Community Based Assessment of Urban Forestry Conditions

Holyoke, Massachusetts

DRAFT

May 2014

Prepared for:
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A Division of The Davey Tree Expert Company

Project Team

Massachusetts Department of Conservation and Recreation provided funding, oversight, and direction.

City of Holyoke provided information regarding existing city plans and vision.

Davey Resource Group completed the 2014 Community Based Assessment of Urban Forestry Conditions, including canopy cover goals and analysis, prioritized planting plans, and environmental and social benefits of the urban forest.

Westfield State University provided an inventory of trees and planting pits in four census tracts, including i-Tree benefits analysis.

Holyoke Steering Committee

**Please provide names and preferred title below for all committee members.*

Andrew Smith Director, Holyoke Conservation Commission

Mary Moriarty Chairperson, Holyoke Conservation Commission

Dr. John Perdrize Ad-Hoc Urban Forestry Committee Member

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Vision Statement

Holyoke's vision is to…

Acknowledgments

The City of Holyoke is thankful for the support they received from (DCR? Nuestras Raices? Etc….)

Funding

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Introduction

The City of Holyoke acquired the services of Davey Resource Group, a division of The Davey Tree Expert Company, to prepare an analysis of the existing urban canopy and provide insight about the benefits and goals for future plantings. The intention was to provide focus and guidance for long-term goals and set the stage to prepare budget, scheduling, staffing, inter-departmental coordination, public outreach, and other planning needs.

Holyoke's trees are a major component of the infrastructure and provide more than the traditionally understood values of aesthetics and shade. Trees also provide numerous quantifiable environmental benefits, including stormwater management, water quality improvements, temperature moderation and cooling, reduction of air pollutants, energy conservation, and overall increases in property values. Equitable access to these environmental benefits often requires affirmative measures within the urban cores and surrounding neighborhoods.

Understanding the City's goal to provide equal access for all to these environmental benefits, this study addressed the priority issues of urban heat island (UHI) effects or energy conservation, stormwater mitigation, public health and well-being, resiliency to climate change, and air quality control.

Study Area

The study area is defined as the Environmental Justice (EJ) community within the City of Holyoke. EJ communities in Massachusetts are defined by the Commonwealth as minority communities lacking proficiency with the English language who earn less than 65% of the statewide median income. The 2010 U.S. Census Bureau identified nine census tracts within the City of Holyoke as meeting the criteria for an EJ community. The study area is made up of the following census tracts: 811400, 811500, 811600, 811700, 811800, 812001, 812002, 812103, 812104. These tracts cover about 4,500 acres or 7.03 square miles of land. Excluding one forested region with no residential or developed property, the study area covers 3,368 acres, or 5.26 square miles (Figure 1).

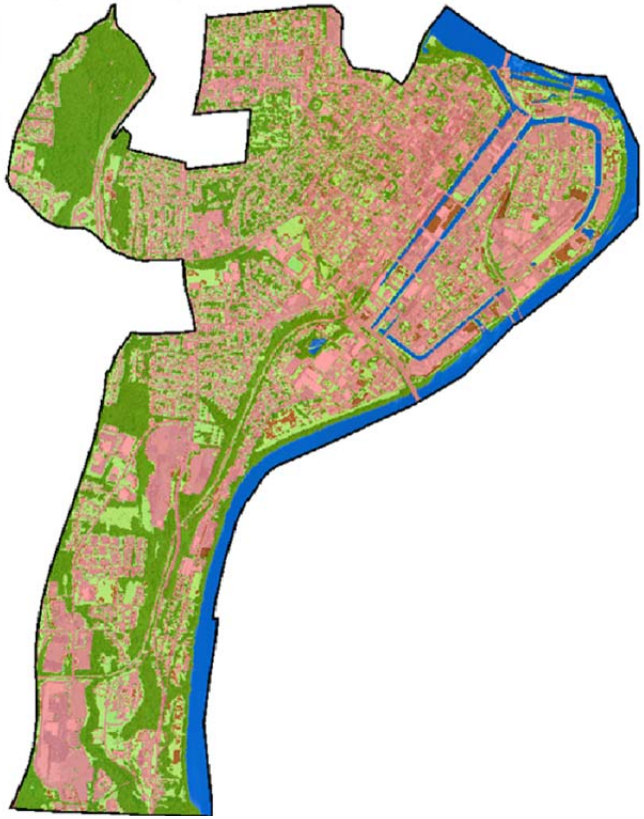

Figure 1. The City of Holyoke's urban core and Environmental Justice community study area.

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Purpose and Scope

The purpose of the study was to define the existing Urban Tree Canopy (UTC) cover, determine the potential for increase, acknowledge the benefits, and create a prioritized planting plan based on environmental and social benefits. Environmental priorities were to focus on UHI effects, or energy conservation, and stormwater mitigation; whereas social benefits looked at population density and demographics.

Aerial photographs with geographic information systems (GIS) data were utilized to map and analyze the existing UTC and identify target areas for planting trees in Holyoke's EJ community. Mapping and quantifying UTC would allow Holyoke to establish baseline conditions for current use and future monitoring, set goals for improvement, and create plans for planting and protecting trees. Quantifying the benefits of the urban forest will also allow Holyoke to promote the benefits of trees and the urban forest to staff, elected officials, stakeholders, and citizens and gain support for urban forest management, stormwater, and sustainability programs. The scope of work includes:

- Establishing a UTC baseline of known accuracy and performing a land cover analysis
- Providing historical images and land change assessments
- Creating a timetable to achieve canopy cover goals
- Developing a prioritized planting strategy based on mitigating UHI effect, stormwater mitigation, and energy conservation
- Providing information and planting plans to maximize green infrastructure benefits for stormwater management
- Relating UTC to socio-economic data and documenting ecosystem benefits to citizens
- Using ecosystem benefits calculations to predict benefits from future plantings
- Providing an overall urban forestry health assessment using i-Tree Canopy analysis

The following deliverables will be provided in addition to this report:

- UTC fact sheet
- Large-format map of UTC results
- Mapbook of prioritized planting locations
- PowerPoint® presentation of results

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Summary

The City of Holyoke contracted Davey Resource Group to review current and historical land cover classifications, analyze data for environmental benefits and demographic trends, and provide recommendations for prioritized planting areas for the City of Holyoke's EJ community. The study area is approximately 3,368 acres, or about 24% of the City's total acreage, which includes approximately 31,219 residents (roughly 78% of the community) (Figure 1).

Using National Agricultural Imagery Program (NAIP) leaf-on digital imagery, the City's 2012 land cover classification assessment showed 26.5%* of the land was covered by tree canopy. Since 2004, Holyoke's UTC had diminished slightly from 26.9%.

The maximum UTC possible is 47.7%; this is the sum of the existing UTC and the preferred plantable area.

The preferred plantable area, which is based on an analysis of the maximum possible planting areas, would add 21.2% canopy coverage and includes areas of pervious surfaces and bare soils within land uses designated as highways, streets, parks, and residential parcels. Land uses such as agricultural land, cemeteries, golf courses, utility rights-of-way, and recreational and sports fields were excluded from the preferred plantable analysis and are referred to as other pervious surfaces.

Within the preferred plantable area, 62.8% (447 acres) is designated as high or very high priority areas for planting. Priority is based on multiple environmental factors, including the risk of soil loss and degradation from storm and flood events, the effects of UHI, and forest fragmentation.

With a maximum total of 75 acres of preferred planting sites available on public property, representing a potential 2.2% increase in canopy, obtaining 30.0% UTC in 30 years is a reasonable goal. This would mean adding 5,300 trees, including 3,400 trees on public property and 1,900 on private property. In order to achieve this goal, the current trend of canopy decline first needs to be addressed. Next, the minimum estimated number of trees must be planted within the next ten years in order to achieve the canopy growth necessary to reach 30.0% canopy cover in 30 years.

Holyoke's existing UTC is a vital asset providing a value of nearly $4.2 million in ecosystem benefits. An increase in UTC to 30.0% would provide a value of $4.5 million in ecosystem benefits. Increasing the City's UTC by 3.5% will increase ecosystem benefits by 6.7%, with many benefits coming from stormwater runoff reduction and UHI-effect reduction.

With the completion of this UTC assessment, the City of Holyoke can now use the data to set goals towards increasing the amount of UTC within the City. Reaching the projected UTC will be a challenge; however, improving the health and preserving existing UTC, establishing realistic UTC goals, and harnessing the maximum amount of ecosystem benefits by planting large-growing trees when appropriate are prudent and responsible endeavors.

Appendix A contains the methodology and accuracy assessment.

* All percentages are reported to the tenth place within the report, and to the one hundredth place in figures and table.

Urban Tree Canopy Assessment

Land Cover Analysis

The 2012 NAIP leaf-on, multispectral imagery acquired and processed by the United States Department of Agriculture (USDA) was used as the primary source to identify the City's current land cover. Remote sensing and GIS software extensions provided the automated feature-extraction tool used to generate the baseline percentage of the final existing tree canopy and land cover layers. This data was further analyzed to determine percent of land cover classes by parcel and block group. Maps were created to assist with comparisons and analysis. A summary of the map generation process is demonstrated in Figure 2.

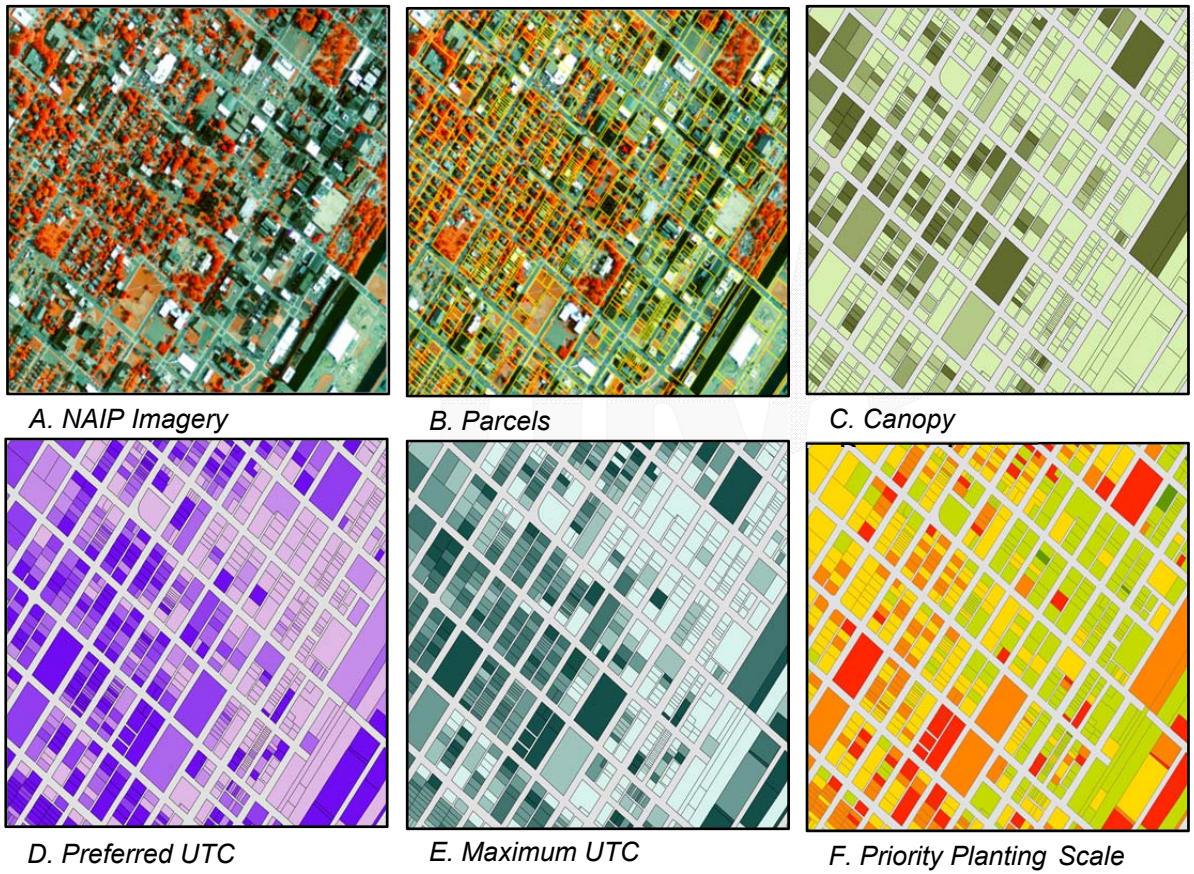

Figure 2. Sequence of map generation for land cover classification and analysis.

Image A *demonstrates the use of National Agriculture Imagery Program (NAIP) leaf-on extraction of canopy from aerial images.*

Image B *demonstrates the ability to activate different layers such as parcels or other land use data in the Geographic Information System (GIS) program.*

Image C *demonstrates a map generated by isolating one land cover classification and mapping at the parcel level by percent cover.*

Image D *demonstrates the same type of map showing preferred plantable areas.*

Image E *demonstrates the same type of map showing maximum possible UTC for comparison.*

Image F *represents the same type of map for analysis with planting locations by parcel mapped for priority.*

Data were generated for five land cover types: tree canopy, pervious, impervious, open water, and bare soil. Tree canopy cover is the area of land surface that is covered by the tree's leaf-covered branches as seen from above. Pervious cover land allows rainfall to infiltrate the soil and includes grasses and low-lying vegetation as found in parks, golf courses, and residential lawns. Impervious land cover is an area that does not allow rainfall to infiltrate and typically includes buildings, roads, and parking lots. Open water includes all lakes, ponds, streams, wetlands, and other mappable water features. Bare soil includes areas such as vacant lots, construction areas, and baseball fields. Bare soils are considered a pervious surface.

These land cover types were mapped for Holyoke's EJ community and are shown in Figure 3. A large format wall map of the final existing UTC was presented to the City of Holyoke to accompany this report.

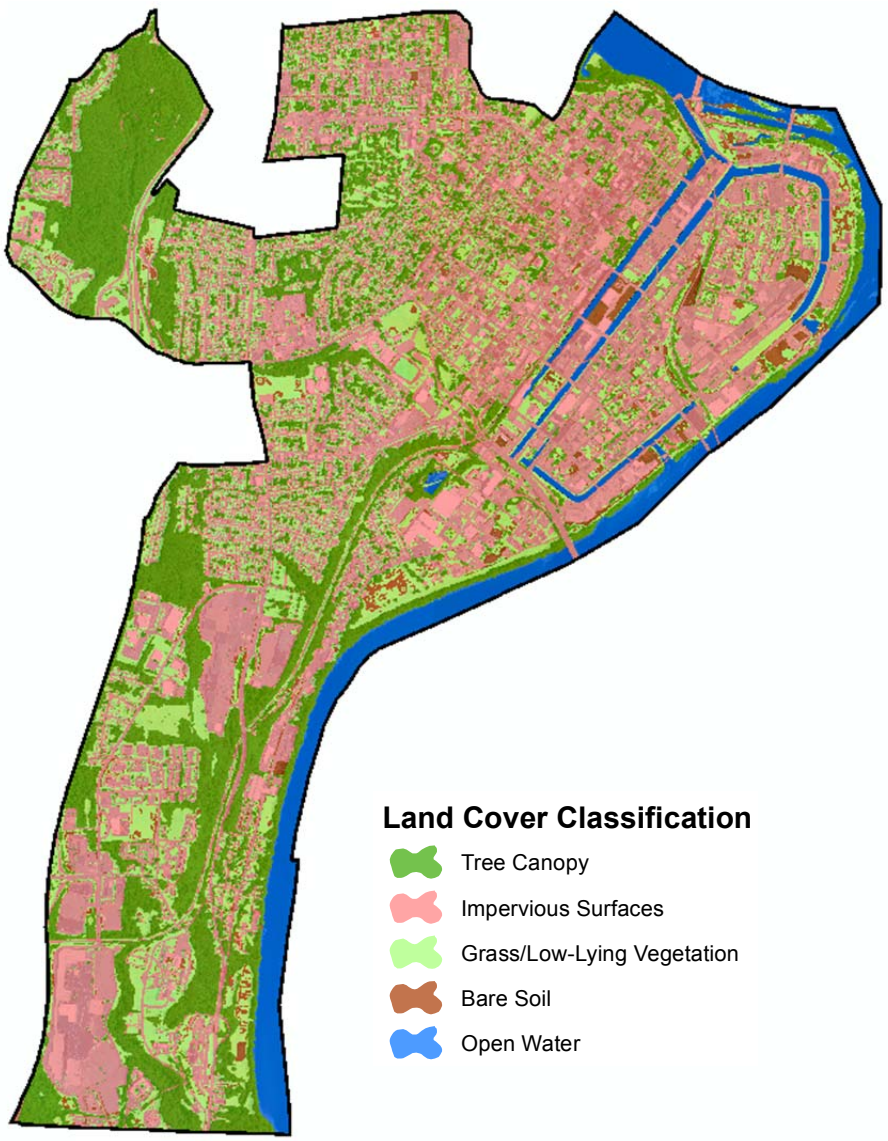

Figure 3. 2012 Holyoke 5-Class land cover map.

The City of Holyoke's EJ community's boundary for this study covers approximately 3,368 acres (5.26 square miles). The total acreage and percentages of each land cover type within this area are shown in Table 1 and Figure 4. Based on the results of the land cover analysis, the estimated tree canopy coverage of this area is 26.5%. Pervious surfaces—grass, low-lying vegetation, and bare soils—cover 20.8% of the total land area. All other land cover types (buildings, roads, other impervious, and open water) make up the remaining 52.7% of the total land area.

Further detailed land cover analysis was performed using ArcGIS® and Overwatch's Feature Analyst® GIS and remote sensing software to complete the automated extraction process. Feature Analyst® is a powerful automated feature extraction (AFE) tool for extracting object-specific geographic features. This program can set the minimum mapping unit (MMU) prior to the initial feature extraction process, which allows for more accurate detailed analysis. Through this process, further land cover detail can be extracted from the five classes, such as buildings, road, and other impervious surfaces. The results of the detailed land cover extraction are mapped and shown in Figure 5.

Table 1. 2012 Land Cover Classification

Land Cover Classification	Acres	Percentage
Total Area	3,367.87	100
Tree Canopy	893.18	26.52
Impervious	1,381.76	41.03
Pervious	699.99	20.78
Bare Soil	94.61	2.81
Open Water	298.33	8.86

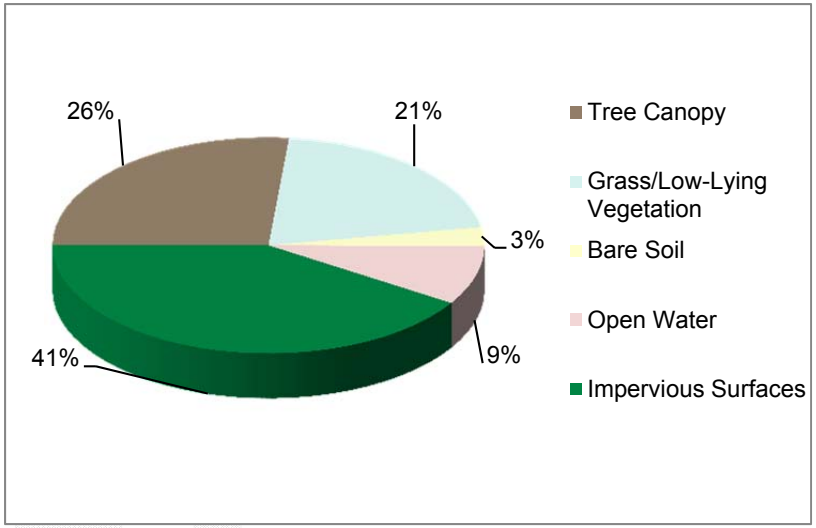

Figure 4. Percentages of 5-Class land cover.

As demonstrated in the sample sequence of map generation (Figure 2), each of the five classes of land cover can be categorized by land cover percentage within a Census Tract, Block Group, or Parcel. This single land cover extraction can isolate data for visual comparison by mapping locations. Observing areas that are low in canopy but high in impervious surfaces will indicate a greater need for canopy increase. The canopy percent by Block Group within Holyoke's EJ boundary is shown in Figure 6 and the impervious surface percent by Block Group is shown in Figure 7. The canopy percent by Parcel and the impervious surface percent by Parcel are shown in Figures 8 and 9.

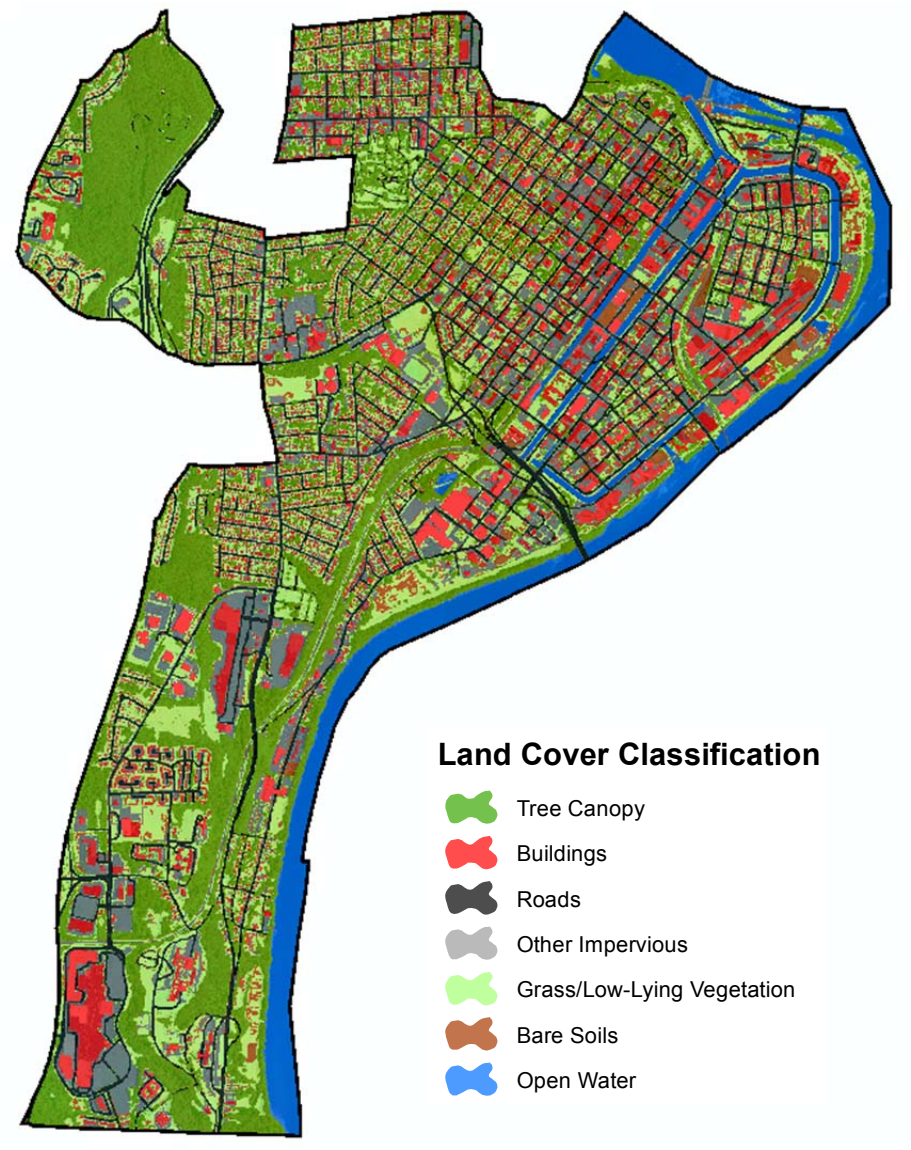

Figure 5. 2012 Holyoke detailed land cover map.

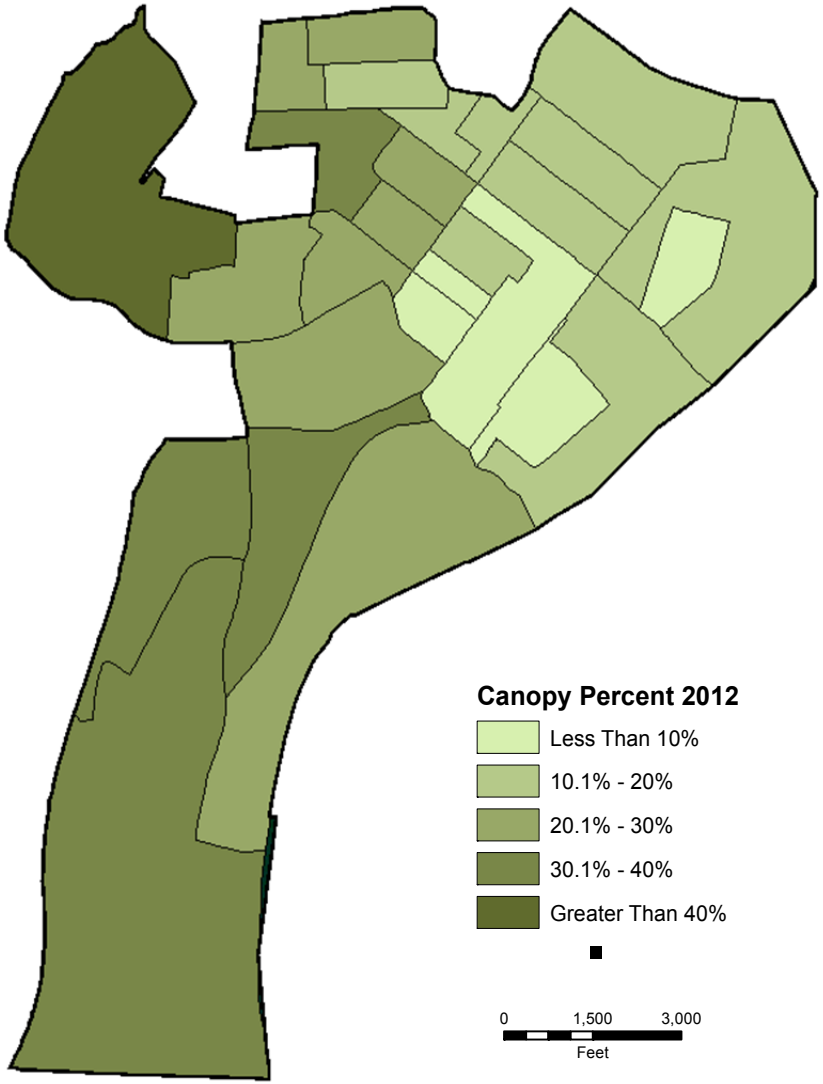

Figure 6. 2012 Holyoke percent canopy cover by Block Group.

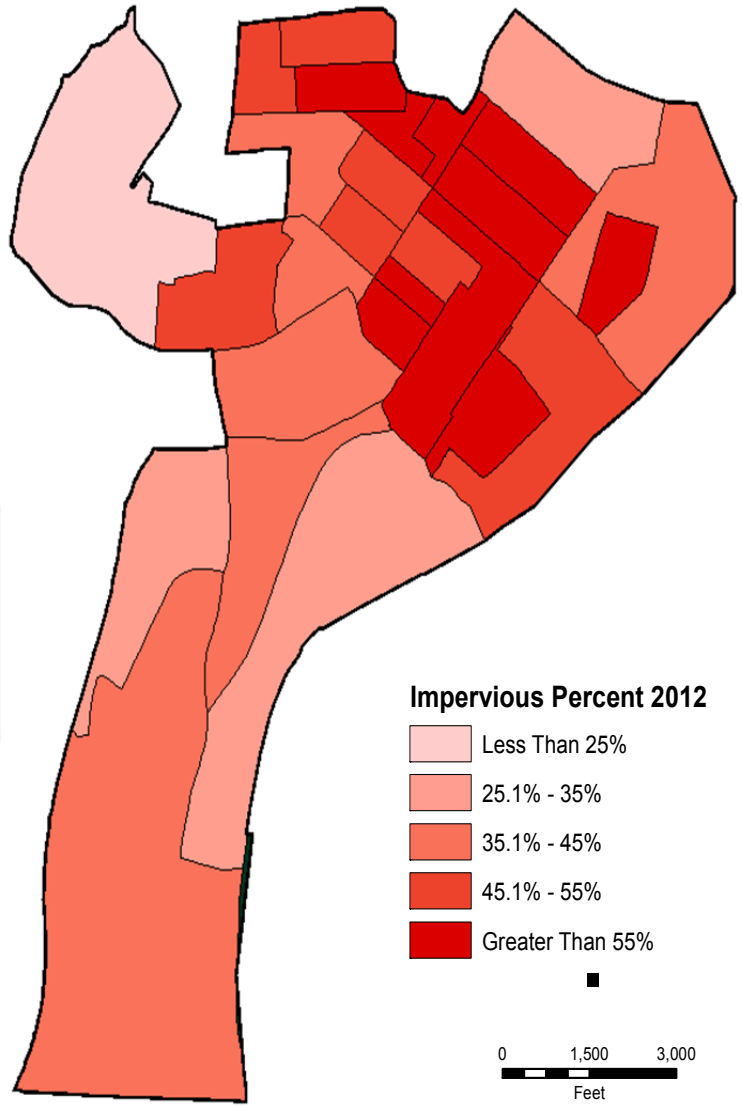

Figure 7. 2012 Holyoke percent impervious surfaces by Block Group.

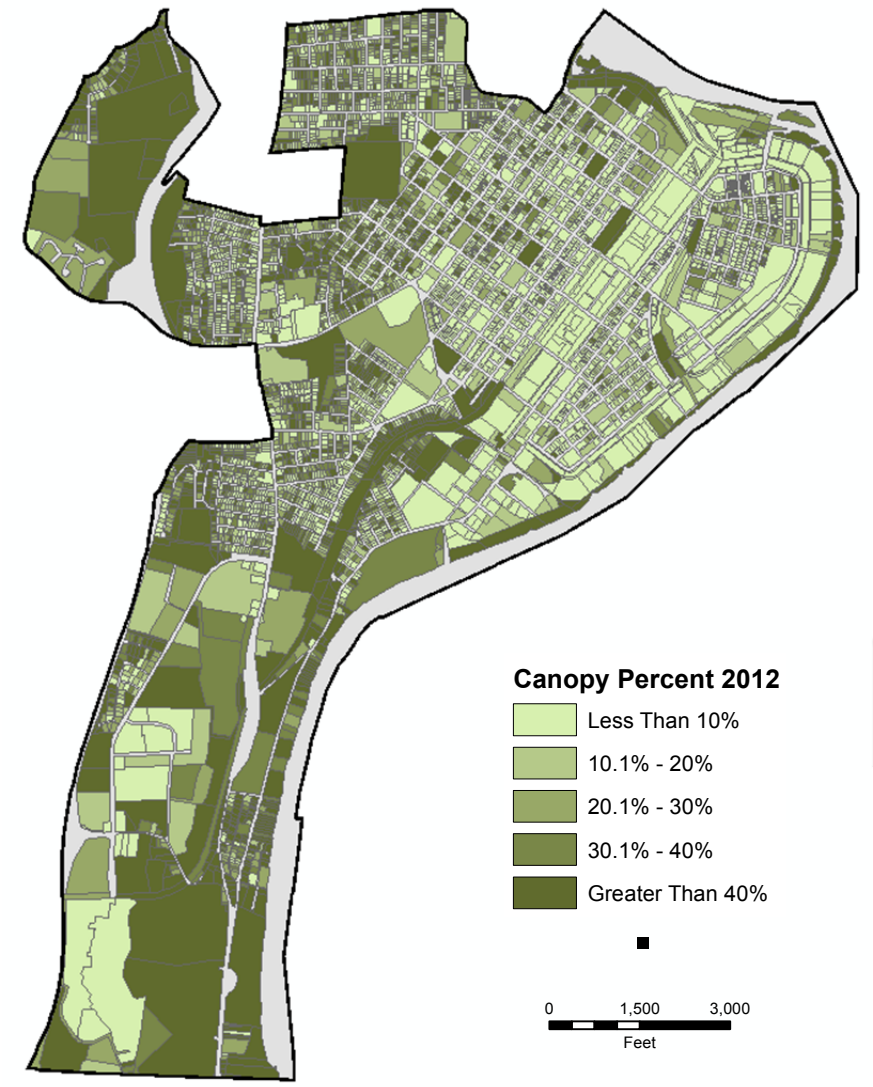

Figure 8. 2012 Holyoke percent canopy cover by Parcel.

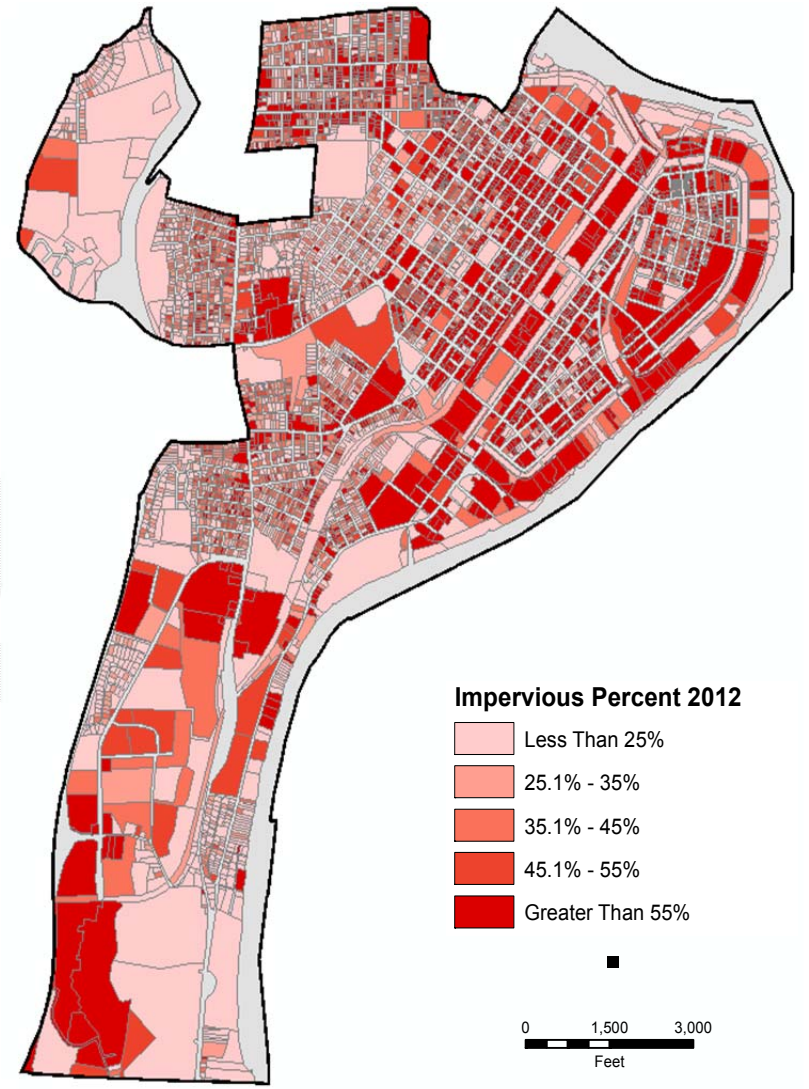

Figure 9. 2012 Holyoke percent impervious surfaces by Parcel.

Historical Land Cover Change Assessment

i-Tree Canopy Analysis

In order to track gains and losses of tree canopy in the recent history of Holyoke's EJ community, Davey Resource Group performed an additional UTC analysis for 2004. i-Tree Canopy was used in conjunction to determine the study area's historical land cover percentage values.

The i-Tree Canopy tool (Figure 10) allows users to easily interpret Google Earth™ aerial imagery for areas of interest and produce statistical estimates of tree cover and other cover types. Calculation of estimate uncertainty is provided as well. This tool provides a quick and inexpensive means for communities, government stakeholders, urban forest managers, and non-profits to accurately estimate tree canopy cover.

This i-Tree Canopy tool can be used by Holyoke in future land cover assessments to provide land cover analysis using new aerial images as they become available in Google Maps™. The random point locations derived from i-Tree Canopy can be re-imported in future works to produce a statistically valid estimate of land cover. Holyoke can use this tool to quickly evaluate canopy effects after future severe weather events, increased development, and collective planting efforts.

As with the current land cover classification assessment, the results from this analysis were mapped for the five-class land cover classification and the detailed land cover classification. This provided a suitable baseline to track changes that occurred between 2004 and 2012 imagery and for future analysis. Results of the land cover change analysis are reported in Table 2. Over an eight-year period, Holyoke's tree canopy coverage decreased by 0.4%. The impervious surfaces also decreased coverage by 0.2%. Pervious surfaces increased by 0.2% and bare soils increased by 0.4%. The loss in canopy and reduction in impervious surfaces represents an environmental need and opportunity for growth.

Table 2. Land Cover Percent Change in Holyoke's Environmental Justice Community Between 2004 and 2012 (Excluding the Connecticut River)

Land Cover Class	2004	2012	% Change
Tree Canopy	28.75%	28.36%	−0.39%
Impervious Surfaces	44.44%	44.29%	−0.15%
Pervious Surfaces	22.21%	22.41%	0.20%
Bare Soils	2.63%	2.99%	0.36%
Open Water	1.96%	1.95%	−0.01%

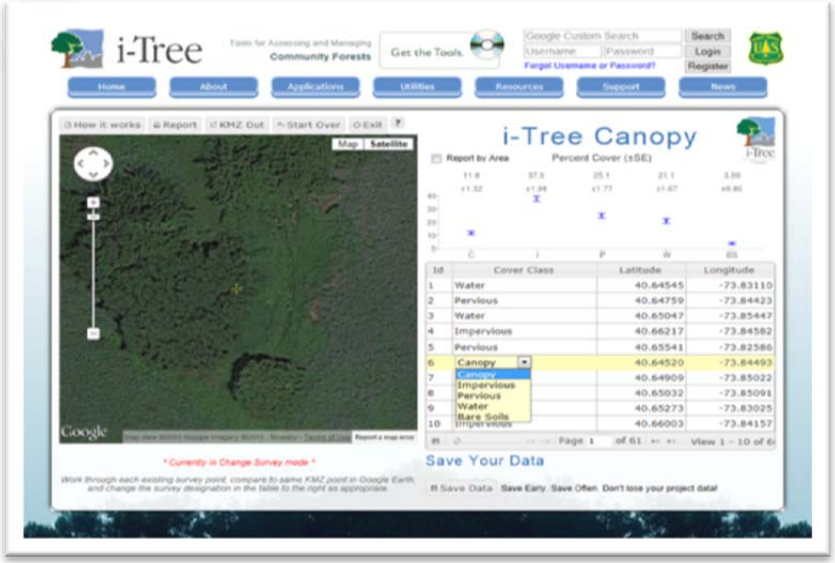

Figure 10. Screen shot of i-Tree Canopy interface.

As an example of historical change, a parcel level analysis took the tree canopy percent change from 2004 to 2012 and mapped parcels where there were gains, losses, and unchanged amounts of tree canopy. This is demonstrated in Figure 11 and Table 3. By comparison, Figure 12 and Table 4 show the parcel change of impervious surfaces from 2004 to 2012. The City of Holyoke can utilize these maps to identify individual parcels that have had significant change over the eight-year time span and look into the details about that change from the ground level or on a site-by-site basis. These maps can guide Holyoke towards identifying areas for further investigation into understanding what planning, policies, or actions have been leading to an increase, decrease, or no change in canopy cover. This can indicate to the City which areas of development could use more assistance with incorporating environmental benefits into the development process.

Table 3. Change in Canopy Cover as Percent by Parcel in Holyoke's Environmental Justice Area

Percent Change	Number of Parcels
More Than −10%	192
−10% – −5%	60
−5% – −1 %	81
Unchanged	4,961
1% – 5%	144
5% – 10%	54
More Than 10%	36

The percentages reflect the exclusion of the Connecticut River in this study due to the assumed lack of change in land cover use and the known unsuitability for planting.

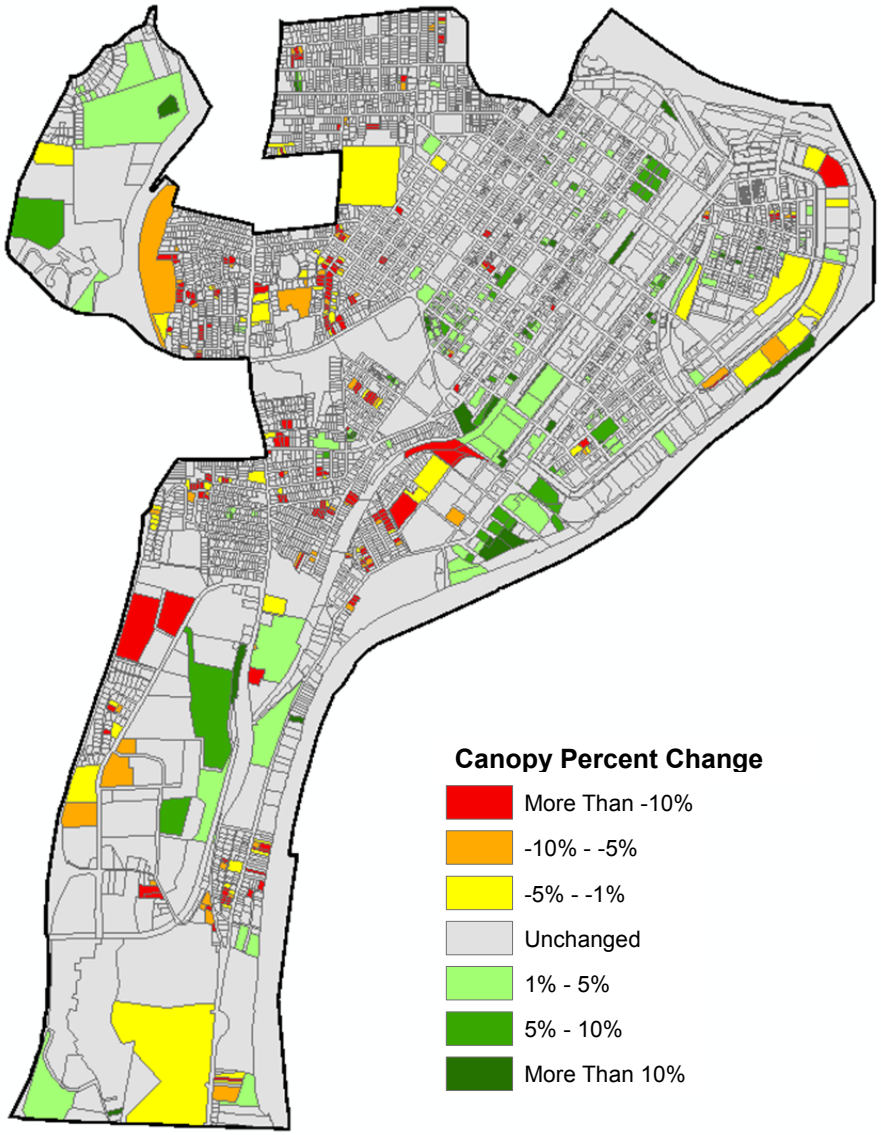

Figure 11. Change in percent canopy cover in Holyoke's Environmental Justice community from 2004 to 2012.

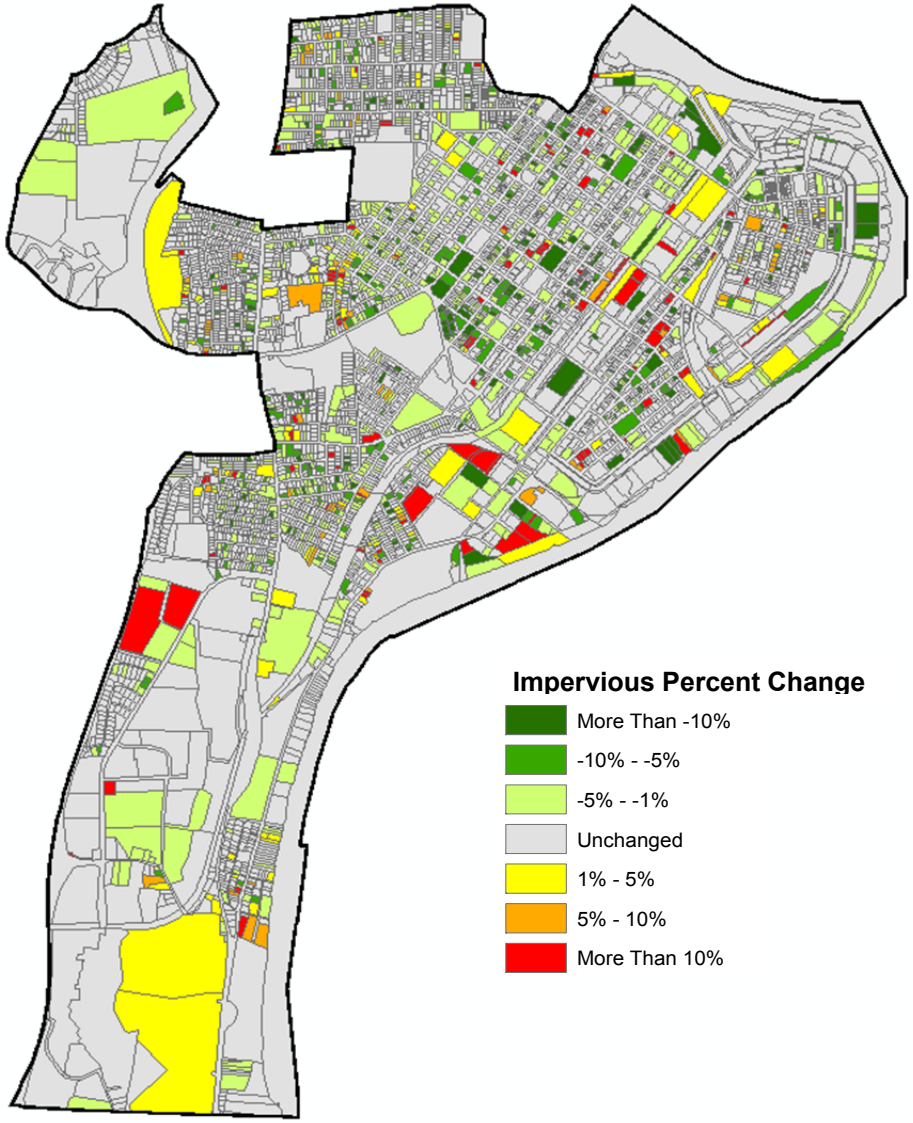

Figure 12. Change in percent impervious surfaces in Holyoke's Environmental Justice community from 2004 to 2012.

Table 4. Change in Impervious Surfaces as Percent by Parcel in Holyoke's Environmental Justice Area

Percent Change	Number of Parcels
More Than −10%	195
−10% – −5%	238
−5% – −1 %	699
Unchanged	4,079
1% – 5%	121
5% – 10%	74
More Than 10%	122

The percentages reflect the exclusion of the Connecticut River in this study due to the assumed lack of change in land cover use and the known unsuitability for planting.

Finding general trends in the data can also assist in identifying areas that may be in greater need for environmental benefits, or it can show where those benefits have already begun taking place. Such trends can indicate regions that would benefit from further investigation about the cause for change in land cover classification and whether canopy can be incorporated into such changes to alleviate the resulting environmental costs.

To identify trends, change in canopy and impervious surfaces were mapped at the Block Group scale. These trends and each individual Block Group percentage change are shown in Figure 13 and Table 5 for Canopy Cover and Figure 14 and Table 6 for Impervious Surfaces.

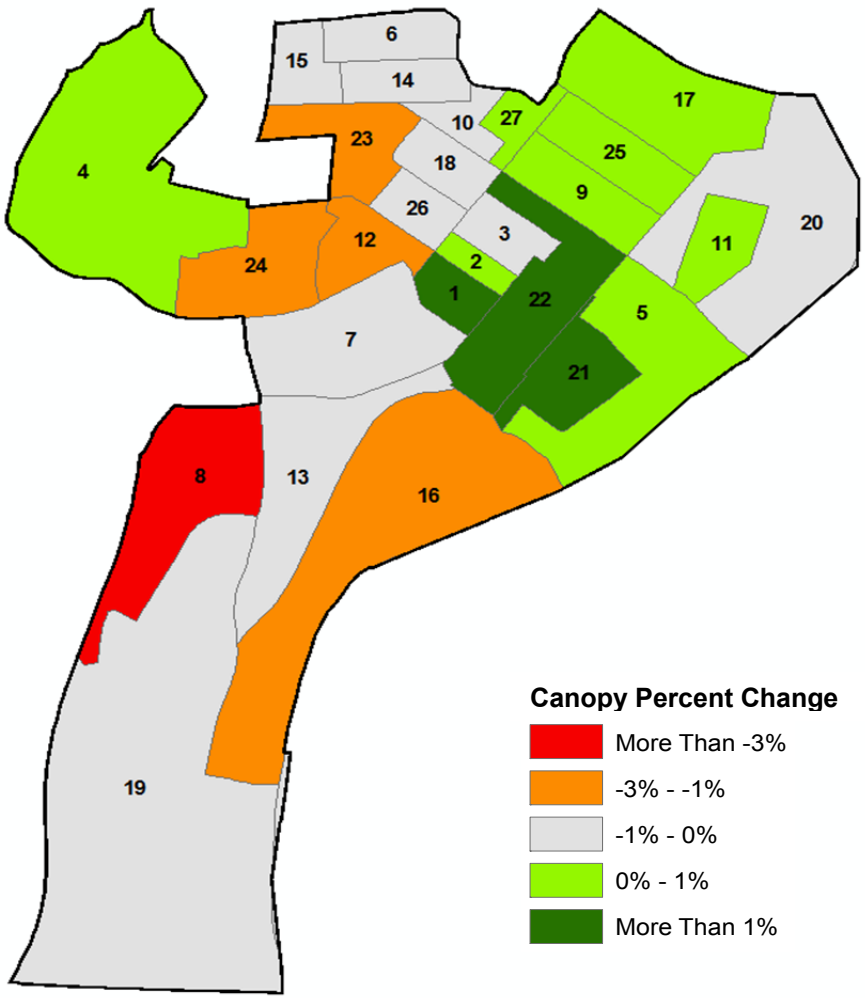

Figure 13. Change in percent canopy cover by Block Group in Holyoke's Environmental Justice community from 2004 to 2012

Table 5. Change in Canopy Cover as Percent by Block Group in Holyoke's Environmental Justice Community from 2004 to 2012

ID	Canopy 2004	Canopy 2012	Percent Change
1	4.19	5.70	1.51
2	8.15	8.39	0.24
3	19.81	18.96	−0.85
4	56.54	57.39	0.85
5	10.25	10.56	0.31
6	21.09	20.79	−0.30
7	23.11	22.63	−0.48
8	42.86	38.58	−4.28
9	9.88	10.76	0.88
10	17.88	17.88	0.00
11	8.70	8.98	0.28
12	32.04	29.92	−2.12
13	36.58	35.84	−0.74
14	16.51	16.32	−0.19
15	24.38	24.00	−0.38
16	26.08	24.80	−1.28
17	17.17	17.34	0.17
18	27.00	26.90	−0.10
19	32.82	32.70	−0.12
20	11.25	10.70	−0.55
21	7.62	8.87	1.25
22	7.02	8.76	1.74
23	33.99	32.36	−1.63
24	27.75	25.79	−1.96
25	10.53	11.30	0.77
26	25.30	24.97	−0.33
27	15.98	16.00	0.02

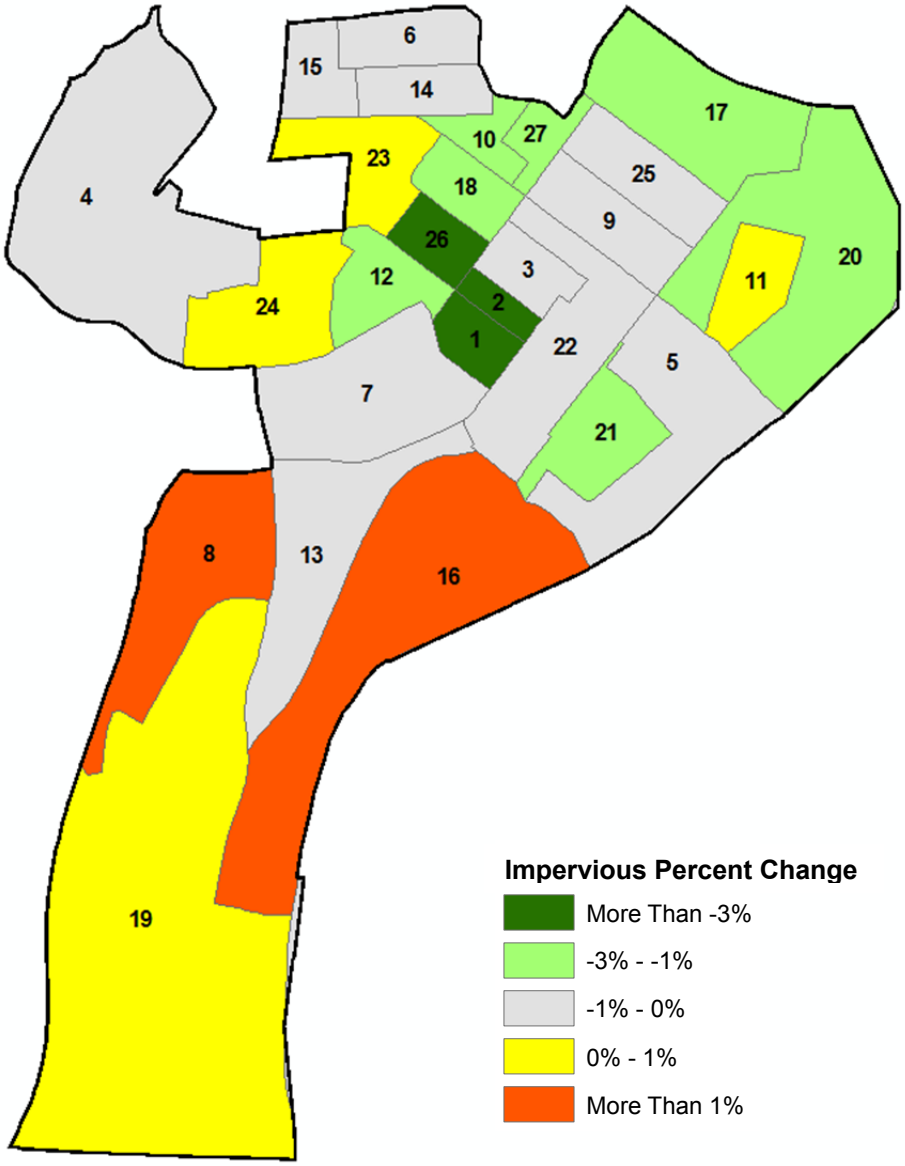

Figure 14. Change in percent impervious surface by Block Group in Holyoke's Environmental Justice community from 2004 to 2012

Table 6. Change in Impervious Surface as Percent by Block Group in Holyoke's Environmental Justice Community from 2004 to 2012

ID	Impervious 2004	Impervious 2012	Percent Change
1	68.86	65.17	−3.69
2	71.49	67.27	−4.22
3	53.33	53.13	−0.20
4	21.29	21.21	−0.08
5	48.49	48.49	0.00
6	54.13	53.69	−0.44
7	43.65	43.42	−0.23
8	31.54	34.24	2.70
9	71.42	70.68	−0.74
10	58.81	57.74	−1.07
11	63.42	63.69	0.27
12	43.05	41.29	−1.76
13	40.20	39.31	−0.89
14	60.12	59.39	−0.73
15	50.18	49.76	−0.42
16	30.72	31.77	1.05
17	26.48	25.46	−1.02
18	49.35	48.12	−1.23
19	37.24	37.51	0.27
20	41.52	39.96	−1.56
21	69.42	68.31	−1.11
22	61.82	61.66	−0.16
23	39.01	39.16	0.15
24	47.98	48.13	0.15
25	70.20	69.23	−0.97
26	48.75	45.62	−3.13
27	57.19	55.37	−1.82

Setting a Goal for Increasing Urban Tree Canopy

The amount of tree canopy drives the amount of benefits that an urban forest provides. Whether the City of Holyoke wants to increase or maintain tree canopy, setting goals will help organize tree planting programs and direct tree preservation. Establishing realistic and achievable tree canopy goals will help capitalize on the environmental, economic, and social benefits trees provide to the community.

One set of industry standards for UTC goals in metropolitan areas has been established by American Forests, a recognized leader in conservation and urban forestry. These goals are an accepted standard and can be used as a general guideline or target for communities to achieve.

American Forests recommends that cities set a canopy cover goal of 40.0% overall. American Forests further recommends the core central business district should strive for 15.0% coverage, and urban neighborhoods and fringe business areas for 25.0%. Suburbs, which have more growing space for trees, should be able to reach a tree canopy of 50.0%. A breakdown of the land use classifications can be seen in Table 7.

While categories of Central Business District, Urban Residential, and Suburban Residential are general, similar land use zones, as determined by the Holyoke zoning and GIS land use data, have been mapped by parcel in Figure 15.

Table 7. American Forests' Recommended Canopy Cover for Metropolitan Areas East of the Mississippi River

Area	Recommended Cover
Average of All Zones	40%
Suburban Residential Zones	50%
Urban Residential Zones	25%
Central Business Districts	15%

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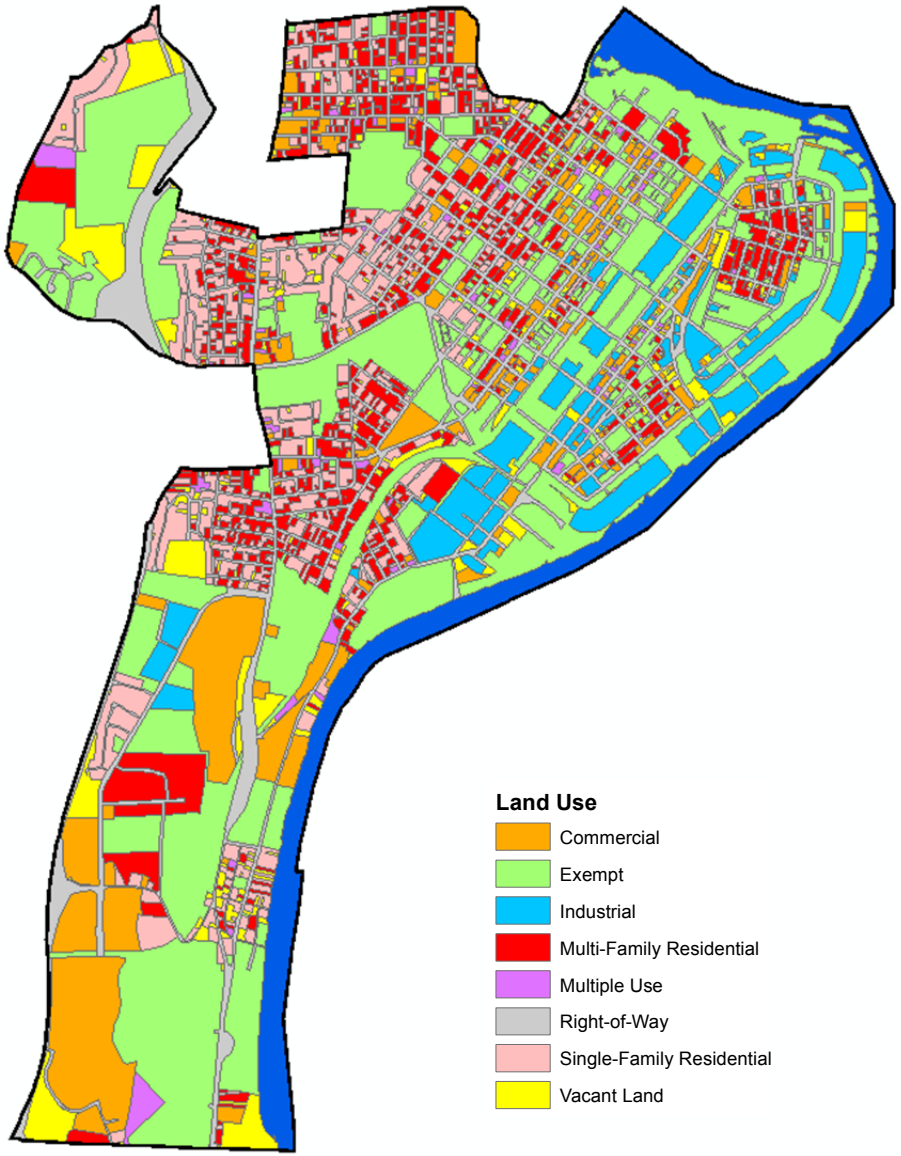

Figure 15. 2012 Zoning land use in Holyoke's Environmental Justice community by parcel.

UTC-Based Planting Plan

Determining the possible amount of planting space that is available for the City of Holyoke's EJ community is the first step to setting realistic goals. Pervious surface data alone (grass/low-lying vegetation or bare soil) does not indicate all practical locations to be planted. Some pervious surfaces are determined to be undesirable for tree planting based on their previous acquisition for other land uses, such as right-of-ways, golf courses, agricultural fields, cemeteries, airports, and recreational fields, and it is a common practice to remove these land cover types from the list. The remaining pervious surfaces indicate the amount of canopy increase that is possible and the amount of additional UTC preferred, referred to as Preferred Plantable Area. The potential for canopy increase, or Preferred UTC Percent by Block Group, is shown in Figure 16.

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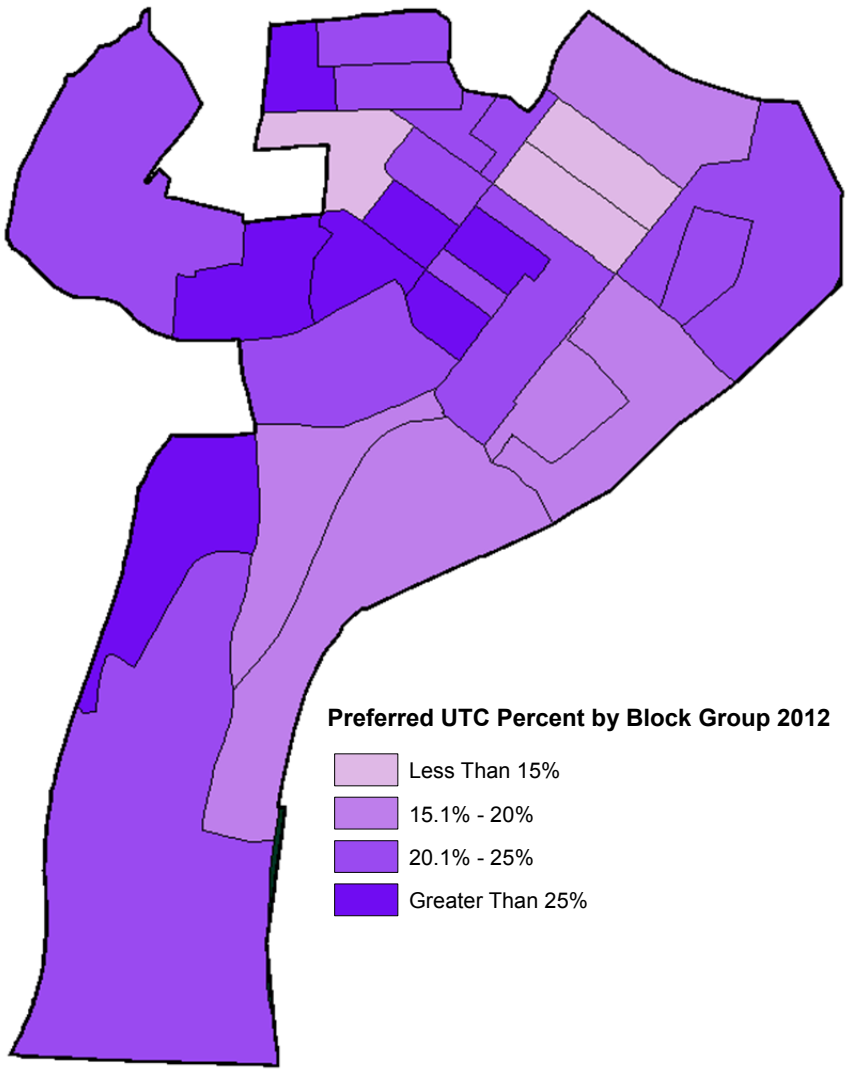


Figure 16. Preferred UTC as percent by Block Group for Holyoke's Environmental Justice community.

The maximum possible UTC would be the addition of the existing UTC percent (Figure 6) to the Preferred UTC percent (Figure 16) and is represented in Figure 17. If every location were planted with the largest canopy-producing tree possible for that location, then the maximum UTC for the City would be achieved. This does not include any changes to infrastructure or development, but existing pervious surface planting space potential only.

The resulting assessment of Holyoke's EJ community indicates there are 712.2 possible acres of land that could be planted with trees. With the current UTC at 26.5%, this is an increase of about 21.2% to a total of 47.7% maximum UTC possible.

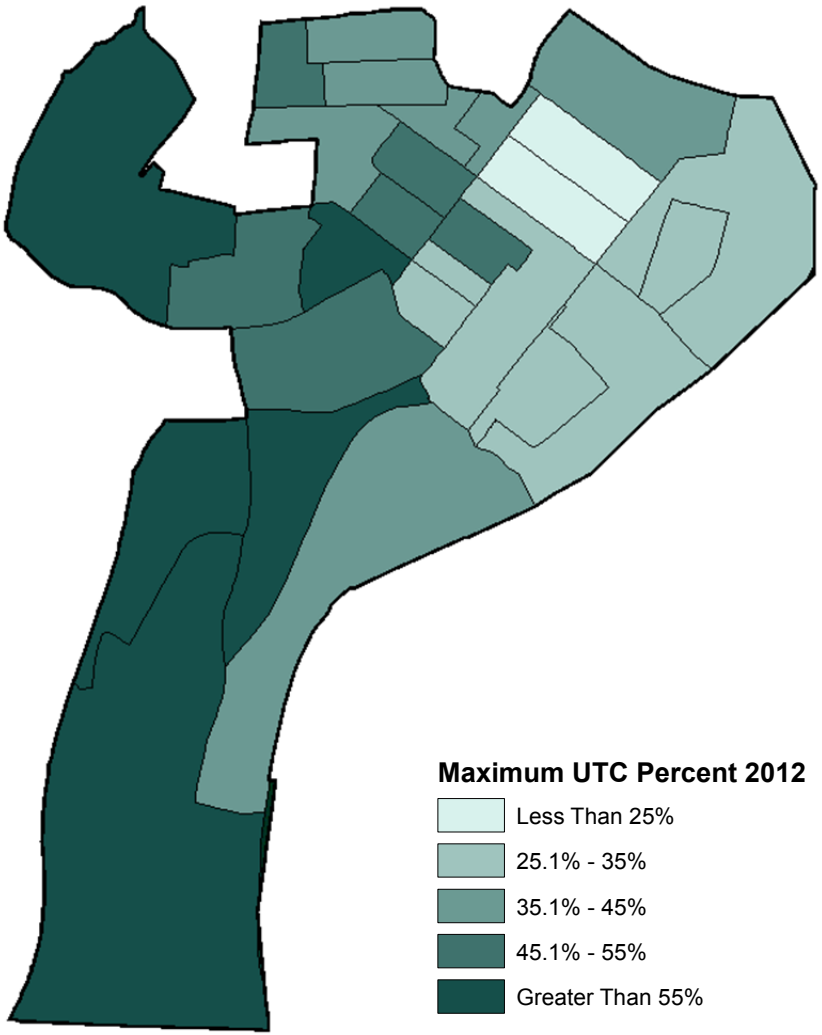


Figure 17. Maximum possible UTC as percent by Block Group for Holyoke's Environmental Justice Community.

The study area was comprised primarily of Urban Residential or Central Business District zones and does not include much of the Suburban Residential area. Due to the elimination of the suburban communities, which often contribute a greater potential for UTC coverage, the American Forests' recommended overall goal of 40% tree canopy coverage (Table 7) may not accurately represent a reasonable goal for the City's EJ community. Given this restriction, the current UTC of 26.5% for Holyoke's EJ community not only surpasses the 25.0% Urban American Forests' Residential Goal but is also significantly higher than the 15.0% Central Business District goal.

The number of acres of additional UTC required, and the number of trees needed to achieve the specified 40%, 35%, or 30% UTC goals, are represented in Table 8. These numbers assume an average crown diameter of 35 feet (970 square feet per tree). Ideally, Holyoke's EJ community would have growth from the current canopy, but the recent trend shows the canopy decreasing. Over the past five years, there have been an average of 55 trees removed by the City annually with virtually no plantings to replace the lost canopy cover. Based on the land cover analysis, the amount of canopy cover loss from 2004 to 2012 indicates an average loss of 70 trees per year (no public/private distinction) over the eight year period, assuming average tree size of 35-foot diameter canopy. In order to hit the American Forests' goals, Holyoke will need to focus on reversing the trend as well as preserving and maintaining what is already there. Once the trend in canopy reduction has been stabilized, Holyoke can then focus on increasing canopy and setting a projected time frame for meeting the goals.

Isolating the possible Preferred Planting Areas in the public property only, there are 2.2% (75 acres) of possible increased canopy (3,395 trees). If all possible public Preferred Planting Areas were planted, the UTC for the EJ community would increase to 28.7%, assuming no further canopy loss. This indicates significant participation is required from private property owners to contribute to the UTC increase beyond 28.7%.

For Holyoke's EJ community, a goal of 30.0% UTC in 30 years, or 5,300 trees planted, is not only an obtainable goal, but also a realistic one. Within this goal, the community should strive to reach 15.0% canopy coverage in the Central Business District to benefit from environmental gains in the core of the City.

Planting 530 trees a year for 10 years is a possible operational and budget strategy that would help meet the 30.0% goal in 30 years. In reality, the anticipated number to be planted would be higher since this strategy assumes a net annual growth of 0.30% and no decrease in current canopy or mortality from current or planted canopy. Because it takes time for trees to establish themselves and reach a canopy spread that contributes significantly to the overall UTC, it is important that these trees be planted within the first 10 years in order to achieve the UTC goal within 30 years. Depending on the anticipated additional loss in current canopy, more trees will also have to be planted in the first ten years to achieve 30.0% canopy cover. Additional funds to plant more trees could be obtained through grants.

Table 8. Number of Acres and Quantity of Trees Required to Reach UTC Goals in Holyoke's Environmental Justice Community

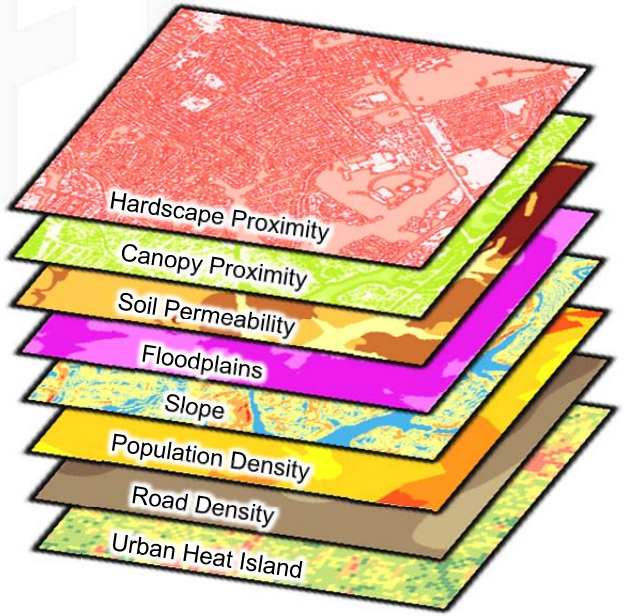
UTC Goal (%)	Additional Acres Required	Number of Trees Required
40%	454	20,600
35%	286	13,000
30%	117	5,300

On April 4, 2014, a press release from the Massachusetts Executive Office of Energy and Environmental Affairs announced that a tree planting program would be funded to reduce energy usage and costs in three cities including Holyoke, MA. For more details on this grant, see the Energy and Environmental Affairs Press Release on April 4, 2014, Patrick Administration Announces Urban Tree Planting Program to Reduce Energy Use. A total of 15,000 trees are anticipated to be distributed in targeted areas across the three cities (~5,000 trees each). The areas in Holyoke may not duplicate the boundaries of this study identically, but this effort would make the goal of 30.0% canopy cover in 30 years more easily attainable and help to reallocate other funds towards reversing current canopy decrease.

As a more ambitious goal, 35.0% canopy cover could also be attainable with extensive private property participation. There is a current trend for decrease in canopy cover and funding must first be allocated to reverse that trend. Existing mature trees contribute a great deal to the UTC and environmental benefits, so maintaining their health is important for the City to gain the benefits of their existing resource. In order to achieve this, Holyoke needs a complete inventory of trees including their risk rating and condition. This can assist the City with budgeting for pruning or removal of all existing poor condition or high risk trees, creating a healthy urban forest canopy on a proactive pruning and removal maintenance cycle, thus reversing the trend in canopy decline. Once the decline in existing canopy has been stabilized, growth from new canopy can contribute to the increased percent cover. Once on track for achieving the goal of 30.0% canopy cover in 30 years, a future vision of 35.0% canopy cover can be established with a new timeline.

Prioritized Planting Plan

Once a goal has been established, target locations within the Preferred Plantable Areas can be prioritized based on satisfying ecological and social needs. The City of Holyoke indicated a desire for UHI effects reduction and stormwater mitigation, as well as information to guide decisions for equal opportunity to access environmental benefits. Planting trees in areas of high and very high need can reduce the risk of soil loss and degradation from storm and flood events as well as increase shade and reduce energy costs from heating and cooling.



To identify planting areas that will return the greatest and most diverse amount of benefits to Holyoke's EJ community, Davey Resource Group assessed a number of environmental and social features, including existing canopy and land cover, soil permeability (where available), riparian areas, urban heat island, slope, road density, and population density. An explanation of the eight environmental and social factors used to prioritize future planting sites is provided in Appendix A. Each of these eight features was used to create individuals grids that were assigned a value between 0 and 4 equating to priority planting levels from Very Low to Very High. The resulting information can then be mapped for individual categories of information, such as UHI priorities (Figure 20, Table 9). By overlaying these grid maps and adding the values at any given point, a priority planting scale can be developed based on the cumulative level of environmental need. This overall priority planting scale can be mapped to create a prioritized planting plan based on combined environmental need (Figure 21, Table 10). A mapbook with detailed prioritized planting plans for each neighborhood within the study area was delivered along with this report.

Additional items were taken into consideration for this final prioritized planting plan, including publicly vs. privately owned property and forest fragmentation, which is encompassed within the canopy proximity data*.

*Planting areas less than 100 square feet were eliminated from this analysis due to irregularly shaped polygons. These locations were omitted because they were found to not have enough suitable planting space. This equals a 240-acre difference in planting area.

Table 9. Priority Planting Level of Holyoke's Environmental Justice Community Based on Urban Heat Island

Priority Level	Number of Locations	Acres
Very Low	1,373	8.83
Low	1,045	277.77
Moderate	1,156	61.54
High	1,408	230.79
Very High	781	133.37
Total		712.29

Table 10. Priority Planting Level of Holyoke's Environmental Justice Community Based on Environmental Need

Priority Level	Number of Locations	Acres
Very Low	1,303	3.20
Low	692	71.07
Moderate	1,398	190.63
High	1,585	339.37
Very High	785	108.03
Total		712.29

Urban Heat Island Threat

- Very Low
- Low
- Moderate
- High
- Very High

Figure 20. Sample of prioritized planting locations in Holyoke's Environmental Justice community based on urban heat island.

Environmental Need

- Very Low
- Low
- Moderate
- High
- Very High

Figure 21. Sample of prioritized planting locations in Holyoke's Environmental Justice community based on environmental need.

Forest Fragmentation

Urban forests provide numerous environmental and socioeconomic benefits, but the benefits to wildlife may not always be fully appreciated. The urban ecosystem is extremely complex and diverse, existing in a multitude of layers formed by small, functional ecosystems that together form a larger system. The overall health of the urban ecosystem depends highly on the ability of the trees, plants, wildlife, insects, and humans to interact collectively. However, a key factor in declining urban health is urban build-up and sprawl, which can lead to the removal and decrease of canopy across a community. Often this effect causes canopies to be fragmented and leads to the degradation of ecosystem health, which in turn leads to a decline in habitat quality and canopy connectivity. This decline results in changes and imbalance to microclimates and increases the risk and susceptibility to invasive species.

As a part of the UTC assessment, Davey Resource Group analyzed Holyoke's existing UTC for fragmentation. This analysis focused on how tree canopy is spatially distributed throughout the EJ community and provided an index displaying the degree of fragmentation (Figure 22). Often, the health and diversity of the overall canopy can be greatly improved by creating linkages between multiple patches of forest. The analysis found that Holyoke's urban forest includes the following:

- **294 acres of Core Canopy.** Tree canopy that exists within and relatively far from the forest/non-forest boundary (i.e., forested areas surrounded by more forested areas).
- **16 acres of Perforated Canopy.** Tree canopy that defines the boundary between core forests and relatively small clearings (perforations) within the forest landscape.
- **344 acres of Edge Canopy.** Tree canopy that defines the boundary between core forests and large non-forested land cover features. When large enough, edge canopy may appear to be unassociated with core forests.
- **239 acres of Patch Canopy**. Tree canopy that comprises a small forested area that is surrounded by non-forested land cover.

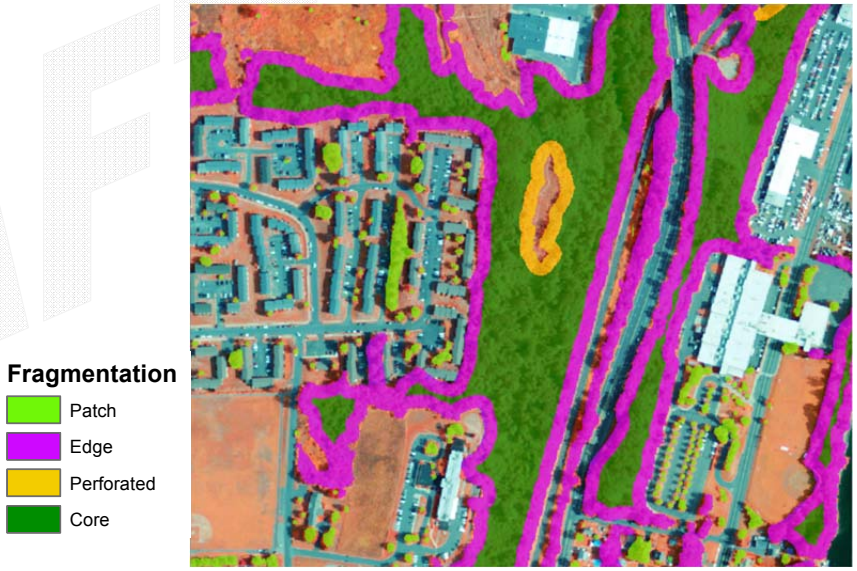


Figure 22. Forest fragmentation identified by canopy structure.

Socio-Economic and Demographic Analysis

Trees directly affect air quality by reducing local air temperatures, removing pollutants from the air, and emitting volatile organic compounds. Lower local air temperatures alter pollution concentrations and reduce ozone (O_3) formation. Air pollutants that are intercepted are absorbed into tree leaves as gasses or retained on leaf surfaces as particles. Those particles that gather on leaf surfaces are re-suspended into the atmosphere, wash off in rain events, or drop to the ground with leaf fall. Pollen, a volatile organic compound, and tree maintenance equipment contribute to the formation of ozone and carbon monoxide. However, trees have a much greater indirect effect on air quality through altering energy use with shade on buildings and slowing wind speeds. Because less electricity is required to cool and heat buildings, there are fewer power plant emissions. More information on this subject can be found in the research by Nowak et al. (2010) with the U.S. Department of Agriculture (USDA) Forest Service.

It is important that all people have equal opportunity to access environmental benefits, including those provided by trees. Analyzing census data and comparing it to tree canopy percentages can offer a wealth of information. For this study, Davey Resource Group downloaded census data information at the tract and block group levels. According to the U.S. Census Bureau definition, census tracts are designed to be relatively homogeneous units with respect to population characteristics, economic status, and living conditions and usually average about 4,000 inhabitants.

Due to the size of the EJ area within the City of Holyoke, the number of census tracts for data analysis was rather small and did not provide enough data points to make appropriate correlations. Therefore, to complete a more robust analysis and identify trends and correlations, Davey Resource Group downloaded Block Group data to analyze the socio-economics and demographics within the EJ area.

Given a wide array of information, Davey Resource Group compiled data for five socio-economic and demographic categories—Population Density, Median Household Income, Ethnicity, Education, and Age. Census data are quite extensive in terms of the amount of breakdowns within each data category. To reduce the number of breakdowns to a much more friendly number, census data were aggregated into approximately 4–5 classes for each category.

While no true statistical analyses were performed using the study's data sets, basic observations on trends have been made between tree canopy coverage and demographic trends. Some of the more interesting and readily observable correlations are presented in this section; however, if true causality and statistically significant correlations are needed, more in-depth research is required.

Trends and Observations

Results of the five socio-economic and demographic categories analyzed are graphed in Figures 23-24. A map of the median income by Block Group (Figure 25) demonstrates where the various income categories are located. This data can be used by the City of Holyoke to help guide planting prioritization to offset historically underserved neighborhoods in the EJ community. Ideally, all possible planting locations will be addressed equally, but in the context of prioritization, socio-economic and demographic data can be used alongside environmental needs data to maximize benefits in all communities. The City of Holyoke may choose how to apply information gained from this data for social benefits, and using it in conjunction with the environmental factors can guide planting location priority.

Canopy percent declines as population density rises.

This may be due to greater levels of infrastructure and more impervious space. This could indicate a need to address development practices to incorporate more trees into the dense infrastructure. As population rises, that also indicates that more people will benefit from each tree in that location.

Canopy percent increases as median income increases.

This indicates that lower income households are not gaining the same amount of environmental benefits as higher income households. For equal opportunity to access the benefits, the initial cost of plantings and on-going maintenance may need to be supplemented in lower income areas.

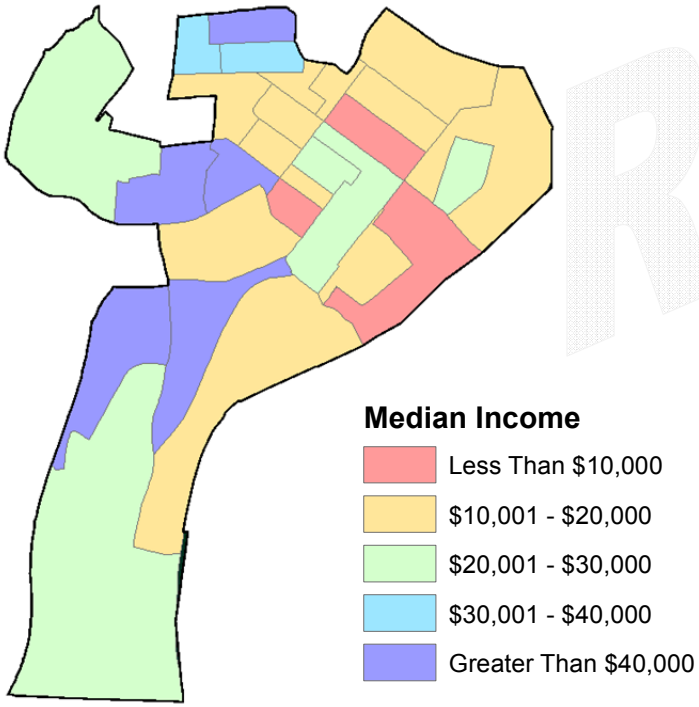


Figure 25. Map of percent median income by Block Group for Holyoke's Environmental Justice community.

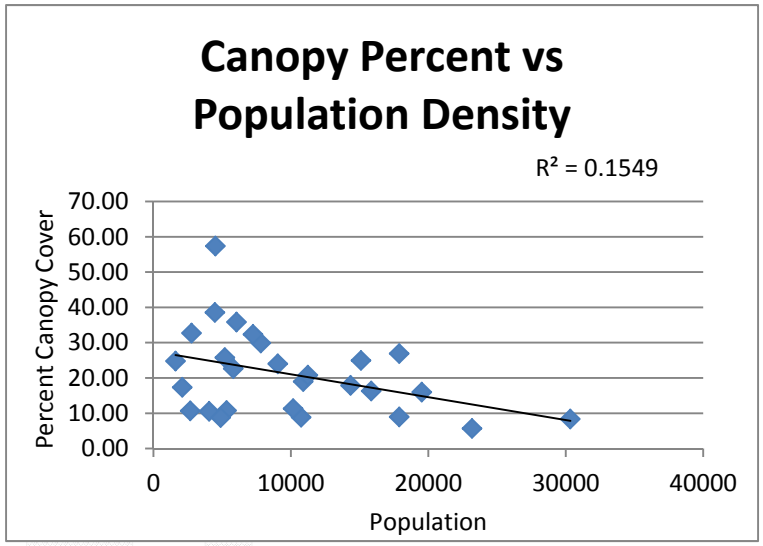


Figure 23. Canopy percent vs. population density for Holyoke's Environmental Justice community.

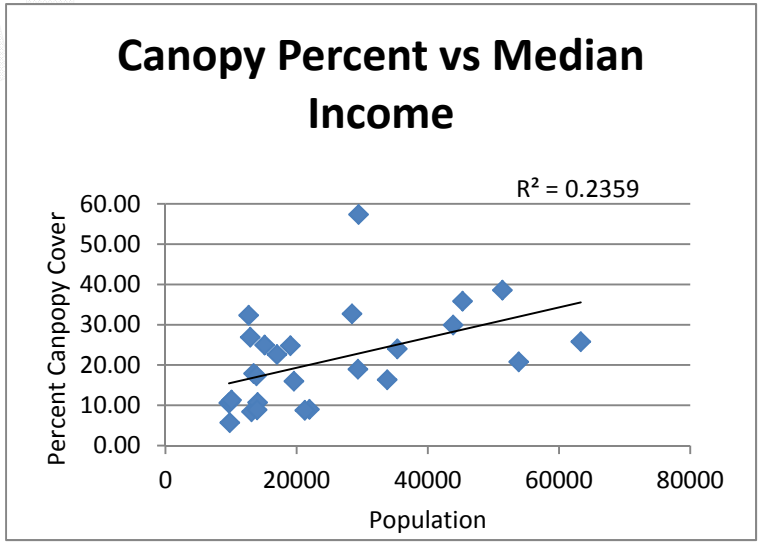
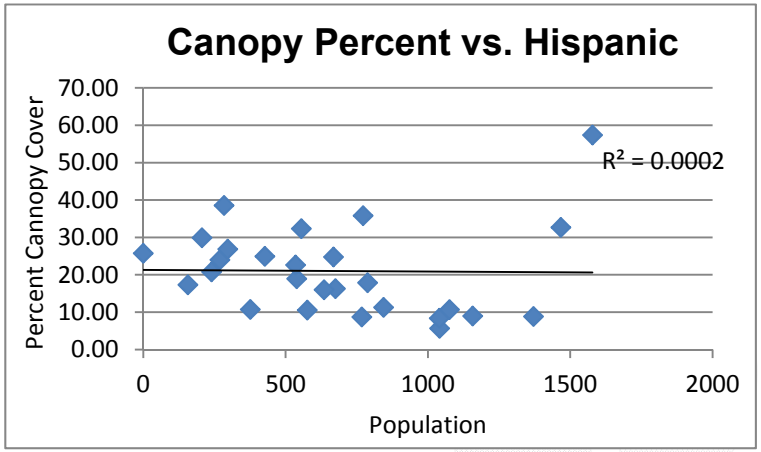
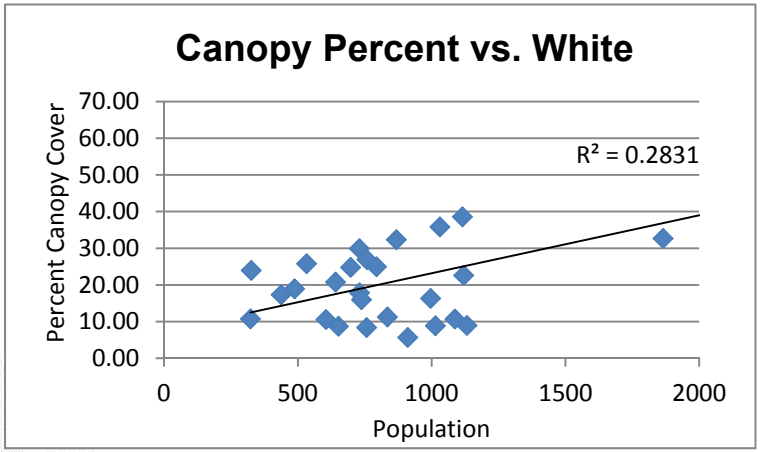


Figure 24. Canopy percent vs. median income for Holyoke's Environmental Justice community.

Canopy percent decreases slightly in areas where Hispanic population increases, and it increases in areas reporting greater ratios of both white and other races.

This indicates that Block Groups with higher Hispanic populations could be addressed for planting opportunities before Block Groups dominated by other races.





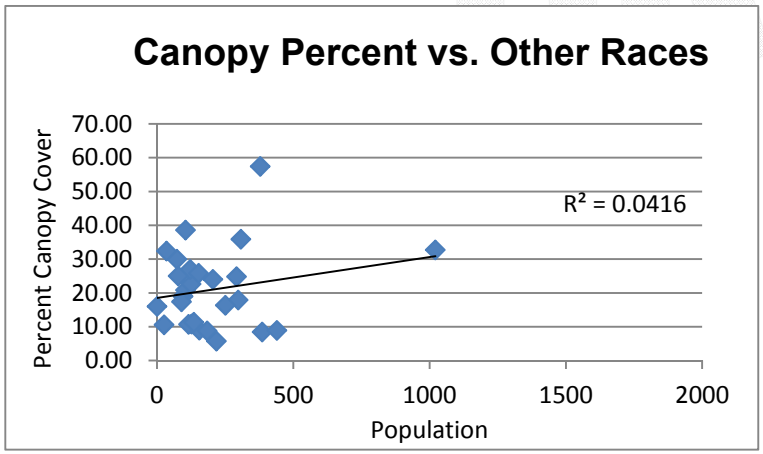


Figure 26. Canopy percent vs. Hispanic, white, and other races for Holyoke's Environmental Justice community.

Canopy percent increases as the population holding a bachelor's or advanced degree increases and decreases as the population holding only an associate's degree or high school diploma increases.

This indicates that lower degree-holding individuals are not gaining the same amount of environmental benefits as higher degree-holding individuals. Locations of this trend may overlap with other trends or may be unique. If unique, this indicates that opportunities for lower degree holding individuals could be addressed for planting before higher degree holding individuals.

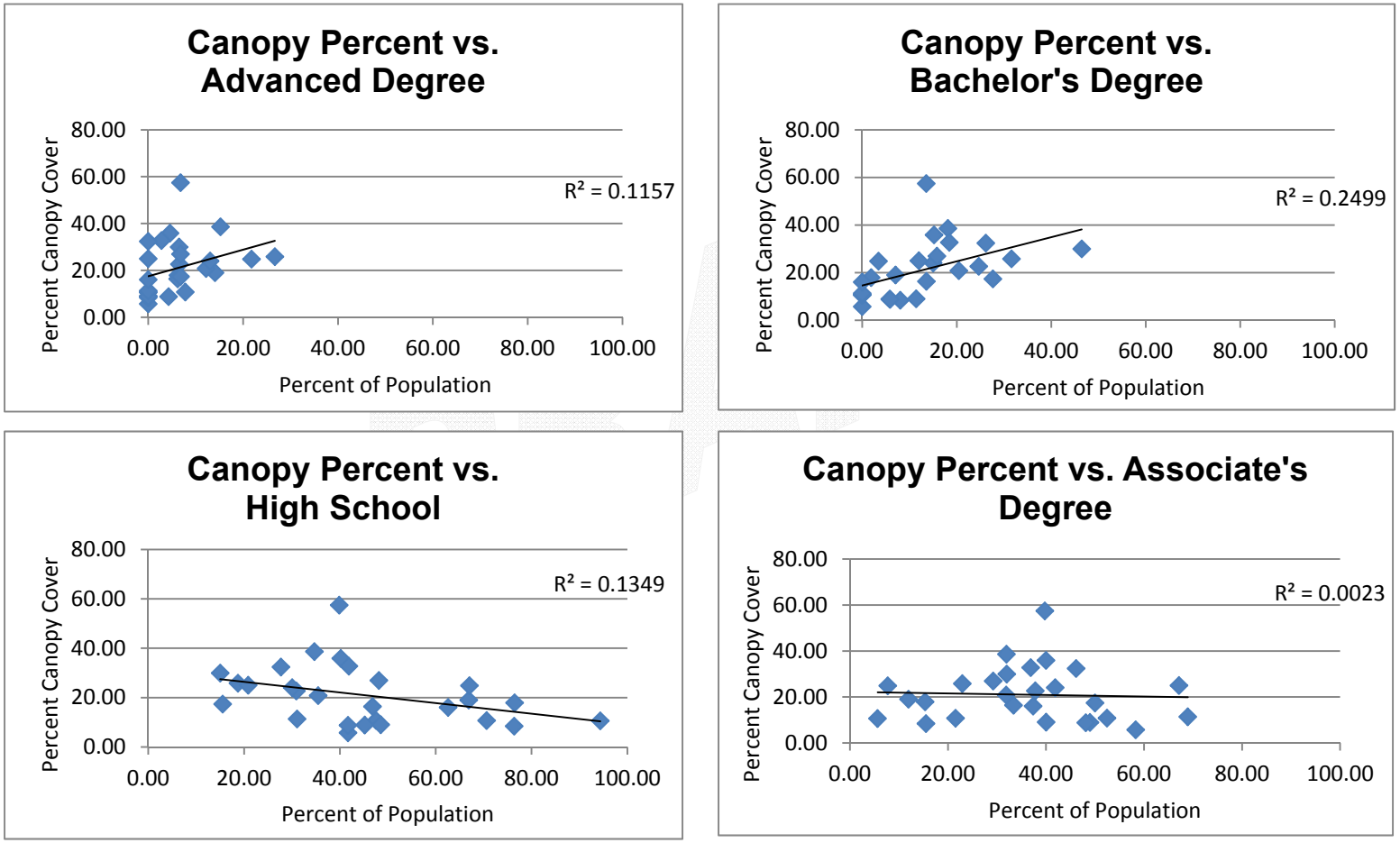
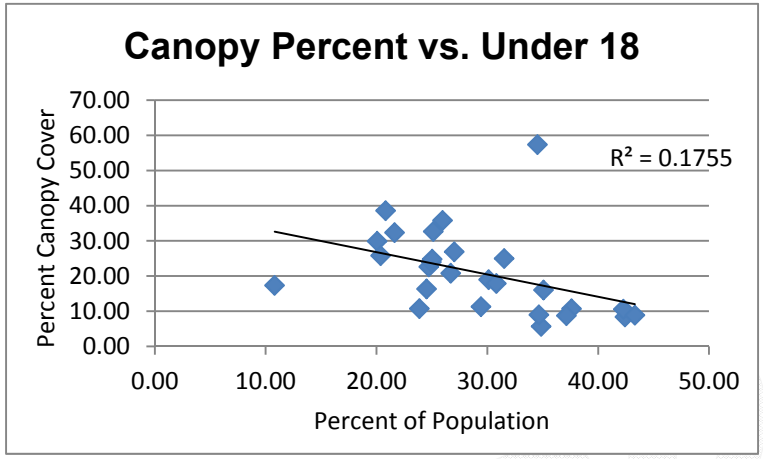


Figure 27. Canopy percent vs. the percent of the population holding an advanced degree, a bachelor's degree, an associate's degree, or a high school diploma for Holyoke's Environmental Justice community.

Canopy percent for ages under 18 and from 18–24 decreases as population increases; whereas, canopy percent for ages 25–44, 45–64, and 65 and up increases as population increases.

This indicates that youth and young adults are not gaining the same access to environmental benefits that older populations have. Prioritizing plantings in these populations could have a greater return on the benefits.



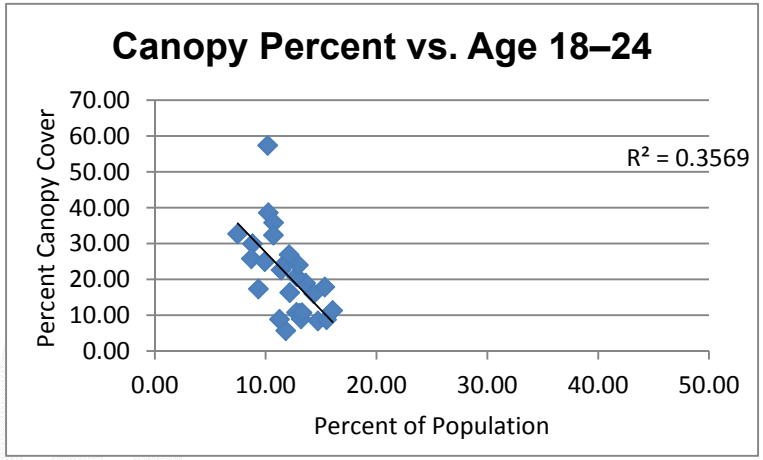
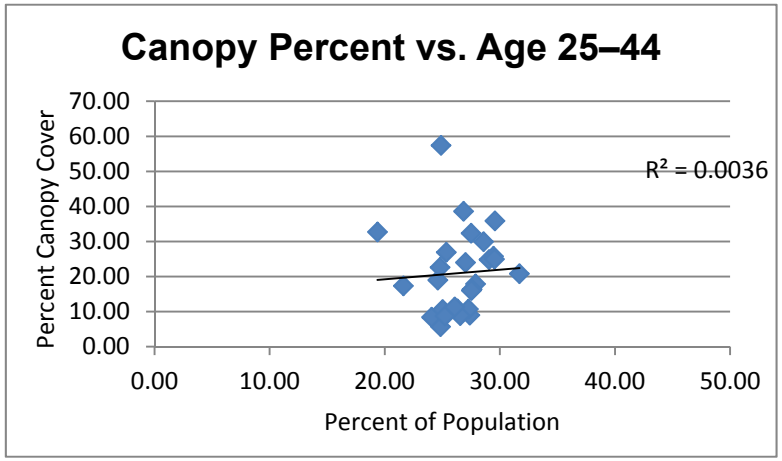
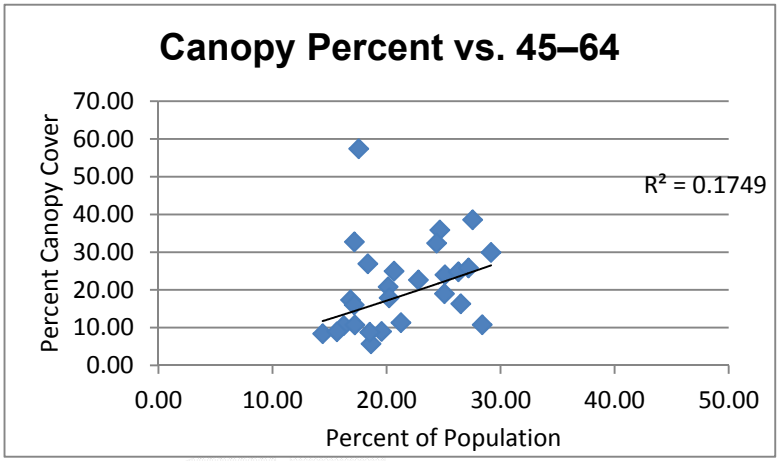


Figure 28. Canopy percent vs. age under 18 and ages 18–24 for Holyoke's Environmental Justice community.





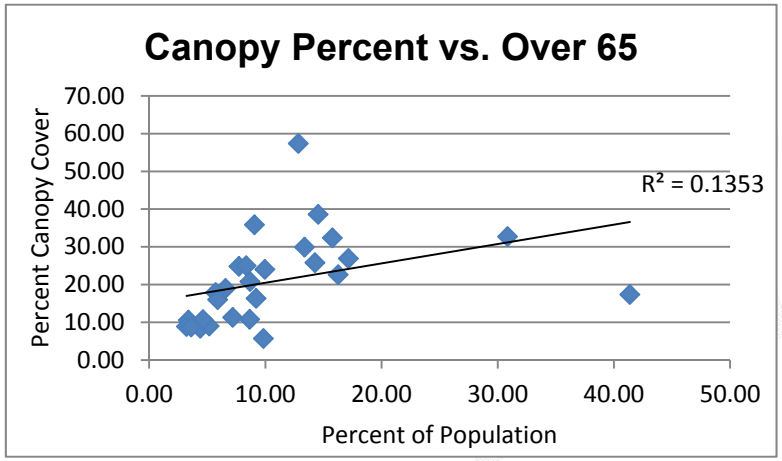
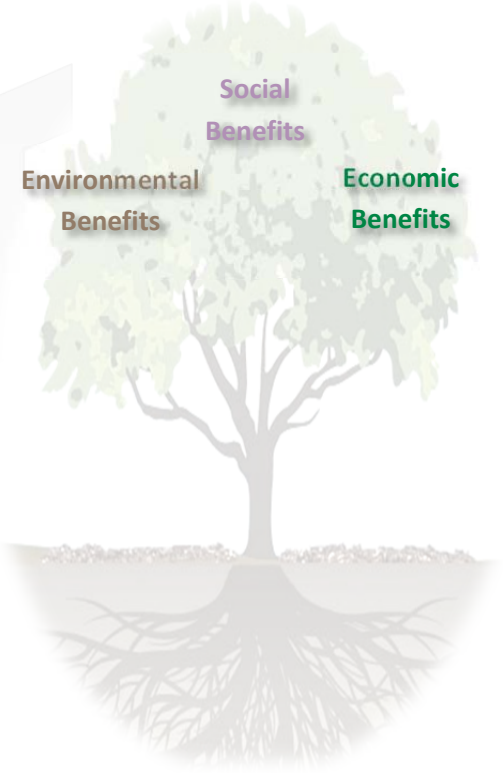


Figure 29. Canopy percent vs. ages 25–44, ages 45–64, and age 65 and over for Holyoke's Environmental Justice community.

Benefits of the Urban Forest

The urban forest plays an important role in supporting and improving the quality of life in urban areas. When properly maintained, trees provide abundant environmental, economic, social, and health benefits far in excess of the time and money invested in their planting, pruning, protection, and removal.

- There is a strong tie between the presence, number, and location of trees and the amount of time inner-city residents spend outdoor in common spaces (Coley 1997). Additionally, the more time residents spend outdoors, the stronger the network they had with their neighbors and the greater the sense of community (Kuo 1998).
- The greater presence of trees along streets and in parks and other green spaces increases adult supervision of children during outdoor activity positively influencing healthy childhood development leading to fewer delinquent behaviors (Kuo 2003).
- Children in green spaces with trees were found more often engaged in play activities than other kinds of activities, and there was also increased creativity (Faber 1998).
- When surrounded by trees, physical signs of personal stress, such as muscle tension and pulse rate, were measurably reduced within 3–4 minutes (Ulrich 1991).
- Employees who see nature from their desks experience 23% less sick time and report greater job satisfaction than those who do not (Wolf 1998b). Hospital patients recovering from surgery with a view of nature required fewer pain relievers, experienced fewer complications, and left the hospital sooner than similar patients who had a view of a brick wall (Ulrich 1984, 1986).
- Trees increase residential property values an average of 7% when present in the yard or neighborhood. Commercial property rental rates were 7% higher when trees were on the property (Wolf 2007).
- On average, consumers will pay about 11% more for goods in landscaped areas, with this figure being as high as 50% for convenience goods (Wolf 1998a, Wolf 1999, and Wolf 2003).
- The quality of landscaping along the routes leading to the business district had a positive influence on consumers' perceptions of the area (Wolf 2000).
- The presence of trees in the urban landscape offers a variety of jobs at all skill and income levels (Casey Trees 2008).
- Trees generate many traditional products for the marketplace that include lumber, pulpwood, hobbyist woods, fruits, nuts, mulch, composting materials, firewood, and nursery plants (Coder 1996).
- Trees moderate temperatures in the summer and winter, saving on heating and cooling expenses (North Carolina State Univ. 2012, Heisler 1986).
- Trees act as mini-reservoirs, helping to slow and reduce the amount of stormwater runoff that reaches storm drains, rivers, and lakes. One hundred mature tree crowns intercept about 100,000 gallons of rainfall per year (U.S. Forest Service 2003).
- Trees help reduce noise levels, cleanse atmospheric pollutants, produce oxygen, absorb carbon dioxide, and lessen ozone production (Nowak 1992).
- Trees can reduce street-level air pollution by up to 60% (Coder 1996). Lovasi (2008) suggested that children who live on tree-lined streets have lower rates of asthma.
- Trees stabilize soil, enhance landscapes, provide habitat for wildlife, and give easier access to environmental education opportunities (National Urban Forestry Unit 2005).
- One well-placed tree provides average savings of $39 in home heating costs each year. (McPherson 2007)



Ecosystem Benefit Analyses

Trees conserve energy, reduce carbon dioxide levels, improve air quality, and mitigate stormwater runoff. In addition, trees provide numerous economic and social benefits.

The ecosystem benefits of the City of Holyoke's UTC resource were quantified using the i-Tree Canopy and CITYGreen models. i-Tree Canopy estimates carbon storage and sequestration and air pollutant removal. Air pollutants included (in estimates) are carbon monoxide (CO), nitrogen dioxide (NO_2), O_3, particulate matter (PM_{10}), and sulfur dioxide (SO_2). TR-55 hydrologic equations created by the USDA were used to model stormwater runoff.

Data analysis shows Holyoke's existing UTC coverage of 26.5% provides an estimated $4,225,855 in annual benefits and savings to the community. Holyoke's entire urban forest removes 56,636 pounds of pollutants from the air annually, a benefit valued at $227,652. Additionally, the community's urban forest stores approximately 136,755 tons of carbon and each year sequesters approximately 4,509 tons of carbon dioxide; these benefits are valued at $2,648,025 (storage) and $87,298 (annual carbon sequestration). Trees also intercept over 20,890,887 cubic feet of runoff every year, a benefit valued at $1,262,880 (Table 11).

Table 11. Annual Ecosystem Benefits Provided by Holyoke's UTC

Ecosystem Factor		2012 UTC 26.50%	
		Units	Value
Air Quality[1] (pounds)	CO	296	$196
	NO_2	6,260	$1,321
	O_3	38,640	$58,672
	SO_2	2,040	$136
	PM_{10}	7,320	$22,874
	$PM_{2.5}$	2,080	$144,453
	Subtotal	56,636	$227,652
Carbon[1] (tons)	Storage	136,755	$2,648,025
	Sequestration	4,509	$87,298
	Subtotal	141,264	$2,735,323
Stormwater[2] (cubic feet)	Runoff	20,890,887	$1,262,880*
	Subtotal	20,890,887	$1,262,880**
	Total		$4,225,855

1. *Air pollution and carbon values are derived using i-Tree Canopy.*
2. *Stormwater values are calculated in CITYGreen. Stormwater values are calculated based on the cost of building man-made structures to hold peak runoff flows. Annual stormwater costs are derived by taking the actual cost of the man-made structures financed at 6% interest.*

Projected Ecosystem Benefits Estimator

Increasing UTC coverage can bring greater economic and environmental benefits to Holyoke's EJ community. Projecting the net change in value can demonstrate the costs or benefits of attaining different goals. Davey Resource Group's Projected Ecosystem Benefits Estimator extrapolates future ecosystem benefits for tree planting projects with different goals. The detailed estimator predicts ecosystem benefits provided by trees in 5-year intervals for up to 40 years after tree planting. It uses unit values derived from the USDA Forest Service Pacific Southwest Research Station. Currently, unit values have been established for 19 climates zones in the United States.

To estimate benefits, the calculator uses resource units derived from tree data collected for a reference city within each climate zone. The reference city for the Northeast climate zone was Queens, New York. The estimator uses resource units and utility costs as well as an estimated number of trees over a period of years to calculate costs and benefits. To account for variable differences in utility costs within the climate zones, the input utility costs are adjustable. The City of Holyoke provided costs for the electricity, natural gas, and stormwater treatment to use for this study.

The results of the estimator will detail benefits of planting new trees over time by tracking their contribution to reducing air pollution, carbon, and stormwater runoff as well as accounting for aesthetics.

Tables 12–15 show the cost-benefit summary of planting one small, medium, and large tree over 40 years using adjusted utility costs for electric ($0.12/kWh), natural gas ($1.017/therm), and stormwater treatment ($0.0005/gallon) for Holyoke's EJ community. Planting one small tree will have a total of $805 in estimated benefits over 40 years with $654 in estimated costs. The net estimated value after 40 years would be $151 in benefits. The net benefits of planting one medium tree would be $810 in benefits and one large tree would net $2,585 in benefits over 40 years. Initial costs are higher, but calculating in five-year increments, benefits would be realized after 10 years and would continue to increase through year 40. If one small, one medium, and one large tree were all planted, the total annual benefits of each tree would be $20 per year over 40 years.

Table 12. Total Net Cost or Savings of a Small, Medium, or Large Tree Over 40 Years.

Planting Interval	Year 5	Year 10	Year 15	Year 20	Year 25	Year 30	Year 35	Year 40
Small	−$393	$33	$62	$101	$142	$181	$130	$151
Medium	−$229	$327	$458	$630	$819	$1,014	$702	$810
Large	−$347	$255	$597	$1,039	$1,132	$1,606	$2,096	$2,585

Table 13. Summary of Benefits Using 40-Year Value

Benefit Factor	Dollars Small	Medium	Large	Total	Percent of Benefit
Electricity (kWh)—Cooling	$134	$350	$1,018	$1,502	21.24%
Natural Gas (kBtu)—Heating	$52	$104	$178	$334	4.72%
Net CO_2 (lb.)	$31	$54	$140	$225	3.19%
Ozone (lb.)	$44	$104	$131	$280	3.95%
Nitrogen dioxide (lb.)	$53	$122	$292	$468	6.62%
Sulfer dioxide (lb.)	$38	$104	$137	$278	3.93%
Particulate matter (lb.)	$65	$214	$268	$548	7.75%
VOCs (lb.)	$2	$5	$19	$26	0.37%
Biogenic VOCs (lb.)	$0	−$26	$398	$371	5.25%
Hydrology (gal.)	$13	$43	$108	$164	2.32%
Aesthetics and Other	$372	$1,085	$1,419	$2,876	40.67%
Grand Total	$805	$2,159	$4,108	$7,072	100.00%

Table 14. Summary of Costs Using 40-Year Values

Cost Factor	Dollars Small	Medium	Large	Total	Percent of Cost
Tree and Planting	$10	$10	$10	$30	25.56%
Pruning	$185	$739	$739	$1,663	35.42%
Remove and Dispose	$77	$101	$130	$309	6.58%
Pest and Disease	$7	$9	$11	$27	0.57%
Infrastructure Repair	$79	$104	$134	$316	6.74%
Clean-Up	$18	$23	$30	$71	1.52%
Irrigation	$0	$0	$0	$0	0.00%
Liability and Legal	$0	$0	$0	$0	0.00%
Admin and Other	$278	$363	$468	$1,109	23.62%
Grand Total	$654	$1,349	$1,522	$3,525	100.00%

Table 15. Net Benefits Using 40-Year Values

	Dollars Small	Medium	Large	Total
Benefits	$805	$2,159	$4,108	$7,072
Costs	$654	$1,349	$1,522	$3,525
Net Benefits	$151	$810	$2,585	$3,547

Table 16 illustrates the total annual ecosystem benefits that the existing UTC provides to Holyoke compared to the goals of 30% UTC and 35% UTC.

Table 16. Projected Ecosystem Benefits Provided by Holyoke's UTC

Ecosystem Factor		2012 UTC 26.50%		Goal: UTC 30%		Goal: UTC 35%	
		Units	Value	Units	Value	Units	Value
Air Quality[1] (pounds)	CO	296	$196	327	$217	383	$254
	NO_2	6,260	$1,321	6,920	$1,458	8,100	$1,707
	O_3	38,640	$58,672	42,640	$64,753	49,940	$75,837
	SO_2	2,040	$136	2,240	$151	2,620	$176
	PM_{10}	7,320	$22,874	8,080	$25,245	9,460	$29,566
	$PM_{2.5}$	2,080	$144,453	2,300	$159,425	2,680	$186,714
	Subtotal	56,636	$227,652	62,507	$251,249	73,183	$294,254
Carbon[1] (tons)	Storage	136,755	$2,648,025	150,929	$2,922,492	176,764	$3,422,738
	Sequestration	4,509	$87,298	4,976	$94,346	5,827	$112,838
	Subtotal	141,264	$2,735,323	115,905	$3,018,838	182,591	$3,535,576
Stormwater[2] (cubic feet)	Runoff	20,890,887	$1,262,880*	20,890,887	$1,262,880	20,008,147	$1,459,668
	Subtotal	20,890,887	$1,262,880**	20,890,887	$1,262,880	20,008,147	$1,459,668
	Total		$4,225,855		$4,532,967		$5,289,498

[1] *Air pollution and carbon values are derived using i-Tree Canopy.*
[2] *Stormwater values are calculated in CITYGreen. Stormwater values are calculated based on the cost of building man-made structures to hold peak runoff flows. Annual stormwater costs are derived by taking the actual cost of the man-made structures financed at 6% interest.*

A Closer Look at Stormwater Benefits

Urban trees help manage stormwater runoff depth, time of concentration, peak flow, and volume (Figure 29). With the presence of trees in the urban environment, there is less need for investment in man-made stormwater structures to accommodate peak flows during storm events. Using TR-55 hydrologic equations, Davey Resource Group has captured how Holyoke benefits from having urban trees.

Holyoke's trees intercept an additional 0.65 inch of runoff depth that would not otherwise be captured. This additional rainfall abstraction increases the time of concentration by slowing down the time it takes for the stormwater flows to reach pre-storm flow rates. The gain of 1.26 hours in time of runoff concentration decreases the peak flow rates by 748 cubic feet per second. By reducing these peak flow rates, Holyoke benefits from slower runoff velocities, which reduces the amount of soil erosion and sediment deposition and reduces overall runoff volumes by 7,930,668 cubic feet of stormwater (Table 17).

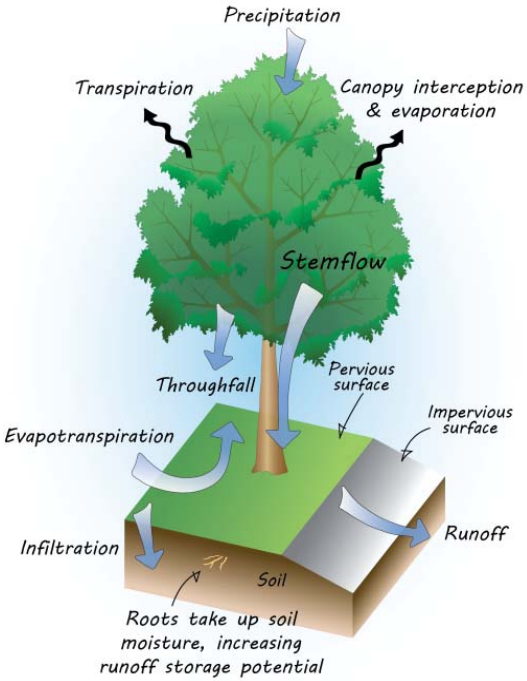


Figure 30. Stormwater benefit process.

Table 17. Stormwater Runoff Benefits Based On 2012 UTC of 26.5%

Stormwater Factor	2012 UTC of 26.50%		
	Without Trees	With Tree Canopy	Gain or Loss
Runoff Depth (inches)	2.36	1.71	Reduced by 0.65
Time of Concentration (hours)	3.87	5.13	Increased to 1.26
Peak Flow (cubic feet per second)	1,694	946	Reduced by 748
Runoff Volume (cubic feet)	28,821,555	20,890,887	Reduced by 7,930,668

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Citywide Planting Strategy

This planting strategy is based on achieving a range of 30% tree canopy cover within 30 years. Growing the existing tree canopy to 30% cover will require planting, preserving, and maintaining both public and private trees. Planting 5,300 trees over the next 10 years will require trees to be planted on both public and private property. This assumes that a mix of large, medium, and small statured trees that appropriately correlate with the planting space size available will be planted. Planting public park and street trees along highway corridors, in parks, and adjacent to parking lots currently under City control can account up to 64% of the trees needed for planting. The approximate remaining 1,900 trees (36% of the new trees) will have to be planted on private property including residential areas, repurposed agriculture lands, or other commercial and industrial areas.

Public Tree Canopy Increase

Approximately 3,400 trees can be planted on public property to reach 30% tree canopy cover Citywide in 30 years. Public areas identified for planting include vacant planting sites within City rights-of-way, highway corridors, parks, and public parking lots. The number of public trees needed to reach the Citywide UTC targets of 30% in 30 years or 35% in future years is provided in Table 18. Since the maximum number of public property Preferred Planting Areas is 3,400, the remaining increase from 30% to 35% canopy cover must be obtained through private property plantings. To reach the UTC goal within 30 years, all trees will need to be planted within the next 10 years.

Private Tree Canopy Increase

In order to reach the target of 1,900 trees to be planted on private property, the City will need to bolster its programs and policies that encourage the planting of new trees by homeowners and discourage the removal of existing trees by homeowners. Encouraging the creation of non-profits and/or community advocacy groups to promote these ideas along with providing training and educational programs on the benefits of trees and proper tree planting and tree care techniques will support these efforts. Maintaining and enforcing a current landscape tree ordinance can help ensure canopy coverage is maintained and that removal of trees are properly documented and mitigated.

Table 18. Total Public and Private Trees Needed to Reach Each of Holyoke's Environmental Justice Urban Tree Canopy Targets

Citywide UTC Target	Total Public Trees Planted by the City	Total Trees to be Planted on Private Property
30%	3,400	1,900
35%	3,400	9,600

Tree Canopy Prediction

Recent history demonstrates a trend towards decline in Holyoke's UTC. Holyoke estimates an average of 55 trees a year were removed by the City and 0–5 trees a year were planted by the City between 2009 and 2014. Through land cover analysis, there was an estimated average net loss of 70 trees a year (with average estimated canopy diameter of 35 feet) from 2004 to 2012. This analysis includes both public and private canopy. The current projected UTC does not include the growth or removal of trees planted by the City and in private areas from 2013 to 2014. In order to achieve the goal of 30.0% canopy cover in 30 years, it has been estimated that Holyoke would need to plant 530 trees a year for 10 years. This assumes no gain or loss in the existing canopy.

Table 19 illustrates three scenarios for projected canopy growth in 10-year increments over 40 years based on planting 530 trees a year for ten years. The first scenario assumes the continued loss of canopy at 70 trees a year throughout the 40 year period. After 30 years, the UTC would be 26.6%, only 0.1% greater than Holyoke's current canopy cover. The second scenario assumes the continued loss of canopy at 70 trees a year for only the first ten years, then a stabilization of existing canopy cover. After 30 years, there would be 28.3% canopy cover and the goal of 30.0% canopy cover would be achieved within 40 years. The third scenario assumes no loss of a canopy over the forty year period and 30.1% canopy cover would be achieved within 30 years and 33.4% canopy cover within 40 years.

These are ambitious goals and will require not only planting but proper care and preservation of the existing tree canopy.

Table 19. Projected Tree Canopy Growth in 10-Year Increments Over40 Years

Planting Scenario	Existing	Projected			
	2014	Year 10	Year 20	Year 30	Year 40
Scenario 1—With Annual Loss Trend[1]	26.52%	26.20%	26.16%	26.64%	28.16%
Scenario 2—Trend Reversed in 10 years[2]	26.52%	26.20%	26.96%	28.28%	30.66%
Scenario 3—Assumed No Loss and Canopy Growth[3]	26.52%	27.46%	28.70%	30.51%	33.38%

[1] *Scenario 1 assumes no canopy growth because the growth trend is negative losing 1.54 acres each year or approximately 70 trees per year.*

[2] *Scenario 2 assumes no canopy loss after 10 year. Trend has been reversed and canopy growth is increasing.*

[3] *Scenario 3 assumes there is no tree mortality and canopy is growing normally.*

Tree Planting

Planting trees is a worthwhile goal as long as tree species are carefully selected and correctly planted. Without upfront planning and follow-up tree care, a newly planted tree may become a future problem instead of a benefit to the community. Appendix B contains additional information about tree planting and tree care.

When planning for a tree planting program:

- Consider the specific purpose of the tree planting.
- Assess the site and know its limitations, for example, overhead wires, confined spaces, and/or soil type.
- Select the species or cultivar that best matches site conditions.
- Examine trees before buying them, and buy for quality.

Trees and Utilities

The Right Tree in the Right Place is a mantra for tree planting used by the Arbor Day Foundation and many utility companies nationwide (Figure 31). Trees come in many different shapes and sizes, and often change dramatically over their lifetime. Some grow tall, some grow wide, and some have extensive root systems. Before selecting a tree for planting, make sure it is the right tree—know how tall, wide, and deep it will be at maturity. Equally important to selecting the right tree is choosing the right spot to plant it. Blocking an unsightly view or creating some shade may be a priority, but it is important to consider how a tree may impact existing utility lines as it grows taller, wider, and deeper. If at maturity, the tree's canopy will likely reach overhead lines, it is best to choose another tree or a different location. Taking the time to consider location before planting can prevent power disturbances and improper utility pruning practices.

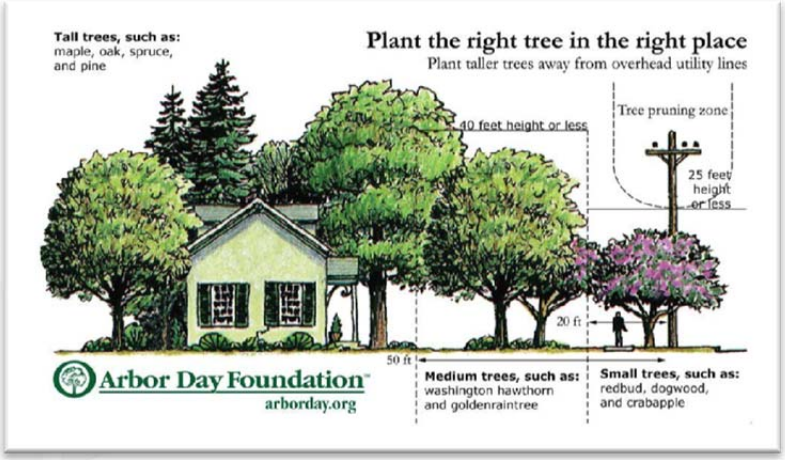

Figure 31. Choosing the right tree for the right place.

Species Diversity

Species diversity affects maintenance costs, planting goals, canopy continuity, and the City's ability to respond to threats from invasive pests or diseases. Davey Resource Group recommends that no single species represent more than 10% and no genus represent more than 20% of the total population. Due to the increased threat of exotic invasive pests and diseases, it is advisable that Holyoke consider adopting a species diversity policy that limits a single species to no more than 10% and a single genus to no more than 20% of the population. A variety of species types can decrease the impact of species-specific pests and diseases by limiting the number of trees that are susceptible. Additionally, a wide variety of tree species may help to limit the impacts from a number of weather events as different trees respond differently to stress.

Tree Species Recommendations

The City of Holyoke is located in USDA Hardiness Zone 6a, which identifies a climatic region where the average annual minimum temperature is between −10°F and −5°F. Tree species selected for planting in Holyoke should be appropriate for this zone. Appendix C lists tree species recommended for planting based on inventory findings; this list provides expected height at maturity for each species and is designed to promote species diversity.

Durability and Low Maintenance

Tree species should be selected for their durability and low-maintenance characteristics. These attributes are highly dependent on site characteristics below ground (soil texture, soil structure, drainage, soil pH, nutrients, road salt, and root spacing). Matching a species to its favored soil conditions is the most important task when planning for a low-maintenance landscape. Plants that are well-matched to their environmental site conditions are much more likely to resist pathogens and insect pests and will, therefore, require less maintenance overall.

Species-Specific Characteristics

A major consideration for street trees is the amount of litter dropped by mature trees. Trees such as *Ailanthus altissima* (tree-of-heaven) have weak wood and typically drop many small branches during a growing season. Others, such as *Liquidambar styraciflua* (American sweetgum), drop high volumes of fruit. In certain species, such as *Ginkgo biloba* (ginkgo), female trees produce offensive smelling/large fruit; male trees, however, produce no fruit. Furthermore, a few species of trees, including *Crataegus* spp. (hawthorn) and *Robinia pseudoacacia* (black locust), may have substantial thorns. Avoid planting these species in high-traffic areas or find varieties that mitigate the nuisance characteristic.

Seasonal Interest

Seasonal interest should also be considered when planning tree plantings. Leaf shape, size, and color can add a variety of interest in the summer. Flowering varieties are particularly welcome in the spring. Deciduous trees that display bright colors in autumn can add a great deal of interest to surrounding landscapes. Exfoliating, patchy bark, or bark of unique color or texture can also add winter interest. Some trees hold their fruit or leaves throughout the winter, adding more texture to the canopy in the long, white winter months.

Student Inventory

Between April and May 2013, students from Westfield State University's GARP: 0219: Land Use Planning and Natural Resources Management class completed a street tree inventory in a portion of Holyoke's EJ community (the study area for this report). The four census tracts they included were 8114, 8115, 8116, and 8117. Students collected tree data, including diameter at breast height (DBH), species, location, available planting sites, and other information. The data collected were compatible with i-Tree software, and ecosystem benefits of the trees were calculated. The results of this inventory can be found in Appendix D.

Public Input

A draft of this report was provided to the public for review on the City of Holyoke's _____ website. The results of their comments, questions, and feedback are summarized in Appendix E.

Recommendations

This report used several available tools and techniques to assess and quantify the benefits of trees as they relate to Holyoke's EJ community. The UTC assessment provided a baseline understanding of tree canopy cover while historical analysis showed recent trends in canopy change. Based on existing conditions, a realistic but ambitious goal for canopy increase was set and prioritized planting locations were identified based on environmental need. This prioritized planting plan could also be evaluated against the most recent demographic data available. Different planting goals gave the ability to quantify tree benefits using i-Tree Canopy and compare the outcomes.

This report examines trends and makes observations about the urban forest performance. Based on the resource analyses, Davey Resource Group recommends the City of Holyoke create a complete Urban Forestry Master Plan with the goal of planting, preserving, and maintaining trees to increase tree canopy. The plan should include budget guidelines, maintenance schedules, policy recommendations, and goals for achieving a healthy urban canopy with equal opportunity for access by all. See Appendix F for recommended components of a comprehensive Urban Forestry Master Plan.

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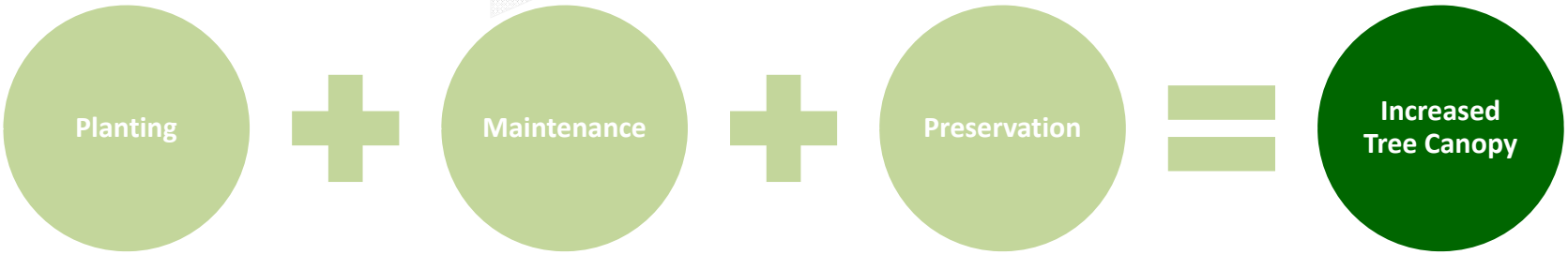

Glossary

Block Group: geographic information system statistical division of a Census Tract generally defined as containing between 600 and 3,000 people

canopy: The part of the tree crown composed of branches, small twigs, and leaves.

canopy cover: As seen from above, it is the area of land surface that is covered by tree canopy.

carbon sequestration: Carbon sequestration is the process by which trees absorb carbon dioxide, release the oxygen, and store the carbon.

census tract: Geographic Information System term for a small, relatively permanent statistical subdivision generally having a population size of 1,200 to 8,000 people, with an optimum size of 4,000 people.

Environmental Justice (EJ) community: The Massachusetts Executive Office of Energy and Environmental Affairs (EEA) defines EJ populations as neighborhoods that meet one or more of the following criteria: Median annual household income is at or below 65% of the statewide median income; 25% or more of the residents are a minority; 25% or more of the residents are foreign born; or 25% or more of the residents are lacking English language proficiency.

geographic information systems (GIS): A technology that is used to view and analyze data from a geographic perspective. The technology is a piece of an organization's overall information system framework. GIS links location to information (such as people to addresses, buildings to parcels, or streets within a network) and layers that information to give you a better understanding of how it all interrelates.

greenspace: Urban greenspace can range from playing fields to highly maintained environments to relatively natural landscapes. They are commonly open to public access; however, urban greenspace may be privately owned. Time spent in an urban greenspace for recreation offers a reprieve from the urban environment among many other benefits.

impervious surface land cover: Hard surfaces that does not allow rainfall to infiltrate the soil and typically includes buildings, parking lots, and roads.

i-Tree Design: Links Google maps and allow uses to sketch their home and see how the trees around their home affect energy use and savings, and other environmental services.

i-Tree Tools: State-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the structure of community trees and the environmental services that trees provide.

i-Tree Vue: The i-Tree Vue tool makes use of freely available National Land Cover Data (NLCD) maps to assess land cover, including tree canopy, and some of the ecosystem services, carbon storage and sequestration, and air quality provided by the current urban forest. The effects of planting scenarios on future benefits can also be modeled using Vue.

land cover: Physical features on the earth mapped from satellite or aerial imagery. Land cover types include bare soils, canopy, impervious, pervious, or open water.

nitrogen dioxide (NO_2): Nitrogen dioxide is a compound typically created during the fossil fuel combustion processes and is a major contributor to smog formation and acid deposition.

open water land cover: The land cover areas mapped as water typically include lakes, oceans, rivers, and streams.

Orthographic projection: a method of projection in which an object is depicted or a surface mapped using parallel lines to project its shape onto a plane.

ozone (O_3): A strong-smelling, pale blue, reactive toxic chemical gas with molecules of three oxygen atoms. It is a product of the photochemical process involving the Sun's energy. Ozone exists in the upper layer of the atmosphere as well as at the Earth's surface. Ozone at the Earth's surface can cause numerous adverse human health effects. It is a major component of smog.

particulate matter: A major class of air pollutants consisting of tiny solid or liquid particles. Examples are soot, dust, smoke, fumes, and mists.

pervious surface land cover: The vegetative area that allows rainfall to infiltrate the soil and typically includes parks, golf courses, and residential areas.

Preferred Plantable Area: The area determined to be plantable by land cover analysis which includes pervious surfaces and bare soils, but excludes land uses designated to remain unplanted for canopy cover, such as agricultural land, cemeteries, golf courses, utility rights-of-way, and recreational and sports fields.

segmentation classification:

street tree: A street tree is a public tree located within a street right-of-way.

species: Fundamental category of taxonomic classification, ranking below a genus or subgenus and consisting of related organisms capable of interbreeding.

sulfur dioxide (SO_2): A strong-smelling, colorless gas that is formed by the combustion of fossil fuels. Sulfur oxides contribute to the problem of acid rain.

tree: A tree is defined as a perennial woody plant that may grow more than 20 feet tall at maturity. Characteristically, it has one main stem, although many species may grow as multi-stemmed forms.

tree benefit: An economic, environmental, or social improvement that benefits the community and results mainly from the presence of a tree. The benefit received has real or intrinsic value associated with it.

urban forest: All public or private trees within a municipality or a community.

urban heat island (UHI) effect: The phenomenon whereby the concentration of structures, pavement, and waste heat from human activity (such as air conditioners and internal combustion engines) results in a slightly warmer envelope of air over urbanized areas when compared to surrounding rural areas.

urban tree canopy (UTC) assessment: A study performed of land cover classes to gain an understanding of the tree canopy coverage, particularly as it relates to the amount of tree canopy that currently exists and the amount of tree canopy that could exist. Typically performed using aerial photographs, GIS data, or Lidar.

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Appendix A
Methodology and Accuracy Assessment

Davey Resource Group Classification Methodology

Davey Resource Group utilized an object-based image analysis (OBIA) semi-automated feature extraction method to process and analyze current high-resolution color infrared (CIR) aerial imagery and remotely-sensed data to identify tree canopy cover and land cover classifications. The use of imagery analysis is cost-effective and provides a highly accurate approach to assessing your community's existing tree canopy coverage. This supports responsible tree management, facilitates community forestry goal-setting, and improves urban resource planning for healthier and more sustainable urban environments.

Advanced image analysis methods were used to classify, or separate, the land cover layers from the overall imagery. The semi-automated extraction process was completed using Feature Analyst, an extension of ArcGIS®. Feature Analyst uses an object-oriented approach to cluster together objects with similar spectral (i.e., color) and spatial/contextual (e.g., texture, size, shape, pattern, and spatial association) characteristics. The land cover results of the extraction process were post-processed and clipped to each project boundary prior to the manual editing process in order to create smaller, manageable, and more efficient file sizes. Secondary source data, high-resolution aerial imagery provided by each UTC city, and custom ArcGIS® tools were used to aid in the final manual editing, quality checking, and quality assurance (QA/QC) processes. The manual QA/QC process was implemented to identify, define, and correct any misclassifications or omission errors in the final land cover layer.

Classification Workflow

1) Prepare imagery for feature extraction (resampling, rectification, etc.), if needed.
2) Gather training set data for all desired land cover classes (canopy, impervious, grass, bare soil, shadows). Water samples are not always needed since hydrologic data are available for most areas. Training data for impervious features were not collected because the City maintained a completed impervious layer.
3) Extract canopy layer only; this decreases the amount of shadow removal from large tree canopy shadows. Fill small holes and smooth to remove rigid edges.
4) Edit and finalize canopy layer at 1:1,500 scale. A point file is created to digitize-in small individual trees that will be missed during the extraction. These points are buffered to represent the tree canopy. This process is done to speed up editing time and improve accuracy by including smaller individual trees.
5) Extract remaining land cover classes using the canopy layer as a mask; this keeps canopy shadows that occur within groups of canopy while decreasing the amount of shadow along edges.
6) Edit the impervious layer to reflect actual impervious features, such as roads, buildings, parking lots, etc., to update features.

7) Using canopy and actual impervious surfaces as a mask, input the bare soils training data and extract them from the imagery. Quickly edit the layer to remove or add any features. Davey Resource Group tries to delete dry vegetation areas that are associated with lawns, grass/meadows, and agricultural fields.

8) Assemble any hydrological datasets, if provided. Add or remove any water features to create the hydrology class. Perform a feature extraction if no water feature datasets exist.

9) Use geoprocessing tools to clean, repair, and clip all edited land cover layers to remove any self-intersections or topology errors that sometimes occur during editing.

10) Input canopy, impervious, bare soil, and hydrology layers into Davey Resource Group's Five-Class Land Cover Model to complete the classification. This model generates the pervious (grass/low-lying vegetation) class by taking all other areas not previously classified and combining them.

11) Thoroughly inspect final land cover dataset for any classification errors and correct as needed.

12) Perform accuracy assessment. Repeat Step 11, if needed.

Automated Feature Extraction Files

The automated feature extraction (AFE) files allow other users to run the extraction process by replicating the methodology. Since Feature Analyst does not contain all geoprocessing operations that Davey Resource Group utilizes, the AFE only accounts for part of the extraction process. Using Feature Analyst, Davey Resource Group created the training set data, ran the extraction, and then smoothed the features to alleviate the blocky appearance. To complete the actual extraction process, Davey Resource Group uses additional geoprocessing tools within ArcGIS®. From the AFE file results, the following steps are taken to prepare the extracted data for manual editing.

1) Davey Resource Group fills all holes in the canopy that are less than 30 square meters. This eliminates small gaps that were created during the extraction process while still allowing for natural canopy gaps.

2) Davey Resource Group deletes all features that are less than 9 square meters for canopy (50 square meters for impervious surfaces). This process reduces the amount of small features that could result in incorrect classifications and also helps processing performance.

3) The Repair Geometry, Dissolve, and Multipart to Singlepart (in that order) geoprocessing tools are run to complete the extraction process.

4) The Multipart to Singlepart shapefile is given to geographic information systems (GIS) personnel for manual editing to add, remove, or reshape features.

Accuracy Assessment Protocol

Determining the accuracy of spatial data is of high importance to Davey Resource Group and our clients. To achieve to best possible result, Davey Resource Group manually edits and conducts thorough QA/QC checks on all urban tree canopy and land cover layers. A QA/QC process was completed using ArcGIS® to identify, clean, and correct any misclassification or topology errors in the final land cover dataset. The initial land cover layer extractions were edited at a 1:1,500 quality control scale in the urban areas and at a 1:2,500 scale for rural areas utilizing the most current high-resolution aerial imagery to aid in the quality control process.

To test for accuracy, random plot locations were generated throughout the city area of interest and verified to ensure that the data meet the client standards. A 3×3 grouping of pixels were compared with the most current National Agriculture Imagery Program (NAIP) high-resolution imagery (reference image) to determine the accuracy of the final land cover layer. Points were classified as either correct or incorrect and recorded in a classification matrix. Accuracy was assessed using four metrics: overall accuracy, kappa, quantity disagreement, and allocation disagreement. These metrics were calculated using a custom Excel® spreadsheet.

Table 1. Land Cover Classification Code Values

Land Cover Classification	Code Value
Tree Canopy	1
Impervious	2
Pervious	3
Bare Soil	4
Open Water	5

Land Cover Accuracy

The following describes Davey Resource Group's accuracy assessment techniques and outlines procedural steps used to conduct the assessment.

1. *Random Point Generation*—Using ArcGIS, 1,000 random assessment points are generated. These points are utilized as "center points" of 3×3 pixel groupings. A box is drawn around the 9-pixel grouping. The 1,000 randomly generated groupings are used for the accuracy assessment. Using a 3×3 grouping of pixels provides more information for the accuracy assessment since adjacent pixels are also looked at. It also increases the number of pixels assessed since nine pixels are assessed instead of just a single pixel. This method reduces the weight of the center pixel from 1 to 1/9 since the 3×3 grouping is assessed as a whole.

2. *Point Determination*—Each pixel of the 3×3 grouping is carefully assessed by the GIS analyst for likeness with the aerial photography. The number of pixels for each land cover type is recorded. The land cover class with the most pixels represented in the pixel grouping is determined to be the correct land cover class, unless visually disputed on high-resolution sub-meter imagery. To record findings, two new fields, CODE and TRUTH, are added to the accuracy assessment point shapefile. CODE is a numeric value (1–5) assigned to each land cover class (Table 1) and TRUTH is the actual land cover class as identified according to the reference image. If CODE and TRUTH are the same for all nine pixels assessed, then the point is counted as a correct classification. Likewise, if none of the pixels assessed match, then the point is classified as incorrect. If the location has been 100% egregiously misclassified (all nine pixels incorrect), then the results have the same outcome as using just a single pixel. The same is true for a correct classification.

   In most cases, distinguishing if a point is correct or incorrect is straightforward. Points will rarely be misclassified by an egregious classification or editing error. Often incorrect points occur where one feature stops and the other begins. Using nine pixels for the accuracy assessment instead of only one pixel allows for better identification of transitional pixels and assignment of varying degrees of correctness. For example, if the center pixel of the nine-pixel box is considered incorrect, the other eight pixels surrounding it may still be classified correctly. Thus, instead of the accuracy of this location being completely correct or completely incorrect, it can be classified as mostly correct as opposed to being classified completely incorrect.

3. *Classification Matrix*—During the accuracy assessment, if a point is considered incorrect, it is given the correct classification in the TRUTH column. Points are first assessed on the NAIP imagery for their correctness using a "blind" assessment—meaning that the analyst does not know the actual classification (the GIS analyst is strictly going off the NAIP imagery to determine cover class). Any incorrect classifications found during the "blind" assessment are scrutinized further using sub-meter imagery provided by the client to determine if the point was incorrectly classified due to the fuzziness of the NAIP imagery or an actual misclassification. After all random points are assessed and recorded; a classification (or confusion) matrix is created. The classification matrix for this project is presented in Table 2. The table allows for assessment of user's/producer's accuracy, overall accuracy, omission/commission errors, kappa statistics, allocation/quantity disagreement, and confidence intervals (Figure 1 and Table 3).

Table 2. Classification Matrix

Reference Data	Classes	Tree Canopy	Impervious Surfaces	Grass & Low-Lying Vegetation	Bare Soils	Open Water	Row Total	Producer's Accuracy	Errors of Omission
	Tree Canopy	242	9	15	1	0	267	90.64%	9.36%
	Impervious	3	398	15	2	0	418	95.22%	4.78%
	Grass/Vegetation	9	12	180	3	0	204	88.24%	11.76%
	Bare Soils	0	8	0	20	0	28	71.43%	28.57%
	Water	0	1	0	0	82	83	98.80%	1.20%
	Column Total	254	428	210	26	82	1,000		
	User's Accuracy	95.28%	92.99%	85.71%	76.92%	100.00%		Overall Accuracy	92.20%
	Errors of Commission	4.72%	7.01%	14.29%	23.08%	0.00%		Kappa Coefficient	0.8890

4. Following are descriptions of each statistic as well as the results from some of the accuracy assessment tests.

   Overall Accuracy—Percentage of correctly classified pixels; for example, the sum of the diagonals divided by the total points ((242+398+180+20+82)/1,000 = 92.20%).

   User's Accuracy—Probability that a pixel classified on the map actually represents that category on the ground (correct land cover classifications divided by the column total [242/254 = 95.28%]).

   Producer's Accuracy—Probability of a reference pixel being correctly classified (correct land cover classifications divided by the row total [242/267 = 90.64%]).

   Kappa Coefficient—A statistical metric used to assess the accuracy of classification data. It has been generally accepted as a better determinant of accuracy partly because it accounts for random chance agreement. A value of 0.80 or greater is regarded as "very good" agreement between the land cover classification and reference image.

   Errors of Commission—A pixel reports the presence of a feature (such as trees) that, in reality, is absent (no trees are actually present). This is termed as a false positive. In the matrix below, we can determine that 4.72% of the area classified as canopy is most likely not canopy.

   Errors of Omission—A pixel reports the absence of a feature (such as trees) when, in reality, they are actually there. In the Table 2 matrix, we can conclude that 9.36% of all canopy classified is actually present in the land cover data.

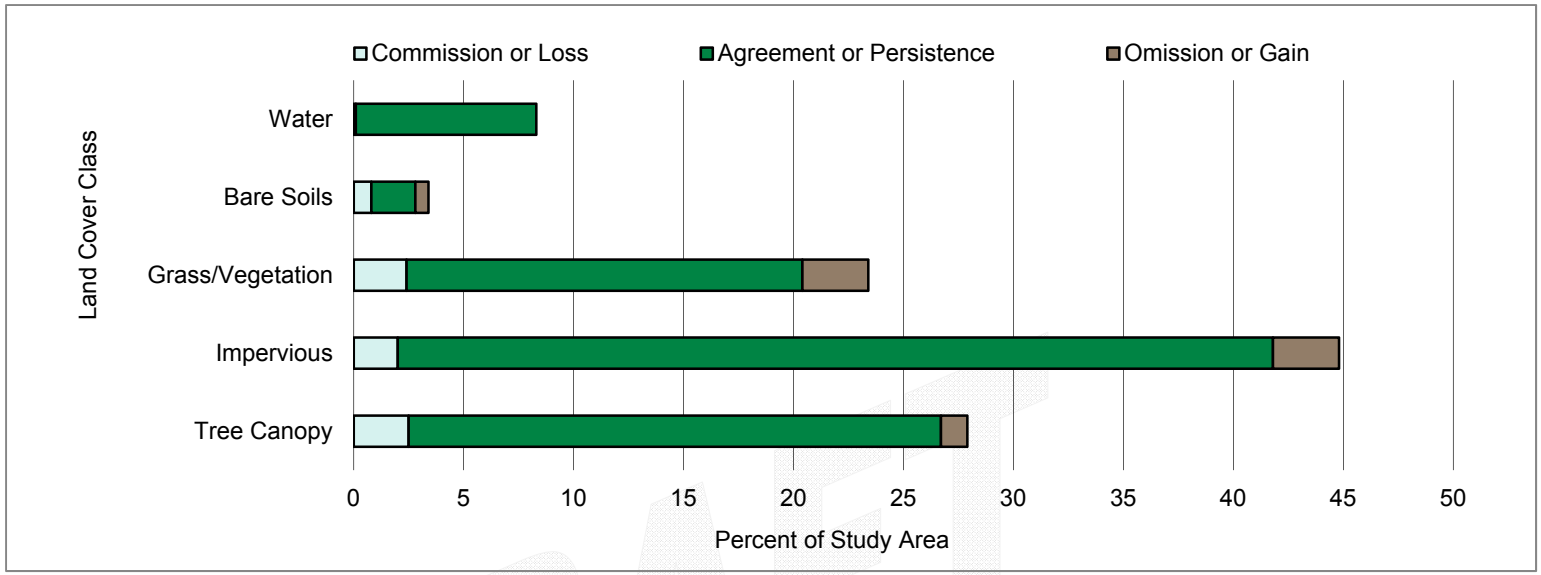


Figure 1. Omission/Commission Errors

A
l
location Disagreement—The amount of difference between the reference image and the classified land cover map that is due to less than optimal match in the spatial allocation (or position) of the classes.

Quantity Disagreement—The amount of difference between the reference image and the classified land cover map that is due to less than perfect match in the proportions (or area) of the classes.

Confidence Intervals—A confidence interval is a type of interval estimate of a population parameter and is used to indicate the reliability of an estimate. Confidence intervals consist of a range of values (interval) that act as good estimates of the unknown population parameter based on the observed probability of successes and failures. Since all assessments have innate error, defining a lower and upper bound estimate is essential.

Table 3. 95% Confidence Intervals, Accuracy Assessment, and Statistical Metrics Summary

Confidence Intervals

Class	Acreage	Percentage	Lower Bound	Upper Bound
Tree Canopy	893	26.52%	25.8%	27.3%
Impervious Surfaces	1,382	41.03%	40.2%	41.9%
Grass & Low-Lying Vegetation	700	20.78%	20.0%	21.5%
Bare Soils	95	2.81%	2.5%	3.1%
Open Water	298	8.86%	8.4%	9.3%
Total	3,368	100.00%		

Statistical Metrics Summary	
Overall Accuracy =	92.20%
Kappa Coefficient =	0.8890
Allocation Disagreement =	6%
Quantity Disagreement =	2%

Accuracy Assessment

Class	User's Accuracy	Lower Bound	Upper Bound	Producer's Accuracy	Lower Bound	Upper Bound
Tree Canopy	95.3%	93.9%	96.6%	90.6%	88.9%	92.4%
Impervious Surfaces	93.0%	91.8%	94.2%	95.2%	94.2%	96.3%
Grass & Low-Lying Vegetation	85.7%	83.3%	88.1%	88.2%	86.0%	90.5%
Bare Soils	76.9%	68.7%	85.2%	71.4%	62.9%	80.0%
Open Water	100.0%	100.0%	100.0%	98.8%	97.6%	100.0%

Ecosystem Benefits Estimator

Stormwater Modeling and Prioritized Plantable Area

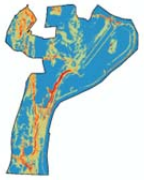
CITYGreen®

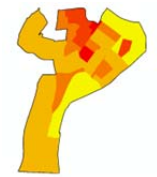
Stormwater: Stormwater assessment was completed using the TR-55 hydrologic equations created by the U.S. Department of Agriculture for modeling stormwater runoff. These equations are commonly used to assess stormwater runoff in urban watersheds by generating a curve number. This number is correlated with hydrologic soil groups which identify a soil's permeability. In addition, the curve number also uses current land cover as an input. To calculate runoff, the equation uses rainfall data, potential maximum retention, and initial abstraction. CITYGreen® for ArcView® 3.x software was utilized to quantify the monetary and unit values of pollution reduction and stormwater.

Prioritized Plantable Scale

The prioritized planting scale (PPS) is a weighted analysis using multiple environmental variables and data from an urban tree canopy assessment. By using the results of this weighted analysis, the City of Holyoke can focus their efforts on locations with higher priority to increase tree canopy. The priority scale was calculated by combining a weighted sum approach with statistics to rank each feature in the dataset. For the purposes of this project, each parcel within the Environmental Justice community boundary of Holyoke was ranked on a scale from 0 (lowest priority) and 100 (highest priority) with a higher value being indicative of a high environmental need for tree canopy as well as having a high percentage of available planting space. An area can have a high priority of environmental need for tree canopy, but if there were very small amounts of planting space, that area will have a lower value on the PPS. This scale can help decision-makers formulate planting strategies by determining areas in need of tree canopy withfeasible amounts of planting space. The last part of the ranking includes a public/private property designation to help prioritize locations since planting on public property is much easier than planting on private property. By combining all three factors (environmental need, available planting space, and public/private property) and normalizing their respective rankings, an aggregate PPS score was created.

Environmental and Social Factors

Factor	Justification
	<u>Floodplain:</u> A floodplain is an area of land adjacent to a stream or river that stretches from the banks of its channel to the base of the enclosing valley walls and experiences flooding during periods of high discharge. Floodplains can support particularly rich ecosystems, both in quantity and diversity. Protecting them is ecologically important.
	<u>Hydrologic Soil Group:</u> Soils are assigned groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The soils have four groups (A, B, C, and D). *A* soils have a high infiltration rate (low runoff potential) while *D* soils have slow infiltration rates (high runoff).
	<u>Slope:</u> Slope is a measure of change in elevation. It is a crucial parameter in several well-known predictive models used for environmental management. A higher degree of slope increases the velocity of stormwater runoff causing a greater risk of erosion due to sheeting, especially if slopes are bare.
	<u>Hardscape Proximity:</u> Impervious surfaces vastly increase the amount of runoff during storm events. By identifying these locations and their surroundings, measures can be taken to reduce the amount of runoff by planting trees close to hardscapes.
	<u>Canopy Proximity:</u> Canopy fragmentation has many ecological downsides by degrading the overall health of the trees and wildlife habitat. It is essential to close as many gaps as possible and create more connectivity to increase biodiversity and canopy health.

	<u>Road Density:</u> The amount of road density signifies how much noise and air pollution are being released in the atmosphere. Controlling these factors helps maintain quieter neighborhoods as well as reduced levels of air pollution emissions such as carbon dioxide, ozone, and particulate matter.
	<u>Population Density:</u> Population density represents the number of people within a given area. Having greater amounts of people within an area attracts the need for more trees to aesthetically improve the urban landscape. By planting in areas with higher population density, there is more return on investment because more people receive this benefit.
	<u>Urban Heat Island:</u> An urban heat island is a metropolitan area that is significantly warmer than its surrounding rural areas due to human activities. The main cause of the urban heat island effect is from the modification of land surfaces, which use materials that effectively store short-wave radiation. Reducing the effects of urban heat island provides great health and social benefits to the community.

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Appendix B
Tree Planting Tips

To ensure a successful tree planting effort:

- Handle trees with care. Trees are living organisms and are perishable. Protect trees from damage during transport and when loading and unloading. Use care not to break branches, and do not lift it by the trunk.
- If trees are stored prior to planting, keep the roots moist.
- Dig the planting hole according to the climate. Generally, the planting hole is two to three times wider than and not quite as deep as the root ball. The root flair is at or just above ground level.
- Fill the hole with native soil unless it is undesirable; in which case, add soil amendments as appropriate for local conditions. Gently tamp and add water during filling to reduce large air pockets to ensure a consistent medium of soil, oxygen, and water.
- Stake the tree as necessary to prevent it from shifting too much in the wind.
- Add a thin layer (1 to 2 inches) of mulch to help prevent weeds and keep the soil around the tree moist. Do not allow mulch to touch the trunk.

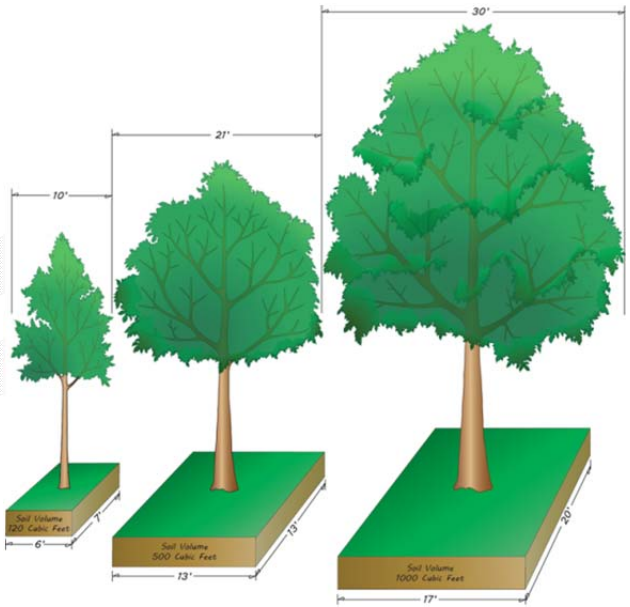

Illustration based on the work of Casey Trees, 2008.

Newly Planted and Young Tree Maintenance

Equal in importance to planting trees is caring for them after they are planted. After planting a tree, it must receive maintenance for several years.

Initially, watering is the key to survival; new trees typically require at least 60 days of watering to establish. Determine how often to irrigate trees based on time of planting, drought status, species selection, and site condition.

Mulch can be applied to the growspace around a newly planted tree (or even a more mature tree) to ensure that no weeds grow, the tree is protected from mechanical damage, and the growspace is moist. Mulch should be applied in a thin layer, generally one to two inches, and the growing area covered. Mulch should not touch the tree trunk or be piled up around the tree.

Life-Long Tree Care

After the tree is established, it will require routine tree care, which includes inspections, routine pruning, and watering, plant health care, and integrated pest management as needed.

The City should employ qualified arborists to provide most of the routine tree care. An arborist can determine the type of pruning necessary to maintain or improve the health, appearance, and safety of trees. These techniques may include eliminating branches that rub each other; removing limbs that interfere with wires and buildings; or that obstruct streets, sidewalks or signage; removing dead, damaged, or weak limbs that pose a hazard or may lead to decay; removing diseased or insect-infested limbs; creating better structure to lessen wind resistance and reduce the potential for storm damage; and removing branches, or thinning, to increase light penetration.

An arborist can help decide whether a tree should be removed and if so how urgent the removal is. Additionally, an arborist can provide advice about and perform tree maintenance when disasters such as storms or droughts occur. Storm-damaged trees can often be dangerous to remove or trim. An arborist can assist in advising or performing the job in a safe manner, while reducing further risk of damage to property.

Plant Health Care, a concept of preventive maintenance to keep trees in good health, will help a tree better defend itself against insects, disease, and site problems. Arborists can help determine proper plant health so the City's tree population will remain healthy, providing benefits to the community for as long as possible.

Integrated Pest Management is a process involving common sense and sound solutions for treating and controlling pests. These solutions incorporate basic steps: identifying the problem, understanding pest biology, monitoring trees, and determining action thresholds. The practice of Integrated Pest Management can differ dramatically site by site, individual tree by individual tree; a qualified arborist will be able to make sure that the City's trees are properly diagnosed and that a beneficial and realistic action plan is developed.

Cabling or bracing for added support to branches with weak attachment, aeration to improve root growth, and installation of lightning protection systems are also practices which which the arborist can help.

Educating the community in basic tree care is a good way to promote the City's urban forestry program and encourage tree planting on private property. The City should encourage citizens to water trees on the ROW adjacent to their homes and to reach out to the City if they notice any changes in the trees such as: signs or symptoms of pests, early fall foliage, or new mechanical or vehicle damage.

Appendix C
Suggested Tree Species

Proper landscaping and tree planting are critical components of the atmosphere, livability, and ecological quality of a community's urban forest. The tree species listed below have been evaluated for factors such as size, disease and pest resistance, seed or fruit set, and availability. The following list is offered to assist all relevant City personnel in selecting appropriate tree species. These trees have been selected because of their aesthetic and functional characteristics and their ability to thrive in the soil and climate (USDA Hardiness Map Zone 6a with minimum temperatures of -10 to -5 Fahrenheit) conditions found throughout the state of Massachusetts.

This suggested species list was compiled through the use of the references *Dirr's Hardy Trees and Shrub's* (Dirr 1997), *Dirr's Trees and Shrubs for Warm Climates* (Dirr 2002), and *Manual of Woody Landscape Plants (5th Edition)* (Dirr 1998). This list is not inclusive, and the listed species are offered only as recommendations based on Davey Resource Group's experience. Note that tree availability in the nursery trade varies considerably.

Deciduous Trees

Large Trees: Greater than 45 Feet in Height at Maturity

Botanical Name	Common Name	Cultivar/Notes
Acer rubrum	red maple	'Autumn Flame'; 'Red Sunset'
Acer saccharum	sugar maple	'Green Mountain'
Celtis laevigata	sugarberry	'All Seasons'; 'Magnifica'
Celtis occidentalis	hackberry	
Cercidiphyllum japonicum	katsuratree	
*Eucommia ulmoides**	hardy rubbertree	
*Ginkgo biloba***	ginkgo	
*Gymnocladus dioicus***	Kentucky coffeetree	
Nyssa sylvatica	black gum	
Platanus × acerifolia	London planetree	'Bloodgood'
Quercus bicolor	swamp white oak	
Quercus imbricaria	shingle oak	
Quercus rubra	northern red oak	
Quercus shumardii	Shumard oak	
Tilia cordata	littleleaf linden	
Tilia tomentosa	silver linden	
Ulmus parvifolia	Chinese elm	'Dynasty'
Zelkova serrate	Japanese zelkova	'Green Vase'

Medium Trees: 31 to 45 Feet in Height at Maturity

Botanical Name	Common Name	Cultivar/Notes
Acer truncatum	Shantung maple	
Carpinus betulus	European hornbeam	'Fastigiata'
Cladrastis kentukea	American yellowwood	
Corylus colurna	Turkish filbert	
Gleditsia triacanthos	honeylocust	inermis
Koelreuteria paniculata	goldenraintree	
Maackia amurensis	Amur maackii	
Ostrya virginiana	eastern hophornbeam	
Phellodendron amurense	Amur corktree	
Prunus maackii	Amur chokecherry	
Prunus sargentii	Sargent cherry	
Prunus × yedoensis	Yoshino cherry	
Quercus acutissima	sawtooth oak	

Small Trees: 15 to 30 Feet in Height at Maturity

Botanical Name	Common Name	Cultivar/Notes
Acer buergerianum	trident maple	
Acer campestre	hedge maple	
Acer griseum	paperbark maple	
Acer tataricum	Tatarian maple	
Acer tataricum ginnala	Amur maple	
Acer triflorum	three-flower maple	
Aesculus × carnea	red horsechestnut	
Amelanchier × grandiflora	apple serviceberry	'Autumn Brilliance'
Carpinus caroliniana	American hornbeam	
Cercis canadensis	eastern redbud	
*Chionanthus retusus**	Chinese fringetree	use tree form only

Small Trees: 15 to 30 Feet in Height at Maturity (Continued)

Botanical Name	Common Name	Cultivar/Notes
*Chionanthus virginicus**	white fringetree	use tree form only
Cornus florida	flowering dogwood	
Cornus kousa	kousa dogwood	
*Cornus mas**	Corneliancherry dogwood	
*Cornus officianalis**	Japanese Cornel dogwood	
*Cotinus obovatus**	American smoketree	use tree form only
Crataegus crusgalli	cockspur hawthorn	inermis
Crataegus laevigata	English hawthorn	'Superba'
*Crataegus phaenopyrum**	Washington hawthorn	
Crataegus viridis	green hawthorn	'Winter King'
Crataegus × lavallei	Lavalle hawthorn	
*Magnolia ×**	Galaxy hybrid magnolia	'Galaxy'
Magnolia grandiflora	Southern magnolia	'Edith Bogue', 'Bracken's Brown Beauty'
Malus spp.	flowering crabapple	use disease-free only
Oxydendrum arboreum	Sourwood	
Parrotia persica	Persian parrotia	use single-stem form only
Prunus serrulata	Japanese flowering cherry	'Shirotae'
Prunus subhirtella	Higan cherry	'Autumnalis'; 'Rosy Cloud'
Prunus virginiana	common chokecherry	'Schubert'
Prunus × incamp	Okame cherry	'Okame'
Stewartia koreana	Korean stewartia	
Stewartia monadelpha	tall stewartia	
Syringa reticulata	Japanese tree lilac	'Ivory Silk'; 'Summer Snow'
Zelkova serrate	Japanese zelkova	'Wireless'

Appendix D
Westfield State University Inventory and i-Tree Report

DRAFT

Inventory of Holyoke Street Trees

July 2013
Westfield State University
GARP 0219:
Land Use & Natural Resource Planning

This work was completed by the members of the Westfield State University class GARP 0219: Land Use Planning and Natural Resource Management during April-May 2013. Members included: Travis Aiken, Wally Alston, Jose Alves Nick Armata, Ryan Daly, Pat Deschenes Mark Difiore, Nadine Lee, Stephanie Lenhardt, LeeAnne MacGillivray, Stephanie Pelletier, Audrey Piubeni, Kyle Richard, Ola Smialek, Chadwick Snow, Robert Wagner, Merrill Wilson, Nicole Wrenn, and Assistant Professor Marijoan Bull, PhD, AICP.

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Westfield
STATE UNIVERSITY
Founded 1838

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BACKGROUND

As part of its commitment to livability and sustainability the City of Holyoke is interested in greening the City. One part of this work is a focus on the trees in the City, and more particularly, the trees the City controls – those within the street right-of-way or in parks. During the fall of 2012, Andrew Smith, Conservation Director, Jeff Burkott, Principal Planner, John Twohig, Tree Warden, and Professor Marijoan Bull met to discuss how students could assist Holyoke in assessing the conditions of the street trees in the City. The goal was to create a data base on the City's street trees for use in allocating maintenance resources and planning for the future. In addition, the spring 2013 work was designed to pilot a protocol for completing this work, with a focus on the downtown area (see Map 1).

PROTOCOL

A standard form was produced for students to complete with codes for the following fields: condition; species; diameter-at-breast height; conflicts with wires; and type of planting (see Figures 1 and 2). The GPS coordinates for each tree was recorded and an open field for making other notes was also provided. Species was limited to the top 12 students were likely to encounter in the City. It is worth noting the form was in part devised to make it compatible with the data required for input in the itree software package developed by the USDA Forest Service (see below and http://www.itreetools.org/). Students were also asked to note the location of any empty street grates they found.

Research shows that shoppers in well-landscaped business districts are willing to pay more for parking and up to 12% more for goods and services.[1]

Teams of 3-4 students went into the field equipped with a clipboard, tree ID field pages, a measuring tape (read diameter in cm through circumference measurement), GPS unit, and map of the area.

Students walked blocks staying on one side of the street and rounding the entire block, filling in the forms tree by tree. Students noted any features or conditions they felt worth noting (such as trash present in the tree, tree suffered fire damage, tree a public danger, etc.) on the form in the open column.

The class worked two afternoons a week from April 1 – May 3, 2013. During this period students inventoried over 450 trees, covering all the blocks within Census Tract 8115 and a portion of the blocks within Census Tract 8116 (see Map 2). It

should be noted during the early weeks identification of species was a challenge as there was no vegetation to confirm species. For this reason the species is perhaps the weakest component of the data set. In addition, species ID is missing from some entries due to the fact many of the student teams were novices in tree ID.

USE THE CODES ON THE OTHER SHEET TO FILL IN SPECIES, CONDITION, PLANTING SITE, WIRES, AND SIDEWALK CONDITIONS

Tree ID	Species (See Codes)	DBH (cm)	Condition (1-4)	GPS_Lat	GPS_Long	Height (est)	Planting Site (See Codes)	Wires (See Codes)	Sidewalk (See Codes)	Survey Date	Comments

Figure 1: Sample Inventory Sheet

Species Code	Scientific Name	Common Name	Tree Type	SPP Value Assignment
TIAM	Tilia americana	American basswood	BDL	TITO
GIBI	Ginkgo biloba	Ginkgo	BDL	FRPE
FRPE	Fraxinus pennsylvanica	Green ash	BDL	FRPE
GLTR	Gleditsia triacanthos	Honeylocust	BDL	GLTR
TICO	Tilia cordata	Littleleaf linden	BDL	TICO
ACPL	Acer platanoides	Norway maple	BDL	ACPL
QUPA	Quercus palustris	Pin oak	BDL	FRPE
ACRU	Acer rubrum	Red maple	BDL	BDL OTHER
ACSA2	Acer saccharum	Sugar maple	BDL	ACSA2
FRAM	Fraxinus americana	White ash	BDL	FRAM
ACSA1	Acer saccharinum	Silver maple	BDL	ACSA1
PYCA	Pyrus calleryana	Callery pear	BDS	PYCA

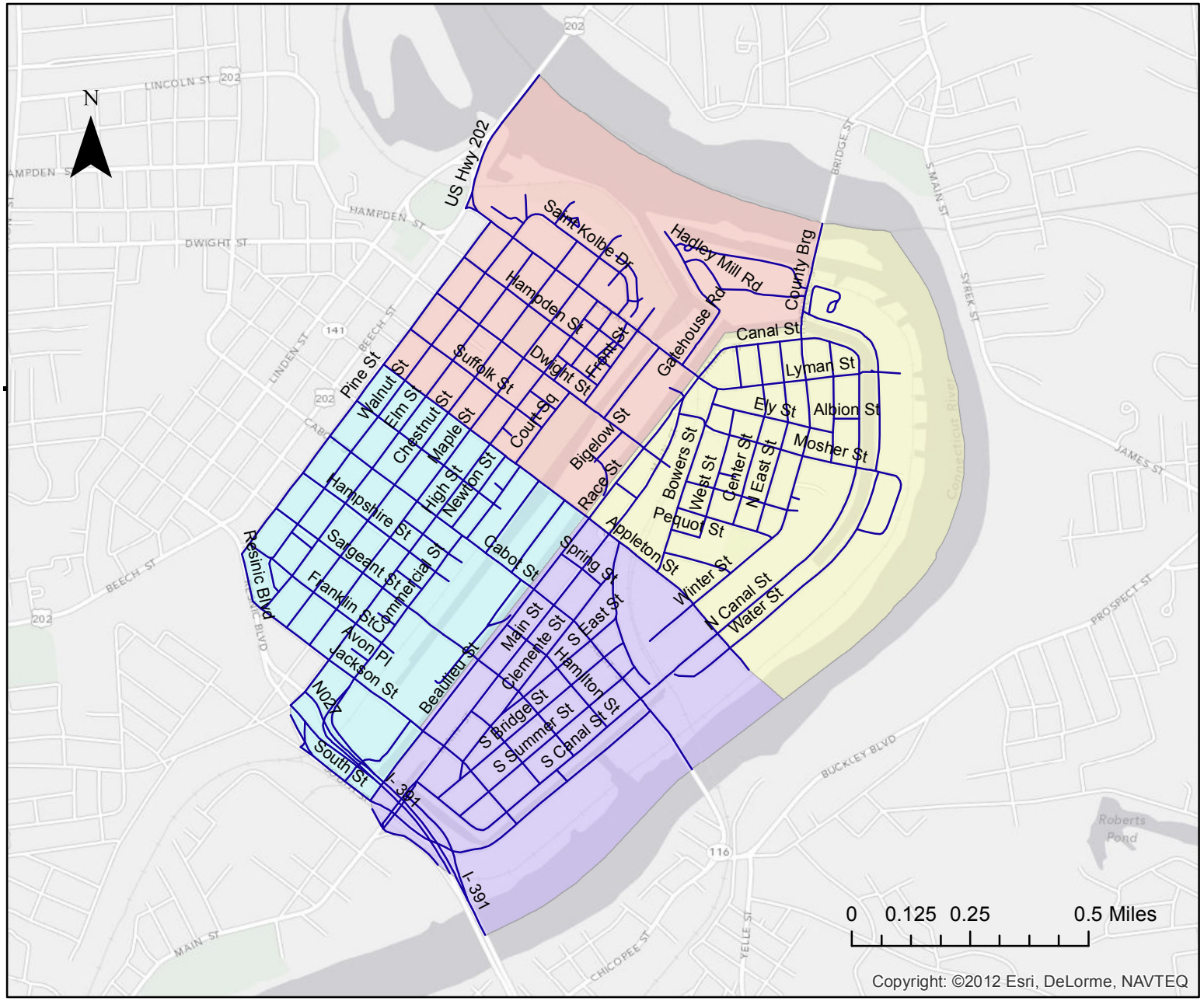
Wire Conflicts	
Over Tree	Y
Not Over Tree	N
Sidewalk Damage	
Buckle Minor	M
Buckle Moderate	MD
Buckle Major	MJ
Condition	
Dead or Dying (10% foliage)	1
Poor (35% foliage)	2
Fair (60% foliage)	3
Good (85% foliage)	4

Planting Site Type	
Tree Grate	TG
Planting Strip	ST
Empty Grate	EG
Container	C
Other	

Figure 2: Codes for Inventory Sheet

Census Tracts in Downtown Holyoke

This maps shows the four census tracks found in Downtown Holyoke.



Census Tracts

Downtown_Census_Tracts

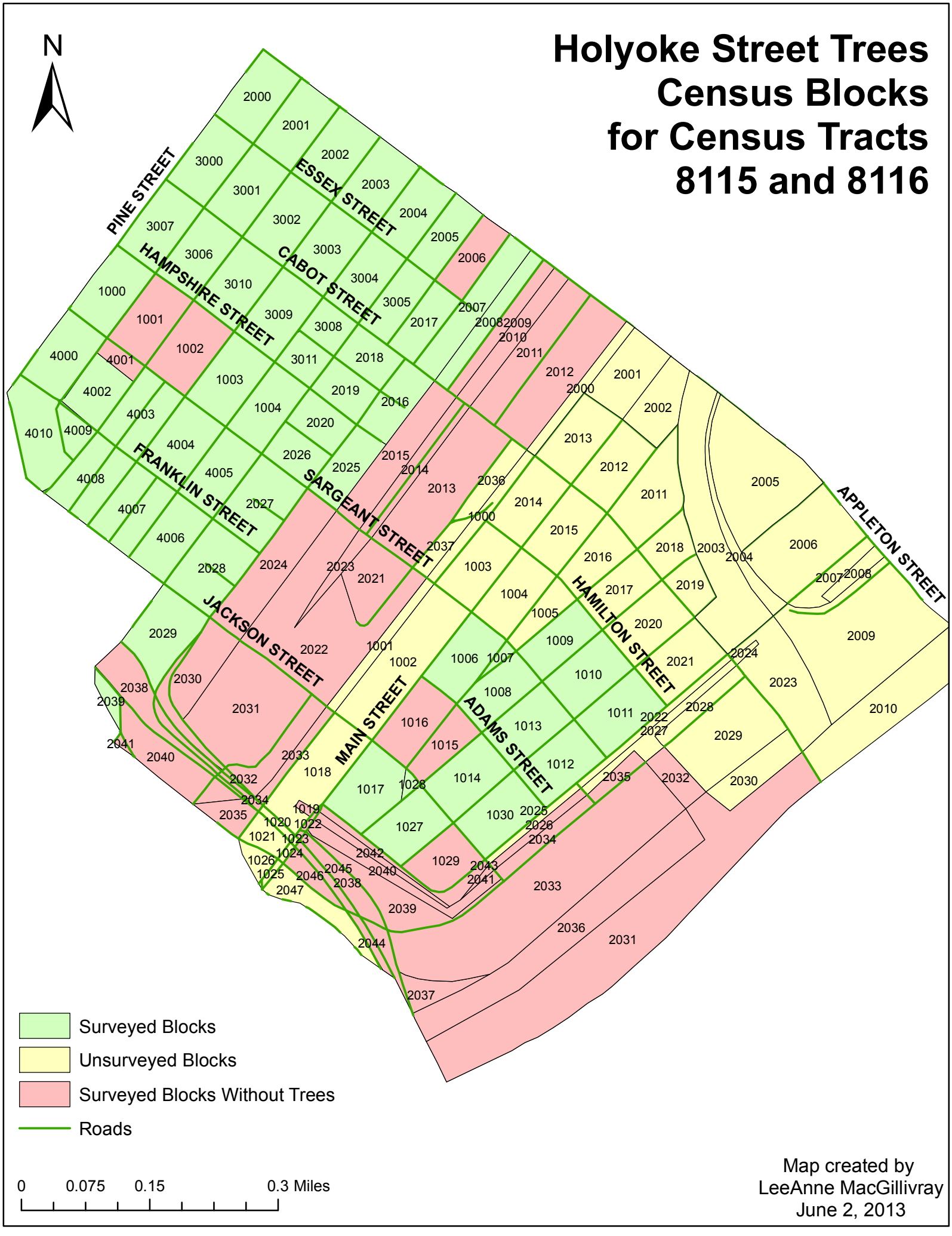
- <all other values>

NAME10

- 8114
- 8115
- 8116
- 8117

All data used was pulled from MassGIS.

Holyoke Street Trees Census Blocks for Census Tracts 8115 and 8116



Map created by
LeeAnne MacGillivray
June 2, 2013

FINDINGS

Map 2 indicates within the census tracts, which blocks were inventoried in the spring of 2013, and which were not. In addition, blocks that were surveyed and found to have no trees are also noted, so it is clear that these blocks were in fact inventoried.

Figure 3 below indicates the species breakdown of trees inventoried within the areas marked on Map 2. The majority of the trees were a species of Maple (29%) followed closely by Ash species (22%) and the remaining trees are a variety of types as indicated.

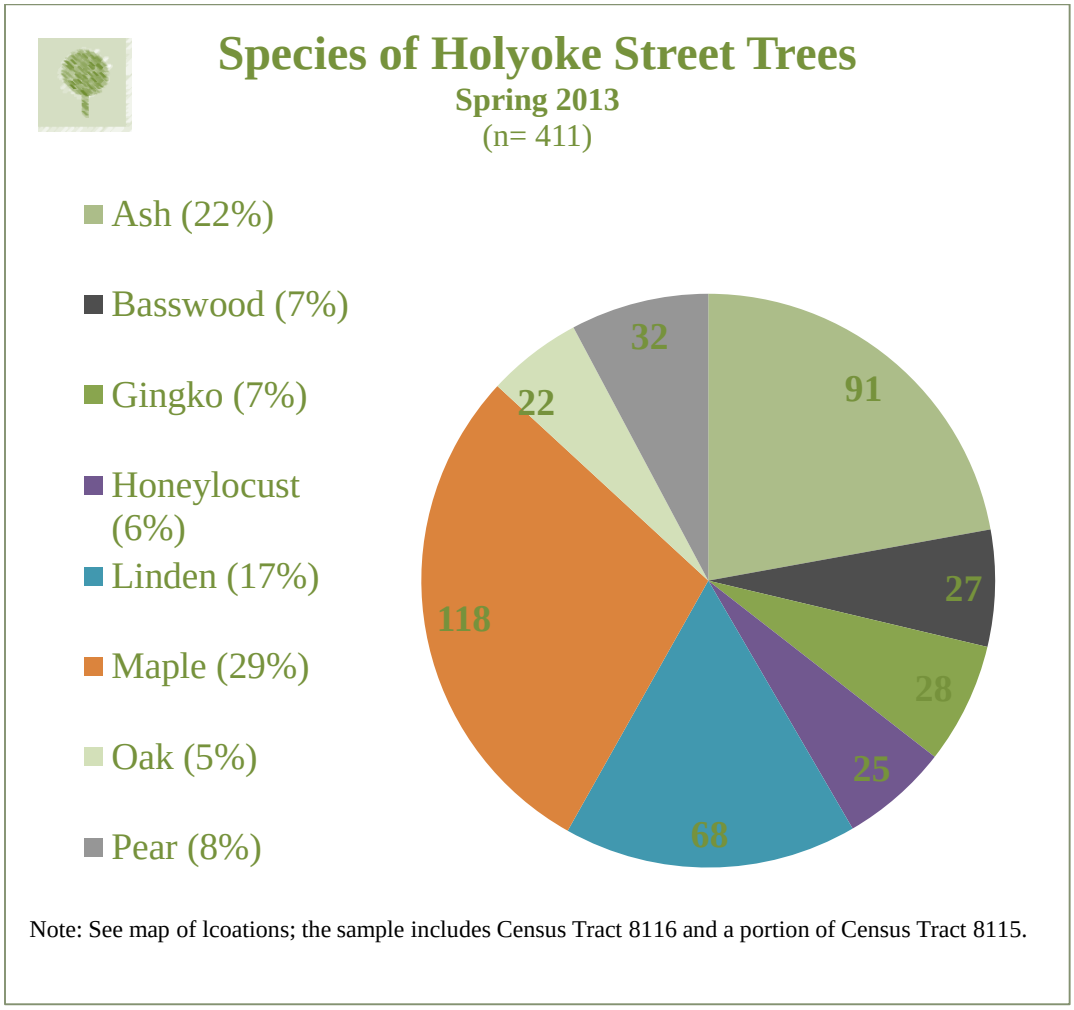
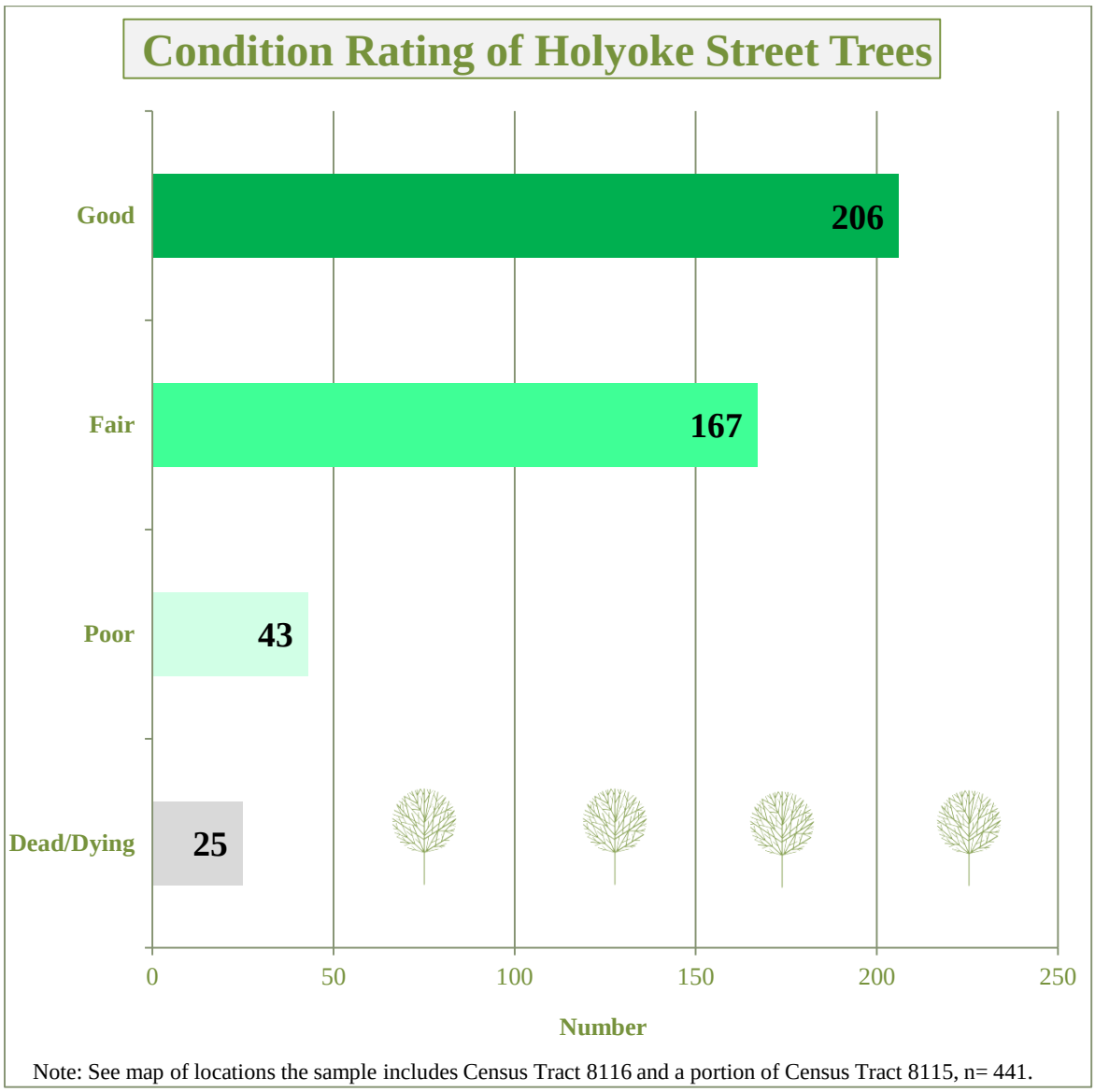


Figure 3 Species of Holyoke Trees (Note: n=411, not all trees could be identified.)

A larger portion of the inventoried trees were given a condition rating. These ratings are somewhat subjective, yet were arrived at through a student team evaluation. Almost half of the trees (47%) were rated as in Good condition, followed by 38% as Fair, 10% as Poor and 6% as Dead or Dying.

Finally, Figure 5 summarizes the size (as expressed as Diameter at Breast Height in centimeters) of the inventoried trees. This indicates 16% of the trees were less than 15 centimeters in diameter, while 70% are between 15 and 45 centimeters in diameter. Students did not include the size of "stumps," that is, dead trees without any branches.

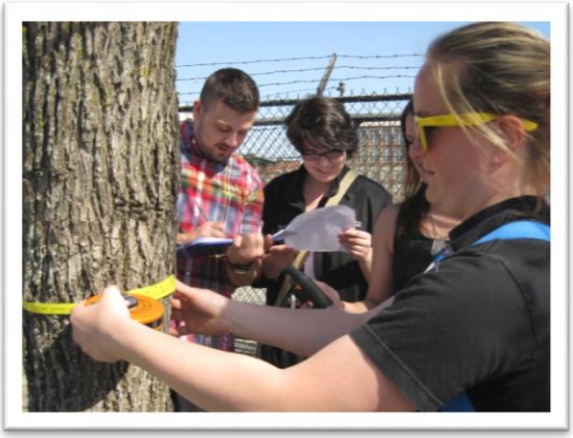


Note: See map of locations the sample includes Census Tract 8116 and a portion of Census Tract 8115, n= 441.

Figure 4: Condition Rating of Holyoke Street Trees.

Holyoke Street Tree Inventory Spring 2013	Diameter at Breast Height (CM)	Number of Street Trees	Percent of Total (n=424)
	0- 15	***75***	16%
	<15- 30	***169***	37%
	<30- 45	***153***	33%
	< 45 – 60	***34***	7%
	< 60 – 75	***12***	3%
	<75	***18***	4%

Figure 5: Street Trees DBH (cm)



In 2006 the USDA developed a software package to estimate the economic value of many ecological and social functions that trees play in the streetscape. The " i-tree" software program (recently updated) is a means of creating tree data-bases and estimating the benefits provided by the tree resources. The free software is modeled off of 15 different reference cities. Data on trees that is collected and entered (species, GPS location, diameter at breast height (DBH), and general condition) is then aligned with the modeled community with the most similar climate conditions. The program calculates an estimate of the value of a variety of ecosystem services, and produces a figure on the annual contributions of the particular tree entered, as well as a lifetime replacement value of each tree based on the functions performed by the tree. The software also groups the total value of the functions provided according to tree species.

Calculations include economic value of: stormwater intercepted; energy saved through wind break and shading of buildings; CO2 stored; and air quality improved. A general category of aesthetics and "other" includes the increase in property values; public health benefits; and general well-being associated with the presence of trees.

Recent studies have established that the presence of trees and "nearby nature" in human communities generates numerous psychosocial benefits.[2]

The data set created in the spring of 2013 was cleaned up and entered into itree. Only complete entries could be used for the calculations. A full report of these calculations is available on a disk. For the purposes of this report, the summary statement for all the trees surveyed is included as Figure 6, below. This indicates the street trees within the portion of downtown inventoried annually provide over $50,000 of ecological functional value for the people of Holyoke. The calculations by specific function are summarized in Figure 6. Additionally, itree calculations, run on the data base created from the student inventory, indicates it would cost over 1.4 million dollars for the City to replace that portion of the street canopy that was inventoried.

Benefits	Total ($)	Standard Error	$/tree	Standard Error
Energy	21,674	(N/A)	51.24	(N/A)
CO2	500	(N/A)	1.18	(N/A)
Air Quality	3,825	(N/A)	9.04	(N/A)
Stormwater	4,784	(N/A)	11.31	(N/A)
Aesthetic/Other	22,286	(N/A)	52.69	(N/A)
Total Benefits	53,069	(N/A)	125.46	(N/A)

Figure 6: Summary of Economic Value of Ecological Functions All trees in Inventory (based on itree).

The more detailed report outputs from itree are available on disk.

REFLECTIONS & FUTURE WORK

During this work students interacted with Holyoke residents they met along the streets of the neighborhoods of Churchill and South Holyoke. Many student teams reported being questioned about what they were doing, and at least five times a resident or residents stopped teams to say, "Please don't take the trees down." Clearly many residents care about and value the street trees near their homes. Students report there were also areas where the trees detracted from the public realm due to either their poor condition or trash stuck in the limbs, often in the form of wind-filled plastic bags. In contrast, the relatively new trees in the Hope VI Churchill development appeared to be thriving and provided a consistent and plentiful street tree line that students felt made the area feel attractive, cared for, and welcoming to pedestrians.

Students acting in the capacity of interns for the Conservation Commission Office will continue the inventorying work, with a goal of completing all of the four downtown Census Tracts – 8115, 8116, 8117 and 8114.

ENDNOTES

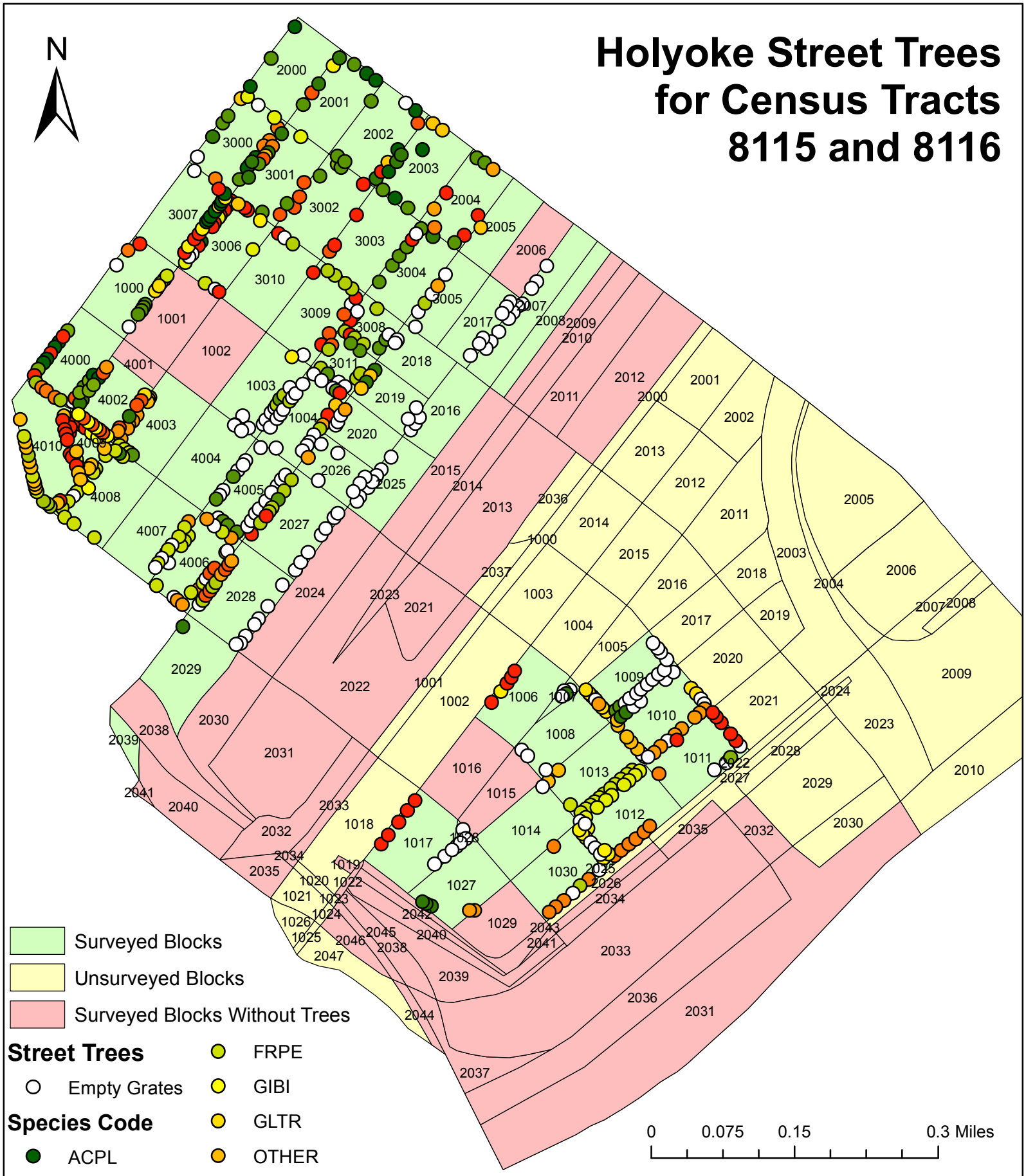
[1] http://www.parksandpeople.org/files/resources/2577_The%20Value%20of%20Trees.pdf
[2] Wolf, Kathleen. 2004. Public Value of Nature: Economics of Urban Trees, Parks and Open Space in Design with Spirit: Proceedings of the 35th Annual Conference of the Environmental Design Research Association. Edmond, OK: Environmental Design Research Association (edra).

APPENDIX

Full itree calculation sheets are available on a disk. Contact the office of the Holyoke Conservation Commission.

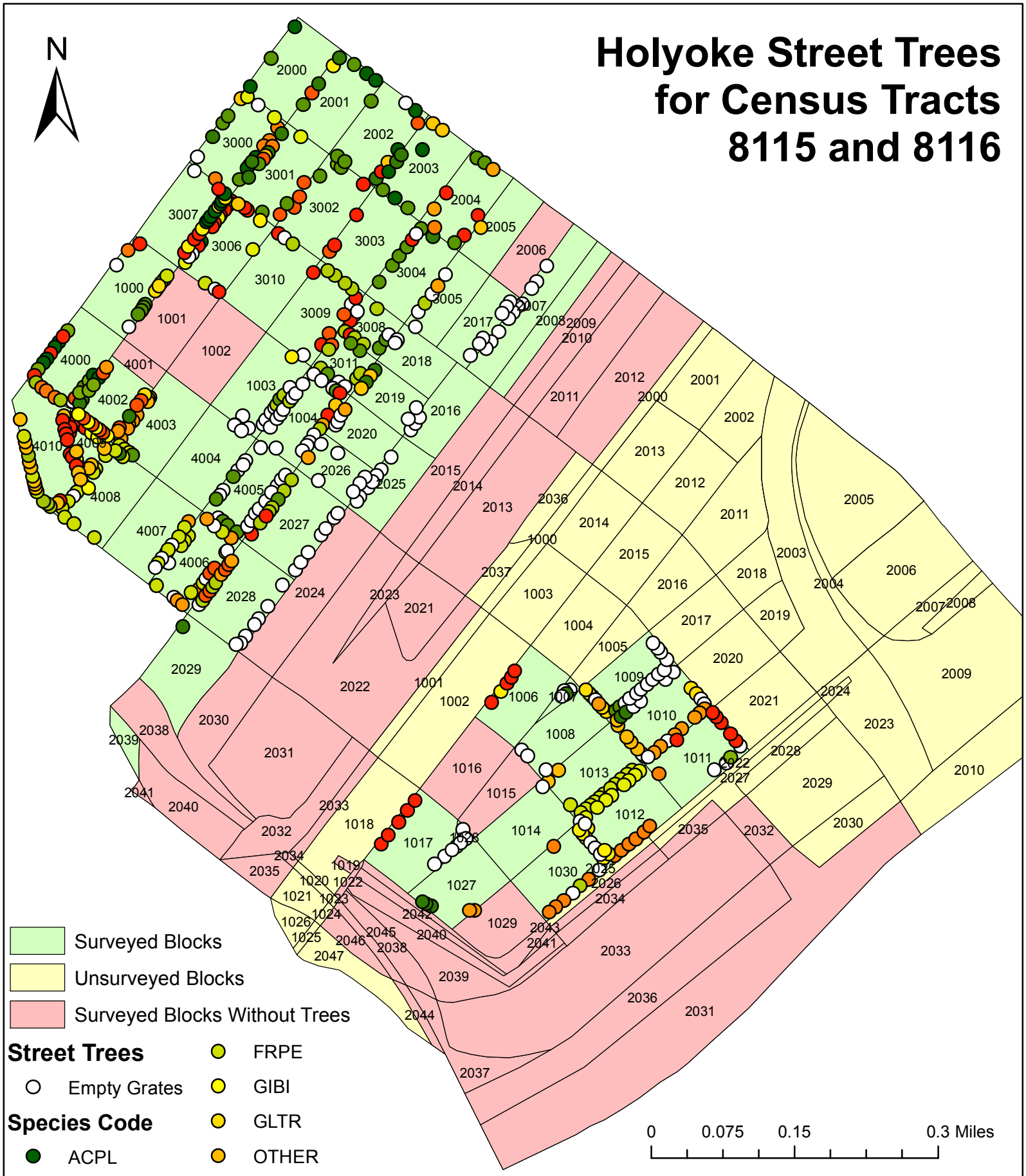
Additional maps are attached indicating the location of trees by species, condition, and size, as well as, the location of empty tree grates.

Holyoke Street Trees for Census Tracts 8115 and 8116



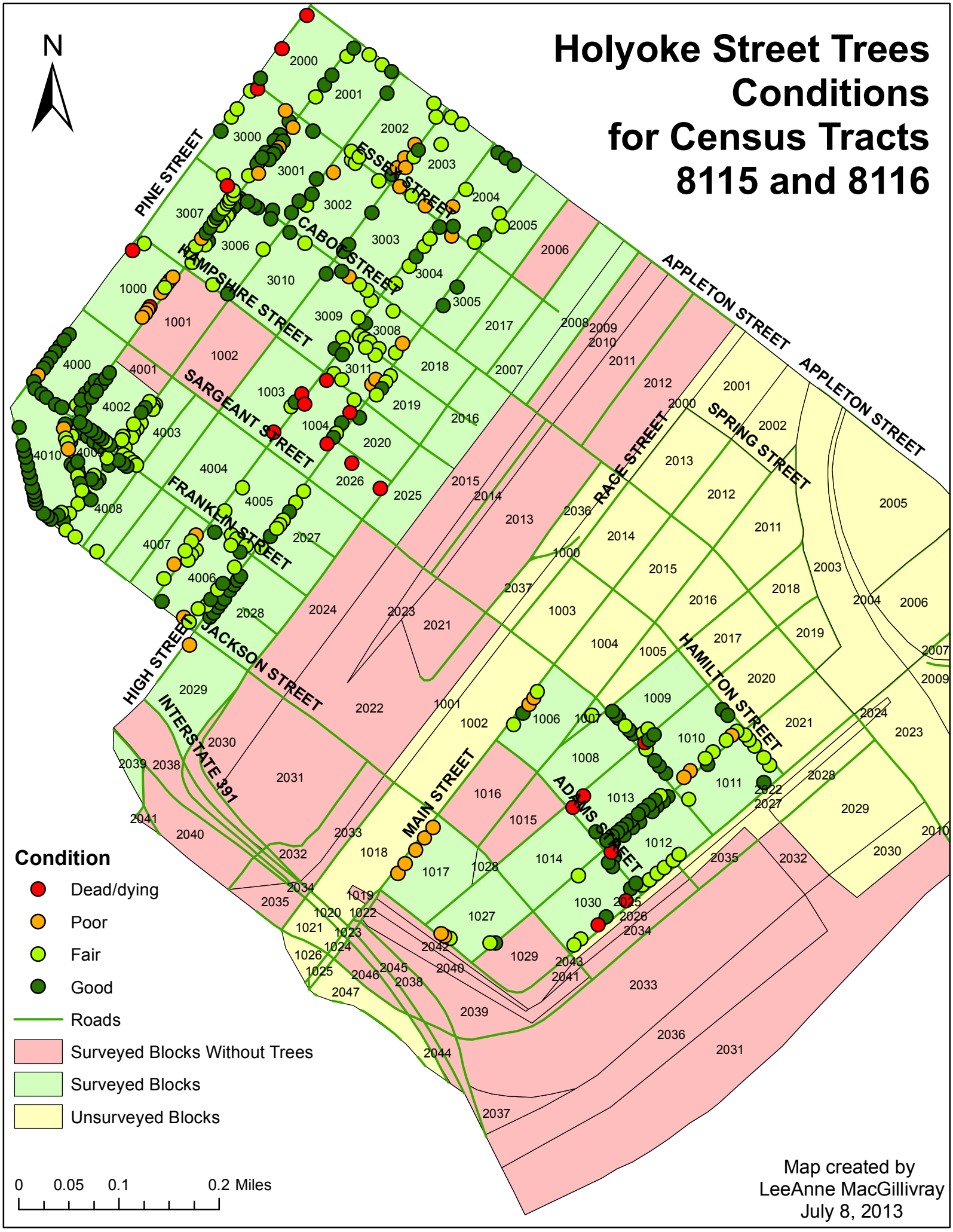
Map created by
LeeAnne MacGillivray
June 2, 2013

Holyoke Street Trees for Census Tracts 8115 and 8116



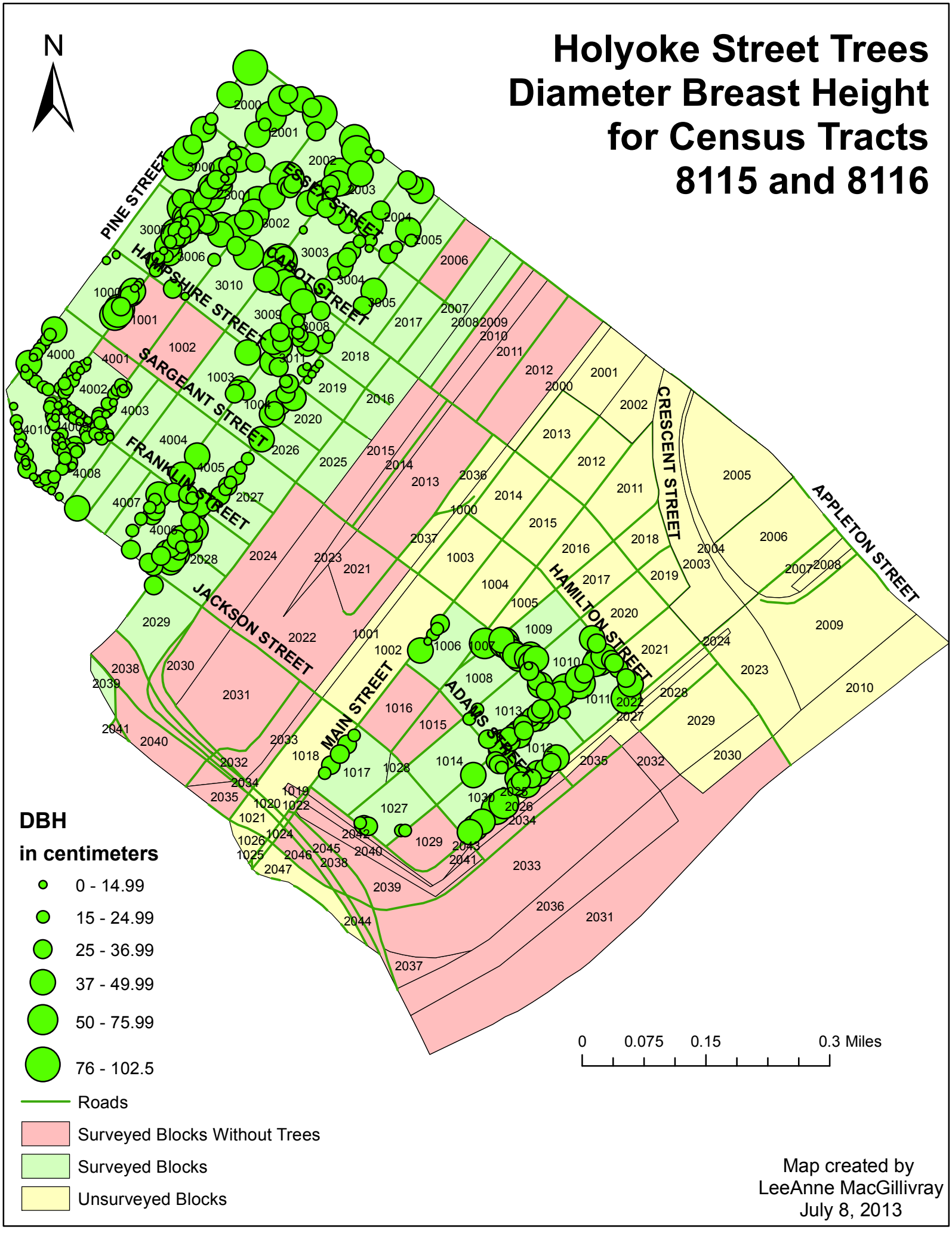
Map created by
LeeAnne MacGillivray
June 2, 2013

Holyoke Street Trees Conditions for Census Tracts 8115 and 8116



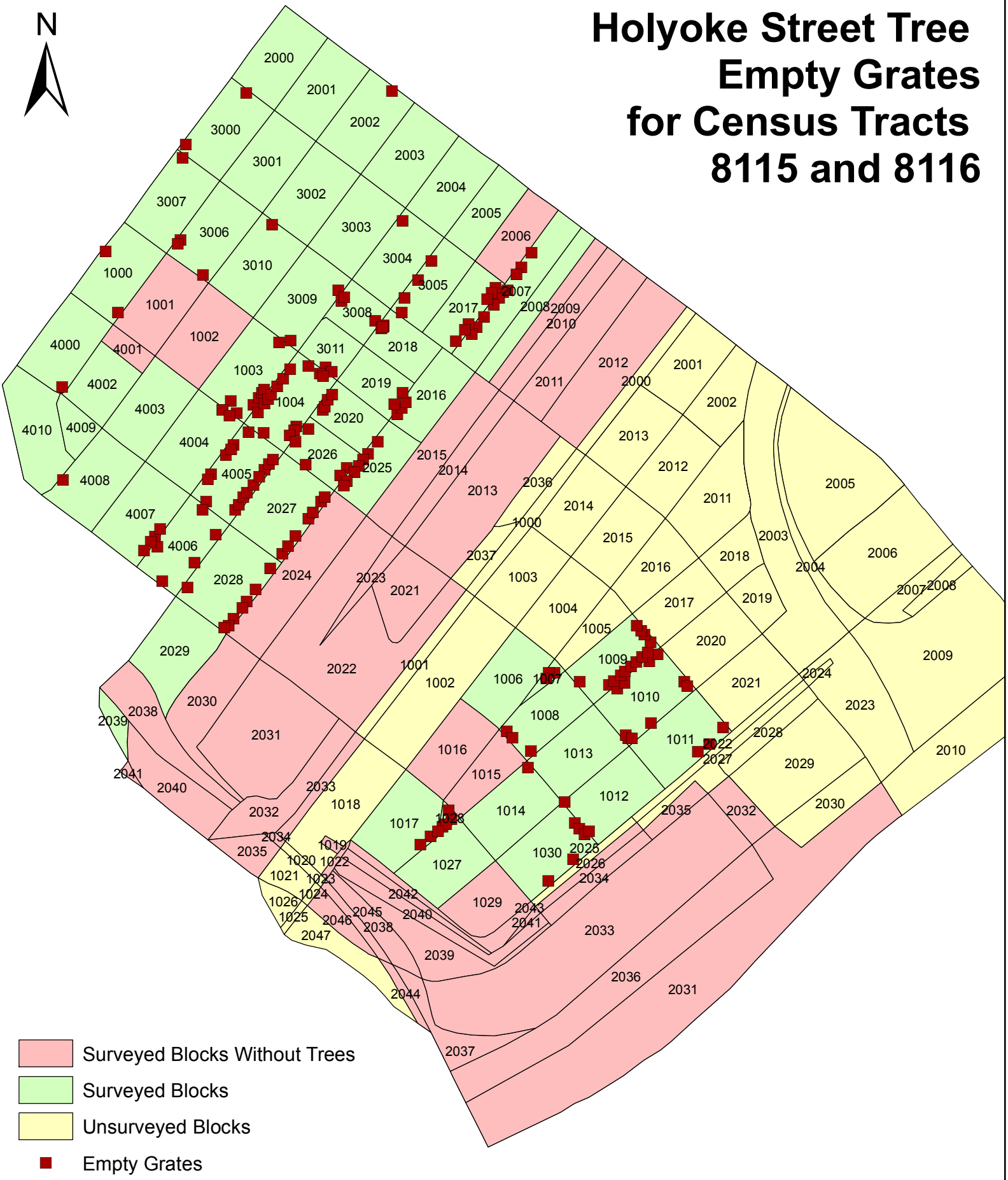
Map created by
LeeAnne MacGillivray
July 8, 2013

Holyoke Street Trees Diameter Breast Height for Census Tracts 8115 and 8116



Map created by
LeeAnne MacGillivray
July 8, 2013

Holyoke Street Tree Empty Grates for Census Tracts 8115 and 8116



Map created by
LeeAnne MacGillivray
June 2, 2013

Holyoke

Annual Energy Benefits of Public Trees By Species

6/18/2013

Species	Total Electricity (MWh)	Electricity ($)	Total Natural Gas (Therms)	Natural Gas ($)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Green ash	6.9	963	2,596.0	3,655	4,619	(N/A)	19.6	21.3	55.64
Littleleaf linden	3.6	503	1,334.8	1,879	2,382	(N/A)	16.3	11.0	34.52
Silver maple	5.3	747	1,959.7	2,759	3,507	(N/A)	12.5	16.2	66.16
Norway maple	2.8	390	1,007.7	1,419	1,809	(N/A)	7.6	8.4	56.54
Callery pear	2.8	395	885.5	1,247	1,641	(N/A)	7.3	7.6	52.95
Red maple	2.3	326	858.6	1,209	1,535	(N/A)	6.4	7.1	56.84
Ginkgo	1.3	178	459.3	647	824	(N/A)	6.4	3.8	30.53
American basswood	1.8	258	695.7	980	1,237	(N/A)	6.4	5.7	45.82
Honeylocust	2.7	382	966.7	1,361	1,744	(N/A)	6.2	8.0	67.06
Pin oak	1.8	252	589.8	830	1,082	(N/A)	5.2	5.0	49.20
River birch	0.7	104	301.3	424	528	(N/A)	2.4	2.4	52.78
White ash	0.6	78	217.2	306	383	(N/A)	1.9	1.8	47.92
Sugar maple	0.3	47	133.8	188	235	(N/A)	1.4	1.1	39.22
OTHER STREET TREES	0.3	35	80.0	113	148	(N/A)	0.5	0.7	73.95
Citywide total	33.2	4,657	12,086.1	17,017	21,674	(N/A)	100.0	100.0	51.24

Holyoke

Annual CO_2 Benefits of Public Trees by Species

6/18/2013

Species	Sequestered (lb)	Sequestered ($)	Decomposition Release (lb)	Maintenance Release (lb)	Total Released ($)	Avoided (lb)	Avoided ($)	Net Total (lb)	Total ($)	Standard Error	% of Total Trees	% of Total $	Avg. $/tree
Green ash	8,862	29	-1,998	-760	-9	20,712	68	26,816	88	(N/A)	19.6	17.7	1.07
Littleleaf linden	8,027	26	-2,316	-554	-9	10,809	36	15,966	53	(N/A)	16.3	10.5	0.76
Silver maple	10,254	34	-3,241	-636	-13	16,066	53	22,443	74	(N/A)	12.5	14.8	1.40
Norway maple	14,086	46	-1,876	-397	-7	8,393	28	20,207	67	(N/A)	7.6	13.3	2.08
Callery pear	8,828	29	-388	-35	-1	8,484	28	16,889	56	(N/A)	7.3	11.2	1.80
Red maple	2,756	9	-1,176	-318	-5	7,004	23	8,266	27	(N/A)	6.4	5.5	1.01
Ginkgo	1,967	6	-508	-201	-2	3,819	13	5,077	17	(N/A)	6.4	3.4	0.62
American basswood	4,519	15	-1,293	-276	-5	5,537	18	8,486	28	(N/A)	6.4	5.6	1.04
Honeylocust	3,852	13	-1,483	-241	-6	8,222	27	10,349	34	(N/A)	6.2	6.8	1.31
Pin oak	5,503	18	-1,566	-222	-6	5,418	18	9,134	30	(N/A)	5.2	6.0	1.37
River birch	907	3	-128	-63	-1	2,226	7	2,943	10	(N/A)	2.4	1.9	0.97
White ash	784	3	-133	-66	-1	1,667	6	2,252	7	(N/A)	1.9	1.5	0.93
Sugar maple	708	2	-241	-47	-1	1,009	3	1,429	5	(N/A)	1.4	0.9	0.79
OTHER STREET TREES	543	2	-62	-13	0	758	3	1,227	4	(N/A)	0.5	0.8	2.02
Citywide total	71,596	236	-16,409	-3,828	-67	100,123	330	151,482	500	(N/A)	100.0	100.0	1.18

Holyoke

Population Summary of Public Trees

4/2/2014

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total	Standard Error
Broadleaf Deciduous Large (BDL)											
Norway maple	2	8	36	27	19	6	5	2	11	116	
Green ash	0	3	13	8	17	13	17	8	10	89	
Honeylocust	1	1	12	19	4	5	3	5	8	58	
Silver maple	0	0	0	2	4	10	11	6	13	46	
American basswood	0	4	4	8	7	5	1	4	7	40	
Ginkgo	1	3	8	5	1	2	4	4	2	30	
Pin oak	1	0	0	5	4	2	4	5	6	27	
White ash	0	1	11	5	2	0	1	0	1	21	
Sugar maple	0	0	3	4	0	0	0	2	0	9	
BDL OTHER	0	0	1	1	0	0	0	0	0	2	
Total	**5**	**20**	**88**	**84**	**58**	**43**	**46**	**36**	**58**	**438**	**(±NaN)**
Broadleaf Deciduous Medium (BDM)											
Red maple	8	7	18	27	3	5	4	3	7	82	
Littleleaf linden	1	1	10	18	13	13	12	7	6	81	
BDM OTHER	0	2	0	0	0	0	0	0	0	2	
Total	**9**	**10**	**28**	**45**	**16**	**18**	**16**	**10**	**13**	**165**	**(±NaN)**
Broadleaf Deciduous Small (BDS)											
Callery pear	0	0	5	8	1	3	2	5	11	35	
BDS OTHER	0	4	3	2	1	0	0	0	0	10	
Total	**0**	**4**	**8**	**10**	**2**	**3**	**2**	**5**	**11**	**45**	**(±NaN)**
Broadleaf Evergreen Large (BEL)											
BEL OTHER	0	0	0	0	0	0	0	0	0	0	
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**(±NaN)**
Broadleaf Evergreen Medium (BEM)											
BEM OTHER	0	0	0	0	0	0	0	0	0	0	
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**(±NaN)**
Broadleaf Evergreen Small (BES)											
BES OTHER	0	0	0	0	0	0	0	0	0	0	
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**(±NaN)**
Conifer Evergreen Large (CEL)											
CEL OTHER	0	0	0	0	0	0	0	0	0	0	
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**(±NaN)**
Conifer Evergreen Medium (CEM)											
CEM OTHER	0	0	0	0	0	0	0	0	0	0	
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**(±NaN)**
Conifer Evergreen Small (CES)											
CES OTHER	0	0	0	0	0	0	0	0	0	0	
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**(±NaN)**
Palm Evergreen Large (PEL)											
PEL OTHER	0	0	0	0	0	0	0	0	0	0	
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**(±NaN)**
Palm Evergreen Medium (PEM)											
PEM OTHER	0	0	0	0	0	0	0	0	0	0	
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**(±NaN)**
Palm Evergreen Small (PES)											
PES OTHER	0	0	0	0	0	0	0	0	0	0	
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**(±NaN)**
UNMATCHED											
OTHER	166	1	6	11	12	4	2	7	9	218	
UNMATCHED OTHER	0	0	0	0	0	0	0	0	0	0	

Population Summary of Public Trees

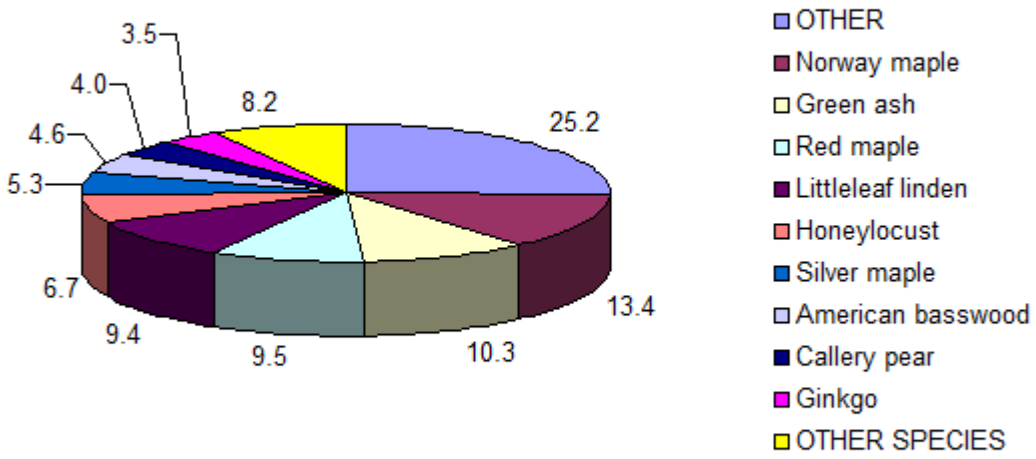
4/2/2014

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total Standard Error
Total	**166**	**1**	**6**	**11**	**12**	**4**	**2**	**7**	**9**	**218 (±NaN)**
Grand Total	**180**	**35**	**130**	**150**	**88**	**68**	**66**	**58**	**91**	**866 (±0)**

Holyoke

Species Distribution of Public Trees (%)

4/2/2014

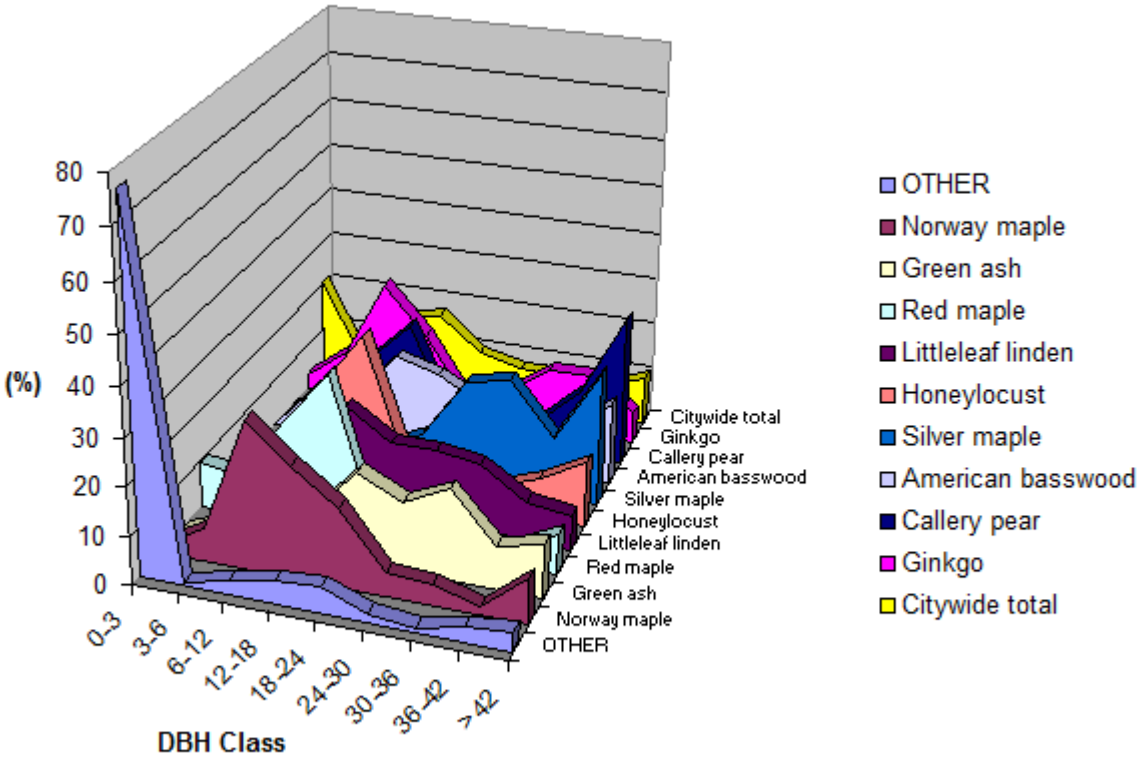


Species	Percent
OTHER	25.2
Norway maple	13.4
Green ash	10.3
Red maple	9.5
Littleleaf linden	9.4
Honeylocust	6.7
Silver maple	5.3
American basswood	4.6
Callery pear	4.0
Ginkgo	3.5
OTHER SPECIES	8.2
Total	100.0

Holyoke

Relative Age Distribution of Top 10 Public Tree Species (%)

4/2/2014



	DBH class (in)								
Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42
OTHER	76.15	0.46	2.75	5.05	5.50	1.83	0.92	3.21	4.13
Norway maple	1.72	6.90	31.03	23.28	16.38	5.17	4.31	1.72	9.48
Green ash	0.00	3.37	14.61	8.99	19.10	14.61	19.10	8.99	11.24
Red maple	9.76	8.54	21.95	32.93	3.66	6.10	4.88	3.66	8.54
Littleleaf linden	1.23	1.23	12.35	22.22	16.05	16.05	14.81	8.64	7.41
Honeylocust	1.72	1.72	20.69	32.76	6.90	8.62	5.17	8.62	13.79
Silver maple	0.00	0.00	0.00	4.35	8.70	21.74	23.91	13.04	28.26
American basswood	0.00	10.00	10.00	20.00	17.50	12.50	2.50	10.00	17.50
Callery pear	0.00	0.00	14.29	22.86	2.86	8.57	5.71	14.29	31.43
Ginkgo	3.33	10.00	26.67	16.67	3.33	6.67	13.33	13.33	6.67
Citywide total	20.79	4.04	15.01	17.32	10.16	7.85	7.62	6.70	10.51

Holyoke

Relative Performance Index for Public Trees

4/2/2014

Species	Dead or Dying	Poor	Fair	Good	RPI	# of Standard Trees Error	% of Public
Norway maple	5.22	26.96	38.26	29.57	0.89	115 (N/A)	13.28
Green ash	0.00	7.87	43.82	48.31	1.08	89 (N/A)	10.28
Red maple	6.10	21.95	32.93	39.02	0.94	82 (N/A)	9.47
Littleleaf linden	1.25	12.50	47.50	38.75	1.01	80 (N/A)	9.24
Honeylocust	1.72	12.07	27.59	58.62	1.09	58 (N/A)	6.70
OTHER	12.73	12.73	32.73	41.82	0.94	55 (N/A)	6.35
Silver maple	4.35	15.22	58.70	21.74	0.91	46 (N/A)	5.31
American basswood	0.00	5.00	32.50	62.50	1.14	40 (N/A)	4.62
Callery pear	5.71	17.14	45.71	31.43	0.93	35 (N/A)	4.04
Ginkgo	3.33	10.00	16.67	70.00	1.13	30 (N/A)	3.46
Pin oak	7.69	3.85	50.00	38.46	1.00	26 (N/A)	3.00
White ash	0.00	0.00	38.10	61.90	1.16	21 (N/A)	2.42
Sugar maple	0.00	22.22	22.22	55.56	1.05	9 (N/A)	1.04
Arnold hawthorn	0.00	0.00	83.33	16.67	0.99	6 (N/A)	0.69
Birch	0.00	0.00	0.00	100.00	1.31	2 (N/A)	0.23
Plum	0.00	50.00	0.00	50.00	0.92	2 (N/A)	0.23
Black cherry	0.00	0.00	0.00	100.00	1.31	1 (N/A)	0.12
Common chokecherry	0.00	0.00	0.00	100.00	1.31	1 (N/A)	0.12
Apple	0.00	100.00	0.00	0.00	0.54	1 (N/A)	0.12
White oak	0.00	0.00	0.00	100.00	1.31	1 (N/A)	0.12
Citywide	3.86	14.71	38.71	42.71	1.00	700 (N/A)	80.83

Holyoke

Importance Values for Public Most Abundant Trees

4/2/2014

Species	Number of Trees	% of Total Trees	Leaf Area (ft²)	% of Total Leaf Area	Canopy Cover (ft²)	% of Total Canopy Cover	Importance Value
Norway maple	116	17.9	322,811	12.0	116,857	13.3	14.4
Green ash	89	13.7	516,931	19.2	170,117	19.4	17.4
Red maple	82	12.7	244,340	9.1	74,338	8.5	10.1
Littleleaf linden	81	12.5	190,382	7.1	76,113	8.7	9.4
Honeylocust	58	9.0	269,261	10.0	98,327	11.2	10.1
Silver maple	46	7.1	387,859	14.4	100,334	11.5	11.0
American basswood	40	6.2	202,780	7.5	50,091	5.7	6.5
Callery pear	35	5.4	137,940	5.1	52,996	6.1	5.5
Ginkgo	30	4.6	112,800	4.2	33,126	3.8	4.2
Pin oak	27	4.2	203,619	7.6	70,411	8.0	6.6
White ash	21	3.2	57,789	2.1	20,079	2.3	2.6
Sugar maple	9	1.4	39,547	1.5	8,815	1.0	1.3
OTHER TREES	14	2.2	9,964	0.4	4,302	0.5	1.0
Total	648	100.0	2,696,023	100.0	875,906	100.0	100.0

Holyoke

Annual Benefits of Public Trees by Species ($/tree)

2/3/2014

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error
Norway maple	46.88	2.24	11.78	15.25	50.27	126.43	(N/A)
Green ash	77.24	2.60	21.04	28.90	47.75	177.52	(N/A)
Red maple	43.95	1.06	10.57	14.99	28.96	99.53	(N/A)
Littleleaf linden	48.10	0.99	10.78	12.96	12.66	85.50	(N/A)
Honeylocust	70.61	1.65	17.37	22.29	33.71	145.62	(N/A)
Silver maple	87.79	2.65	23.61	39.64	33.73	187.42	(N/A)
American basswood	56.05	1.41	13.74	22.24	36.99	130.43	(N/A)
Callery pear	59.20	1.64	17.92	23.34	34.22	136.31	(N/A)
Ginkgo	48.14	1.57	11.83	17.54	41.97	121.06	(N/A)
Pin oak	84.48	4.26	24.17	39.49	71.87	224.28	(N/A)
White ash	46.65	1.29	11.32	14.01	36.25	109.51	(N/A)
Sugar maple	48.82	1.56	11.24	18.90	43.20	123.72	(N/A)
OTHER STREET TRI	18.76	0.62	3.99	4.12	15.43	42.91	(N/A)

Holyoke

Total Annual Benefits of Public Trees by Species ($)

2/3/2014

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
Norway maple	5,439	260	1,367	1,769	5,832	14,666	(±0)	17.0
Green ash	6,874	231	1,872	2,572	4,249	15,799	(±0)	18.3
Red maple	3,604	87	866	1,229	2,375	8,162	(±0)	9.5
Littleleaf linden	3,896	81	873	1,050	1,025	6,925	(±0)	8.0
Honeylocust	4,095	96	1,007	1,293	1,955	8,446	(±0)	9.8
Silver maple	4,038	122	1,086	1,823	1,552	8,621	(±0)	10.0
American basswood	2,242	56	550	890	1,480	5,217	(±0)	6.0
Callery pear	2,072	57	627	817	1,198	4,771	(±0)	5.5
Ginkgo	1,444	47	355	526	1,259	3,632	(±0)	4.2
Pin oak	2,281	115	653	1,066	1,941	6,056	(±0)	7.0
White ash	980	27	238	294	761	2,300	(±0)	2.7
Sugar maple	439	14	101	170	389	1,113	(±0)	1.3
OTHER STREET TREE	263	9	56	58	216	601	(±0)	0.7
Citywide Total	37,668	1,202	9,651	13,557	24,231	86,309	(±0)	100.0

Trees for Narrow Streets

Botanical Name	Common Name	Cultivar
Acer rubrum	red maple	'Armstrong'
Acer saccharum	sugar maple	'Goldspire'
Carpinus betulus	European hornbeam	'Columnaris'
Ginkgo biloba	Ginkgo	'Princeton Sentry'; 'Magyar'
Prunus sargentii	Sargent cherry	'Spire'
Quercus palustris	pin oak	'Pringreen'
Quercus robur	English oak	'Fastigiata'
Sorbus aucuparia	European mountainash	'Fastigiata'

Large Grow Spaces: Along Streets, Adjacent to Parking Lots, or Park Trees

Botanical Name	Common Name	Cultivar
Betula nigra	river birch	Heritage®
*Carya glabra**	pignut hickory	
Carya illinoinensis	Pecan	
*Carya ovata**	shagbark hickory	
Liquidambar styraciflua	American sweetgum	'Rotundiloba'
*Liriodendron tulipifera**	Tuliptree	
Metasequoia glyptostroboides	dawn redwood	
Nyssa sylvatica	black gum	
Quercus alba	white oak	
Quercus bicolor	swamp white oak	
Quercus macrocarpa	bur oak	
Quercus phellos	willow oak	
Quercus prinus	chestnut oak	
*Taxodium ascendens**	Pondcypress	
*Taxodium distichum**	common baldcypress	
Ulmus americana	American elm	'Delaware'

* Denotes species that are *not* recommended for use as street trees.

** Consider male varieties where fruit litter may be an issue.

Coniferous and Evergreen Trees

Large Trees: Greater than 45 Feet in Height at Maturity		
Botanical Name	Common Name	Cultivar
Abies balsamea	balsam fir	
Abies concolor	white fir	'Violacea'
Cedrus deodora	deodar cedar	
Cryptomeria japonica	Japanese cryptomeria	'Yoshino'
Ilex opaca	American holly	
Picea omorika	Serbian spruce	
Picea orientalis	oriental spruce	
Pinus densiflora	Japanese red pine	
Pinus echinata	shortleaf pine	
Pinus heldreichii	Bosnian pine	
Pinus koraiensis	Korean pine	
Pinus ponderosa	ponderosa pine	
Pinus rigida	pitch pine	
Pinus serotina	pond pine	
Pinus strobus	eastern white pine	
Pinus sylvestris	Scotch pine	
Pinus taeda	loblolly pine	
Pseudotsuga menziesii	Douglas-fir	
Thuja plicata	western arborvitae	numerous exist
Tsuga canadensis	eastern hemlock	
Xanthocyparis nootkatensis	Nootka false cypress	'Pendula'

Medium Trees: 31 to 45 Feet in Height at Maturity

Botanical Name	Common Name	Cultivar
Chamaecyparis thyoides	Atlantic whitecedar	numerous exist
Juniperus virginiana	eastern redcedar	‘Princeton Sentry’
Pinus bungeana	lacebark pine	
Pinus flexilis	limber pine	
Thuja occidentalis	eastern arborvitae	numerous exist

Small Trees: 15 to 30 Feet in Height at Maturity

Botanical Name	Common Name	Cultivar
Ilex × attenuata	Foster's holly	
Pinus aristata	bristlecone pine	
Pinus mugo	mugo pine	

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Appendix E
Elements of a Comprehensive Urban Forestry Program

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Appendix F
Elements of a Comprehensive Urban Forestry Program

Developing a comprehensive urban forestry program can provide vision, goals, and focus to the City of Holyoke for greater success and longevity of the Urban Forestry Program. With the appropriate guidance, funds can be properly allocated to save the City money and available resources can be utilized to increase efficiency and maximize benefits. Below is a set of recommended elements to include in the program goals based on similar programs in other municipalities.

- Create a vision for the program to be used as a guiding focus.
- Complete an inventory of all publicly owned trees
  - Include species, size, location (with GPS coordinates), condition, and risk rating as a minimum.
  - Conduct the inventory using qualified and certified arborists.
- Create a Street Tree/Public Tree Master Plan.
  - Use this document as a resource to schedule and budget tasks, communicate goals to other City Departments, and acquire needed funds to complete such goals.
- Develop a maintenance schedule and budget, based on inventory results, to bring the City to a stage of proactive rather than reactive maintenance.
- Update the inventory on a regular basis.
- Acquire a software program to track work orders and changes.
  - Programs with mobile applications are recommended so that fieldwork can be updated instantaneously.
- Plant for diversity in species and age based on inventory results.
- Determine appropriate levels of staffing based on anticipated workloads and budget accordingly.
- Determine appropriate equipment needed to complete annual maintenance and budget accordingly.
- Survey for pests and invasive species on a regular basis.
  - Know local potential threats and have an action plan for if they were to come to Holyoke's community.
  - Set aside funds for treatment or replacement if such threats were to enter the community.
- Establish a Public Tree Ordinance Policy and assign an organized body of people to enforce it regularly and reliably.
- Create a Street Tree Set Back policy to create more opportunity for planting on private property.

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- Protect existing canopy through creation of a Development and Construction Zone Tree Protection policy.
  - Require an inventory of existing trees on the property, including species, size, and condition.
  - Specify critical root zones to be protected and include storage and equipment access roots to avoid compacting these zones.
  - Obtain recommendations for root zone protection from qualified, experienced arborists in the field of tree preservation.
- Collaborate with all appropriate stakeholders.
  - Create a good working relationship with related City Departments, such as Public Works, Parks and Recreation, Conservation Commission, Building Department, Holyoke Water Works, Holyoke Gas and Electric, School Department, Holyoke Public Library, Planning and Economic Development, Community Development, Mayor's Office, City Council, Local Emergency Planning Committee, Fire Department, Police Department, Board of Health, Council on Aging, Historical Commission, etc. Including non-traditional departments helps to understand how trees relate to the department's field of work. Also include boards and associations.
  - Create partnerships with local businesses to support planting programs and work around the community.
  - Work together with local utility companies to share resources and benefits. Focus on energy savings and right-tree right-place policies.
  - Encourage creation of or support for non-profit, non-government, friend's-of type, or other volunteer organizations.
    - Provide training to volunteers.
    - Understand the potential for program support and develop staffing and budgeting needs accordingly.
  - Conduct regular public outreach
    - Understand the communities and what they want, need or are interested in.
    - Encourage participation from all interest groups and demographics, including all age groups.
    - Provide communication through many formats, including all types of media, neighborhood meeting attendance, school program presentations, or special events programs. Maintain an updated website for people to become involved and learn about what is happening in the community.
  - Network with neighboring Cities and local supporting agencies, such as Massachusetts Tree Wardens and Foresters Association, Massachusetts Arborists Association, Massachusetts Nursery and Landscape Association, International Society of Arborists, and Society of Municipal Arborists to learn about current issues and opportunities or ask questions. Include state and federal agencies as well.
- Maintain Tree City USA status.
  - Learn about Arbor Day Foundation recommendations and apply for Growth Awards when possible.
  - Hold an annual Arbor Day event and involve the entire community.