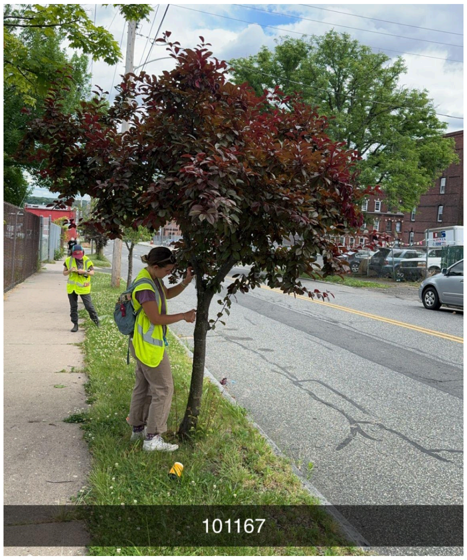
HERO 2024 Stakeholder Report





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1 Introduction

The spatial distribution age of trees in cities are the product of many socioeconomic, cultural, and biophysical legacies (Roman et al., 2021). In the northeast, tree planting movements such as the City Beautiful movement and colonial planning for common greenspace allow for the potential for high amounts of tree canopy cover (Hauer et al., 2017). However, diseases and pests have had negative impacts on the trees in cities - a prime example being the Longhorned Beetle outbreak in Worcester, MA that prompted the removal of over 30,000 trees (Danko et al., 2016). Mid-sized post industrial cities that have lost large amounts of tax revenue due to population decline have restricted money spent on urban forestry in the second half of the twenty first century (Roman et al., 2021; Healy et al., 2022). The legacies of pests and disinvestment have left cities in the north east vulnerable to the impacts of climate change due to their aging infrastructure and lack of environmental services.

Urban forests provide many ecosystem services such as cooling and stormwater control that help cities increase resilience to the impacts of climate change (Huff et al., 2020). Ecosystem services are defined as benefits that humans gain from trees (Escabedo et al., 2011). Recent research has highlighted the benefits that are related to the increased impacts of climate change such as extreme heat and flooding that cities are more vulnerable to due to the existing built environment (Huff et al., 2020). While mature trees are the ones that provide the majority of the benefits, even juvenile trees have been shown to provide a small amount of benefits (Moody et al., 2019). This effect was apparent in Worcester, MA after the loss of 30,000 mature trees led to a significant increase in temperature and cooling costs (Rogan et al., 2013; Elmes et al., 2017). Many cities are encouraging tree planting initiatives (TPI) to increase their cities' resilience to climate change as well as address decades of neglect and need.

TPIs are an important development in urban forestry but are often independent programs from traditional urban forestry departments and professionals (Eisenman et al., 2021). TPIs often have two primary goals: to increase climate resilience in cities as well as address historic legacies of structural inequality and racism. They are funded separately and for shorter periods of time - this funding is often related to a specific goal such as raising tree canopy cover by a certain percent or planting a specific number of trees (Breger et al., 2019; McPherson et al., 2011). The TPIs also differ in structure as many operate as tree giveaway programs while only a few plant trees as part of the program In both cases TPIs often depend on residents for post-establishment stewardship and care (Roman et al. 2015). However, there is a need to understand how residents understand their roles as well as the long-term monitoring of trees planted.

Residents are vital stakeholders in TPIs due to the variety of ways residents participate in tree planting. Residential land accounts for the majority of available planting areas in cities - especially dense urban environments with little available green space. Residents can be effective communicators of the TPIs goals and messaging to community members, family, and neighbors (Geron et al., 2023). Residents can participate as negotiators, helping to make decisions on tree species and location (Geron et al., 2023). Most importantly, residents provide critical tree care stewardship during the establishment phase (0-5 years) that often determine the projected life span of the tree. TPIs need to understand how to work with residents to achieve success but since residents have a variety of motivations, TPIs must appeal to a broad range of people instead of focusing on a specific goal. More needs to be understood about why residents choose to not participate in TPIs.

Massachusetts is one of the only states in the country to offer a state government funded TPI. This is known as the Greening the Gateway Cities Program (GGCP). It started in 2014 with the goal of increasing canopy cover by 5% in priority neighborhoods in Gateway Cities throughout Massachusetts. Their pilot cities included Chelsea, Fall River, and Holyoke. "Gateway Cities" are defined as potential gateway to regional socioeconomic success when given support to foster post-industrial recovery. They categorically require populations of around 30,00-250,000 people, with median household income and education attainment lower than the Massachusetts average. There are 26 Gateway Cities in all of Massachusetts and the DCR conducts plantings in 23.

There are many potential barriers for residents to participate in the GGCP including in broad categories: personal aesthetics, environmental conditions, maintenance issues, lack of knowledge, institutional concerns, and a lack of physical space (Pearsall et al., 2024). These barriers are of concern for a planting program such as the GGCP which operates in specific planting zones where many of the barriers overlap with each other. For example, a planting zone with very little green space might face issues with physical space as well as the environmental and site conditions needed for trees to survive. In this context, there could be a lack of institutional support for juvenile trees as local government is not adjusted to providing watering/green space services to these areas.

The Human-Environment Regional Observatory (HERO) program at Clark partnered with the GGCP in 2017 to assist in monitoring tree health and survivorship as well as the contributions of residents and stakeholders across Gateway Cities. Data has been collected in 7 cities by HERO, and this summer marks the revisitation and data collection in two of the pilot cities; Chelsea and Holyoke.

2 Research Questions

2.1 Biophysical

The biophysical objectives for the HERO in 2024 were to measure the growth and survivorship of trees planted by the DCR's Greening the Gateway Cities Program in Holyoke and Chelsea, MA using methods from the US Forest Service's *Urban tree monitoring:a field guide* (Roman et al., 2020). The questions that framed our research were:

1. What is the current status of tree health and structure in these cities?
2. What factors have the greatest impact on tree growth and survivorship for each city?

Additionally, we had the opportunity to compare these findings with the original HERO sample study from 2017 in each city to create a direct and focused resurvey analysis of a specific tree cohort over time. Here we asked:

3. How has survivorship and tree health in this cohort changed over time in these cities?

2.2 Social

The social research objectives for the HERO in 2024 were to interview community members in Chelsea and Holyoke about their perceptions around tree planting and stewardship. Here we asked:

4. How do residents perceive the role of trees on their property and in their neighborhood?

Guided by previous findings on urban governance and barriers to action (Geron et al., 2023), we also wanted to gain perspective into how the organizations that support the GGCP function at their best by asking:

5. How does the DCR collaborate with community partners during tree planting initiatives?

3 Study Area

3.1 Holyoke

Holyoke has a population of 38,238 people with a population density of 1,806 people per square mile (US Census, 2020). 42.7% of Holyoke speaks a language other than English at home, with a 39.6% Spanish speaking population. Interestingly, Holyoke also has the largest Puerto Rican population per capita out of any U.S. municipality besides Puerto Rico. The median household income here is $49,007 which is significantly lower than the Massachusetts state average of $95,505. Educational attainment of a Bachelor's degree or higher in people over 25 is only 22.2% which is less than half of the Massachusetts state average of 46.6%.

Table 1. Racial demographics in Holyoke and MA

Racial Demographics	**Holyoke**	***Massachusetts***
White	67.5%	*79%*
Hispanic or Latino	51.7%	*13.5%*
Black or African American	4.6%	*9.6%*
Asian	0.8%	*7.9%*

Holyoke has a humid continental climate with an average temperature of 48.9℉ with annual rainfall approximately at 44.1 inches (ClimateData.org). Canopy cover in greater Holyoke is equivalent to 53.7%, but it is only 14.2% for the original planting zone which has acted as our study area focus (Figure 1). Holyoke began planting with the GGCP in 2014. Since then, the DCR has planted over 2,509 trees in Holyoke, and expanded their planting zone to all Environmental Justice neighborhoods in the city. This year, HERO was able to survey 1,500 of those trees.

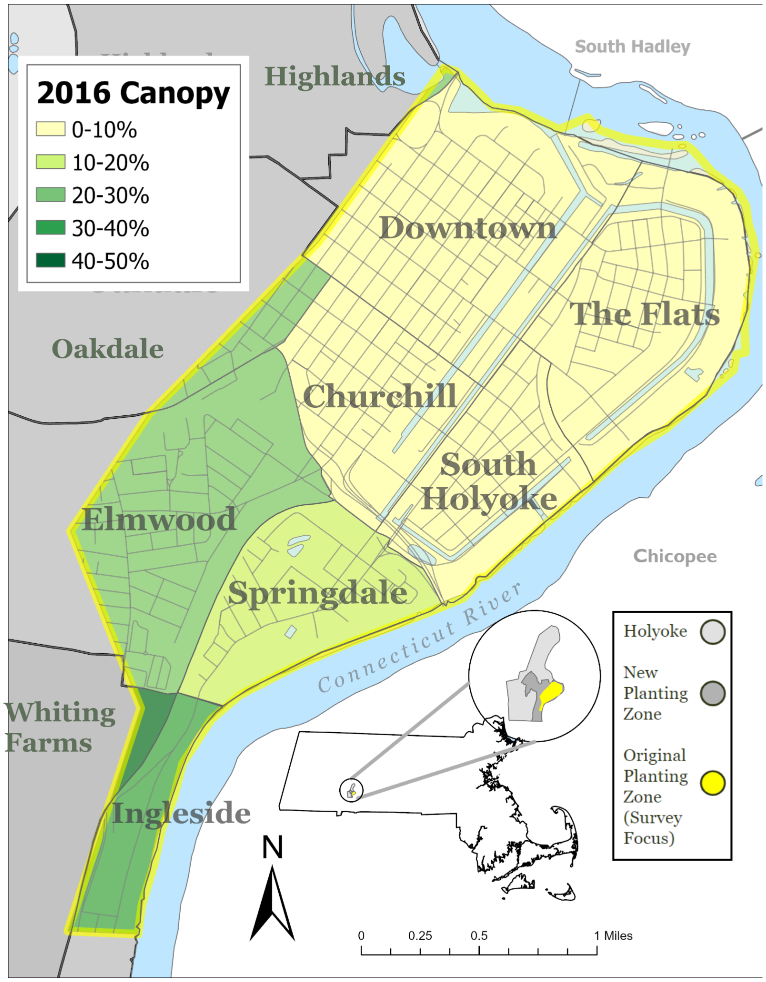

Figure 1. Map of Holyoke neighborhoods and canopy cover from 2016 in 10% intervals

3.2 The History of Holyoke

In 1847, the Hadley Falls Dam Canal System opened in Holyoke, an ideal location for paper milling along the Connecticut River. It quickly became the paper milling capital of the world, with a thriving industrial center around the canal system in the Churchill, Flats, South Holyoke, and Downtown neighborhoods which still bears the remnants of old industry. Historic paper milling factories line the streets of downtown Holyoke and are now sites for offices, art studios, businesses, and housing.

3.3 Chelsea

Chelsea has a population of 40,787 people with a population density of 17,974 people per square mile which is close to ten times the population density in Holyoke. This makes sense as Chelsea is much closer to the urban center of Boston and receives a lot of migration and outflow from there. This also helps to explain Chelsea's comparatively higher median household income of $71,051 which is still lower than Massachusetts's average ($95,505). Educational attainment of a Bachelor's degree or higher in residents over the age of 25 is 21.6%, lower in comparison to Massachusetts's state average (45.9%) (US Census, 2020).

Table 2. Racial demographics in Chelsea, MA.

Racial Demographics	**Chelsea**	***Massachusetts***
White	33.9%	*79%*
Hispanic or Latino	67.4%	*13.5%*
Black or African American	6.2%	*9.6%*
Asian	2.9%	*7.9%*

The climate in Chelsea is defined by the Koppen-Geiger classification as coastal humid climate, with an average annual temperature of 50℉ (Climate Data.org). Average annual rainfall is around 46.2 inches. The canopy cover collected in 2016 LANDSAT imagery revealed Chelsea had an average canopy cover of only around 10.9%. Like Holyoke, Chelsea began planting with the GGCP in 2014 and has planted over 2,567 trees. We were able to sample 1,509 of those trees.

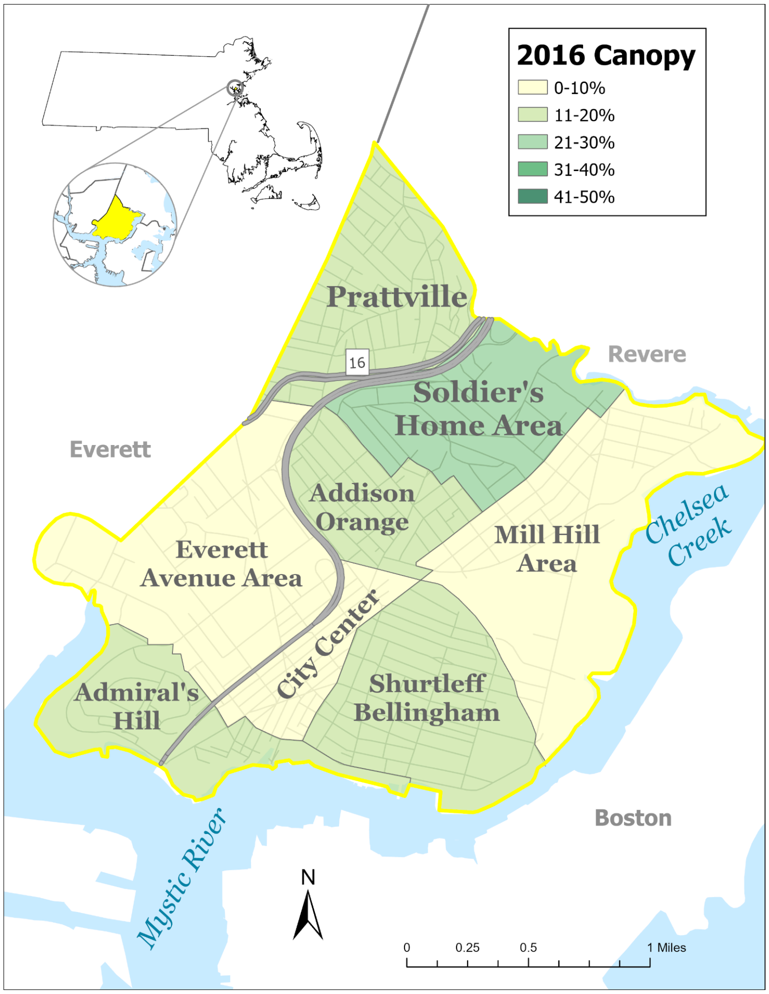

Figure 2. A map of Chelsea neighborhoods and canopy cover from 2016 in 10% intervals

3.4 The History of Chelsea

Chelsea was established as a resort town for Boston's elite. As ports developed, Chelsea became a major shipping and manufacturing hub and became incorporated as a city in 1857. Notable manufacturing in the area includes the Chelsea Clock Company which is still open today. There were two major fires that burnt large percentages of Chelsea's housing and industry to the ground in 1908 and 1973, the latter happening at a time when manufacturing jobs began leaving the city and raising rates of poverty in the area. A large corruption scandal was uncovered here in 1991 when 4 mayors were tried for the embezzlement of city tax revenue, leaving Chelsea under state council management until 1995 (Economy League, 2014)

3.4.1 Construction of the U.S. Route 1 Expressway

Construction of the Tobin Bridge over Mystic River was completed in 1950, allowing for the expansion of Route 1 to continue through Chelsea. Construction took place from 1956-1958 and has heavily impacted rent, population distribution, and access to green space in Chelsea at large. It creates a physical and climatic barrier to certain areas in Chelsea like the Everett Avenue Area as will be further explored in the “Other Analysis” section of this report.

4 Methods

4.1 Sampling Methods

Data representing planted trees were provided by the DCR for two cities, Holyoke and Chelsea. Planting dates ranged from April 2014 to November 2023. Additionally, the HERO database contained the sample of trees that had been measured previously in 2017. The 2017 HERO survey data was joined using the xy coordinates of the point, as well as planting year and month.

A total number of 2,509 tree points were provided for trees planted in Holyoke. The data was subset using a random sample, separated by public and private trees. Each site address was sampled using a random sample stratified by number of trees per site address. The public and private samples were then combined to form an overall sample of 1,055 tree points.

A total of 2,567 tree points were provided for trees planted in Chelsea. The data was subset using a random sample, stratified by the number of trees per property. The number of trees per site address was calculated, and an equal number of addresses from each quintile of trees per address were selected. Then, the trees on each selected address were used to form the final sample. The final sample of Chelsea trees included 1,296 tree points. In addition to the random samples described above, the remaining trees inventoried in 2017 were resurveyed.

4.2 Survey Methods

Our tree survey and measurement methods for data collection have come from US Forest Service’s *Urban tree monitoring:a field guide* (Roman et al., 2020). Each tree was surveyed in groups of two to three HERO team members. We moved through the survey areas by zones that were determined prior to data collection and depended on the density and distribution of trees throughout the study city. Each tree was photographed and labeled with its appropriate ID number using Instagram, Snapchat, or Whatsapp. The survivorship of the tree was noted as being “Alive”, “Standing Dead”, “Stump”, “Removed”, or “Unknown”. “Unknown” trees refer to a tree that was not accessible for surveying, or a tree that couldn't be located (Figure 3).

Figure 3.. Examples of the differing mortality types. From left to right; “Alive”, “Standing Dead”, “Stump”, and “Removed”

Diameter at Breast Height (DBH), crown width and height were taken on living trees. DBH was measured in inches around the trunk with a standard diameter tape at a height of 54 inches or the closest unobstructed point. If there was a previous DBH height noted on a tree that was being re-surveyed, we would measure DBH at that height for consistency's sake. If the tree had two trunks, the DBH of both would be taken. Crown width was measured using a standard measuring tape in feet to the nearest quarter of a food. Two people would stand underneath the tree canopy as close to the trunk as possible to assess the length that the crown stretches. If there was not enough room to measure the width across, the length from the trunk to the crown edge would be taken and multiplied by two. Height was taken using a Nikon Forestry Pro II rangefinder/Hypsometer using the two-points mode, from the base of the trunk to the very top of the crown.

Crown vigor was assessed on a scale of 1-5, each number referring to the percentage of canopy fullness. A vigor of 1 being where 100%-90% of the tree canopy was foliated, 2 being where 90%-75% of the tree canopy was foliated, 3 where 75%-50% of the tree canopy was foliated, 4 where less than 50% of the tree canopy was foliated, and 5 being a dead tree (Figure 4).

Figure 4. Swamp White Oak (*Quercus bicolor*) in varying states of vigor, from left to right, 1-4

The overall condition of the tree was recorded using the categories “Good”, “Fair” and “Poor”. This assessment was based on the health and structure of the trunk, bark, and leaves. Things we looked out for were insect damage or disease on the leaves or bark, evidence of abrasion on the base of the trunk, insufficient/poor pruning, or rotting of the wood. The presence or absence of basal sprouts was also recorded. Land use refers to the space surrounding the tree and was noted as being one of the following: single family residence detached, single family residence attached (row houses and duplexes), multi-family (three or more units including triple deckers), mixed use, commercial, industrial, institutional (includes schools), maintained park, natural area, transportation, utilities, or vacant. The site type where the tree was planted was also recorded as being one of the following: sidewalk cutout, sidewalk planting strip, median, front yard, side yard, backyard, maintained park, natural area, or other maintained area (Figure 5).

Figure 5. Examples of trees on multiple land use/site types. From left to right: institutional in a maintained park, multi-family in a sidewalk planting strip, single family detached in a front yard, and commercial in a sidewalk cutout. All of this data was recorded using Esri software into the ArcGIS Field Maps mobile app.

4.3 Interview Methods

Our primary objective for the social assessment was to interview residents in the study area, local NGOs/community organizations, city officials and DCR employees to understand perceptions of trees and the Greening the Gateway Cities Program. We utilized the term City Partners to refer more specifically to local organizations and city officials. We created three sets of interview questions: one for residents, questions for local organizations and a third for DCR employees. We relied on a combination of phone calls and convenience sampling to scheduling interviews with stakeholders. A call list was provided by the DCR for each city and included the phone numbers of residents whose properties had received a tree from the GGCP. We made a total of 498 phone calls using phone numbers from these two lists. We conducted spontaneous interviews after encountering residents on their properties or in public spaces in order to employ convenience sampling. Between Holyoke and Chelsea, we conducted 51 interviews, 41 of which were resident interviews. We completed another 10 with city partners and DCR employees. 48 interviews were conducted in English and 3 were held in Spanish. 124 trees were associated with interviewees' properties and had an 84% survivorship rate, higher than the average for either city. 30% of trees associated with interviews were planted by the GGCP but were not part of our sample.

Interviewees signed a consent form prior to answering questions. Ensuing interviews ranged from under 20 minutes to over 60 minutes and were audio recorded. Interviewees who were comfortable filled out a basic demographic questionnaire with basic questions regarding age, education level, race, ethnicity, language(s) spoken at home, gender, income, current living arrangement and time of home occupancy. Residents were asked about topics covering their neighborhood background and community, their experiences with trees and the GGCP and larger environmental issues related to trees and outdoor spaces in their respective city. Interviews with city partners and DCR were organized into two sets of questions. Each set addressed similar topics, however, and any differences were implemented solely to differentiate the roles of interviewees. We asked city partners and and DCR employees about their role and goals, partnerships, community inclusion, lasting impact and, finally, general feedback that they wished to share.

After all interviews had been conducted, we transcribed the audio using a combination of manual transcription, Otter.ai, and Restream. We then used NVivo to process interview transcripts. Using this software, we assigned attributes to interviews to assess correlations between demographics and interview responses. We then sorted quotes into 24 codes, including eight primary (parent) codes and 16 sub- (child) codes. The parent codes addressed Tree Health, Tree Stewardship, Tree Perceptions, GGCP Involvement, Neighborhood, Community Engagement, Role in the Community and Environmental Concerns. Codes were developed in an iterative process. Parent codes addressed general recurring themes from interviews. Each interview was coded by two HERO members to ensure intercoder reliability. Once interviews were fully coded, we identified key emerging themes to understand residents' opinions, perceptions and experiences with the GGCP.

4.4 Analysis Methods

4.4.1 Biophysical Analysis Methods

The biophysical analysis was done with the use of the programming language, R and ArcGIS Pro 3.3.0. Statistical analyses were created in base R while plots were generated with the use of ggplot2. Maps and the priority analysis in section 7.1 were created with the use of ArcGIS Pro.

5 Biophysical Analysis Results

5.1 2017 Overall Results

In both Holyoke and Chelsea HERO fellows surveyed the trees planted between 2014-2016 in the summer of 2017. This summer HERO fellows returned to these trees. 731 trees were resurveyed in Holyoke while 426 were found alive and 305 were dead, removed, or stump. In Chelsea 385 trees were resurveyed 224 were found to be alive and 161 were dead, removed, or stump.

5.1.1 Resurvey Mortality Comparison

In both Chelsea and Holyoke the survivorship of the trees was higher in 2017 which is expected. In 2017 there was a higher survivorship in Chelsea compared to in Holyoke at the same time (Figures 6-9). In 2017 Chelsea had a survivorship of 88.6 % at the same time Holyoke had a survivorship of 79.2% (Figures 6-7). Currently the survivorship of the resurveyed trees in both cities is around 58% (Figures 8-9).

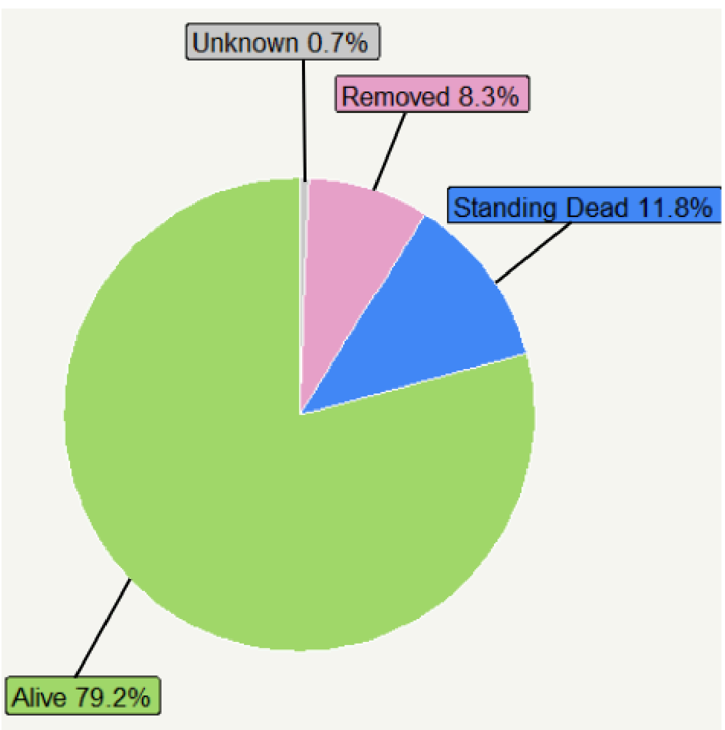

Figure 6. Mortality of trees in Holyoke in 2017

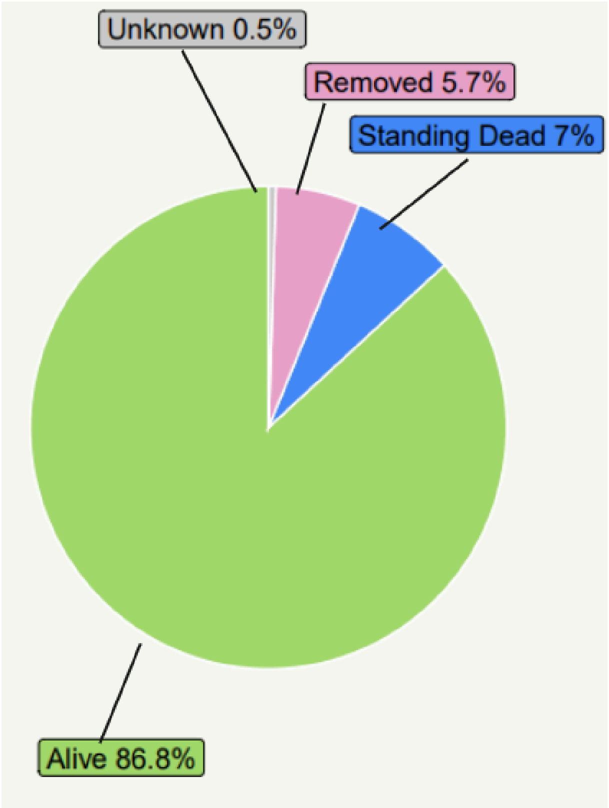

Figure 7. Mortality of trees in Chelsea in 2017

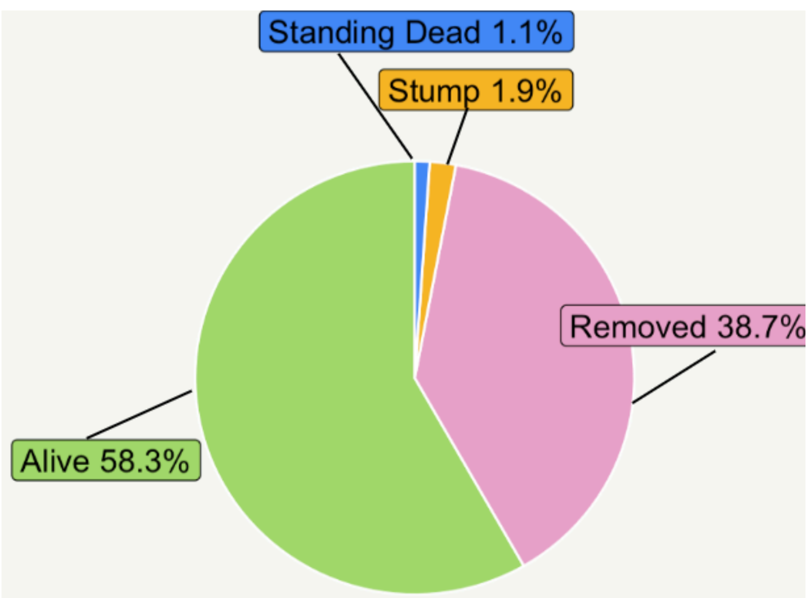

Figure 8. Resurvey mortality in Holyoke

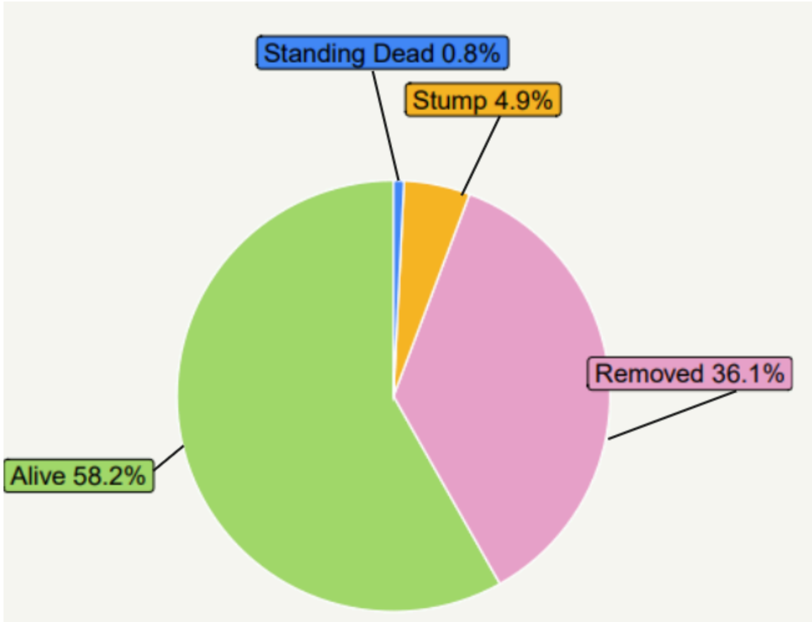

Figure 9. Resurvey Mortality in Chelsea

5.1.2 Change in Vigor Measurements

In both Holyoke and Chelsea there was a lower percentage of alive trees with a vigor of one (Figures 10, 11). In Chelsea 80.7% of the alive trees had a vigor of one and 88.3% of the alive trees in Holyoke had a vigor of one (Figures 12, 13). This is probably because if trees have a vigor of three or four over time they are more likely to be removed over time.

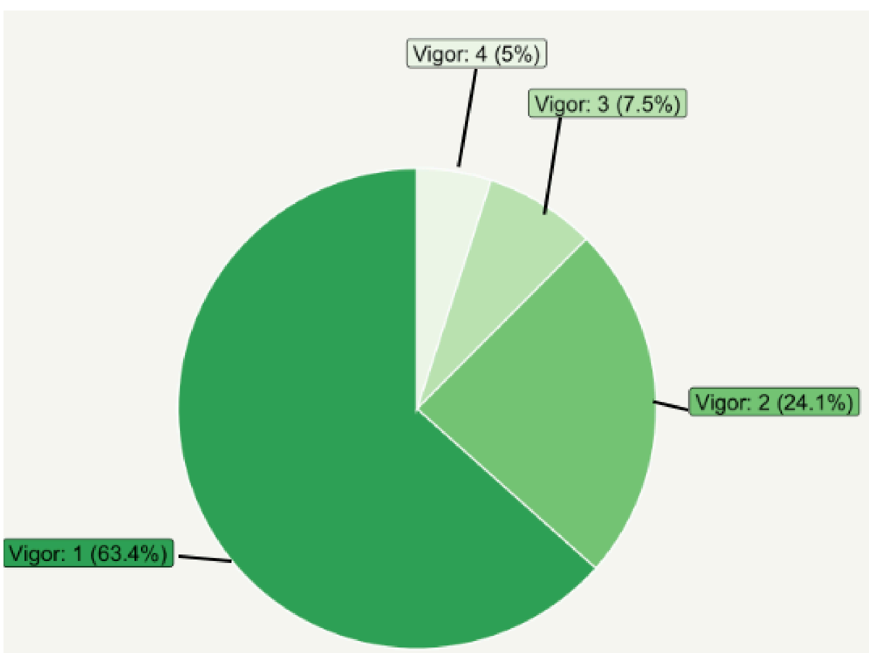

Figure 10. Vigor breakdown of alive trees in Chelsea in 2017

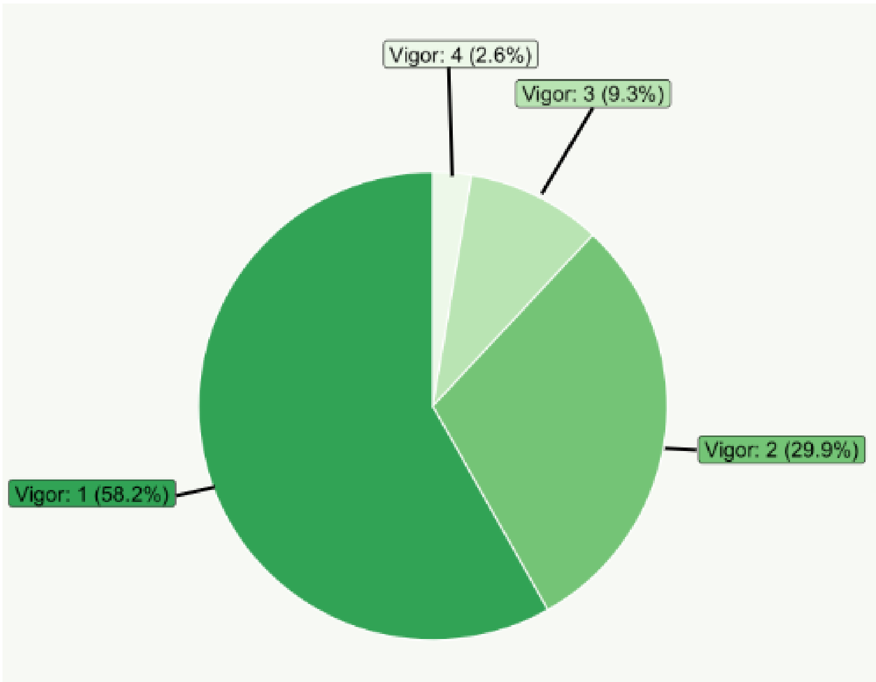

Figure 11. Vigor breakdown of alive trees in Holyoke in 2017

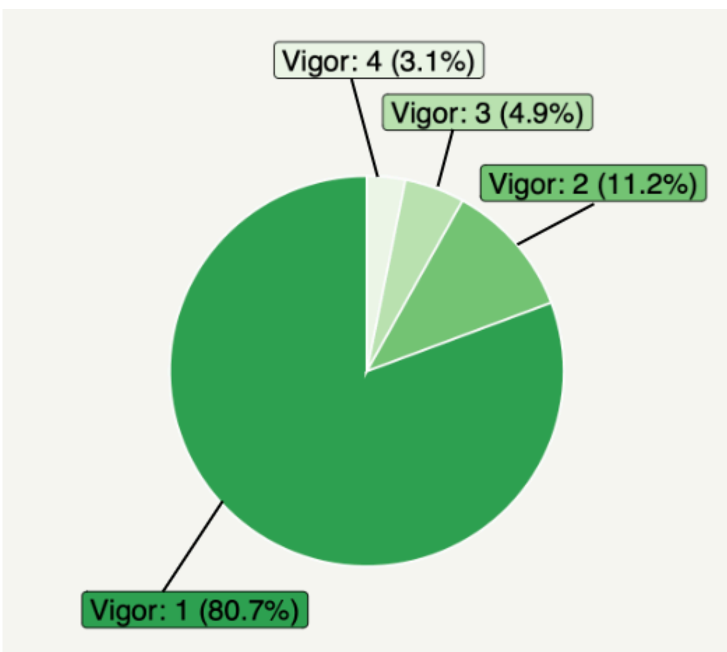

Figure 12. Chelsea resurvey alive trees vigor breakdown

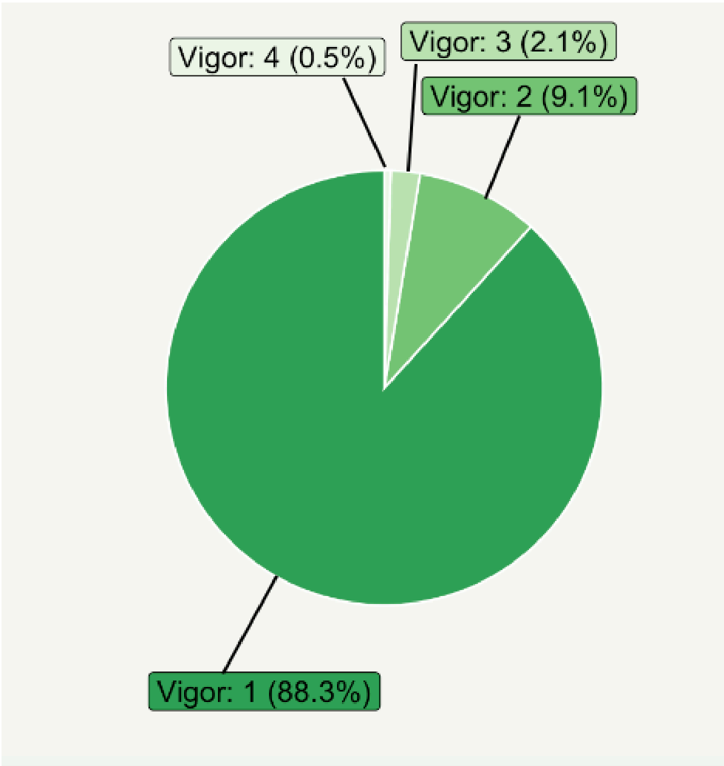

Figure 13. Holyoke resurvey alive trees vigor breakdown.

5.2 2024 Overall Results

The trees in our overall survey have been planted between 2014 to 2023. In this section we will consider the survivorship of these trees in relation to other factors.

In our overall sample in Holyoke, there was a 72% rate of survivorship (Figure 14). When the trees planted are broken down into year cohorts there is a noticeable correlation between the age of the trees and rate of survivorship. In Holyoke the trees planted between 2020-23 have a 92.7% rate of survivorship. While trees planted between 2017-2019 had a 69.1% of survivorship.

In Chelsea a 65.4% survivorship was found (Figure 15) which is not as high survivorship as Holyoke. When the Chelsea trees are broken down into year cohorts the same pattern is seen as in Holyoke. The trees planted between 2020-2023 in Chelsea have an 81.7% rate of survivorship which is significantly lower than in Holyoke. The other year cohort's survivorship rates are similar to those in Holyoke.

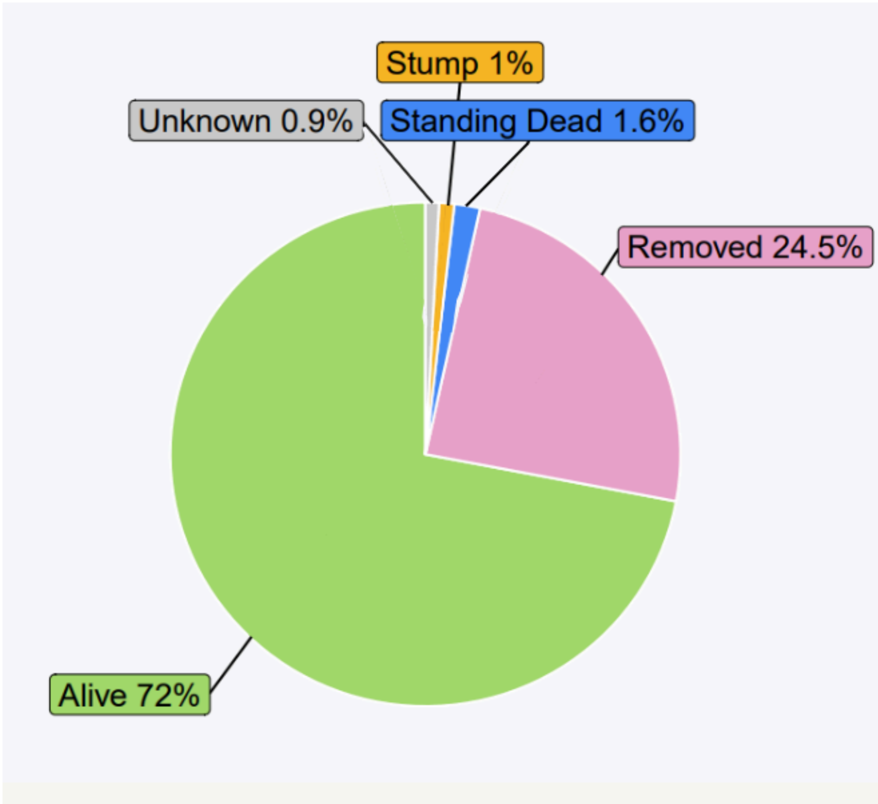

Figure 14. This shows the survivorship of the overall trees in Holyoke

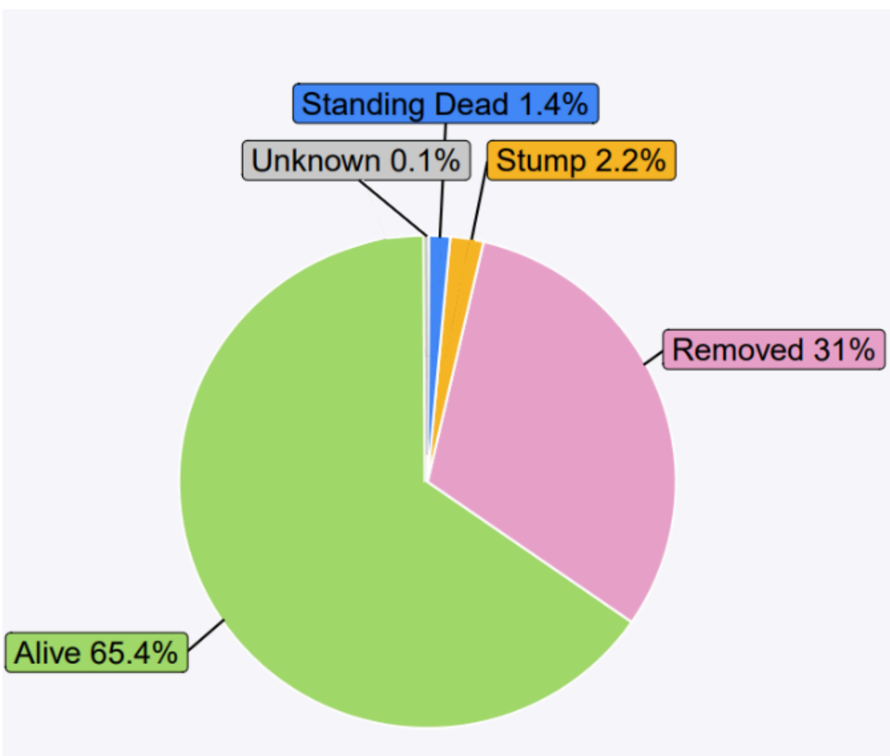

Figure 15. This shows the survivorship of the overall trees in Chelsea

When looking at the rate of annual survivorship by yearly cohort for Holyoke, we were able to compare the trees in their establishment (>5 years) vs their post-establishment (<6 years) (Figure 16). Holyoke trees had higher rates of survivorship during the establishment period (95.3%) than during the post establishment period (93.8%). Holyoke trees in the establishment period had a survivorship rate at or above the national median establishment survivorship rate (93.2%). However, Holyoke trees in the post-establishment period had lower rates of survival than the national median post-establishment survivorship rate (96.7%). When comparing these rates to the average precipitation in inches per year, we did not find a consistent correlation. It is also important to note that in Holyoke there were fewer trees planted in 2018, which explains the lower rate of survivorship for that year.

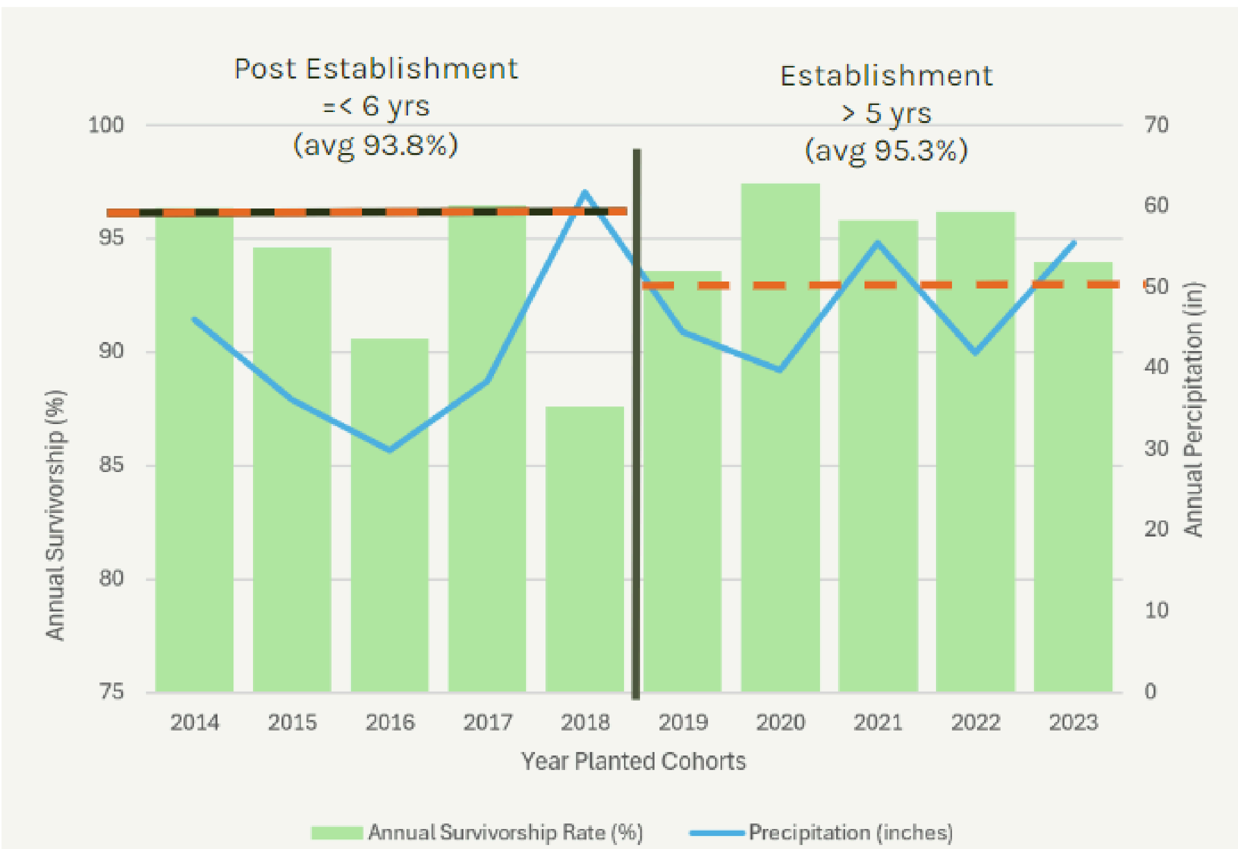

Figure 16. The last 10 years of annual survivorship rates for Holyoke trees by yearly cohorts. Left side of the graph is post-establishment period (<6 years) , right side of the graph is establishment period (>5 years). The orange line refers to the national median establishment rate of survivorship, the orange and black line refers to the national median post-establishment rate of survivorship. Blue line indicates the average amount of precipitation in inches.

When looking at the rate of annual survivorship by yearly cohort for Chelea, we were able to compare the trees in their establishment period (>5 years) vs their post-establishment period (<6 years) (Figure 17). Chelsea trees had lower rates of survivorship during the establishment period (90.9%) than during the post establishment period (94.2%). Chelsea trees in the establishment period had a survivorship rate lower than the national median establishment survivorship rate (93.2%), except for the years 2020 and 2021. Chelsea trees in the post-establishment period also had lower rates of survivorship than the national median post-establishment survivorship rate (96.7%), except for the years 2016 and 2017. When comparing these rates to the average precipitation in inches per year, we did not find a consistent correlation.

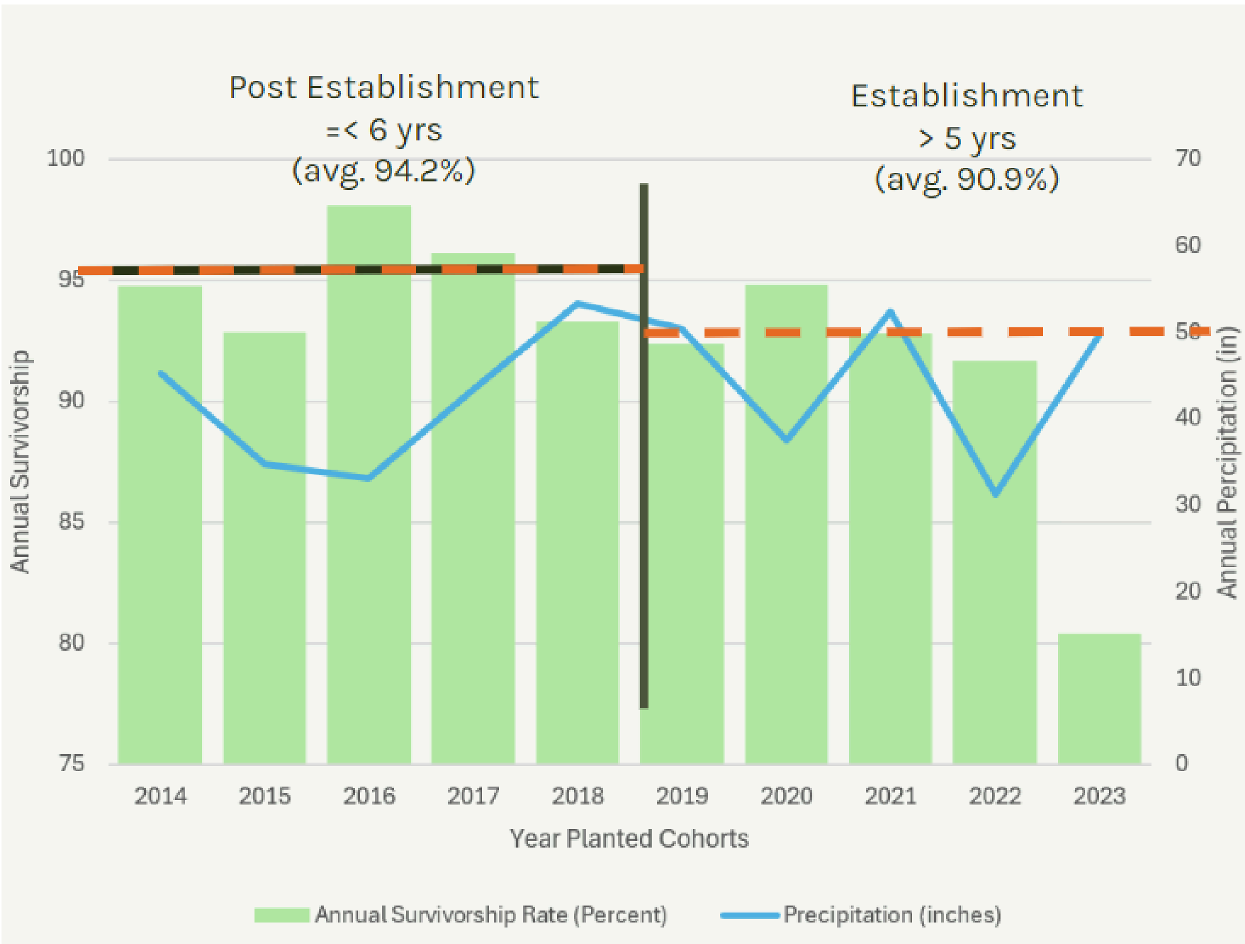

Figure 17. The last 10 years of annual survivorship rates for Chelsea trees by yearly cohorts. Left side of the graph is post-establishment period (<6 years) , right side of the graph is establishment period (>5 years). The orange line refers to the national median establishment rate of survivorship, the orange and black line refers to the national median post-establishment rate of survivorship. Blue line indicates the average amount of precipitation in inches.

5.3 Factors for Survivorship
5.3.1 Survivorship and Site Type

Depending on the location of planting the site types available for planting will be different. In this study the two cities, Holyoke and Chelsea, have very different landscapes meaning that the site types distribution will be very different.

In Holyoke there is almost an even split between the three different site type groups (Figure 18). The majority of the trees in Holyoke were planted in other maintained areas which includes commercial and industrial areas (Figure 18). In Holyoke there are also a significant amount of street trees (Figure 18). In Holyoke the site type with highest survivorship is street trees with 81% survivorship for sidewalk planting strips and 91% for sidewalk cutouts (Figure 19). Other maintained areas had the most trees planted and a survivorship of 67% which is slightly lower than overall survivorship in Holyoke (Figures 14, 18-19).

In Chelsea 53% of trees are street trees planted in sidewalk cutouts or sidewalk planting strips (Figure 20). In Chelsea street trees had some of the best survivorship but not as high as in Holyoke (Figures 19, 21). Maintained parks had the lowest survivorship in Chelsea with only 38% survivorship, but this only consisted of 39 trees (Figure 21).

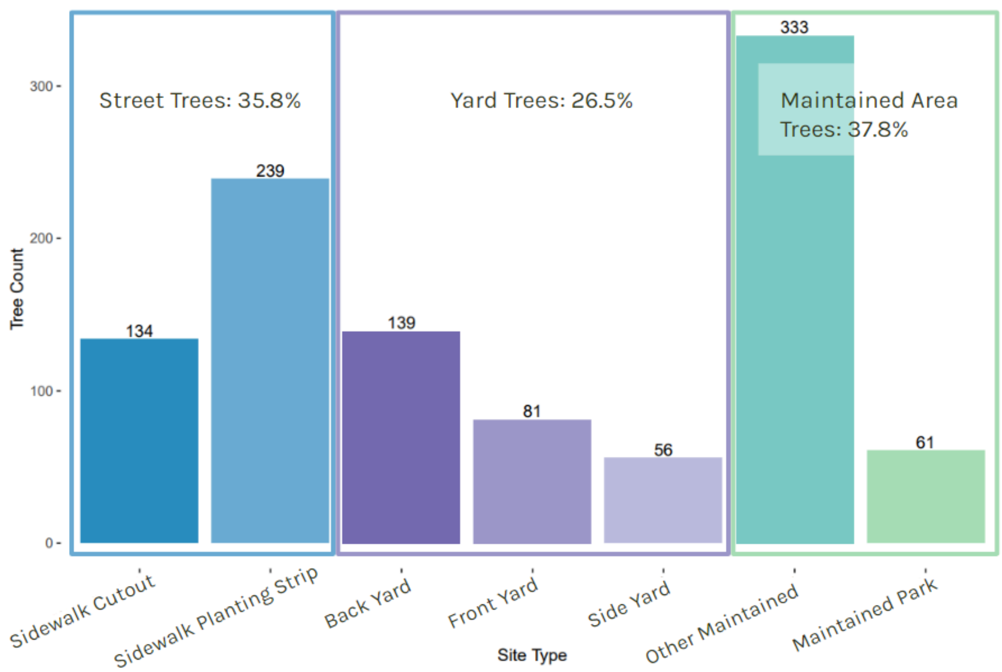

Figure 18. Site type distribution in Holyoke for the overall sample

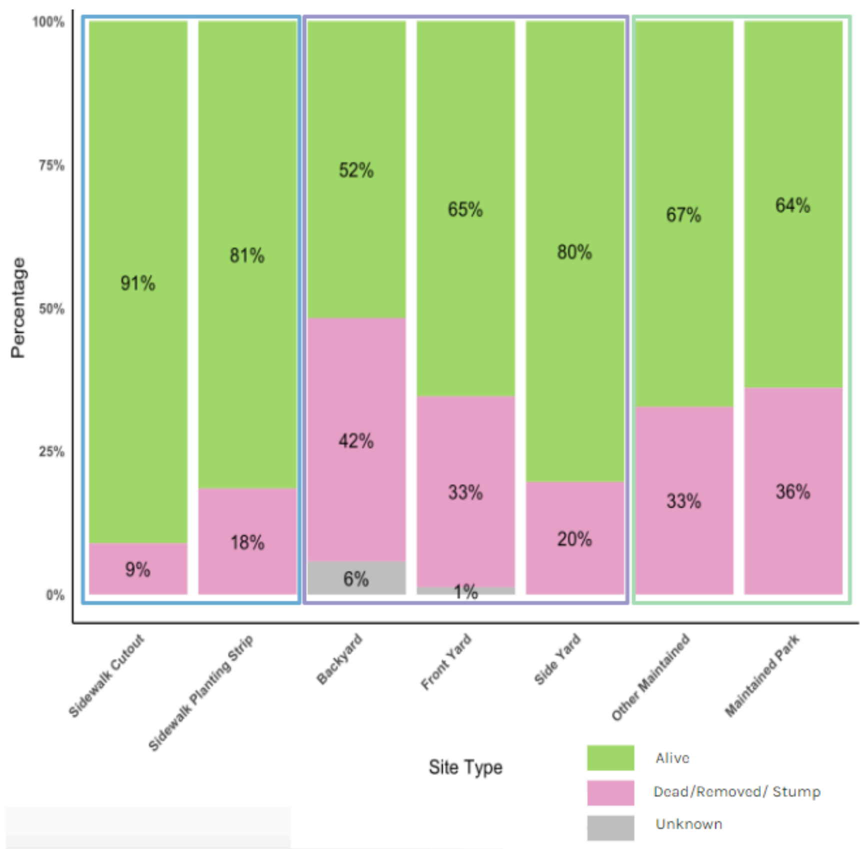

Figure 19. Holyoke survivorship by site type with boxes and same order as figure 18

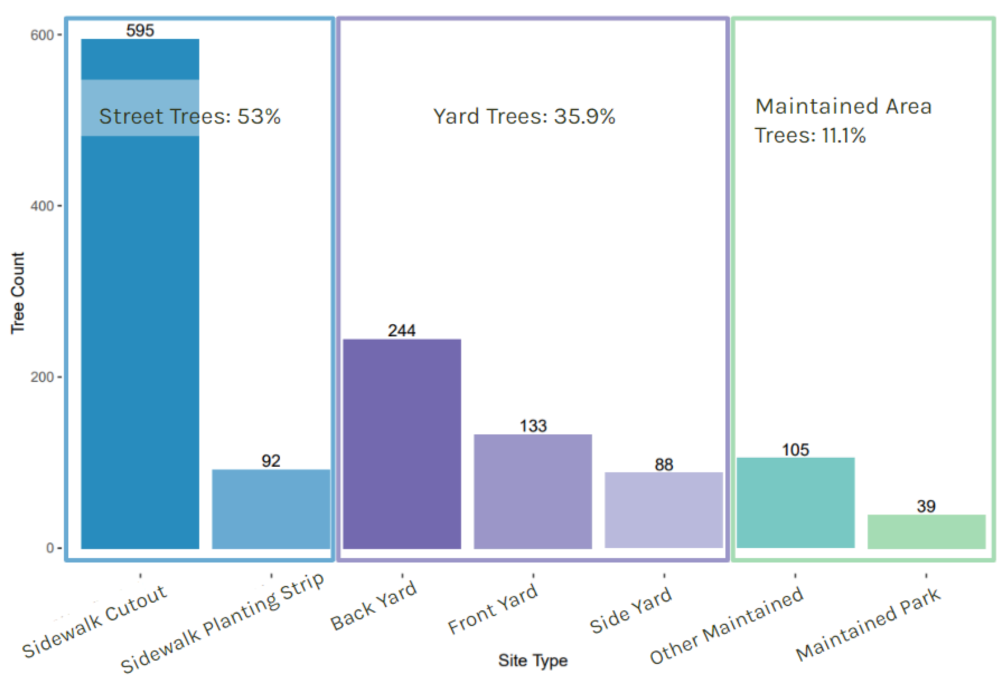

Figure 20. Site type distribution in Chelsea for overall sample

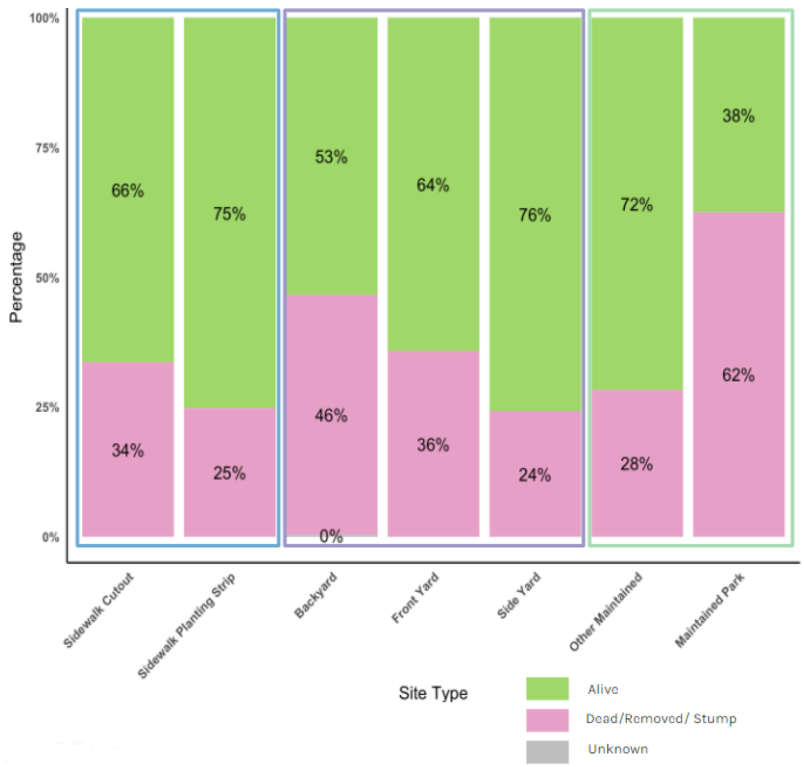

Figure 21. Survivorship by site type in Chelsea with boxes grouping in same order as figure 20

5.3.2 Survivorship and Land Use

In Holyoke the land use type with the most trees, institutional, had 18.5% of Holyoke's trees. These trees had the lowest survivorship of only 51%. Residential land uses had a majority of trees and a better rate of survivorship (Figures 22, 23). In Chelsea the majority of trees are located in or near residential areas (Figure 24). Single-family attached homes do the best with survivorship of 75%, but these trees only make up 8.6% of overall trees surveyed. Single-family detached homes make up 31.2% of the overall trees sampled and have a survivorship of 67%. Multi-family residences make up 36.2 % of the overall sample and have the lowest rate of residential survivorship with 62% survivorship (Figures 24, 25). In both Chelsea and Holyoke the best survivorship is 100% which is mixed use for Holyoke and transportation for Chelsea, but these areas only make up 1.1% and 0.5% of their city's trees respectively (Figures 22-25).

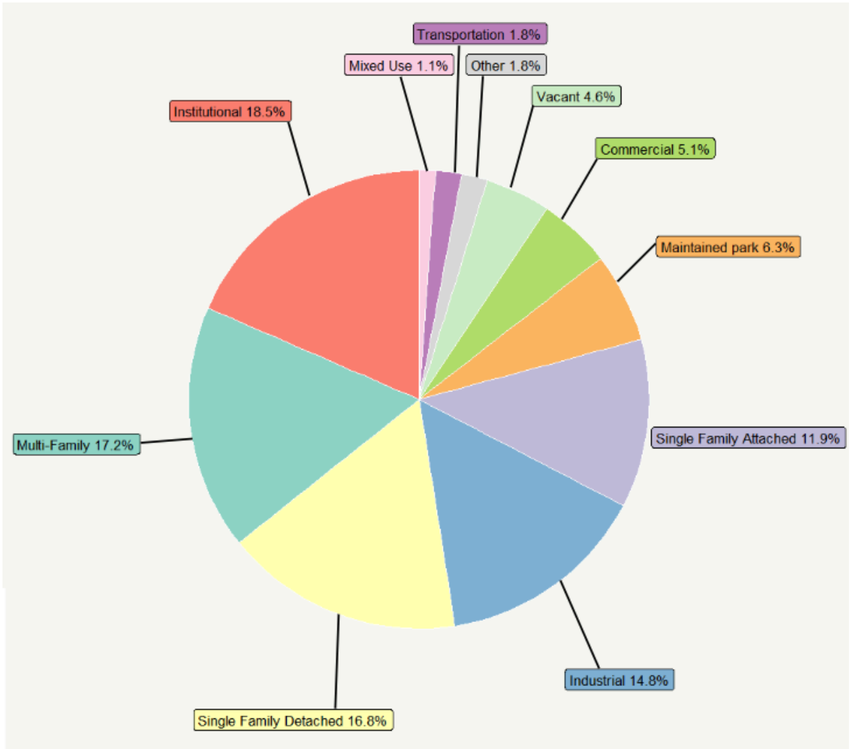

Figure 22. Land use distribution in Holyoke for overall sample

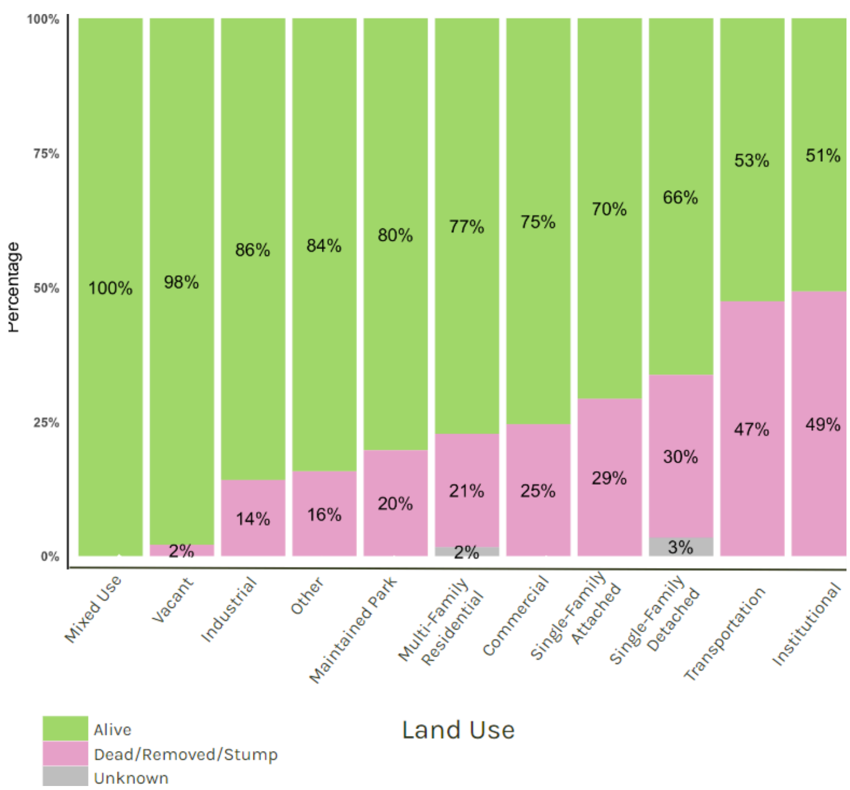

Figure 23. Survivorship of trees based on land use in Holyoke

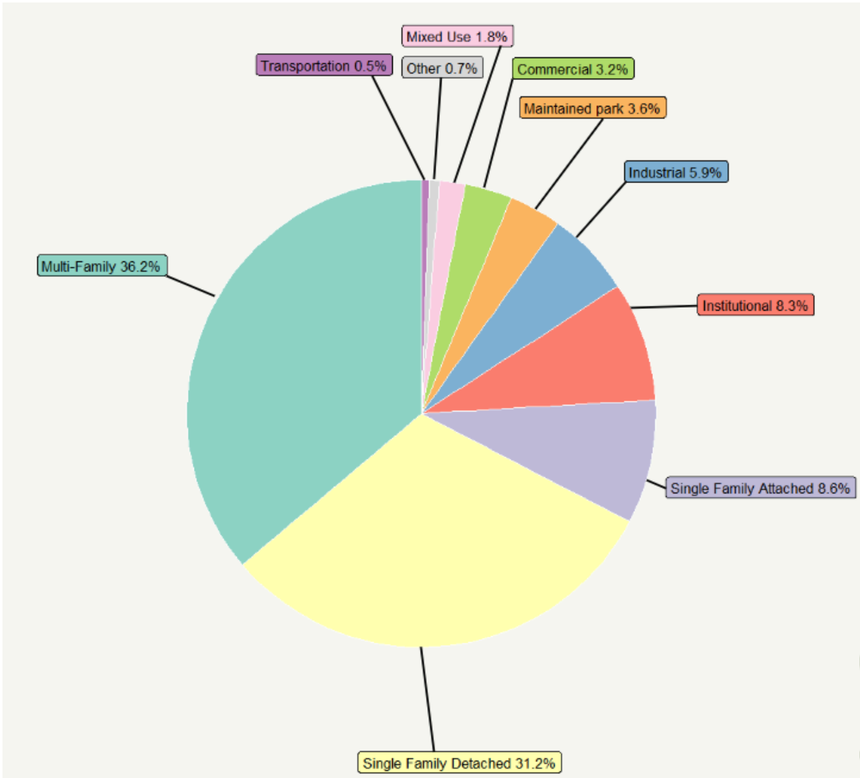

Figure 24. Land use distribution in Chelsea for overall sample

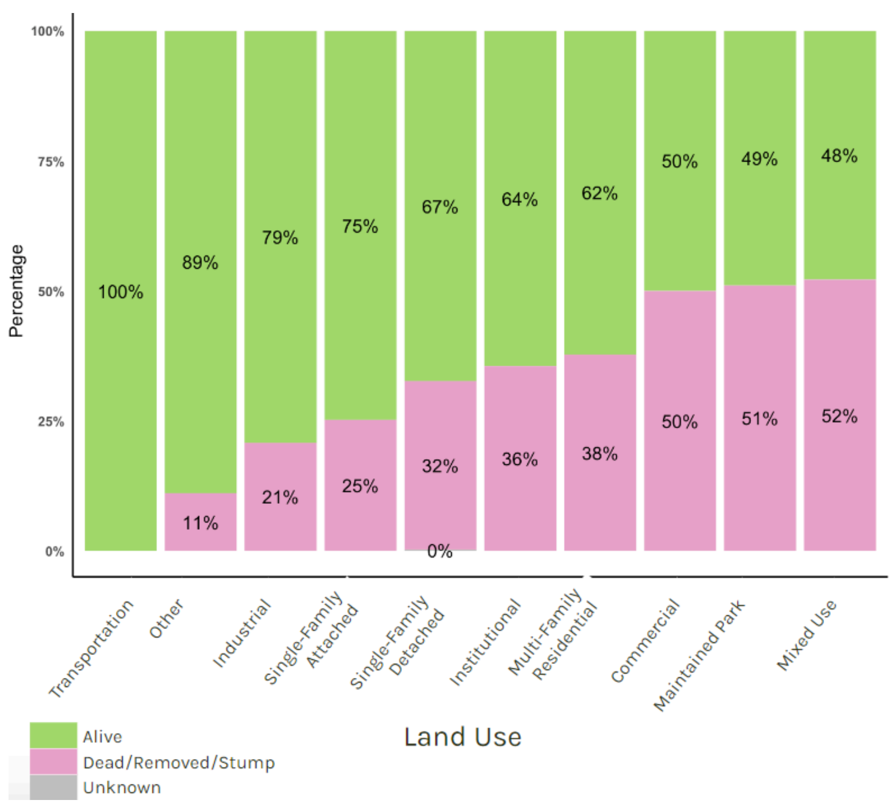

Figure 25. Survivorship of trees based on land use in Chelsea

5.3.3 Private and Public Trees

In both Chelsea and Holyoke public trees have higher rates of survivorship (Figures 26-29). In Holyoke there is a larger difference in the rate of survivorship between public and private trees (Figures 26, 28).

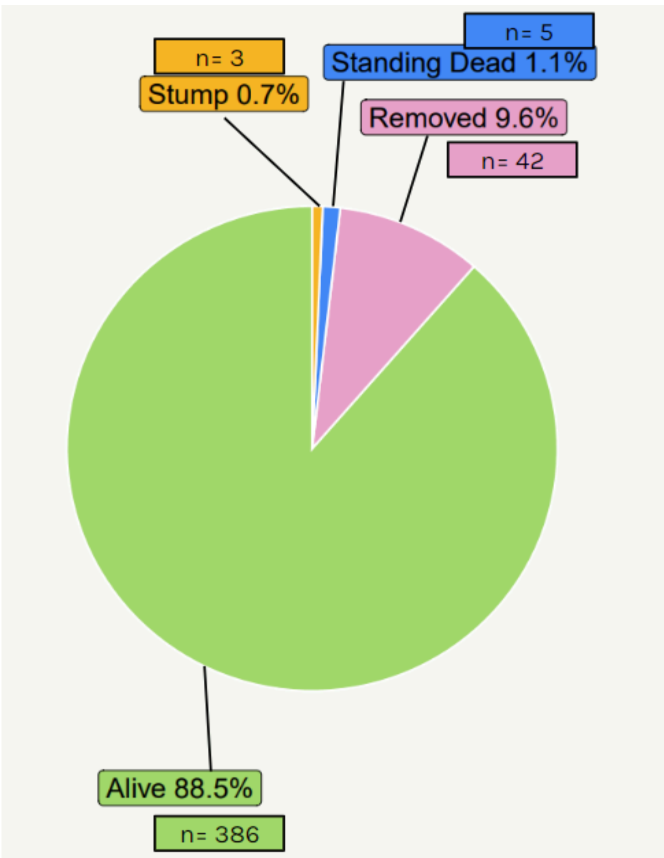

Figure 26. Public trees survivorship in Holyoke overall sample

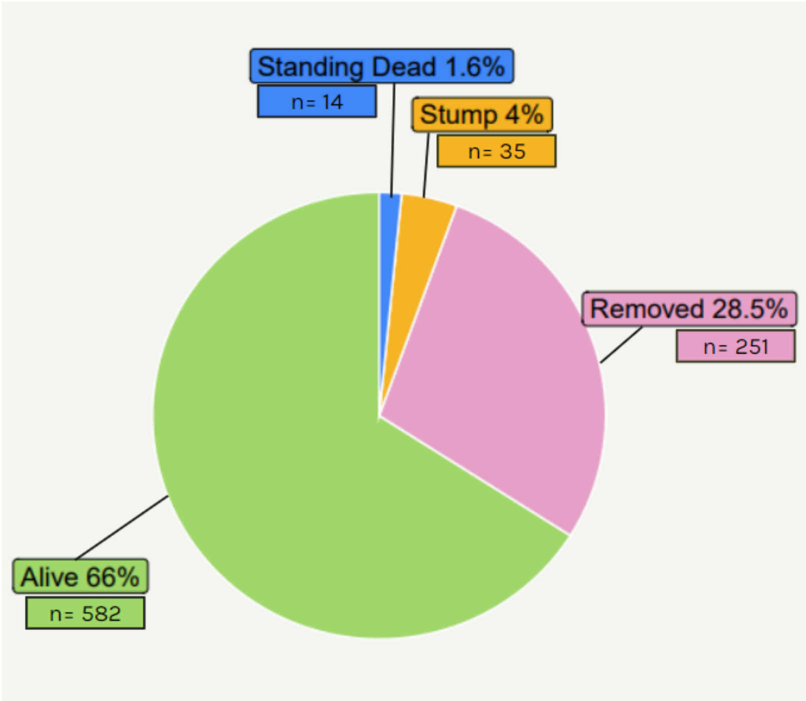

Figure 27. Public trees survivorship in Chelsea overall sample

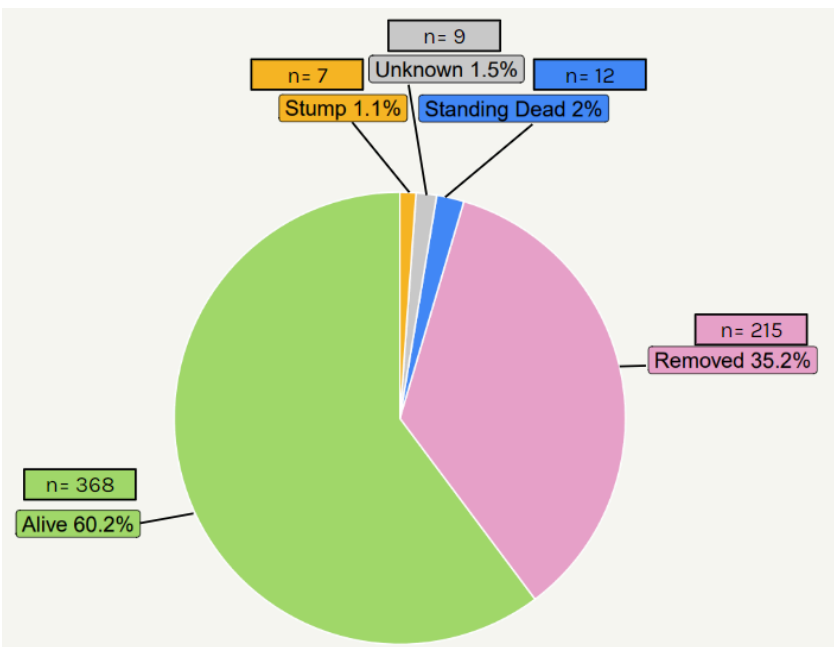

Figure 28. Private trees in Holyoke overall sample

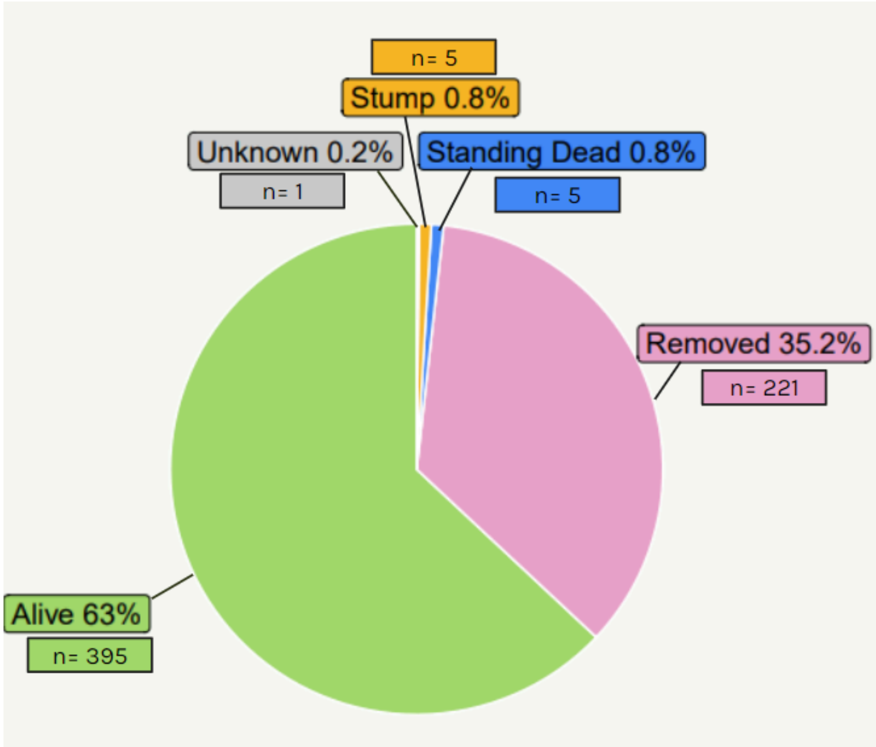

Figure 29. Private trees survivorship Chelsea overall sample

5.3.4 Tree Health

In both cities over 80% of the living trees have a vigor of one (Figures 30, 31). While the distribution of vigor is similar in both cities, the percentage of trees with vigor one is slightly higher in Chelsea thus overall these living trees are doing slightly better (Figures 30, 31). When looking at the condition of the living trees both cities have a very similar distribution. In both Holyoke and Chelsea over 80% of the living trees have a condition of good.

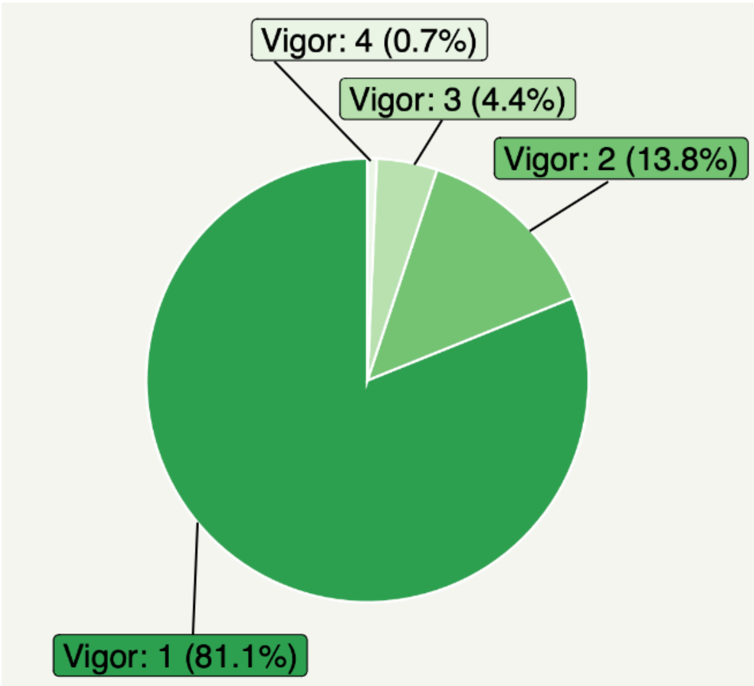

Figure 30. Vigor for alive trees in overall sample Holyoke

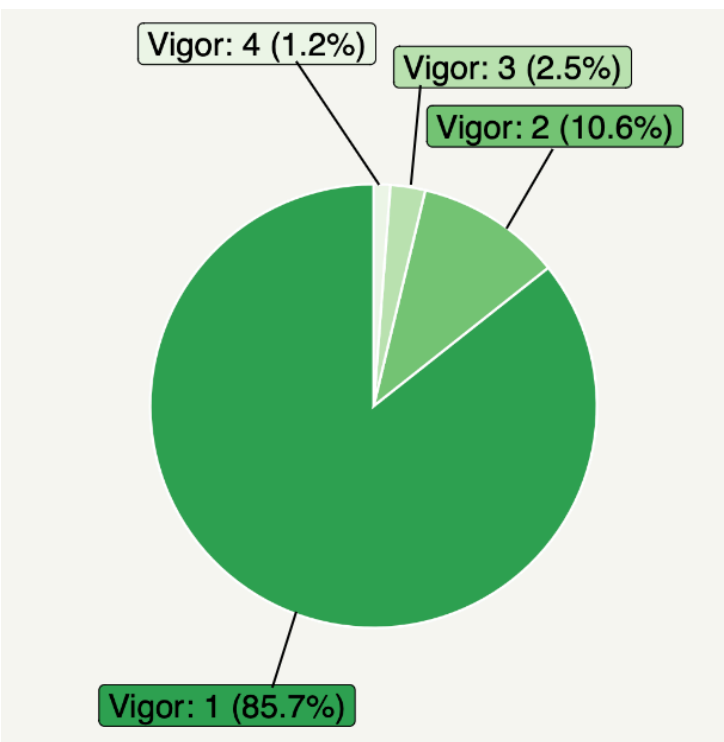

Figure 31. Vigor for alive trees in overall sample in Chelsea

5.4 Species Analysis

In our combined overall sample between Holyoke and Chelsea, we surveyed 2,343 trees distributed across 108 individual tree species. The five most common tree species surveyed were Apple (*Malus spp.*), American Hornbeam (*Carpinus caroliniana*), Japanese Tree Lilac (*Syringa reticulata*), Freeman Maple (*Acer x freemanii*), and Tulip Tree (*Liriodendron tulipifera*) (Figure 32). Among trees surveyed 10 or more times, two tree species had 100% survivorship: Common Hackberry (*Celtis occidentalis*) and Chokecherry (*Prunus virginiana*). Notable tree species with high survivorship include Swamp White Oak (*Quercus bicolor*), Eastern redbud (*Cercis canadensis*), Cherry Plum (*Prunus cerasifera*), Pin Oak (*Quercus palustris*), and Apple (*Malus spp.*) (Figure 33). Notable tree species with lower survivorship include Tulip Tree (*Liriodendron tulipifera*), Black Tupelo (*Nyssa sylvatica*), Kousa Dogwood (*Cornus kousa*), Sugar Maple (*Acer saccharum*), and River Birch (*Betula nigra*) (Figure 33).

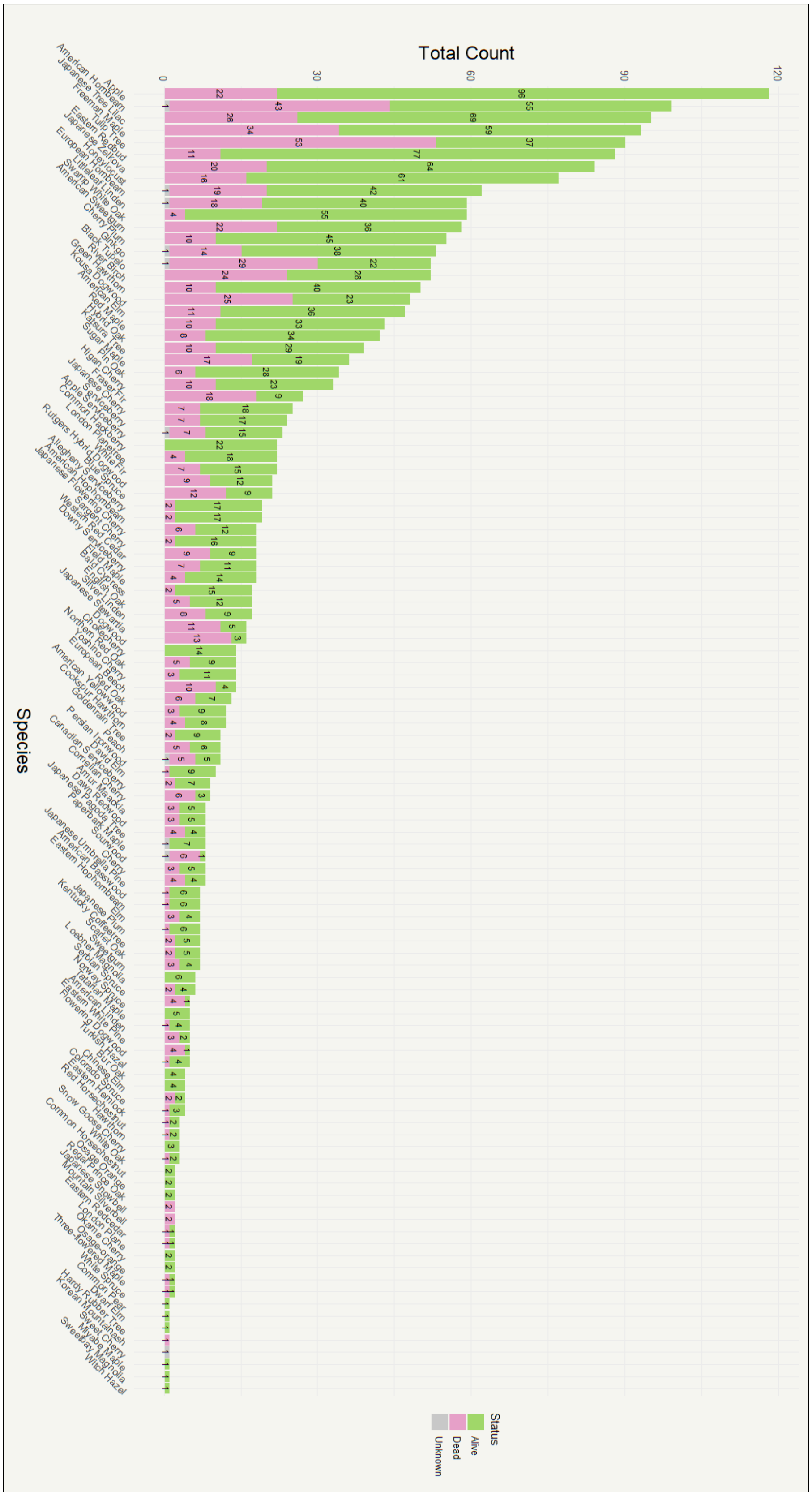

Figure 32. Combined overall sample species survivorship distribution

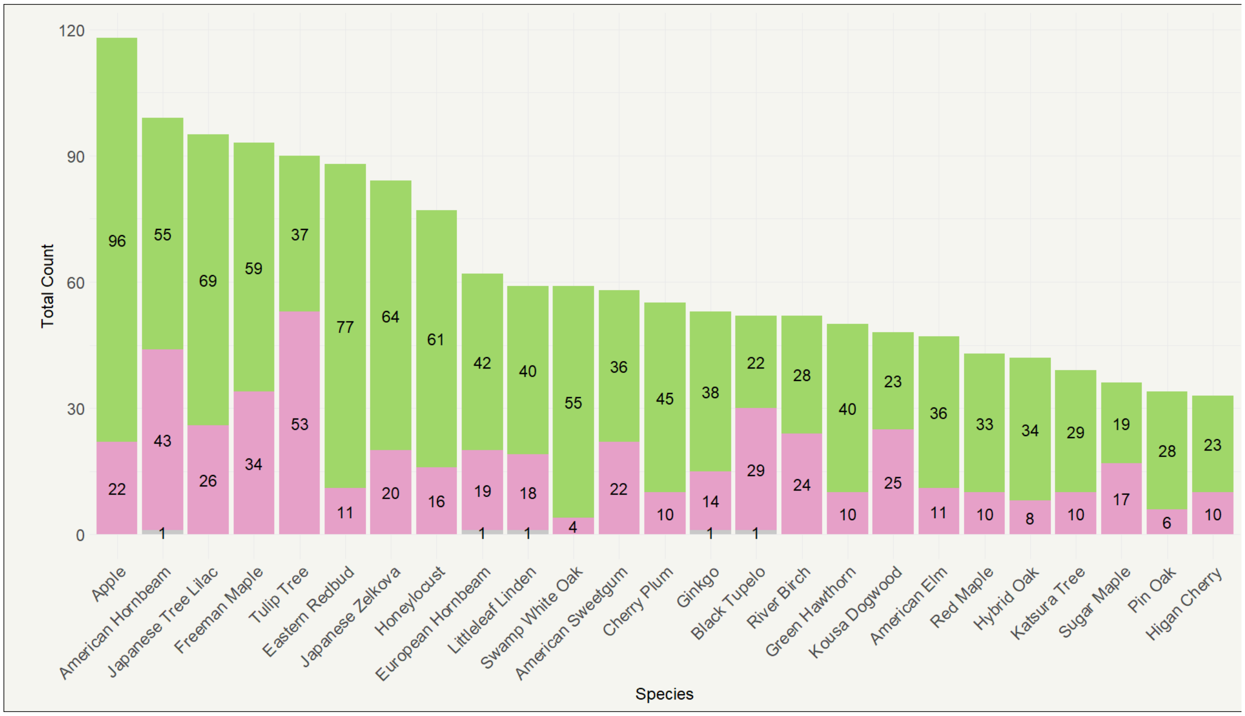

Figure 33. Combined overall sample species survivorship distribution showing species with 30 trees surveyed or more

5.4.1 Holyoke Species

In our overall sample in Holyoke, we surveyed 1,055 trees distributed across 75 individual species. The five most common tree species surveyed were Tulip Tree (*Liriodendron tulipifera*), American Sweetgum (*Liquidambar styraciflua*), Eastern redbud (*Cercis canadensis*), Japanese Zelkova (*Zelkova serrata*), and Freeman Maple (*Acer x freemanii*) (Figure 34). Among trees surveyed ten or more times, three tree species had 100% survivorship: Honeylocust (*Gleditsia triacanthos*), Common Hackberry (*Celtis occidentalis*), and Sargent Cherry (*Prunus sargentii*) (Figure 35). Other notable species with high survivorship are Swamp White Oak (*Quercus bicolor*), Pin Oak (*Quercus palustris*), and Green Hawthorn (*Crataegus viridis*) (Figure 35). Notable tree species with lower survivorship include Black Tupelo (*Nyssa sylvatica*), Tulip Tree (*Liriodendron tulipifera*), Western Red Cedar (*Thuja plicata*), River Birch (*Betula nigra*), and Peach (*Prunus persica*) (Figure 35).

Analysis of individual properties in Holyoke with high amounts of trees planted on them revealed that these sites have high impacts of overall survivorship. One site in particular, 100 Bigelow st, had 87 trees surveyed trees on its property. 60 of those treeswere dead or removed. This site contained high concentrations of four species in particular: Black tupelo (*Nyssa sylvatica*), Tulip Tree (*Liriodendron tulipifera*), River Birch (*Betula nigra*), and American Sweetgum (*Liquidambar styraciflua*). This individual site's effect on individual species survivorship is quite large, so much so that analysis done while removing the trees planted at this property revealed these species had much higher survivorship than before: 33% higher for Black Tupelo, 25% higher for River Birch, and 10% higher for Tulip and American Sweetgum (Figure 36).

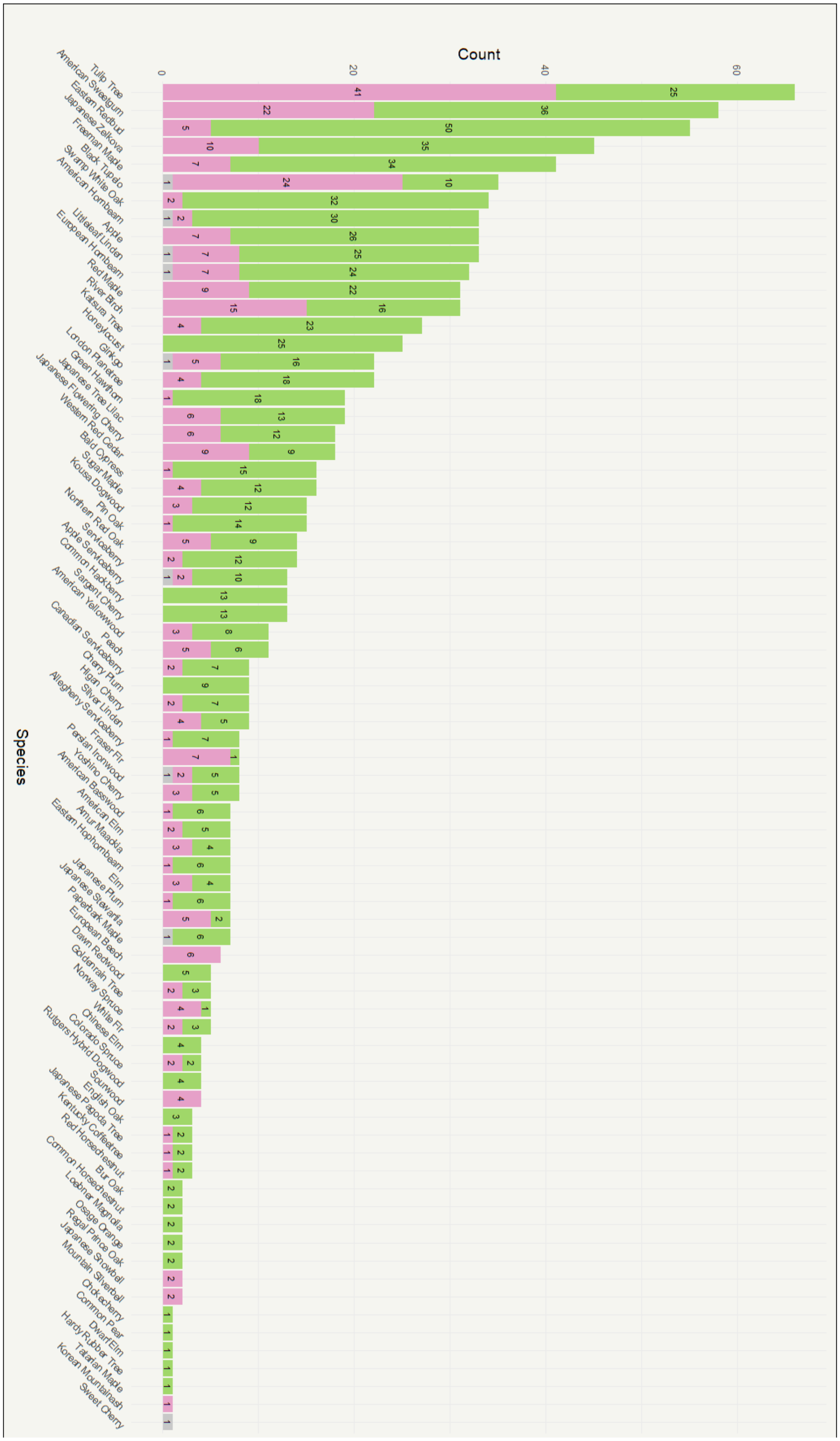

Figure 34. Holyoke overall sample species survivorship distribution

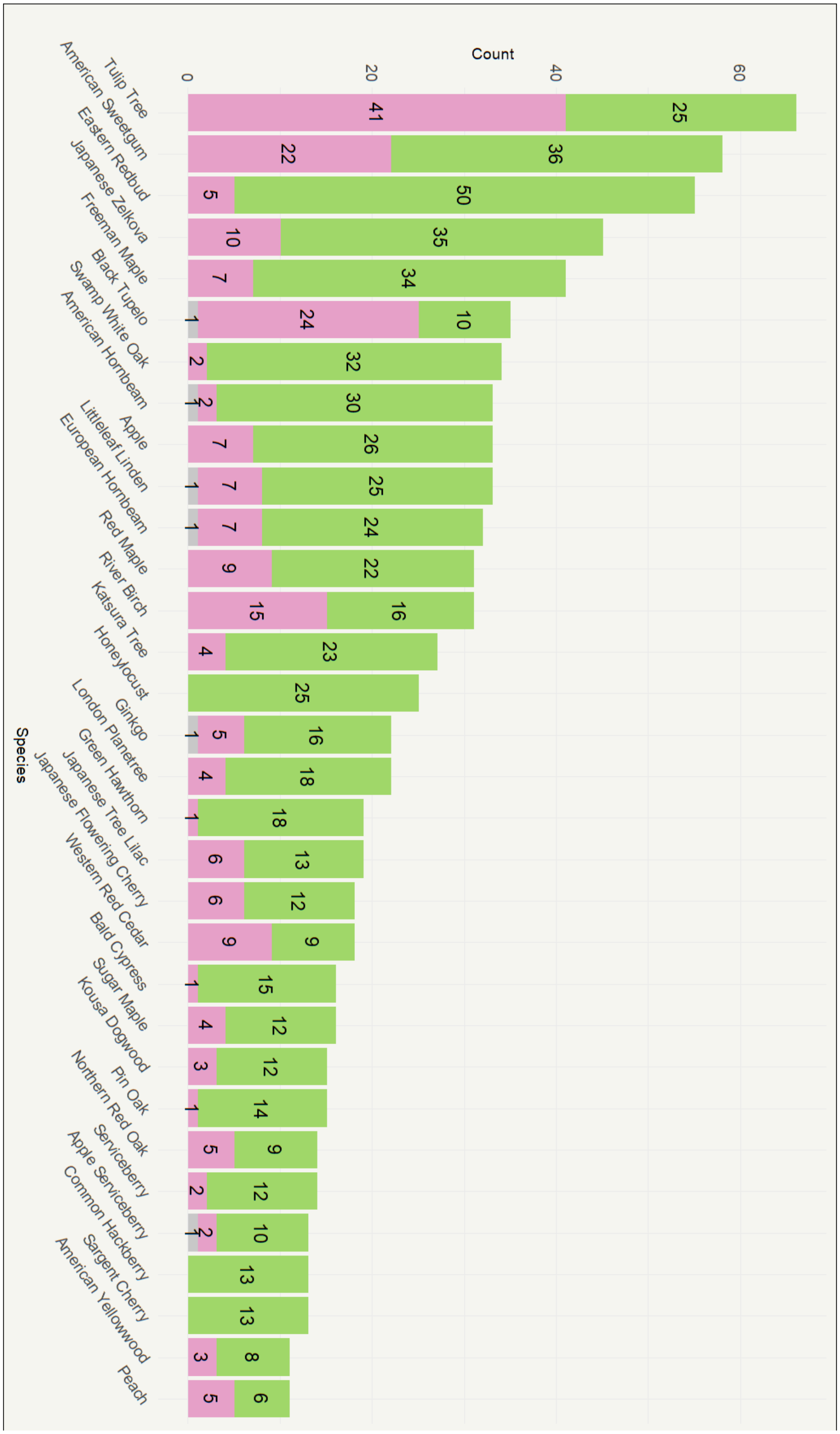

Figure 35. Holyoke overall sample species survivorship distribution showing species with 10 trees surveyed or more

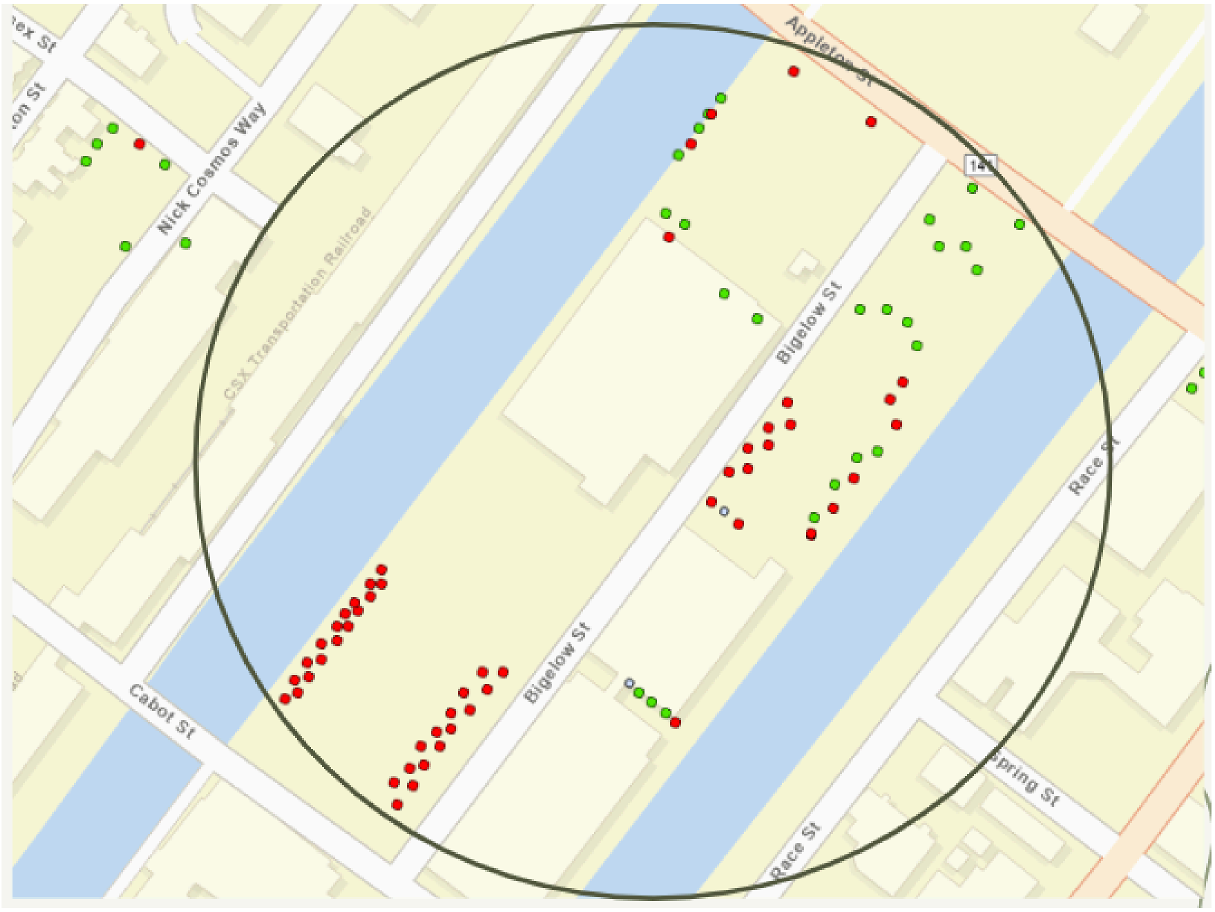

Figure 36. Map showing trees planted at 100 Bigelow St Holyoke, MA. Green dots are alive trees, red dots are removed or dead trees.

Table 3. Table showing percent change in survivorship for 4 tree species if trees planted at 100 Bigelow were removed from analysis.

Species	Percent Change in Overall Survivorship without 100 Bigelow
American Sweetgum	+ 10.02
Black Tupelo	+ 33.09
Tulip Tree	+ 10.12
River Birch	+ 24.86

5.4.2 Chelsea Species

In our overall sample in Chelsea we surveyed 1,296 trees distributed across 83 individual species. The five most common tree species surveyed were Apple (*Malus spp.*), Japanese Tree Lilac (*Syringa reticulata*), American Hornbeam (*Carpinus caroliniana*), Freeman Maple (*Acer x freemanii*), and Honeylocust (*Gleditsia triacanthos*) (Figure 37). Among trees surveyed ten or more times, one tree species, Chokecherry (*Prunus virginiana*), has 100% survivorship (Figure 38). Other notable tree species with high survivorship include Swamp White Oak (*Quercus bicolor*), American Hophornbeam (*Ostrya virginiana*), Apple (*Malus spp.*), Eastern Redbud (*Cercis canadensis*), and Hybrid Oak(*Quercus × warei*) (Figure 38). Notable tree species with lower survivorship include Dogwood (*Cornus*), Kousa Dogwood (*Cornus kousa*), Sugar Maple (*Acer saccharum*), American Hornbeam (*Carpinus caroliniana*), and Fraser Fir (*Abies fraseri*) (Figure 38).

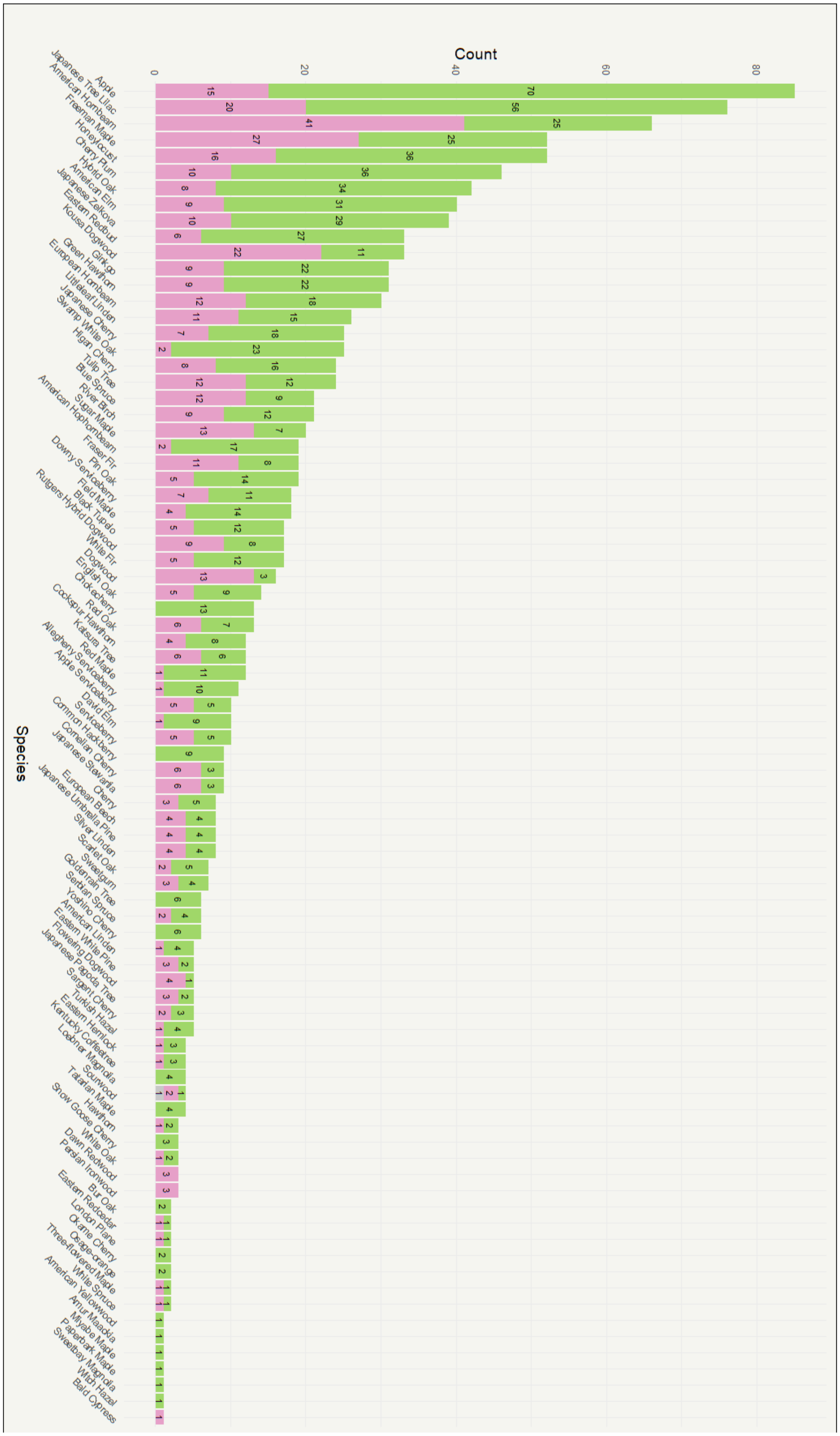

Figure 37. Chelsea overall sample species survivorship distribution

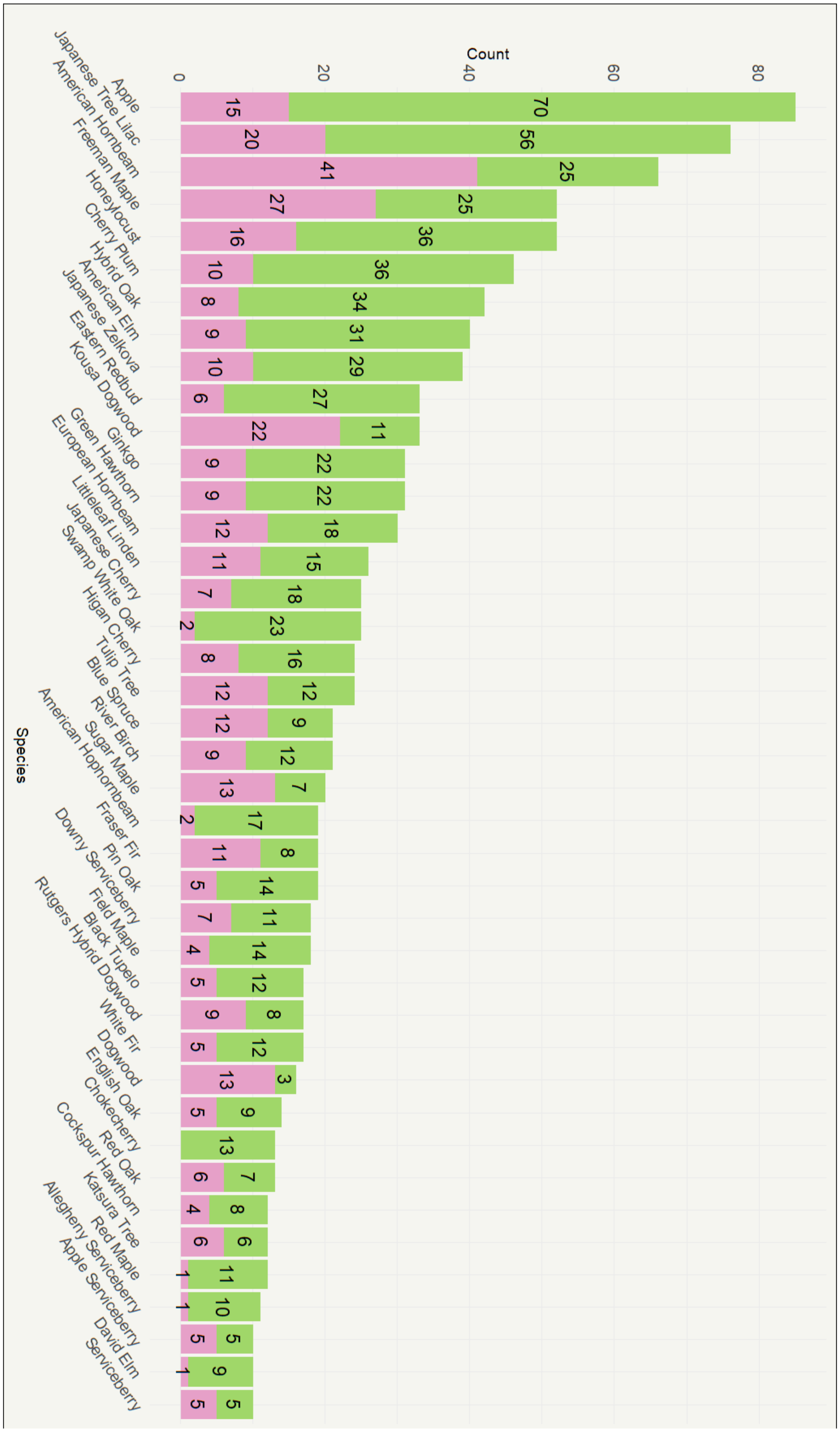

Figure 38. Chelsea overall sample species survivorship distribution showing species with 10 trees surveyed or more

5.4.3 Species Comparisons and Factors by City

Between the two cities in the study area there was some difference between survivorship for individual species. Analysis was done with 9 tree species that were surveyed 25 or more times in both Chelsea and Holyoke. All trees analyzed except for Apple had higher survivorship in Holyoke than in Chelsea (Figure 39). The highest differences in survivorship between the two cities were found in American Hornbeam which has 53% higher survivorship in Holyoke than in Chelsea, Freeman Maple which has 35% higher survivorship in Holyoke than in Chelsea, and Honeylocust which has 31% higher survivorship in Holyoke than Chelsea (Figure 39). These two cities have very different landscapes and built environments, with Holyoke being a less dense city with more trees planted in yards and open space, and Chelsea being the second densest city in MA and having higher amounts of impervious surfaces leading to more trees being planted on streets. Differences in individual species survivorship may be due to these species doing better in one kind of planting environment over the other.

Analysis of DCR and GGCP Tree Categories which were listed on a March 2024 handout provided by the DCR yielded mixed results (Figure 40). The three categories are preferred urban canopy trees, secondary consideration trees, and use sparingly trees. The list is used as a reference when deciding what trees to plant. In Holyoke survivorship analysis showed that use sparingly tree species had higher survivorship (83%) than the other two categories (preferred 64%, secondary 67%) (Figure 41). In Holyoke this difference is less pronounced with more even survivorship across the three categories (Preferred 68%, Secondary 55%, Sparingly 67%) (Figure 42). Differences in use sparingly survivorship is likely due to the high amount of ornamental trees included in this category. Ornamentals tend to survive more in yards where they are well maintained, which is often where they are planted in Holyoke. Chelsea on the other hand planted many apples and dogwoods on streets which tended to have lower survivorship.

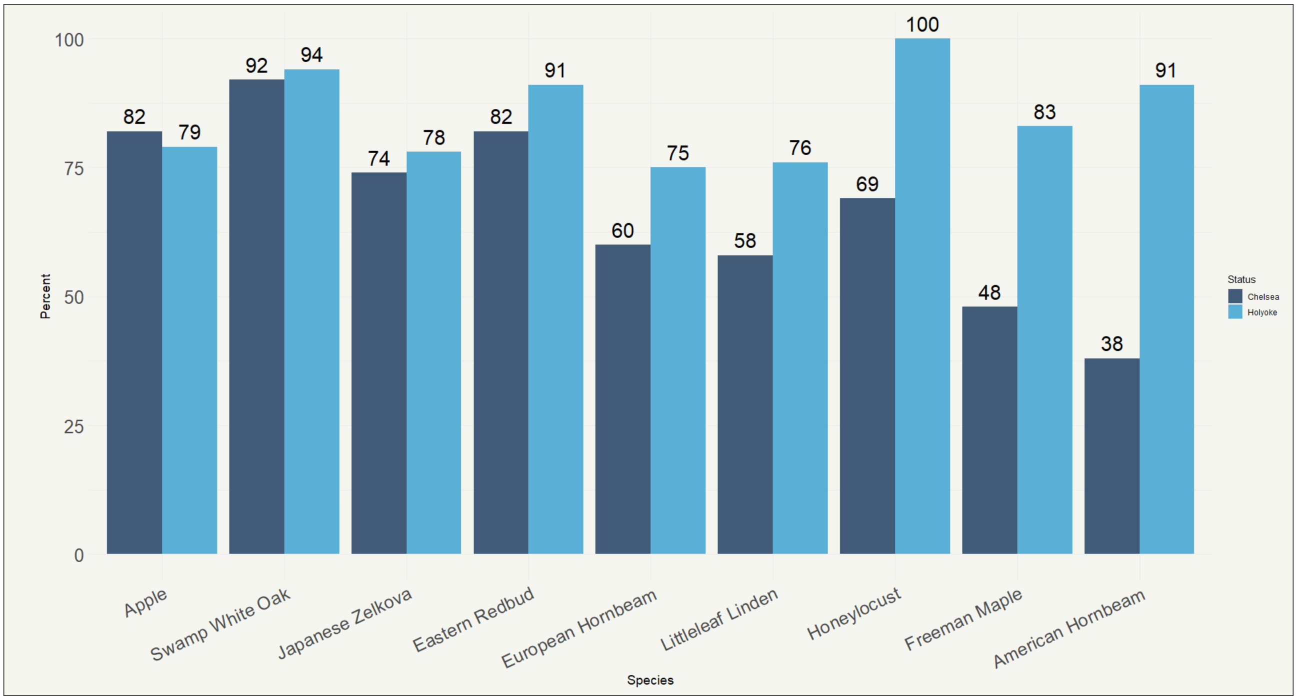

Figure 39. Barchart showing differences in survivorship between Holyoke and Chelsea for tree species surveyed 25 or more times in each city. Chelsea - Dark Blue, Holyoke - Light Blue

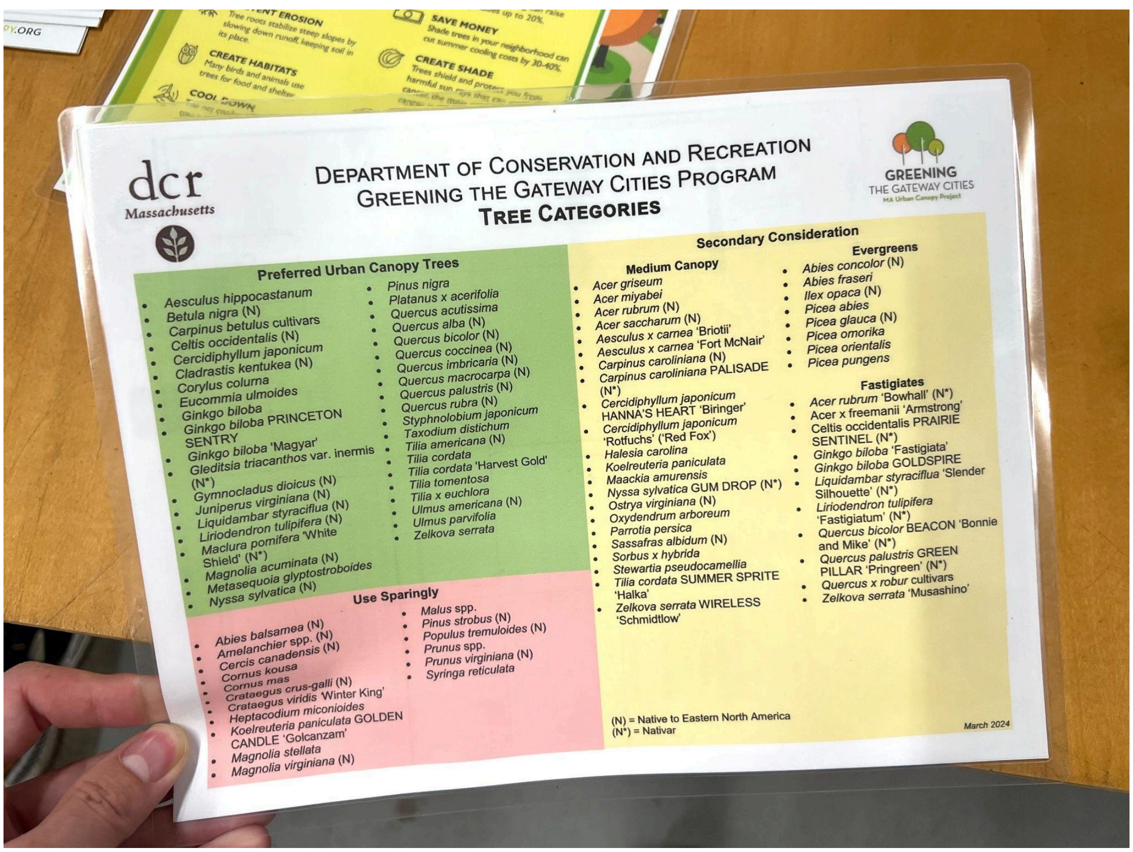

Figure 40. Image of DCR/GGCP tree categories (March 2024)

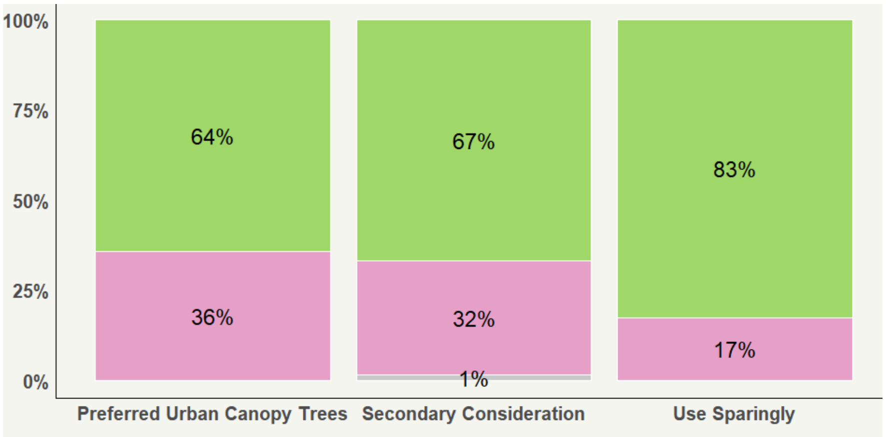

Figure 41. Barchart showing the difference in survivorship of Holyoke trees in the categories outlined in figure 40

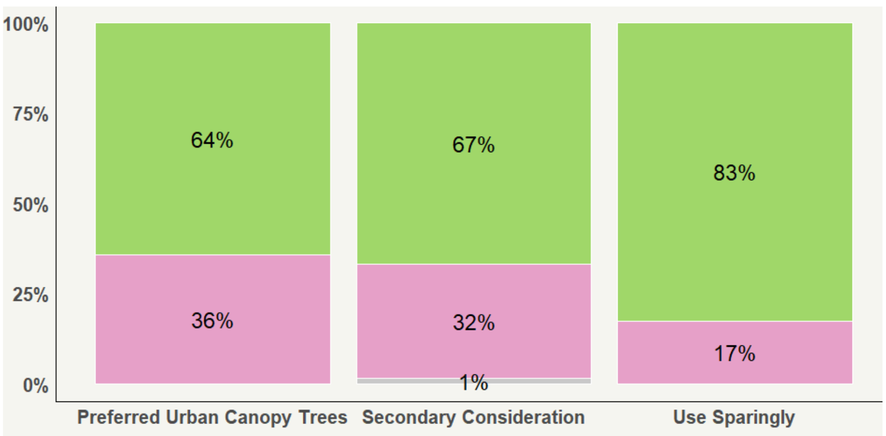

Figure 42. Barchart showing the difference in survivorship of Chelsea trees in the categories outlined in figure 40

Table 4. Table comparing survivorship between Total, Holyoke, and Chelsea

Top 6 Species	Overall Survivorship	Total Surveyed	Holyoke Surv.	Holyoke n	Chelsea Surv.	Chelsea n
Swamp White Oak	93%	59	94%	34	92%	25
Eastern Redbud	88%	88	91%	55	82%	33
Cherry Plum	82%	55	100%	9	78%	46
Pin Oak	82%	34	93%	15	74%	19
Apple	81%	118	79%	33	82%	85
Hybrid Oak	81%	42	NA	NA	81%	42

n=1566

Bottom 6 Species	Overall Survivorship	Total Surveyed	Holyoke Surv.	Holyoke n	Chelsea Surv.	Chelsea n
Tulip Tree	41%	90	38%	66	50%	24
Black Tupelo	42%	52	29%	35	71%	17
Kousa Dogwood	48%	48	80%	15	33%	33
Sugar Maple	53%	36	75%	16	35%	20
River Birch	54%	52	52%	31	57%	21
American Hornbeam	56%	99	91%	33	38%	66

5.4.4 Resurvey Summary

Between Chelsea and Holyoke, 1,114 trees from 86 species were resurveyed (Figure 43). In Holyoke 731 trees planted before 2017 distributed across 58 species were resurveyed (Figure 44). The most common tree species that were resurveyed were Tulip Tree (*Liriodendron tulipifera*), American Sweetgum (*Liquidambar styraciflua*), Apple (*Malus spp.*), Honeylocust (*Gleditsia triacanthos*), and Freeman Maple (*Acer x freemanii*) (Figure 44). Notable tree species with high survivorship include Cherry Plum (*Prunus cerasifera*), Honeylocust (*Gleditsia triacanthos*), Pin Oak (*Quercus palustris*), Green Hawthorn (*Crataegus viridis*), and Western Red Cedar (*Thuja plicata*) (Figure 46). Notable tree species with lower survivorship include Black Tupelo (*Nyssa sylvatica*), Ginkgo (*Ginkgo biloba*), Fraser Fir (*Abies fraseri*), River Birch (*Betula nigra*), and Tulip Tree (*Liriodendron tulipifera*) (Figure 46).

In Chelsea 385 trees planted before 2017 distributed across 57 species were resurveyed (Figure 45). The most common tree species that were resurveyed were Apple (*Malus spp.*), Freeman Maple (*Acer x freemanii*), European Hornbeam (*Carpinus betulus*), Dogwood (*Cornus*), and Honeylocust (*Gleditsia triacanthos*) (Figure 45). Notable tree species with high survivorship include Pin Oak (*Quercus palustris*) which had 100% Survivorship, Japanese Zelkova (*Zelkova serrata*), Japanese Tree Lilac (*Syringa reticulata*), Freeman Maple (*Acer x freemanii*), and Honeylocust (*Gleditsia triacanthos*) (Figure 47). Notable tree species with lower survivorship include Rutgers Hybrid Dogwood (*Cornus × rutgersensis*), Cornelian Cherry (*Cornus mas*), Dogwood (*Cornus*), Apple Serviceberry (*Amelanchier arborea*), and Downy Serviceberry (*Amelanchier arborea*) (Figure 47).

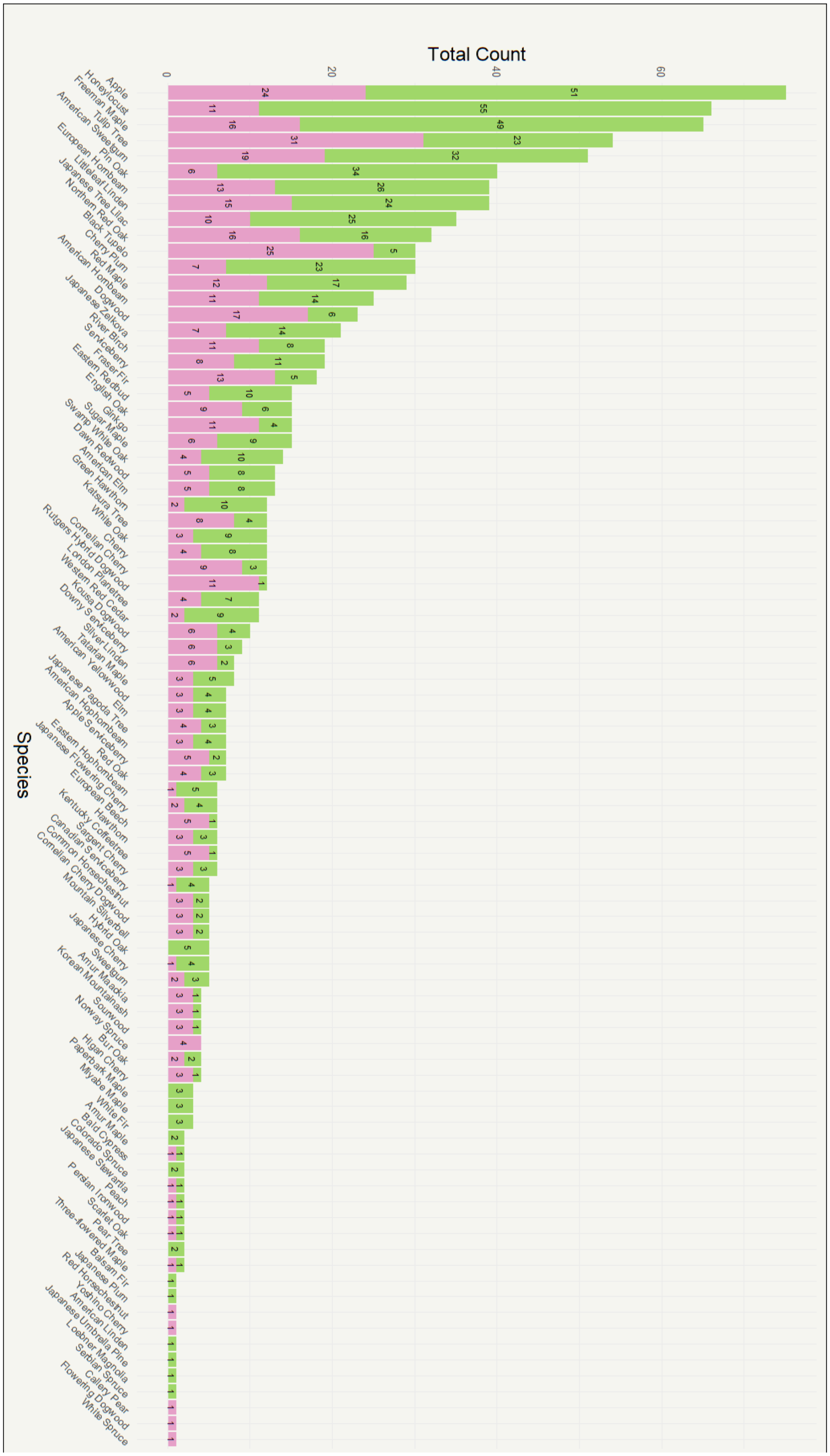

Figure 43. Resurvey species survivorship distribution

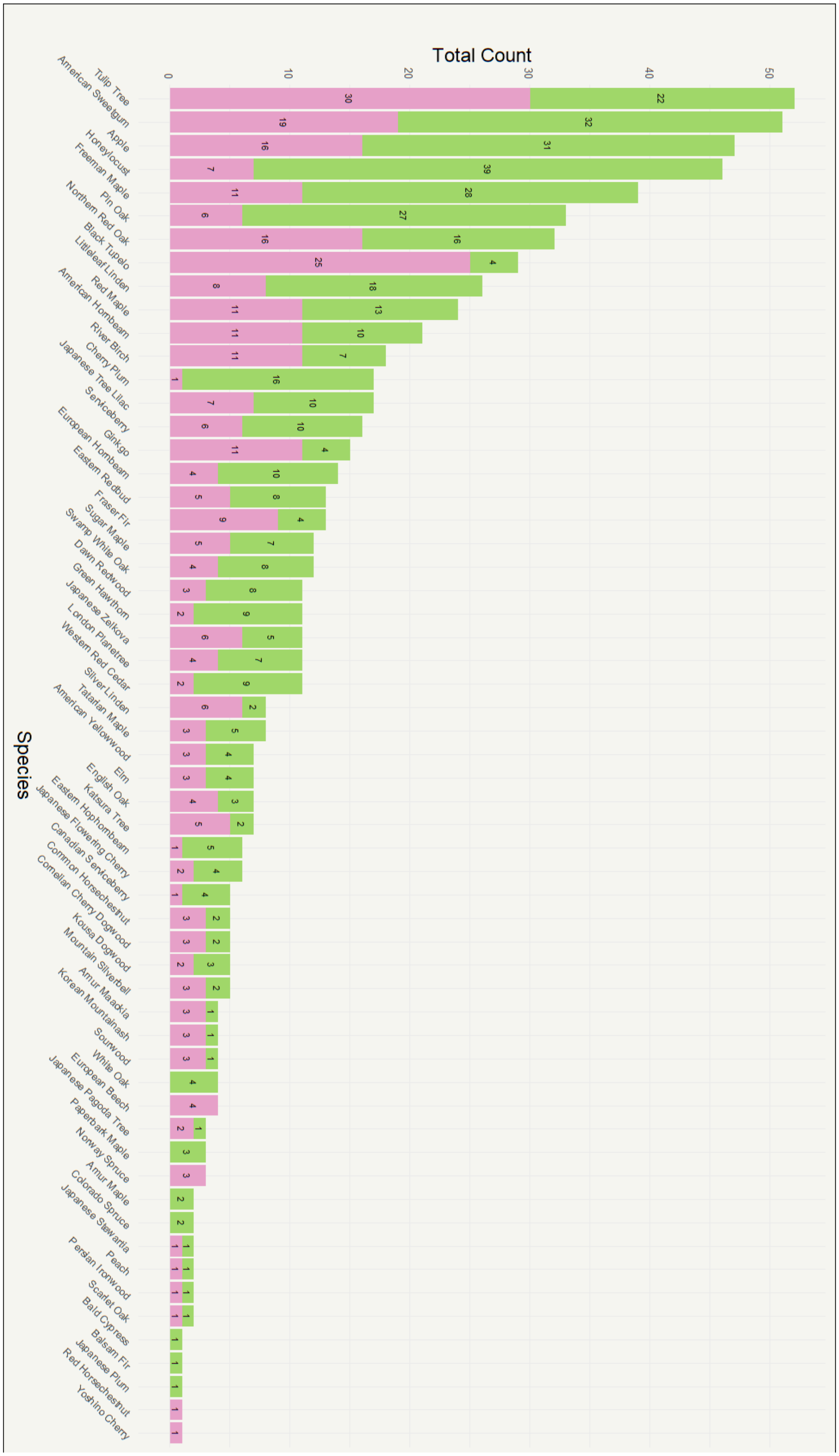

Figure 44. Holyoke resurvey species survivorship distribution

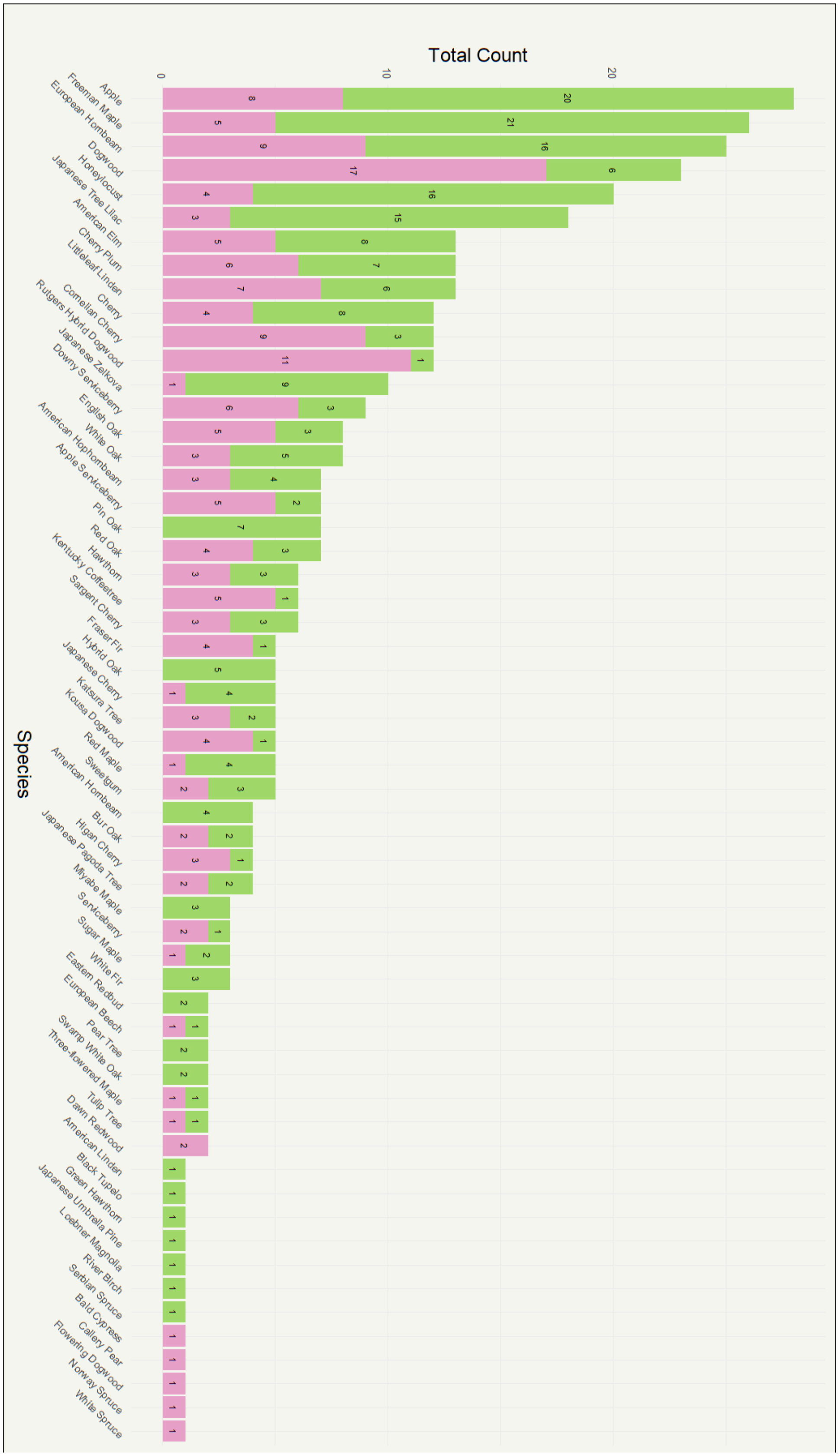

Figure 45. Chelsea resurvey species survivorship distribution

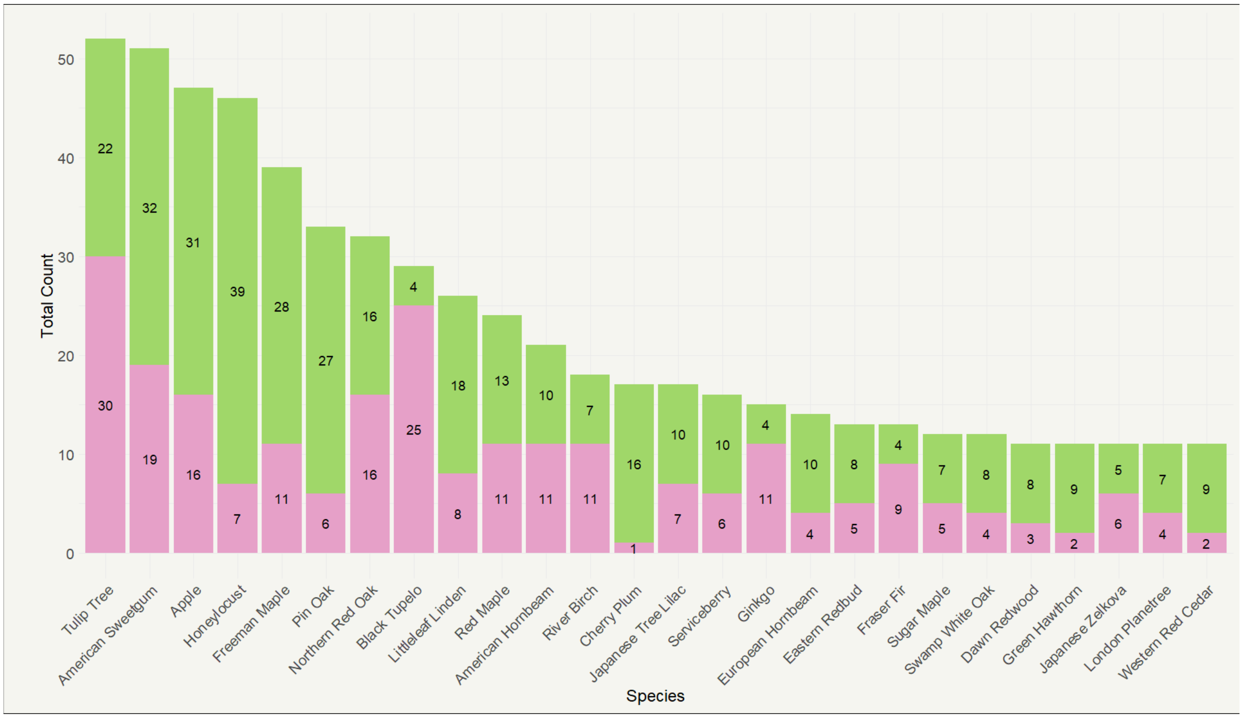

Figure 46. Holyoke resurvey species survivorship distribution showing species with 10 trees surveyed or more

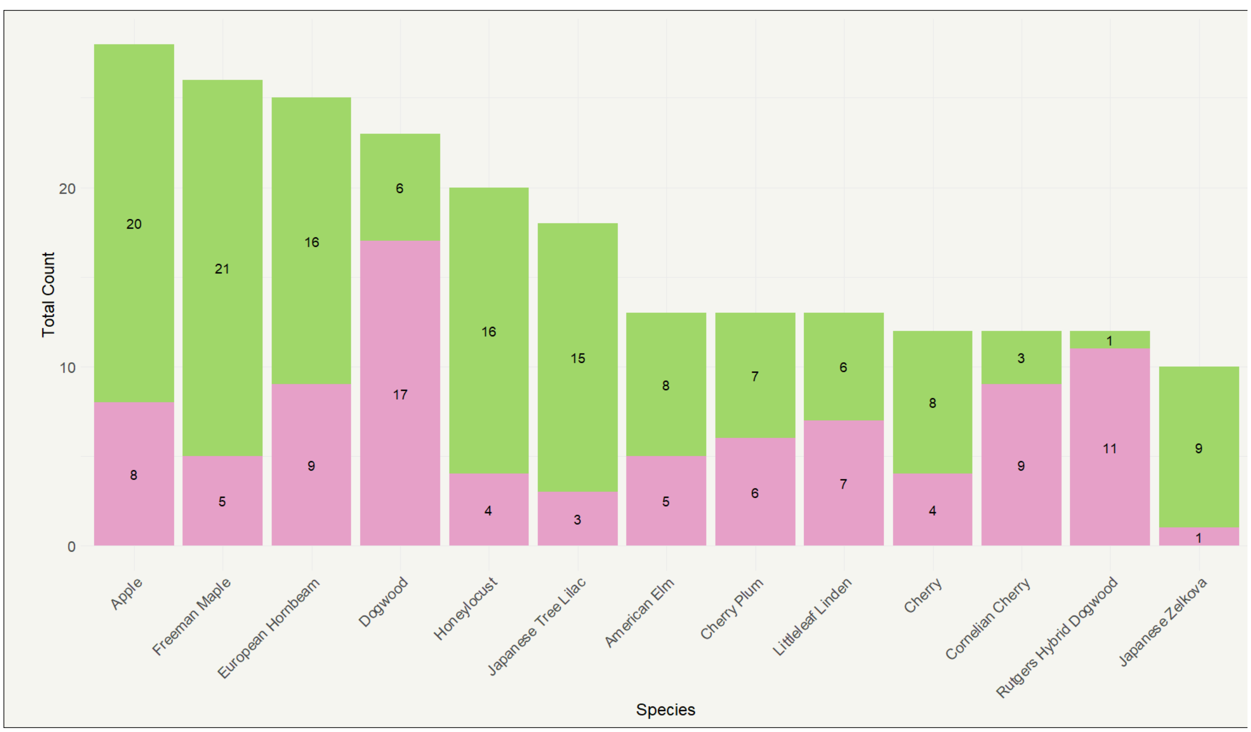

Figure 47. Chelsea resurvey species survivorship distribution showing species with 10 trees surveyed or more

5.4.5 Tree Species Growth

From the resurvey tree measurements we were able to do growth change analysis on trees that were alive when surveyed in 2017 and alive again when resurveyed in 2024. Tree growth analysis was done using genus as opposed to species to have larger counts and be able to generalize more. Measures analyzed were median DBH change from 2017 to 2024, median tree height change from 2017 to 2024, and median tree canopy width change from 2017 to 2024. These three measures were normalized on a 0-1 scale (0-100 for visualization purposes), and averaged to create a composite growth index. Genera that scored highest on the index and by proxy grew the most from 2017 to 2024 are Elms (*Ulmus*), Birches (*Betula*), Tulips (*Liriodendron*), and Oaks (*Quercus*) (Figure 48). Genera that scored lowest, and thereby grew the least were Lilacs (*Syringa*), and Dogwoods (*Cornus*) (Figure 48).

The growth index is designed to favor trees that are larger and that grow faster early in development. This is because we wanted to see which trees provided the most ecosystem services to their urban environments. In doing so we realized that in order for trees to provide ecosystem services they must also still be alive to do so. In order to add this aspect to analysis we created a new measure called the Succes Index which combines the Tree Growth index with tree genus survivorship (3(Growth index) +2(Survivorship)/5). Analysis results show that some Genera score similarly, and others score much higher or lower than on the growth index. Elms (*Ulmus*) and Birches (*Betula*) still score in the top two due to having a high growth index and above average survivorship (Figure 50). Other genera like Honey Locust (*Gleditsia*) scored much higher on the success index due to having very high survivorship (Figure 50).

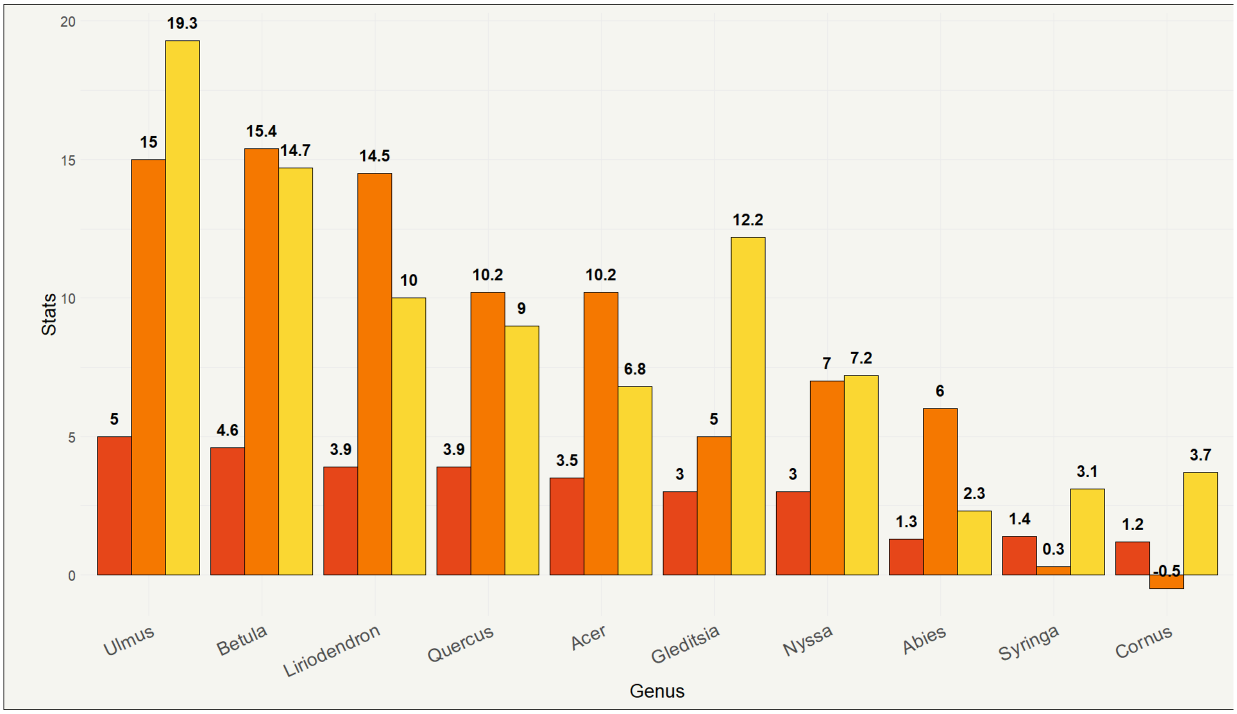

Figure 48. Barchart showing median change in growth measures from 2017 to 2024 for select genera. DBH - Red, Height - Orange, Tree Canopy Width - Yellow

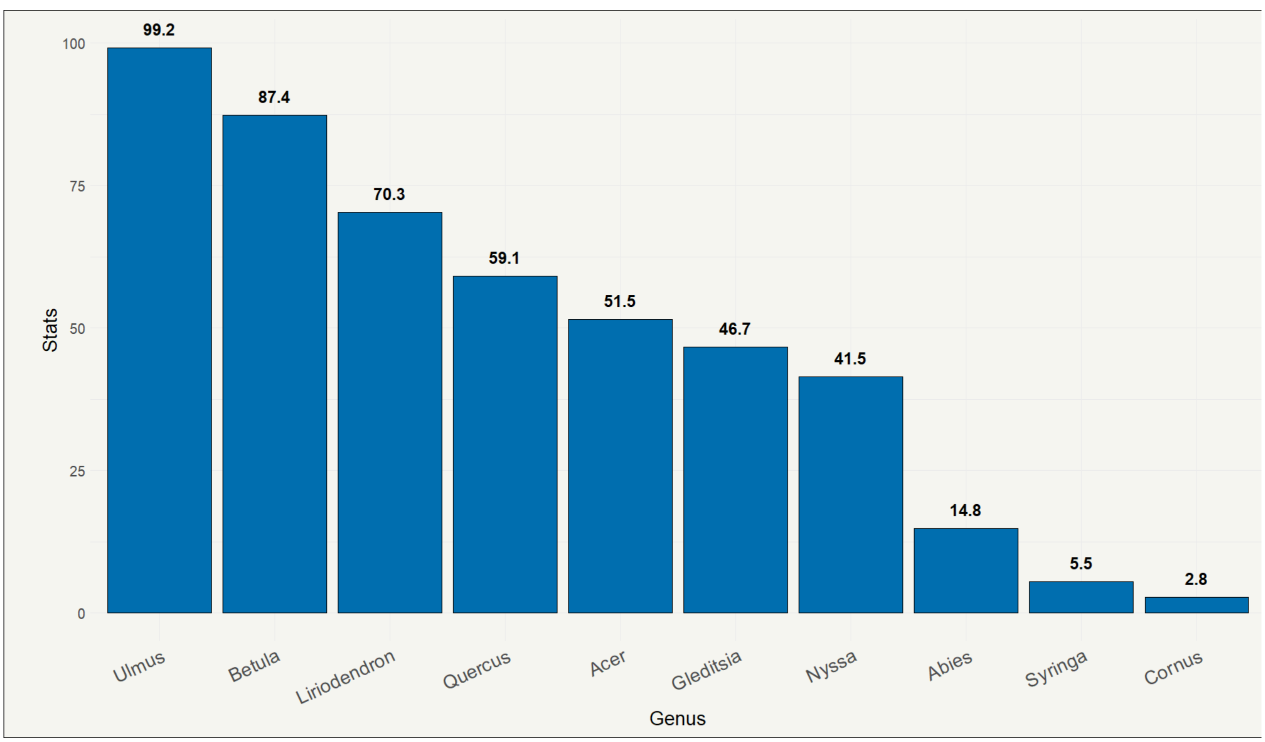

Figure 49. Barchart showing tree growth composite index

Table 5. Table showing genera and their success index scores compared with survivorship, growth index and count.

	Species	Success Index	Resurvey Survivorship	Growth Index	Count
Top 4	Elm	83.5	60%	99.2	12
Top 4	Birch	69.3	42%	87.4	7
Top 4	Oak	61.5	65%	59.1	84
Top 4	Honey Locust	61.3	83%	46.7	54
	Tulip	59.1	43%	70.3	22
	Maple	58.9	70%	51.1	84
	Sweetgum	56.0	63%	51.7	30
	Apple	41.4	68%	23.7	48
Bottom 4	Lilac	31.8	71%	5.5	24
Bottom 4	Tupelo	31.6	17%	41.5	5
Bottom 4	Fir	25.3	41%	14.8	5
Bottom 4	Dogwood	11.8	25%	2.8	16

5.5 Ecosystem Services

We analyzed the ecosystem services provided by the private trees within the study area using iTree Eco v6. The following parameters were used as inputs: species, DBH, total tree height, distance to nearest building, and direction from nearest building.

In Holyoke a total of 533 trees were included in this calculation. Only trees for which all above metrics were recorded were included in the calculation of ecosystem services, therefore our findings do not fully represent the ecosystem services provided by the entire sample. Distance from and direction to nearest building were calculated in ArcGIS Pro 3.1.2, and the building layer was sourced from MassGIS. Trees in Holyoke provided $2,683 worth of ecosystem services annually. The other annual ecosystem services and amounts are as follows: producing 2.66 tons of oxygen to the atmosphere, sequestering 2.0 tons of carbon, removing 32 pounds of air pollution, and preventing runoff of 13,290 gallons of water. In addition to this, these trees had a combined replacement value of $158,000.

In Chelsea a total of 760 trees were included in this calculation. The same methods were used as in Holyoke. Trees in Chelsea provided $6,226 worth of ecosystem services annually. The other annual ecosystem services and amounts are as follows: producing 6.31 tons of oxygen to the atmosphere, sequestering 2.4 tons of carbon, removing 12 pounds of air pollution, and preventing runoff of 21,910 gallons of water. In addition to this, these trees had a combined replacement value of $255,000.

6 Social Analysis Results

6.1 Sample Population

In Holyoke the interviews conducted were distributed throughout the study area. At least 1 interview was conducted in each of the 4 different environmental justice criteria areas (Figure 50). There were 67 trees associated with interviews and 77.6% of those trees were in the sample. The survivorship of these trees was 82.6%, about 10% higher than the average for the city. Interviewees had an average of 3 trees per property. Trees were a mix of "public" and "private" because some trees were public but stewarded by residents. Table 6 shows the demographic statistics of the interviewees in Holyoke compared to the statistics for the city at large. Interviewees could opt out of any questions they did not wish to answer. The summary includes statistics only of interviewees that responded. About 0.06% of the population was surveyed. Several of the demographics of interviewees were not representative of the city at large, (Median Age, Bachelor's Degree, Percent Renter, Percent Hispanic), but they are probably representative of tree recipients in the GGCP in Holyoke.

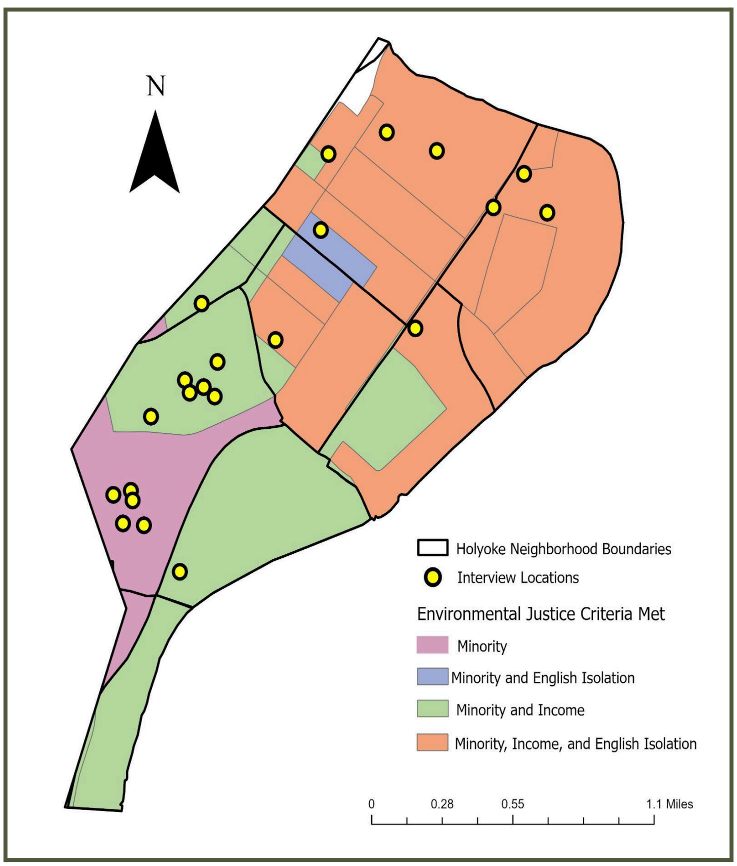

Figure 50. Interview Locations and Environmental Justice Criteria Areas

Table 6. Demographic Statistics of Holyoke at Large and Residents Interviewed

Demographics	Holyoke	Interviewees
Population	37,628	22
Median Age	37.5	55-64
Bachelor’s Degree	22.20%	47.62%
% Renters	58.50%	4.76%
Percent Hispanic	51.70%	23.53%
Percent White	67.50%	70.59%
Median Household Income	$49,007	$75,000-$99,999
English Only Household	57.30%	60%

In Chelsea the interviews conducted were distributed throughout the study area. At least 1 interview was conducted in each of the 4 different environmental justice criteria areas (Figure 51). There were 49 trees associated with interviews and 73.5% of those trees were in the sample. The survivorship of these trees was 86.1%, about 20% higher than the average for the city. Interviewees had an average of 3 trees per property. Trees were a mix of “public” and “private” because some trees were public but stewarded by residents. Table 7 shows the demographic statistics of the interviewees in Chelsea compared to the statistics for the city at large. Interviewees could opt out of any questions they did not wish to answer. The summary includes statistics only of interviewees that responded. About 0.05% of the population was surveyed. All of the demographics of interviewees were not representative of the city at large, but they are probably representative of tree recipients in the GGCP in Chelsea.

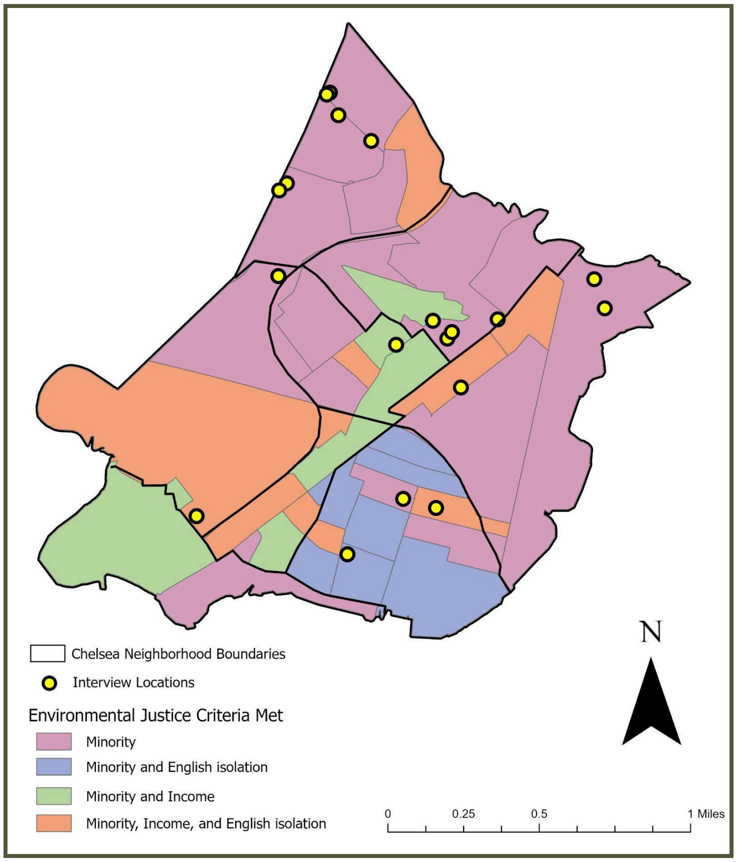

Figure 51: Chelsea Interview Locations and Environmental Justice Criteria Areas

Table 7. Demographic Statistics of Chelsea at Large and Residents Interviewed

Demographics	Chelsea	Interviewees
Population	40,787	19
Median Age	34.5	65+
Bachelor's Degree	21.60%	55.56%
% Renters	72.10%	5.56%
Percent Hispanic	67.40%	22.22%
Percent White	33.90%	72.22%
Median Household Income	$71,051	$100,000-$149,999
English Only Household	29.00%	61.11%

All 41 interviews were analyzed together for this report. There were 124 trees associated with interviews and about 70% were part of the surveyed sample. The average survivorship of these trees was 84%, about 15% higher than the overall average for both cities.

6.2 Resident Perceptions

6.2.1 Resident Perceived Tree Benefits

Residents were asked about the benefits of trees on their property and in general, and throughout their responses 19 key benefits were identified (Figure 52). The notable top 5 were aesthetics (70%), shade (65%), air quality (57.5%), temperature (47.5%), and mental health (30%). Responses discussed how aesthetic benefits help cultivate a homey and beautiful space to live in that also increases property value and perceptions of their neighborhoods and respective cities. There was a significant trend in resident responses that drew out the environmental benefits of trees such as a decrease in temperatures, more shade, air that is fresh and clean, better drainage of rainwater, and less noise pollution.

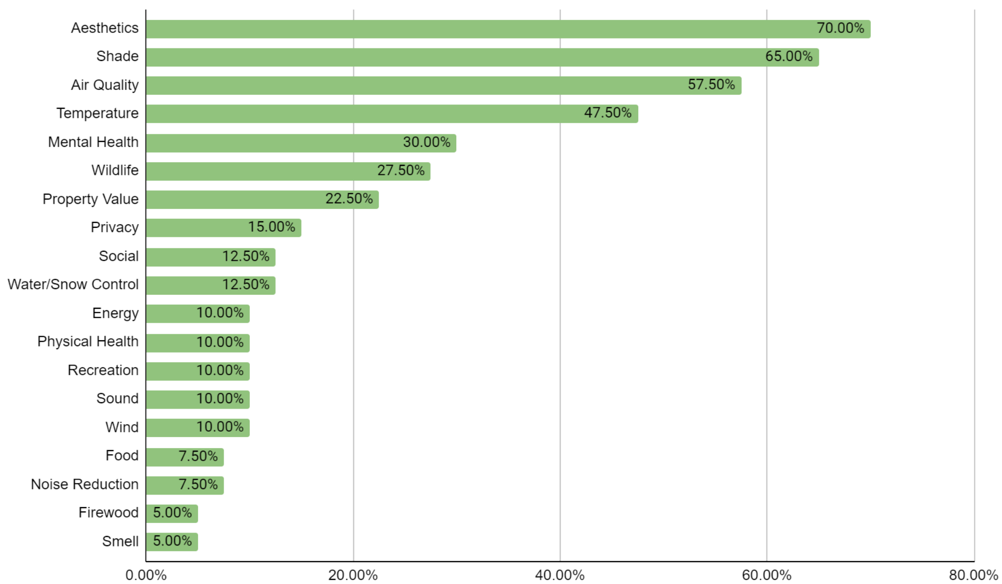

Figure 52. Resident perceptions of tree benefits and the percentage of residents that noted these benefits out of our resident responses

6.2.2 Resident Perceived Tree Challenges

Residents were also asked about the challenges they experience in terms of trees in their property or neighborhood (Figure 53). The challenges most frequently reported were maintenance (56.1%), hazards and damages (39%), tree size (24.4%), and clean up due to leaves and branches falling (21.9%). Another notable challenge that respondents gave was not having enough space for trees (12.2%), even though they would in theory want more trees on their property. This is not so much a challenge that trees bring, but a challenge when trying to obtain more trees. Residents who are homeowners especially note the challenges regarding their property and damages that a tree could contribute to.

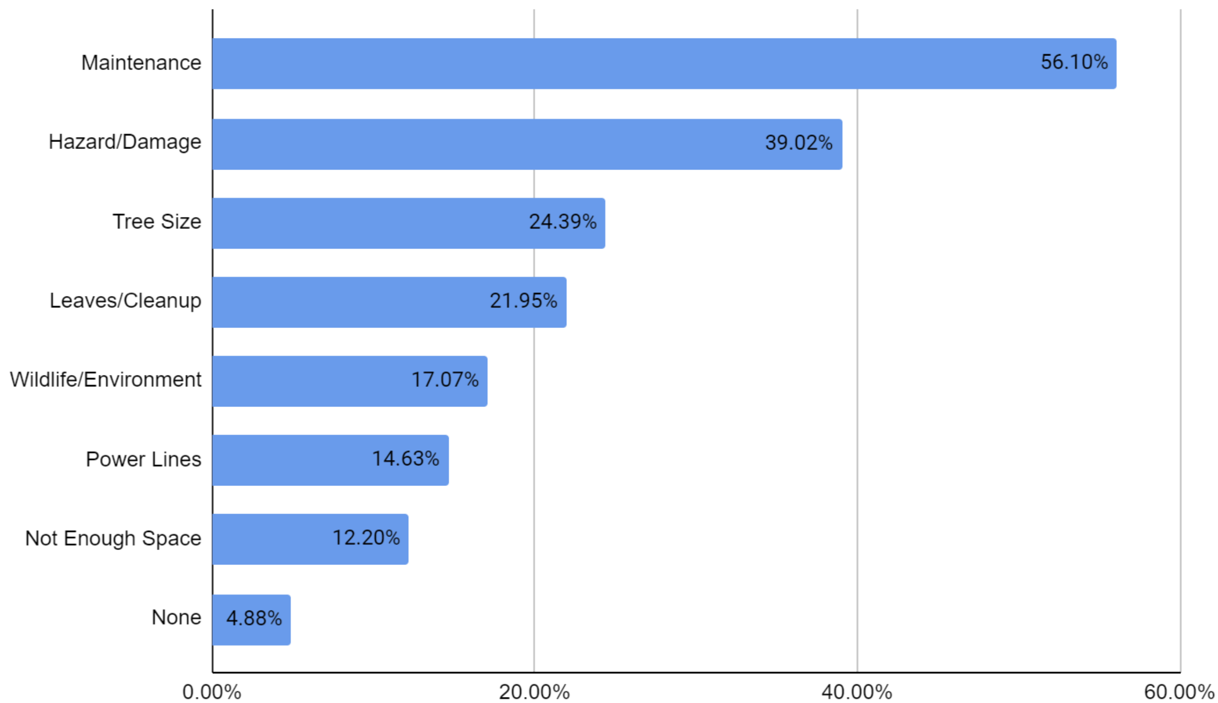

Figure 53. Resident perceptions of tree challenges and the percentage of residents that noted these challenges out of our resident responses

6.2.3 Resident Tree Maintenance

Residents were asked if and how they maintained trees on their property. 97.6% of respondents said they do some form of maintenance for their trees. 6 types of maintenance were identified by the residents with the three most common being watering (73.2% of residents), pruning (56.1% of residents), and mulching (31.7% of residents).

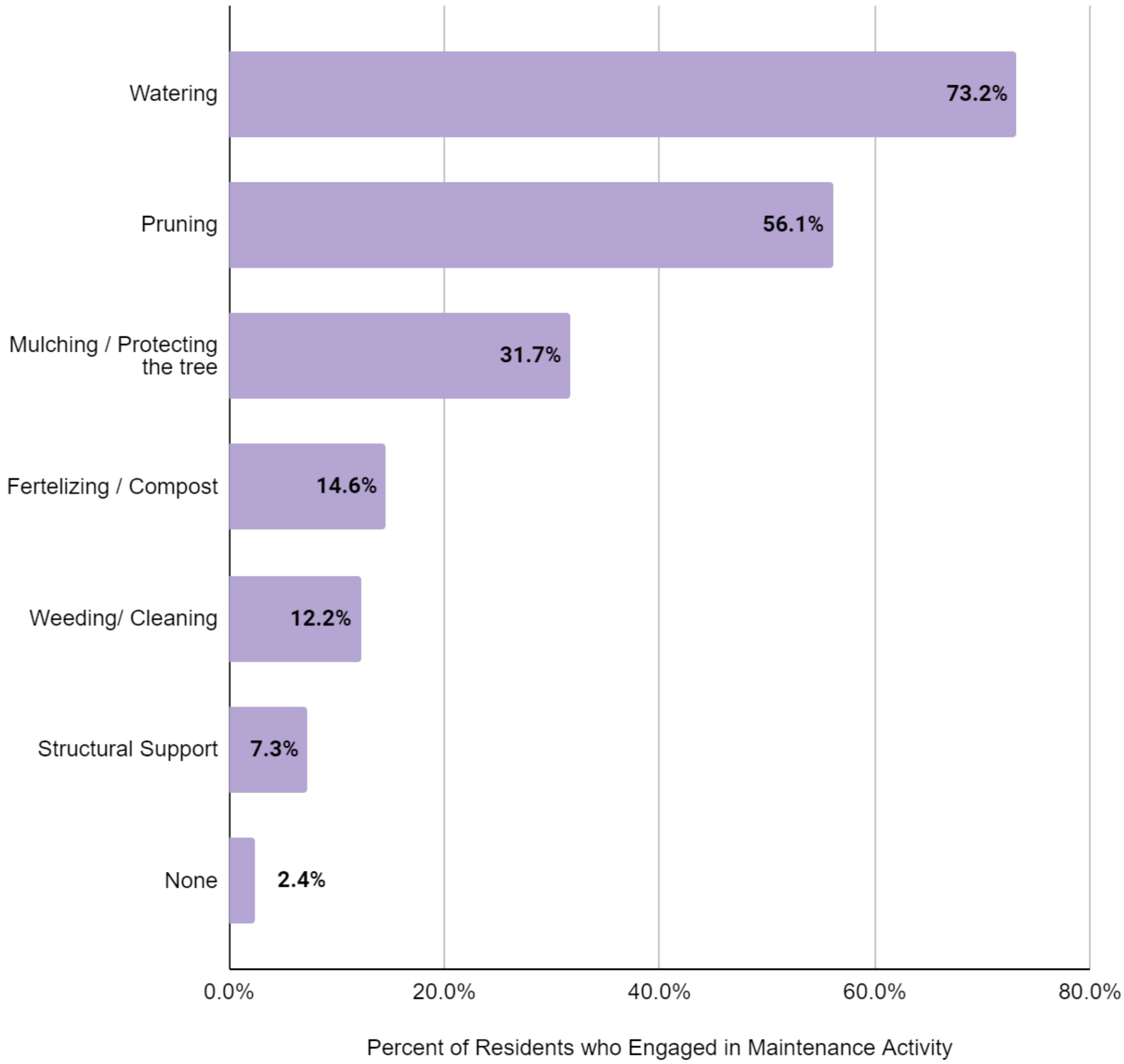

Figure 54. Percentage of surveyed residents who engaged in maintenance activity

6.2.4 Resident Perceptions of Yards and Outdoor Space

When interviewed residents were asked about where they usually spend their time outside, 71% responded with their yards or other spaces on their property while 22% responded with only public green space. When residents were asked if the outdoor spaces in which they spend time adequately serve their needs, 92% of respondents said yes except when asked about the number of trees in their neighborhood, with 80% of residents saying they would like to see more trees planted. When asked about their perceptions of public parks and green space in their cities, however, there was general dissatisfaction, with residents saying there are not enough suitable outdoor spaces close by and that they are often not well maintained.

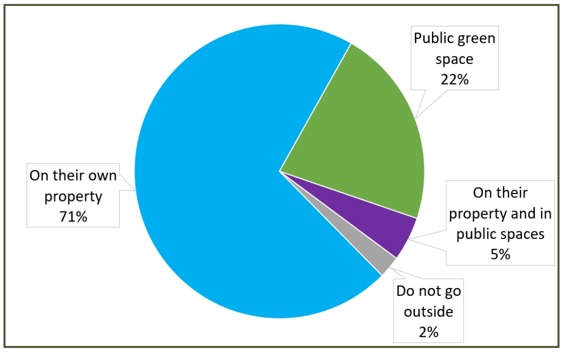

Figure 55. Spaces where residents spend their time outside

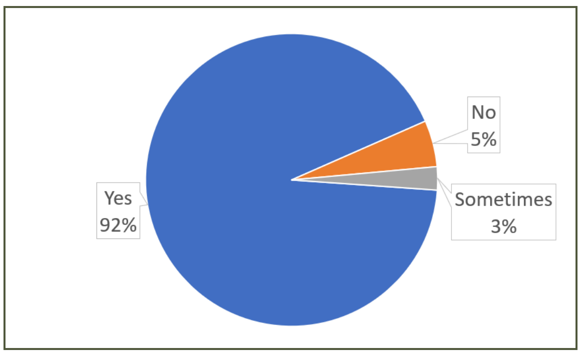

Figure 56. Outdoor spaces serving resident needs

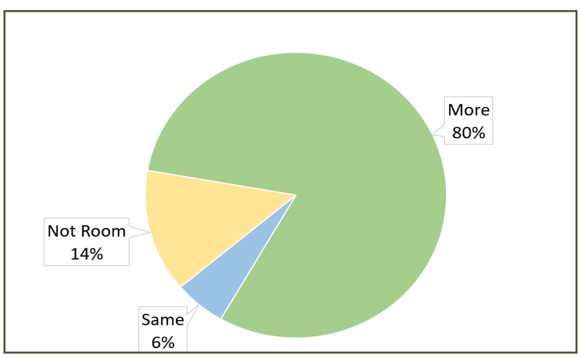

Figure 57. Resident opinions on the number of trees in their neighborhoods

6.2.5 Residents Feeling Heard in Decision Making Around Trees and Outdoor Space

When residents from both cities were asked whether or not they felt heard in decision making processes surrounding outdoor spaces and trees in their communities, 30.5% said they did, 47% said they did not, 5% responded with neutrality, and 25% said they do not try to participate in those processes. In Holyoke 20% of residents felt heard and 50% did not, while in

Chelsea it more evenly split, with 44% saying yes and 44% saying no. When asked about existing community engagement in Chelsea surrounding outdoor space, many residents referred to the Chelsea Tree Board as an example of the city listening to its residents.

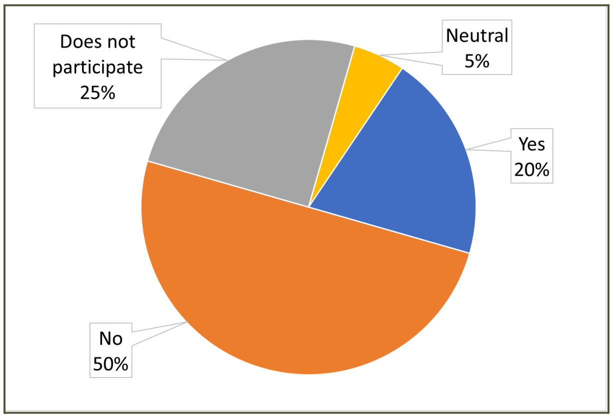

Figure 58. Residents feeling heard in decision making around trees and outdoor space in Holyoke

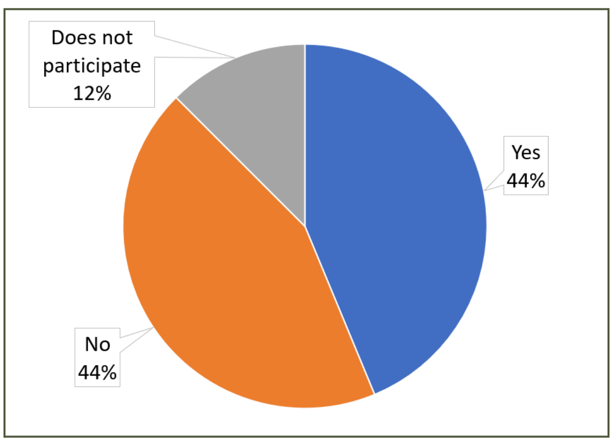

Figure 59. Residents feeling heard in decision making around trees and outdoor space in Chelsea

6.2.6 Outreach to Residents by the GGCP

Residents were asked to recall how they originally heard about the GGCP. The majority of residents heard about the program directly from the DCR either through receiving information in the mail/door hanger or by speaking with someone directly from the DCR (likely because of door-to-door canvassing efforts).

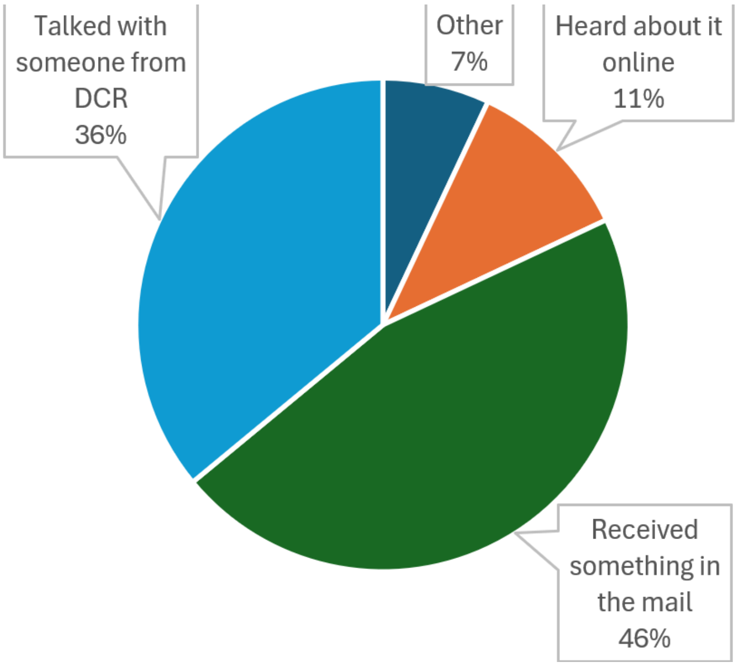

Figure 60. Resident responses to how they heard about the GGCP

6.2.7 Resident Roles in the GGCP

Residents were asked a series of questions about their participation in the GGCP to assess what role they were playing in the program. Table 8 shows a summary of questions related to tree choice at planting and resident responses. 100% and 95% of respondents chose the location and species of their trees, respectively. Only 77.5% said they received the tree species that they originally requested. Residents were also asked whether or not they communicated about the GGCP. 75% of interviewed residents spoke about the GGCP to others with 51% of the residents speaking about the program with neighbors.

Table 8. Tree choice questions asked to residents and percentage of responses

Did you get to choose the location of your tree(s)?	**Percentage of Residents**
Yes	*100%*
No	*0%*
Did you get to choose the species of your tree(s)?	
Yes	*95.00%*
No	*5.00%*
Did you get the tree species you originally requested?	
Yes	*77.50%*
No	*17.50%*
I don't know	*2.50%*

6.2.8 Resident Experience with the GGCP

Residents were asked to rate their experience with the GGCP on a scale from 1 through 10 (with 10 being the best). On average residents rated their experience as a 9.3. 67% of residents rated their experience as a 10 and no residents rated their experience below a 5 (Figure 61). The lower ratings given by interviewees can be largely attributed to residents experiencing more drastic tree growth than they were expecting, with some respondents saying they had been told by the DCR that their trees would be smaller and expressing concern over the size of their trees and potential damage to their properties that they could create.

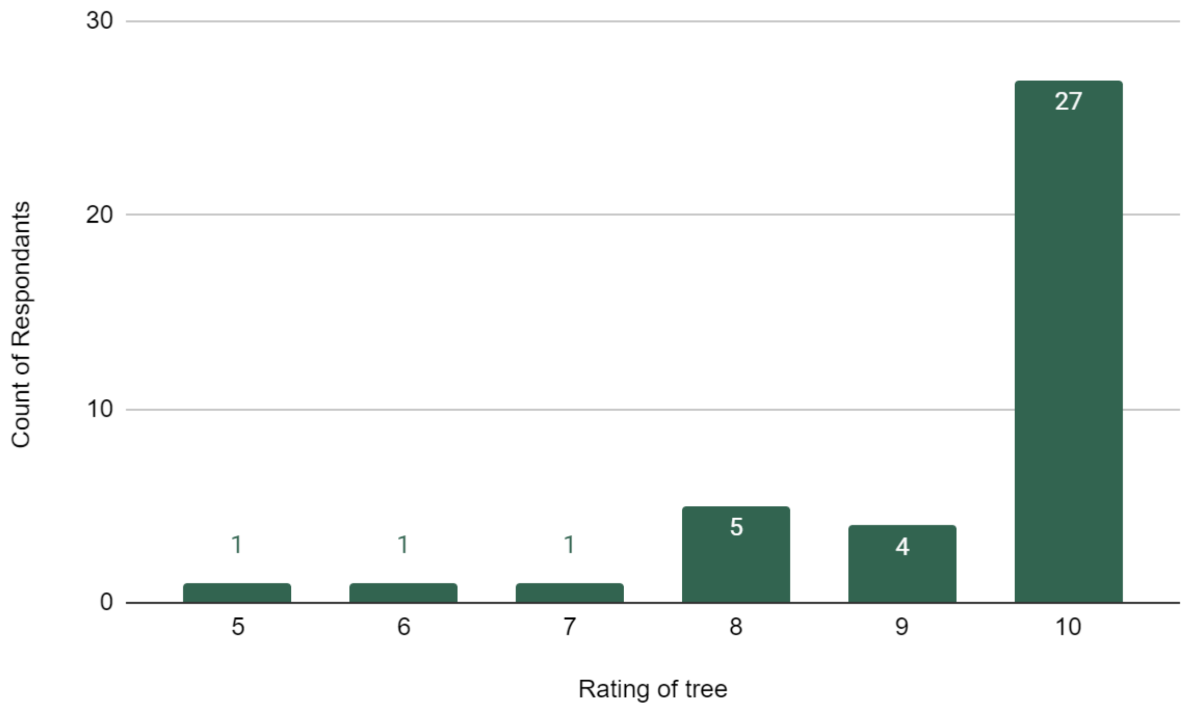

Figure 61. Count of resident ratings of the GGCP

6.3 Community Partners

6.3.1 Creating and Maintaining Good Partnerships

When asking both DCR foresters and community partners about what they feel is necessary when creating and maintaining good partnerships, both groups highlighted sustaining good communication and having aligning goals and strategies as being instrumental. Community partners brought attention to the importance of transparent communication and awareness of other partners' needs and abilities, and both community partners and foresters stressed the value of setting up consistent meetings and keeping each other updated with what they are doing and what needs they have. Community partners seemed willing and ready to take on more active roles not just in conceptual work, but also on the ground with tree planting and outreach, as long as the DCR is willing to listen to them about what they actually have capacity for. They also want the DCR to meet them with realistic goals and expectations based on what their abilities are at that time.

Figure 62. Conceptual diagram best practices for establishing relationships between community partners and DCR foresters

6.3.2 DCR Challenges in Resident Outreach

When speaking to DCR foresters about challenges they face when it comes to community outreach, there were three very clear categories of challenges: language barriers, messaging, and marketing. Foresters said that they are heavily lacking in resources surrounding live translation, and have been struggling with communicating with those communities when it comes to in person conversations. This challenge appeared to not only impact individual resident participation, but also affect which areas they are able to plant trees on private properties more largely in both cities. The foresters we interviewed also brought up concerns surrounding outreach and marketing, saying that while many residents are aware that trees are being planted, there is a general lack of awareness about who is planting them, what the GGCP is, and how residents can involve themselves. These challenges were also mentioned as being deeply related to the perceived language barrier existing with Spanish speaking communities.

Figure 63. Conceptual diagram of outreach challenges, including language barrier, messaging, and marketing

6.3.3 Community Partnership Benefits

Community partners expressed that there have been several benefits of collaboration since the establishment of the program. Benefits have been separated into three categories to address local organizations', city officials', and DCR foresters' respective perceived benefits of their partnerships with one another. Themes were also assigned to these benefits: Explore and Outreach (E&O), Income (I), Language Bridge (LB) and Equitable Tree Planting (ETB). Local organizations noted that the GGCP has provided residents with additional avenues to provide extra income and build relationships with neighbors (I). One organization claimed that the GGCP helped them gain more exposure in the DCR and their city while another discussed the importance of combining outreach opportunities with other community groups (E&O). One city official claimed that the GGCP "has helped put front and center the role that tree planting plays in environmental justice", while another credited the tree planting program with providing valuable tools and resources for more people (ETP). Finally, DCR employees regularly mentioned how active local organizations have been in outreach, including bridging language barriers. One forester stated, "[a community partner] helped us get in with the Spanish speaking community…. We used them a lot during our site visits to just connect through the language barrier" (LB).

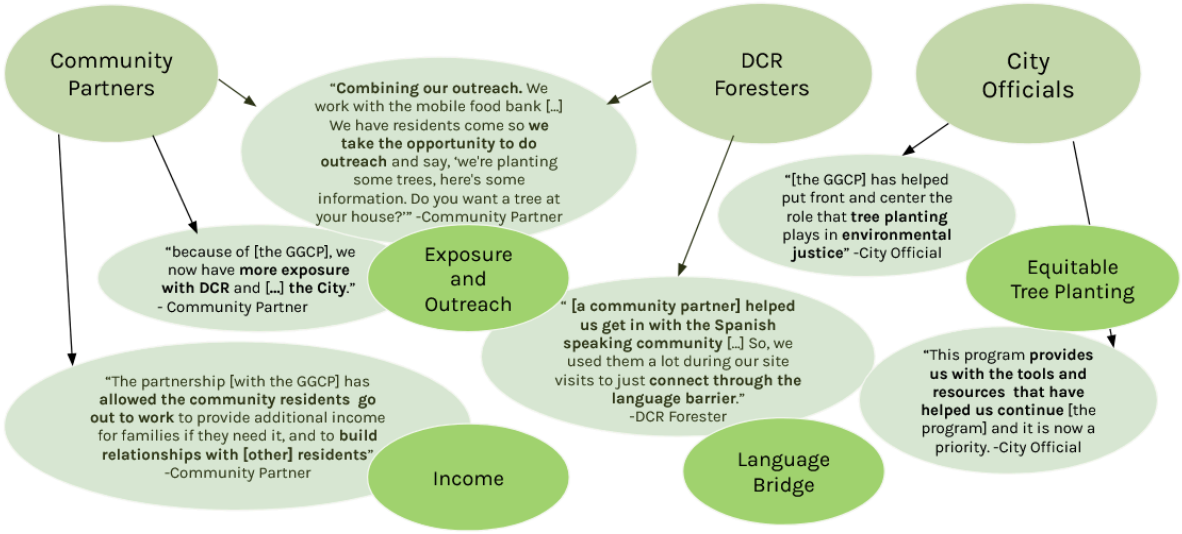

Figure 64. Conceptual diagram of benefits gained by community partners, DCR foresters, and city officials through collaboration. Benefits include exposure and outreach, income, language bridge, and equitable tree planting.

6.3.4 Community Partner Perceptions of Tree Planting and Maintenance Challenges

We found varying levels of distinction between residents' and community partners' perceptions of tree challenges. Overall, residents were more concerned with maintenance, hazards and cleanup, while community partners viewed wildlife and a lack of space as primary challenges. Tree size was a concern of similar proportion for both groups. Residents often felt unprepared for their trees to grow as tall as they did and the ensuing maintenance. This misunderstanding is among the reasons why community partners are seeking to improve outreach initiatives. This concern about tree size intersects with community partners and residents' worries about power lines, as trees often interfere and have their growth impacted by overhead cables. This is a threat to surrounding infrastructure and people as well as to trees, as they may be deemed hazardous and therefore reduced in size or even removed.

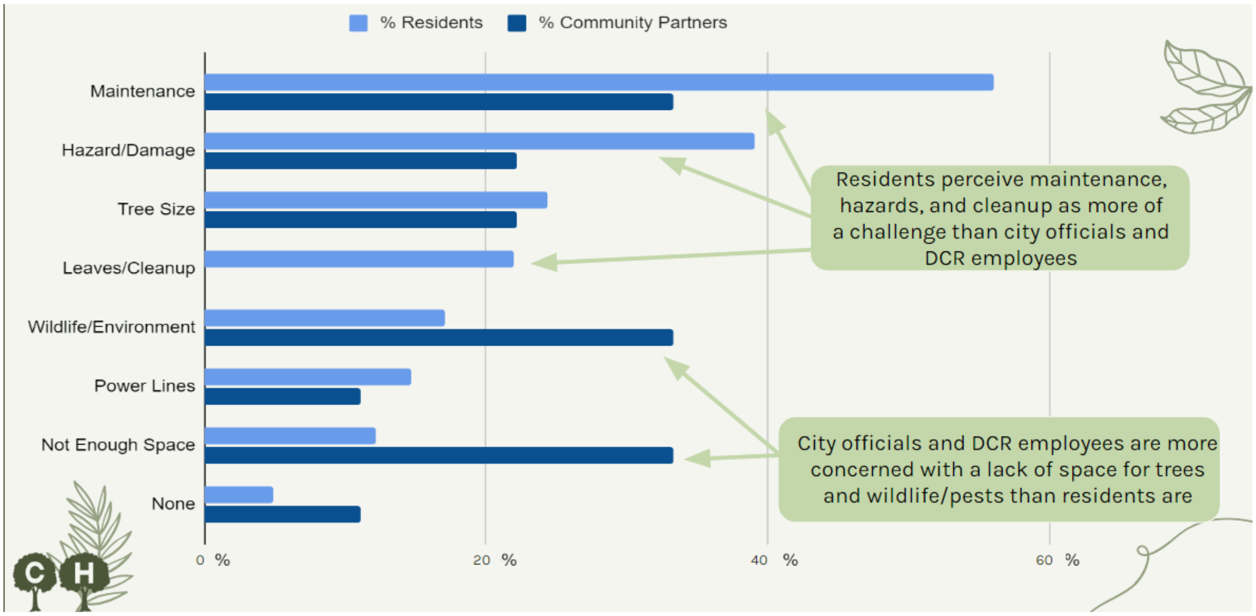

Figure 65. Resident and Community Partner Tree Challenges Comparison

7 Other Analysis

7.1 Priority Areas

We were interested in identifying which areas in our study area cities are most in need of additional tree planting

The imagery obtained in the previous section was imported into ArcGIS Pro, and converted into points using the 'raster to point' tool. The 'optimized hot spot analysis' tool, based on the Getis-Ord Gi* hot spot statistic, was used. A 95% confidence interval was used to identify hot spots of high temperature and low vegetation. The resulting layers were converted to rasters and then vectors for visualization purposes, applying polygon smoothing. Areas that overlapped as having high temperatures and low vegetation were designated as priority areas.

High temperature hot spots and low vegetation hotspots were concentrated in the northeast region of Holyoke, in the Flats, South Holyoke, Downtown, and Churchill neighborhoods. In Chelsea, these hot spots were broadly distributed, and priority areas were concentrated in the west of the city, in the Everett Avenue Area and City Center neighborhoods (Figure 66).

In Holyoke, most of the high priority areas were in commercial or industrial areas, but some had residential land use as well (Figure 74). In Chelsea, most of the high priority areas were in commercial areas, but some were in residential areas as well (Figure 68).

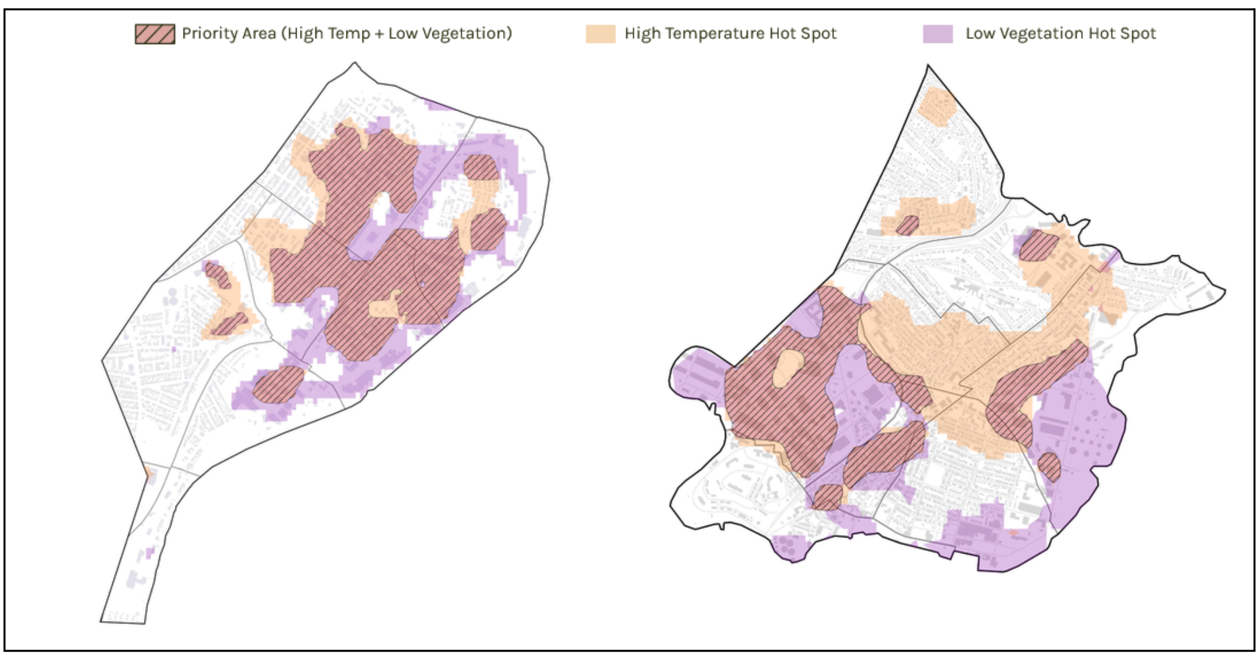

Figure 66. Holyoke and Chelsea study areas with high temperature hot spots, low vegetation hot spots, and the overlap, defined as priority areas

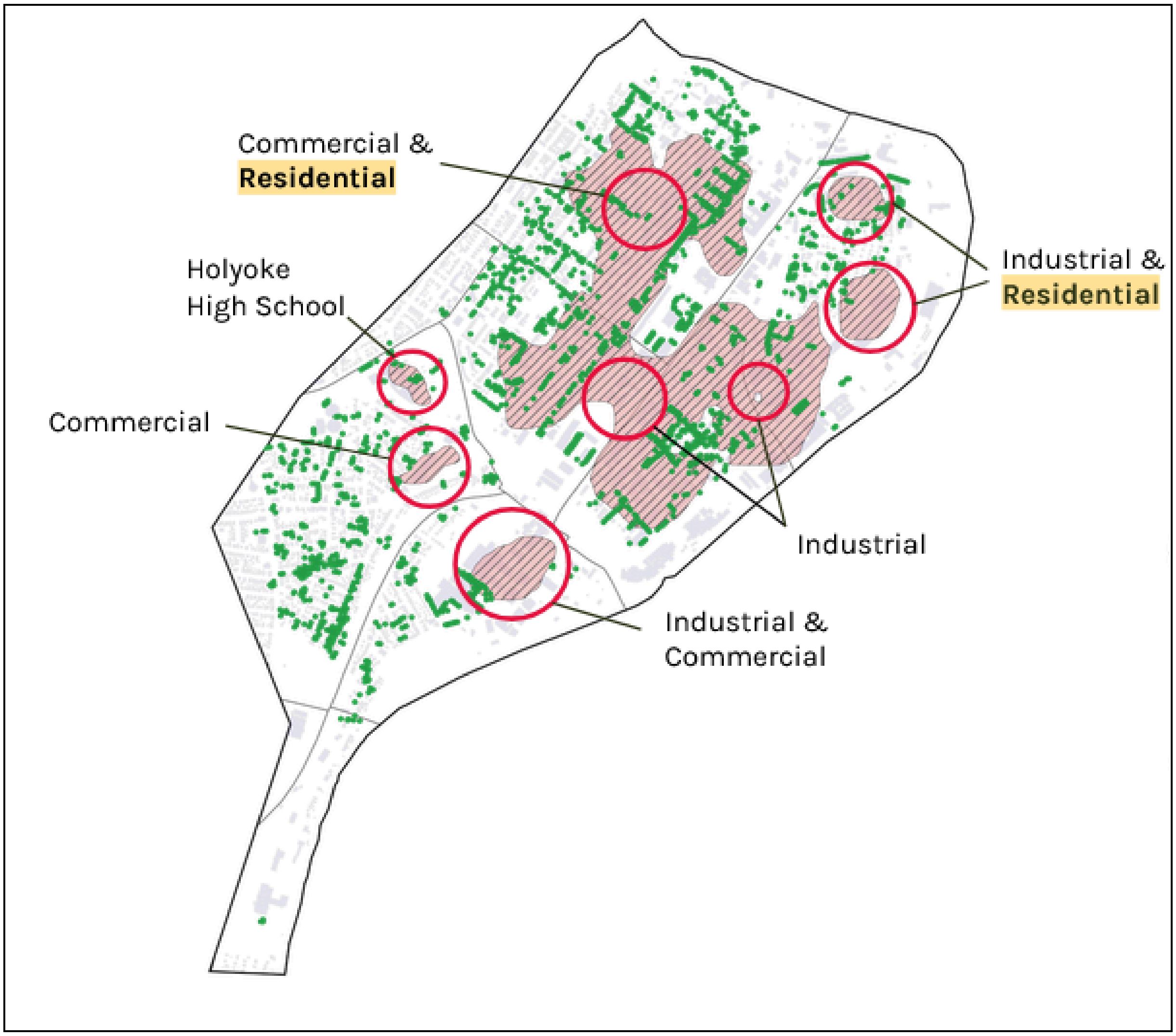

Figure 67. Priority planting areas with GGCP trees planted, showing land uses in priority areas

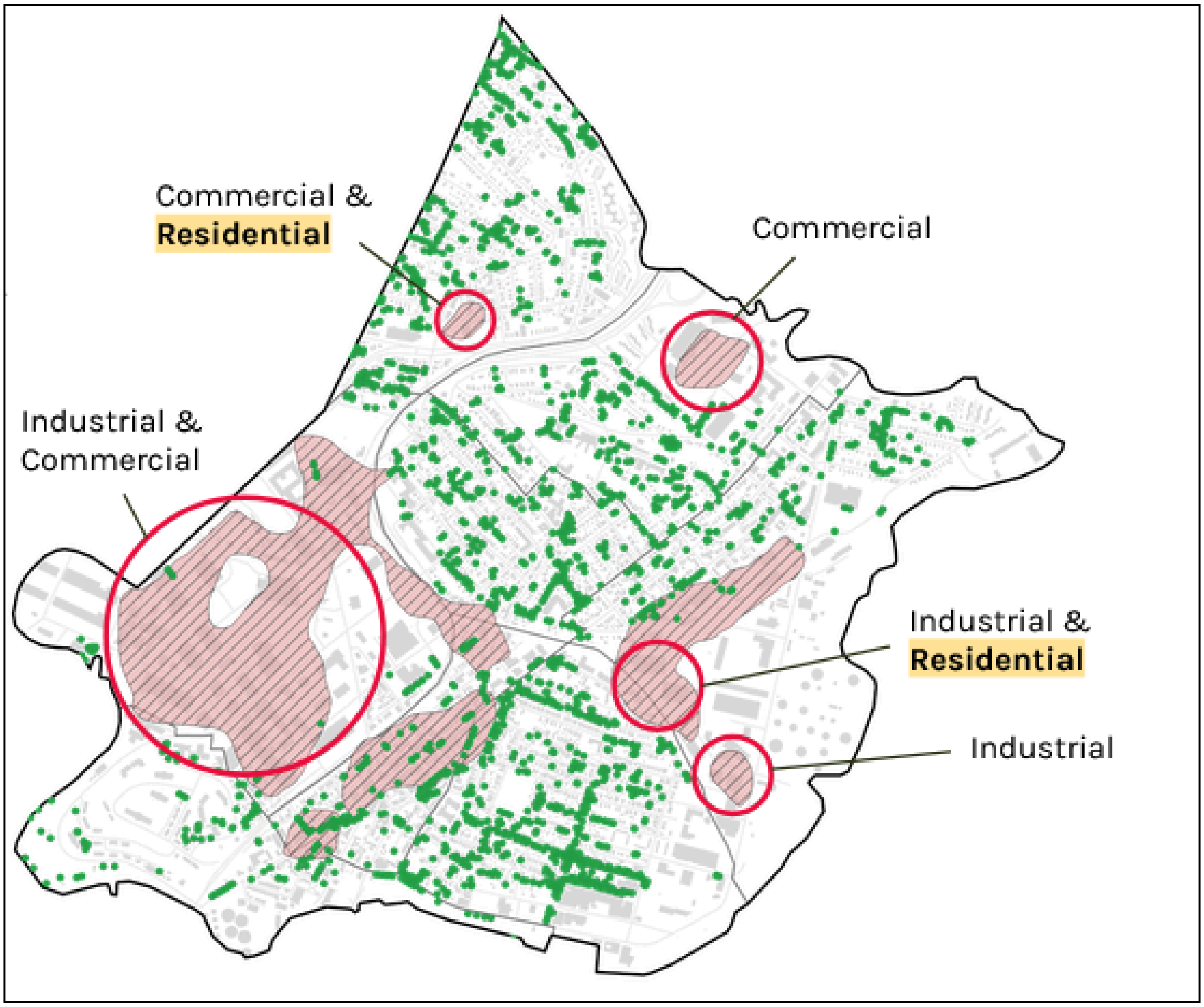

Figure 68. Priority planting areas with GGCP trees planted, showing land uses in priority areas

8 Discussion

The annual survivorship for holyoke of post-establishment trees (93.8%) is below the national median of 96.7%. However, the survivorship of establishment trees (95.3%) is higher than the national median of 93.2%. This is atypical, as generally annual survivorship increases as tree cohorts age (Hilbert et al. 2019). The unusually high annual survivorship in the past 5 years in Holyoke is likely due to increased standards in tree sighting, planting, and tree choice, as well as implementation grants, which have been used to clear compacted and poor quality soils from tree planting sites (DCR, personal communication).

Annual survivorship of trees in Chelsea shows a similar pattern as the national averages. Post-establishment annual survivorship is 94.2% and establishment annual survivorship is 90.9%. These are both well below the national median, which could be due Chelsea's nature as a highly urban city. Post-establishment annual survivorship in Chelsea is higher than that in Holyoke, indicating that tree planting in the early years of GGCP (2014-2018) in Chelsea were more successful than those in Holyoke.

In our assessment of Holyoke and Chelsea GGCP tree recipient's actions, we found that 75% of tree recipients communicated about the program to others and 100% negotiated for the location or species of tree. These findings differ from previous research. In a study of Leominster, Pittsfield, Fall River, and Chicopee, Geron and colleagues found only 31% of GGCP tree recipients communicated with others about the program, and only 69% negotiated tree location or species (Geron et al., 2023).

9 Conclusion

9.1 Tree Species

The top 5 species of trees that showed highest rates of survivorship overall and high growth index are American Elm *(Ulmus americana)*, Swamp White Oak *(Quercus bicolor*), Scarlet Oak *(Quercus coccinea)*, Pin Oak *(Quercus palustris)*, and River Birch *(Betula nigra).* The bottom 3 species of trees that showed the lowest rates of survivorship overall as well as a poor growth index are Dogwoods *(Cornus florida)*, specifically the Kousa Dogwood *(Cornus kousa)*, and the Black Tupelo *(Nyssa sylvatica)*. Looking specifically at the 2017 resurveyed trees, the Cherry Plum *(Prunus cerasifera)* and Honeylocust *(Gleditsia triacanthos)* also had very high survivorship and high growth index.

9.2 Tree Health

We found that public trees had higher survivorship rates than private trees, and street trees in particular had higher levels of survivorship in both Holyoke and Chelsea. In Holyoke, institutional sites were the land use with the highest number of trees planted, although they also had the lowest survivorship rates. The multi-family homes land use type had the most trees planted on it in Chelsea, but it had a low survivorship rate. In both cities, greater than 80% of surviving trees had a vigor of 1 and condition of good.

9.3 Community Perceptions

Overall community perceptions revealed that residents value trees primarily for their aesthetic, shade, and air quality benefits. 80% of residents claimed that they want more trees planted in their neighborhood. Collaboration efforts have also revealed certain benefits, as partnerships centered around the GGCP allow for combined and increased outreach, multilingual communication, network building and resource access. On the other hand, challenges include communication between the DCR and the two cities' English limited residents. There is also a need for more engagement between local organizations, city officials and DCR employees.

9.4 Recommendations to the DCR

9.4.1 Tree Health Recommendations

- An increase in support for watering of private trees may increase survivorship
- Encourage planting of genera with high growth index and survivorship rates
- Encouraging collaboration and communication between Gateway Cities Program foresters
- More explicit maintenance agreements especially for non residential private land receiving many trees

9.4.2 Environmental Justice Recommendations

- Increased efforts for multilingual outreach in GGCP cities
- Establish and maintain strong relationship with community partners to help increase outreach, planting, and survivorship
- Planting in priority areas could ease social and environmental disparities

10 Works Cited

Cheng, J., & Yuan, F. (2016). Urban Vegetation Index (UVI) for Assessing Vegetation Health in Urban Areas: A Case Study of Los Angeles. *Remote Sensing*, 8(5), 386.
Danko III, J. J., Delauer, V., Martin, D. G., & Rogan, J. (2016). Worcester, Massachusetts: A History of Urban Forestry Practices. *Northeastern Geographer*, *8*.

From Corruption to Collaboration in Chelsea, MA | Economy League of Greater Philadelphia. (2014, November 24). Www.economyleague.org.

Eisenman, T. S., Flanders, T., Harper, R. W., Hauer, R. J., & Lieberknecht, K. (2021). Traits of a bloom: a nationwide survey of US urban tree planting initiatives (TPIs). *Urban Forestry & Urban Greening*, *61*, 127006.

Escobedo, F. J., Kroeger, T., & Wagner, J. E. (2011). Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. *Environmental pollution*, *159*(8-9), 2078-2087.

Geron, N. A., Martin, D. G., Rogan, J., & Healy, M. (2023). Residents' roles as environmental policy actors using an urban governance framework: A case study of a tree planting program. *Cities*, *135*, 104201.

Huff, Emily S.; Johnson, Michelle; Roman, Lara; Sonti, Nancy Falxa; Pregitzer, Clara C.; Campbell, Lindsay; McMillen, Heather. 2020. A literature review of resilience in urban forestry. Arboriculture and Urban Forestry. 46(3): 185-196.

Hauer, R. J., Miller, R. W., Werner, L. P., & van den Bosch, C. C. K. (2017). The history of trees in the city. In *Routledge Handbook of Urban Forestry* (pp. 17-32). Routledge.

Healy, M., Rogan, J., Roman, L. A., Nix, S., Martin, D. G., & Geron, N. (2022). Historical urban tree canopy cover change in two post-industrial cities. *Environmental Management*, *70*(1), 16-34.

Holyoke climate: Weather Holyoke & temperature by month. (n.d.). En.climate-Data.org. Retrieved July 19, 2024, from https://en.climate-data.org/north-america/united-states-of-america/massachusetts/holyoke-18828/

McPherson, E. G., Simpson, J. R., Xiao, Q., & Wu, C. (2011). Million trees Los Angeles canopy cover and benefit assessment. *Landscape and Urban Planning*, *99*(1), 40-50.

Roman, L. A., Pearsall, H., Eisenman, T. S., Conway, T. M., Fahey, R. T., Landry, S., ... & Staudhammer, C. (2018). Human and biophysical legacies shape contemporary urban forests: A literature synthesis. *Urban Forestry & Urban Greening*, *31*, 157-168.

Rogan, J., Ziemer, M., Martin, D., Ratick, S., Cuba, N., & DeLauer, V. (2013). The impact of tree cover loss on land surface temperature: A case study of central Massachusetts using Landsat Thematic Mapper thermal data. *Applied Geography*, *45*, 49-57.

Appendix A

A.1 Raster Image Acquisition

In order to analyze greenness and heat across our two study areas this summer, we obtained satellite imagery of land surface temperature and 'Urban Vegetation Index', or UVI. UVI is an index used to quantify the amount and lushness of vegetation in urban environments (Cheng, J., & Yuan, F, 2016). The index is calculated as follows: (NIR - Red) / (NIR + Red + Blue), with the result being an index between -1 and 1, where 1 is equivalent to maximum greenness. All satellite images for this project were obtained using a Python interface leveraging the pyStac and stackstac libraries, among others.

UVI images are a median composite of images between June - September, 2013, and 2023, respectively. These dates allow us to compare changes in urban greenery across the full span of the GGCP program, so far. These images are visualized in figures A1 - A7 with relevant metadata in the captions.

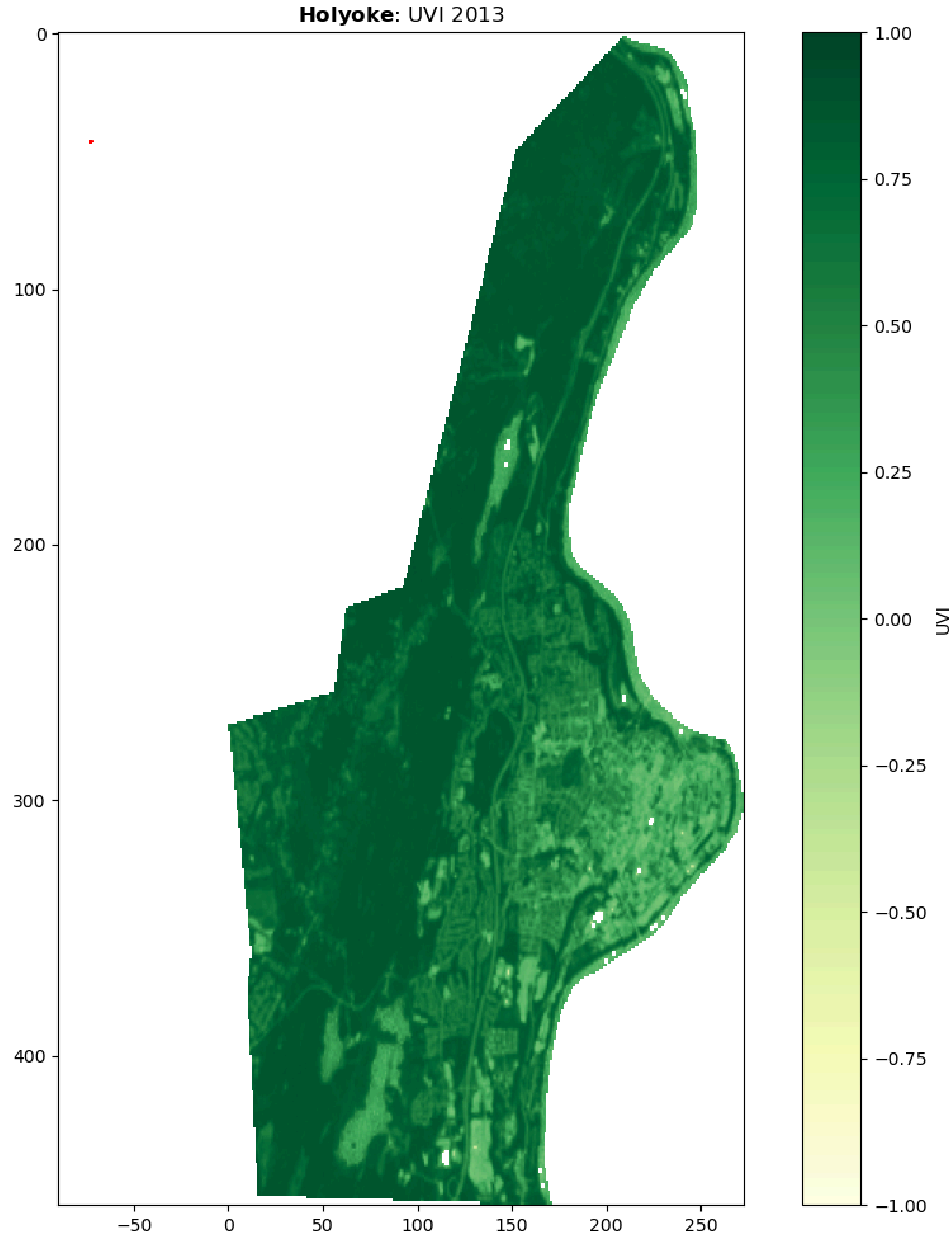

Figure A1. Map of urban vegetation index in Holyoke in 2013. The mean is 0.6709, the median is 0.7740, and the range is from -0.4426 to 0.8967.

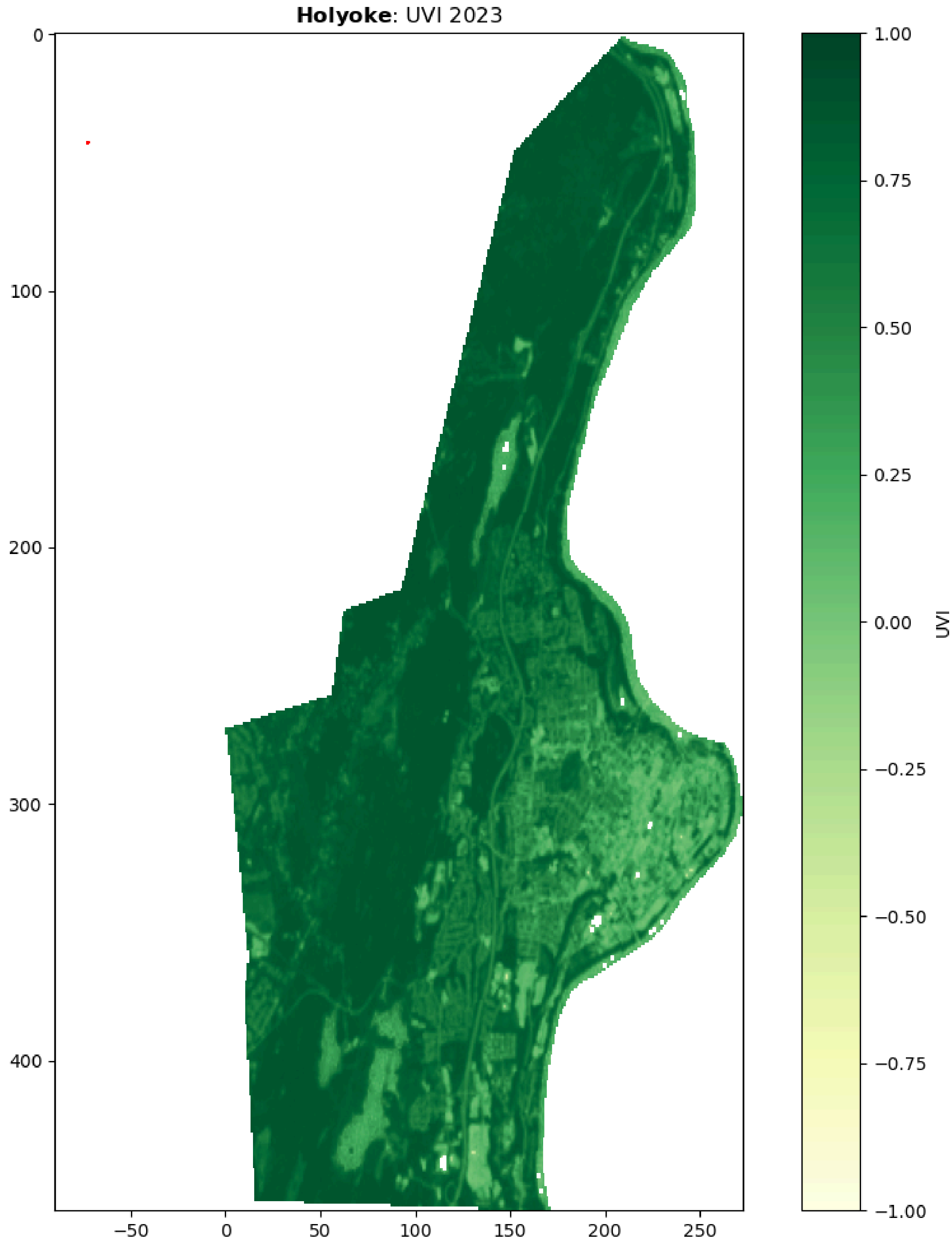

Figure A2. Map of urban vegetation index in Holyoke in 2023. The mean is 0.6591, the median is 0.7471, and the range is from -0.0776 to 0.8846.

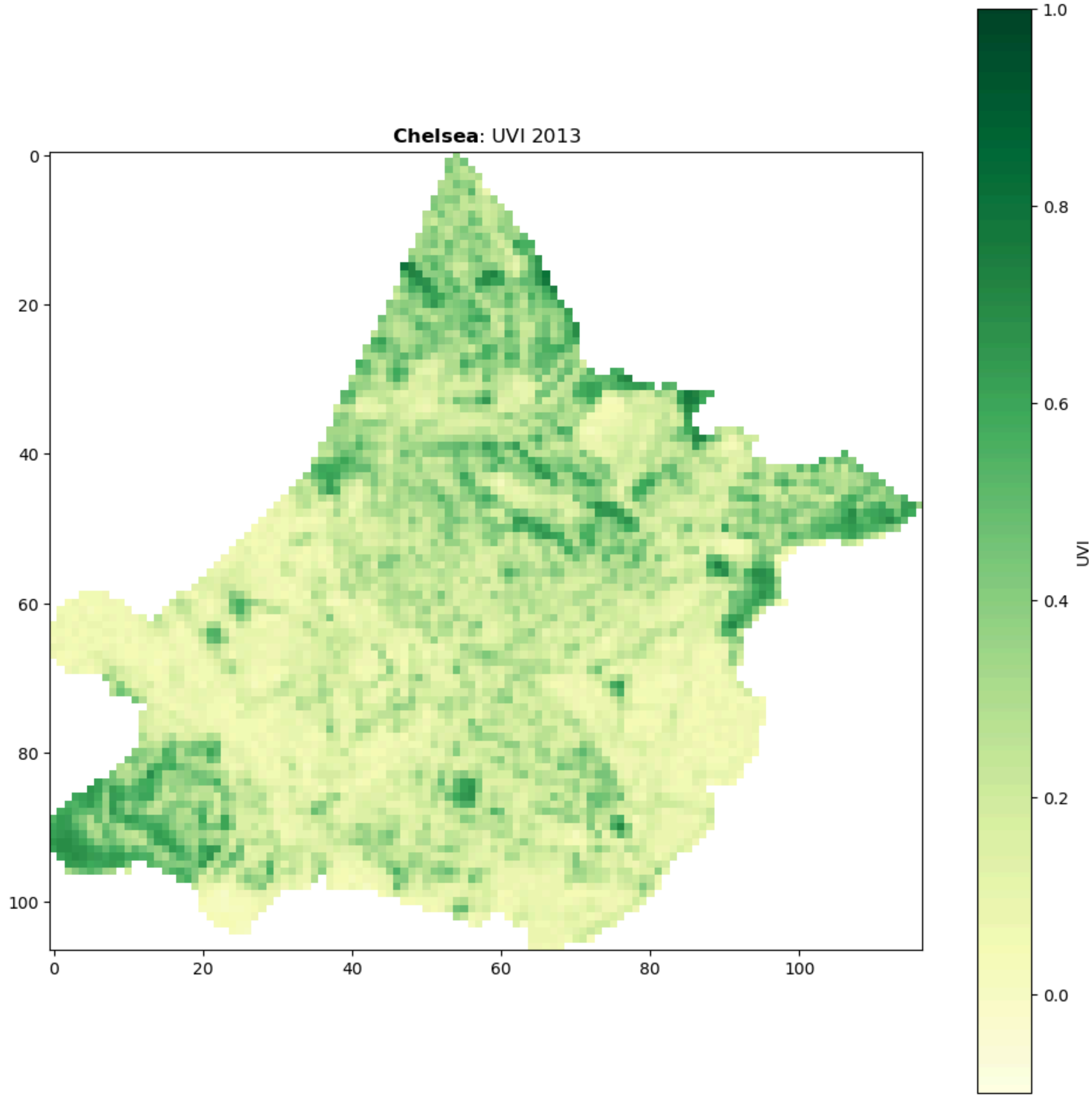

Figure A3. Map of urban vegetation index in Chelsea in 2013. The mean is 0.2593, the median is 0.2337, and the range is from -0.0208 to 0.8331.

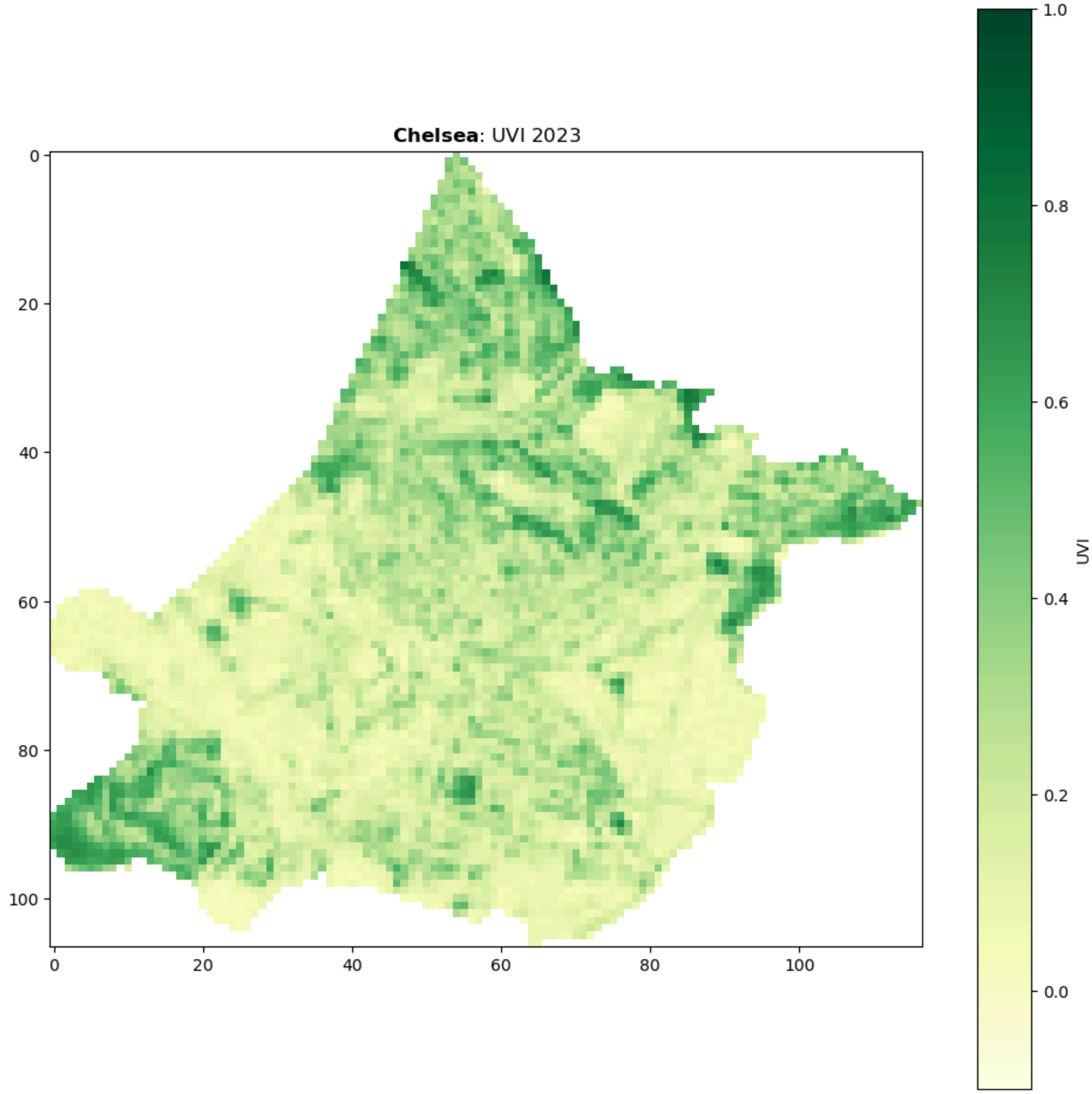

Figure A4. Map of urban vegetation index in Chelsea in 2023. The mean is 0.2400, the median is 0.2063, and the range is from -0.0114 to 0.8048.

As can be seen from the mean UVI statistics, greenness has, in the aggregate, declined in both cities between 2013 and 2023. In the coming section we will analyze how effectively GGCP tree planting correlates with initial UVI, and UVI change during this period.

When analyzing a metric such as UVI over the area of an entire city between two time points, the most impactful changes (to the aggregate numbers) are most likely to be multi-acre land change events, such as clearing a tract of forest for a construction project. Urban greening, on the other hand, whereby street or yard trees grow large enough to have a measurable impact on the 30m x 30m pixels sensed by landsat satellites, takes a long time, and dramatic differences are unlikely to be discernible within the first 10 years of a tree planting program.

These two facts about measuring urban greenness with remote sensing are evident when we calculate and view UVI difference images, as seen below. The clusters of red pixels are likely to be construction projects. In Chelsea, the only area that grew significantly greener is the easternmost part of the city, where an abandoned industrial site has been left fallow, and trees are taking over the land again.

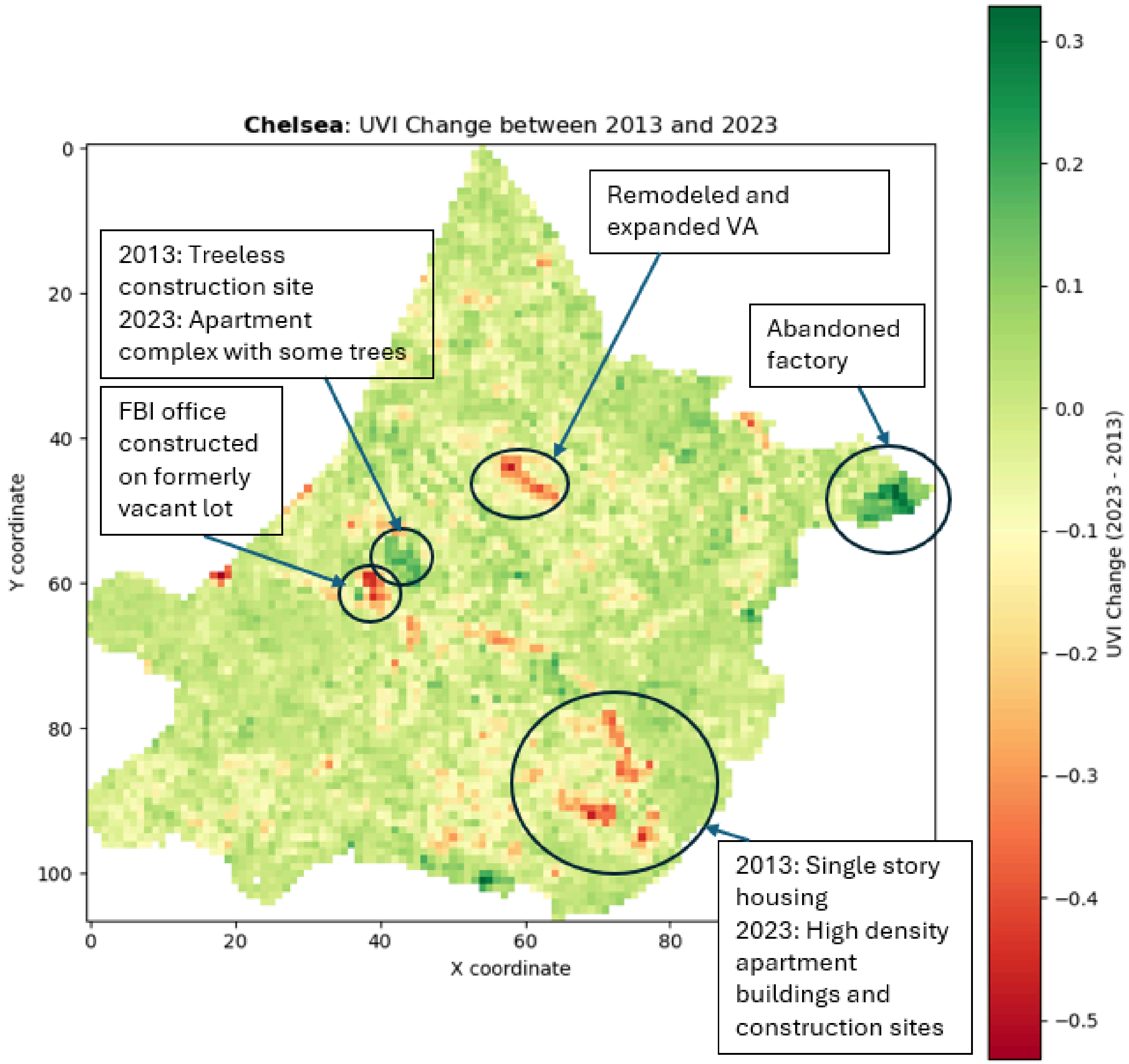

Figure A5. Map showing UVI change between 2013 and 2023 in Holyoke with areas of noteworthy change labeled.

Land surface temperature images, unlike vegetation or land cover, are very difficult to compare in absolute terms between different time points. In the analysis completed here, we take relative heat for each study area from a single time point. The main criteria for a good LST image is a clear, hot day, which will put into stark relief the differences in temperature in different parts of the city on a hot day. For Holyoke, our land surface temperature (LST) image is from June 16, 2024, and for Chelsea, the LST image is from July 17, 2023.

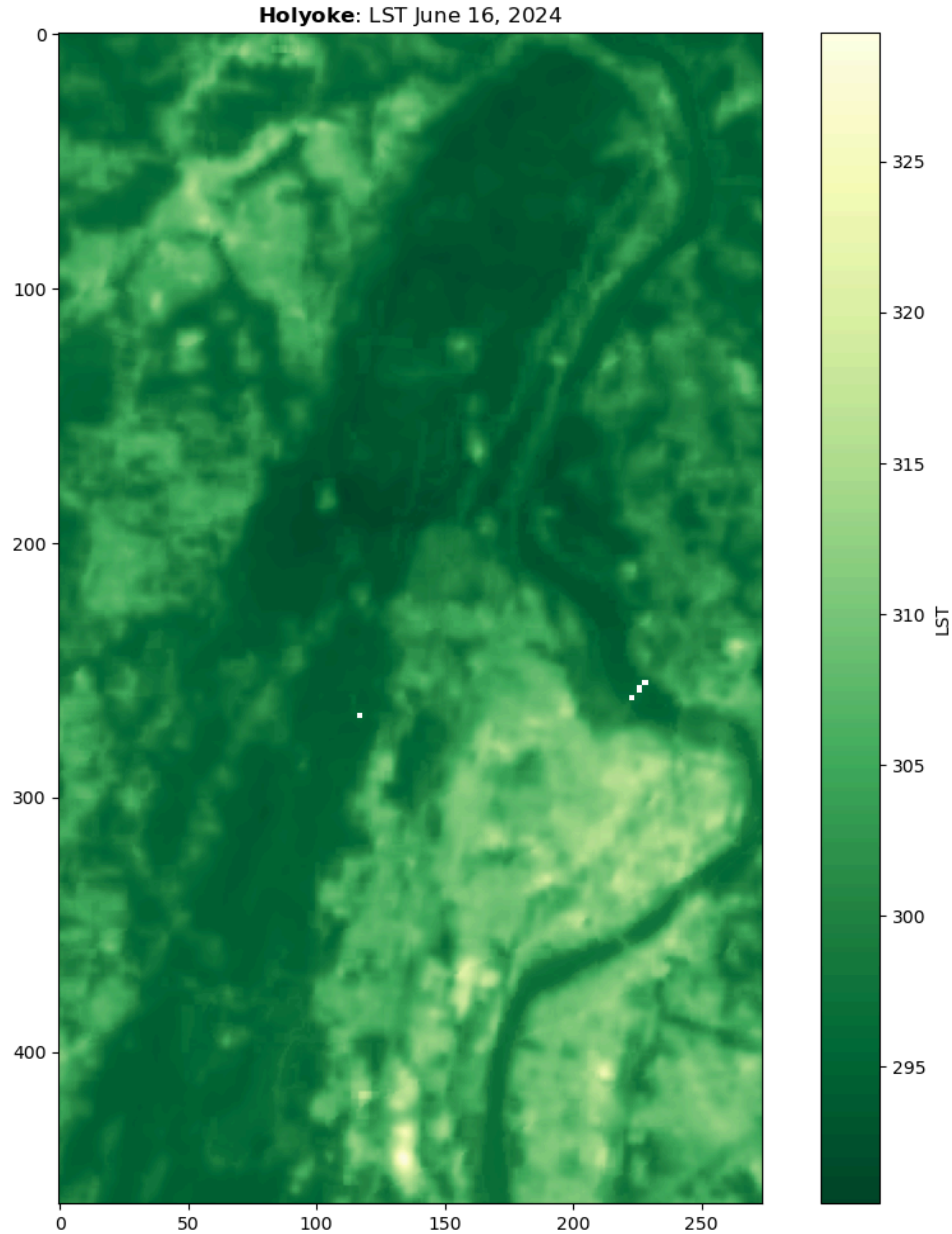

Figure A6. Map of land surface temperature in Holyoke on June 16, 2024. The mean is 300.0494 Kelvin (26.8994 Celsius). The median is 298.8563 Kelvin (25.7063 Celsius). The range is from 290.4616 Kelvin (17.3116 Celsius) to 329.2664 Kelvin (56.1164 Celsius).

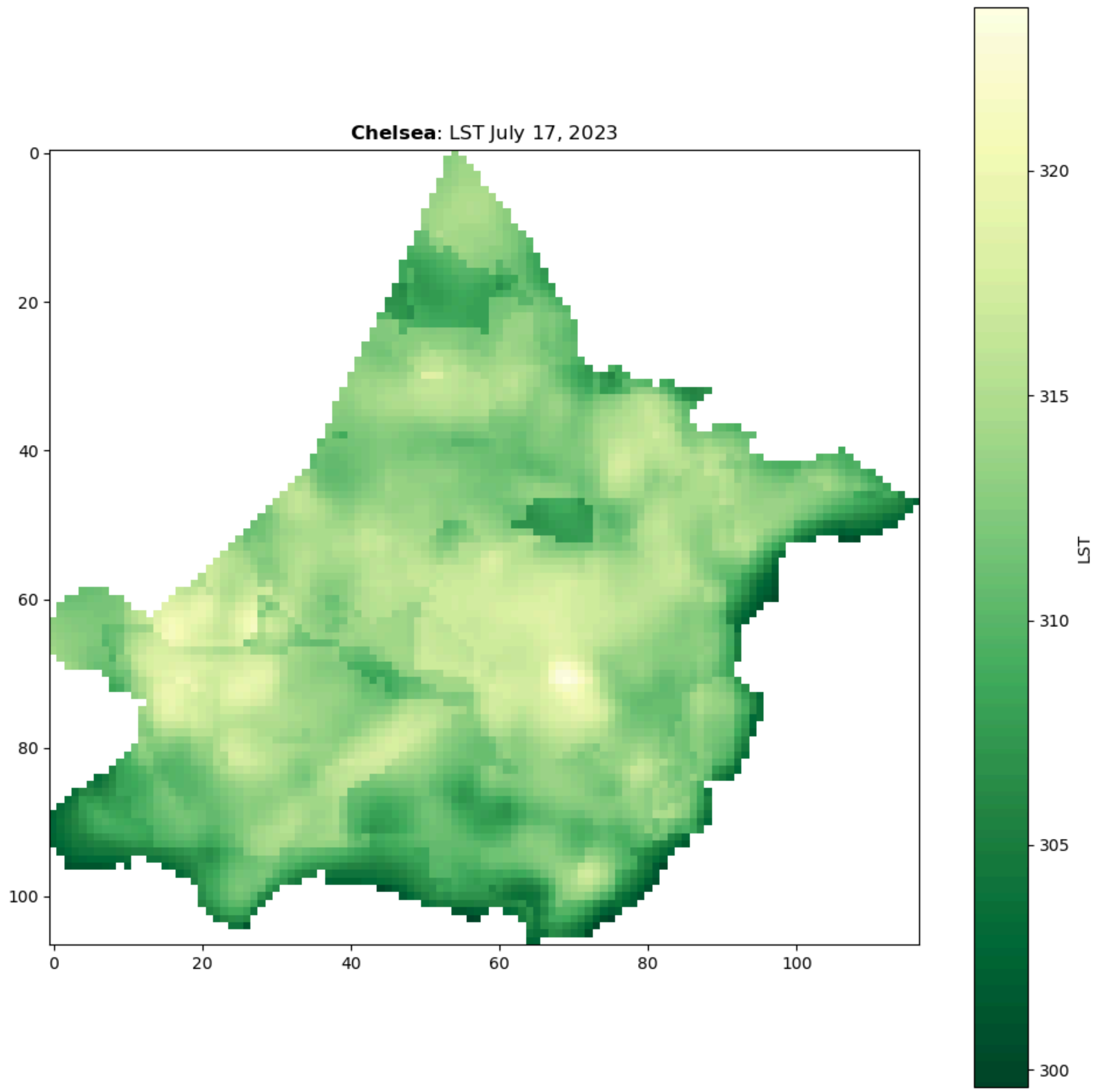

Figure A7. Map of land surface temperature in Holyoke on July 17, 2023. The mean is 312.5705 Kelvin (39.4205 Celsius). The median is 312.9419 Kelvin (39.7919 Celsius). The range is from 299.6185 Kelvin (26.4685 Celsius) to 323.6301 Kelvin (50.4801 Celsius).

A.2 Tree Planting and Greenness by Census Block Group

Another analysis that can be done with raster imagery is analyzing greenness by different city subdivisions, and correlating this to tree planting. The main idea behind tree planting initiatives (TPIs) is to plant trees where they are needed. UVI can be considered a proxy for urban greenness. It does not correlate perfectly with canopy, because it also includes non shading greenery, such as lawns, or gardens. The following analysis uses UVI from 2013, the year before GGCP began, in order to analyze how closely tree planting targeted the less green parts of the city.

A.2.1 Holyoke 2013 UVI Analysis by Census Block Group

Figure A8 includes all block groups in Holyoke. This includes a number of highly forested block groups in the north and west of the city where no trees were planted, therefore rendering a strong negative correlation between initial greenness (2013 UVI) and GGCP trees planted per acre by census block group.

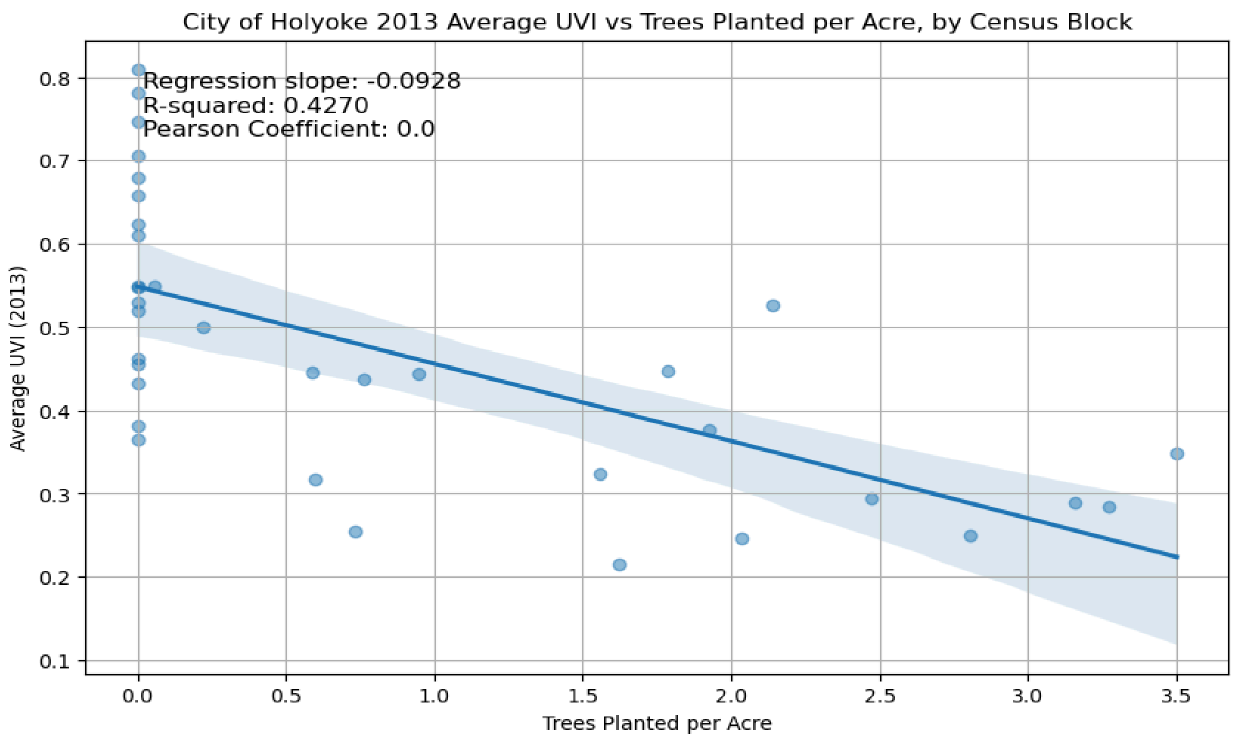

Figure A8. All Holyoke census block groups 2013 UVI vs GGCP trees planted per acre

Figure A9 takes into account all of the block groups with at least 1 EJ criteria, i.e. the expanded planting zone. It still shows medium strength negative correlation between initial greenness (2013 UVI) and trees planted per acre between 2014 and 2023 by the GGCP.

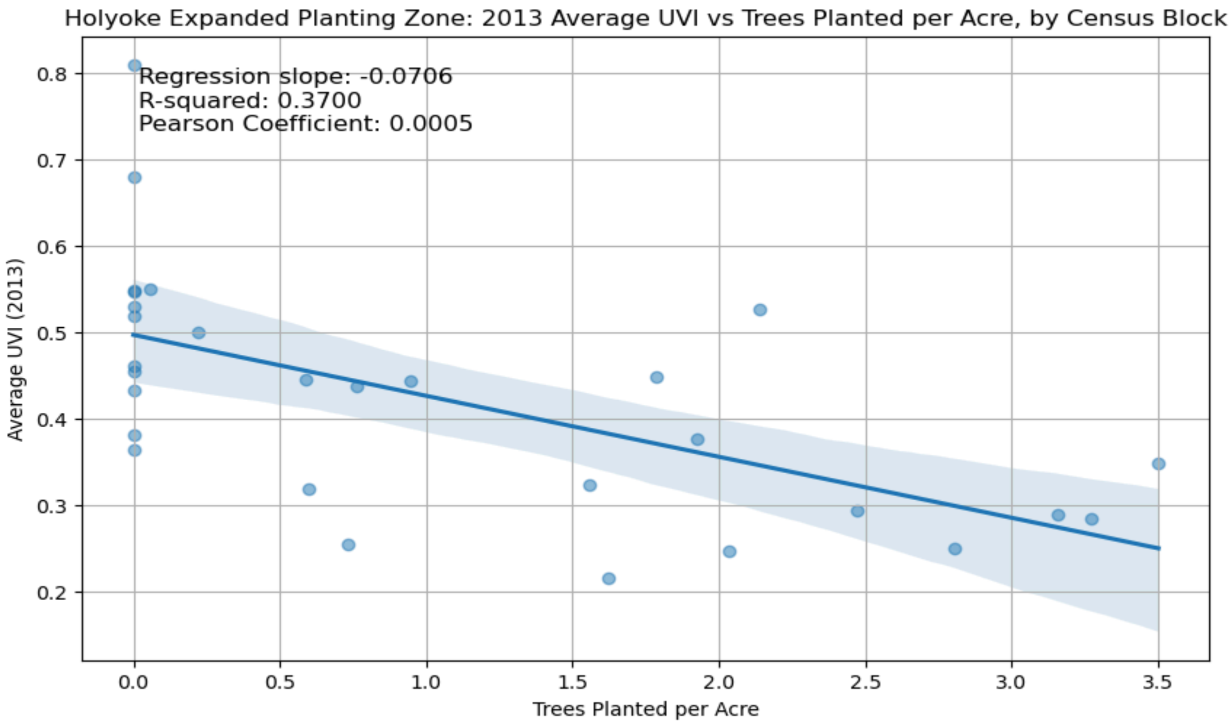

Figure A9. All EJ census block groups in Holyoke 2013 UVI vs GGCP trees planted per acre

Figure A10 is probably the most relevant initial greenness correlation, using for analysis only the original study area/planting zone. It shows a weak to moderate strength correlation between initial greenness (2013 UVI) and trees planted per acre between 2014 and 2023 by the GGCP. This means that on average, GGCP trees were planted in greater numbers in areas with lower initial greenness.

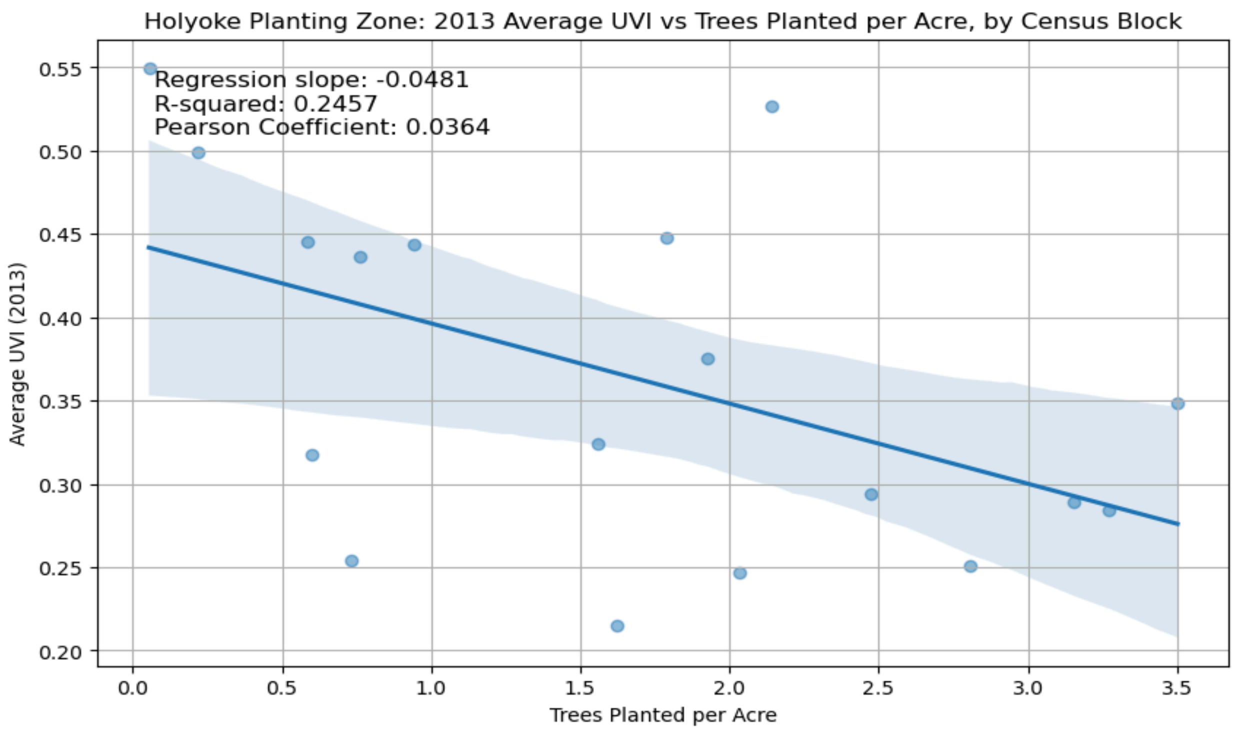

Figure A10. Original planting zone 2013 UVI vs GGCP trees planted per acre by census block group

A.2.2 Holyoke 2013-2023 UVI Difference by Census Block Group

As discussed in section 7.3.1, UVI images can be compared between different time points to calculate how much each pixel has changed. We can then see how tree planting correlates with UVI change in the study area.

We see in figure A11 a positive relationship between trees planted per block group and UVI difference. It is important to note that the average UVI across the entire study area has declined between 2013 and 2013, so most of the block group UVI difference numbers are negative. However, as the plot shows, there is on average less decline in areas with more trees planted.

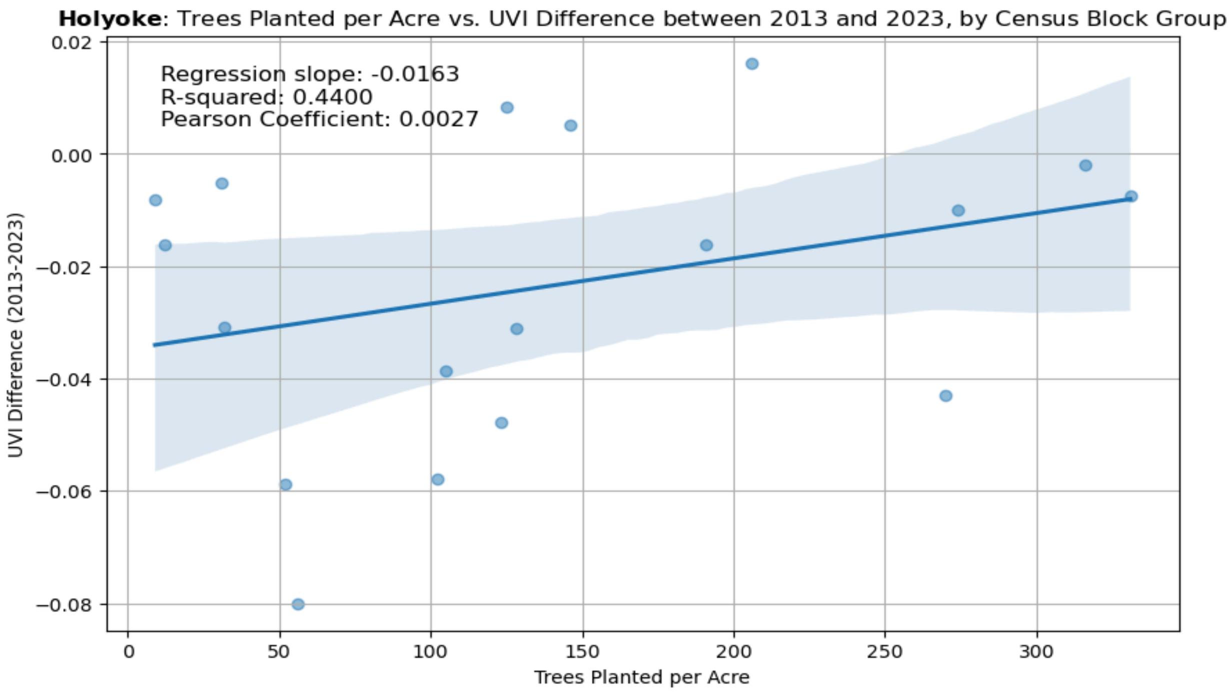

Figure A11. Holyoke UVI Difference 2013-2023 vs GGCP trees planted by census block group

A.2.3 Chelsea 2013 UVI Analysis by Census Block Group

The relationship in figure A12 is positive, which suggests that on average, GGCP trees have been planted in higher numbers in areas with higher initial greenness (2013 UVI). In other words, the trees planted by DCR have been disproportionately planted in areas that are already greener than the city average. This is probably due to the logistical difficulty of planting trees in the large commercial/industrial zones in the west, north, and east of the city, respectively.

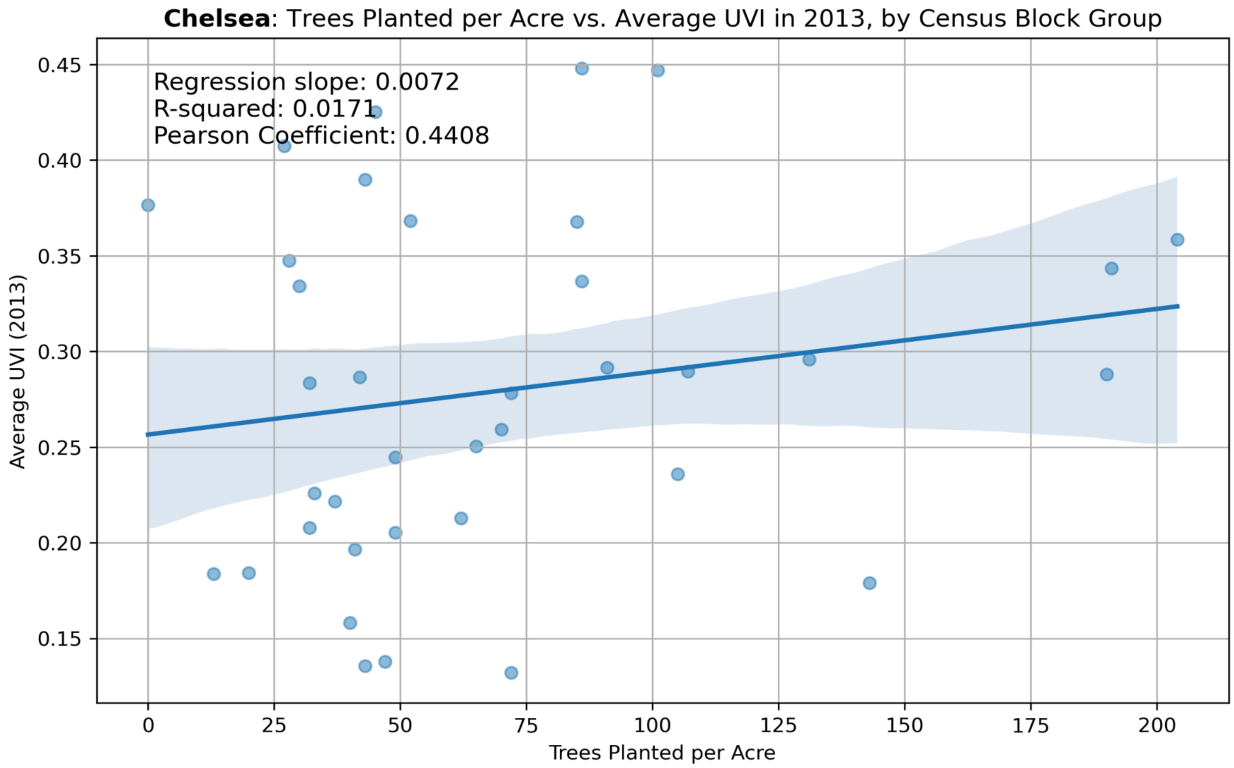

Figure A12. Chelsea 2013 UVI vs GGCP Trees Planted per Acre by Census Block Group

A.2.4 Chelsea 2013-2023 UVI Difference Analysis by Census Block Group

We see in figure A13 a weak negative relationship between trees planted per acre and UVI difference, by block group. It is important to note that the average UVI across the entire study area has declined between 2013 and 2013, so most of the block group UVI difference numbers are negative to begin with. However, as the plot shows, there is very little relationship between UVI difference, and trees planted per block group. An interesting outlier here is the dot in the upper left corner of the plot, representing the abandoned factory mentioned previously in figure A5, in section A.1 of this report. As can be seen this is the only area of the city to have gotten significantly greener during the time span of our study.

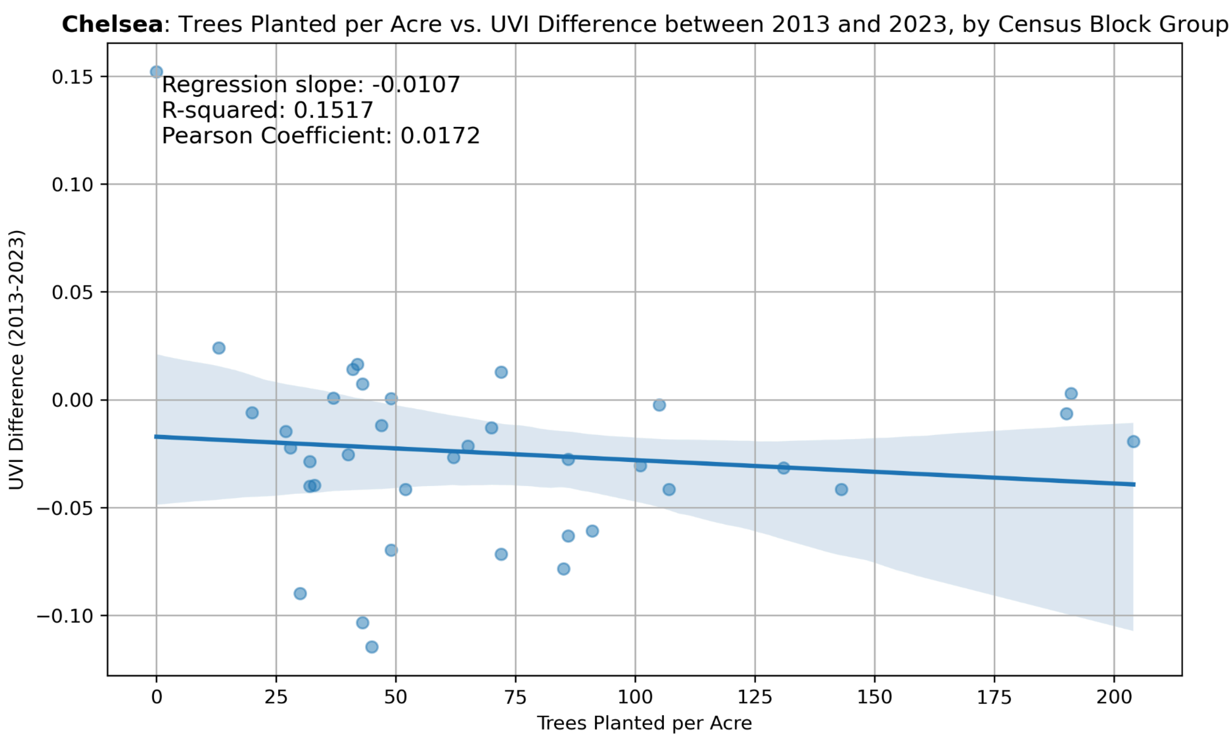

Figure A13. Chelsea UVI Difference 2013-2023 vs GGCP trees planted by census block group