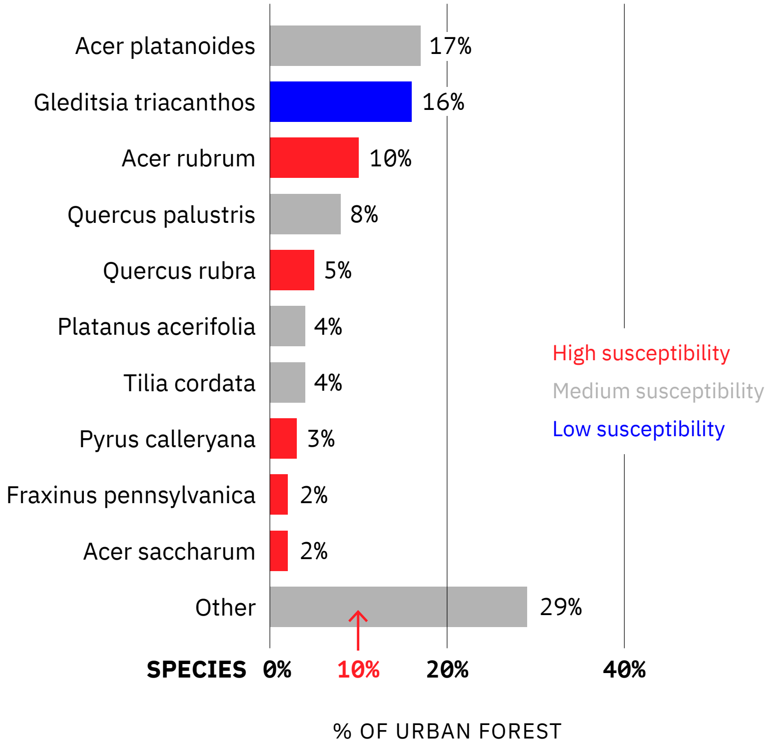


FIGURE 3.13 — EXISTING SPECIES MAKEUP OF THE URBAN FOREST IS SUSCEPTIBLE TO CLIMATE RISKS OF INCREASED PESTS/DISEASES, DROUGHT AND FLOODING. 10% is the diversity threshold for a single species abundance.

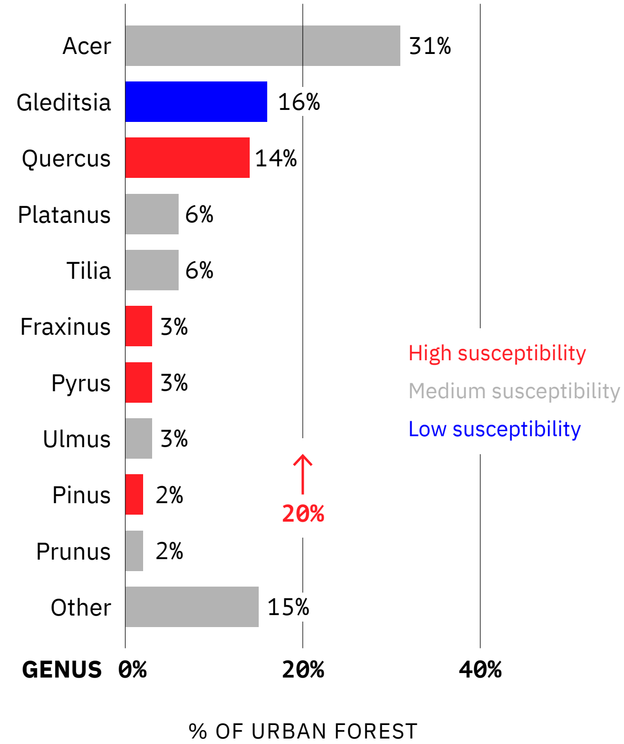


FIGURE 3.14 — EXISTING GENUS MAKEUP OF THE URBAN FOREST IS SUSCEPTIBLE TO CLIMATE RISKS OF INCREASED PESTS/DISEASES, DROUGHT AND FLOODING. 20% is the diversity threshold for a single genus abundance.

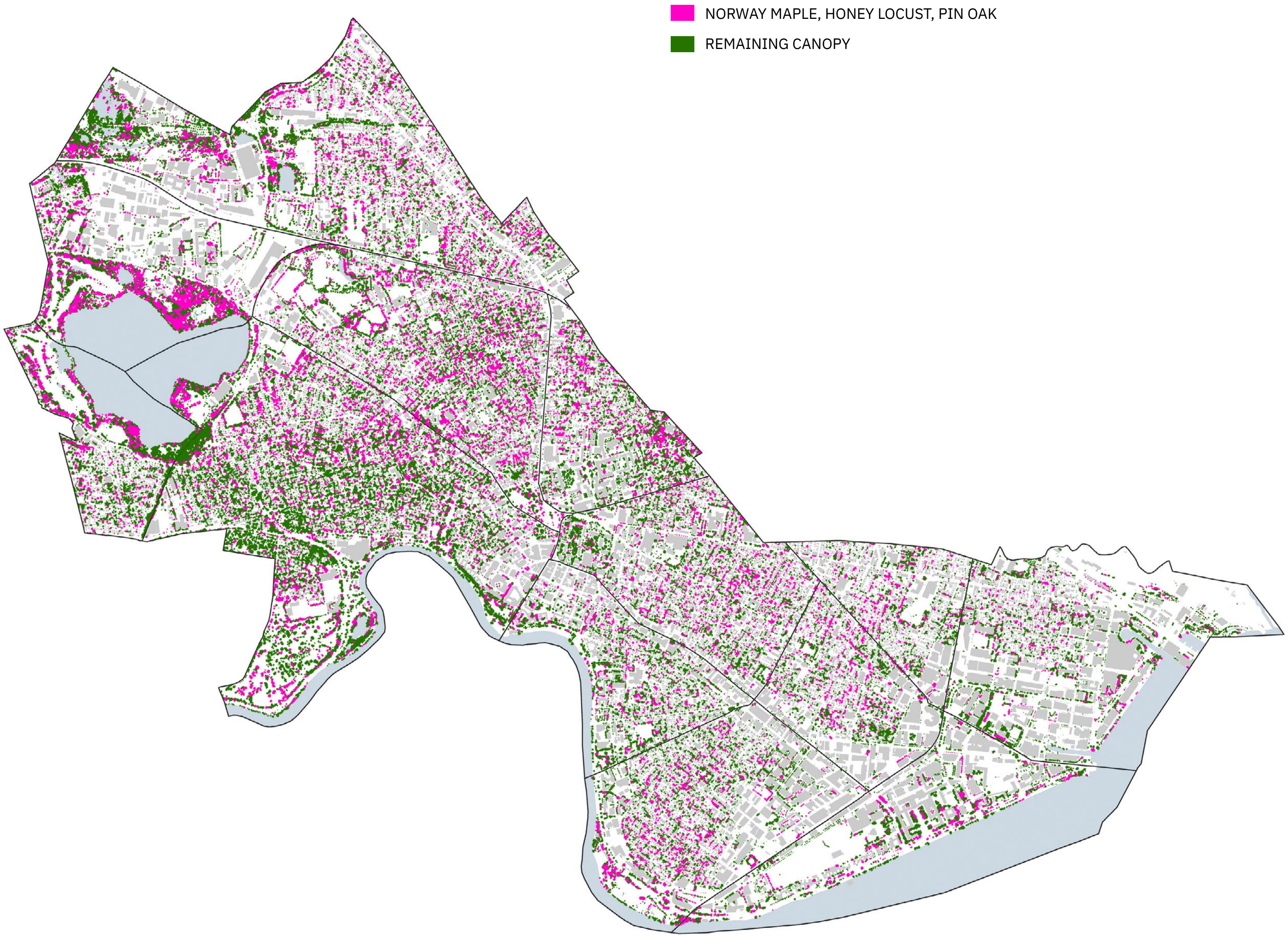


FIGURE 3.15 — CURRENTLY 3 SPECIES (NORWAY MAPLE, HONEY LOCUST, PIN OAK) COMPRISE OF 33% OF THE CANOPY COVER CAMBRIDGE FOREST, AND CATASTROPHIC LOSS OF THESE 3 SPECIES WOULD MEAN CANOPY COVER WOULD DROP TO 17% COVER CITYWIDE.

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5 CCVA
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4. Response Strategies

A healthy forest contributes to the well-being of a community, its trees live longer and thrive during predicted changing climate conditions, and it supports a more resilient, connected ecosystem. The City should strive to maintain, plan, build, and sustain a healthy, connective urban forest at a time when the urban forest is more important than ever.

As there is no one single cause of the current state of the Cambridge urban forest (see *Section 2*), there is no single strategy to realize a healthy connected forest. An "all-of-the-above" approach is necessary, leveraging the collective effort of many actors across the city.

Because more than 50% of total canopy loss in the past ten years has occurred on private property, private landowners will need to play a significant role in the solution. Whether through increasing the valuation of a “Significant Tree” within the Tree Protection Ordinance to deter removal or through the establishment of a trust to fund planting on private land — something which has the potential added benefit of involving institutions and corporations —it will take concerted efforts and policy changes by the City to reach private landowners. Outreach and education that reaches broadly across the community will also be important tools to decrease reliance on punitive measures to preserve existing trees and to encourage planting for the next generation of shade trees.

In addition to including private entities as responsible partners, this study also recommends that the City develop clear mandates that can be endorsed politically and adopted across departments. These mandates should be linked to other City priorities and efforts, like climate resiliency and social equity. In order to hold all parties accountable, the City should issue an annual report summarizing progress towards the goals of the master plan. These recommendations and others detailed in the following section will take time to have an impact on the city. And they will require commitment on all sides. But together, these strategies will build a healthier, more resilient urban forest for current residents to enjoy and for future generations to treasure.

4.1 Ground Strategies in a Framework for Understanding the Urban Forest

A healthy, connective and equitably distributed forest is the goal of this study. If the City is to re-align its approach to the stewardship of the urban forest toward this goal, then it must transform and broaden the way it is understood.

There are four core concepts that frame this deeper understanding of the urban forest.

DEFINE CORE CONCEPTS

UNDERSTAND THE FOREST AS A SYSTEM

The urban canopy is more than a collection of trees, it is a living system that functions on a regional scale. Trees are a part of a system of flows in the city. When it rains, some of the drops are held on the leaves of trees, slowly evaporating or dripping down, and much is absorbed into the permeable surface around the tree. Water is absorbed by tree roots, transported through the trunk, branches and leaves and used to produce food, and oxygen is transpired back into the atmosphere. As part of the water cycle in the city, trees provide a valuable service of reducing stormwater runoff and improving water quality.

Trees are also an essential component of the carbon cycle. Carbon dioxide generated through natural or man-made processes is absorbed by trees, broken down by sunlight to create food and becomes the branches, roots, fruits, leaves and bark of the tree. In this way carbon is bound into the tree biomass and only released when the trees die and decay, though some of this carbon stays locked in the soil.

Each tree individually is an ecological workhorse, but a connected forest produces ecosystem service greater than the sum of its parts. Thus, the City should focus on the performance and resilience of the forest as a whole particularly rather than on individual trees as the City strives to balance the needs of the trees with other interests.

VALUE THE FOREST AS A PUBLIC RESOURCE

The urban forest is a public resource that has measurable value and impacts to everyone. It cools the surface we walk on, provides food and habitat for birds, insects, and small mammals, filters air pollutants, absorbs and mitigates stormwater impacts, reduces building energy loads, gives identity to our neighborhoods and improves our health and well-being.

Trees don't merely beautify the city, they are a necessary and vital component of the urban infrastructure, similar to utilities such as water and sewer systems. As with any City infrastructure, significant up front investments are needed to create and maintain the urban canopy. This means implementing practices to improve tree establishment rates and longevity and a robust tree tracking program so that lessons learned can inform management change toward improved outcomes. The City should also stay abreast of the latest advances in climate research and arboricultural practices to anticipate and adapt to the gradual effects of climate change and extreme climate events.

INVEST IN THE PUBLIC REALM

The benefits of the urban forest are most strongly felt in the public realm and common spaces (sidewalks, front yards, parks, schoolyards, and commercial and institutional campuses). Trees provide shade while we walk on sidewalks or wait for buses. They create a sense of calm and peace for children in schools. With the challenges of a warming climate exacerbating heat islands, trees will be more important than ever to cool the areas we gather and the networks we travel. These ideas support the development of "cool corridors", a concept put forth by The City's Climate Change Preparedness & Resilience Plan (CCPR).

Enhancing the canopy that intersects with the public realm deserves the City's primary attention and investment. By investing in the public realm, the City can create a network of trees along highly traveled networks to connect and enhance commercial and cultural centers, residential neighborhoods and green spaces across the city. Trees within front yards and private lands that front on the public realm and publicly accessible open spaces owned by private entities contribute greatly to creating these green corridors as well.

Access to the benefits of the urban forest should be equitable for all Cambridge citizens. Investing in the public realm also means more evenly distributed urban canopy and that can reduce the disproportionate impacts of urban heat island on the city's populations at risk.

GALVANIZE COLLECTIVE ACTION

A thriving urban forest requires the mutual care of many parties, including city government, homeowners, businesses, developers, local organizations, institutions and state agencies. The current canopy decline cannot be reversed without buy-in and action from the many constituents of the City.

Currently, open space land use contributes the most canopy area per acre in the City, followed by R.O.W. and Residential. Commercial land uses contribute the least canopy area per acre, and institutional, industrial, and public uses contribute less canopy per acre than the average. The largest canopy losses are seen in residential areas (29%), followed by industrial (24%) and institutional (20%), and then commercial (11%). Since residential land uses are such a high percentage of the city's total land use, 72% of the net canopy loss occurred in residential land use areas (Table 4.1). Thus, having a significant impact on citywide canopy cover will require reducing loss rates by maintaining and nourishing existing trees and growing canopy on residential properties.

Land Use Type	2018 Acres of Land Use Overall (%)	# Canopy acres/ acre	% net change from 2009 to 2018	% of citywide canopy loss
Residential	1501 (36%)	0.27	-29%	72%
ROW	812 (20%)	0.28	-5%	7%
Open Space	521 (13%)	0.44	-2%	3%
Commercial	452 (11%)	0.10	-11%	3%
Institutional	436 (11%)	0.20	-20%	10%
Industrial	216 (6%)	0.10	-24%	3%
Public	128 (3%)	0.13	-5%	1%

TABLE 4.1 — UNDERSTANDING LAND USE TYPES BY CANOPY CONTRIBUTION BY AREA AND NET LOSS

Clearly some land use types (institutional, industrial and commercial) are lagging behind in canopy cover and have also experienced high rates of loss, and these areas may need particular examination. Open space experienced the lowest loss at 2%, but as this is still a loss, all constituents need to contribute towards reversing the trend.

The City of Cambridge has direct control over approximately 20% of the land area in the form of R.O.W., and an additional 7% in the form of public parks and open space. While the City can do much to improve the areas that the public most commonly frequent, there is still limited impact.

DEFINE CORE VALUES

The three core values of equity, resilience and shared responsibility will help guide decision making when prioritizing where and how to act. We aim for an equitable, resilient urban forest where all city constituents are invested in and participate in its care.

EQUITY

A healthy urban forest provides benefits for all the people in the City. Currently, low canopy cover corresponds to areas where populations at risk reside. This means these populations are subject to more urban heat island impacts, exposed to fewer air quality benefits, obtain fewer energy savings, and experience fewer social and mental well-being benefits from trees. We should first focus on growing canopy in these areas of existing deficient. With more trees, we can mitigate some of the urban heat island impacts for those populations generally less able to respond or adapt to the threats of heat extremes.

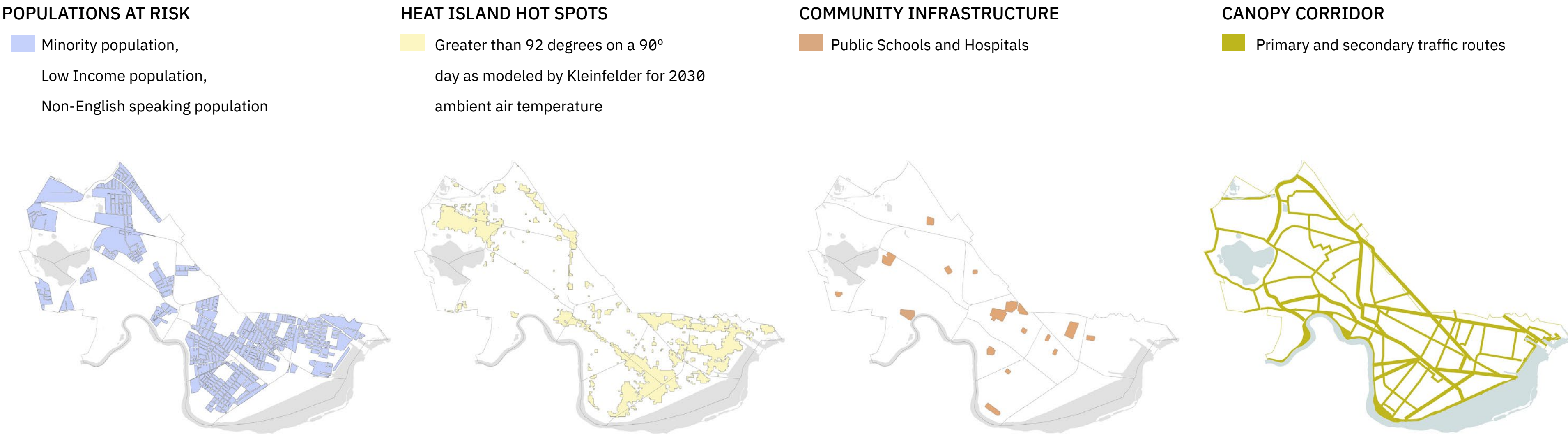


FIGURE 4.1 — PRIORITY AREA CRITERIA. Criteria are overlaid to produce a spatial recommendation for where the City and others can focus efforts.

RESILIENCE

A resilient urban forest is able to recover quickly from disturbances and catastrophic pest and disease outbreaks. An urban forest that is more diverse and does not contain an overabundance of a single species, genus, or family would be better able to withstand the increasing pressures of climate change.

A resilience city contains a robust urban forest that benefits human health and well being. Trees can reduce the spread and intensity of heat island hotspots and create shaded corridors for pedestrians, bicyclists, transit, scooter and vehicular users. A resilience city also contains a network of parks with dense canopy cover that provide cooling benefits for the entire city.

SHARED RESPONSIBILITY

An equitable, resilience urban forest relies on the collective choices of many actors in the city. As there is not one single cause of canopy decline, there is no single solution and we must take an all-of-the-above approach. Within city government, choices about policy, enforcement, planning, and practice are also dispersed and shared. There is no single department or individual who speaks for the urban forest. In order to keep the city accountable and to ensure advancement, this study recommends developing clear mandates that can be endorsed and adopted across departments. These should be linked to other city priorities and efforts, like climate resiliency and social equity.

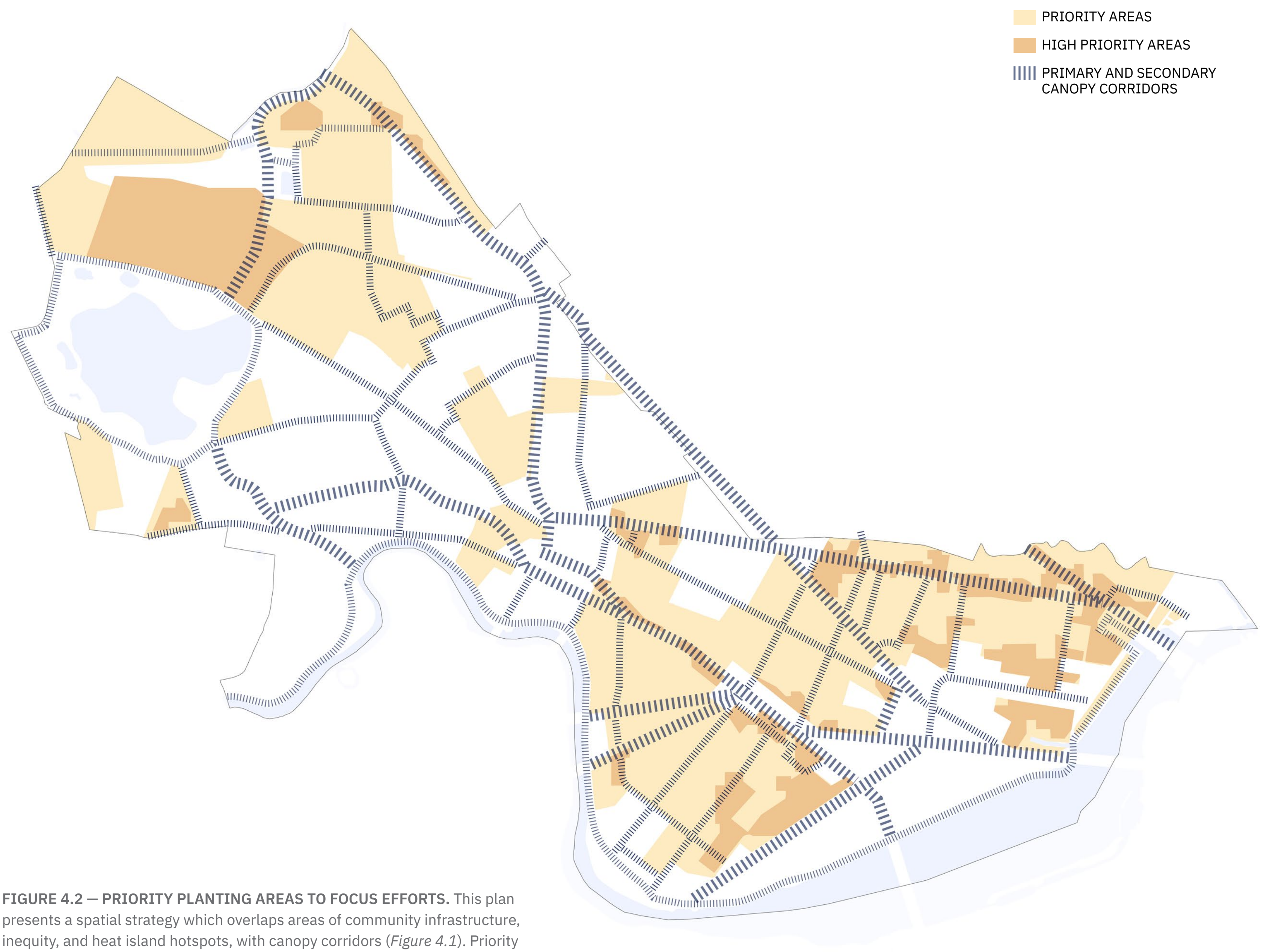


FIGURE 4.2 — PRIORITY PLANTING AREAS TO FOCUS EFFORTS. This plan presents a spatial strategy which overlaps areas of community infrastructure, inequity, and heat island hotspots, with canopy corridors (*Figure 4.1*). Priority areas are where one of the criteria are met, while high priority areas are where two or more criteria are met. Growing canopy in high priority areas will have a disproportionate benefit and the City can update the priority areas as data for the criteria will change over time.

4.2 Prioritize Where to Act

The urban forest does not self-regenerate. Most removals and new plantings are intentional acts. Trees that do self-seed are generally invasive species and left alone would outnumber desirable species over time. In this way, the urban forest is a cultivated landscape more akin to an orchard than a native forest. As a consequence, new plantings should be planned with intention and by design, taking account of the existing deficits and anticipating future areas of opportunity.

As the City, its citizens, and its partners approach these replanting efforts, dispersed and scattershot interventions will have limited effect. Our collective efforts should be guided by a series of shared priorities to have the greatest and most immediately felt impact.

Building upon the belief that the canopy is a public resource that should be equitably distributed, this report focuses on first tackling areas of existing canopy deficit as organized by the following priorities: canopy corridors, populations at risk, heat island hotspots, and community infrastructure (*Figure 4.1*). These criteria are overlaid to produce a spatial plan of priority areas (one criteria is met) and high priority areas (two or more of these criteria intersect) (*Figure 4.2*).

FOCUS ON POPULATIONS AT RISK

Low income, minority, and English isolation communities were identified as the populations that would be especially vulnerable to climate impacts, including increased summer heat. Environmental justice maps were created using thresholds identifying populations at risk (minority, low income, and English isolation) as defined in CCVA[1].

MINIMIZE HEAT ISLAND HOTSPOTS

This Master Plan defines areas that are projected to experience greater than 92 degree ambient air temperature on a 90 degree day in the 2030 climate model as “heat island hotspots”. Heat island has an inverse relationship with existing canopy cover.

SHADE COMMUNITY INFRASTRUCTURE

Community infrastructure such as public schools, hospitals, and bus stops were identified as important community resources, providing adequate canopy cover can aid all populations, particularly those who may lack shade at their residence and who may not have resources for air conditioning.

BUILD ROBUST CANOPY CORRIDORS

A resilient, connected ecosystem that enhances shading and cooling along the City’s primary circulation networks and connects green spaces across the City relies on thriving trees within the public R.O.W., publicly accessible spaces, and front yards and private lands that front on the public realm. Shade along these corridors not only increases the comfort in the city in summer but can also help to reduce greenhouse gas emissions by incentivizing public transportation, biking and walking. To prioritize efforts to create distinct Canopy Corridors, the City should focus efforts on planting along primary arteries and neighborhood connectors, around existing public transit stations, and along the most commonly used walking, running and bicycle routes[2], especially where they connect to publicly accessible open spaces. (See *Figure 4.2*)

ENHANCE CARE FOR TREES THAT SHADE THE R.O.W.

Trees within the R.O.W. are the main source of canopy for creating this network of canopy corridors. With limited horticultural resources and requiring significant artificial support to establish, street trees face more challenges than the typical tree. 81% of non-R.O.W. trees are in good condition while only 62% of R.O.W. trees are in good condition. The *Section 4.4* on Practices details recommendations to support these trees.

PLANT MORE TREES TO SHADE THE R.O.W.

The total land area of the R.O.W. in Cambridge is 812 acres, 229 acres of which are canopy covered. The City manages approximately 13,000 street trees and historically plants around 400 street trees per year. Based on literature review[3] the average street tree mortality rate is 4.5% per year. At this rate, the City would have to plant 600 trees per year just to replace trees that have died. Thus, in order to increase canopy in the R.O.W., the City must be planting more than 600 trees per year. The city currently does not plant a street tree in front of a home or business if the property owner does not want one, but the City could transition to eliminating opt-outs for street trees plantings as these trees constitute a broader public benefit.

ALIGN PLANTING AND MAINTENANCE STRATEGIES TO EACH PLANTING SITUATION

Not all street tree planting situations are the same. This study has found that tree condition can differ greatly based on physical surroundings (*Figure 4.3*). An analysis of R.O.W. tree condition and nearby setbacks revealed that 50% of R.O.W. with zero setback were in poor condition compared to city acreage of 23% for R.O.W. trees (*Figures 4.4* and *4.5*) Having permeable surfaces in proximity to street trees likely means the tree roots can take advantage of the additional soil volume, irrigation, and nutrients beyond the tree pit, which has many benefits. This suggests that the City should prioritize street trees that are not located adjacent to front yards or additional soil volume without additional care such as increased frequency of irrigation, and should generally plant drought tolerant species in these conditions.

The canopy that shades the public realm does not all have to come from street trees. In Cambridge, approximately 22% of canopy falling on the R.O.W. likely comes from trees in front yards (see Appendix B,D). Trees growing in front yards have access to greater resources, and where possible, the planting of front yard trees on private property should be encouraged when street trees are not possible or when they are not able to grow to a size to provide for robust canopy.

FIGURE 4.3 — CREATING ROBUST CANOPY CORRIDORS IN THE CITY

FIGURE 4.4 — CONDITION OF STREET TREES CITYWIDE. Poor condition trees are more prevalent in East Cambridge, and along Massachusetts Avenue and adjacent streets in Cambridgeport, Area 2/MIT, and the Port.

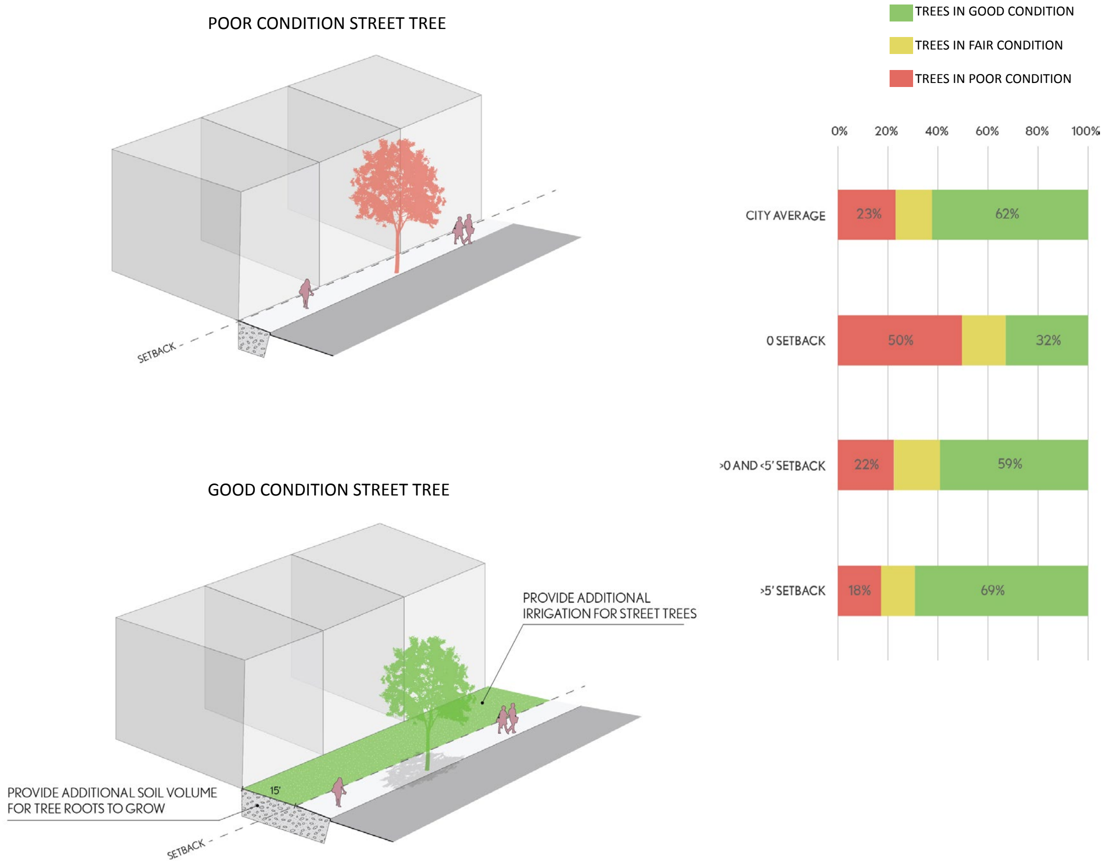


FIGURE 4.5 — STREET TREES IN EAST CAMBRIDGE (TOP) AND WEST CAMBRIDGE (BOTTOM). Sidewalks adjacent to front yard setbacks are in good condition, while those that are directly adjacent to buildings are in varied condition.

FIGURE 4.6 — LARGER FRONT YARD SETBACKS ENCOURAGE HEALTHY STREET TREES. 50% of street trees with no setbacks are in poor condition.

4.3 Target Strategies to Urban Condition

IDENTIFY OPPORTUNITY AREAS BY URBAN CHARACTER, SITE CONDITIONS, AND USES.

The patterns of open space (where trees can be grown) are not uniform across the city. They are impacted by land use, building age and type, zoning regulations and other historical influences. Therefore, as the city begins to deploy strategies to plant in priority areas, they will need to be tailored specifically to the unique conditions of each area.

To guide specific approaches, this study has categorized the city as a series of urban typologies. These are descriptions of existing condition that may limit or may suggest opportunities for growing additional canopy. These categories are generalized and based on observation. They are not legal designations based on zoning.

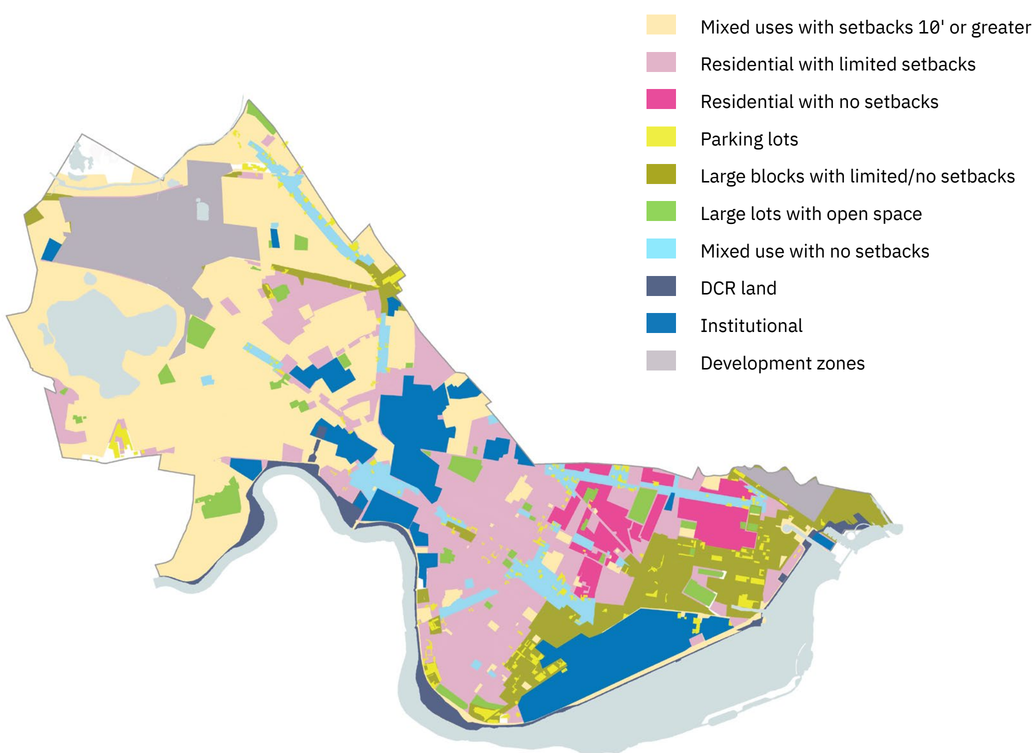


FIGURE 4.7 — SITE CONDITIONS AND USES IN THE CITY

FIGURE 4.8 — MIXED USE AREAS WITH SETBACK GREATER THAN 10'

FIGURE 4.9 — RESIDENTIAL AREAS WITH LIMITED SETBACK

Mixed Use with Front yard Setbacks greater than 10'.

The prevalent use type is residential with front, side and backyards. Planting opportunities are numerous, and efforts should be focused on front yard trees that shade in the public realm. This typology mainly occurs in West Cambridge, Strawberry Hill, Neighborhood Nine, and North Cambridge.

Residential with Limited Setbacks.

The prevalent use type is residential with limited front, side and backyards. Planting opportunities may be possible in front yards, backyards and side lots. This typology mainly occurs in Mid Cambridge, Cambridgeport and Riverside.

FIGURE 4.10 — RESIDENTIAL AREAS WITH NO SETBACKS

FIGURE 4.11 — LARGE BLOCKS WITH LIMITED/NO SETBACKS

Residential with no setbacks

The prevalent use type are zero lot line buildings that are built directly adjacent to the sidewalk. In these areas, planting opportunities are limited to the R.O.W. and backyards. Canopy cover is low in this area. This urban character is largely prevalent in large portions of East Cambridge and The Port and Wellington-Harrington.

Large blocks with limited/no setbacks

The prevalent use type are commercial and industrial buildings with large asphalt parking lots. There are no requirements for commercial/industrial areas to maintain setbacks so space for trees is limited and planting opportunities are mainly confined to parking lots that service large commercial/industrial buildings. Because of the dominance of buildings, asphalt roadways and asphalt parking lots, conditions are windy, hot and dry and very harsh for trees. Current canopy cover is lowest in this type of typology. This typology is common in East Cambridge, The Port, and Cambridgeport.

FIGURE 4.12 — MIXED USE WITH NO SETBACKS

FIGURE 4.13 — LARGE LOTS WITH OPEN SPACES

Mixed use with no setbacks

The prevalent use type is retail on the ground floor with residential or office on other floors. Canopy is especially important as these are areas where people frequent during the day and spend time walking, biking or waiting at bus stops. Planting opportunities are usually limited to the R.O.W. This urban typology is common along Massachusetts Ave, River Street, JFK St. and Cambridge St.

Large lots with open spaces

These prevalent use type are passive or active recreational parks or playgrounds. Active uses such as soccer or baseball fields require open skies and the potential for planting include creating or thickening a planting buffer at the edge of the lots. For passive parks, trees could be planted at higher densities. This type of use is spread out throughout Cambridge.

FIGURE 4.14 — INSTITUTIONAL AREAS

FIGURE 4.15 — REDEVELOPMENT AREAS

Institutional areas

The prevalent use type are university campuses and hospitals. This type has lower than average canopy cover with significant loss over the last decade. The two dominant universities in the area are Harvard University (29% canopy cover) and MIT (14% canopy cover). This type of use is concentrated in Area 2/MIT, Riverside, MidCambridge, and Agassiz.

Redevelopment areas

This refers to two special development zones. Through the Envision Cambridge process, an Alewife District Plan has been created to guide future development in Cambridge Highlands/North Cambridge. A 44 acres project called Cambridge Crossing in East Cambridge will introduce a new mixed use neighborhood. Planting opportunities will depend on the zoning ordinance guiding the development in these areas. These are two large areas of the city that will experience new construction where zoning can influence planting opportunity.

FIGURE 4.16 — DCR LAND

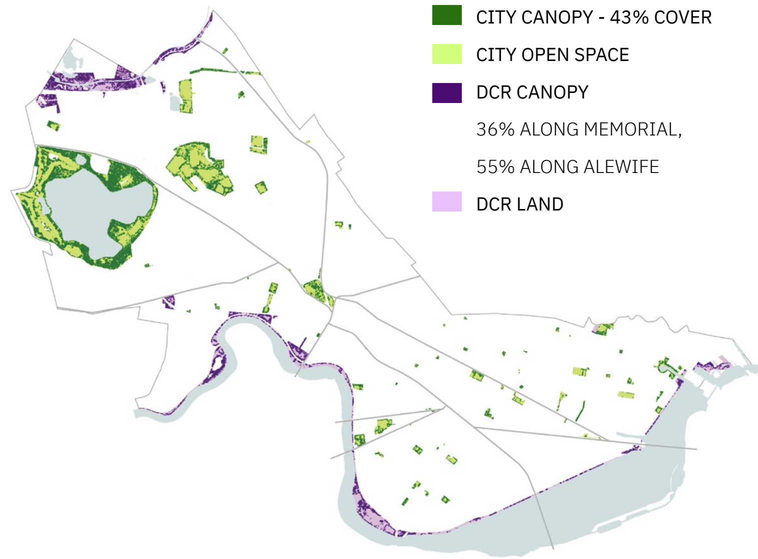


FIGURE 4.17 — COMPARISON OF CITY OPEN SPACE AND CANOPY AND DCR LAND AND CANOPY

DCR land

These prevalent use type are passive or active recreational parks or playgrounds. Planting opportunities are numerous as DCR land is open space. Canopy cover on DCR along the Charles River (36%) is less than the city average for open space (43%) (*Figure 4.16*).

PLANT WISELY

There is no single best-practices approach to planting trees in the public realm. Each opportunity must be approached critically and smart choices made to align species, planting detail, and soil strategy, to each unique condition. And in some cases, existing conditions may not be conducive to cultivating a canopy tree to maturity. In those situations, it may be better to not to plant trees and focus resources elsewhere, where a tree will thrive and apply other strategies to realize green infrastructure goals.

It is not a wise use of limited resources to invest money and time in planting trees in places where they are likely to fail. If trees are to be planted in challenging conditions, additional funds should be expended to enhance the chance of survival, which may include enlarging work areas to install additional soil volume, installing suspended pavements or structural soils, connecting treeways to front yards, or installing irrigation infrastructure.

For example, the analysis shows that street tree condition benefits greatly from adjacency to properties with front yard setbacks (*Figure 4.5*). Thus, planting strategies in the R.O.W. should differ based on sidewalk width and whether there is sufficient front yard setback. In areas with sidewalks less than 6', trees cannot be planted as American Disability Act Accessibility Guidelines (ADAAG) R301.3.1 recommended minimum width for a sidewalk pinch point is 4', leaving less than 2' for a street tree pit. In areas with sidewalks between 6 to 8' and without front yard setbacks, street trees should not be planted unless the conditions can be improved for the tree (*Table 4.2*). And in areas with limited initial soil volume, smaller bare root trees may be warranted, assuming they can be adequately protected in the early years of establishment. In areas with sidewalks greater than 8', the City should continue to improve management practices for existing trees, and for new trees, consider installing suspended pavement systems.

ON SIDEWALKS WITH....

SIDEWALK WIDTH	SUFFICIENT FRONT YARD SETBACK		INSUFFICIENT FRONT YARD SETBACK			
	ENCOURAGE FRONT YARD PLANTINGS	NEW STREET TREES SHOULD FOCUS ON PRACTICES	NO NEW STREET TREE PLANTINGS	ALTERNATIVE STREET DESIGN	ALTERNATIVE STRATEGIES	FOCUS ON PRACTICES
< 6' WIDE	√		√	√	√	
6' to 8'	√	√		√	√	√
> 8'	√	√		√	√	√

TABLE 4.2 — THE STRATEGY FOR HOW THE CITY ENCOURAGES PUBLIC REALM PLANTING NEAR THE R.O.W DIFFERS BASED ON SIDEWALK WIDTH AND WHETHER THERE IS SUFFICIENT FRONT YARD SETBACK.

4.4 Balance Competing Interests

While tree canopy forms an important part of the experience and functioning of the City, it is one among many physical elements that the City must provide provisions for. There are competing pressures for resources of space, time, and funding to respond. While many economic and social issues may seem more pressing, the urban forest is a critical component of many pressing concerns — climate resilience, equity, and livability — and is also one of many solutions.

SITUATE AND LINK PRIORITIES

The urban forest is not about a single issue, but is one linked to equity, resiliency, ecological diversity, and livability. It would be most efficient to link efforts to tackle these broad issues. In the process of designing streets, the City considers design for bicyclists, pedestrians, trees, scooterists, and public transportation riders. Transportation trends predict a less car-centric future and this provides an opportunity to envision a future city that provides more room for trees (see *Section 4.5*).

SHAPE SENSIBLE REGULATIONS

Because approximately two thirds of the trees in the city are on private property, the City should develop effective strategies for influencing planting and care on private property. The most broadly felt and impactful way to do that is through the Tree Protection Ordinance, which was amended in 2019. Prior to the amendment, the Tree Protection Ordinance only covered parcels that were undergoing a large development review or special permit process with the City. In 2019, the Tree Protection Ordinance was expanded onto property, with a one year moratorium on any issuance of tree permits on private property with exceptions. The City should balance sensible regulations for tree protection with the need to disincentivizing tree removals without making it too punitive. Refer to "Curb Loss With Tree Protection Ordinance" in *Section 6.3* for this Master Plan's recommended changes to the Tree Protection Ordinance.

TAKE A LONG-TERM VIEW THROUGH ZONING BYLAWS

Zoning is another effective way to influence planting on private property but is only relevant for new or redevelopment projects. In a city that is largely already built out, where open space is already at a premium and density continues to rise, there are few spaces to make significant immediate impacts with new planting. However, the city is always changing, being reshaped slowly by numerous projects to renew, reshape, and replace building stock.

Enhancing the City's Zoning bylaws to protect and advocate for the value of trees is an important long-term step in growing the City's canopy cover. Zoning can provide the space for trees by specifying setback requirements, and front yard setbacks are especially important for encouraging planting that will shade the R.O.W. Additionally, this study has found that permeable setbacks are associated with healthier R.O.W. trees (*Figure 4.5*). Refer to *Section 4.5* Policy Strategies for a discussion on potential zoning changes to encourage tree planting.

The City could also explore innovative approaches that rethink how space works on private property and encourage cooperative planting or maintenance between neighbors. As an example, a private homeowner may have a limited amount of open space on their property, but may be adjacent to a neighbor with a similar amount of open space. By aggregating open space between neighbors, enough room for trees and/or contiguous areas of canopy could be created.

This Master Plan has set canopy cover targets by land use type by looking at current canopy cover and what is feasibly plantable in the area remaining for each land use type (*Section 6.3*). This has informed recommendations for canopy cover requirements in the zoning ordinance (*Section 4.5* Policy Strategy 3A).

4.5 Strategy Toolbox

This study organizes potential response strategies into two buckets — curb loss and grow canopy — the two primary vectors by which we can change the future of the urban forest. Within these buckets, we further organize the range of response options into the following categories: Planning — broad urban design objectives that can be implemented at a range of scales. Policy — the legal and procedural frameworks developed by city government that can reduce removals or encourage planting. Design — innovative approaches to the design of landscapes to enhance the growth and vitality of trees. Practice — the day-to-day care of our trees, public and private, including soil vitality, watering, pruning, and pest and disease management. And Outreach and Education — the communications and strategies, including partnerships with existing institutions and groups to advance the goals of the study.

POLICY STRATEGIES

There are a variety of policy interventions available to cities and towns to help protect the urban forest. Policy options range from statutory and regulatory requirements to incentives, education, and partnerships. For Cambridge, there were several categories of intervention identified based on local and national best practices. These include: (1) enhancing and expanding the tree protection ordinance; (2) formalizing practices for planting and inspection; (3) strengthening zoning ordinance requirements; (4) enhancing the role of the Committee on Public Planting, and (5) leveraging public-private partnerships through grantmaking. Each of these options have benefits and drawbacks that should be used to assess the cost versus benefit and to prioritize implementation.

The various interventions detailed below are not exclusive. They can, and in some cases should, be pursued together to establish a more comprehensive policy framework for the City's management of the urban forest. Ultimately, the implementation of policies will need to address competing priorities and conform more holistically to the City's long-term vision.

The costs associated with implementing these policies are generally administrative costs to push forward ordinance changes, formalizing protocols, and institutionalizing recommendations.

RECOMMENDED POLICY STRATEGIES

1 Enhance and Expand the Tree Protection Ordinance
   - a. Redefine "Significant Trees"
   - b. Create an "Exceptional Tree" Category
   - c. Increase Mitigation Requirements
   - d. Expand Protections to all Private Property
   - e. Transition to elimination of "opt-out" option when siting street trees

2 Formalize Practices for Planting and Inspection
   - a. Align Priority Planting Areas with City's Commitment to Equity
   - b. Require City Arborist Inspection Prior to Occupancy
   - c. Improve Data Collection for Tree Replacement Fund and Fines
   - d. Develop and Implement Pruning Practices for Utilities

3 Leverage Land Use Requirements
   - a. Establish Canopy Coverage Requirements by Parcel through Zoning Ordinance
   - b. Increase Setback and Open Space Requirements in Priority Areas through Zoning Ordinance
   - c. Establish Flexible Landscape Requirements through Zoning Ordinance
   - d. Create New Parks in Canopy Deficient Neighborhoods through Land Transfers

4 Leverage Public-Private Partnerships
   - a. Earmark Tree Replacement Fund Dollars for Community Grants
   - b. Establish a Tree Trust
   - c. Strengthen and Clarify Existing Back of Sidewalk Program

5 Institutionalize Tree Priorities
   - a. Enhance the Role of the Committee on Public Planting
   - b. Institutionalizing importance of trees in the City Departments
   - c. Add Landscape Architect to Planning Board as Recommended by the UFMP Task Force

Cambridge Urban Forest and Strategy Matrix

STRATEGIES

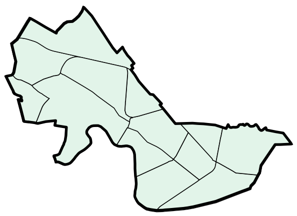
	in response to …	Policy: 1 Enhance and Expand the Tree Protection Ordinance	Policy: 2 Formalize Practices for Planting and Inspection	Policy: 3 Leverage Land Use Requirements	Policy: 4 Leverage Public-Private Partnerships	Policy: 5 Institutionalize Tree Priorities	Design: 6 Plant Resilient Species	Design: 7 Street Tree Planting Strategies	Design: 8 Site New Parks and Open Space Strategically	Practices: 9 Improve Monitoring	Practices: 10 Expand Maintenance	Practices: 11 Expand Planting Practices	Outreach: 12 Invest in Educational Programs	Outreach: 13 Build Community Partnerships	Other: 14 Seek Alternative Green Strategies	Other: 15 Integrate UFMP into Complementary Planning Studies
Curb loss	Mature canopy decline	•					•							•		
	Land conversion	•		•										•		•
	Tree removals	•		•		•							•	•		
	Poor tree condition	•	•	•			•				•	•	•	•		
	Planting conditions			•								•			•	
	Understanding the value of trees				•	•							•	•		
Grow canopy	Equity in distribution of canopy cover	•	•	•	•	•		•	•	•	•	•	•	•		•
	Shading and cooling / pedestrian thermal comfort	•	•	•	•	•		•	•	•	•	•		•		•
	Environmental quality / wellbeing and public health	•	•	•	•	•	•	•	•	•	•	•		•	•	•
	Ecological connectivity	•		•		•	•	•	•	•	•	•			•	•
	Diversity of forest composition					•	•	•		•	•					

TABLE 4.3 — STRATEGY MATRIX

POLICY STRATEGY 1A

Redefine Significant Trees to 6” DBH

IMPACT AREAS



STEM LOSS

GROW CANOPY

SUMMARY

For projects requiring a special permit from the Planning Board or development projects subject to large project review (25,000 sq. ft. or more), the city’s tree protection ordinance provides certain protections. These protections only apply to “Significant Trees,” which are defined as trees greater than 8” DBH.

Other cities and towns locally and across the country offer protections for trees with a lower DBH. In particular, protections for trees with 6” DBH or greater is common.

ANALYSIS

The statistical sample of Cambridge’s tree population completed as part of this study found that of 4,118 trees inventoried, 41 percent measured greater than 8 inch DBH versus 60 percent which measured 6” DBH or greater. If the city were to redefine Significant Trees as 6” DBH or greater, this would increase the number of trees captured under the ordinance for the purposes of new or redevelopment by about 49 percent.

PROS

Increases the number of trees protected by the ordinance

Burdens large projects rather than individual residents or the City

CONS

Applies to more proposed development projects and thus requires additional city resources to review and approve plans

Adds cost to certain projects, including those which provide housing and other community values

PRECEDENTS

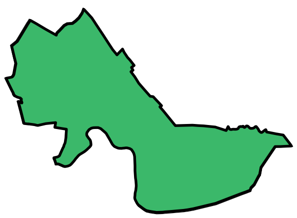
National:
Atlanta, Georgia
Seattle, Washington
Oakland, Florida
Miami, Florida
Anna, Texas

Local:
Concord, Massachusetts
Lexington, Massachusetts
Brookline, Massachusetts

POLICY STRATEGY 1B

Protect trees over 30” DBH as Exceptional Trees

IMPACT AREAS



STEM LOSS

GROW CANOPY

SUMMARY

The Tree Protection Ordinance currently treats all trees over 8” DBH the same, no matter their age or size. The City’s largest trees, however, provide unique ecosystem services and it takes decades to replace their benefits.

Other cities have designated their largest, most significant trees “Exceptional Trees” and provided additional layers of protection for them. In some cities, Exceptional Trees cannot be removed unless they are diseased or hazardous. In others, they simply require greater mitigation or demonstration that preserving the tree is infeasible. Exceptional Tree designations are often based on size, age, species, or horticultural, cultural or historical value.

ANALYSIS

The city can use the addition of an Exceptional Trees category to implement more stringent standards without applying these standards broadly to all trees. Defining “Exceptional Trees” as those trees over 30” DBH is an objective, easily applied standard.

Increasing scrutiny of their proposed removal and increasing mitigation costs upon removal could reduce loss of the City’s largest and oldest trees. The Ordinance could also define additional protective measures for maintenance of these trees during adjacent construction. While this would not increase the City’s jurisdiction or the number of trees under the Tree Protection Ordinance, it would help protect the city’s most valuable trees.

PROS

Protects the City’s most valuable trees

Establishes explicit statutory preference for large trees

CONS

Does not increase the number of trees under the jurisdiction of the tree protection ordinance

Requires additional city resources for tracking and enforcement

Adds cost to certain projects, including those which provide housing and other community values

PRECEDENTS

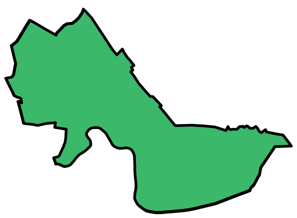
National:
Seattle, Washington
Washington, DC
Atlanta, GA
Arlington, VA
Savannah, GA
Pasadena, CA
Miami, FL

Local:
Wareham, Massachusetts

POLICY STRATEGY 1C

Increase mitigation costs

IMPACT AREAS



STEM LOSS

GROW CANOPY

SUMMARY

Under the current Tree Protection Ordinance, a large project proposing to remove a Significant Tree must either replace the total trunk diameter of the tree onsite or make an in-lieu payment into the Tree Replacement Fund.

The current formula for payment is based on the average cost of a 2-inch caliper tree multiplied by a factor of 4 for installation, maintenance, and potential replacement over a five-year period plus additional maintenance costs associated with watering and pruning (about $1700/tree). For example a 12” tree requires a payment of $10,200 (12” / 2 (number of 2” trees to equal 12”) X $1,700).

Many other cities use a standard called the Trunk Formula Method which recognizes the value of larger trees and adjusts costs with respect to tree health and the value of different species.

ANALYSIS

In light of the exceptional value of land in Cambridge, there is little incentive under the current system for a project proponent to minimize tree removal or replant onsite. The costs are small compared to development value.

Increasing mitigation requirements and providing an incentive to preserve trees onsite could help curb canopy loss. Employing the International Society of Arboriculture’s (ISA) Trunk Formula Method, which calculates tree replacement by trunk area rather than by diameter could change the cost of removing the same 12” tree to anywhere between $7000 to $50,000 depending on the tree species, tree location, and tree condition.

This formula also factors in species, tree condition, and location, recognizing that not all trees are equal in value. Other factors such as land ownership and economic status can also mitigate costs and enhance equity.

PROS

Dramatically increases the replacement costs for tree removal, which would either incentivize proponents to preserve trees on site or generate greater contributions to the Tree Replacement Fund, which can be used to plant elsewhere

CONS

Adds cost to certain projects, including those which provide housing and other community values

Requires more City resources for enforcement and replanting practices

May de-incentivize new tree plantings for owners concerned about future removal costs

PRECEDENTS

Many other cities and towns use the ISA Trunk Formula Method for appraising costs; however, not all are tied to tree protection ordinances and mitigation requirements.

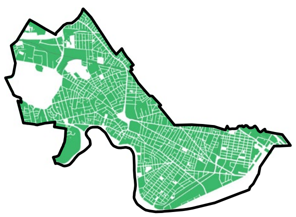
National:

Seattle, WA (fines for violation)
Palo Alto, CA
Boulder, CO
New York, NY

POLICY STRATEGY 1D

Extend Tree Protection Ordinance jurisdiction to all private property

IMPACT AREAS



STEM LOSS   GROW CANOPY

SUMMARY

The City of Cambridge historically has had no jurisdiction over the removal of trees on private property except when subject to large project review (25,000 sq. ft. or more). In 2019, City Council passed an amendment to the Tree Protection Ordinance requiring a city-administered permit for all removals and placing a one-year moratorium on the removal of all Significant Trees, including on private property, except in specific circumstances.

Other cities have expanded local jurisdiction to all private properties, requiring a permit for all tree removals and including various mitigation costs for removals of significant trees.

ANALYSIS

Expansion of the Tree Protection Ordinance to trees on all private property would vastly expand the number of tree removals receiving scrutiny each year.

Requiring a permit for removal (with a nominal filing cost) will allow the City to track removals and encourage owners to replant when trees are removed. Requiring mitigation replanting or payment (see Policy Strategy 1C) may reduce removals, but measures will need to be taken to make sure the process is not economically burdensome and inequitable. It would be possible to phase in more stringent requirements if initial efforts did not adequately stem loss.

PROS

Curbs cumulative canopy loss on private property

Generates revenue to offset administrative costs associated with the permit program and enforcement efforts

CONS

Could be a cost burden and/or bureaucratic inconvenience for city residents

May act as a disincentive for property owners to plant new trees on their properties fearing future penalties

Could be resource-intensive and difficult to monitor and enforce, resulting in high administrative costs

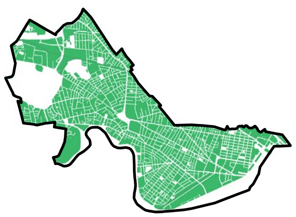
PRECEDENTS

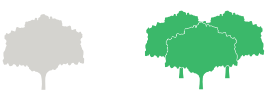
Local:	National:
Arlington, MA	Nashville, TN
Concord, MA	Dallas, TX
Brookline, MA	Atlanta, GA
Lexington, MA	Seattle, WA
	Portland, OR
	Washington, DC
	Providence, RI

POLICY STRATEGY 1E

Transition to remove “opt-out” option when siting new street trees

IMPACT AREAS





STEM LOSS GROW CANOPY

SUMMARY

When the City proposes to plant a street tree in the public realm, the City allows immediately adjacent landowners to opt out, effectively blocking the planting. Owners do not need to provide any rationale or reason behind their decisions.

This effectively reduces opportunities to increase canopy cover over the public right of way and elevates the rights of single property owners over the public good.

ANALYSIS

There are no records to identify how many sites have been impacted by opt-outs, but anecdotal reports from the City suggest it is a significant number.

Transition to the elimination of the "opt-out" option as the number of trees being planted in the ROW increases. The transition will be assisted by the development of the education and outreach plan which will further build support in the neighborhoods for more street trees planted in groves and with less separation from each other. Removing this option may have ramifications for individual land-owners, but will likely provide improvements to the connectivity of shaded canopy corridors in the public ROW.

PROS

Increases the number of planting opportunities within the public right of way

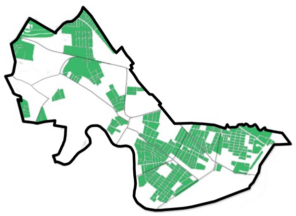
CONS

Impacts perceived independent property rights

POLICY STRATEGY 2A

Align planting protocols with the City's commitment to equity

IMPACT AREAS



STEM LOSS

GROW CANOPY

SUMMARY

Cambridge does not currently have a formal policy that governs how the City determines the location of new City-sponsored tree planting. No protocols govern how resources for planting are prioritized or allocated across the city's neighborhoods.

Historically, the City has planted trees where residents have requested plantings, where existing tree pits exist need to be filled, or where construction projects are underway. This practice has the tendency to perpetuate existing patterns and, consequently, inequity in the distribution of trees across the City.

ANALYSIS

Tree canopy plays a major role in mitigating the urban heat island effect and green infrastructure forms an essential part of stormwater management systems potentially reducing localized flooding, yet the these ecosystem services are inequitably distributed across the City.

The City can address this inequity by establishing a formal protocol for new plantings that is based on objective tree survey data and that prioritizes areas with poor canopy coverage and/or environmental justice communities that are likely to experience disparate extreme heat impacts. The City of Boston has implemented a similar system for sidewalk repair in response to an analysis that showed inequitable distribution of new sidewalks when undertaken in response to citizen request.

PROS

Prioritizes new trees in areas of the city that are in the most need

Helps to better mitigate climate impacts for populations at risk

Protocol is formal and based on data

Allows city to reinforce its commitment to equity

CONS

Requires regular analysis of canopy distribution and updating of priorities that depends on staffing resources

PRECEDENTS

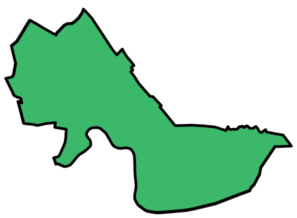
Local:
Boston, MA (for sidewalk replacement)

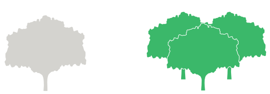
National:
New York, NY
Cleveland, OH

POLICY STRATEGY 2B

Require City Arborist Inspection Prior to Occupancy

IMPACT AREAS





STEM LOSS GROW CANOPY

SUMMARY

Cambridge's City Arborist does not currently verify that Replacement Trees have been planted at construction sites in accordance with the requirements of the Tree Protection Ordinance. It is presumed that trees planted will be properly maintained for a period of 5 years, but there is no independent and recurring verification.

As such, compliance is hard to track and it is currently unclear to the Department of Public Works how often proponents are meeting their requirements.

ANALYSIS

Amending the Tree Protection Ordinance to include a verification requirement before giving a Certificate of Occupancy could increase compliance and also improve DPW's ability to collect data/information on compliance. Arborist verification can take many forms including assessment of the placement, soil suitability, planting depth and pit size to ensure that the planting of trees is consistent with city guidelines and practices. This review could be expanded even further to include a "performance guarantee" held in case standards are not met. This is the practice in Concord, MA where all replacement trees must be planted within 90 days, otherwise the city requires a performance guarantee in an amount equal to the mitigation cost.

PROS

Incentivizes projects to submit landscape plans that are achievable and appropriate for the lot

Increases compliance with the Tree Protection Ordinance and allows DPW to collect better data/ information on compliance

CONS

Requires additional staff time that could be cost-intensive for the city

May be logistically challenging to determine how the City Arborist fits into the existing inspection process and would need to be coordinated with other city departments

PRECEDENTS

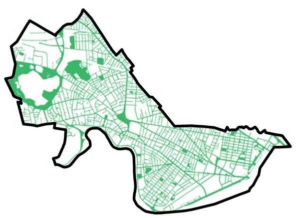
Local:
Concord, MA

National:
Dallas, TX
Miami-Dade County, FL
Portland, OR
Atlanta, GA

POLICY STRATEGY 2C

Improve data collection for Tree Replacement funds and fines

IMPACT AREAS



STEM LOSS GROW CANOPY

SUMMARY

At present, the efficacy of the Tree Protection Ordinance is difficult to quantify due to a lack of data around enforcement and compliance. Without a baseline measure for the efficacy of the current protections, it will be hard to gauge the success of amendments/revisions to the Ordinance.

ANALYSIS

The Department of Public Works is working to expand data collection associated with payments into the Tree Replacement Fund, the collection of fines for removal, marking or injuring a tree under MGL Chapter 87 and future fines for violations of the Tree Protection Ordinance. The City currently has a project to add enforcement cases, including tree violations, to the same online permitting platform that tracks the new Tree Protection Ordinance. The Department has also begun exploring ways to bring Tree Replacement approvals and payments related to large development projects onto this online system. Doing so would provide more robust data collection, monitoring and enforcement and enable the City to better gauge the success of new policies and programs.

PROS

Improves city's baseline knowledge of enforcement and compliance

Makes it easier for the city to gauge the success of new policies/programs

Could help inform a more strategic approach to enforcement

CONS

Could be time and resource intensive for the City

PRECEDENTS

National:

Seattle, WA*
Columbus-Muscogee County, GA
Athens-Clarke County, GA
*currently considering more strategic data collection and monitoring

POLICY STRATEGY 2D

Develop and implement pruning practices for utilities

IMPACT AREAS

STEM LOSS GROW CANOPY

SUMMARY

Under MGL Chapter 87 Section 14, it is within the power of the City Arborist to require utility companies to submit annual Vegetation Management Plans and Hazard Tree Removal Plans. A Vegetation Management Plan lays out the maintenance work to be conducted within a city or town over the year and a Hazard Tree Removal Plan details the trees to be removed. These plans provide the tree maintenance standards to be followed and include any proposed variations from those standards, giving the City Arborist insight into locations where standards are not followed and why. Cambridge also has the authority to institute local regulations governing the placement of utility infrastructure and street trees. Under Chapter 87 Section 14 utilities are required to comply with any additional local ordinances and regulations that standardize utility tree pruning across a city or town.

ANALYSIS

It is unclear whether the City currently utilizes its full authority under this statute to obtain plans or regulate the maintenance of trees by utility companies. Obtaining this information allows Cambridge to predict where future utility maintenance work and tree removal will occur and plan accordingly.

Instituting local regulations that govern the placement of utility infrastructure and street trees could also help to limit conflicts between trees and utilities. Formalizing pruning standards may also improve the long-term structure and health of City trees near above-grade utilities.

PROS

Formalizes practices with utility companies so they are consistent over time and staff changes

Creates consistency for utility companies

Gives City an enforcement role

CONS

Could be time and resource intensive for the City

PRECEDENTS

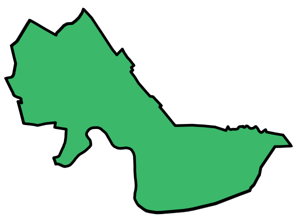
National:

New York,
NY; Providence, RI;
Hillsboro, OR;
Southborough, MA

POLICY STRATEGY 3A

Establish canopy coverage requirements by parcel through Zoning Ordinance

IMPACT AREAS



STEM LOSS GROW CANOPY

SUMMARY

Today, Cambridge has 26 percent of its land area covered by canopy. Between 2009 and 2018, the canopy declined on average by 16.4 acres every year. At this rate, canopy cover will be 21.6 percent in 2030.

This is also a time period in which significant redevelopment has taken place, and long-term plans such as Envision Cambridge are currently setting out a vision for the next areas of significant development. Zoning is the most effective way to influence development, but currently Cambridge zoning has little specific direction about trees or canopy cover.

The concepts behind this strategy have been taken under consideration by the Resilient Zoning Task Force.

ANALYSIS

If the City amended the Zoning Ordinance to require specific canopy coverage percentages by land use or district, future development would be structured to contribute to overall City-wide goals. Emphasis or higher percentages could be applied to priority areas such as canopy corridors through an overlay district. If cover requirements were to apply citywide, they could be incorporated into the existing requirements/standards for open space or established as a separate minimum requirement alongside the existing setback and open space requirements applied to each zoning district and land use type.

Land Use Type	2018 Acres of Land Use Overall	2018 canopy cover	Canopy cover target (DRAFT)	Plantable area (not currently canopy covered)	New canopy acres to meet canopy cover targets
Residential - no setbacks	192	16%	20%	44	17
Residential - setbacks	1363	29%	35%	440	86
Institutional	436	20%	30%	111	44
Commercial/industrial	558	9%	15%	126	34

PRECEDENTS

National:

Chapel Hill, NC
Providence, RI
Manassass, VA
Augusta, GA

PROS

Creates more consistency and predictability for property owners and developers

Focuses coverage goals in high priority areas

Targets areas where canopy growth is most appropriate

CONS

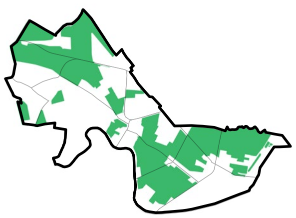
Conflicts with competing priorities in the zoning/ development processes

Requires amendments to zoning, which is likely to be a complex process

Applies only to new development and construction projects, having impact only over the long term

Increase front setback and open space requirements in priority areas through Zoning Ordinance

IMPACT AREAS



STEM LOSS GROW CANOPY

SUMMARY

Various tree-related requirements and landscape mandates are currently scattered throughout City zoning. Most of these requirements are tied to narrowly defined site uses (such as parking facilities or townhouses) and limited districts (such as the Parkway or Prospect Street Overlay Districts).

The Zoning Ordinance also includes requirements for setbacks and open space, which have implications for the amount of area available for planting on sites, but do not specifically define the amount of planting required.

The concepts behind this strategy have been taken under consideration by the Resilient Zoning Task Force.

ANALYSIS

The City of Cambridge could increase the minimum front setback and open space requirements for all or certain zoning districts to increase the amount of space available for planting on lots. While many of the City's residential districts have substantial requirements, most industrial and business districts in the city have little or no front setback and open space requirements. This would not require the implementation of a new concept; rather it would simply involve a revision to the existing minimum requirements. The city could coordinate increased requirements to match the areas designated as "high priority" for planting and preservation. The City could customize enhanced planting areas based on building typology, land use, urban form, and other factors.

PROS

Increases plantable area on new development sites

Targets high priority areas

CONS

Conflicts with other City goals of density and consistency with existing urban form

Require amendments to zoning, which is likely to be a complex political process

Places burdens on redevelopment projects

Applies only to new development and construction projects, having impact only over the long term

PRECEDENTS

National:

Baltimore, MD*

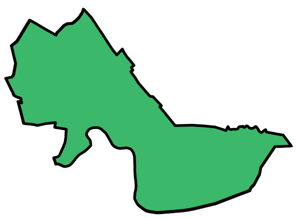
Austin, TX*

*Note that these cities did not increase setbacks and open space requirements for the sole purpose of facilitating planting in high priority areas but did use sociodemographic and other factors to determine high priority planting areas.

POLICY STRATEGY 3C

Establish flexible landscape requirements through Zoning Ordinance

IMPACT AREAS



STEM LOSS

GROW CANOPY

SUMMARY

Cambridge's Zoning Ordinance currently takes a broad approach to landscape requirements based on land use types and zoning district. The Ordinance includes separate definitions for the following areas: (i) open space, green area; (ii) open space, permeable; (iii) open space, public; (iv) open space, publicly beneficial; (v) open space, private. Some of the zoning articles refer to the term "landscaped green area," but this is not a defined term in the ordinance.

Other cities have implemented more comprehensive systems to describe, value and encourage integrated green infrastructure including tree preservation and planting. These systems are flexible, recognize that not all properties can accommodate the same landscape elements, and allow for trade offs with other zoning values, like density.

The concepts behind this strategy have been taken under consideration by the Resilient Zoning Task Force.

ANALYSIS

Implementing a more flexible system that acknowledges and balances the value of all green infrastructure including contributions to canopy cover could help to consolidate the existing landscape requirements, making them more consistent across the city and more flexible for property owners.

Sometimes referred to as a "Green Factor," this type of system can be designed to encourage mature tree retention and tree planting through multipliers "increasing" their relative value, but would allow property owners who cannot meet canopy coverage requirements to achieve similar goals with alternative green infrastructure features like green roofs, rain gardens, planting areas, and other features. This is a complex system needing thorough analysis and periodic review to ensure the goals of the system are being realized.

PROS

Creates a more flexible framework for development while encouraging integrated green infrastructure

Allows differential valuation of mature tree retention and new tree planting

Supports and is integrated with proposed zoning revisions related to overall City-wide resiliency

CONS

Needs to balance competing priorities in the zoning/ development processes

Applies only to new development and construction projects, having impact only over the long term

Is time intensive for staff to evaluate, monitor and enforce

PRECEDENTS

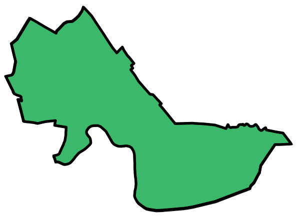
National:

Washington, DC (Green Area Ratio)

Seattle, WA (Green Factor)

Create new parks in canopy deficient neighborhoods through land transfers

IMPACT AREAS



SUMMARY

In many of Cambridge's neighborhoods with the lowest canopy cover percentages, there is limited space — due to density, street width and land use type — to plant more trees. In these neighborhoods, the only option may be to create new landscaped spaces which can be developed with significant canopy density.

ANALYSIS

Within the zoning / development review process as the City negotiates with private and institutional development partners, it can prioritize creation of new parks as outcome of zoning compliance negotiation. This process can lead to land transfers making new park space possible in dense areas.

The construction of new parks by private developers is a cost effective avenue for the creation of new parks within Cambridge, although these values must be weighed against the City's need to create more housing and other civic infrastructure.

PROS

Finances the expansion of open space and new tree canopy with private money

CONS

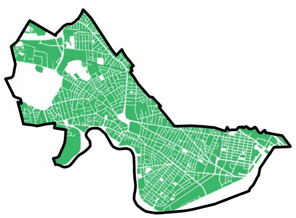
Displaces other uses for new park creation

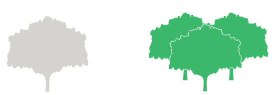
May not be able to align new open spaces with areas of canopy deficit and could increase canopy inequality

POLICY STRATEGY 4A

Earmark Tree Replacement Fund dollars for community grants

IMPACT AREAS





STEM LOSS GROW CANOPY

SUMMARY

The city is limited in its ability to financially support tree planting on private property outside of the development review process. State law prohibits direct improvements to private property by the City, and planting trees could be considered a form of aid to private owners.

The current Back of Sidewalk program utilizes the authority under the State's Public Shade Tree law to plant shade trees within 20 feet of the public right-of-way with the property owner's consent, but the program has had limited success and only applies to front yards.

ANALYSIS

Given the legal constraints of the State's Public Shade Tree law and the limited success of the existing Back of Sidewalk Program, an alternative strategy available to the city to encourage planting is voluntary and privately organized programs that assist property owners in obtaining, planting, and/or paying for new trees.

The City should review the legal framework for earmarking a portion of funds deposited in the Tree Replacement Fund for community-based grant making that could help fund operations to encourage planting on private property. This could be modeled on Portland's "Neighborhood Planting Days," where the non-governmental organization Friend of Trees organizes a planting day, trains volunteers, and notifies residents of the availability of trees.

PROS

Provides multiple benefits including planting, education, and community-building

Increases the capacity of residents to plant trees in underserved neighborhoods by providing technical assistance and subsidizing the costs associated with planting or maintenance

CONS

Requires legal framework to avoid challenge in courts

Depends on the residents/neighborhoods to opt-in and take advantage of the services (including subsidies), and therefor may further exacerbate inequitable distribution of canopy across the City

PRECEDENTS

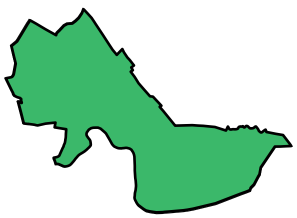
These cities do not necessarily earmark mitigation dollars for these programs but run voluntary planting programs that could provide a model for Cambridge.

Local:
Somerville, MA
National:
Portland, OR
San Francisco, CA
Los Angeles, CA
Denver, CO
Washington, DC

POLICY STRATEGY 4B

Establish a Tree Trust

IMPACT AREAS



STEM LOSS

GROW CANOPY

SUMMARY

The City does not currently have a mechanism for accepting private contributions to support their tree canopy operations including planting and maintenance programs. The existing Tree Replacement Fund is narrowly defined in the Tree Protection Ordinance and is comprised primarily of mitigation payments from development projects.

Examples of Tree Trusts are mixed between ones run out of a government department and ones that are a standalone 501(c)(3), with the potential for the City to have a seat on the board of the organization.

ANALYSIS

A Tree Trust could be a useful mechanism for the City to solicit and manage private contributions from individuals, foundations, organizations, and corporations. These funds can assist the City with carrying out a range of activities related to urban forestry including public awareness and education campaigns, tree planting and maintenance, and more. The establishment of the Trust could also help facilitate stronger public-private partnerships to support expanding the tree canopy in Cambridge beyond monetary contributions. For example, a Trust could help lay the foundation for individuals or businesses to volunteer time or lead planting efforts. This report recommends that a legal analysis be undertaken to assess the ability of such a trust to also fund planting on private property.

PROS

Facilitates public-private partnerships

Assists the city in tree-related activities by supplementing resources

CONS

Requires a strong legal framework and organizational development

Requires dedicated staff to manage

PRECEDENTS

National:	Local:
New York, NY	Brookline, MA
Baltimore, MD	Lowell, MA
Twin Cities, MN	Newton, MA
Portland, ME	
Montgomery, OH	

POLICY STRATEGY 4C

Strengthen and clarify existing Back of Sidewalk program

IMPACT AREAS

STEM LOSS

GROW CANOPY

SUMMARY

Under MGL Chapter 87, the City Arborist, using public funds and with the permission of the private property owner — can plant a public shade tree within 20 feet of the public right of way. This designation bestows all the protections of a public shade tree onto the new tree, including that a hearing must be held for its removal if the tree is larger than 1.5 inches DBH. Cambridge exercises this authority through its Back of Sidewalk program, which is voluntary program for residents who wish to have a tree planted in their front or side yard by the City and at the City's expense.

Currently, public understanding of and participation in the program is low.

PROS

Builds on an existing program/mechanism

Increases visibility and/or effectiveness of program

CONS

Could discourage residents from participating

Adds costs and requires resources from the City

ANALYSIS

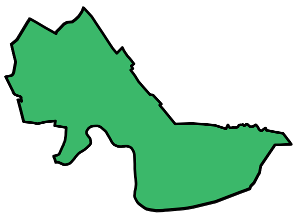
While enforcing the Public Shade Tree law for trees planted under the program may discourage participation, it could be argued that it would strengthen protections for these trees on private property. The Back of Sidewalk program should be coupled with an educational outreach campaign to homeowners who may have a public shade tree or may want a public shade tree. Increasing the visibility of the program may increase participation.

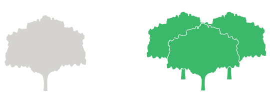
Public education is important so that participants are fully aware of what the designation as a public shade tree entails and how to find out if a tree is a public shade tree. This information could be provided through a user-friendly city resource. If promoted appropriately, it would help boost knowledge of the program's existence and the stipulations attached to public shade tree designation.

POLICY STRATEGY 5A

Enhance the role of the Committee on Public Planting

IMPACT AREAS





STEM LOSS GROW CANOPY

SUMMARY

The Cambridge Committee on Public Planting is established under Chapter 2 of the City Code of Ordinances. The stated purpose of the Committee is to promote and improve the quality and diversity of public plantings throughout all areas of the City. Specifically, the Committee is charged with advising the city administration, Public Works Commissioner and other departments on public planting matters including effective maintenance; to serve as a local resource for public planting programs and ideas; to review planting plans for public works in the City for the appropriateness of plants, placement, and maintenance concerns; to provide support for the City Arborist and Tree Warden; to encourage the public's interest in plantings across all neighborhoods; and to undertake any other activities in line with the Committee's purpose.

ANALYSIS

The Committee serves in an advisory capacity. However, for Residential Zone C-2B [single- and two-family detached dwellings, townhouse dwellings, multi-family dwellings (apartments and condos), and some institutional uses,] the Committee on Public Planting is required to review and approve plans for landscaping and maintenance pursuant to Article 5 of the City's Zoning Ordinance.

As the Committee is an existing, city-sanctioned body its advisory role could be enhanced to assist with interpreting recommendations, updating analysis based on current research, reviewing pilot projects, and reviewing/monitoring progress toward the targets set in this report. An example could include workshops on advances in urban forestry practices, and participation in annual meetings with the bicycle, pedestrian, transit and disability committees to discuss policies relative to the public right of way.

PROS

Enables specific advocacy for urban forest within city planning processes

CONS

Increases costs for and requires attention of City staff

Adds to the burden on volunteer committee members

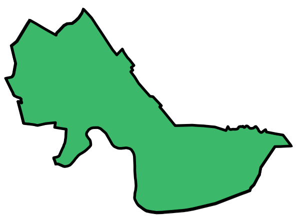
PRECEDENTS

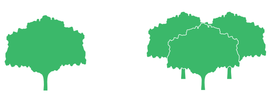
National:
Chicago, IL
Atlanta, GA
Edgewood, PA

POLICY STRATEGY 5B

Emphasize the importance of trees across City departments

IMPACT AREAS





STEM LOSS GROW CANOPY

SUMMARY

The findings of this report suggest that trees are integral to realizing multiple goals defined by the City — climate resiliency, public health, equity, economic development, and livability. Yet responsibility for the urban forest is closely held within DPW and the City Arborist.

A more integrated approach to advancing the goals for the forest can galvanize deeper and broader support for this report's recommendations and can advance other civic goals as well.

ANALYSIS

In order support the goals of the UFMP, the City could institutionalize the importance of trees within relevant departments and committees. For example:

-The Committee on Public Planting, Bicycle Committee, Pedestrian Committee, and the Climate Protection Action Committee should meet annually to ensure tree planting and protection are integrated into initiatives.

-Tree planting with best-practice planting details should be integrated into all infrastructure and transportation planning efforts.

-The City's Five Year Sidewalk and Street Reconstruction Plan already includes the stated goal of including tree planting whenever feasible. While the plan states that "the City Arborist will review each street and sidewalk project to determine tree planting opportunities," the City should consider explicitly assigning additional responsibility to design professionals within the engineering department for creating new planting opportunities whenever possible.

POLICY STRATEGY 5C

Add Landscape Architect to Planning Board

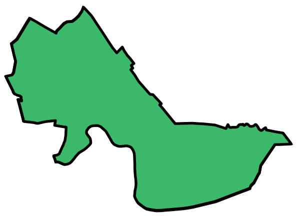
SUMMARY

While the Cambridge Planning Board reviews and advises on projects that influence the public realm and often include decisions about tree removals and landscape development, there is no defined role for a landscape architect at the table.

ANALYSIS

Requiring that a landscape architect to hold one seat on the Planning Board would ensure that the interests of the public realm and urban forest are given voice during important deliberations. This policy strategy was recommended by the UFMP Task Force

IMPACT AREAS



STEM LOSS

GROW CANOPY

DESIGN STRATEGIES

Design strategies pertaining to tree planting are organized by considering what tree species should be planted, where should the trees be planted, and how should they be planted.

1. WHAT DO YOU PLANT?

Plant resilient species

To create a resilient urban forest, this plan recommends:

- Plant well-adapted species with a higher climate resiliency score (refer to *Section 3.5* Climate Resilience Score)
- Plant fewer species that already have met their proportion limits
- Diversify forest to the extent possible

To add resiliency to the urban forest, this plan recommends diversifying the number of species and the abundance of species to the fullest extent possible. Santamour (1990) recommends arborists plant no more than 10% of any species, no more than 20% of any genus, nor more than 30% of any family.[4] Melbourne Urban Forest Diversity Guidelines (2011), has put forth an ambitious target of no more than 5% of the forest is to be any single species, no more than 10% is to be of any one genus, no more than 20% is to be of any one family by 2040[5]. Melbourne target is one to certainly strive for, but may be difficult to achieve because the Northeastern forests are composed mostly of certain genus such as oaks and maples. While this plan recommends aiming to follow Santamour's guidelines at a minimum, the city can strive for the more ambitious target in the long term.

Current species on the City's recommended list that have exceeded their current distribution thresholds are Honey Locust, Pin Oaks and Red Oaks. Current genus that have exceeded their current distribution thresholds are Maples. This plan does not recommend planting these species, but to consider other species first, and to plant these species more sparingly. The top three species in Cambridge (Norway maple, honey locust, pin oak) comprise 33% of the canopy cover in the Cambridge forest, and catastrophic loss of these species would mean canopy cover would drop to 17% cover citywide. Thus, it is important to diversity species to avoid losing too much canopy associated with one species.

Species were evaluated based on their climate resiliency (pest/disease resiliency, drought tolerance, flood tolerance, further discussed in *Section 3.5* Climate Resiliency Score), and their relative urban street tolerance (RUST). The RUST score, developed by Dr. Bryant Scharenbroch, evaluates trees by how well they tolerate urban stresses of pH, hardiness, sun, insects/diseases, physiology/environmental, moisture, salt, texture, compaction[6]. Species with higher tolerances to urban stresses and higher wood densities appear to have the highest potential for sequestering. Carbon sequestration rates are greatest for species such as cedar and larch, then pines, spruce, first and hemlock, then oak, maple hickory, beech and birch, and finally short lived species such as aspen, alder, cottonwood and willow have the lowest carbon sequestration potential.

One of the potential products of this Master Plan is an on-line interactive database to help the City and the public select tree species based on resiliency, planting situation, condition and current abundance in the forest. Users can sort by size, planting location, sun exposure, flooding tolerance, native/non-native, and soil type. See Appendix N for a static version of the database.

While native versus non-natives remains an ongoing academic discussion, recent studies conclude that there is little significant difference between the two in supporting wildlife[7, 8, 9]. Thus, in the urban environment, well adapted native and non native species are recommended because diversity is important for a healthy forest, and many nonnatives are proven to do well in the tough conditions of city sidewalks.

Underwire trees

Latin Name	Common Name
Acer campestre	Hedge Maple
Acer griseum	Paperbark Maple
Amelanchier sp.	Serviceberry
Cercis canadensis	Eastern Redbud
Maackia amurensis	Amur maackia
Prunus 'Accolade'	Accolade cherry
Prunus sargentii	Sargent cherry
Prunus serrulata 'Kwanzan'	Kwanzan cherry
Prunus serrulata 'Snowgoose'	Snowgoose cherry
Prunus subhirtella 'Autumnalis'	Autumun cherry
Prunus x yedoensis 'Akebono'	Akebono cherry
Prunus x incarn 'Okame'	Okame cherry
Malus sp.	Crabapple sp.
Syringa reticulata	Japanese Lilac Tree

Canopy trees

Latin Name	Common Name
Acer x fremanii	Armstrong Red Maple
Acer rubrum	Red Maple
Betula nigra	River Birch
Carpinus caroliniana	Hornbeam
Celtis occidentalis	Hackberry
Cercidiphyllum japonicum	Katsuratree
Ginkgo biloba	Ginkgo
Gleditsia triacanthos	Honeylocust
Gymnocladus dioicus	Kentucky Coffeetree
Koelreuteria paniculata	Golden Raintree
Liriodendron tulipifera	Tuliptree
Liquidambar styraciflua	Sweetgum
Metasequoia glyptostroboides	Dawn Redwood
Nyssa sylvatica	Black Tupelo
Platanus x acerifolia	London Planetree
Pyrus sp.	Pear spp.
Quercus bicolor	Swamp White Oak
Quercus palustris	Pin Oak
Quercus rubra	Red Oak
Quercus velutina	Black Oak
Sophora japonica	Sophora
Tilia cordata	Littleleaf Linden
Tilia tomentosa	Silver Linden
Ulmus americana	American Elm
Ulmus sp.	Elm cultivars
Zelkova serrata	Zelkova

Trees with low condition ratings
Trees that exceed diversity target
Trees that have high susceptibility to climate risks

TABLE 4.4 — EVALUATION OF LOW CONDITION AND EXCEEDING DIVERSITY TARGETS

The recommended list of species should be revisited on a five year basis and adjusted per diversity targets.

Current additional recommendations to the City's tree planting list are:

Under-wire trees

Ostrya virginiana	American Hop Hornbeam
Chionanthus retusus*	Chinese Fringetree
Maclura pomifera 'White Shield'**	White Shield Osage Orange
Syringa pekinensis	Peking Lilac
Cornus x	Hybrid Dogwoods
Parrotia persica	Persian Parrotia

Canopy trees

Aesculus hippocastanum***	Horsechestnut
Aesculus flava***	Yellow Buckeye
Carya glabra***	Pignut Hickory
Carya ovata***	Shagbark Hickory
Eucommia ulmoides	Hardy Rubber Tree
Taxodium distichum	Bald Cypress
Taxodium distichum var. Imbricatum	Pond Cypress
Cryptomeria japonica 'Yoshino'	Yoshino Cryptomeria
Quercus acutissima	Sawtooth Oak
Quercus dentata	Daimyo Oak
Quercus imbricaria	Shingle Oak
Quercus macrocarpa	Bur Oak
Quercus shumardii	Shumard Oak
Quercus texana	Nuttall Oak

* In lab test, Chinese Fringetree was found to be inhospitable to EAB larvae[13]
** Thornless cultivar
*** Nuts can create litter issues

The existing street trees list covers 26 genera and 40 species. With the new recommendations, it grows to 33 genera and 47 species.

2. WHERE DO YOU PLANT?

Advocate for trees within Complete Streets planning.

Tree canopy provides benefits for all but requires valuable space. As the City creates the next version of the Five Year Sidewalk and Street Reconstruction Plan, tree planting should be one of the most important components of a healthy street. The City of Cambridge is committed to the vision of Complete Streets[10] which are streets that are designed with the well-being of all users in mind – pedestrians, bicyclists, motorists, and those that take public transportation. Dedicating adequate space for the well being of trees should be an important part of negotiations amongst user groups.

Plant to minimize risk.

To minimize future canopy loss, the city can use tolerant species in certain risk zones. In flood prone areas identified by Cambridge's CCVA, flood tolerant species can be planted. In areas that may experience coastal flooding, salt and flood tolerant species should be planted. Because flooding is predicted to increase in extent and possibly in duration after 2030, flood-tolerant species should be planted beyond the currently flooding areas of the city. In impervious surface areas where summer air temperatures will be highest in the city, and at locations that are unlikely to be tended or irrigated during drought, drought tolerant species should be planted. More generally, species resilient against future pests and diseases (those with a high climate resiliency score) can be planted in greater abundance.

Create new parks and open space strategically. Particularly in priority areas and neighborhoods with canopy deficits, new parks and shaded open spaces should be considered. Current canopy cover in Cambridge's open spaces average 40%, so new parks and open spaces is perhaps the most effective ways to add canopy cover and reduce heat island impacts in the city. Additionally, the permeable conditions of parks and open spaces generally provide for more rooting space, more natural irrigation, and less compacted conditions than street tree plantings. This recommendation supports Envision Cambridge's goal of increasing public open space from 446 acres to 462 acres by 2030[11].

Identify underutilized spaces for new tree plantings.

Tree planting does not need to have a design or be planted in a large space. Tree canopy on all City owned land should be cataloged, and parcels that are not planted to the maximum extent possible should be identified for new tree plantings.

3. HOW DO YOU PLANT?

Design new street tree planting opportunities.

Street trees live in a very constrained space between the sidewalk and the curb. There is limited space for roots to grow and limited surface area above to gather rainwater for trees to use. These conditions make it hard for trees to be healthy and to live to maturity in cities. The average street tree lives for 19 to 28 years whereas trees in the forest live for hundreds of years[12].

Innovative approaches to designing the public realm design can create opportunities to plant trees in places that are inhospitable to tree growth today and improve current locations to provide trees the horticultural support they need to survive.

The following design strategies focus on maximizing the plantable area in the public realm. They primarily propose integrating new sidewalk and R.O.W. design concepts into the City and creating new open spaces where there is limited existing public land.

The typical street tree layout of planting trees 30' apart, disconnected by soil volume without other layers of vegetation are not the conditions in which trees have evolved. Varying planting typologies, recommending diverse and well-adapted plants and connecting soil volumes are suggested methods for creating better conditions for trees. Because trees function as natural sponges, trees can also be proposed with integrated systems where the soil volume is part of a stormwater management system connected to the catch basins.

It is recognized that many of these strategies are intensive and require large capital costs. But, in areas of the city, the public realm is the only place for additional canopy. Thus, street redesign should be opportunistic and strategies that create additional space for street trees should be integrated into the process of street reconstruction. Additionally, it is recognized that the street serves various users such as vehicles, bikes and pedestrians, and the needs of those user groups should be balanced with that of street trees.

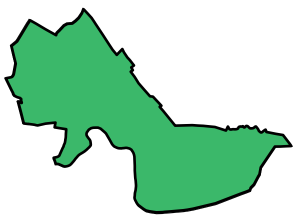
RECOMMENDED DESIGN STRATEGIES IN THE PUBLIC REALM

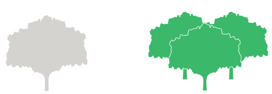
a. Bare root tree in typical tree pit
b. Bare root tree with expanded soil volume
c. Redesign streets to create new planting opportunities
d. Encourage planted open spaces by diversifying setbacks

DESIGN STRATEGY 2A

Plant bare root trees in amended soils when filling existing tree pits

IMPACT AREAS





STEM LOSS

GROW CANOPY

SUMMARY

Traditional tree pits have limited soil volumes and often exhibit poor drainage characteristics., but reconstructing existing tree pits to provide ideal growing conditions is expensive and logistically complex. Although full reconstruction is preferred, it is not always possible due to available funding or construction conflicts.

ANALYSIS

As this report recommends significantly increasing the number of trees planted annually, one approach to existing tree pits is to plant bare root trees and to amend soils in place. Bare root trees are field grown and shippped without soil around the roots. Planting bare root trees lessens transplant shock by avoiding tree root damage and allows the tree to adapt faster. Existing tree pit soils should be tested and amended in place and drainage can be improved through in-situ

PROS

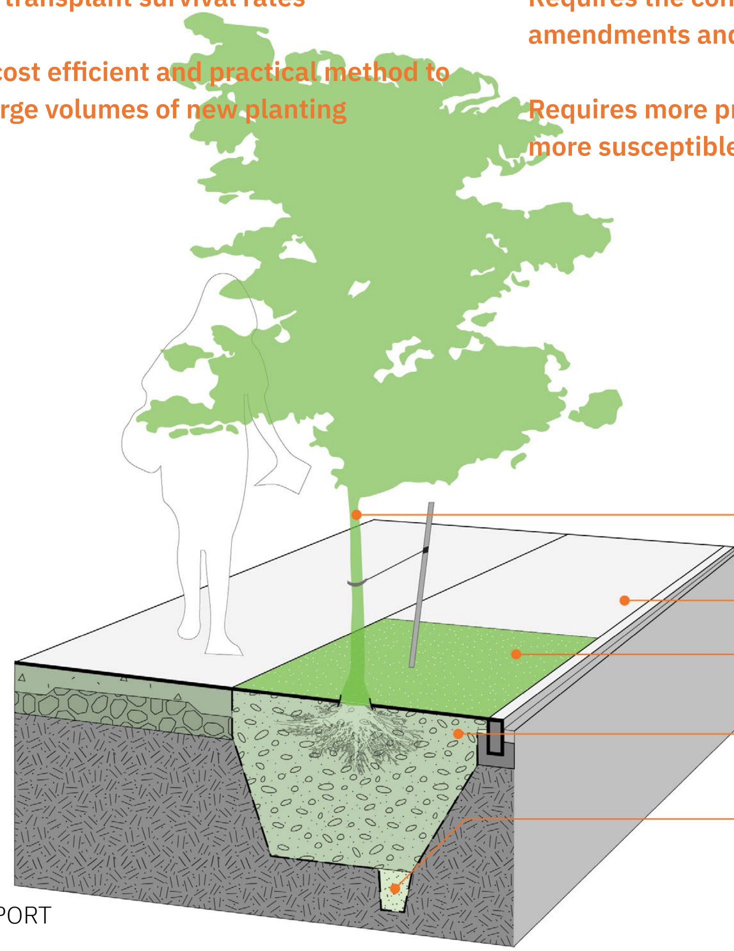
Increases transplant survival rates

Provides cost efficient and practical method to achieve large volumes of new planting

CONS

Requires the consultant to advise on amendments and trees specific to soil conditions

Requires more protection as bare root trees are more susceptible to damage



DESIGN STRATEGY 2B

Plant bare root trees in expanded and enhanced tree ways where possible

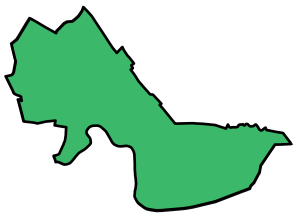
SUMMARY

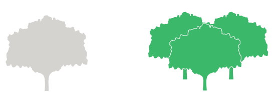
Street trees establish more quickly and survive longer, especially in the face of drought conditions, when they have larger soil volumes. In cases where the back of sidewalk condition is pervious, it is beneficial for the long term health of the tree to connect the tree pit soil to the back of the sidewalk, providing a larger continuous soil volume for the roots to access.

ANALYSIS

Unless infeasible, the City should improve planting pits before installing new trees. New or amended soils should be placed in the open tree pit, with structural soils under sidewalks for root growth into adjacent areas. Bare root trees are field grown and shippped without soil around the roots. Bare root trees are recommended over balled and burlapped trees due to the ability to plant a larger number of bare root trees and bare root trees being quicker to establish.

IMPACT AREAS





PROS

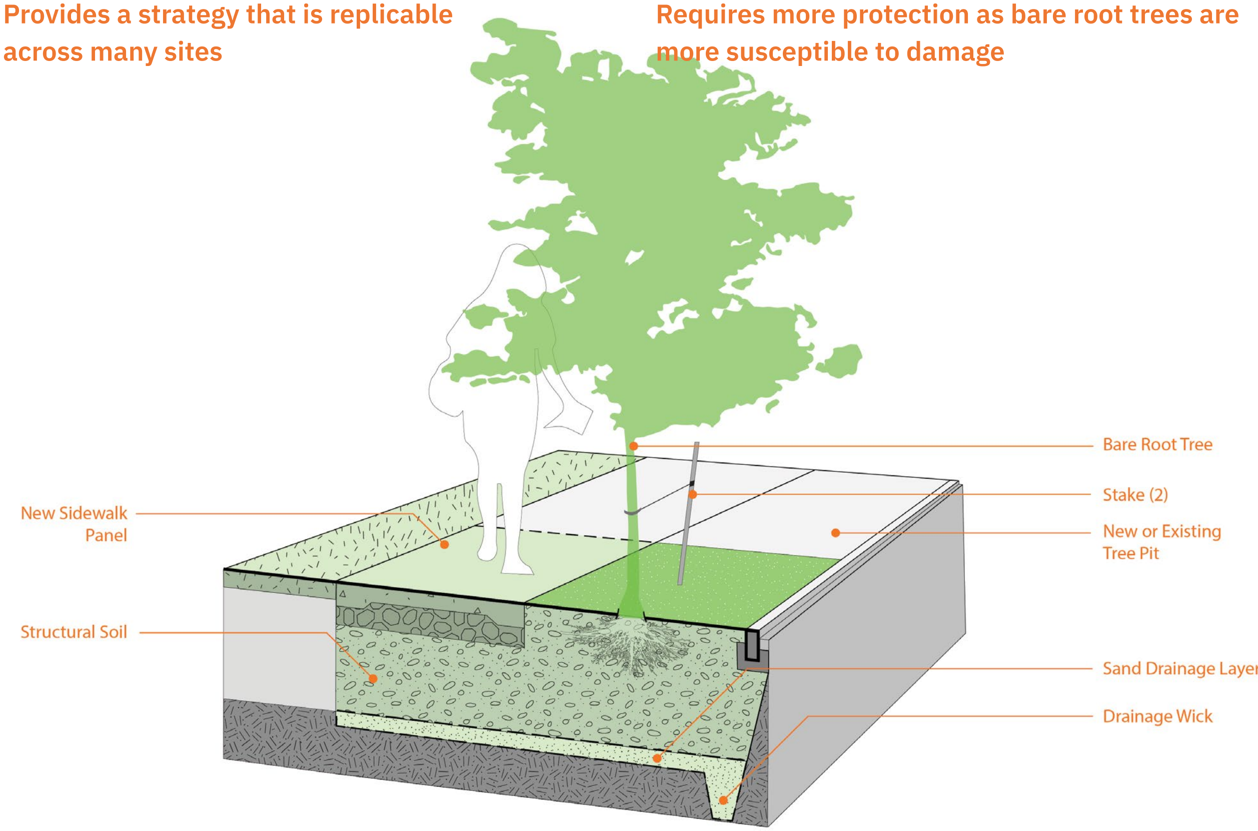
Improves establishment success and life-span

Provides a strategy that is replicable across many sites

CONS

Requires additional investment in each replanting

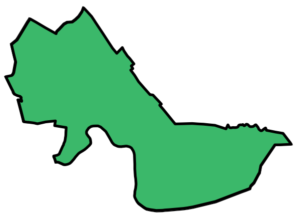
Requires more protection as bare root trees are more susceptible to damage

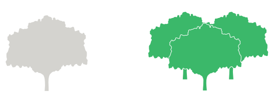


DESIGN STRATEGY 2C

Redesign streets to create optimal conditions when constraints limit tree viability

IMPACT AREAS





STEM LOSS GROW CANOPY

SUMMARY

In many parts of Cambridge today street tree planting is not viable due to existing constraints. In some neighborhoods sidewalks are too narrow to provide accessible sidewalks and adequate room for a tree pit. In others tree pits are so narrow that trees simply can not thrive and grow into mature canopy trees.

Over the coming decades, the City will gradually rebuild many of its streets, renewing infrastructure, adding bike lanes, and responding to changing transit requirements, including a potential reduced need for parking as automobile loads decrease.

ANALYSIS

As the City rebuilds its streets, the health of its trees should be a central component of the redesign, providing for optimal and at times novel approaches to rebuilding the urban forest. In the following pages, a series of possible approaches is described.

In these optimal approaches, planting balled and burlapped trees is a viable approach. Though a bare root planting is quicker to establish, there is also benefit to having a larger canopy at planting is situations where the ideal conditions can be provided, e.g. good drainage, good aeration, large soil volumes.

PROS

Optimal conditions for tree growth

Opportunities to diversify beyond street trees

Co-benefits with green infrastructure

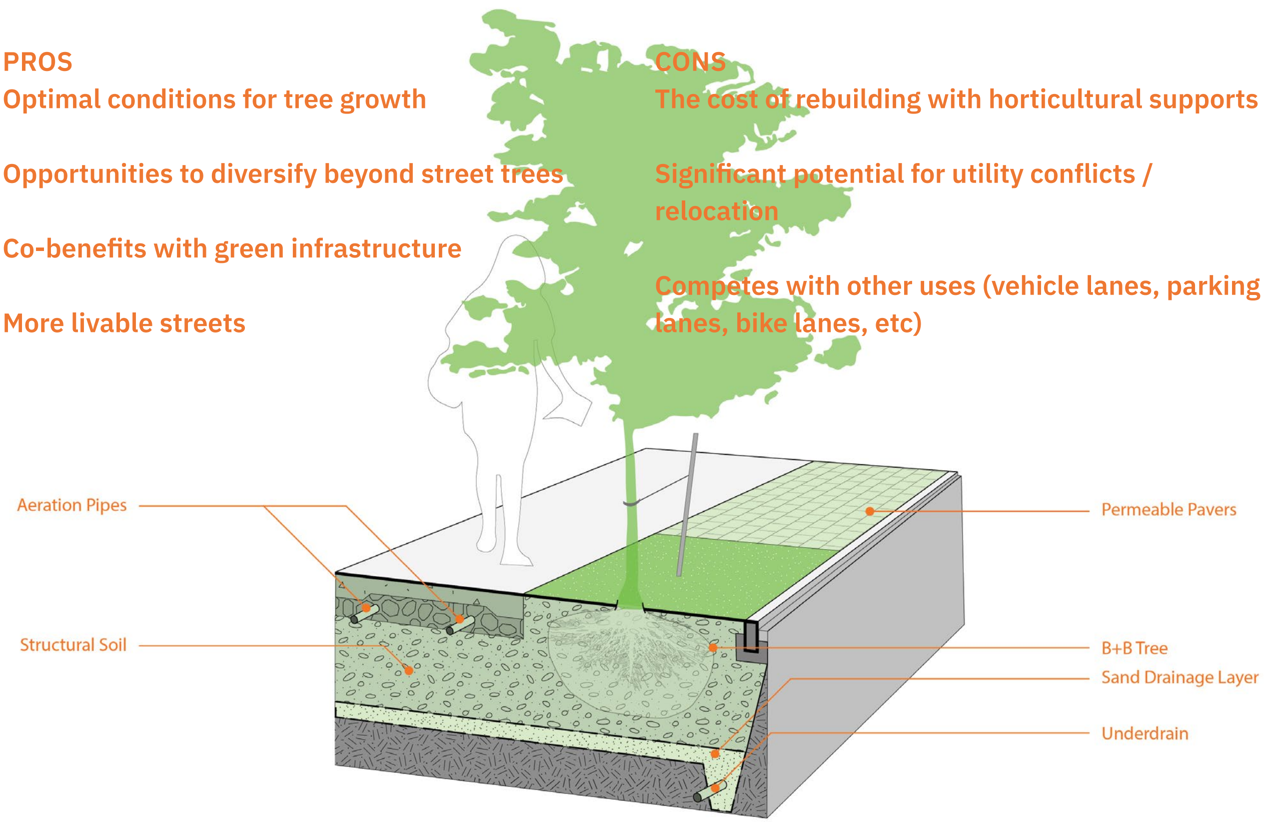
More livable streets

CONS

The cost of rebuilding with horticultural supports

Significant potential for utility conflicts / relocation

Competes with other uses (vehicle lanes, parking lanes, bike lanes, etc)

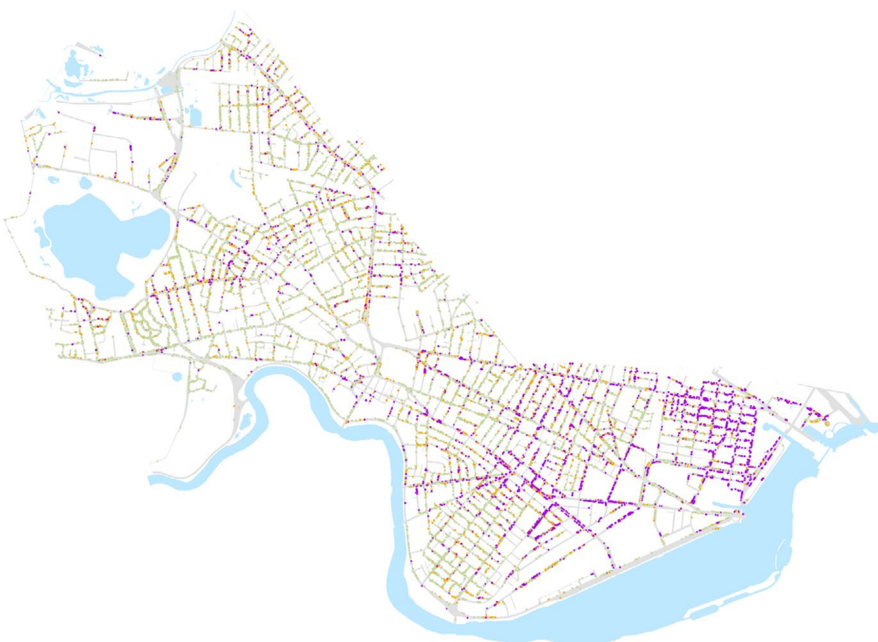


ADDITIONAL INFORMATION

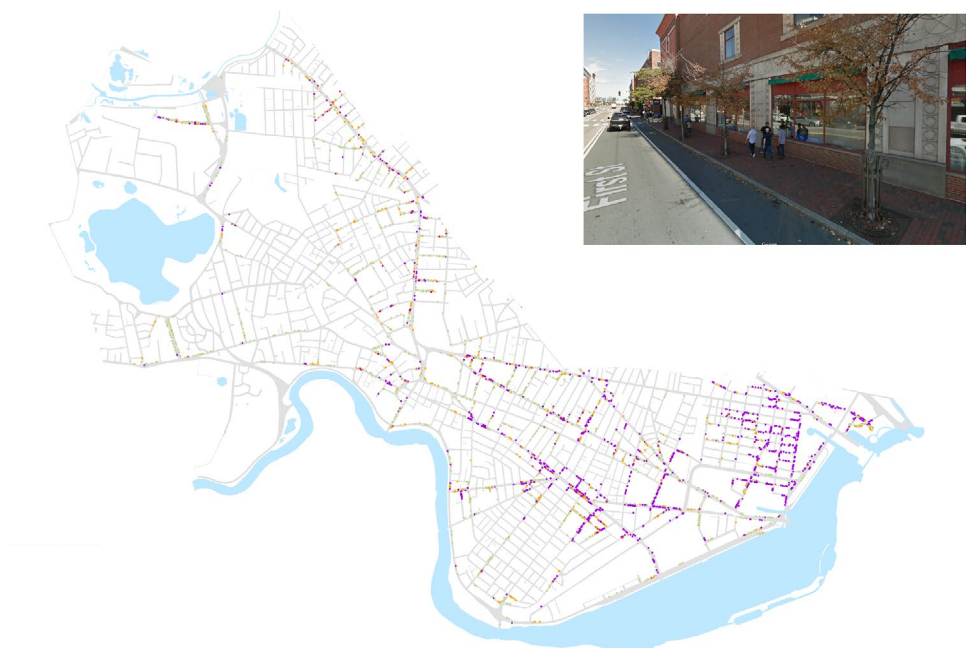
This study assessed the health and condition of street trees within different neighborhoods and planting conditions, such as the width and character of the sidewalks and distance to adjacent buildings. While it might be assumed that trees would perform best when sidewalks are generously dimensioned, this was not the case. The findings show that most of the streets with wider sidewalks also have no setbacks between the sidewalk and the adjacent building. Where the street trees have no adjacent soil volume for root expansion, they performed worse. The drawings below study sidewalk width distribution to understand where in the ROW there are front yards will support street trees.

Tree Health Conditions

- Good
- Fair
- Poor



Condition of street trees



Condition of street trees on sidewalks 8' or greater

Front yard setbacks greater than 10'

Limited setbacks

No required setbacks

Sidewalks less than 6' wide

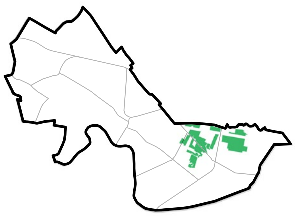
Sidewalks between 6' and 8'

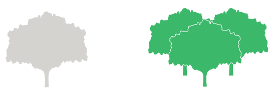
Sidewalks 8' or greater

DESIGN STRATEGY 2C

Narrow sidewalks: reduce roadway to increase planting

IMPACT AREAS





STEM LOSS GROW CANOPY

RESIDENTIAL STREETS

EXISTING:
Narrow residential streets with no setback

PROPOSED:
Remove street pavement by shifting two-way traffic to one-way; push the curb out to get a wider planting zone

PROS

New space and soil volume for tree planting

More livable street

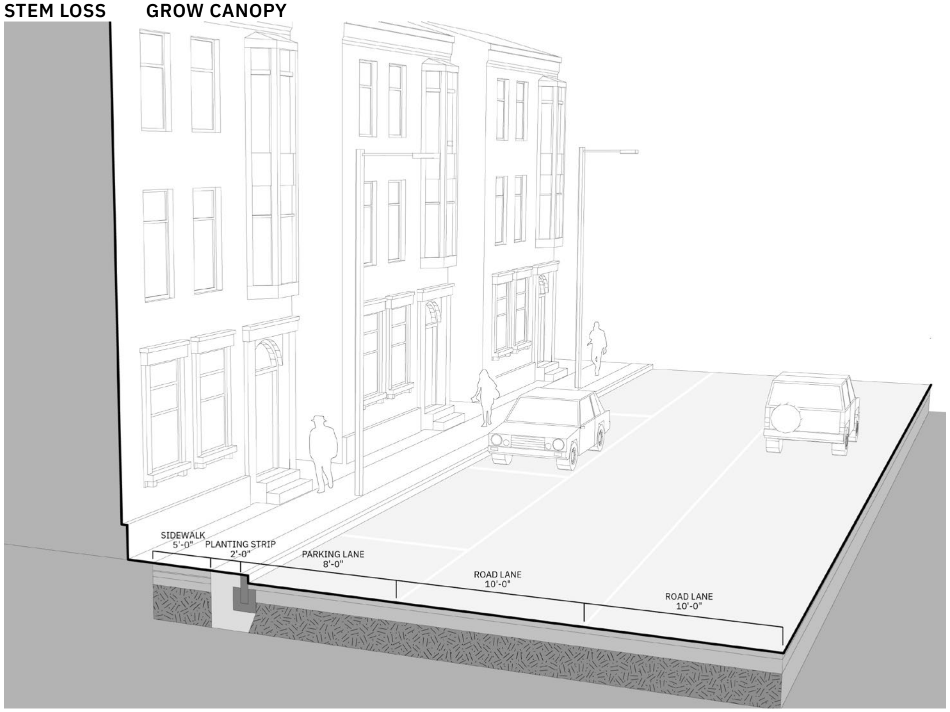
Healthier trees due to greater soil volume

CONS

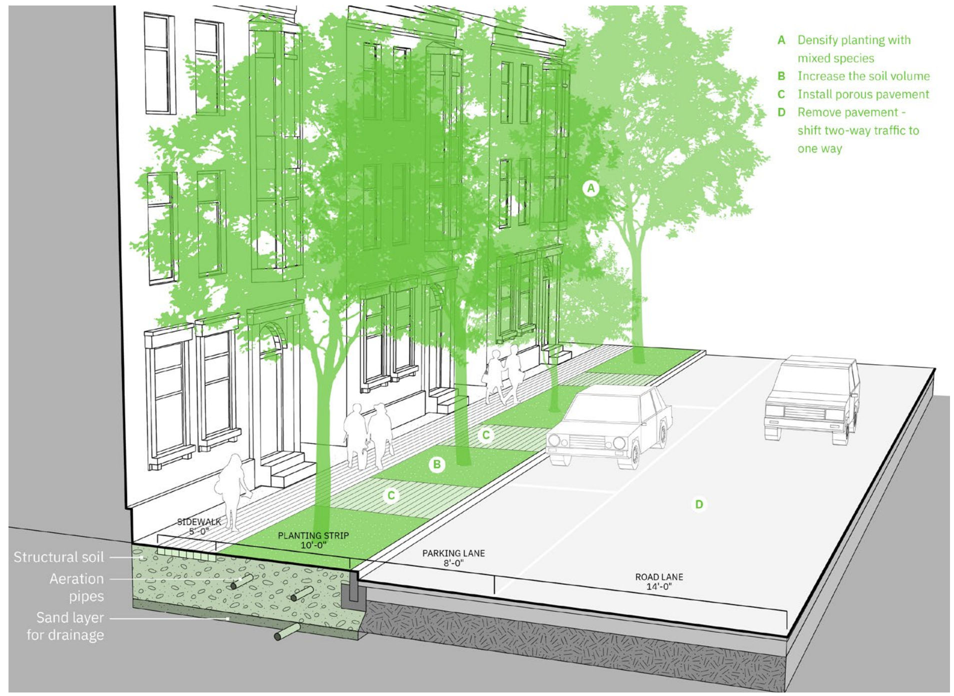
Reduced connectivity for vehicle traffic (one way)

The cost of redesigning the street

Utility conflicts



EXISTING

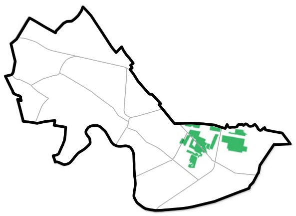


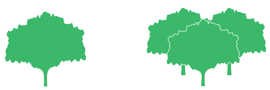
PROPOSED

DESIGN STRATEGY 2C

Narrow sidewalks: make shared streets to increase planting

IMPACT AREAS





STEM LOSS GROW CANOPY

RESIDENTIAL STREETS

EXISTING:
Narrow residential streets with no setback

PROPOSED:
Develop a shared street, moving the curb to create front yards for planting; best suited to short or dead-end streets (i.e.., Longfellow Road, implemented by the City)

PRECEDENTS

Longfellow Road, Cambridge

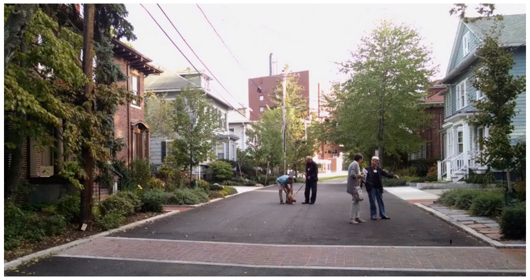


Photo by Meg Muckenhoupt

PROS

New space and soil volume for tree planting

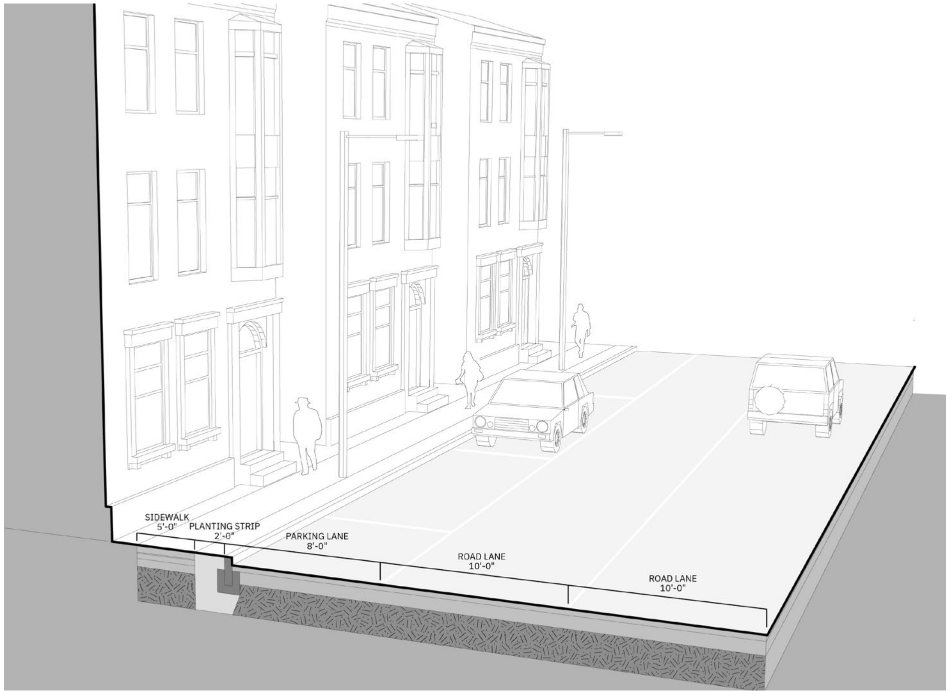
Developing community

CONS

No sidewalks; pedestrians share the road

The cost of redesigning the street

Utility conflicts



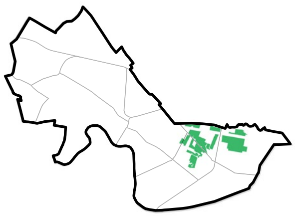
EXISTING

PROPOSED

DESIGN STRATEGY 2C

Narrow sidewalks: reduce roadway to increase planting

IMPACT AREAS



STEM LOSS

GROW CANOPY

RESIDENTIAL STREETS

EXISTING:
Narrow residential streets with no setback

PROPOSED:
Add space for a thickened row of trees and expand soil volume by removing a parking lane

PROS

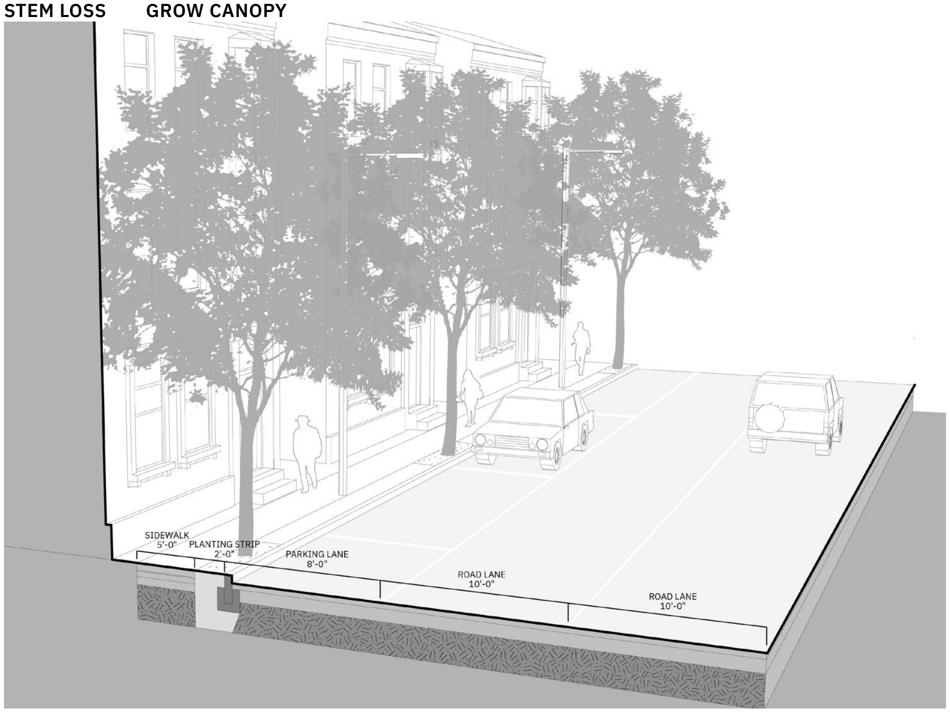
Improved conditions to support tree longevity

CONS

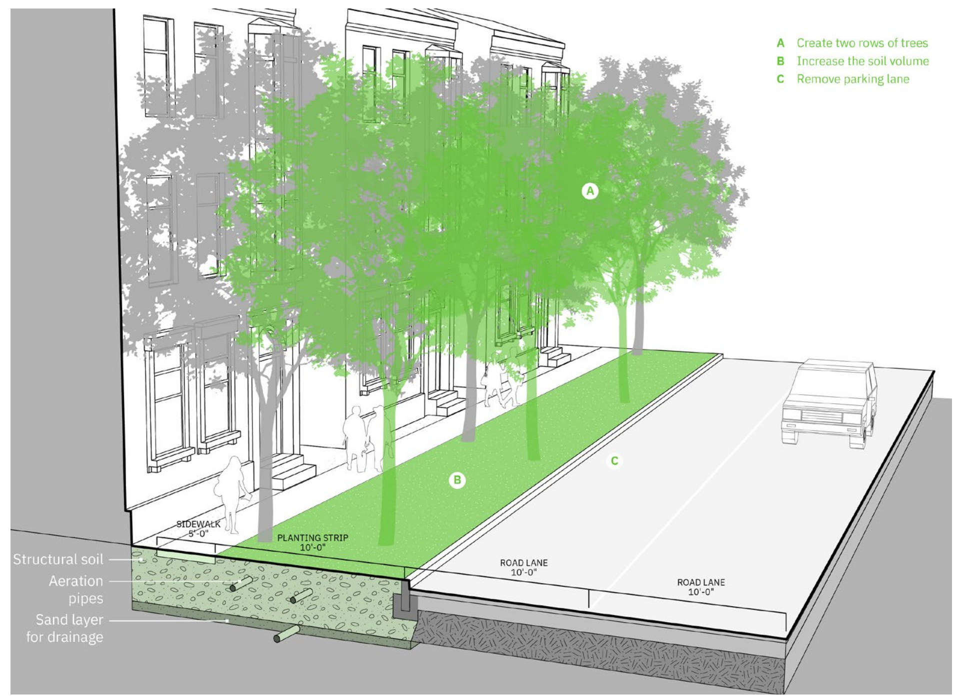
No parking lane

The cost of redesigning the street

Utility conflicts



EXISTING

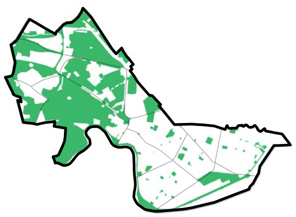


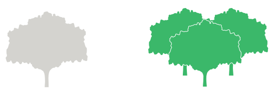
PROPOSED

DESIGN STRATEGY 2C

Narrow sidewalks: plant shade trees in front yards

IMPACT AREAS





STEM LOSS GROW CANOPY

RESIDENTIAL STREETS

EXISTING:
Narrow residential streets with wide front yard

PROPOSED:
Encourage front yard planting when there is not enough space for street trees (potentially aided by Partnerships and Tree Trust funding). Add structural soil to connect existing tree pits to back of sidewalk soils.

PROS

Uses existing spaces with limited reconstruction

Engages homeowners and community

CONS

Requires voluntary participation by property owners

EXISTING

PROPOSED

DESIGN STRATEGY 2C

Average sidewalk: develop robust planting strips

IMPACT AREAS

STEM LOSS GROW CANOPY

COMMERCIAL STREETS

EXISTING: Major commercial streets with a narrow sidewalk and a bike lane

PROPOSED: Create a continuous planting strip with expanded soils volume and multiple stories of vegetation in a pervious pavement

PROS

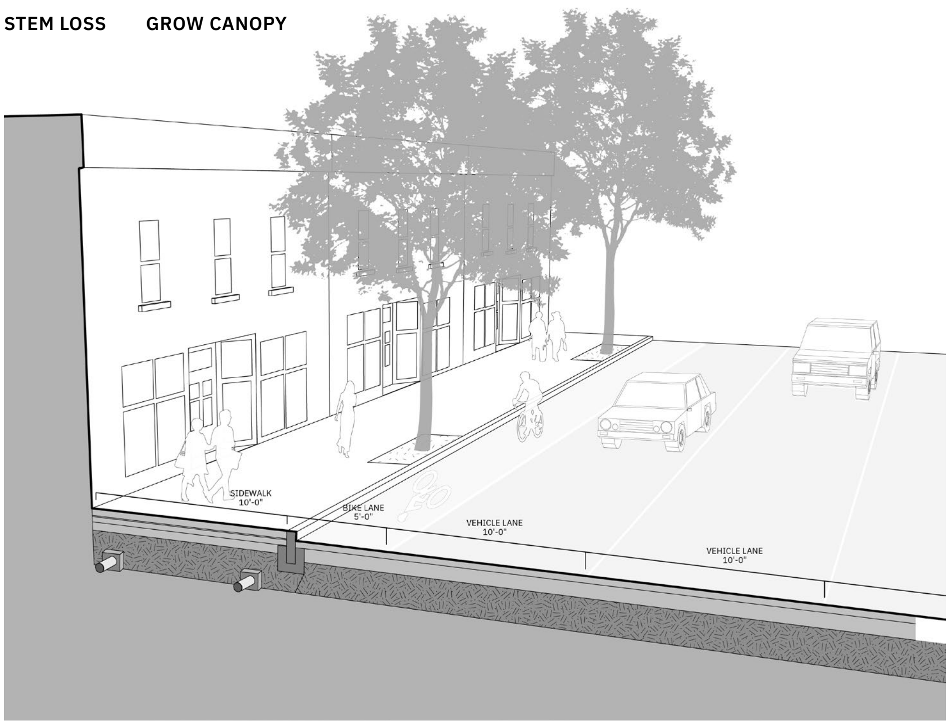
Increased canopy on major streets

More diverse and resilient planting

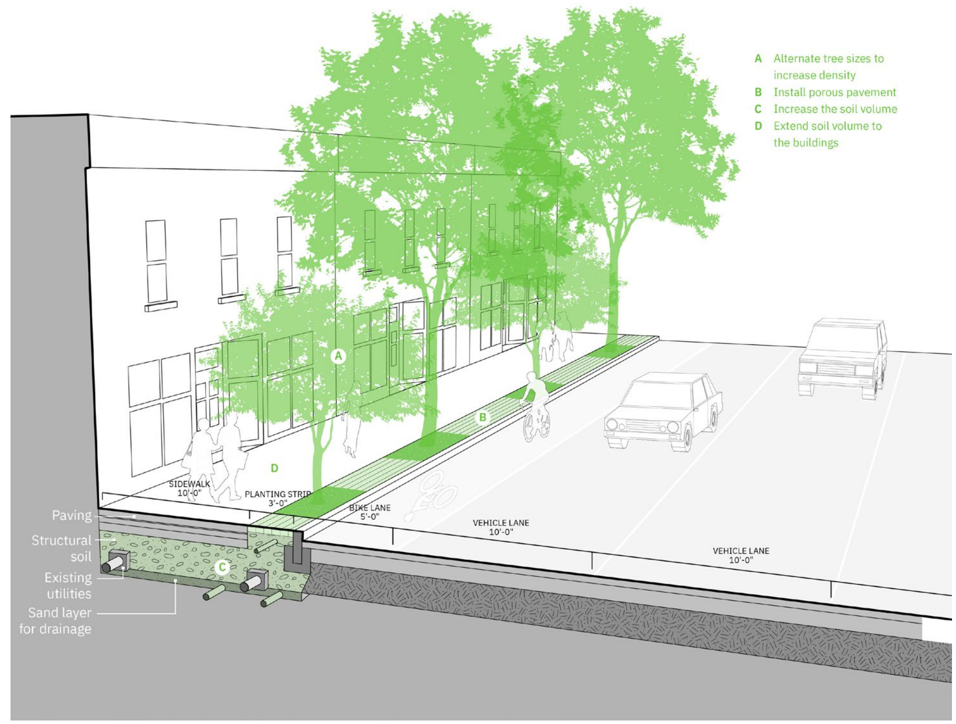
CONS

Increased maintenance

Reduced connectivity with street



EXISTING

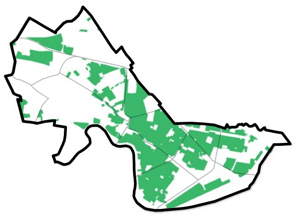


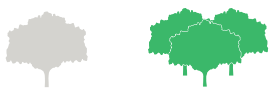
PROPOSED

DESIGN STRATEGY 2C

Average sidewalks: depave yards to support root growth

IMPACT AREAS





STEM LOSS GROW CANOPY

RESIDENTIAL STREETS

EXISTING:
Narrow residential streets with front yard

PROPOSED:
Encourage property owners to depave their front yards and then connect tree pit soils to back of sidewalk soils with new pervious condition.

PROS

Uses existing spaces

Supports green infrastructure goals

Engages the community

CONS

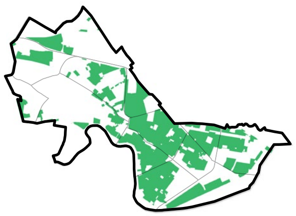
Requires voluntary participation by property owners

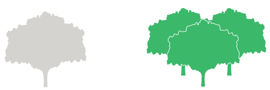
EXISTING

PROPOSED

Average sidewalks: create planting area in parking spots

IMPACT AREAS





STEM LOSS   GROW CANOPY

RESIDENTIAL STREETS

EXISTING:
Narrow residential streets with front yards

PROPOSED:
Turn some parking spaces into green spaces to plant trees

PROS

Creates more space for trees

Reduces impervious area

CONS

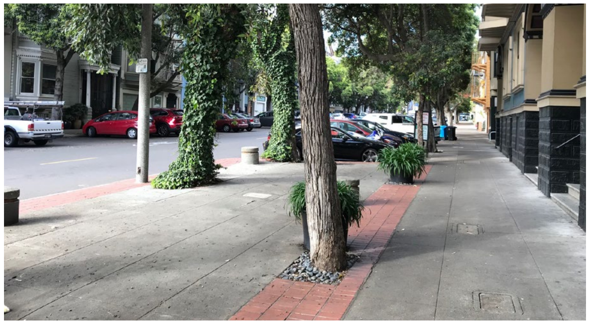
Reduces parking space

The cost of redesigning the street

Utility conflicts

PRECEDENTS

Western Avenue, Cambridge
San Francisco



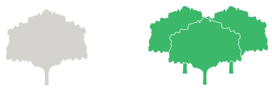
EXISTING

PROPOSED

DESIGN STRATEGY 2C

Wide sidewalks: expand canopy zone and soil volume

IMPACT AREAS



STEM LOSS GROW CANOPY

COMMERCIAL STREETS

EXISTING: Major commercial streets with a wide sidewalk, parking and bike lanes

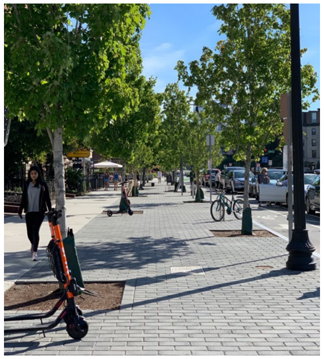
PROPOSED: Without changing the curb, the whole volume under the sidewalk provides soil volume, pervious pavement, improved aeration and drainage support soil function and tree health; trees are planted more closely, improving resilience and creating plant communities

PROS

More resilient soils and trees

PRECEDENTS

Boston



CONS

Additional maintenance

The cost of redesigning the street

EXISTING

PROPOSED

DESIGN STRATEGY 2C

Wide sidewalks: plant communities of vegetation

IMPACT AREAS

STEM LOSS GROW CANOPY

COMMERCIAL STREETS

EXISTING: Major commercial streets with a wide sidewalk, parking and bike lane

PROPOSED: Plant diverse groves of trees, including multiple stories of vegetation, which support each other; provide pervious pavement on the surface, which allows other amenities such as bike parking, outdoor dining and street furnitures

PRECEDENTS

Passeig Sant Joan, Barcelona

PROS

Diversify canopy on major streets

Increased resilience

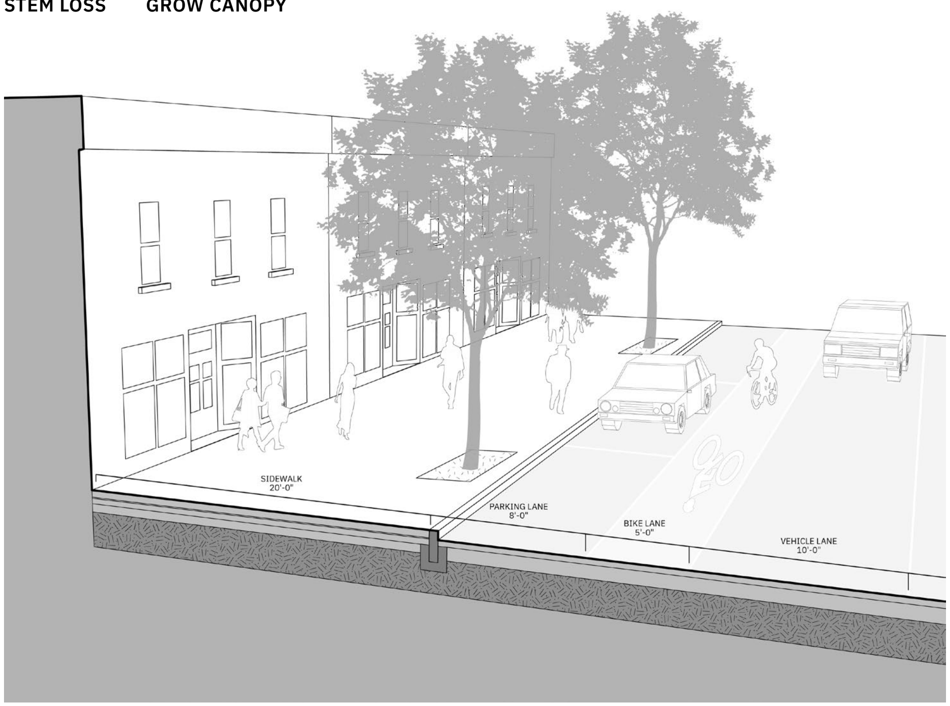
Healthier trees due to greater soil volume

CONS

Additional maintenance

Limits flexibility of uses

The cost of redesigning the street



EXISTING

PROPOSED

DESIGN STRATEGY 2C

Wide sidewalks: provide suspended pavement systems

IMPACT AREAS

STEM LOSS

GROW CANOPY

COMMERCIAL STREETS

EXISTING: Major commercial streets with a wide sidewalk, parking and bike lane

PROPOSED: Develop a suspended grate system instead of a pavement, with vegetation below that supports symbiotic plant communities, which also allows other amenities such as bike parking, outdoor dining and street furnitures

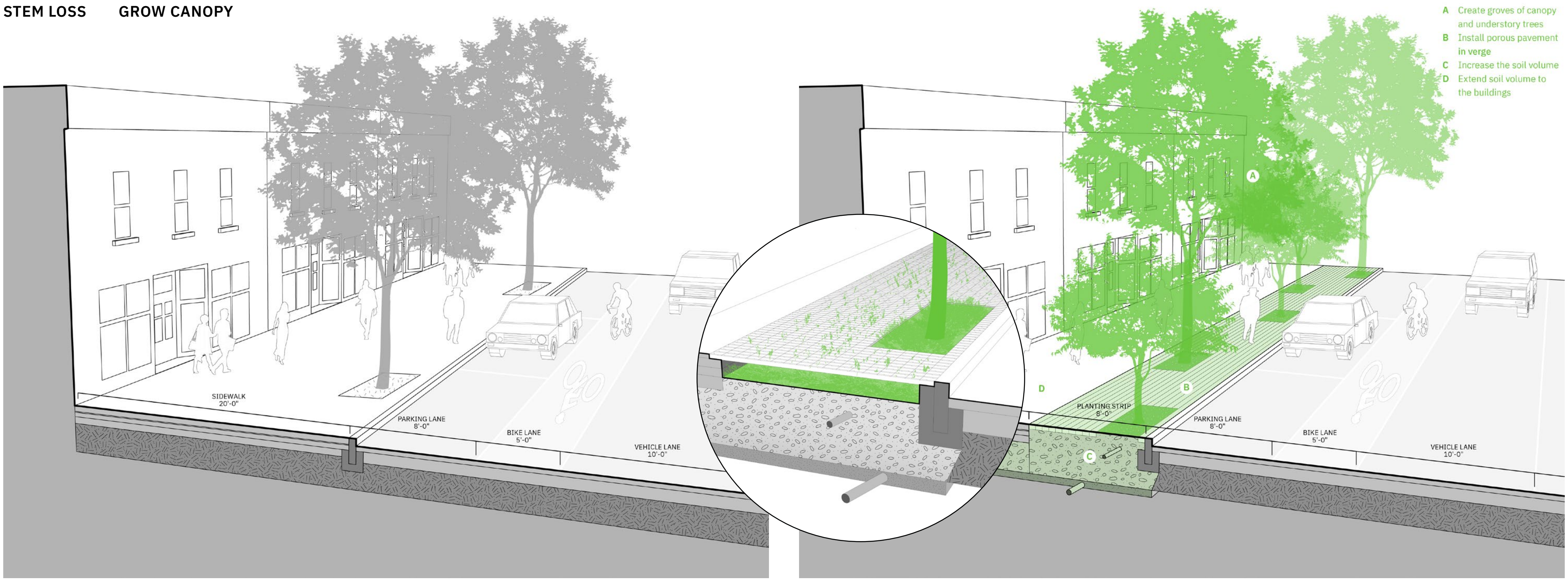
PROS

Diversify the urban forest by adding multiple layers of vegetation

CONS

Additional maintenance

The cost of redesigning the street



EXISTING

PROPOSED

DESIGN STRATEGY 2C

Wide sidewalks: integrate bike lanes and tree plantings

IMPACT AREAS

STEM LOSS GROW CANOPY

COMMERCIAL STREETS

EXISTING: Major commercial streets with a wide sidewalk, parking and bike lane

PROPOSED: Relocate the curb, move the bike lane off the street and increase the soil volume

PROS

Incentivizes biking by providing a safer bike lane

Expands continuous soil volume

CONS

Requires complex utility coordination

The cost of redesigning the street

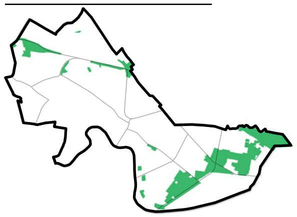
EXISTING

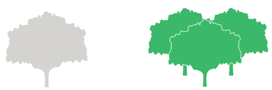
PROPOSED

DESIGN STRATEGY 2D

Encourage frontage planting with varied setbacks

IMPACT AREAS





STEM LOSS GROW CANOPY

COMMERCIAL STREETS

EXISTING:
Major streets with commercial buildings

PROPOSED:
Create periodic setbacks in the frontage zone, providing for landscaped spaces; where there is no parking implement multiple stories of vegetation in verges

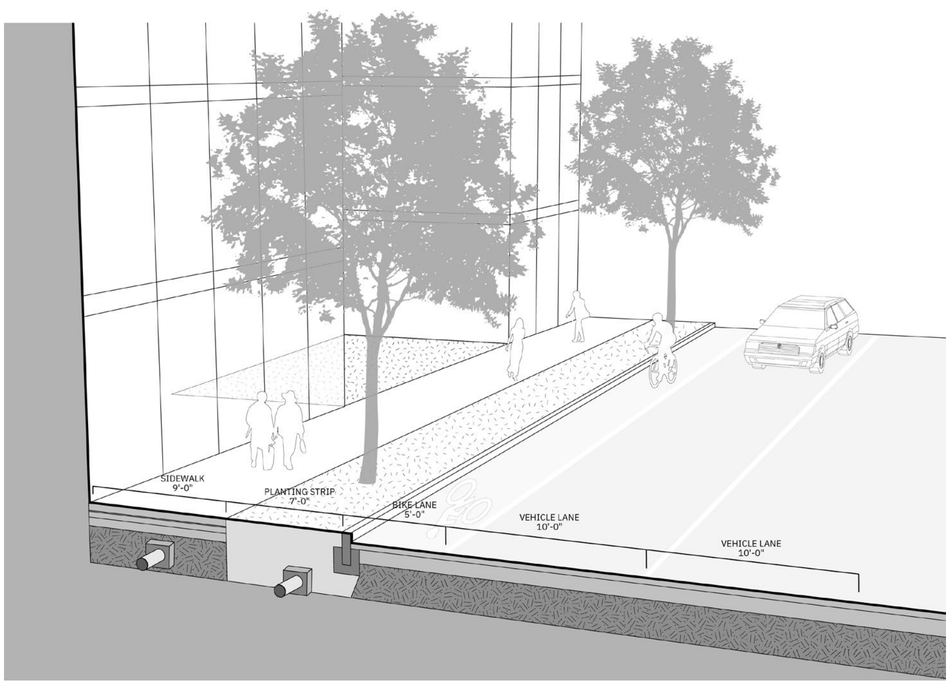
PROS

Diversify the urban forest by adding multiple layers of vegetation

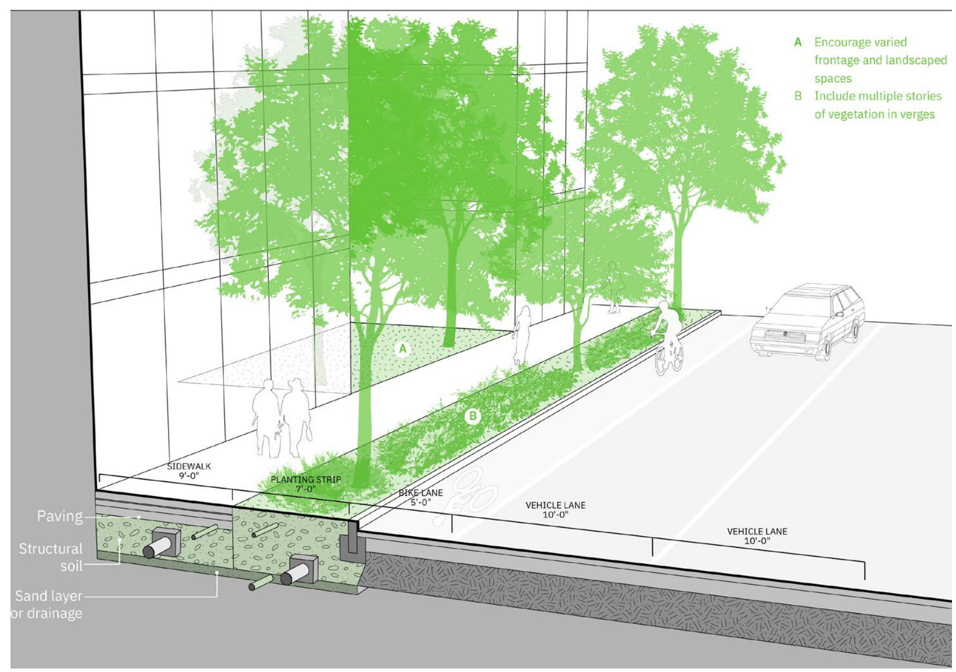
Use groundcover vegetation to discourage foot traffic that compacts soils

CONS

Improperly selected plants could create root competition with trees.



EXISTING



PROPOSED

PRACTICE STRATEGIES

Practice improvements are the primary opportunity for stemming loss of City-owned canopy. The City of Cambridge forest management practices are generally aligned with best industry standards, but there is still room for improvement. The recommendations below were determined to have the most efficacy for the investment.

RECOMMENDED PRACTICE STRATEGIES

1 Improve monitoring
   a. Create management risk zones
   b. Increase frequency of city-wide tree assessments
   c. Implement soils testing for stressed trees
2 Expanded maintenance
   a. Establish a soils management program
      1. Short term: Treat newly planted trees with liquid biological amendments
      2. Long term: Treat all street trees with liquid biological amendments
   b. Implement structural pruning for young trees
   c. Expand watering program
   d. Treat private trees for EAB
3 Establish a gravel bed nursery to increase flexibility and success of new bare root plantings

PRACTICE STRATEGY 1A

Implement risk zones to structure forest management

SUMMARY

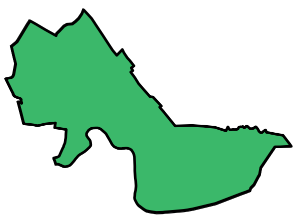
Despite very different canopy cover rates, planting conditions, stressors, and rates of development change, the Cambridge Urban Forest is currently managed as a single unit.

Other cities have divided their land area into management zones that organize practices based on conditions analysis and existing tree stressors.

ANALYSIS

Areas of the city with no setbacks and/or high pedestrian traffic are challenging environments for trees. Creating zones based on higher or lower risks to tree health will help manage resources more efficiently. This requires reevaluation over time as conditions on the ground change over time, e.g. new development with glass curtain wall creating heat stress or growth of tree canopy creating better growing conditions for younger trees.

IMPACT AREAS



PROS

Minimal investment required

CONS

Requires evaluation over time to assess efficacy of management divisions

Increase frequency of city-wide tree condition assessments

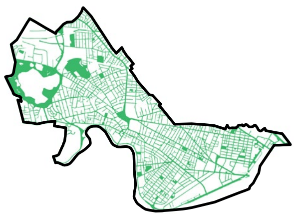
SUMMARY

Increased frequency of tree assessments will give staff a more accurate picture of the state of the urban forest and helps prevent issues from going unnoticed.

ANALYSIS

A high level cost comparison for in-house assessments versus adding them into the existing pruning contract suggested that it would be more cost efficient to add assessments into the existing contract. The downside to this approach is that the existing pruning contract divides the city into 6 zones and one zone is pruned per year. This 6 year cycle would result in 6 years between assessments for each tree.

IMPACT AREAS



STEM LOSS

GROW CANOPY

PROS

Better understanding of health of forest

Cost efficient solution

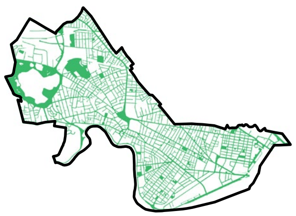
CONS

Tree health data only updated every six years

PRACTICE STRATEGY 1C

Implement soils testing for stressed trees

IMPACT AREAS



STEM LOSS GROW CANOPY

SUMMARY

The health of a tree depends largely on the health of its soil. Nutrient availability, organic matter levels, compaction, and pH are all critical elements of soil health which can be assessed and managed in situ.

ANALYSIS

Testing soils of trees showing signs of stress can reveal treatable conditions which can reduce tree loss. With this information, City staff can develop efficient and targeted treatment programs to respond to failing trees. Additionally, trends and findings can inform a more broadly applied soils management program aimed to prevent predictable and treatable problems with soil performance.

PROS

Understand of cause of tree decline, allowing for more effective treatment

CONS

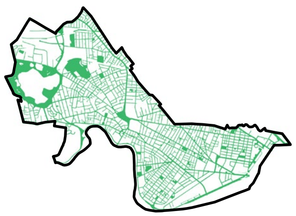
Cost associated with staff time and testing

Tree health threshold would be tied to six year assessment cycle which may not catch sudden decline in health

PRACTICE STRATEGY 2A

Establish a soils management program

IMPACT AREAS



STEM LOSS GROW CANOPY

SUMMARY

Currently the City mulches some of its trees on a regular basis, which is a good way to support organic matter renewal and good soil function. The City has also begun to monitor the impact of salts on street tree soil.

Implementing a program to improve soils health represents an important opportunity to reduce tree mortality and increase canopy growth.

ANALYSIS

Injecting liquid biological amendments (compost tea) is an effective method of improving and maintaining soil health. The City is currently in the process of establishing an in-house liquid biological amendment program to treat all newly planted trees. Long term, the City could develop the capacity to treat all street trees once a year on a two year cycle.

PROS

Increased survival rates

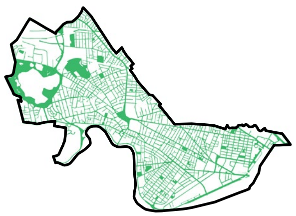
CONS

Cost, primarily for staff time

PRACTICE STRATEGY 2B

Implement structural pruning for young trees

IMPACT AREAS



STEM LOSS GROW CANOPY

SUMMARY

The City does not currently conduct structural pruning for young trees and this represents a significant opportunity to improve the long term health of street and park trees.

ANALYSIS

Structural pruning is a type of pruning typically performed on young to middle-aged shade and ornamental trees. The objective is to create a strong and healthy structure so that trees are sturdier under wind, snow and ice loads, and less prone to failures, and so they can live full and useful lives in the landscape. The sooner in the life of the tree that structural pruning is started, the easier and less expensive it is. Waiting until the tree is mature often means larger more disfiguring pruning cuts, cabling and much greater expense.

PROS

Avoided long term costs

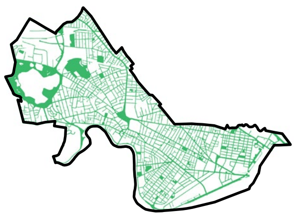
CONS

New operational costs

PRACTICE STRATEGY 2C

Expand watering program

IMPACT AREAS



SUMMARY

Water availability is the primary determinate of tree health. Providing sufficient water during establishment, when roots are expanding to find additional sources of water is critical to their long term success.

The current tree contract requires the contractor to water newly planted trees for three years, and the City currently utilizes the Tree Ambassador program to water trees for two summers following this initial three year period.

ANALYSIS

Given the increased planting targets, the City will need to increase its watering program to cover an increased number of new trees. In addition, the City should consider emergency watering during drought.

PROS

Increased survival rates

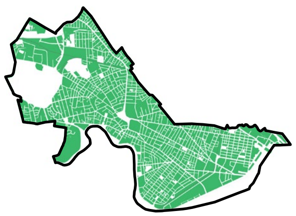
CONS

Increased labor hours

PRACTICE STRATEGY 2D

Treat private trees for EAB

IMPACT AREAS



STEM LOSS GROW CANOPY

SUMMARY

Pests and diseases do not respect property lines or ownership designation. If a catastrophic pest, such as Emerald Ash Borer (EAB) begins to spread on private property, its impact will be felt broadly, no matter what actions the City takes on public property.

ANALYSIS

Despite the fact that the City currently treats its own ash trees for EAB, there are approximately 650 ash trees on private property in Cambridge, and these trees comprise roughly 2% of the City's canopy. A lost of these trees would adversely impact overall canopy cover and take years to replace. Analysis has shown that it would be more cost effective to treat ash trees over a certain size than to pay for removing them. Any replacement trees would likely be smaller, and there is the possibility that the homeowner does not replace a tree at all.

The City should determine a minimum DBH threshold for treatment and undertake a legal review to determine whether and how this can be done.

PROS

Prevents the loss of 2% of the city canopy

CONS

Cost to the City

Complexity of coordination / approvals from private owners

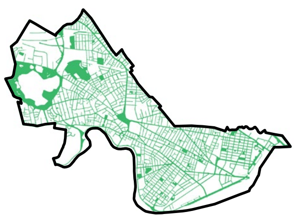
ALTERNATIVE PRECEDENT

Over 25 municipalities in the Twin Cities area of Minnesota negotiated with one vendor to set a discounted rate for residents to pay to treat their tree(s)

PRACTICE STRATEGY 3

Establish a gravel bed nursery

IMPACT AREAS



STEM LOSS   GROW CANOPY

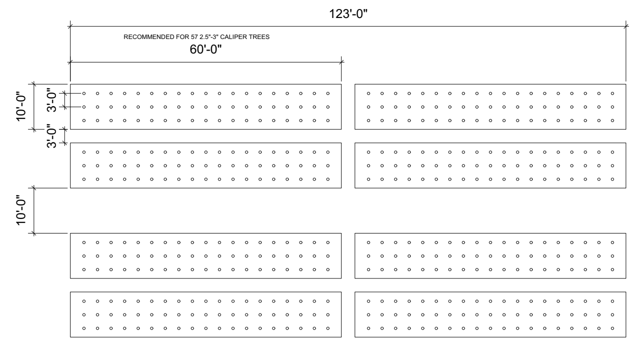
SUMMARY

With municipal tree planting, especially at large scale, there is an inevitable holding period between digging and acquiring the trees and planting them. Balled and burlapped trees are less likely to survive if they have extended periods out of the ground, so their planting season is constrained to a few weeks in spring and a few in the fall. If cared for properly, bare root trees enjoy the benefit of an extended planting season. Root dessication is the most critical disadvantage to planting bare root trees, however, proper care in a gravel bed nursery mitigates the risk.

ANALYSIS

A gravel bed is an irrigated bed of gravel to place and safely hold bare root or washed containerized stock (aka "heeling in") for up to 3-6 months. Doing this dramatically increases fibrous root volume, decreasing transplant shock and increasing survivability of the plant. Since bare root stock is typically only available during spring, this also allows for staged plantings throughout the year.

8,200 sf of space is required to store 456 bare root trees



PROS

Increases root mass at planting

Increases survival rates

Extends planting season

CONS

Initial capital outlay to build beds

PRECEDENTS

PHS, Philadelphia
Various municipalities in Minnesota

OUTREACH AND EDUCATION STRATEGIES

Communicating the value of trees is essential for building the support for the large replanting effort necessary on both public and private land.

The City has control over less than 30% of the land area in the City, so the City will have to rely mainly on outreach and educational strategies to curb loss or grow canopy on private land. Education and outreach will be essential for building public support. Research has shown that for people to take action, several circumstances have to line up (Fogg Behaviour model). Action is only triggered if something is easy to do, or someone has high motivation. To make planting trees easy, the City could consider a mechanism for providing trees, planting and maintenance help or materials beyond the Back of Sidewalk program. To increase motivation, the City could implement educational and outreach initiatives emphasize the value of trees and that everyone can have an impact. Outreach initiatives can also play a role in protecting the current urban forest through citizen science projects.

A Cambridge UFMP outreach and education plan should be developed to help guide and prioritize these efforts across various City departments.

RECOMMENDED OUTREACH & EDUCATION STRATEGIES THAT SUPPORT MASTER PLAN CORE CONCEPTS:

1 Understand the forest as a system
   a. Advocate for the value of trees in education curriculum
   b. Organize tree tours for citizens to engage with trees
   c. Educate local businesses about the dangers of pest outbreaks

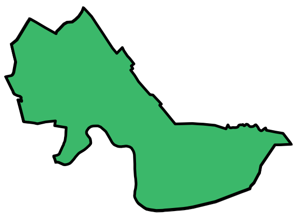
2 Value the forest as a public resource
   a. Continue to publicize ecosystem benefits of trees
   b. Publish annual reports to give feedback on progress
   c. Improve the online tree map to engage citizens

3 Invest in the public realm
   a. Partnership outreach
   b. Support alternative education approaches, art installations
   c. Promote existing City programs

4 Share responsibility for a healthy forest
   a. Support citizen science projects
   b. Support community tree planting efforts
   c. Publicize Back of Sidewalk programs at public events

Advocate for the value of trees in education curriculum

IMPACT AREAS



STEM LOSS

GROW CANOPY

SUMMARY

It is important to educate children about the values and ecosystem services of the urban forest. An environment based education helps children to understand the role and benefits of trees and encourages them to advocate for trees.

Outreach to schools:

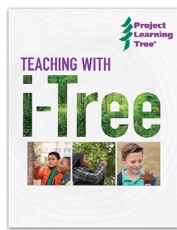
- Can build on existing school curriculum about the services that trees provide
- Can utilize ready-made lesson content from Audubon Society or Project Learning Tree which incorporates i-Tree and also Trees Louisville's science curriculum unit on ecosystem services

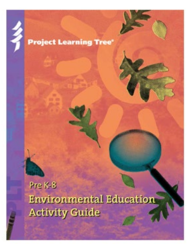
PRECEDENTS

Teaching with i-Tree
Project Learning Tree
Trees Louisville
Mass Audubon

ANALYSIS

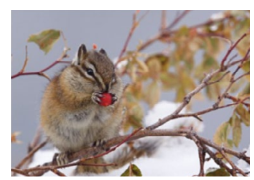
Currently Cambridge Public Schools curriculum include 'exploring woodland and freshwater habitats through class-maintained terrariums and aquariums' in kindergarten, and in grades 1,2 and 3, they learn that animals and plants share similar characteristics and they depend on other living things and their environment to grow, thrive, and survive. These programs can be enhanced with subjects directly associated with the urban forest around them.





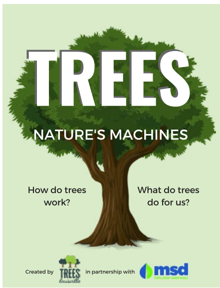
PRE K-8 GUIDE

K- GRADE 2 E-UNIT
TREMENDOUS SCIENCE



GRADES 3-5 E-UNIT
ENERGY IN ECOSYSTEMS

GRADES 6-8 E-UNIT
CARBON & CLIMATE



TREE-MENDOUS TREES
STEM Preschool Teaching Unit
Ages 2.9-5 years
www.massaudubon.org/education

OUTREACH AND EDUCATION STRATEGY 1B

Organize tree tours for citizens to engage with trees

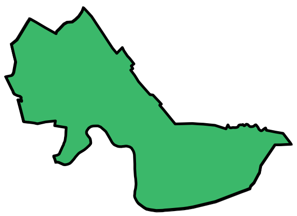
SUMMARY

Organizing tree tours could foster good working relationships between the community and DPW. This is something that the City has implemented in the past but currently is not in practice.

ANALYSIS

There are examples of guided walking and biking tree tours in neighborhoods and parks in various cities. For example, the City of Chesapeake, Virginia, organizes guided tours once every season, or four times a year. There are also self-guided tours that allow citizens to access a tree map by using smart phones in some cities such as Seattle (Tree Walk app), Nevada City, Sacramento, and Atlanta.

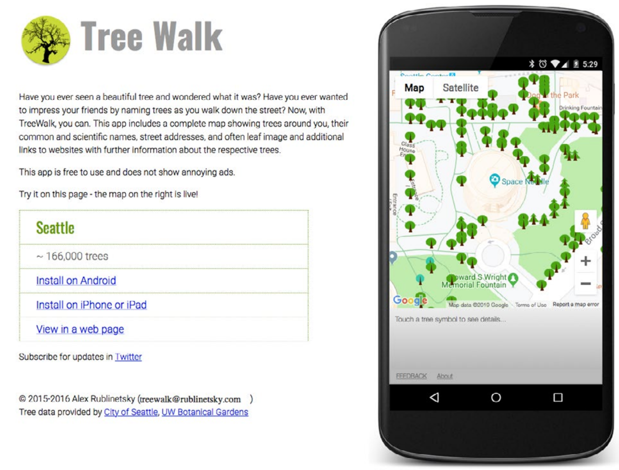
IMPACT AREAS



STEM LOSS   GROW CANOPY

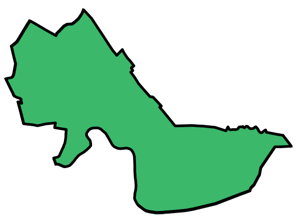
PRECEDENTS

Friends of the Urban Forest, San Francisco
Tree Walk app, Seattle



Educate local businesses about the dangers of pest outbreaks

IMPACT AREAS



STEM LOSS   GROW CANOPY

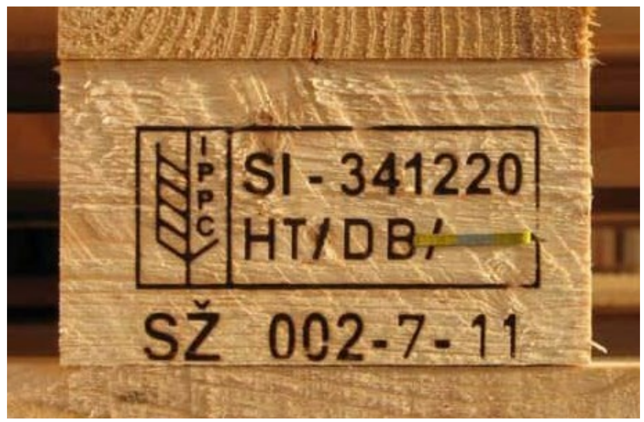
SUMMARY

Businesses can help protect the forest by ensuring all wood products are pest free by using ISPM 15 regulated wood packaging material in international trade.

ANALYSIS

In 2008, the Asian Longhorn Beetle was found in Worcester, MA, presumably brought in through wood pallets. The city lost 35,000 trees either killed by the beetle or felled by foresters working to contain the infestation.

The ISPM 15 standard describes phytosanitary measures that reduce the risk of introduction and spread of quarantine pests associated with the movement in international trade of wood packaging material made from raw wood.

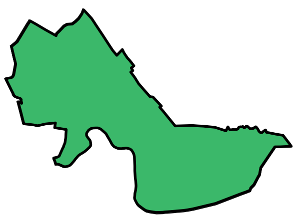


Continue to publicize ecosystem benefits of trees

SUMMARY
Continue publicizing the benefits of trees, expand number of locations around city, and expand content to include other benefits.

ANALYSIS
Cambridge currently has signs on the streets to educate people on the dollar value of trees under Adopt a Tree program. This helps people to understand the ecosystem services provided by different species and trees in general.

IMPACT AREAS



STEM LOSS **GROW CANOPY**

PRECEDENTS
Cambridge, MA
Chicago

Publish annual reports to document progress

SUMMARY

A yearly report card that evaluates the efforts to expand the urban forest can remind citizens of the state of the forest, communicate the goals of this report, and hold communities accountable for reaching their goals.

ANALYSIS

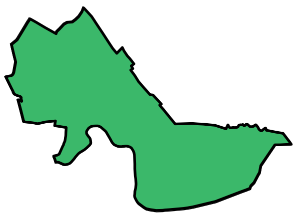
As an example, Casey Trees' tree report card rates Washington DC's urban forest based on four metrics: Tree coverage, tree health, tree planting and tree protection. It also compares previous years' grades.

As with the Cambridge Water Department's Drinking Water Quality Report, the Urban Forest report card could be mailed to all residents.

PRECEDENTS

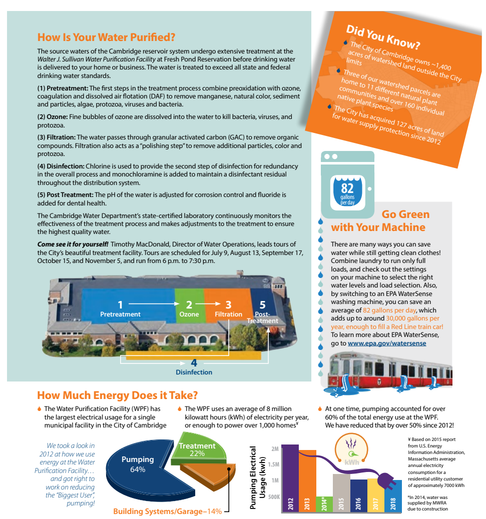
Tree Report Card, Washington, D.C.
Cambridge MA Annual Drinking Water Quality Report

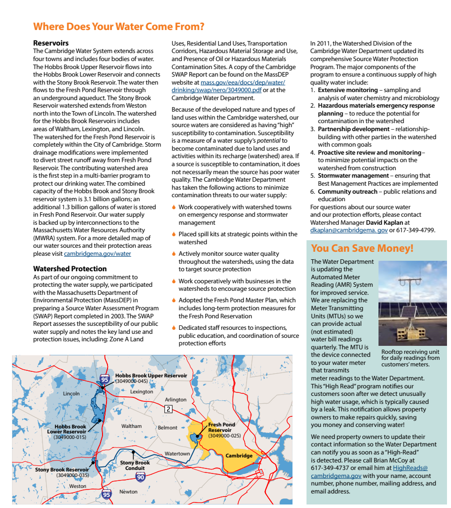
IMPACT AREAS



STEM LOSS

GROW CANOPY





OUTREACH AND EDUCATION STRATEGY 2C

Improve the online tree map to engage citizens

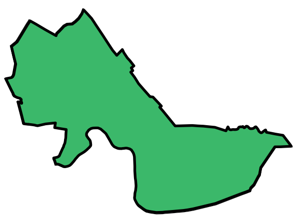
SUMMARY

Cambridge Tree Walk, the City's online tree map, currently has information on tree locations and species. However, it needs a more interactive user interface in order to allow people to see more details about individual trees.

ANALYSIS

An engaging precedent, the New York City Street Tree map, is clickable, providing more information that tells how many times a tree is favorited, shows tree care and ecological benefits of the tree. Also, people can record informal care such as watering, weeding, managing soil, mulching or clearing litter/waste with the data.

IMPACT AREAS

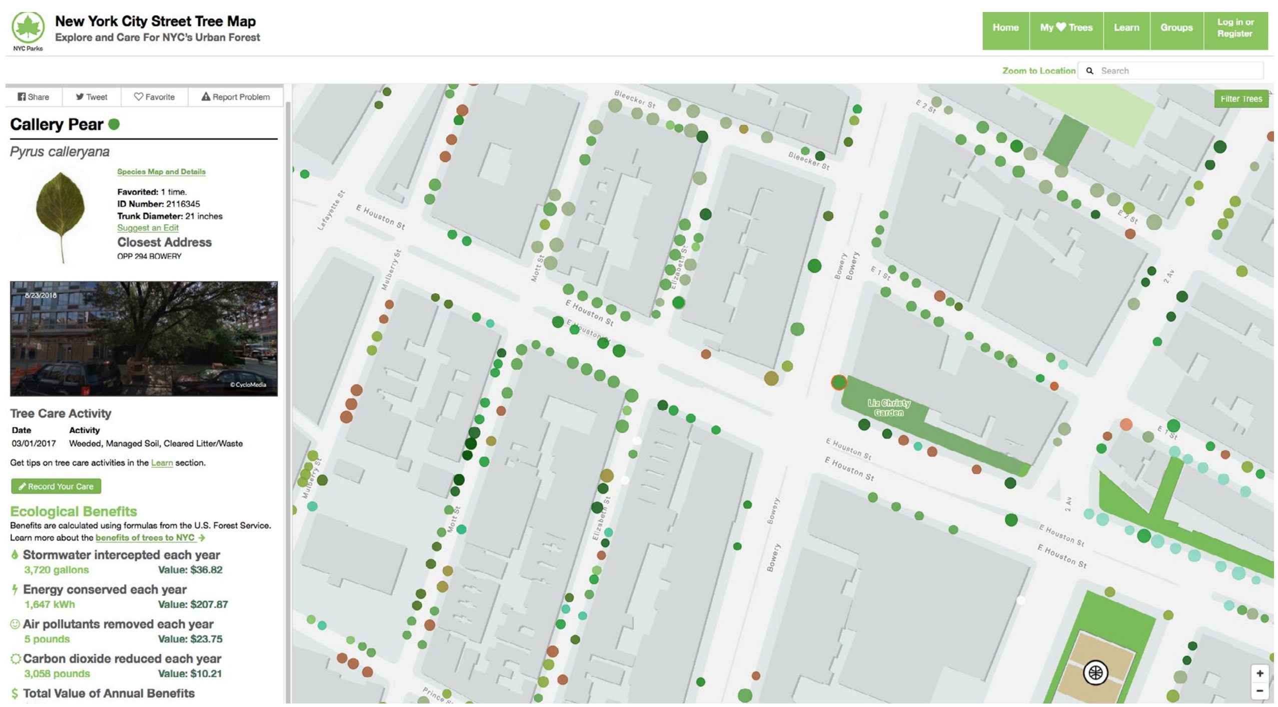


STEM LOSS

GROW CANOPY

PRECEDENTS

New York City Street Map



Build community partnerships (Multi-agency partnerships)

SUMMARY

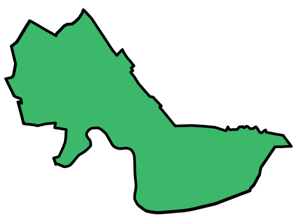
Partnerships with existing state-wide initiatives that already have staff infrastructure and broad community ties can open new avenues for the City to advance its urban forest goals.

PRECEDENT

MA Greening Gateway Cities is a multi-agency partnership among MA EEA, DCR, DOER, and DHCD and gateway cities (including Chelsea, Fall River, and Holyoke). Trees planted by DCR crews and local labor field crews, led by DCR foresters

Funding: State grant program funded with energy efficiency and state capital funds.

IMPACT AREAS



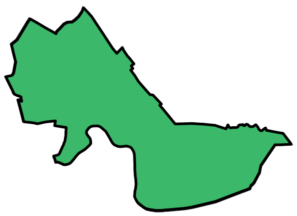
STEM LOSS   GROW CANOPY

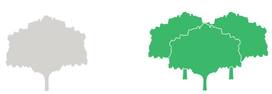
GREENING
THE GATEWAY CITIES
MA Urban Canopy Project

OUTREACH AND EDUCATION STRATEGY 3A

Build community partnerships (Public-private partnerships)

IMPACT AREAS





STEM LOSS GROW CANOPY

SUMMARY

Partnerships with non-governmental organizations and community-based groups can support the City in its efforts to grow canopy by providing additional funding, engagement, and education efforts.

PRECEDENTS

Green Tacoma Partnership

PRECEDENT

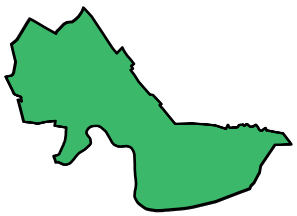
A public-private partnership between the City of Tacoma, Metro Parks Tacoma, Forterra, Citizens for a Healthy Bar, Pierce Conservation District and local businesses. This effort connects stewardship groups through resources/training and organizing public outreach

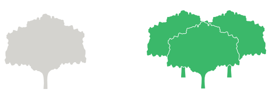
Funding: City of Tacoma, individual donations, corporate sponsorship. Forterra appears to be the nonprofit sponsor that houses the operations of the partnership and is likely the fiscal agent.

OUTREACH AND EDUCATION STRATEGY 3A

Build community partnerships (Public-private partnerships)

IMPACT AREAS





STEM LOSS GROW CANOPY

SUMMARY

Partnerships with non-governmental organizations and community-based groups can support the City in its efforts to grow canopy by providing additional funding, engagement, and education efforts.

PRECEDENT

Tree Pittsburgh is a public-private partnership between Tree Pittsburgh and Pennsylvania Urban and Community Forestry Council, Penn State University and conservation groups (Friends of the Riverfront, Western Pennsylvania Conservancy, Pittsburgh Parks Conservancy). the organization supports:

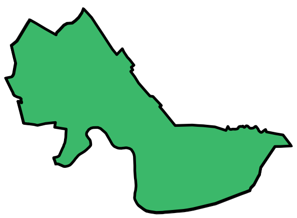
- Community tree plantings, Tree Tender volunteer program

- A variety of engaging classroom and field learning opportunities year-round. Tree Pittsburgh staff, ISA Certified Arborists, guest lecturers, or Heritage Nursery staff run all programs.

Funding: Tree Pittsburgh is a registered 501(c)3 funded by individual donations, corporate matching gifts, corporate sponsorships.

Support alternative education approaches, such as art installations

IMPACT AREAS



STEM LOSS GROW CANOPY

SUMMARY

Public art installations on urban trees and forestry can educate and engage citizens to protect and plant trees. The City can create programs to fund local artists to exhibit their work related to urban forestry and trees around the city through events, exhibitions, competitions, performances etc.

ANALYSIS

An example of publicizing ecosystem benefits and educating people on the value of trees is David Buckley Borden's "Shade Collection Box" (Put something in to get something out).

Another example of describing tree health as a public resource is "Voice of Nature" by Thijs Biersketer. Sensors connected to a tree in Chengdu, China monitor environmental conditions such as CO_2 level, temperature, moisture in the soil, and light level. This data then generates digital rings every second and documents the tree's health in real time.

PRECEDENTS

Shade Collection Box, by David Buckley
Voice of Nature by Thijs Biersketer

Promote existing City programs

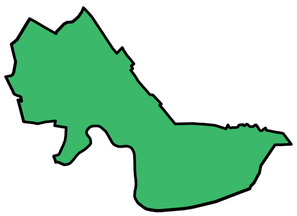
SUMMARY

DPW has a variety of programs for tree care and tree planting available for residents including Adopt a Tree program and Junior Forester program. Most respondents were not aware of the city's existing tree planting programs.

ANALYSIS

The City should continue to promote programs that support the Urban Forest. It is critical that these efforts be expanded to neighborhoods in the most critical need and to communities who have not traditionally responded to these programs. Efforts should rely on existing community organizations, events, and cultural activities.

IMPACT AREAS



STEM LOSS GROW CANOPY

CAMBRIDGE
JUNIOR FORESTER
APPLICATION

I WOULD LIKE TO ADOPT A TREE

I UNDERSTAND IT IS MY RESPONSIBILITY TO :

1. WEED AROUND THE BASE OF THE TREE
   Pull weeds by hand and throw away.
2. WATER THE TREE - FILL THE GATOR BAG ONCE A WEEK
   Dpw will provide a 'gator bag' to hold 20 gallons of water
3. MULCH OR ADD COMPOST TO THE SOIL
   Apply 2 – 3 inches of mulch or compost to planting area.
   Not touching the trunk of the tree.
4. PICK UP LITTER – It is important to keep the tree well clean
5. LET THE DPW KNOW IF THERE IS INJURY TO THE TREE.
   617 349-4885

Name______________________ Address______________________

Email:______________________ Phone #______________________

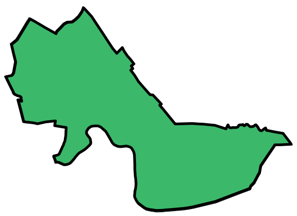
Signatures:
Jr. Forester______________________ Parent/Guardian______________________

www.cambridgema.gov/tree Mail to: Dave Lefcourt, 147 Hampshire Street, Cambridge, MA 02139

OUTREACH AND EDUCATION STRATEGY 4A

Support citizen science projects

IMPACT AREAS



STEM LOSS GROW CANOPY

SUMMARY

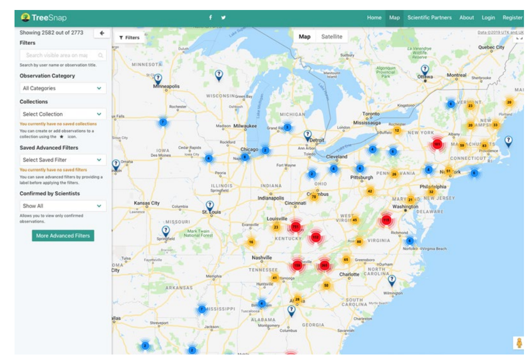
Communicating the value of trees helps people to understand that everyone shares the responsibility to preserve and support the urban forest. With programs funded by the City such as citizen science projects, people can contribute to scientific research and learn more about the trees, for example by identifying pests and diseases.

PRECEDENTS

Backyard Bark Beetles, University of Florida

Sudden Oak Death (SOD) Blitz, University of California at Berkeley

Tree Snap App, Nationwide



PRECEDENT

Backyard Bark beetles: This citizen science project provides a rare opportunity for the public to participate in real-world scientific research. Participants help to advance the understanding of bark and ambrosia beetles, which will help to protect forests and the species that depend on them.

SOD Blitz: SOD-blitzes inform and educate the community about Sudden Oak Death, get locals involved in detecting the disease, and produce detailed local maps of disease distribution. The map can then be used to identify those areas where the infestation may be mild enough to justify proactive management.

Tree Snap App: Tree Snap enables foresters, landowners, and citizens to record the location of healthy trees of a particular threatened species that scientists can then study for genetic diversity or breeding programs. In the northeast, the species of concern are American chestnut, elm, ash, white oak, hemlock, and eastern larch.

Support community tree planting efforts

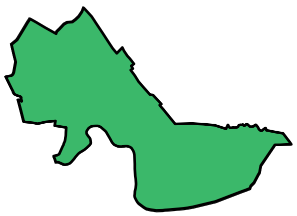
SUMMARY

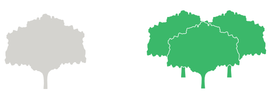
Supporting community tree planting efforts may lead citizens to work together and create more energy and momentum behind planting trees. This may result in groups advocating and planting trees within neighborhoods that are underserved today.

PRECEDENT

Keep Indianapolis Beautiful is a nonprofit organization. They offer a community forestry program which residents can apply for tree planting if they find at least 20 spots for trees in their neighborhood. Applicants need to form a small group and need to agree with their neighbors and local business owners to commit to tree preservation.

IMPACT AREAS





STEM LOSS   GROW CANOPY

PRECEDENTS

Keep Indianapolis Beautiful

OUTREACH AND EDUCATION STRATEGY 4C

Publicize Back of Sidewalk program at public events

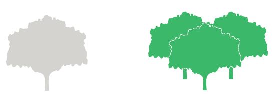
SUMMARY

Currently the Back of Sidewalk program is an underutilized resource for improving shade over the public right of way.

ANALYSIS

Roughly 80% of respondents to the public opinion survey were not aware of this existing program, and out of those respondents who were aware of it only a handful had actually had a tree planted through the program (see chapter 2.6 Public Opinion on the State of the Forest). Promoting this program could be a cost effective way of increasing residential tree planting.

IMPACT AREAS



STEM LOSS   GROW CANOPY

OTHER/SUPPORTING STRATEGIES

Trees require space, below ground infrastructure and maintenance. Trees are not appropriate everywhere as physical site constraints can prevent adequate conditions for trees to survive. In these cases, complementary strategies should be considered. All of the recommended strategies below have a vegetation component, which contributes to the health and well-being of the people in the city.

PLANTING GREEN ROOFS

- reduce heat island effect
- could have supporting strategies such as solar panels, which could help shade plants
- provides habitat
- provides potential for urban agriculture
- maintenance heavy
- may be cost prohibitive

GREEN/VEGETATED WALLS

In areas that are

- provides cooling for buildings
- provides habitat

ALTERNATIVE PLANT COMMUNITIES

Alternative plant communities refer to assemblages of plants outside of canopy trees and includes understory trees, grassland, shrubs and rain gardens. This type of strategy provides:

- increased permeability for stormwater retention
- Reduces urban heat island through the cooling effect of vegetation
- provides habitat for small mammals, birds and insects
- community gardens/urban agriculture opportunities Other/Supporting Strategies

References

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5. Scenario Models

EVALUATION OF PLANTING OPPORTUNITIES AND STRATEGIES

Tree cover can provide significant cooling citywide when planted along the Right of Way (R.O.W.)

Increasing tree cover in neighborhoods with low existing rates of canopy can have a meaningful impact on urban heat island (UHI).

To maximize heat island reduction while considering equitable distribution of canopy:

↳ Plant trees strategically along R.O.W. corridors to provide cooling benefits for pedestrians, bikers, and transit users.

↳ Prioritize planting species with high leaf area density along R.O.W.

↳ Increase tree cover in parks in neighborhoods with low existing canopy cover.

↳ Where possible, create new publicly accessible open spaces with significant canopy cover in areas with low existing canopy cover.

↳ Maintain canopy in areas with existing high canopy cover.

The case studies presented here are simplified scenarios that do not take into account all real-world planting constraints. They provide a picture of what could be possible through concerted action and they test the feasibility of the minimum neighborhood canopy cover targets that this study proposes.

How do the strategies discussed in *Section 4* actually hit the ground? What impacts do they have? And how can they be most efficiently and effectively deployed at the scale of the whole city and within individual neighborhoods?

This section presents case studies that identify potential planting opportunities and constraints, that test strategies for maximizing canopy coverage, and that evaluate impact by the extent to which planting more trees mitigates the urban heat island effect.

5.1 Citywide Canopy Corridor Study

Question: We strive for a network of shaded corridors throughout the City, linking squares, green spaces and commercial districts along primary and secondary travel routes. If the City were to maximize planting in the R.O.W. to create canopy corridors, how many trees would the City have to plant and how much would this strategy mitigate heat island? *Figure 5.1*

Discussion: The current canopy cover over the R.O.W. is 28% (229 canopy acres of 812 total R.O.W. acres). This analysis, further detailed in Appendix M, identified approximately 12,000 additional tree planting opportunities within the R.O.W. If the City planted 1,200 trees per year over 10 years, these trees at full maturity (25' diameter canopy and not accounting for mortality) would provide an additional 62 acres of canopy, increasing canopy cover in the R.O.W. to 36%. In the context of the whole City, canopy cover would increase from 26% to 27.5%. This scenario represents an ambitious target at the upper range of what is possible in the R.O.W. given specific site constraints that are not able to be evaluated at the scale of city-wide data available for this model.

With this additional canopy cover, 25% of the city would experience a significant decrease in temperature (> 0.5 °F) and more than half of that area would experience cooling of 1 degree or more. In addition, 47% of the public R.O.W.

	Maximum Planting Opportunity
Sidewalks greater than 6'	10,000
Along other ROW	2,000
TOTAL	**12,000 Trees**
Sidewalks less than 6' wide	3,000

FIGURE 5.1 — POTENTIAL PLANTING IN R.O.W.

FIGURE 5.2 — 12,000 NEW R.O.W. trees at maturity increase canopy cover from 26% to 29.4% (idealized scheme of R.O.W. planting does not consider conflicts with utilities, etc.)

would experience a significant decrease in temperature (378 acres of 812 acres). This suggests that concerted planting along the R.O.W. does provide significant and pervasive cooling and has the potential to support continuous cool corridors through the City.

The heat island model used in this study represents the average temperature change in a 100 ft by 100 ft square (see Appendix L), so it is necessarily generalized. Field studies on ambient air temperature under canopy have shown the impact of trees to be even more significant — reducing ambient temperature by up to 13 degrees relative to unshaded areas[1]. Based on this evidence, the City can expect that the cooling benefit of significant planting in the R.O.W. would be even greater than what is demonstrated by the model.

This analysis is hypothetical in nature and does not account for the annual mortality rate of street trees. Just to maintain existing canopy in the R.O.W., the City needs to replant trees that die on an annual basis. The City currently maintains approximately 13,000 street trees. Adding the proposed 12,000 new street trees, the City would manage a total of 25,000 street trees. To keep pace with an annual mortality rate for street trees of 3%, which is lower than the current rate and represents a planning target, the City would need to plant 750 trees each year just to cover this loss.

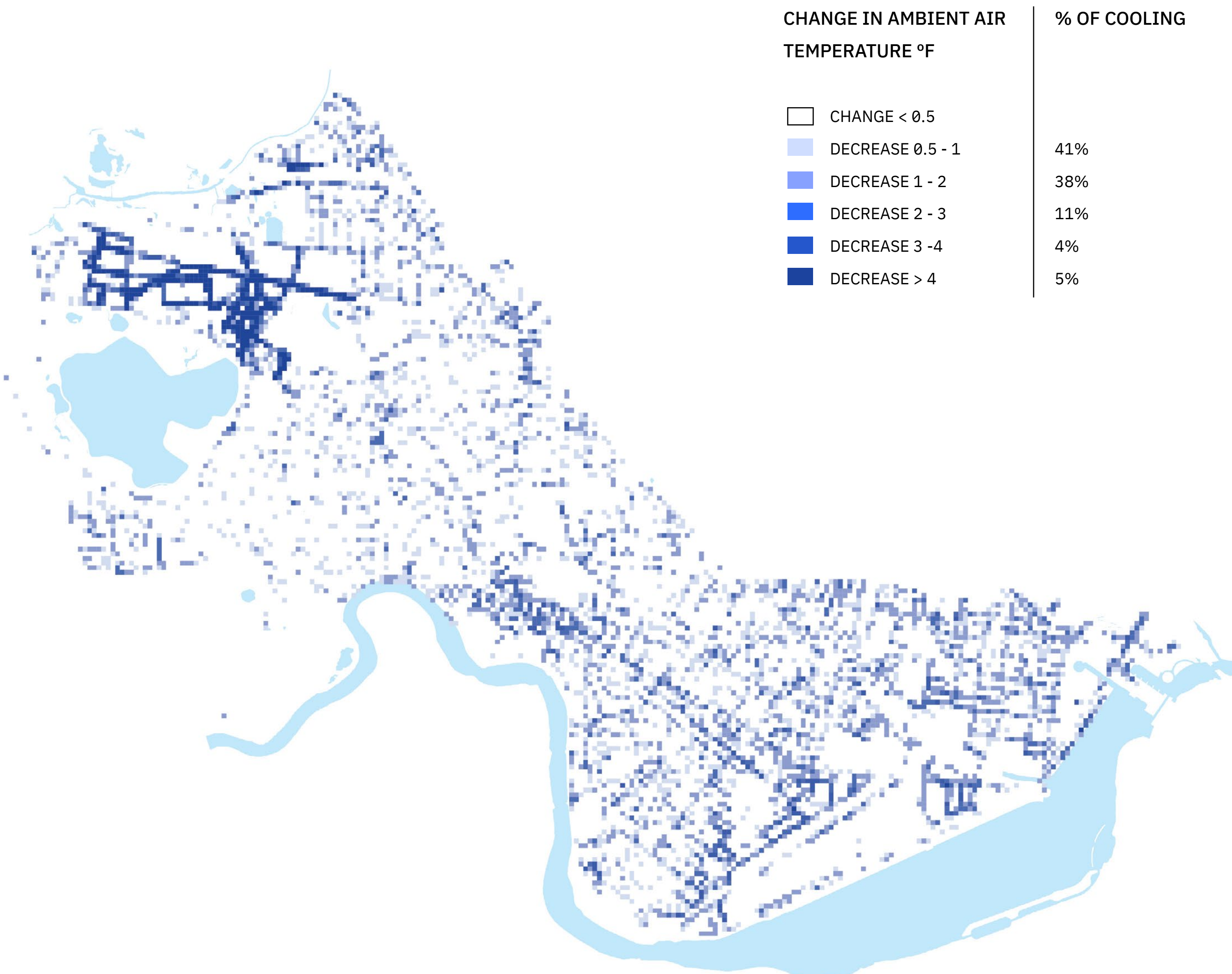


FIGURE 5.3 — 25% OF THE CITY WOULD EXPERIENCE A SIGNIFICANT DECREASE IN TEMPERATURE (> 0.5 °F) AND COOLING IS PERVASIVE AND CREATES CONTINUOUS COOL CORRIDORS THROUGH THE CITY

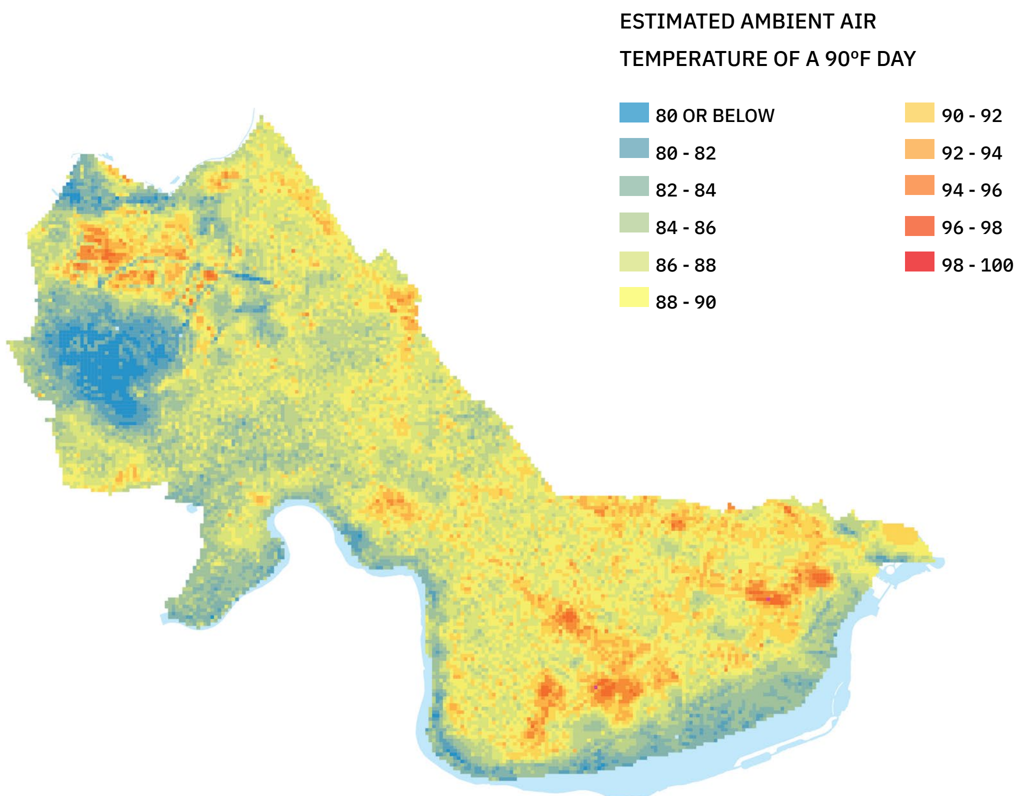


FIGURE 5.4 — 2018 CANOPY PLUS 12,000 NEW R.O.W TREES AT MATURITY

ADDITIONAL PLANTING OPPORTUNITIES

Even with this ambitious approach to maximizing plantable area within the R.O.W., the City can still only achieve a 36% canopy cover over the public realm people occupy most frequently. To further increase this percentage a transformation in the design of the R.O.W. would need to take place.

Currently, 65% of Cambridge is impervious — covered by buildings, roadways, sidewalks, or recreational facilities, and essentially these areas have no ecological value. A significant portion of the city, about 26% of the total city land area, is dedicated to asphalt — roads, driveways, and surface parking facilities. The City's Community Development Department is currently producing a New Mobility Blueprint to be completed in 2020, which will outline a transition to a more pedestrian, bicycling, and transit friendly future, including scooter shares and car sharing. Lower levels of car ownership, more shared transport and alternative transportation methods will likely lead to a reduced reliance on personal car parking and therefore a reduced need for pavement area in the R.O.W., just where more trees are needed.

In the years ahead, it is vital that urban forestry planning be coordinated with transportation planning. The possible repurposing of space allocated for personal vehicular transport to space for trees and permeable materials is an opportunity to create complete streets for Cambridge.

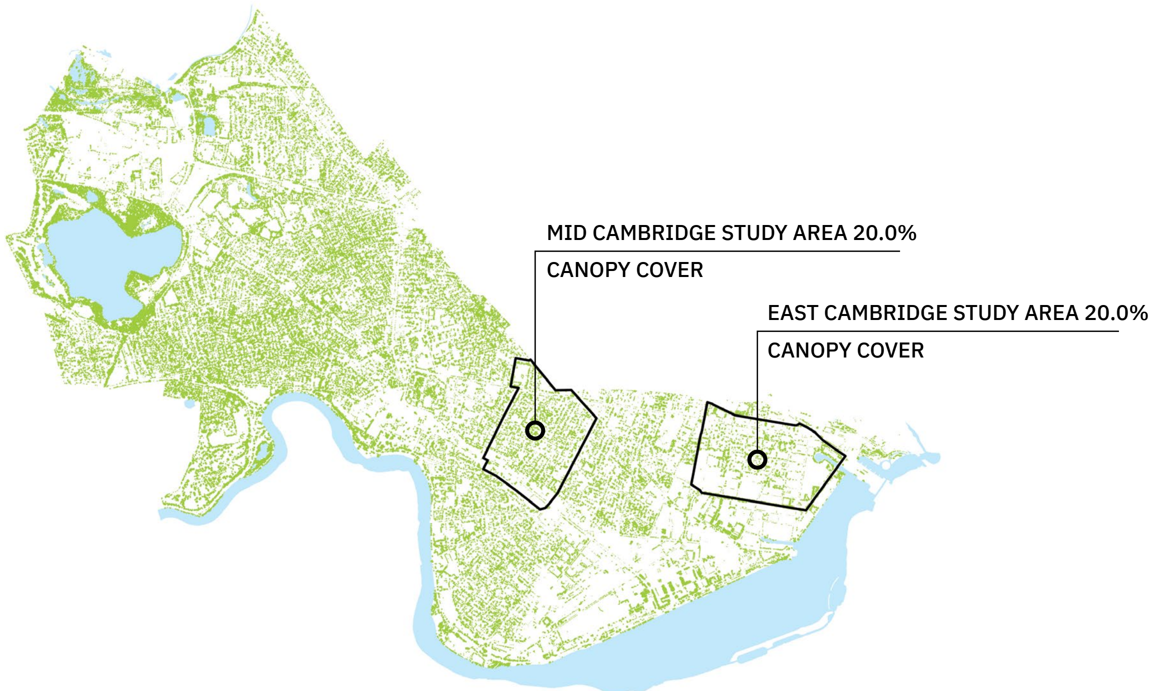


FIGURE 5.5 — EAST CAMBRIDGE AND MID CAMBRIDGE HAVE CANOPY COVER LOWER THAN THE CITY AVERAGE

5.2 Neighborhood Canopy Studies

Question: We seek to increase canopy cover in canopy deficient neighborhoods. The below case studies are a type of sensitivity analysis — with a maximum effort to plant more trees, to what extent can we increase canopy cover in neighborhoods with the least canopy cover?

What available areas exist within some of Cambridge's most dense neighborhoods in which to plant trees? How much can tree planting reduce the urban heat island and what strategies are most effective at moving the needle?

Discussion: East Cambridge and Mid Cambridge were selected for case studies because they both currently have canopy cover lower than City-wide average of 26% (15% and 24%, respectively for the study areas, neighborhood canopy covers are slightly different). These two neighborhoods also include a broad range of urban typologies, so multiple planting strategies could be tested. *Figure 5.5*

EAST CAMBRIDGE CASE STUDY

The East Cambridge study area consists primarily of residences with no front yard setbacks and large blocks with limited setbacks. Residential areas also have a high percentage of imperviousness with many side yards and backyards paved. Large gaps in canopy tend to be associated with large or closely spaced buildings and surface parking lots.

In this idealized scenario, new trees are placed within unplanted areas in the R.O.W. at 30' spacing and at least 4' away from an existing curb cut (driveway or parking lot entrance, for example). Lack of sufficient detail in the GIS data means that trees may have been placed in areas that conflict with existing infrastructure, for example where a fire hydrant might preclude planting.

Because East Cambridge generally has very narrow sidewalks and very limited front yard space for tree planting, the study identified four streets in the residential part of East Cambridge where roadway space could be recaptured for another row of street trees. This additional row of planting would increase the soil volume for both existing and new trees.

Current canopy cover of residential properties is 20%. In this scenario additional trees are planted in backyards to increase canopy cover to 30%. In many cases, impermeable surfaces (pavement) would have to be removed or spaces would have to be allocated within those impermeable areas to create planting opportunities.

For the large parks in the study area, John A. Ahern Park is buffered with another line of trees and Rogers Field Park, a proposed park which is currently all turf, is planted per the current proposed plan with canopy trees.

Lastly, within large commercial/industrial blocks the greatest planting opportunity is to plant more trees in existing surface parking lots. With the canopy cover on parking lots currently only 13%, there is potential to plant additional trees to create a canopy cover of 30% with the caveat that this specific study attempts only to evaluate the cooling effectiveness of different planting strategies, not feasibility. Feasibility of various strategies is discussed in *Section 6.2.*

In this scenario a total of 1,800 new trees are added to the 2018 canopy and projected to have a 25' canopy spread (by 2050). This increased neighborhood canopy cover from 15% to 25%. With this level of increased canopy, 63% of East Cambridge would experience cooling of 0.5°F degrees or more, with almost half of East Cambridge experiencing cooling of 1°F or more. Areas experiencing the greatest cooling are places where planting is more dense and in larger contiguous areas — primarily in parks and backyards. As previously noted, the model averages a 100'x100' grid, and the cooling directly under the shade of a tree will be felt more significantly.

By planting approximately 1,800 trees, and assuming they all grow to be mature canopy trees in 20 years, a significant level of cooling can potentially be provided by shade in this neighborhood.

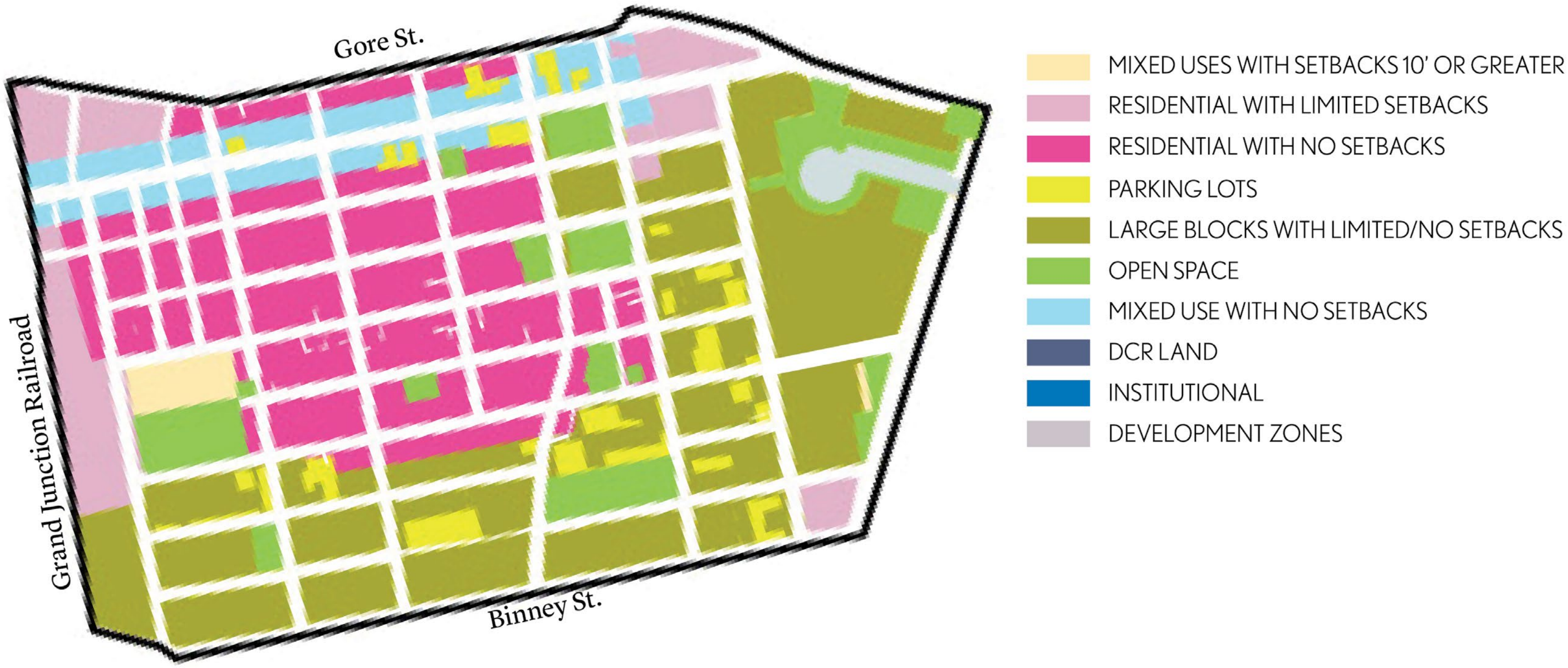


FIGURE 5.6 — PROPERTIES IN EAST CAMBRIDGE ARE PRIMARILY RESIDENCES WITH NO FRONT YARD SETBACKS, LIMITED PERMEABLE BACKYARDS, AND LARGE COMMERCIAL/ INDUSTRIAL DEVELOPMENTS WITH LIMITED SETBACKS.

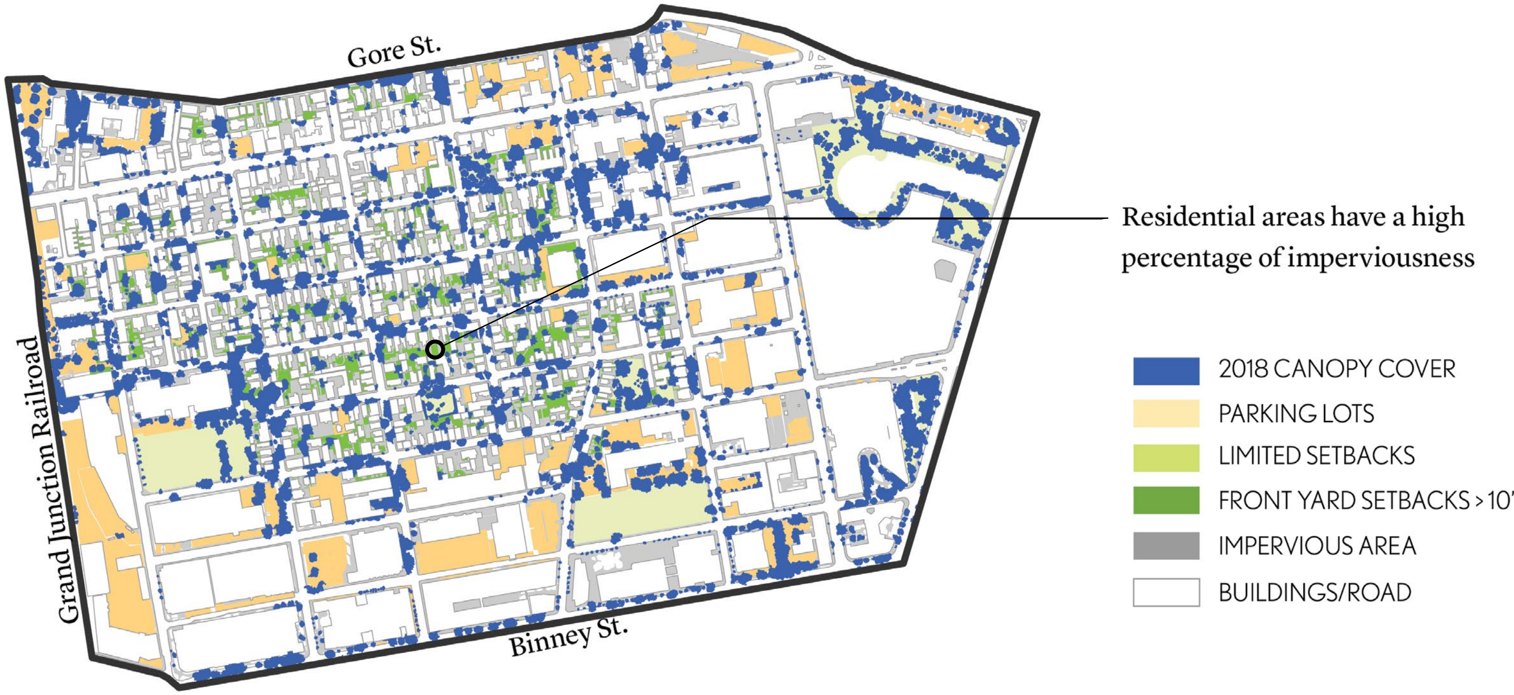


FIGURE 5.7 — EXISTING CANOPY COVER IN EAST CAMBRIDGE IN 2018.

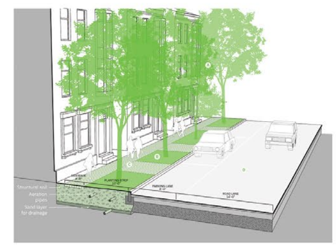
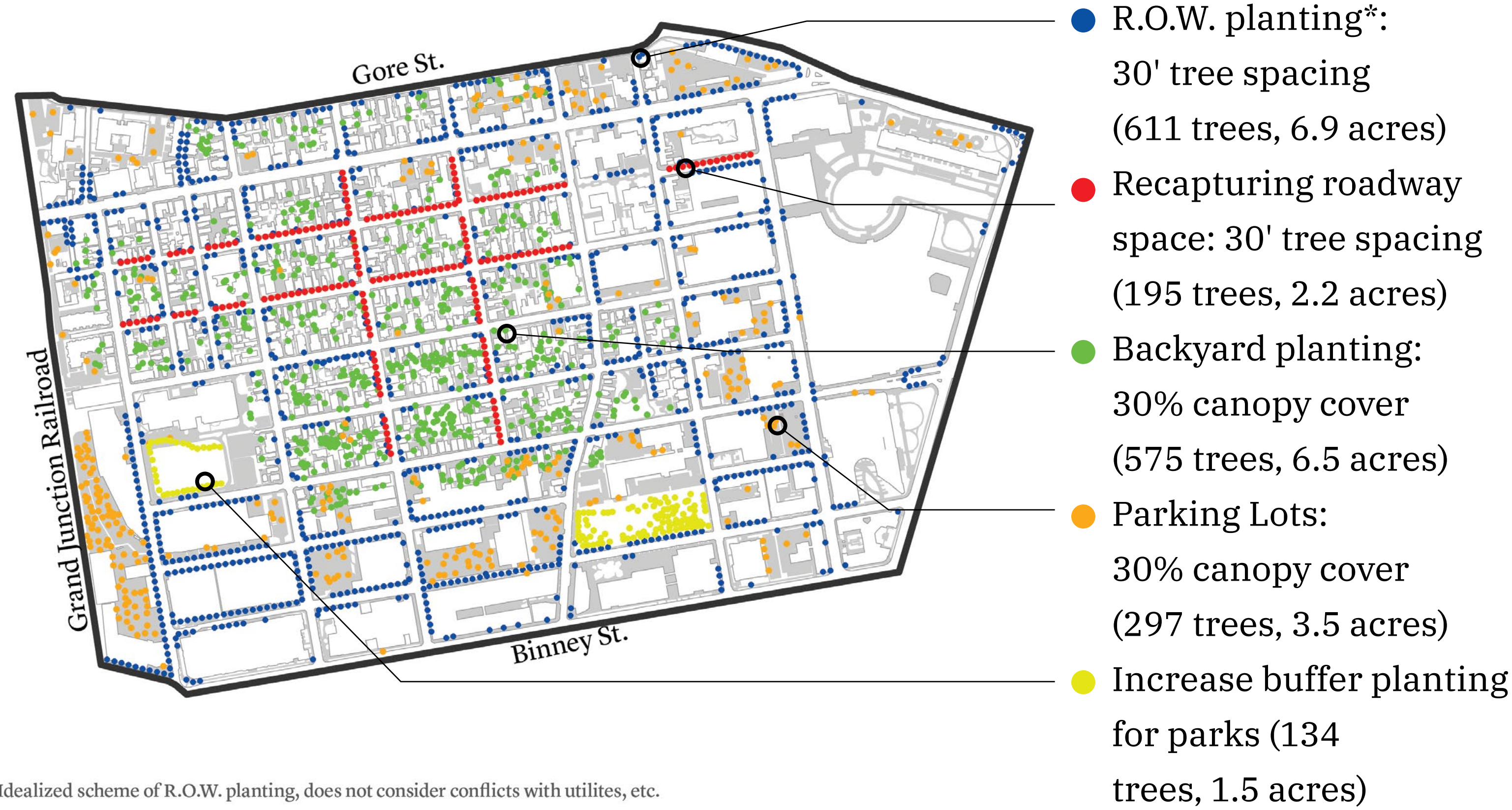


FIGURE 5.8 — PLANTING OPPORTUNITIES IN EAST CAMBRIDGE ARE PRIMARILY ON STREETS, IN BACKYARDS, AND PARKING LOTS.



*Idealized scheme of R.O.W. planting, does not consider conflicts with utilites, etc.

FIGURE 5.9 — IDEALIZED TREE PLANTING SCENARIO

FIGURE 5.10 — IN AN IDEALIZED SCENARIO, BY 2050 CANOPY COVER INCREASES FROM 15.1% TO 25.4%.

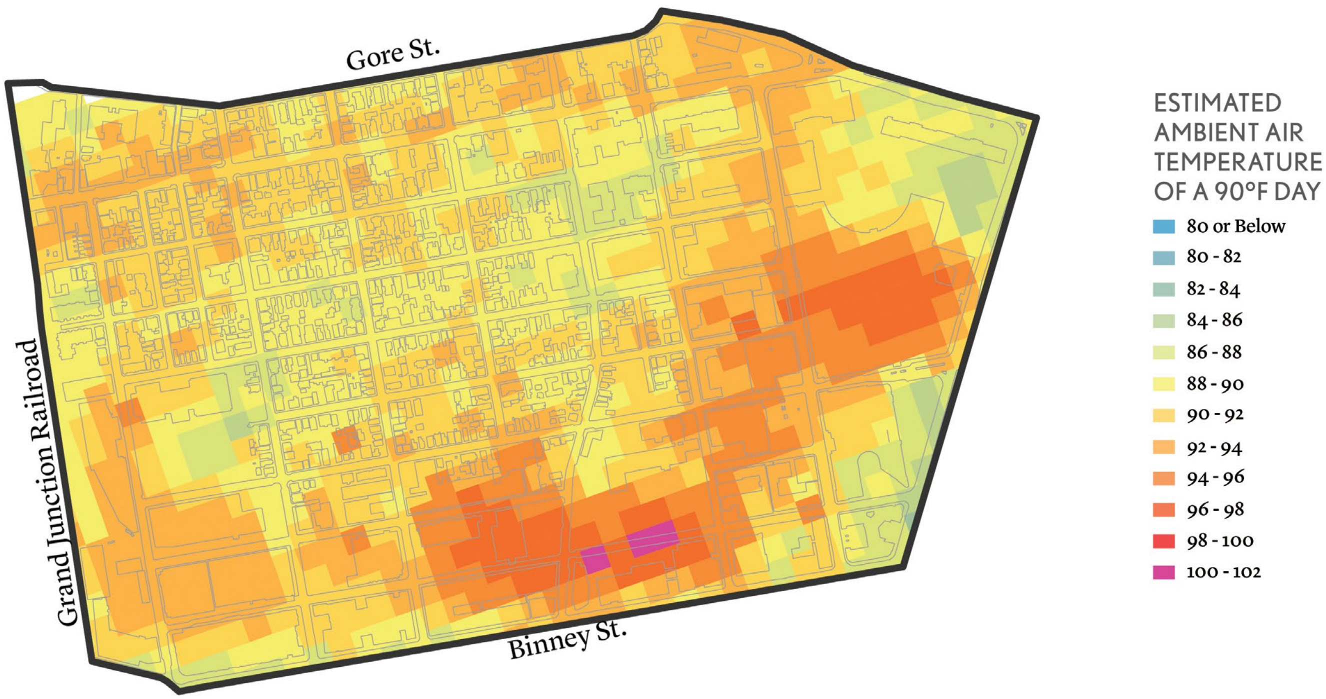


FIGURE 5.11 — HEAT ISLAND MAP FOR 2018 CANOPY.

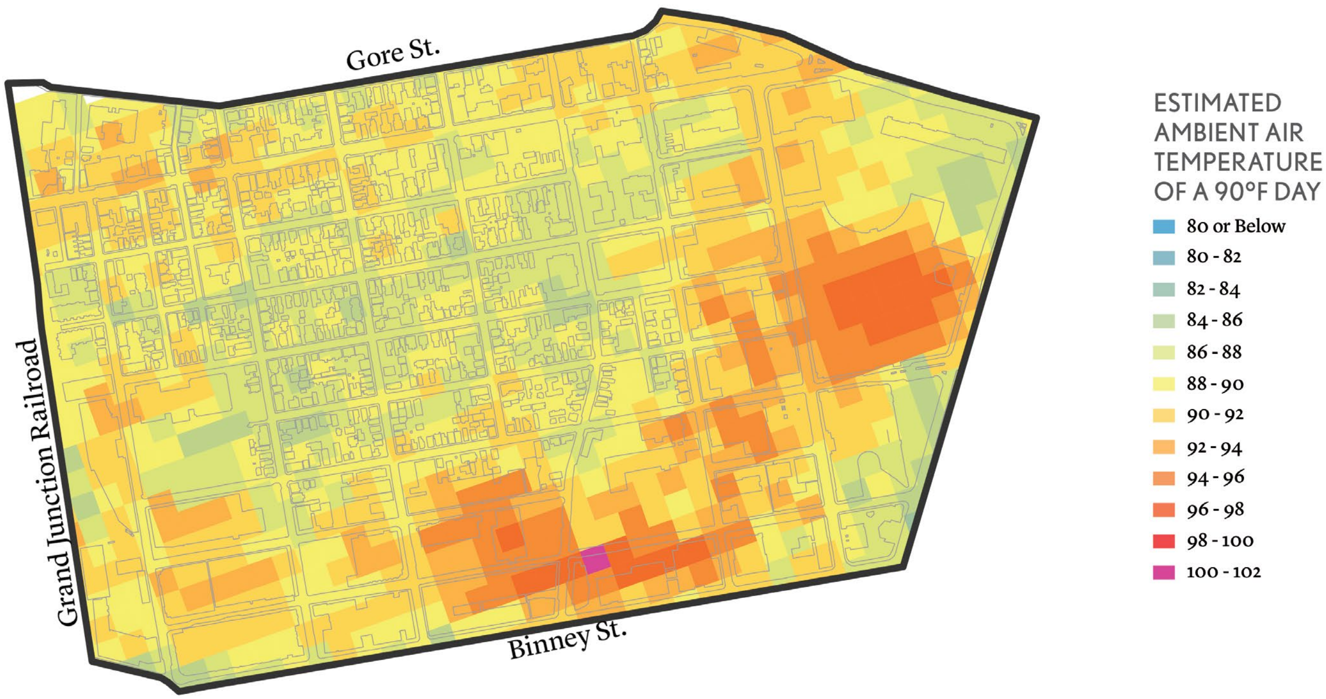


FIGURE 5.12 — HEAT ISLAND MAP FOR IDEALIZED PLANTING SCENARIO

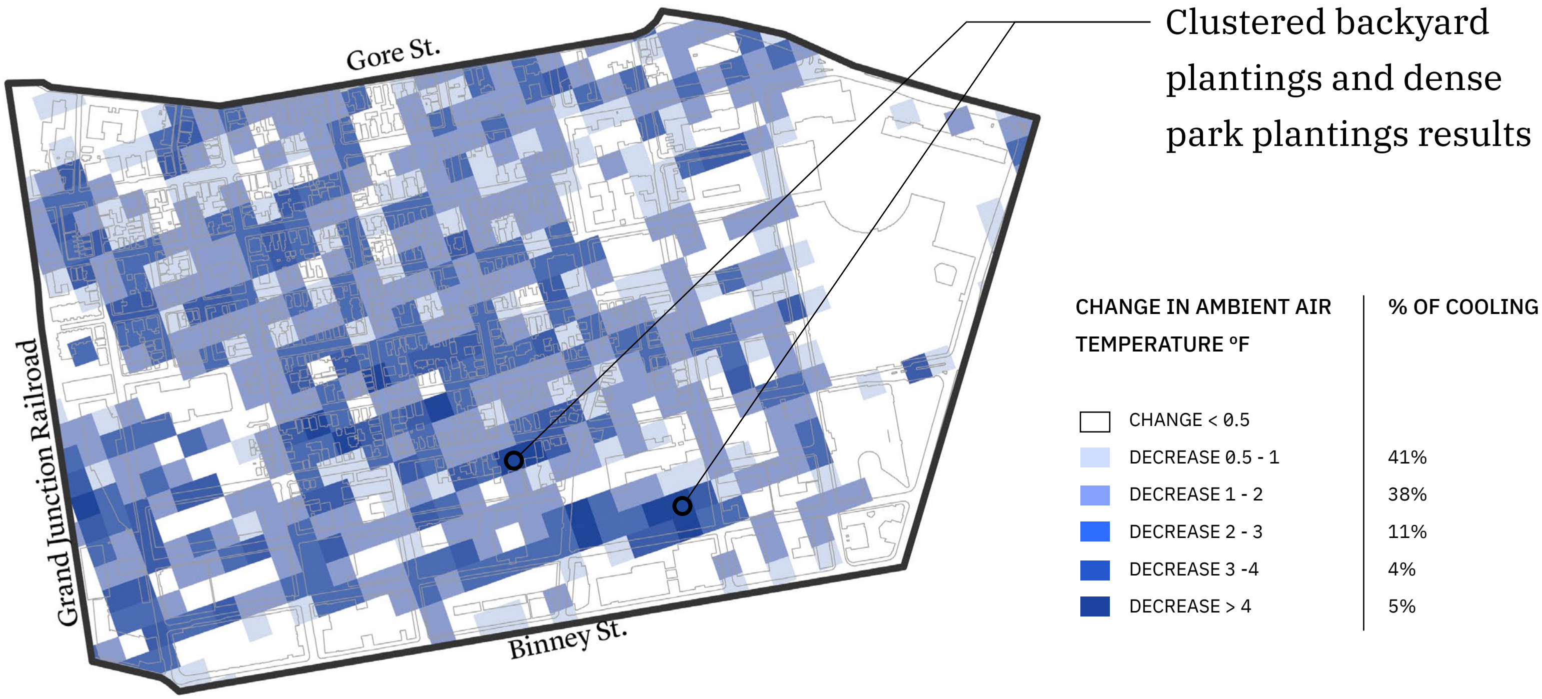


FIGURE 5.13 — 62% OF EAST CAMBRIDGE EXPERIENCES COOLING OF 0.5 DEGREES OR MORE

MID CAMBRIDGE CASE STUDY

The Mid Cambridge study area consists primarily of residences with limited front yard setbacks and mixed use lots along major transportation corridors. Canopy is most dense in areas with front yard setbacks greater than 10', and similar to East Cambridge, large areas without canopy tend to be associated with large buildings and parking lots. There is a noticeable lack of canopy along Massachusetts Avenue.

In this idealized scenario, new trees are placed within unplanted areas in the R.O.W. at 30' spacing and at least 4' away from an existing curb cut (driveway or parking lot entrance, for example). Lack of sufficient detail in the GIS data means that trees may have been placed in areas that conflict with existing infrastructure, for example where a fire hydrant might preclude planting. To take advantage of opportunities for shade to cast on the R.O.W. from trees in front yards, this scenario added trees where there was unplanted space in front yards with setbacks of approximately 10' or more.

Parking lots are prevalent in MidCambridge and currently have 19% canopy cover. This scenario adds trees randomly within the parking lots to increase cover to 30%. Finally, different R.O.W. planting typologies have been tested on major corridors. On Massachusetts Avenue, in areas where sidewalks can support a double row of trees, new trees are placed in a staggered configuration to create a double row of canopy trees. For Broadway and Cambridge Street, where sidewalk widths cannot accommodate a second row of trees, subcanopy trees are placed approximately 15' to 20' from existing street trees.

This scenario models the impact of new canopy trees with a 25' diameter canopy and subcanopy trees with 12' diameter canopies, which approximates projecting their growth to 2050. Adding these new trees to the 2018 tree canopy for Mid Cambridge, canopy cover increases from 24% to 30%.

The model indicates that with this increase in canopy cover, 51% of Mid Cambridge would experience cooling of 0.5 °F or more, with 28% of the neighborhood experiencing cooling of 1 °F or more. The greatest cooling is seen along Massachusetts Avenue and within parking lots.

The result of this case study indicates that by planting approximately 2,000 trees, and maintaining them until they become mature canopy trees in 20 years, a significant level of cooling can be provided in this neighborhood. *Figures 5.14–20*

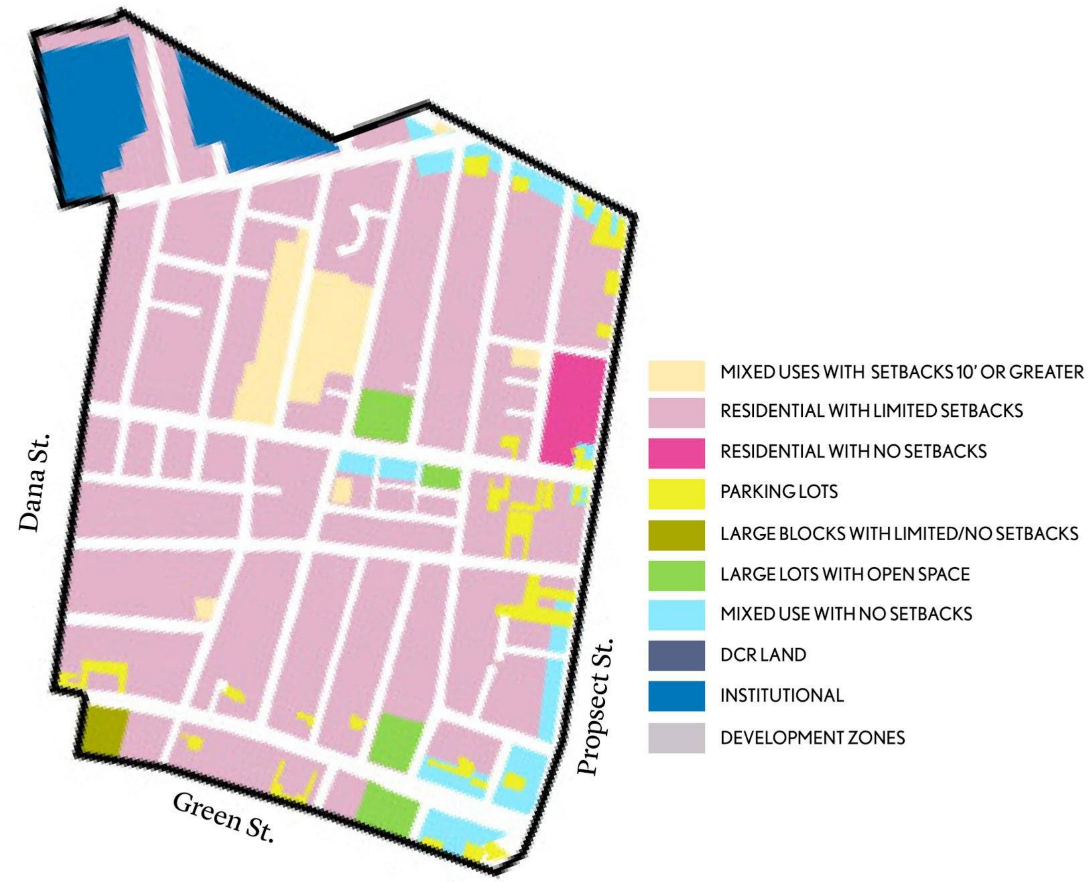


FIGURE 5.14 — MID CAMBRIDGE PROPERTIES ARE PRIMARILY RESIDENTIAL WITH LIMITED SETBACKS WITH SOME MIXED USES.

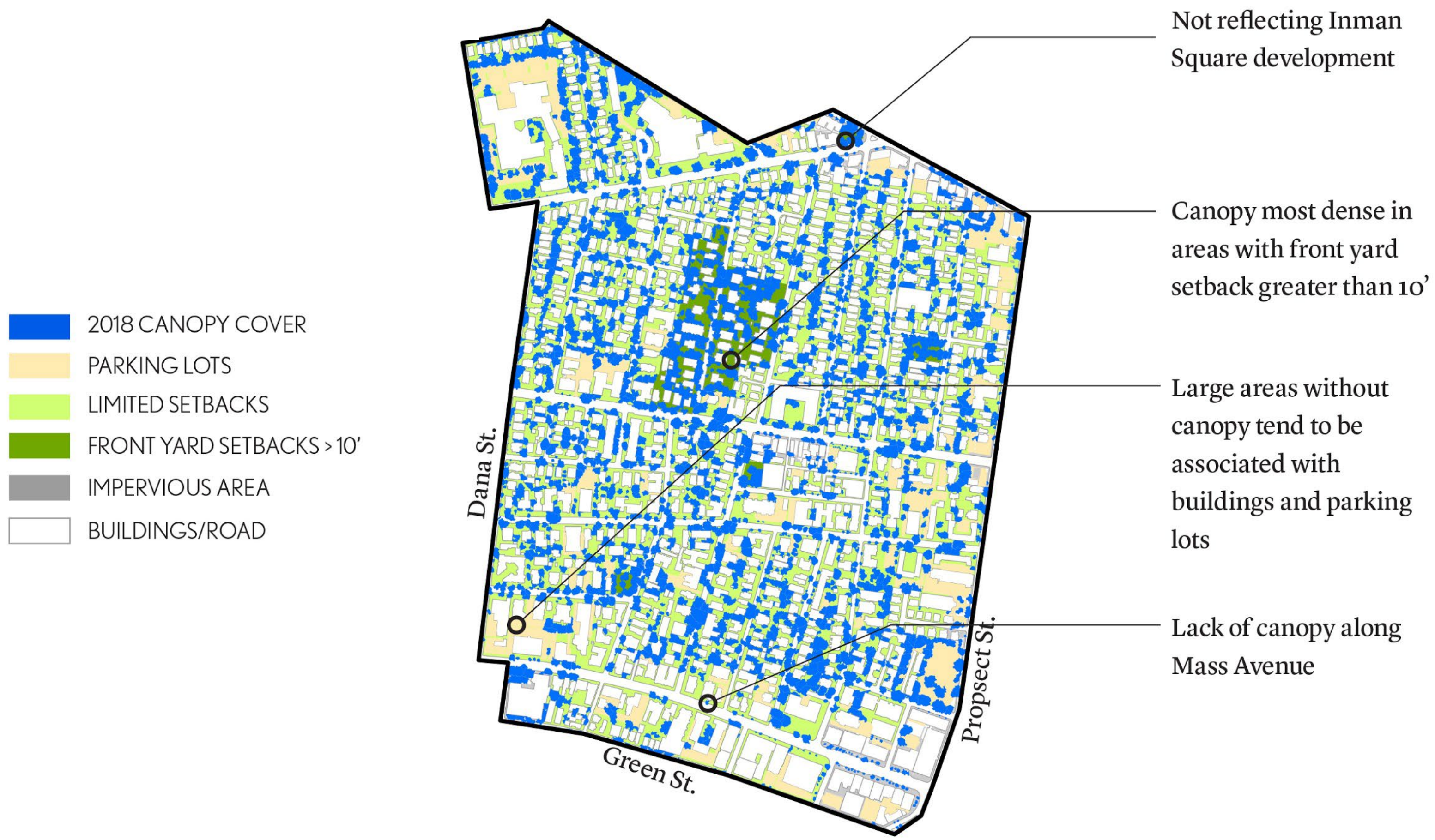


FIGURE 5.15 — EXISTING CANOPY COVER IS 24%.

*Idealized scheme of R.O.W. planting, does not consider conflicts with utilites, etc.

FIGURE 5.16 — PLANTING OPPORTUNITIES IN MID CAMBRIDGE ARE ALONG STREETS, IN FRONT YARDS, AND IN PARKING LOTS

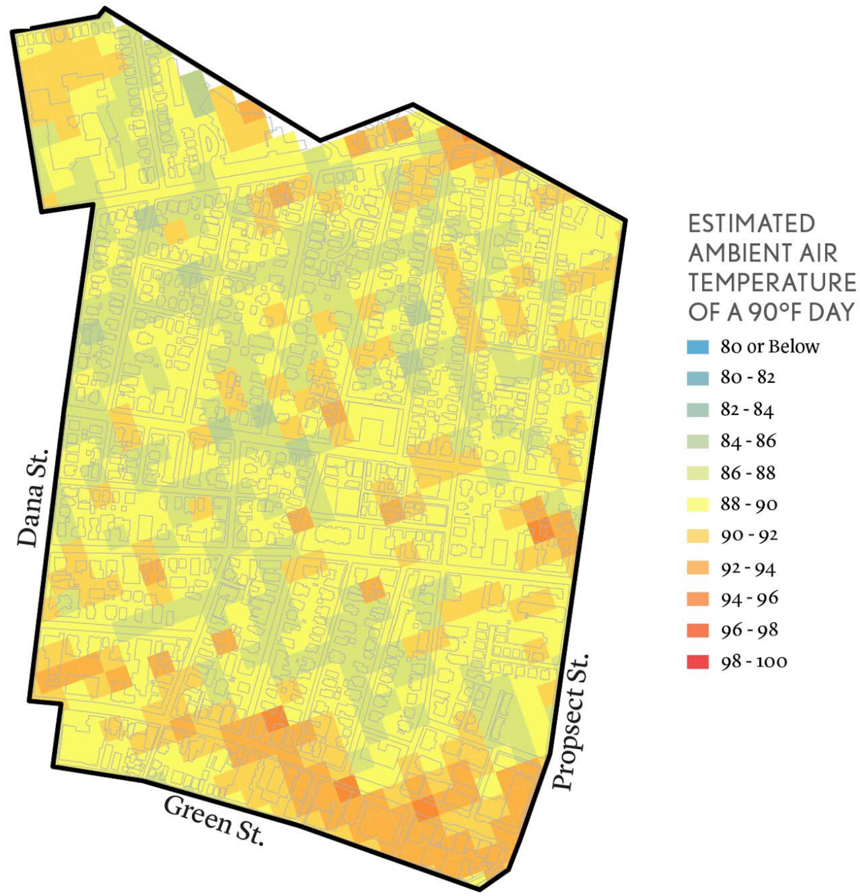


FIGURE 5.17 — HEAT ISLAND FOR 2018 CANOPY.

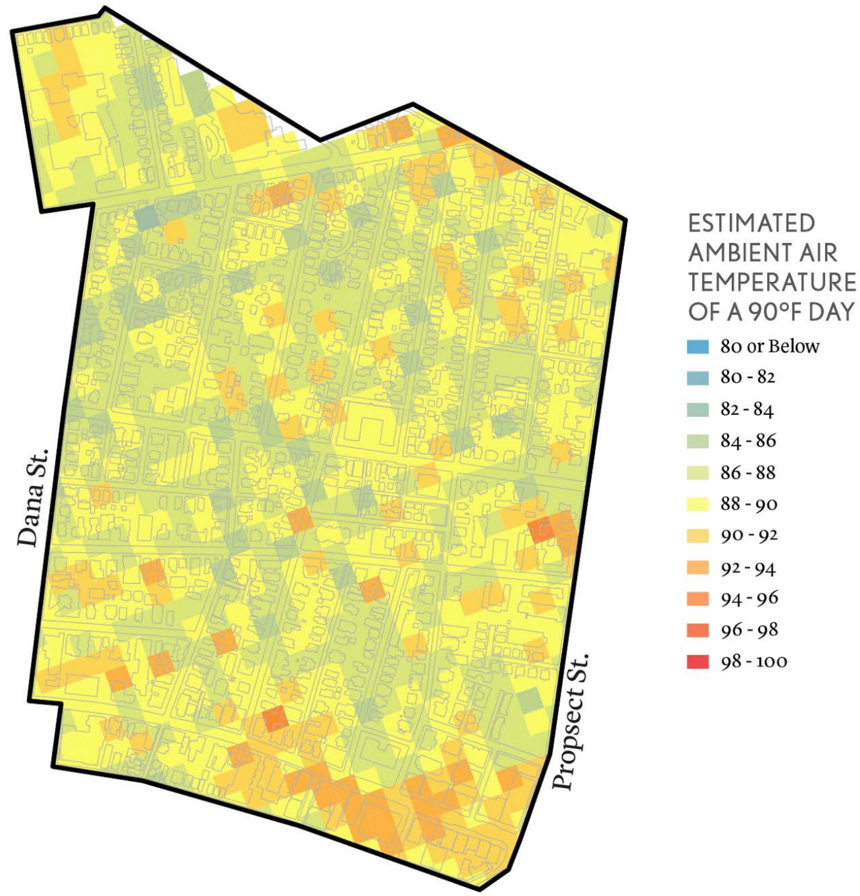
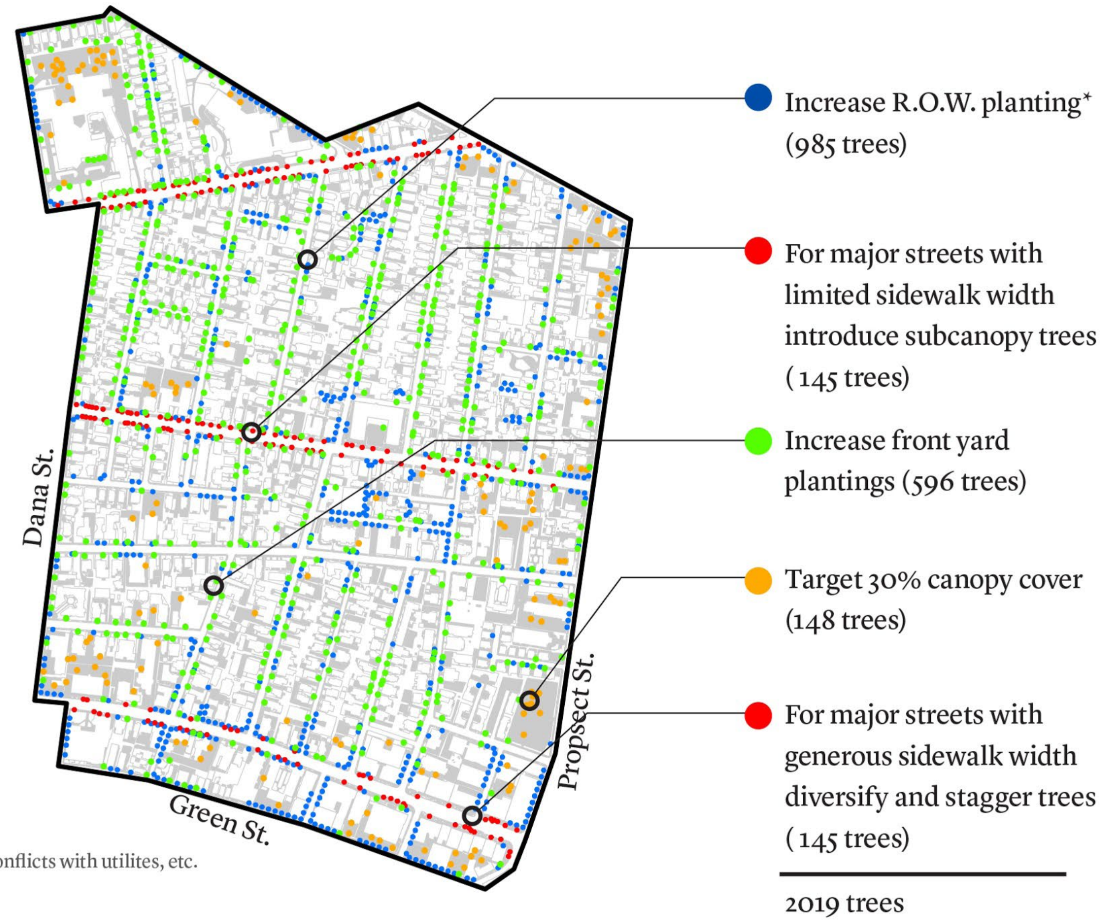


FIGURE 5.18 — HEAT ISLAND MODELING RESULTS OF IDEALIZED PLANTING SCENARIO



*Idealized scheme of R.O.W. planting, does not consider conflicts with utilites, etc.

FIGURE 5.19 — IDEALIZED TREE PLANTING SCENARIO FOR MID CAMBRIDGE

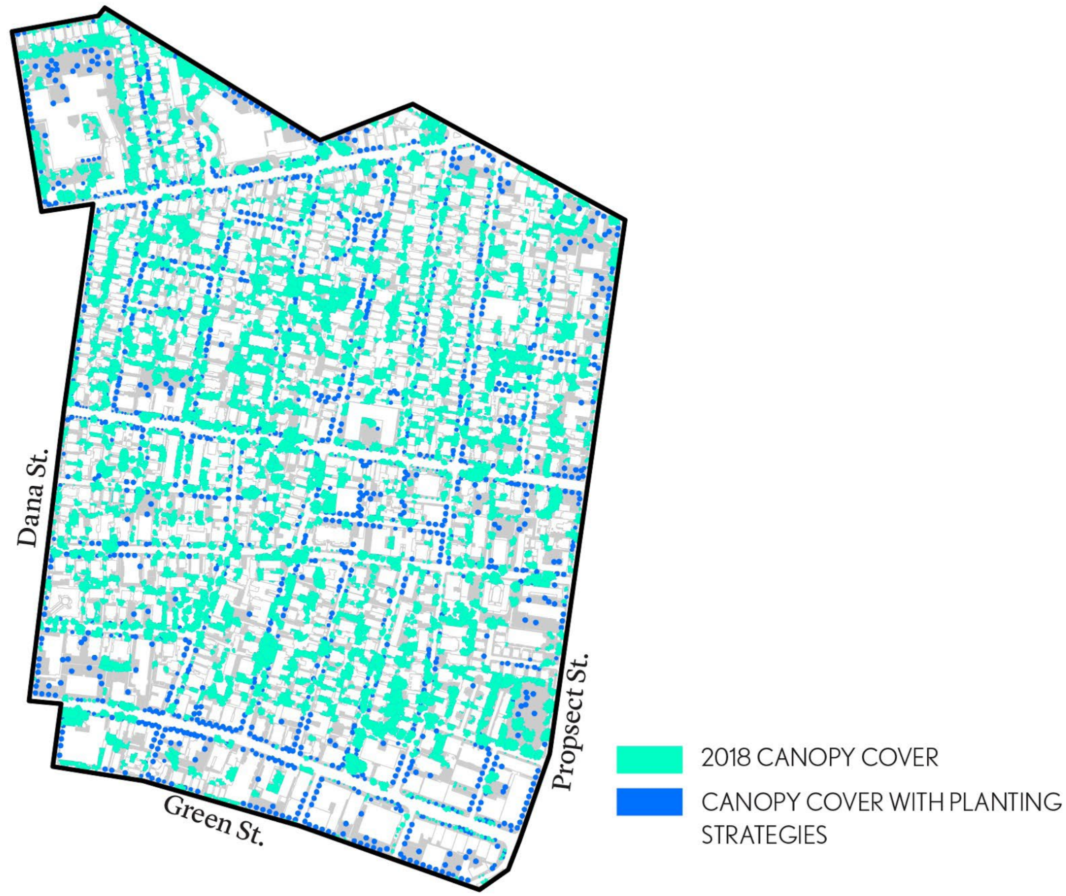


FIGURE 5.20 — IN THE IDEALIZED SCENARIO, CANOPY COVER INCREASES FROM 23.9% TO 30.1%

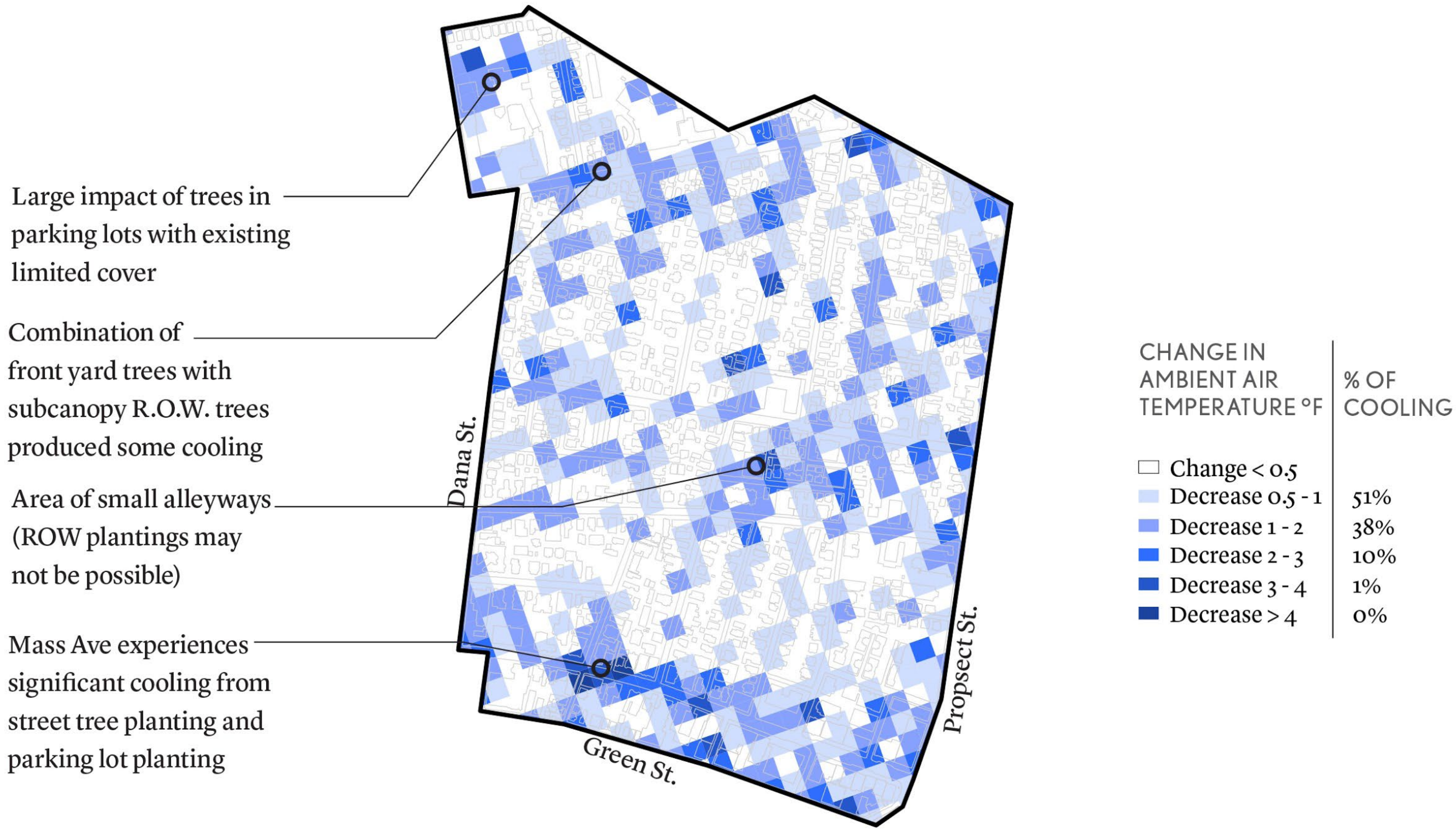


FIGURE 5.21 — 51% OF EAST CAMBRIDGE EXPERIENCES COOLING (>0.5 DEGREES)

5.3 Further Discussion

While the feeling of being in the shade of a tree has a strong impact on the experience of heat at an individual level, research has shown that the cooling from tree canopy is most broadly impactful on ambient temperature at neighborhood scales when shade is aggregated in larger contiguous areas[2]. This appears to be borne out in the neighborhood scenarios where larger zones of new planting show a stronger return on investment in terms of cooling impact. However, even small green areas (less than 200' wide), can have a cooling effect. In one study, green areas less than 200' wide were found to have cooling effects on streets 100' away[3].

Research has also shown a non-linear cooling effect as canopy cover increases[4]. For example, the relative cooling effect is greater when increasing canopy cover from 30% to 40% than from 20% to 30%. Cooling impacts increase dramatically over 40% canopy cover. While it is feasible to obtain a relatively high percentage of cover in certain types of land uses — canopy cover in Cambridge city parks averages 43% — the opportunity for this high percentage of cover is limited in other land use types. This puts significant pressure on parks and other open spaces in the City to provide a greater contribution to cooling, and suggests that increasing the distribution, scale and canopy cover of parks will be a critical factor in growing canopy cover city-wide.

While the priority may be to first target areas with deficient canopy for new planting initiatives, research also points to the importance of preserving areas with high canopy cover for their cooling benefits[5]. For example, it will be important to maintain canopy in areas with a high percentage canopy cover and where those areas are large and contiguous.

Tree species differ significantly in their ability to reduce air and surface temperatures. Trees with a high leaf-area density (e.g. Linden trees) and a high rate of transpiration are more effective in cooling air temperatures[6], therefore the kinds of trees planted when trying to mitigate hot spots is an important consideration.

The cooling effect of tree canopy may be amplified during extreme heat. The impact of shade from canopy cover on ambient temperature is most significant for daytime temperatures. Land cover type matters more for moderating evening temperatures, so to cool public realm spaces in the evenings, strategies such as replacing paved surfaces with pervious surfaces such as turf or plantings should also be considered[7].

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2 Ziter, Carly D., Eric J. Pedersen, Christopher J. Kucharik, and Monica G. Turner. 2019. “Scale-Dependent Interactions between Tree Canopy Cover and Impervious Surfaces Reduce Daytime Urban Heat during Summer.” Proceedings of the National Academy of Sciences 116 (15). Proceedings of the National Academy of Sciences: 7575–80. doi:10.1073/pnas.1817561116.

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7 Ziter, Carly D., Eric J. Pedersen, Christopher J. Kucharik, and Monica G. Turner. 2019. “Scale-Dependent Interactions between Tree Canopy Cover and Impervious Surfaces Reduce Daytime Urban Heat during Summer.” Proceedings of the National Academy of Sciences 116 (15). Proceedings of the National Academy of Sciences: 7575–80. doi:10.1073/pnas.1817561116.

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6. Targets, Prioritization, and Next Steps

This Plan has set forth a framework for understanding the urban forest, a set of values to guide decision-making, and a toolbox of strategies to curb loss and grow the urban forest. In order to galvanize action, evaluate the scale and pace of intervention required, and prioritize action, the city should set a goal for city-wide canopy cover, specific planting targets, and a time frame for achieving that goal.

The goals should be ambitious but feasible. It should grow out of the community's sense of urgency and recognize the need to balance priorities.

Values of equity, resilience, and shared responsibility define primary goals and targets for each neighborhood and land use type. The following pages lay out the rationale for those goals and targets, and an analysis of feasibility — what's required to meet these goals from each member of the community. Finally, this chapter describes immediate next steps and proposes a dynamic and regular process for evaluating impacts and keeping the Cambridge UFMP relevant in the years ahead.

6.1 Set Ambitious Goals

Careful selection of where trees are planted and planting wisely to ensure success, is more important than planting trees at a greater quantity just to meet a target. Thus, primary canopy goals are proposed based on the values of equity, resilience, and shared responsibility.

The city should aim for a minimum of 25% canopy cover within each neighborhood for a more equitably distributed canopy. Current canopy cover within each neighborhood varies from 13% to 37%. The level of effort required to achieve this and the strategies deployed will be dependent on the specific conditions of each neighborhood — urban character which defines plantable areas and the amount of existing canopy cover varies greatly among neighborhoods.

Focusing on resilience and creating connected cool corridors in the public realm, the City should aim to achieve 60% canopy cover over sidewalks and to reduce the prevalence of heat island hotspots along primary urban corridors by 50%.

Recognizing the need for shared action to realize these goals, all constituent groups (residents, the City, institutions, commercial/industrial landowners, etc) should commit to increasing relative canopy cover by 10 to 25% in their respective landholdings (see *Section 6.3* Define Specific Targets and Apply Strategies). Realizing these goals requires a broad cross-section of the community planting a significant number of trees as well as reducing the current rate of loss of the city's existing trees.

These goals support the secondary goal of reaching 30% canopy cover city-wide. At first glance, aiming for 30% may not seem ambitious because canopy cover in Cambridge was nearly 30% in 2009. However, as this study has shown, the systemic causes of canopy loss and the fact that trees need time to grow before they develop significant canopy indicate that it will take significant effort and time to first, reverse the trend, and then, to grow canopy. It will also take time for the City and its partners to implement educational and outreach programs required to stem loss and to ramp up planting efforts and implement policy changes that will grow canopy. Fully implemented, these strategies set a trajectory for an urban forest that can continue to grow beyond 30% canopy cover.

These broad goals are supported by specific quantifiable targets that help direct resources and measure interim progress in a meaningful way. The targets set by this study assume a reduction in canopy loss by 35% to 50%, and the better the Cambridge community can maintain trees and reduce tree removal, fewer trees will need to be planted. Specific targets for the number of trees to plant each year should be set in the short, medium and long term, and should be articulated both city-wide and at a finer grain. Progress should be evaluated by neighborhood and land-use type, with specific attention to the values of equity, resilience and shared responsibility.

IMPROVE EQUITY

Goal: Every neighborhood should have at least 25% canopy cover.

The health of the urban forest should not just be evaluated by overall canopy cover. The distribution of that canopy and how it relates to how people experience the city on a daily basis should be a criterion of evaluation. The amount of shade varies widely across Cambridge's neighborhoods, with

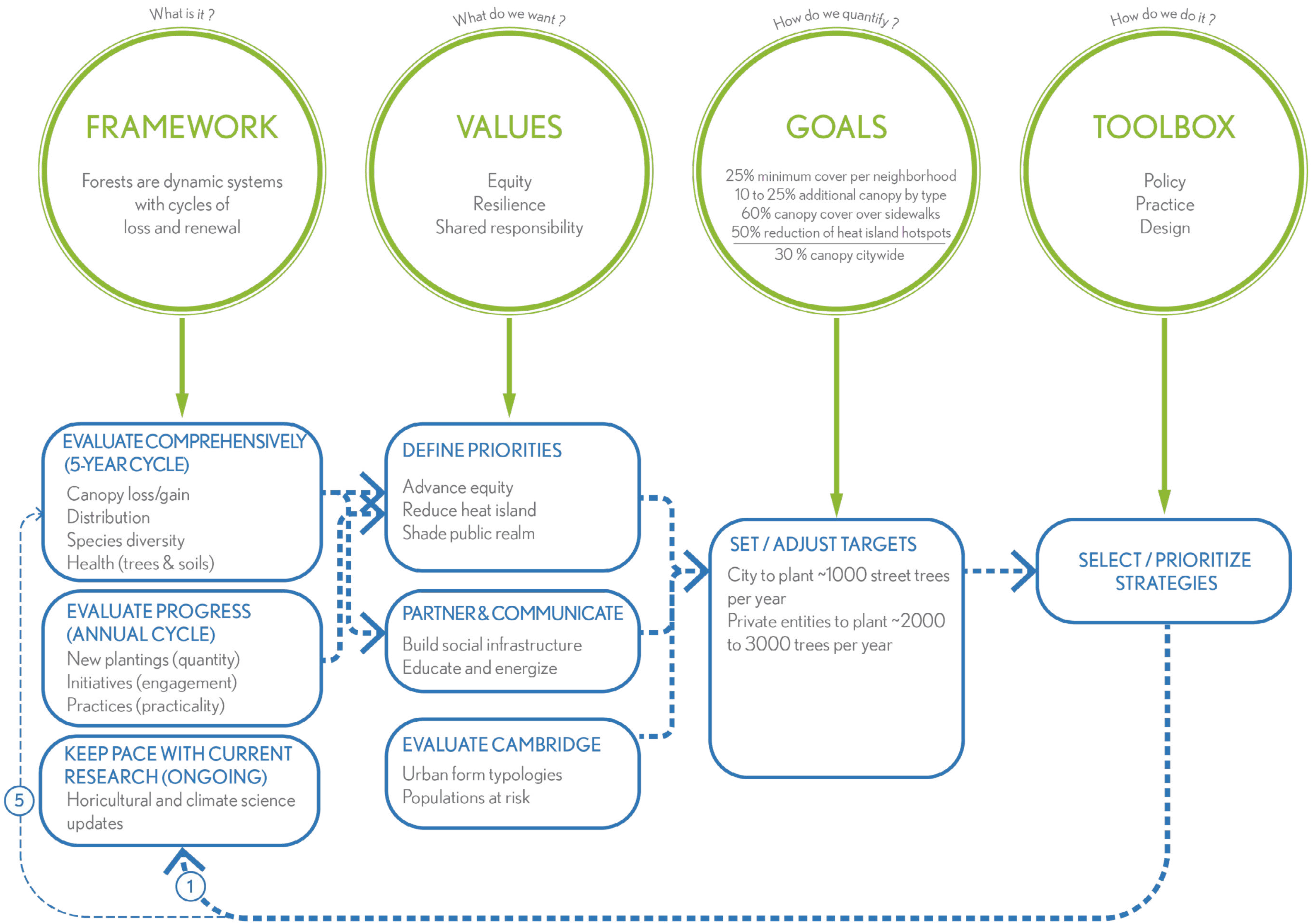


FIGURE 6.1 — URBAN FOREST MASTER PLAN DECISION PROCESS DIAGRAM

DRAFT GOALS AND TARGETS

EQUITY

Goal
Minimum 25% cover per neighborhood

Target
Each year, plant X* trees in neighborhoods deficient in canopy

Feasibility Analysis
Six neighborhoods do not currently meet the target. Will be difficult to achieve in East Cambridge.

SHARED RESPONSIBILITY

Goal
City, residents, universities, developers all to increase their canopy cover by 10 to 25% by 2050

Target
Each year, each constituent plants X* number of trees

Feasibility Analysis
There is enough plantable area to achieve this goal.

RESILIENCE

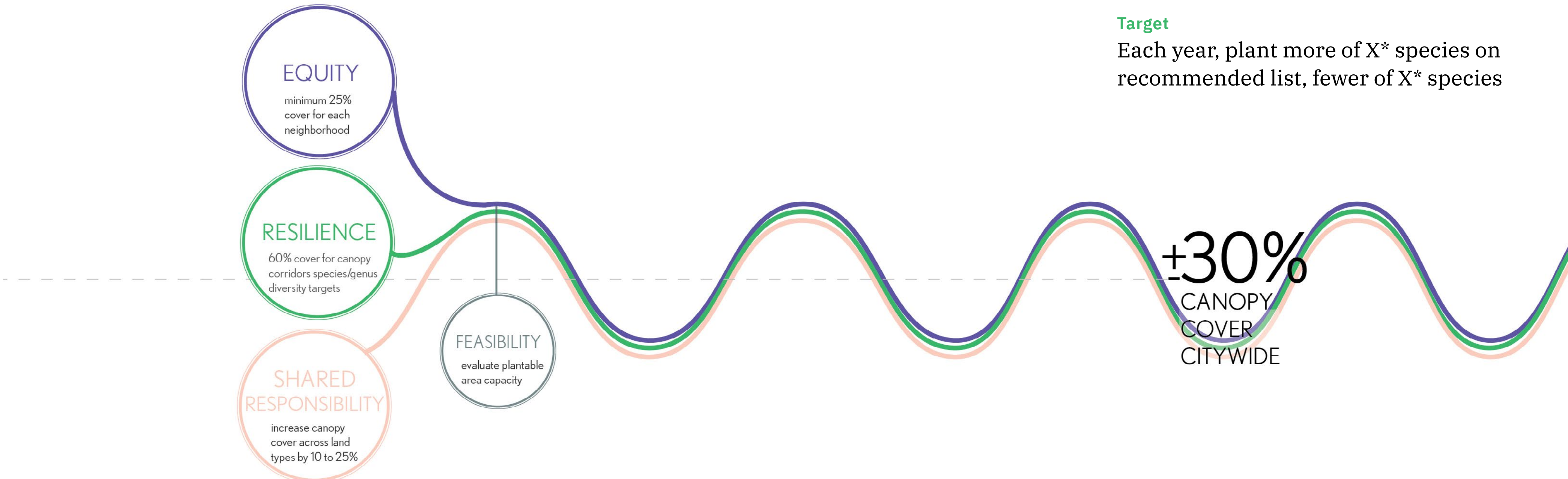
Human resilience goal
1. 60% of sidewalks canopy covered.
2. 50% reduction in the number of hotspots (92 degrees when 90 degree average) in the R.O.W.

Target

Each year, plant X* trees in the R.O.W.

Forest Resilience Goal
No more than 10% of a single species, 20% of a genus and 30% of a family.

Target
Each year, plant more of X* species on recommended list, fewer of X* species



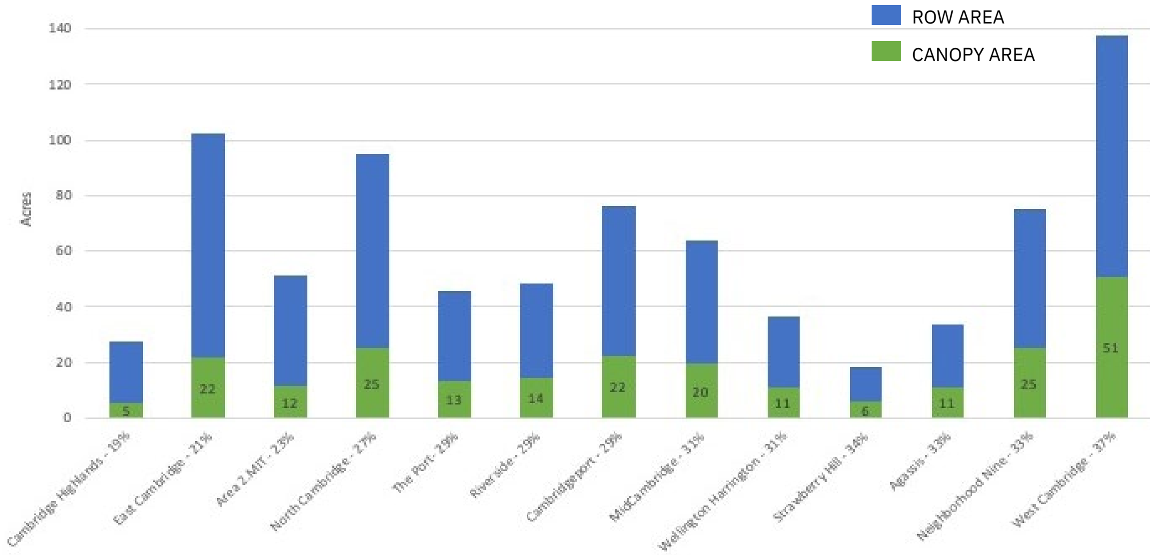


FIGURE 6.2 — RIGHT OF WAY CANOPY COVER BY NEIGHBORHOOD.
Right of Way includes the entire width of the public sidewalk and street.

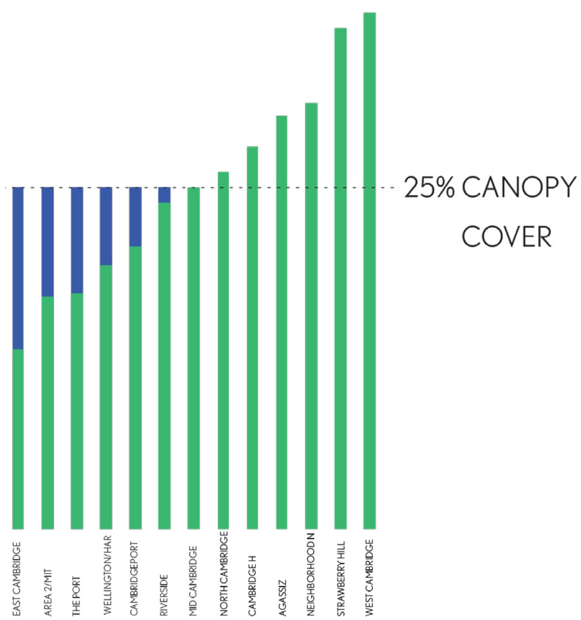


FIGURE 6.3 — EACH NEIGHBORHOOD SHOULD STRIVE FOR 25% CANOPY COVER AND NEIGHBORHOODS EXCEEDING 25% SHOULD FOCUS ON MAINTAINING CANOPY.

West Cambridge having almost triple the amount of canopy (37%) than that of East Cambridge (13%). In Cambridge as in many cities, low canopy cover generally corresponds with the distribution of populations at risk[1].

Currently, the six neighborhoods of East Cambridge, The Port, Area 2/MIT, Wellington/Harrington, Cambridgeport and Riverside have overall canopy cover below 25% (*Figure 6.3*). A similar story appears when examining R.O.W. canopy cover by neighborhood (*Figure 6.2*). East Cambridge, Area 2/MIT, and The Port have lower canopy cover in the R.O.W. than the City average of 28%. The notable exception is Cambridge Highlands, which neighborhood-wide has high canopy cover, but only 19% cover in the R.O.W. Tree planting efforts should be concentrated in these neighborhoods. In neighborhoods that exceed the minimum, efforts should be made to protect the existing canopy.

Neighborhoods with low canopy cover tend to have a similar type of urban form, with limited or no front yard setbacks, commercial or industrial and a greater percentage of impermeable surface. Space for trees both in the public way and on private land is limited. Canopy from street trees forms a large portion of the existing canopy cover — a good portion of the canopy in East Cambridge is from street trees while canopy in West Cambridge is mainly from planting on private property (*Figure 6.4*). To increase canopy cover, a public realm planting strategy is especially important, but to make space for trees, more significant and transformational alternative street design strategies that convert pavement to tree planting areas may be required. Investment solely by the City and primarily within the R.O.W. will not be enough to increase canopy sufficiently to meet the 25% target in many neighborhoods. Other strategies will need to be implemented to encourage new plantings on residential properties, campuses, parks, and large commercial/industrial developments.

An even distribution of canopy across the city is not achievable because of varied urban form and density. However, setting a minimum of 25% canopy cover as a goal for each neighborhood would go a long way in creating a more evenly distributed canopy. Achieving this goal would have a measurable impact on the urban heat island effect, which is most strongly felt by populations at risk who often reside in these same neighborhoods[2].

If neighborhoods that currently have a canopy cover deficit were all to achieve 25% canopy cover, total citywide canopy cover would increase to 28%.

ENHANCE RESILIENCE

ENHANCE HEALTH AND WELL-BEING

Goal: Sidewalks should have 60% canopy cover and hotspots within the R.O.W. should be reduced by 50%.

Note: The sidewalk is the area of pavement where pedestrians walk, and it is where street trees are planted. The R.O.W. includes the sidewalk and the streets. Thus, the canopy goal for sidewalk cover is more ambitious than the one for the R.O.W.

Tree canopy has traditionally been viewed as aesthetically beneficial for cities, but numerous scientific studies have shown that trees are vital for public health. Trees improve air quality, reduce stress, increased exercise, and improve social connections[3]. A recent study using data from 97 cities estimates that tree canopy prevents approximately 1,200 deaths a year from heat related incidents[4] and the presence of canopy results in fewer heat related emergency room visits[5]. Trees also encourage people to exercise more and children who are more exposed to greenery are less likely to be at risk for developing mental disorders as adults. See *Section 2.5* or further description of urban forest benefits and *Section 3.4* for heat island effect discussion.

The Climate Change Vulnerability Assessment (CCVA) proposes the concept of "cool corridors" where the ambient temperature along a travel corridor is cooler than the city average. Sidewalks are typically adjacent to asphalt roadways, a major contributor to urban heat islands as the dark surface of the asphalt captures and releases heat. Planting new trees in and adjacent to the public realm can substantially cool the ambient air temperature and is a primary strategy to achieve cool corridors. Reducing the ambient temperature along a city sidewalk below the city average will also likely require complementary strategies such as deploying light colored pavement, permeable surfaces, white roofs, green roofs, and vertical planting.

Connectivity Goal: To expand the connectivity and impact of cool corridors, the percentage of canopy cover directly over sidewalks citywide should increase. Current canopy cover over sidewalks citywide is 38% (72 acres of 187 total acres) with cover rates varying across neighborhoods and land use types (*Figure 6.5*). As tested in the Citywide Canopy Corridor Study (see *Section 5.1*) an additional 12,000 street trees in the R.O.W. could increase sidewalk canopy cover to 60% (118 acres). This forms the basis for a canopy corridor connectivity goal.

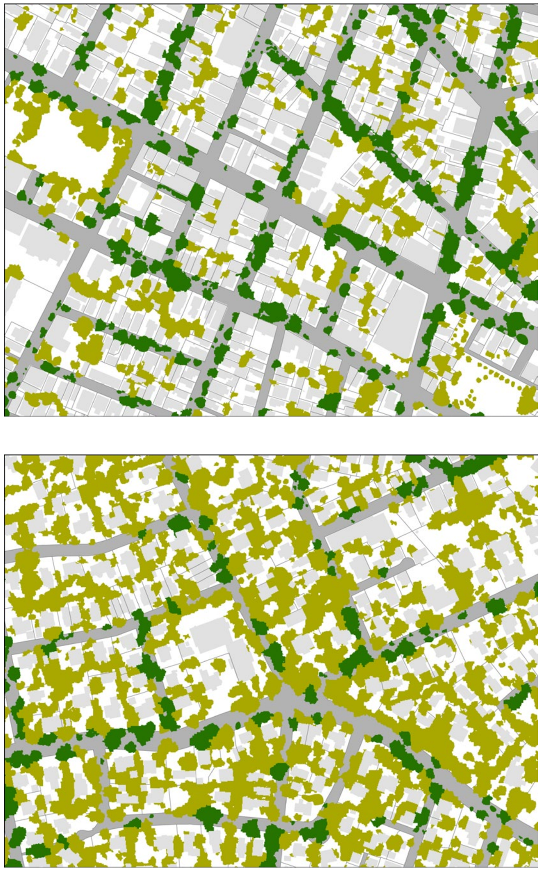


FIGURE 6.4 — THE IMPORTANCE OF TREES ON PRIVATE PROPERTY TO THE PUBLIC REALM: EAST CAMBRIDGE (TOP) AND WEST CAMBRIDGE (BOTTOM) CANOPY COMPARISON. Dark green represent R.O.W. trees and mustard represents private trees. This is an estimation based on GIS analysis.

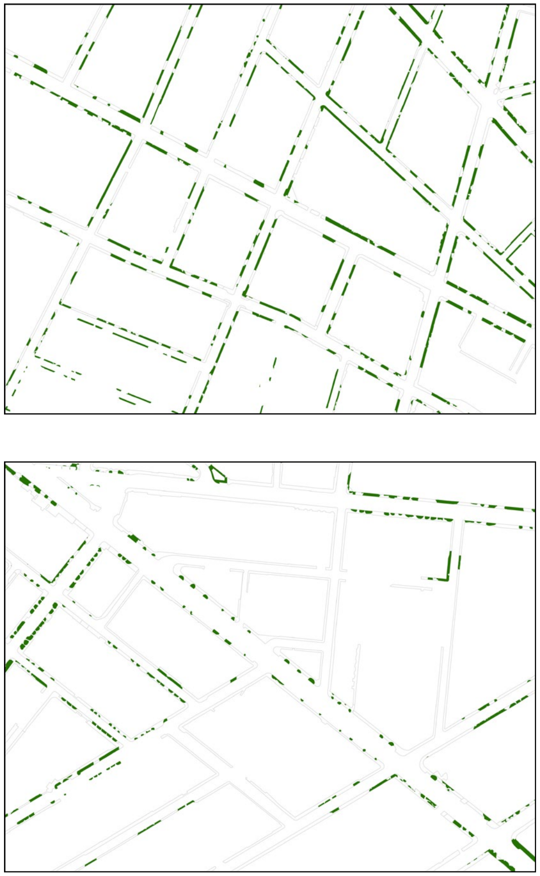


FIGURE 6.5 — 2018 SIDEWALK CANOPY COVER ON A RESIDENTIAL STREET IN EAST CAMBRIDGE (TOP) AND ON A COMMERCIAL STREET IN THE PORT/ CAMBRIDGEPORT NEIGHBORHOODS (BOTTOM)

Hotspots Goal: Critical to the function of cool corridors is continuity of shade, as large gaps create heat islands that act as barriers to use. One indicator of discontinuity is hotspots along proposed cool corridors. For the purposes of this analysis, we consider an area of 2 degrees over city average (92 degrees on a 90 degree day) as a hotspot. Tree canopy can reduce the extent and intensity of heat island hotspots. Currently, 25% of the city exists in a heat island hotspot and 26% of the R.O.W. lies within a hotspot. In order to benefit the greatest number of people, efforts to reduce heat island by increasing tree canopy should focus on the public realm. The largest hotspot areas are in East Cambridge (First, Second, Cambridge, and Binney Streets), Wellington Harrington (Cambridge St.), Area 2/MIT (Vassar, Albany, Waverly), The Port (Main Street), and along Massachusetts Avenue (*Figure 6.6*).

In a coarse large-scale study of planting 12,000 trees in the R.O.W. (See *Section 5.1* Citywide Canopy Corridor Study), a 20% reduction of heat island hotspots was seen (44 acres down to 36 acres). The Citywide Canopy Corridor Study was limited to a single strategy of planting street trees at 30' spacing where there are available opportunities. Traditional street tree planting at 20 to 30' spacing may not be enough to significantly reduce corridor hotspots. To have a larger reduction in hotspots in the R.O.W, other design strategies such as subcanopy planting, staggered tree plantings, and repurposing roadway or parking spaces to create additional space for tree plantings would be necessary. For example, in areas where a large canopy tree may not fit, but there is a large gap between existing trees, a subcanopy tree may fill in the shade needs at that location. Additionally, the City should apply other complementary strategies (permeable pavement, green/white roofs, reflective pavement) in conjunction with tree planting to target heat island hotspots. Based on analysis, an achievable goal would be to reduce hotspots by 50% (to 22 acres) in the R.O.W. citywide.

DIVERSIFY THE FOREST AND MINIMIZE CLIMATE RISKS

Goal: The urban forest should be diversified to better withstand disturbance due to climate change and catastrophic pest and disease outbreaks. Planting practices should aim for a forest that is no more than 10% of any one species, 20% of any one genus, and 30% of any one family.[6]

The current composition of the Cambridge urban forest is already close to fulfilling this goal, with the exception of honey locust, pin oak, and red oak as species, and maples as a genus, which are each overrepresented. This study does not recommend removing trees to meet these targets and does not propose a moratorium on over represented species. It would be counterproductive to stop planting some of our greatest trees when they are well suited to an urban condition. When planting new trees, however, preferencing trees that perform well but are under-represented in terms of diversity should be a City practice and should be recommended as part of the City's plan review process. The City should evaluate this subgoal in future years to see if the more resilient target of no more than 5% of a single species, 10% of a genus and 20% of a family is possible (Melbourne Urban Forest Diversity Guidelines). As so many of the great urban performers of the Northeast are maples and oaks, this may be a hard goal to achieve.

Not only should the City diversify the species palette, but species that have a higher climate resiliency score (see *Section 3.6*) should be prioritized. Climate risks can be mitigated by planting strategically. Drought tolerant species should be planted in areas of high imperviousness and flood tolerant species planted in flood prone areas. The extent of flooding will grow in the future, and flood tolerant species will grow in numbers as well. As climate science and projections continue to advance, other aspects of climate change could be incorporated into the climate resiliency score to inform species recommendations.

SHARE RESPONSIBILITY FOR THE FOREST

Goal: Each stakeholder group within the community (private property owners, institutions, commercial/industrial landowners, and municipal/state entities) should increase its relative canopy cover by 10% to 25%.

A thriving urban forest requires the mutual care of many parties, including city government, homeowners, businesses, developers, local organizations, institutions and state agencies.

The City controls approximately 31% of the land area in Cambridge (R.O.W. and open space). The majority of the City is privately held and there are limited ways the City can help to increase plantings on private properties.

If each category of landowner were to increase canopy cover by 10 to 25%, total citywide canopy cover would increase to 30%. Recognizing that some urban typologies are more conducive to planting, there is a proposed range for canopy gain. For example, public open space already has

FIGURE 6.6 — CURRENT SPREAD OF HEAT ISLAND HOTSPOTS IN THE R.O.W (TOP) AND REDUCTION IN THE NUMBER AND SPREAD OF HOTSPOTS FROM THE CITYWIDE CANOPY CORRIDOR STUDY (BOTTOM)

a significant canopy cover and adding 15% more might impinge on the provision of public amenities like sports fields. For this reason, the target for open space is set at 10% (*Figure 6.7*). Each landowner can grow canopy by curbing loss and planting more trees. See *Section 6.3*, for how this goal can be met by curbing the existing loss rate between 25 to 50%, and by planting new trees.

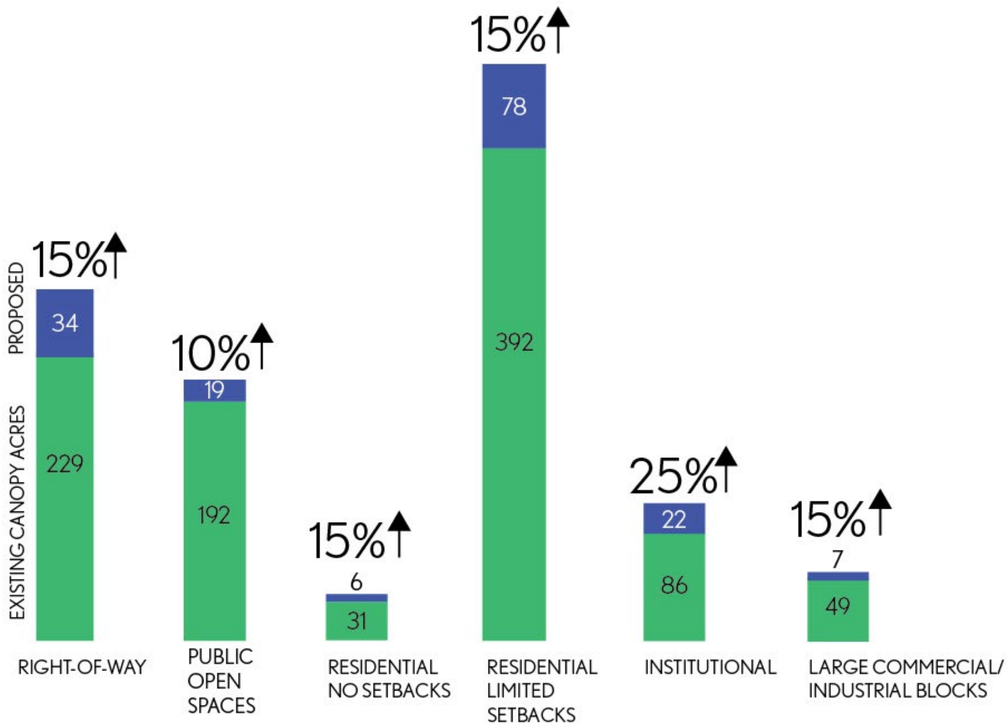


FIGURE 6.7 — EXISTING AND TARGETED CANOPY INCREASE BY URBAN CHARACTER TYPES. Stakeholder groups include the City of Cambridge (R.O.W and public open space), State of Massachusetts (public open space owned by DCR), Cambridge residents (residential no setbacks and residential limited setbacks), Institutions (institutional), and Commercial/Industrial land owners (Large commercial/industrial blocks).

6.2 Confirm Feasibility

Goals that can not be realistically met are dispiriting and ultimately discourage investment and progress. Overly idealistic goals that are not cognizant of competing priorities and practical limitations are also counterproductive. For these reasons, this study tested the goals set above to confirm that they were ambitious and also feasible given the real-world constraints of the city today.

# Additional New Trees Per Year	Reduce Net Loss	Canopy Cover In 2030	Canopy Cover In 2050	Canopy Cover In 2070
0 (do nothing scenario)	by 0%	22.8%	17.5%	13.5%
0	by 25%	23.5%	19.4%	15.9%
0	by 50%	24.3%	21.4%	18.7%
2,000	by 0%	23.4%	22.4%	24.0%
2,000	by 25%	24.2%	24.2%	26.4%
2,000	by 50%	24.9%	26.2%	29.2%
4,000	by 0%	24.0%	27.2%	34.5%
4,000	by 25%	24.8%	29.0%	36.9%
4,000	by 50%	25.5%	31.0%	39.7%

TABLE 6.1 — STUDY OF CANOPY COVER IN 2030, 2050, AND 2070 GIVEN DIFFERENT ANNUAL TREE PLANTING RATES AND REDUCTION OF CURRENT LOSS RATE. Annual canopy growth is based on a set increase in diameter of a 5" caliper tree growing to a 20" caliper in 20 years (average of 0.3947' in radius expansion per year), and assuming that growth rate reduces to half after 20 years.
*over existing planting rates

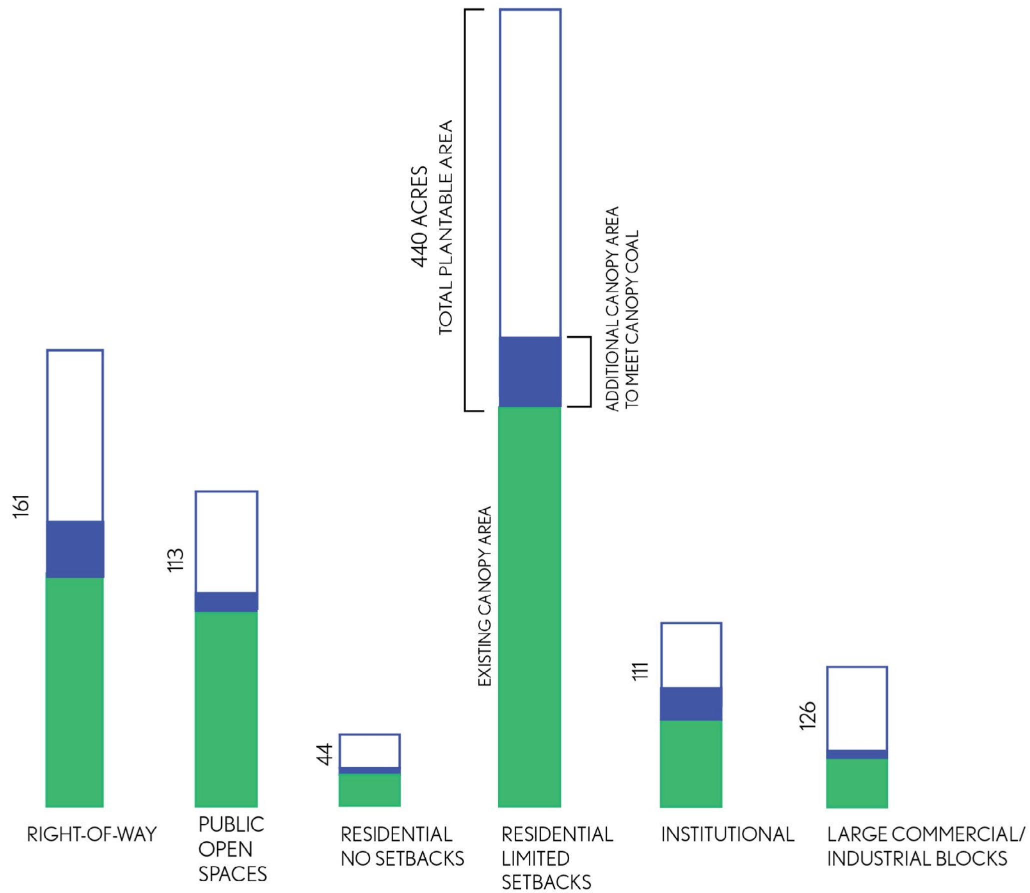


FIGURE 6.8 — TARGETS BY LAND USE TYPE. There exists enough plantable area in each land use type to achieve the canopy cover target.

PLANTABLE AREA

First, goals were tested to confirm there is enough remaining plantable area in the city to accommodate all the new trees that need to be planted. Plantable area is defined as the total area of the city minus the area currently occupied by streets, buildings, water, and athletic fields. Plantable area includes impermeable areas such as parking lots, driveways, and sidewalks, and all other permeable areas. While it is not possible to plant directly in the roadway, canopy from the sidewalk and front yards still overlaps the roadway, and design strategies consider repurposing parking spaces or roadway spaces for trees. We consider the roadway as 35% plantable (existing roadway canopy cover ranges from 18% to 31% depending on neighborhood).

If all plantable area of the city were to become canopy cover, which is not a realistic scenario, 51% of the city would be canopy covered. Thus, aiming for a citywide canopy cover around 30% would seem feasible. The greatest amount of plantable area resides on residential and open space urban typologies (*Figure 6.8*). Refer to Appendix Q for charts and maps that break out plantable area by neighborhood.

If each urban typology were to be planted out at the rate recommended by Policy Strategy 3A Establish canopy cover requirements by parcel through Zoning Ordinance (*Table 6.2*), there would be enough plantable area in almost all neighborhoods to reach the 25% minimum canopy target with the exception of East Cambridge and Area 2/MIT (*Table 6.4*). East Cambridge is 16 acres deficient and Area 2/MIT is 2 acres deficient. To reach 25% canopy cover, these two neighborhoods must further increase planting density for some urban typologies, or create new plantable area, such as creating parks out of private parcels or reducing street width and creating more plantable areas in the right of way. It will be most difficult for East Cambridge to reach 25% due to a lack of existing plantable area.

Land Use Type	2018 Acres of Land Use Overall	2018 canopy cover	Canopy cover target	Plantable area (not currently canopy covered)	New canopy acres to meet canopy cover targets
R.O.W. (roadway and sidewalk)	812	28%	35%	161	55
Open Space	521	44%	50%	133	25
Residential - no setbacks	192	16%	20%	44	17
Residential - setbacks	1363	29%	35%	440	86
Institutional	436	20%	30%	111	44
Commercial/ industrial	558	9%	15%	126	34

TABLE 6.2 — THERE EXISTS ENOUGH PLANTABLE AREA IN EACH LAND USE TYPE TO ACHIEVE THE CANOPY COVER TARGET.

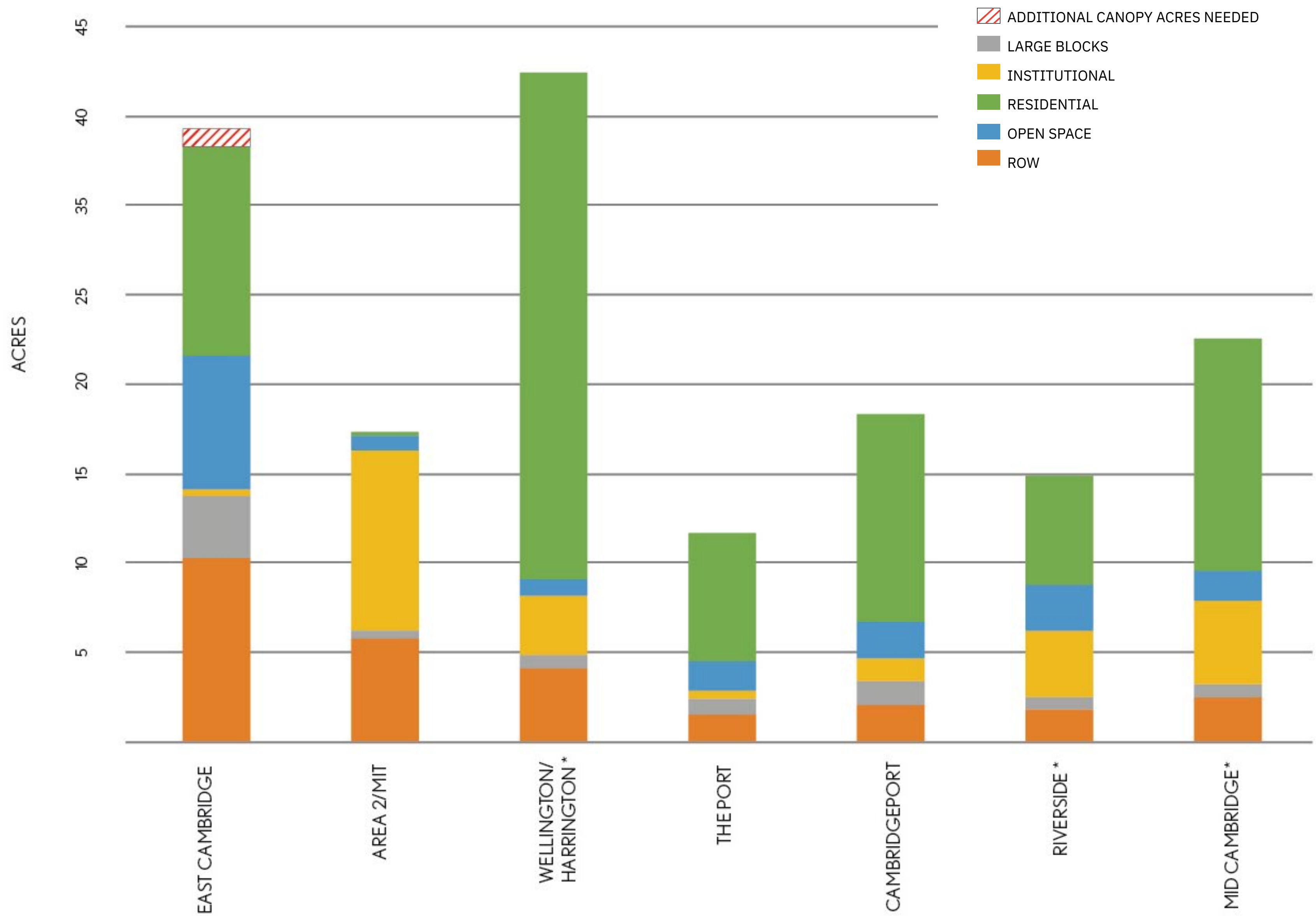


FIGURE 6.9 — PLANTABLE AREAS BY NEIGHBORHOOD. If the existing plantable area were planted out by the recommended canopy cover rate, East Cambridge has 16 acres of deficient and Area 2/MIT has 2 acres of deficient and the remaining neighborhoods can meet their canopy cover targets. Wellington/Harrington has 25 more acres than needed, Riverside has 12 more acres than needed, Mid Cambridge has 22 more acres than needed, and Cambridgeport has 3 more acres than needed. There are just enough plantable acres to achieve the 25% canopy cover target for The Port.

A forest is dynamic — trees sometime never establish while others age well into maturity. There is a constant cycle of growth and decay. The same is true of an urban forest, though trees are intentionally planted and must be cared for.

Even if Cambridge were to plant many trees now, canopy cover will continue to decrease in the next decade if the current rate of loss is not curbed. The reality is that it will take time and considerable effort on the part of all constituents of the City to shift the curve away from a net loss of canopy. Canopy cover only grows under a substantial replanting effort *and* reducing the existing loss rate (*Table 6.1*) . In the short run, the best way to maintain canopy cover is to reduce loss.

RATE OF PLANTING

With the additional tree planting in the R.O.W. comes additional investment in the maintenance and care of the trees. The City would have to double their capacity for watering trucks and more maintenance trucks will be on the road. Substantial additional staff time will be required to manage the effort and to implement other practice recommendations from this Master Plan. The City historically has planted around 400 trees per year and will be planting 600 trees in 2019. It will take time for the City to ramp up to the level of effort and increased labor to reach the target of 1,000 new street trees per year. If the City is able to plant 100 more trees every year, by 2023 the City will reach the target 1,000 trees.

Reaching targets in private property may be more challenging because the City has limited ability to plant and incentivize planting on private property. As discussed below in *Section 6.3*, partnerships with institutions, business owners, and residents will be essential for tracking and reaching the target planting rates. An analysis of LiDAR data between 2009 to 2018 showed approximately 5,726 isolated new trees appeared during that time period, or around 636 new trees per year (Appendix S). The limitation of the analysis is that it can only examine trees that do not share canopy with existing trees, so it does not account for new plantings that occur within groupings of trees (canopy growth within an existing polygon may be attributed to either a new tree planted or existing canopy growth). The City has historically planted 400 trees per year, so a minimum of 236 trees are being planted on private property annually. This Master Plan asks private property owners to significantly increase their tree planting to 2,000 to 3,000 additional trees per year.

Achieving these planting targets in the private realm may require a cultural shift in attitudes towards trees as an aesthetic benefit to trees as a necessary public good that benefits our collective sustainability. The success of programs such as curb side recycling has indicated that if something is made easy, people will do it. To grow canopy, we must make tree planting easy (tree giveways, Tree Trust) and provide citizens with the knowledge to maintain them (outreach and eduction)

LOSS RATE REDUCTION

To maintain the urban forest and account for annual loss rates, we must switch our attention from solely counting the total number of trees in the city toward setting goals for the number of trees planted every year. This report identifies that in order to increase canopy, the City must define the minimum number of tree plantings required just to replace those that experience mortality each year, either through intentional removal or some other reason. Trees take time to mature and the new canopy will take many years to replace the removed canopy. Thus, to grow canopy more quickly, it is necessary to plant at levels that are significantly higher than the annual mortality rate.

This plan proposes that the curb loss targets should be a range from 35% to 50%, and the existing loss rate then would proposed to be reduced from 1.6% to 1% - 0.8%. Our ability to examine this goal from real data for Cambridge is limited to the available LiDAR surveys. The annual net loss rate from 2009 to 2014 was 1%, and from 2014 to 2018 grew to 2.7%. We can only speculate what contributed to this acceleration of loss rate. It's possible that this might be an anomaly. What we can aim for however, is a loss rate that we know has recently existed in Cambridge (Appendix P).

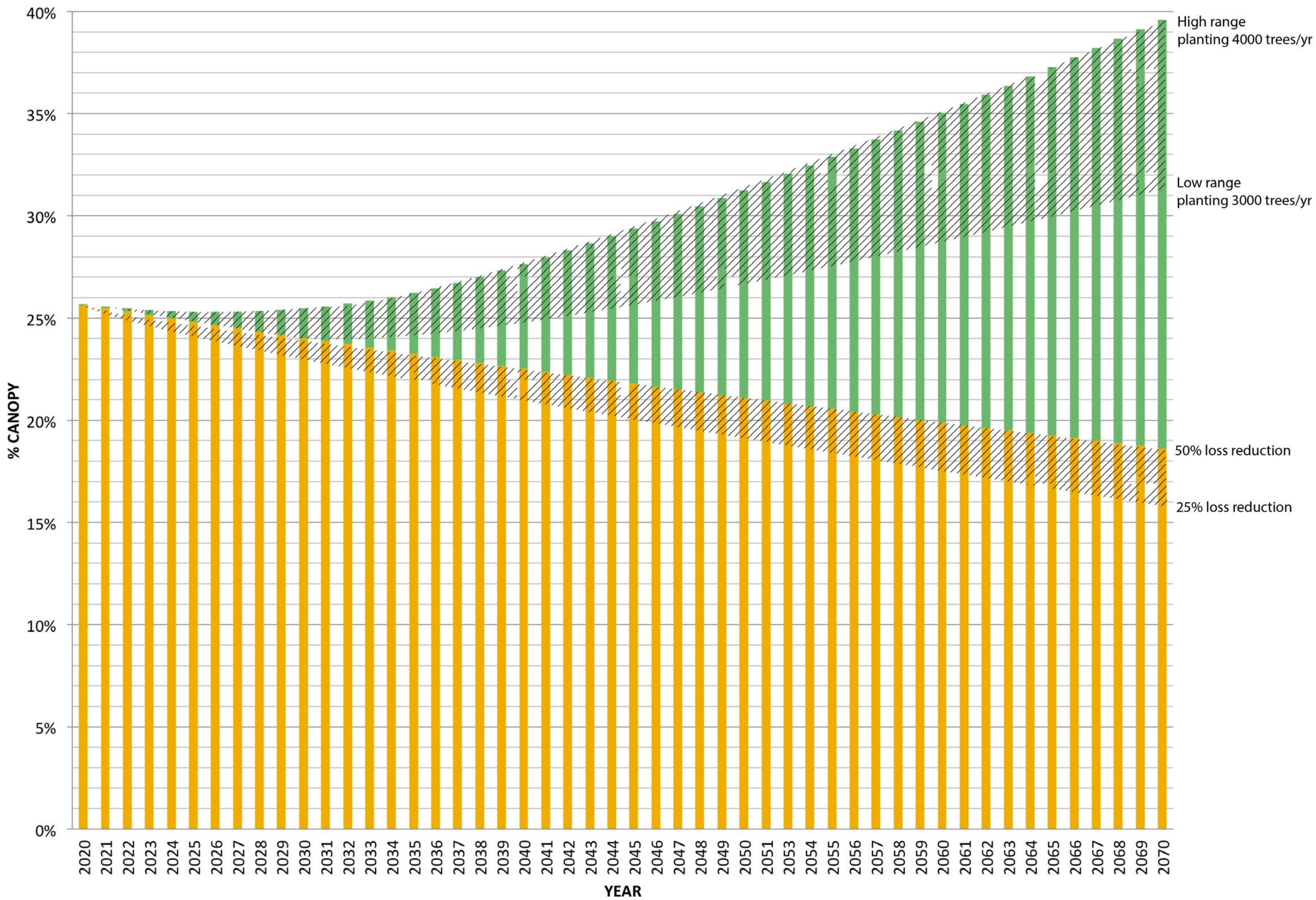


FIGURE 6.10 — CANOPY PROJECTION TO 2070 WITH A RANGE OF CURBING LOSS RATE (25 TO 50%) AND A RANGE OF ANNUAL TREE PLANTING TARGETS (3000 TO 4000 TREES PER YEAR) .

6.3 Define Specific Targets and Apply Strategies

CURB LOSS CITYWIDE

Increasing canopy cover citywide will require curbing the current loss of canopy, whether through reducing the intentional removal of trees or providing better maintenance and care so trees live longer. Because the existing rate of loss is so high for residential land use, this plan asks residential land owners to work towards reducing the current loss rate by 50%. For landowners of other types, the target is to curb loss by a minimum of 35%.

CURB LOSS WITH TREE PROTECTION ORDINANCE

This study proposes a range of ordinance revisions aimed at reducing the rate of tree removal city-wide. The amended tree ordinance passed in 2019 (see *Section 2.5*) expanded the tree protection ordinance to all properties within the city and ensured review and permitting of all tree removals and as part of projects at all scales. The ordinance also prohibited the issuance of any tree removal permits outside of the special permit process for one year, although there were exceptions allowed for hazards and other exigencies. The penalties for unpermitted removals are fines which some parties may agree to pay in order to remove trees during this period.

With the moratorium set to sunset in February 2020, what steps should the City take? First, the City should analyze the impacts of the moratorium and assess whether there was a measurable reduction in the tree removal rate and whether there were any unintended consequences of the new policy.

Mitigation is required to remove Significant Trees as part of the special permit process. If the tree protection ordinance were to be amended to include mitigation requirements for all removals of Significant Trees, it would certainly increase revenue directed to the Tree Fund, which is used by the City to plant new trees on City property and within front yards as part of the Back of Sidewalk Program. While the intent of the mitigation would be to deter tree removal, these costs may not be equitable, impacting low-income residents much more than high-income owners. It is also possible that there will be the unintended consequence of disincentivizing tree planting. Homeowners may not want to be faced with mitigation fees if they decide to remove the tree in the future, so they may avoid planting.

Given this complex set of concerns, this Master Plan recommends proceeding with interventions to disincentivize tree removal, but to evaluate the impact so adjustments can be made if there are unintended consequences, or if the disincentives are not strong enough. Prior to expiration of the moratorium, the tree protection ordinance should be amended to:

— Decrease "Significant Tree" definition to 6" DBH (Policy Recommendation 1a) to protect a greater number of trees in the City.

— Create an “Exceptional Tree” category for trees >30” DBH (see Policy Recommendation 1B) Large canopy trees are the most valuable in terms of providing ecosystem services and their impact will take decades to replicate with new planting.

— Implement the new mitigation formula for tree removal, so while Exceptional Trees may still be removed under a special permit, the cost to do so will be substantially greater than under the current valuation method.

— Require mitigation across all property types, with exception for residents on federal assistance. Residents receive a residential exemption.

— Incentivize replanting by providing exemptions for on and off site planting (for special permit projects), and exemptions for onsite planting for residents.

The expansion of the tree protection ordinance onto all private property may curb loss by asking landowners to consult with the City Arborist in order to obtain a permit. Through this interaction, owners may rethink tree removal by understanding the value of the tree or learning of alternative approaches to managing its condition. If the tree is still removed, landowners may come to understand the value of planting another tree in its place.

Loss rates should be evaluated in five years, and if the target loss reduction of 35% has not been achieved, the City could consider more stringent protections. Residential exemptions could be adjusted for all Significant Trees on private property. At the same time, the City should be evaluating the effectiveness of implemented education and outreach programs and consider adjustments or investments in new programs.

CURB LOSS THROUGH CITY PRACTICE

The City has made significant annual per capita investments in the urban forest, but more is needed in order to reverse the current trend. The recommendations discussed in *Section 4.5* were determined to have the most efficacy for the required level of investment. Making additional investments in the urban forestry operational budget is the most direct way to slow the loss rate. Increasing the frequency of health assessments allows for more immediate intervention when problems are detected and can prevent more serious issues that can arise if problems linger untreated. Implementing a soils testing and maintenance program could be a significant benefit to the health of the urban forest, as soils are currently an under-served component of tree health. Establishing a bare root planting program and setting up a gravel bed to store the trees until planting is a cost-effective way to lengthen the planting season and increase the number of trees planted annually.

GROW CANOPY BY PLANTING

Trees take time to mature and the new canopy will take many years to replace the removed canopy. Thus, to grow canopy, it is necessary not only to replace trees that are removed or die, but to substantially plant more trees.

Section 4.2 discusses prioritizing planting where it's most needed and impactful: in neighborhoods with lower canopy, in priority areas (heat island hotspots, community infrastructure, populations at risk), and along primary urban corridors. To meet equity goals, the City will have to tackle complex street reconstruction projects to create conditions for more planting. Additionally, new open spaces should be considered, particularly since larger high canopied areas can be very effective in mitigating heat island.

How many trees must Cambridge plant to strive towards 30% canopy cover in 30 to 40 years? Given a reduction in loss rate ranging from 35% to 50%, between 3,000 and 4,000 trees should be planted annually citywide. Aiming for this ambitious tree planting target would set the trajectory for a forest that will continue to grow significantly beyond the 30% goal (see Table 6.1). It is not expected for this tree planting number to remain consistent throughout the years but would be adjusted every 5 years when canopy cover is evaluated citywide. The hope is that at some point, the tree planting target could be set at the number required to replace trees that experience mortality annually.

SET PLANTING TARGETS BY URBAN TYPOLOGY

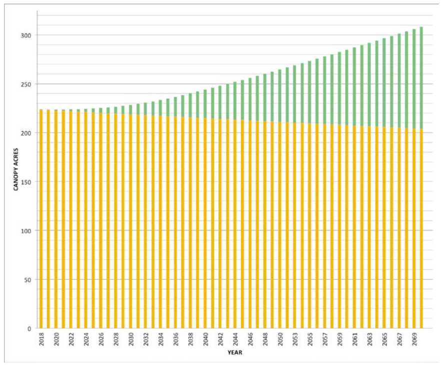
Because planting trees requires permission from the land owner, it makes most sense to set tree planting targets by urban typology. Yearly planting targets by urban typology are proposed below to achieve the overall citywide goal and are based on growing canopy by 10 to 25% for each urban typology (*Table 6.2*).

It is unrealistic to expect that the tree planting targets could be achieved immediately. It will take time for outreach and educational efforts to be implemented, for the City and other entities to build up the infrastructure to maintain and plant the trees, and for partnerships to be established. *Figure 3.12* depicts potential tree planting numbers by year, with the idea that by 2025, tree planting targets could be achieved.

One significant caveat is that the numbers are based on the historic rate of canopy loss by land use type experienced from 2009 to 2018. Loss rates will likely vary in the future and there is no way to predict how this will fluctuate. If loss rates fall drastically, planting rates could also decrease

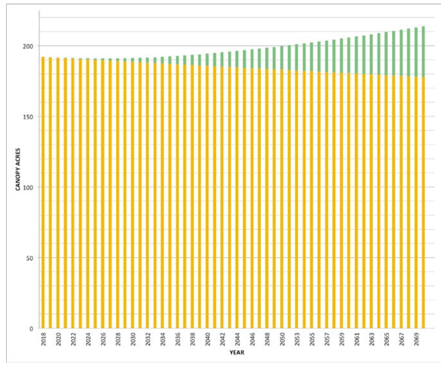
ROW

650 - 1000 TREES / YR



PUBLIC OPEN SPACE

100 - 250 TREES / YR*



2018 EXISTING TREE CANOPY PROJECTION WITH 50% REDUCTION OF LOSS RATE

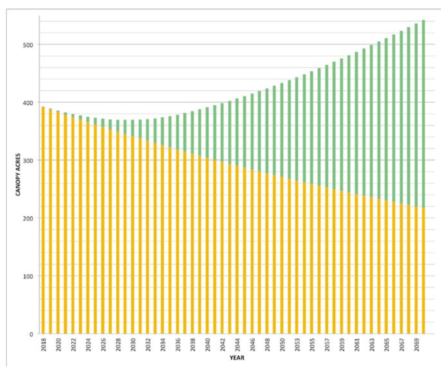
PROJECTION FOR NEW TREE PLANTINGS

RESIDENTIAL - NO SETBACKS

100 - 225 TREES / YR*

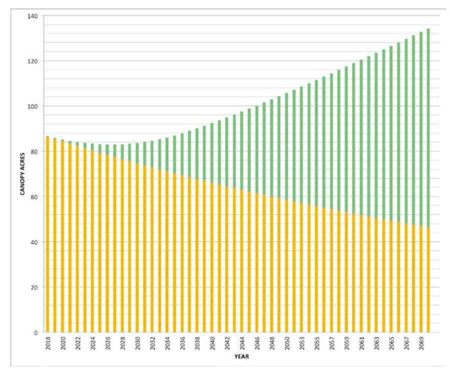
RESIDENTIAL

1025-1800 TREES/ YR*



INSTITUTIONAL

350-600 TREES / YR*



COMMERCIAL/INDUSTRIAL

150-250 TREES/ YR*

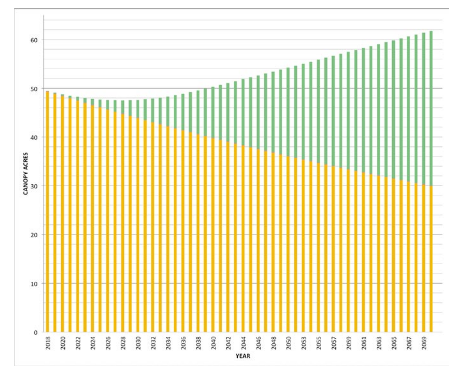


FIGURE 6.11 — TARGETS. The orange bars represent the projected existing tree canopy based on its historic rate of loss with a 50% reduction. The green bars represent new tree planting canopy based on the proposed tree planting numbers. Graphs depicts the upper range of planting numbers. *Numbers representing trees above the current planting rate.

significantly. But if loss rates do not improve, planting rates would adjust to be even higher. The City can react to changing canopy trends and these targets can be adjusted accordingly in response to new information. This could occur every 3 to 5 years as the City updates its canopy survey.

Ultimately, the City would be responsible for tracking yearly tree planting numbers across all urban typologies and for adjusting strategies to reach these targets. For each urban typology below, this study sets a yearly planting target, discusses strategies and identifies responsible parties for doing the planting and maintenance.

Year	ROW/ Public Space	Residential	Institutional	Commercial/ Industrial	Total New Planting
2020	300	300	100	50	750
2021	400	600	200	100	1300
2022	500	900	300	150	1850
2023	600	1200	400	200	2400
2024	700	1600	500	250	3050
2025	850	2000	600	250	3700

TABLE 6.3 — RAMPING UP OF TREE PLANTING NUMBERS

Urban typology	Current canopy cover	Increase canopy by	Canopy acres in 2018	Canopy acres target	Target canopy cover %	# of trees planted/yr to keep up with replacement*
R.O.W.	28%	20%	229	275	34%	735
Open space - publicly owned	37%	10%	192	211	40%	560
Residential- no setbacks	16%	15%	31	36	19%	100
Residential - 10' or more setback	29%	15%	392	450	33%	1200
Institutional	20%	25%	86	108	25%	290
Commercial/ Industrial	9%	15%	49	57	10%	150

TABLE 6.4 — PROJECTED CANOPY COVER % BY URBAN TYPOLOGY GIVEN TARGETS. Note: The urban typologies listed in this table do not capture all of the urban typologies in the city (approximately 77 acres are not captured).
*assuming 3% mortality rate of new trees

It is clear what the canopy cover by urban typology goals are, thus the variable driving planting targets is when the city arrives to this goal. The planting targets are presented as a range, with the lower number representing arriving to the canopy cover goal by 2070, and the upper number arriving to the canopy cover goal by 2050.

Right of Way

To achieve 34% canopy cover over R.O.W., plant 650 to 1,000 trees annually. This means planting 1 tree for every 1,435-2,200 linear feet of R.O.W annually.

The R.O.W. is the area encompassing the streets and the public sidewalks of the city. The existing net rate of loss is low for the R.O.W. at 0.25% and the gross loss rate is high at 3.1%. This indicates a lot of loss is occurring but that new planting and canopy growth is offsetting that loss. The City can first target sidewalks with widths of 6' or greater to plant additional street trees. For sidewalks under 6', the City should wait to plant until the conditions can be adjusted to fully support trees, including widening the sidewalk through reappropriation of roadway.

To accomplish this ambitious target, this plan strategizes to align tree planting practices with site condition to reduce cost and level of effort for tree planting. As described in *Section 4.0* Responses, bare root trees, which are much more cost effective and easier to plant than ball and burlapped trees, are recommended for the majority of street tree planting situations — street tree pit replanting and sidewalk reconstruction projects. The City will need to identify areas to build gravel bed nurseries so transplanting time can be more flexible and occur throughout the growing season. Ball and burlapped trees are recommended only for street reconstruction projects (see *Section 4.5*). Based on preliminary analysis, approximately 85% of the street trees could be expected to be bare root and the rest, ball and burlapped.

The City is mainly responsible for growing the canopy in the R.O.W. through direct planting in the sidewalk, planting trees in front yard setbacks through the back of sidewalk program, and encouraging residents to plant more trees in their front yards.

Public Open Space

To achieve 40% canopy cover in open space, plant an additional 125 to 250 trees annually in parks, recreational fields, and remnant open space parcels. This means planting 1 tree for every 1.7-6.8 acres of public open space annually.

The existing net rate of loss is low for the open space at 0.2% and the gross loss rate is 2%. Public open spaces include both City and State owned properties. Open space experiences the lowest rate of tree removal and tree planting with respect to other land use types. For open space areas with recreational uses such as baseball, soccer, and track, the City can plant a buffer of trees at the edges of the fields, and if a buffer already exists, the City can plant a double row of trees to thicken the buffer. For passive open space areas, such as Fresh Pond Reservation, the City should plant more canopy trees. More trees should be planted on DCR land along the Charles River, as current canopy cover is low for open space at 36%.

As the majority of the open space is owned by the City, the City will be primarily responsible for growing the canopy in open spaces. A partnership with DCR is essential for increasing cover in the open space areas buffering the Charles River. The City should engage and partner with private landowners of open space to see if additional tree planting can happen on those properties.

Residential

To achieve 33% canopy cover in residential lots with setbacks, plant an additional 1,025 to 1,800 trees annually in front, back and side yards. To achieve 19% canopy cover in residential areas without setbacks, plantan additional 85 to 225 trees annually in back and side yards. This means planting 1 tree for every 5.4 -9.9 parcels, or 1 tree for every 57-104 people annually.

The existing net rate of loss is high for residential land uses at 2.3% and gross loss rate is 4.2%. As investigated in *Section 2.2* a multitude of reasons are driving this high rate of change in residential areas. While the largest rate of loss is happening on residential property, this is also where the most plantable area exist. Planting can happen front yards, back yards, side yards, over driveways. A multi-pronged approach of education, incentives, engagement with non profits and non government organizations, and the City's tree planting fund will be required to grow canopy on residential land. These actions will be a priority for the City as Cambridge cannot reverse the citywide trend of loss without addressing canopy loss on residential land uses.

Residential land owners will primarily be responsible for planting and maintaining new trees. However, the City can reduce barriers by providing trees (tree giveaways, back of sidewalk programs), providing the knowledge to plant and care for a tree (educational programs), and by fostering a culture in the City that desires a robust tree canopy (tree tours, school curriculum, artist programs).

Institutional

To achieve 25% canopy cover, plant an additional 350 to 600 trees per year on university and other institutional lands. This means planting 1 tree for every 2.4 -2.9 acres of institutional land per year.

The existing net rate of loss is high for institutional land uses at 1.6% and gross loss rate is high at 3.7%. Institutional land has a low current canopy cover but a lot of plantable area so institutional land is a major opportunity area to grow canopy.

In recent years, universities in Cambridge have been expanding, building new buildings and in the process removing canopy. Partnerships with institutions in which shared goals and planting targets are articulated will be critical to overall success. Because the neighborhoods of MIT/Area 2, East Cambridge, the Port, and Cambridgeport have been identified as neighborhoods to prioritize for tree planting, partnering with MIT will be especially important. Establishing a Tree Trust can play a big role in providing flexibility for parties to contribute to growing canopy when they are not able to direct plant trees on development sites.

Commercial/Industrial

To achieve 10% canopy cover, plant an additional 150 to 250 trees per year on commercial and industrial lands. This means planting 1 tree for every 3.6-6 acres of commercial and industrial land annually.

The existing net rate of loss is moderate for commercial/industrial areas at 1.3% and the gross loss rate is high at 4.5%. Current canopy cover is the lowest for this land use type at 9%. Existing planting opportunities are limited as most of the lots are covered with buildings or paved areas. Commercial and industrial land use types are not required to have front yard setbacks so many buildings are built to the edge of the lot line. For new development, modifications to the zoning ordinance to require minimum setbacks would provide for additional planting area and would support the longevity of adjacent street trees.

The City should reach out to business associations to form partnerships and provide educational resources on the value of trees. The City could work with these associations to develop service or volunteer opportunities to help plant and maintain trees in front of businesses, in parking lots, or other areas. This could all be supported by the Tree Trust.

Other urban typologies

There exist other urban typologies that are not specifically called out above because they do not form a major percentage of the land area citywide. However, many land use types can provide meaningful contributions to overall canopy cover, in particular greening schoolyards. For these areas, canopy cover should be considered at the scale of the parcel.

TARGET SPECIFIC STRATEGIES ACCORDING TO NEIGHBORHOOD CHARACTER

The table below evaluates each neighborhood's land use character and which strategies would be most impactful based on that analysis. Some strategies that are more broadly applicable and less tied to land use typologies are not mentioned (i.e. Redefine Significant Trees, Plant Resilience Species, increase Mitigation requirements, many of the outreach/education strategies). All practice strategies have been omitted from this table for this reason.

Neighborhood	Target	Dominant Typologies	Top policy, design and outreach/education strategies to implement
13 TO 19% EXISTING CANOPY COVER			
East Cambridge	~25%	Residential - No setback, Backyards have high percentage of impermeable area Large commercial/industrial blocks Corridors with significant heat island hotspots North Point Development	Policy: — Create new parks through land transfers. — Earmark Tree Replacement Fund Dollars for Community Grants. — Establish Canopy Coverage Requirements by Parcel through Zoning Ordinance — Increase Setback and Open Space Requirements in Priority Areas through Zoning Ordinance — Align Planting Protocols with City's Commitment to Equity Design: — Redesign streets to create new planting opportunities. — Bare root trees in expanded soil volume. — Site new parks and open space strategically. — Encouraging planted open spaces by diversifying setbacks Outreach/Education: — Support community tree planting efforts
Area 2/MIT	~25%	No setback residential Large university (MIT) presence Corridors with significant heat island hotspots Charles River edge	Policy: — Create new parks through land transfers. — Earmark Tree Replacement Fund Dollars for Community Grants. — Establish a Tree Trust. — Align Planting Protocols with City's Commitment to Equity Design: — Redesign streets to create new planting opportunities. — Bare root trees in expanded soil volume. Outreach/Education: — -Partnership Outreach to MIT and DCR
The Port	~25%	No setback residential Large commercial blocks Corridors with significant heat island hotspots	Policy: — Create new parks through land transfers. — Earmark Tree Replacement Fund Dollars for Community Grants. — Align Planting Protocols with City's Commitment to Equity Design: — Redesign streets to create new planting opportunities. — Encouraging planted open spaces by diversifying setbacks — Bare root trees in expanded soil volume.

TABLE 6.5 — STRATEGIES BY NEIGHBORHOOD

Neighborhood	Target	Dominant Typologies	Top policy, design and outreach/education strategies to implement
Wellington Harrington	~25%	Residential with limited or no setback Mixed use with no setback Corridors with significant heat island hotspots	Policy: — Create new parks through land transfers. — Earmark Tree Replacement Fund Dollars for Community Grants. — Align Planting Protocols with City's Commitment to Equity — Strengthen and Clarify Existing Back of Sidewalk Program Design: — Redesign streets to create new planting opportunities. — Bare root trees in expanded soil volume.

20% TO 25% EXISTING CANOPY COVER

Cambridgeport	~28%	Limited residential setback Corridors with significant heat island hotspots Large university (MIT) presence Charles River edge	Policy: — Establish a Tree Trust — Strengthen and Clarify Existing Back of Sidewalk Program Design: — Redesign streets to create new planting opportunities. — Bare root trees in expanded soil volume. — Partnership Outreach to Harvard, DCR
Riverside	~28%	Limited residential setback Large university (Harvard) presence Charles River edge	Policy: — Establish a Tree Trust Outreach/Education: — Partnership Outreach to Harvard, DCR
Mid-Cambridge	~28%	Limited residential setback Large university (Harvard) presence	Policy: — Establish a Tree Trust — Strengthen and Clarify Existing Back of Sidewalk Program Outreach/Education: — Partnership Outreach to Harvard Outreach/Education: — publicize Back of Sidewalk program

ABOVE 26% EXISTING CANOPY COVER*

North Cambridge	~30%	Residential with large setbacks Corridors with significant heat island hotspots	Policy: — Create an "Exceptional Tree" Category — Expand Protections to all Private Property Design: — Redesign streets to create new planting opportunities. Bare root trees in expanded soil volume. Outreach/Education: — -publicize Back of Sidewalk program
Cambridge Highlands	~30%	New development – Alewife district Residential with large setbacks	Policy: — Create an "Exceptional Tree" Category — Establish Canopy Coverage Requirements by Parcel through Zoning Ordinance — Increase Setback and Open Space Requirements in Priority Areas through Zoning Ordinance — Expand Protections to all Private Property

Neighborhood	Target	Dominant Typologies	Top policy, design and outreach/education strategies to implement
Agassiz	30%	Residential with large setbacks and residential with limited setbacks Large Harvard presence	Policy: — Create an “Exceptional Tree” Category — Expand Protections to all Private Property Outreach/Education: — Partnership Outreach to MIT,
Neighborhood Nine	31%	Residential with large setbacks Corridors with significant heat island hotspots	Policy: — Create an “Exceptional Tree” Category — Expand Protections to all Private Property Design: — Redesign streets to create new planting opportunities. — Bare root trees in expanded soil volume. Outreach/Education: — publicize Back of Sidewalk program
Strawberry Hill	36%	Residential with large setbacks and limited setbacks	Policy: — Create an “Exceptional Tree” Category — Expand Protections to all Private Property
West Cambridge	37%	Residential with large setbacks Charles River edge	Policy: — Create an “Exceptional Tree” Category — Expand Protections to all Private Property Outreach/Education: — Partnership Outreach to DCR

*no change in percentage, focus on curbing loss and replacement planting

Table 6.5 Top policy, design and outreach/education strategies to implement by neighborhood. Neighborhoods grouped by current canopy cover have similar urban typologies, and therefore similar strategy recommendations.

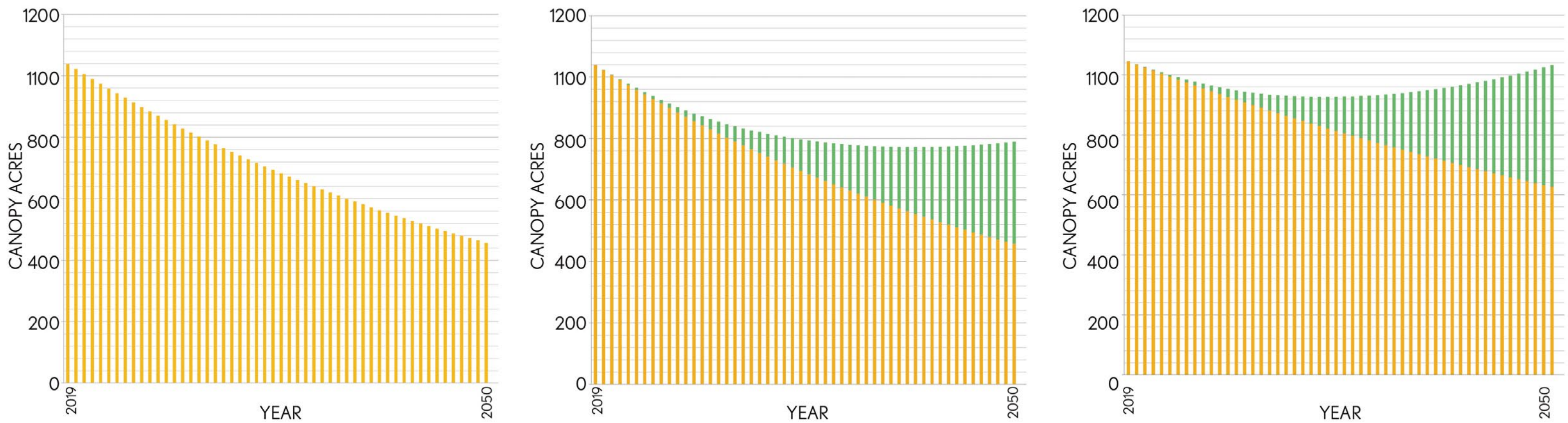
6.4 Track Progress

Setting long-term goals and interim targets enables the City to assess the community's progress on a regular basis and provides information that can guide adjustments if targets are being missed.

YEAR-END ACCOUNTING

Each year the City should undertake an accounting of trees planted, categorizing by location, land-use type, size, species, planting condition, and who planted the tree. Commercial and institutional partners and individual land-owners should be encouraged to report their contributions to the accounting. This information should be reviewed against the specific yearly targets set above. With this information, stakeholders can be held accountable to their commitments, strategy adjustments can be made, and the City can make annual plans for resource allocations. As detailed in Outreach and Strategy 2B, the City should issue a yearly tree annual report card to residents to communicate planting progress that year.

The City will not be able to fully track how many trees are planted on private property, but they can reach out to neighborhood associations, business associations, and other groups that may be able to provide estimates. City will also be able to understand how many trees were given away or planted on private property through the Tree Trust program.



Existing trend with current 400 tree planting rate

Plant 1,200 additional trees per year

Reduce Loss and Plant 1,200 additional trees per year

FIGURE 6.12 — CANOPY VALUATION (CURBING LOSS / GROWING CANOPY)

TREE CENSUS

Every five years, the City should undertake a detailed city-wide tree census. A combination of aerial and computer-generated analysis and ground survey, the census will provide long term data to assess changes in tree mortality rates, overall canopy health, species distribution, and canopy cover. This data can be assessed against the long-term goals of this study, and the City can make larger adjustments to strategies, including implementing new policies or applying additional funding as needed.

During this review period, the City should also review its own canopy management records, now managed through a software called Cartegraph. The relative effectiveness of alternative management strategies (such as liquid biological amendments or watering rates), planting techniques (such as soil mixes and details), and pruning schedules should be used to assess the success of practices. The survival and pest loading rates of individual species should be reviewed. This analysis should guide strategic adjustments to the City's practices such that efforts are being expended in the most efficient and effective manner.

REGULAR INTERAGENCY COORDINATION

Setting targets only matters if there is commitment behind them and agents empowered to realize them. For Cambridge, there are multiple departments which will see benefits from increased canopy to their mission. And a broad range of departments will need to work collectively to effect change. It can't all be done by the City Forestry Division.

The City should form an interagency "resiliency committee" which meets quarterly and assesses progress, coordinates efforts, and clarifies lines of responsibility for meeting goals. This will be critical to the success of the Urban Forest Master Plan goals, but it will equally support many of the climate initiatives the City is undertaking.

URBAN FORESTRY ADVISORS

The City should maintain an advisory group of subject-matter experts who can help the City and the Committee on Public Planting keep abreast of the most current science on climate and horticultural practices. Tapped annually for review and on an as-needed basis, this group will be a sounding board and peer-reviewer as Cambridge takes a leadership role in testing responses to the current rate of canopy loss.

6.5 Evaluate Impacts: Potential Value Gain

The impacts of a shadier city are more than superficial. As documented in The State of the Urban Forest there is real quantifiable value in the forest and its contribution to the City. Every five years, as part of the City's Tree Census, the overall performance value of the urban Forest should be evaluated. Understanding the net loss or gain in value will aid the City in justifying its investment in urban forestry programs. Among many competing needs and interests for the city, the scope of funding directed to the urban forest should be understood as an investment that accrues value and pays for itself over time in terms of ecosystem services, stormwater mitigation, energy reduction, health and well-being, and property value.

In *Section 3,* under the current trajectory of decline, the cumulative value of the forest in 2070 could range from $208 million to $427 million.

If the city were to plant at the recommended rates (4,000 trees per year citywide) and curb loss by 35%, the cumulative value of the forest in 2070 would grow almost sixfold to $1.3 billion. If the community were to pursue less aggressive rates of planting (2,000 trees citywide per year, and curb loss by 25%, cumulative value would fall to $904 million. If loss rates were not curbed at all and 2,000 trees were planted every year, cumulative value would be $702 million.

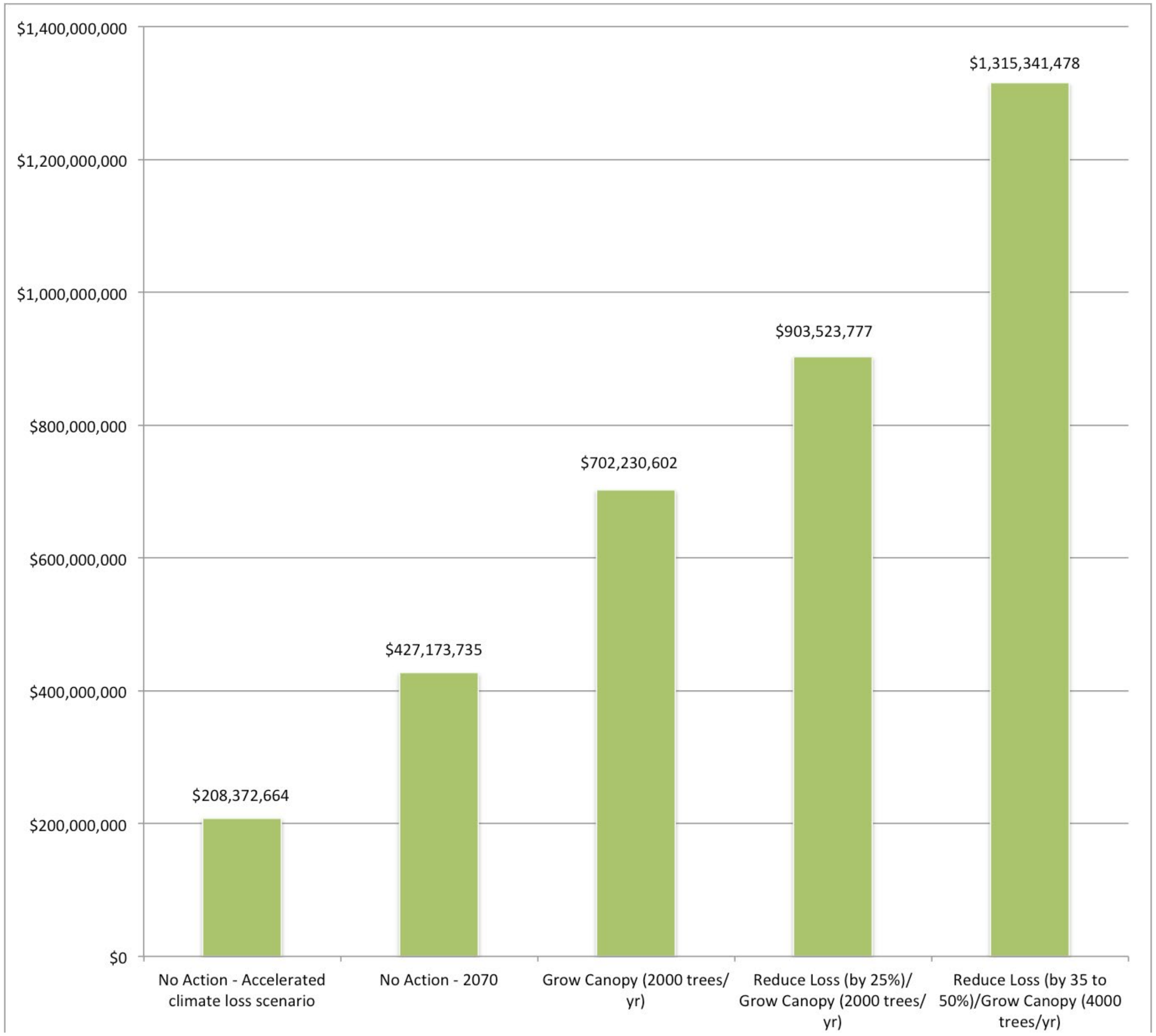


FIGURE 6.13 — THE MONETARY VALUE OF THE URBAN FOREST UNDER DIFFERENT SCENARIOS OF CURBING LOSS AND GROWING CANOPY. See Section 2.5 for calculation assumptions.

6.6 Next Steps

DEVELOP TOOLS TO COMMUNICATE WITH THE COMMUNITY

The findings, goals, and targets of this study should be widely publicized to galvanize the community behind action. This is best accomplished with a broadly accessible communications tool such as a graphically compelling broadsheet and/or a dynamic and engaging web presence. A condensed and digestible version of findings should be created and products should be available on-line.

Cambridge's Department of Public Works (DPW) has an interactive game "Get Rid of it Right"[7] that tests one's knowledge of proper disposal or recycling of different products. Something like this could be created to test residents' knowledge of tree benefits, tree planting and maintenance. New York Times Rent Vs. Buy[8] website calculator allows one to adjust different variables to graphically understand when it makes more sent to buy versus rent, and vice versa. The relationship between curbing loss (maintaining existing trees) and growing canopy (planting new trees) through time could be experienced interactively in a similar way where one could adjust loss rates and tree planting rates to understand projected canopy cover. Reuters has produced an interactive news piece[9] with maps that can be clicked through to show layering of information. One can imagine something similar could be done with Cambridge tree canopy, depicting loss and gain, tree condition, planting scenarios, and heat island effect.

Any published resource needs to be supported by a process to make it available and known to the public, so a concerted effort should be made for wide and repeated distribution and publicity.

DEMONSTRATE IMMEDIATE ACTION

Undertaking and publicizing a series of immediate pilot projects is an important step in demonstrating the City's commitment to the goals of this study and engaging the public in taking part. Pilot projects can include replanting a stretch of a major street, transforming a paved traffic island into a thriving plant community, or replanting significant areas of public parks.

Pilot projects can also include efforts undertaken by partners like DCR or the universities. A concerted effort to distribute and plant trees on private property, either through the schools or through public events would also be a strong sign of change.

Pilot projects should be easily achievable without requiring significant resources or delay, should be broadly visible to the community, and should be paired with outreach measures to explain the benefits they provide to the City. Efforts may include:

- Brainstorming with local artists for innovative ideas to engage and educate the community about the urban forest
- A program to exhibit artists work related to urban forest and trees around the City
- Symbolic tree planting and naming per local celebrity or tree advocate
- Tree planting on small city owned vacant parcels
- Social media engagement — a Twitter or Instagram account that shares new of Cambridge's urban forest, tree benefits, events, and publicizing of tree planting efforts

Many of the strategies detailed in *Section 4* Responses could be implemented quickly and easily. Policy changes would require a political process, but several design and practice strategies could be implemented by the City. These low hanging fruit include:

- Re-vegetating places that could be planted immediately on City property include the edges of existing open spaces, remnant open spaces
- Plant in priority areas and canopy corridors
- Plant wisely only when conditions allow trees to survive and plant flood tolerant trees in flood prone areas
- Start sourcing bare root trees and establish a gravel bed nursery so bare root plantings can happen through the growing season
- Use the recommended species list for City planting, and publicize on the City's website
- Implement education/outreach programs:
    - ↳ Publicize the existing back of sidewalk program
    - ↳ Organize tree tours

- ↳ Provide information on tree benefits and maintenance to residents
- ↳ Educate business owners on the dangers of pest outbreaks

- Improve the on-line tree map to engage citizens
- Support citizen science projects and community planting efforts
- Undertake partnership outreach to institutions and business owners

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