THE CITY OF Fitchburg WISCONSIN

Ground Cover, Heat Island and Carbon Sequestration Study

August 2023
Revised November 2023

Prepared by:

making change personal paleBLUEdot LLC

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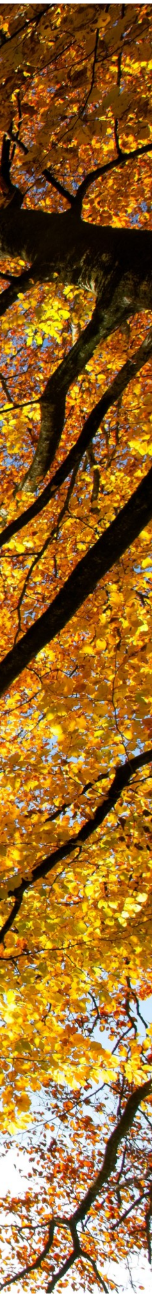
The true meaning of life is to plant trees, under whose shade you do not expect to sit.

Nelson Henderson



Introduction

The City of Fitchburg is developing its first Sustainability Plan to support climate resilience and mitigation City-wide. The plan, which will identify Sustainability strategies and actions through 2030, will help those who live and work in the city imagine and achieve a future where the earth and all who live on it thrive. The plan will define goals, strategies, and actions for implementation and is being developed through a collaborative, multi-stakeholder CARP Planning Team. This Ground Cover, Heat Island and Carbon Sequestration Study is one of multiple planning process documents, referred to as “Baseline Documents” being created to support the planning team in their work. The intent of all baseline assessments is to provide a summary of existing data across a broad base of climate mitigation and adaptation considerations in order to facilitate collaborative dialogue and action identification by the CARP Planning Team. The recommendations included in this document should be understood as preliminary only and created solely for the purpose of supporting a fully collaborative planning team process.

Why Study the City Wide Tree Canopy?

Trees play a central role in supporting community health, improving air and water quality, helping to reduce building energy use, and supporting heat island and climate mitigation.

Community Health Benefit of Trees

Recent studies have shown that sometimes going to a park, or even looking at a single tree can significantly improve a person’s health and stress levels. Our understanding of the value of trees has been expanded to include mental and physical health benefits. Trees are also critical in filtering air, removing harmful pollutants, such as Carbon Monoxide, particulate matter, and Ground-level Ozone - pollutants that can be toxic at high levels and which can cause asthma and other respiratory impacts.

Stormwater Management

Every tree catches the rain as it comes down, increasing the soil’s capacity to retain water longer. A mature White Oak can intercept up to 12,010 Gallons of water in a single year. This water stays in the leaves until it’s absorbed by the tree or evaporates to cool our air. Within an urban environment, this prevents that water from needing to be piped or treated by other stormwater infrastructure.

Introduction

Pollution Absorption

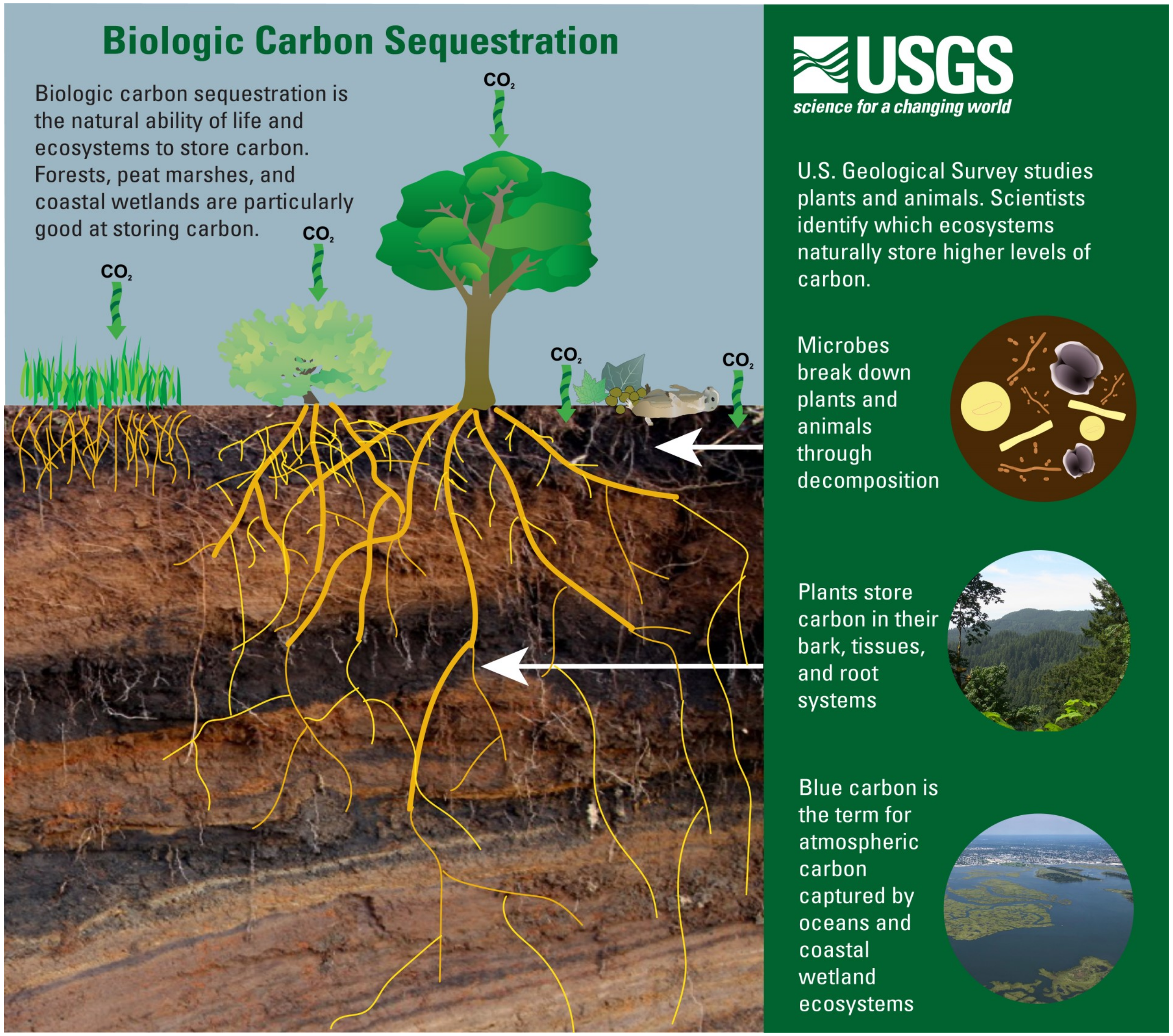
Trees primarily absorb gaseous air pollution through leaf stomata, with some gases captured by the plant surface. Inside the leaf, gases spread to intercellular spaces and can form acids or interact with inner surfaces. Trees also trap airborne particles. [1]

Heat Island and Micro Heat Island Mitigation

Tree transpiration and canopies influence factors like air temperature, wind speed, and surface roughness, impacting the mixing-layer height. This can change pollution levels in cities. For each percent increase in canopy cover, trees can reduce mid-day temperatures by 0.07 to 0.36 degrees F.[2]

Carbon Sequestration

Trees absorb carbon dioxide (CO2) and emit oxygen (O2) during photosynthesis. As they grow, the carbon integrates into their trunks, limbs, roots, and leaves. When tree parts decay or trees perish, the stored carbon returns to the atmosphere through respiration or combustion or moves into the soil.[3]

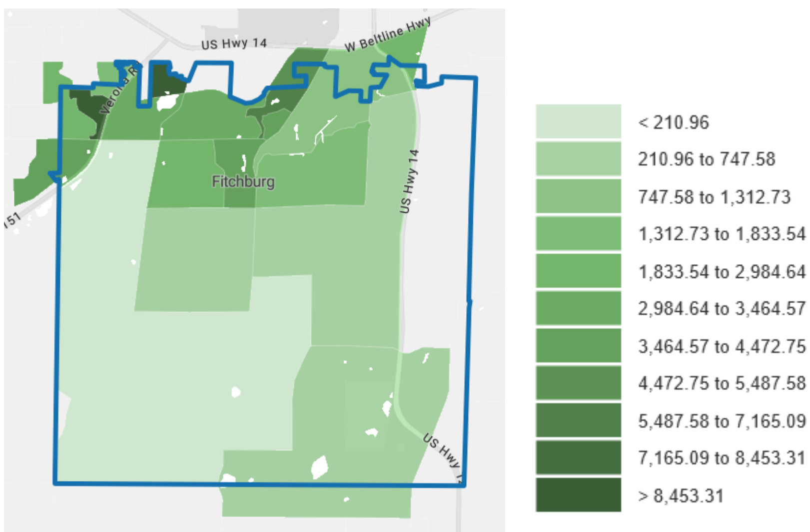


1: David Nowak, Air pollution removal by urban forests in Canada and its effect on air quality and human health; https://doi.org/10.1016/j.ufug.2017.10.019
2: Sevgi Yılmaz, et al., Determination of climatic differences in three different land uses in the city of Erzurum, Turkey; https://doi.org/10.1016/j.buildenv.2006.01.017
3: USDA Forest Service, Forests and Carbon Storage; https://www.fs.usda.gov/ccrc/topics/forests-and-carbon-storage-2012
Graphic Source:
USGS Climate Adaptation Science Centers

Land Coverage Categories Measured

Cover Class	Description
Agriculture / Crop	Cultivated crops, community garden, permaculture site
Dark Impervious - Building	Buildings with Dark Impervious Roof Surfaces
Dark Impervious - Pavement	Pavement with Dark Impervious Surfaces
Lawn	Maintained Grass Areas
Light Impervious - Buildings	Buildings with Light Impervious Roof Surfaces
Light Impervious - Pavement	Pavement with Light Impervious Surfaces
Prairie Grass/Wildflower	Wild, Native, and non manicured grass cover
Tree/Shrub	Trees and large shrubs
Water	Open Water, Lake, Pond, River, Wetland/Marsh

Population Density of City of Fitchburg Per Square Mile by Census Block Group 2021



Methodology

This study establishes recommended goals by analyzing tree canopy, grass/shrub, and impervious surface coverage through aerial imagery and the i-Tree Canopy Software. This tool provides statistically valid estimates using random points. It was applied to interpret 9,913 points across Fitchburg's 19 census block groups, maintaining a standard error of typically 0.2% to 2%.

Coverage categories include Trees/Shrubs, Lawn, Prairie Grass, Agriculture, Water, Impervious Surface Light (buildings), Impervious Surface Light (pavement), Impervious Surface Dark (buildings), and Impervious Surface Dark (pavement). Calculations for Tree Canopy Benefits, Tree Canopy Values, Heat Island Contribution, Stormwater Runoff, and Carbon Sequestration were made by census tract, leading to recommendations for enhancing the city's tree canopy and green infrastructure in the report's Recommendations Section. More technical details are in Appendix 1.

Mapping and Demographic Data in This Report

This assessment includes population data or maps at the Census Tract or Block Group level, as needed to relate to relevant US Census Bureau data. Census boundaries may differ from actual community boundaries. All areas within the official community boundaries are included in the plan this Baseline Document supports, even if not shown on a map. Other assessments might use data at the Census "Place" or city boundary level, leading to differences in reported population counts due to Census boundary variations. See Appendix 3 Reference Map for census areas included in this report.

Section 02

Land Coverage Characteristics

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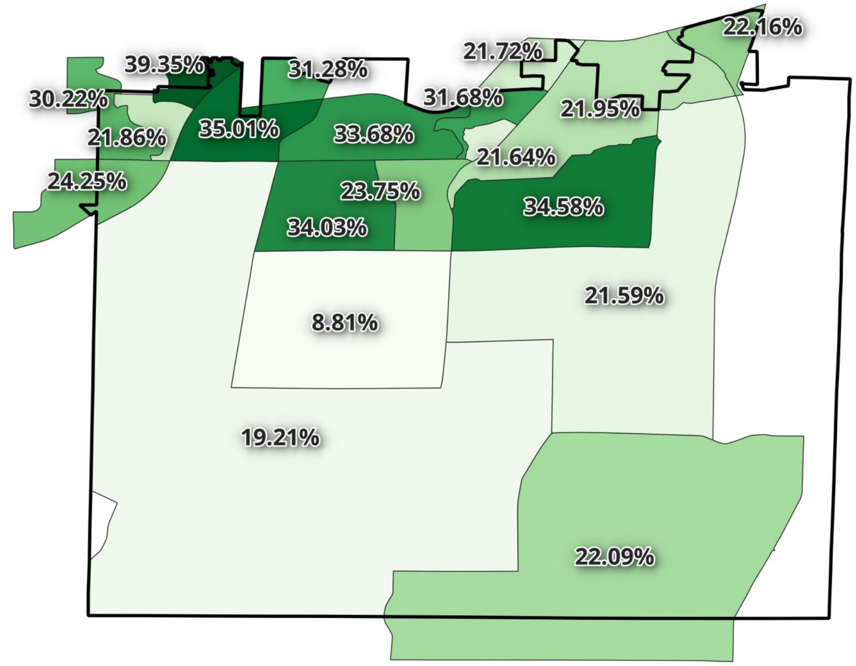
Classification of coverage categories included Tree Canopy, Grass, Water, Impervious Surface Light, and Impervious Surface Dark.



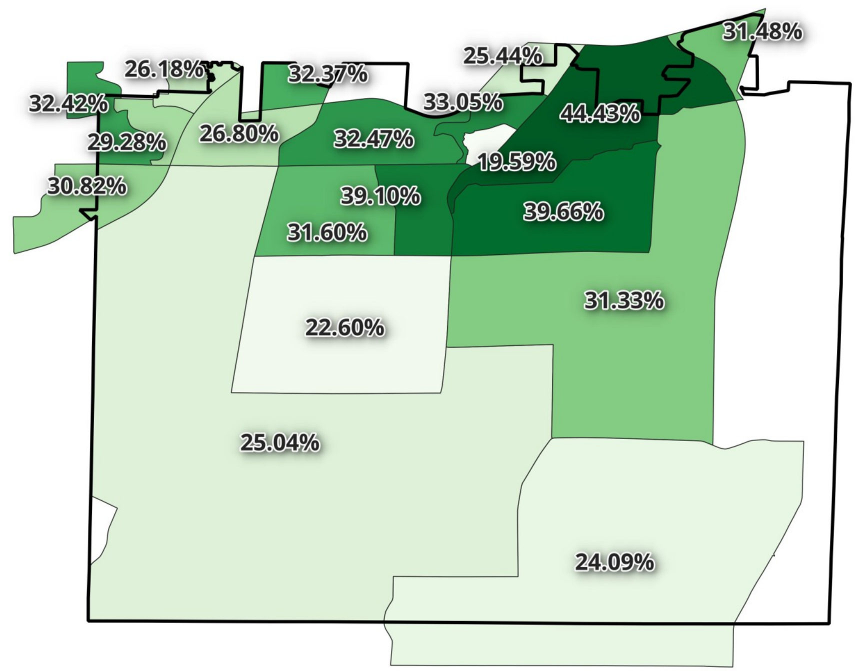
Tree Canopy Coverage

(See Appendix 3 for census area reference map)

City Average: **21.9%**

City High: **39.4%**
Tract 5.01 bg2

City Low: **8.8%**
Tract 107.01 bg3



Lawn and Grass Coverage

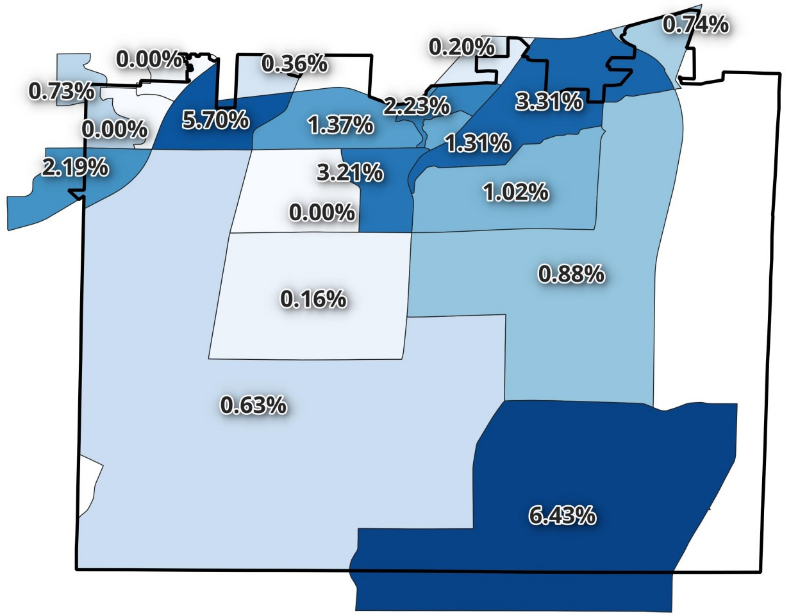
(See Appendix 3 for census area reference map)

City Average: **30.9%**

City High: **44.4%**
Tract 14.05 bg2

City Low: **19.6%**
Tract 14.04 bg 3

Land Coverage Characteristics



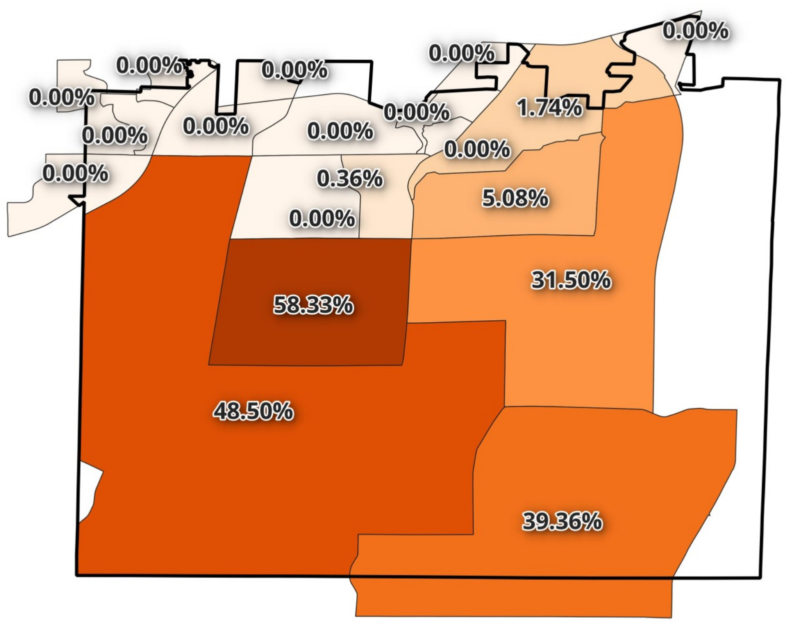
Open Water Coverage

(See Appendix 3 for census area reference map)

City Average: **2.0%**

City High: **5.7%**
Tract 6 bg4

City Low: **0.0%**
multiple tracts



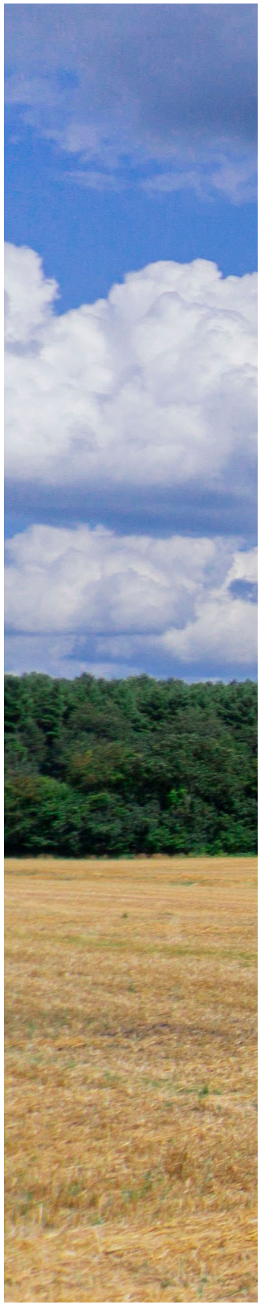
Agriculture Land Coverage

(See Appendix 3 for census area reference map)

City Average: **32.8%**

City High: **58.3%**
Tract 107.01 bg3

City Low: **0.0%**
multiple tracts



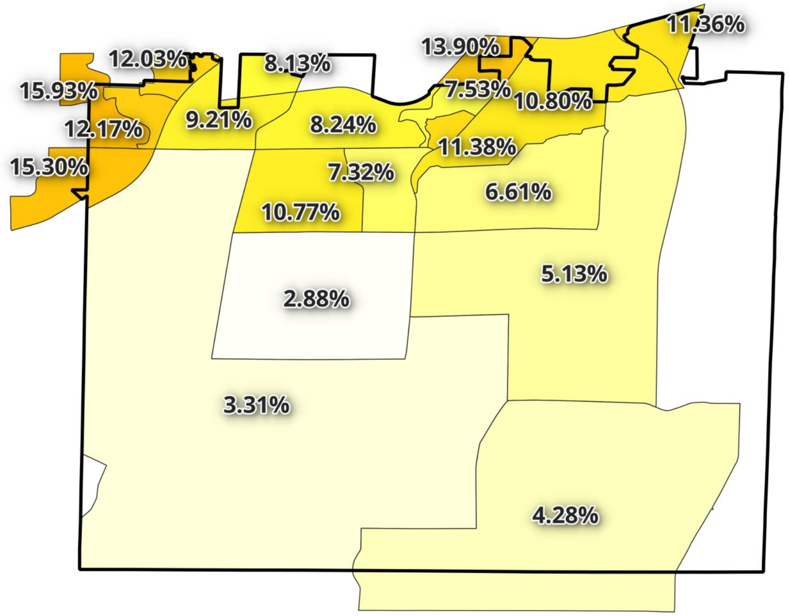
Land Coverage Characteristics

Light Impervious Surface Coverage (buildings+pavement)
(See Appendix 3 for census area reference map)

City Average: **5.5%**

City High: **15.9%**
Tract 5.06 bg1

City Low: **0.0%**
multiple tracts

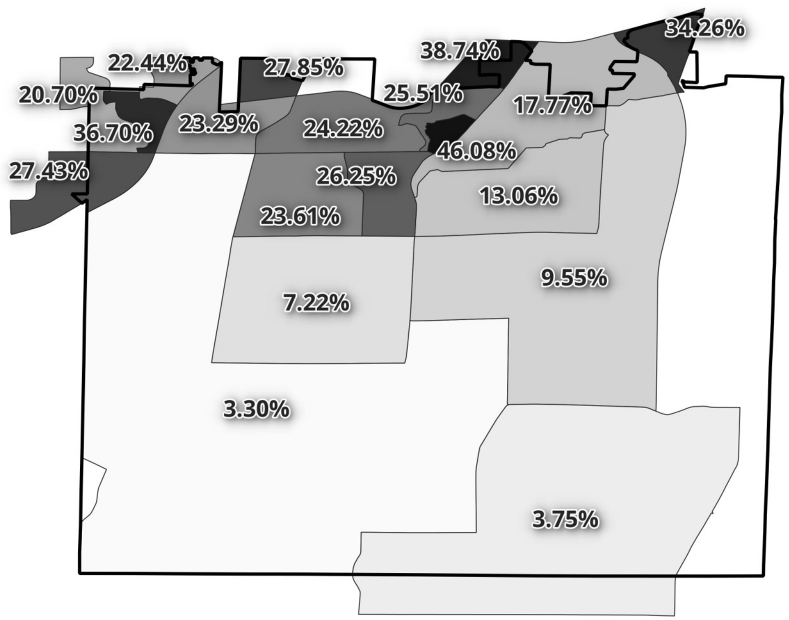


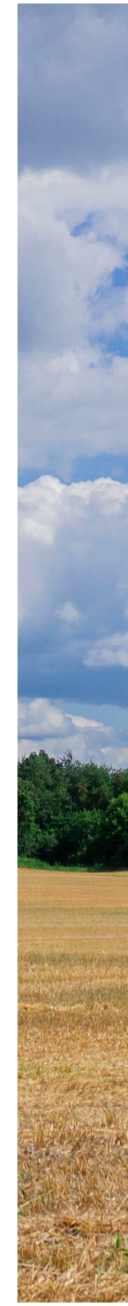
Dark Impervious Surface Coverage (buildings+pavement)
(See Appendix 3 for census area reference map)

City Average: **9.7%**

City High: **46.1%**
Tract 14.04 bg3

City Low: **3.3%**
Tract 107.02 bg1





Section 03 Land Cover Impacts and Benefits

The condition and health of a community's Tree Canopy and green infrastructure and the magnitude and nature of impervious surfaces have meaningful consequences on the area's environment. Estimating the baseline land cover contributions to the community's environment enables the City to project the impact of potential strategies and to track improvements over time. The following maps in this section diagram the impacts and benefits of the City's Tree Canopy, grass, and impervious surface coverage.

Pollution Absorption by Trees

Air pollution is a major environmental concern in most major metropolitan areas globally. Air pollutants are known to increase incidents of heart disease, asthma, emphysema, and cancer. Meanwhile, global warming projections for Wisconsin anticipate an increase in the impacts felt due to air quality issues. Healthy tree canopies offer the ability to remove significant amounts of air pollutants and consequently improve environmental quality and human health.

Pollution Absorption by Trees - Particulates

Particulate matter pollution is divided into two categories: Fine Particulate (PM2.5) and Course Particulate (PM10). Numerous studies have linked fine particulate pollution with a number of health risks including respiratory disease, asthma, bronchitis, and increased heart disease and heart attacks. Course particulate matter has been shown to aggravate heart and lung diseases and to cause lung damage.

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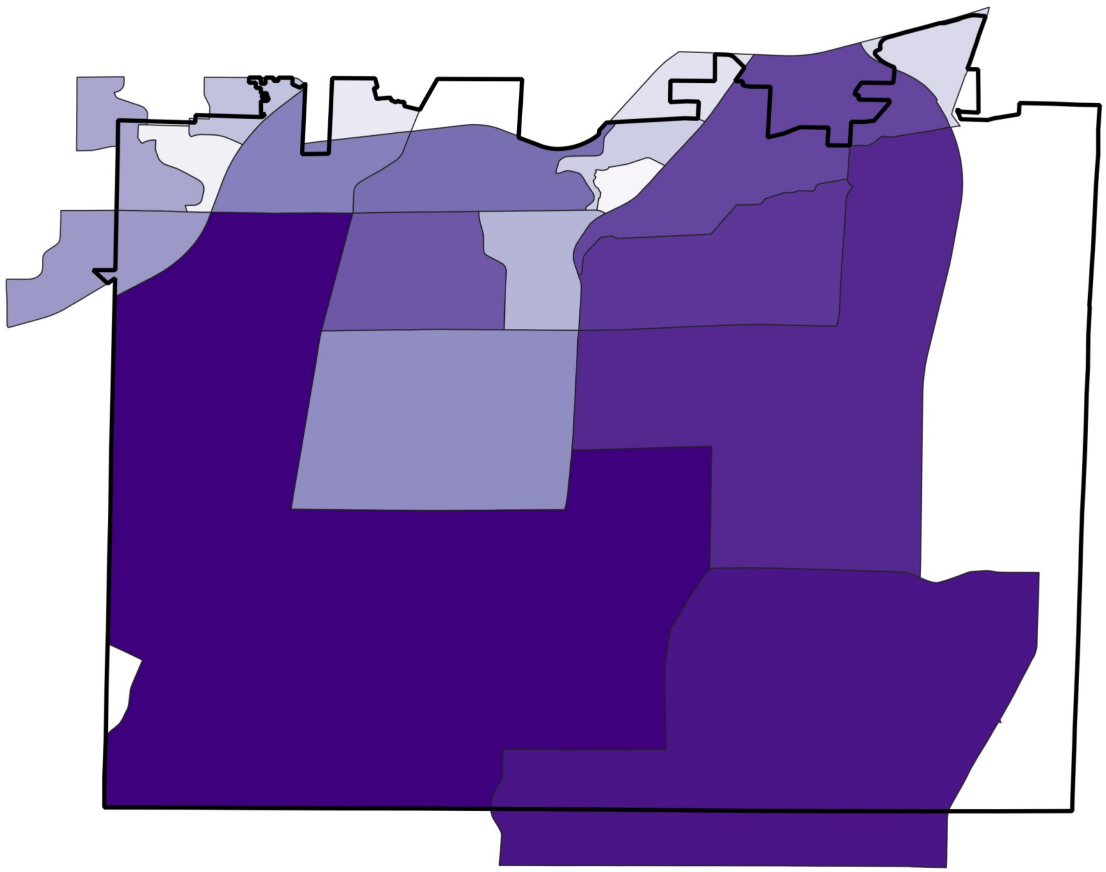


Land Cover Impacts and Benefits

Pollution Absorbed Annually by City's Tree Canopy

Carbon Monoxide 3,704 lbs	Nitrogen Dioxide 32,054 lbs	Ozone 163,691 lbs
12	107	547
24	204	1,044
32	278	1,419
34	292	1,492
36	313	1,598
37	324	1,654
48	416	2,127
63	547	2,796
67	580	2,962
81	699	3,568
111	958	4,894
117	1,008	5,150
142	1,232	6,289
166	1,438	7,341
187	1,619	8,265
258	2,230	11,387
500	4,330	22,111
667	5,769	29,460
1,122	9,710	49,588

Sulfur Dioxide 5,253 lbs	Fine Particulate (PM2.5) 8,842 lbs	Course Particulate (PM10) 45,796 lbs
18	30	153
33	56	292
46	77	397
48	81	417
51	86	447
53	89	463
68	115	595
90	151	782
95	160	829
114	193	998
157	264	1,369
165	278	1,441
202	340	1,759
236	397	2,054
265	446	2,312
365	615	3,186
710	1,194	6,186
945	1,591	8,242
1,591	2,679	13,873

Land Cover Impacts and Benefits

Energy Savings

Trees in urban areas modify climates by providing shade, blocking winds, and cooling through leaf evaporation. For precise energy savings, tree positions relative to buildings must be closely examined. Trees that influence building energy use, like those shading a building from summer sun, are termed energy-affecting trees.

On a broader scale, we can estimate energy savings using average energy-affecting trees per acre from the study on US residential building energy conservation.[2] With these figures, we can gauge the electrical and gas savings of Fitchburg's tree canopy.

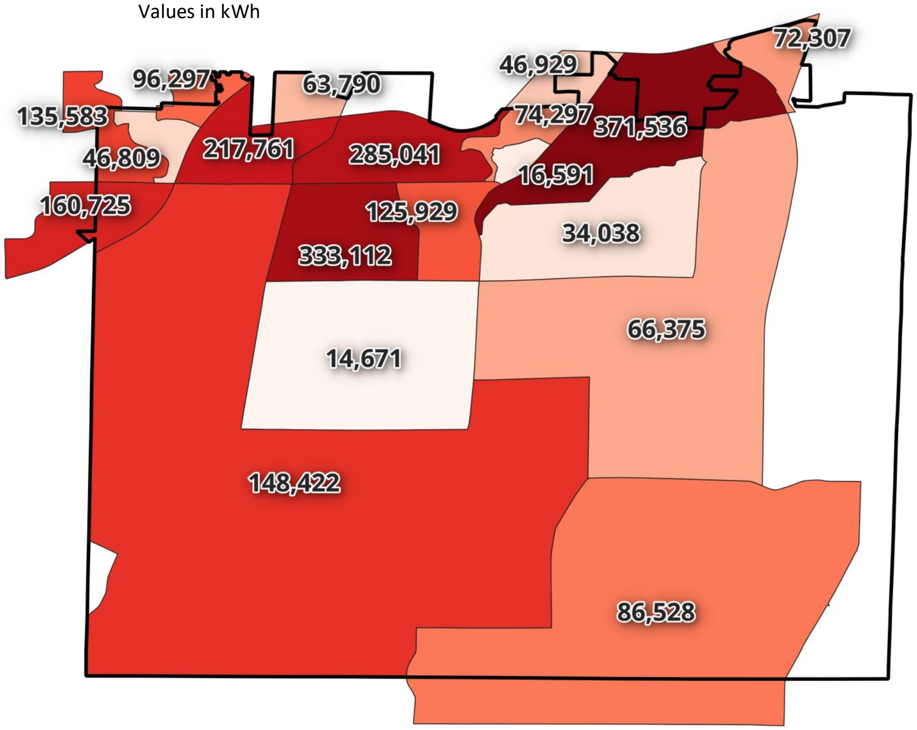
2: David J. Nowak, et al
"Residential building energy conservation and avoided power plant emissions by urban and community trees in the United States",
https://doi.org/10.1016/j.ufug.2016.12.004

Energy Savings Annually From City's Tree Canopy

Electric Savings

2,396,741 kWh

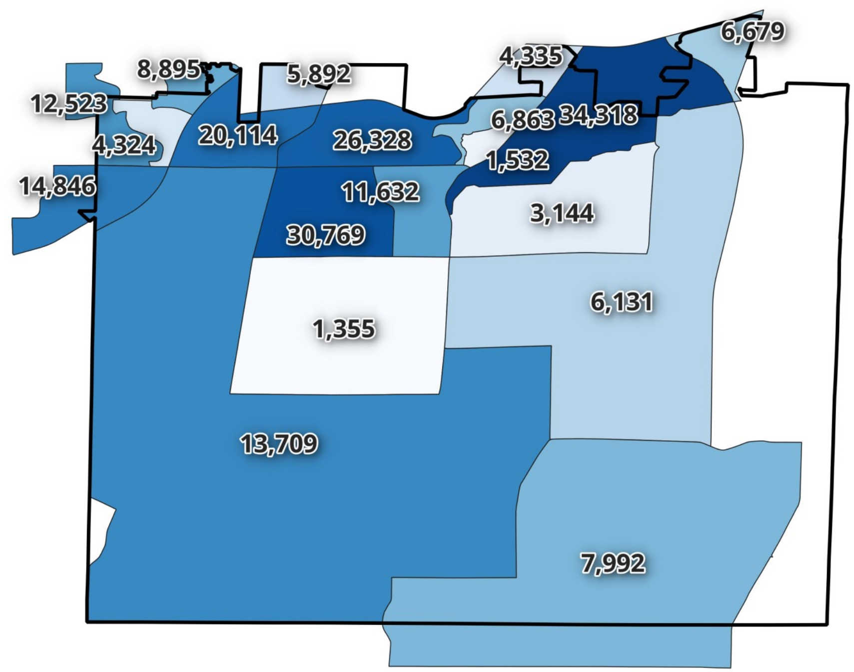
Values in kWh



Heating Fuel Savings

221,380 Therms

Values in Therms



Heat Island Contribution

Heat islands result from higher temperatures in developed areas compared to rural ones, due to human activities and infrastructure. This phenomenon increases discomfort and health risks during hot periods.

NOAA predicts that, if greenhouse gas emissions continue unchecked, Fitchburg will see more days above 95° F (refer to Fitchburg's Climate Vulnerability Assessment). Depending on various factors like humidity and access to air-conditioning, such temperatures can cause discomfort, heat stress, illness, or even death. Therefore, addressing Heat Island effects is crucial for Fitchburg.

A 2006 study by Minnesota State University and the University of Minnesota[3] links a city's impervious surface percentage to its heat island temperature rise, with variations by season. For our analysis, we've focused on the summer ratio since heat-related risks intensify during heat waves. The provided numbers for regions indicate potential temperature increases if a city had uniform impervious characteristics like that region. These numbers do not necessarily represent the actual summer time temperature difference from tract to tract, but instead are a representation of the comparative level of overall heat island impacts for the overall community.

3: Fi Yuan and Marvin Bauer, "Comparison of impervious surface area and normalized difference vegetation index as indicators of surface urban heat island effects in Landsat imagery"; https://www.sciencedirect.com/science/article/abs/pii/S0034425706003191

Micro Heat Island Contribution of City of Fitchburg Impervious Surfaces (summer values)

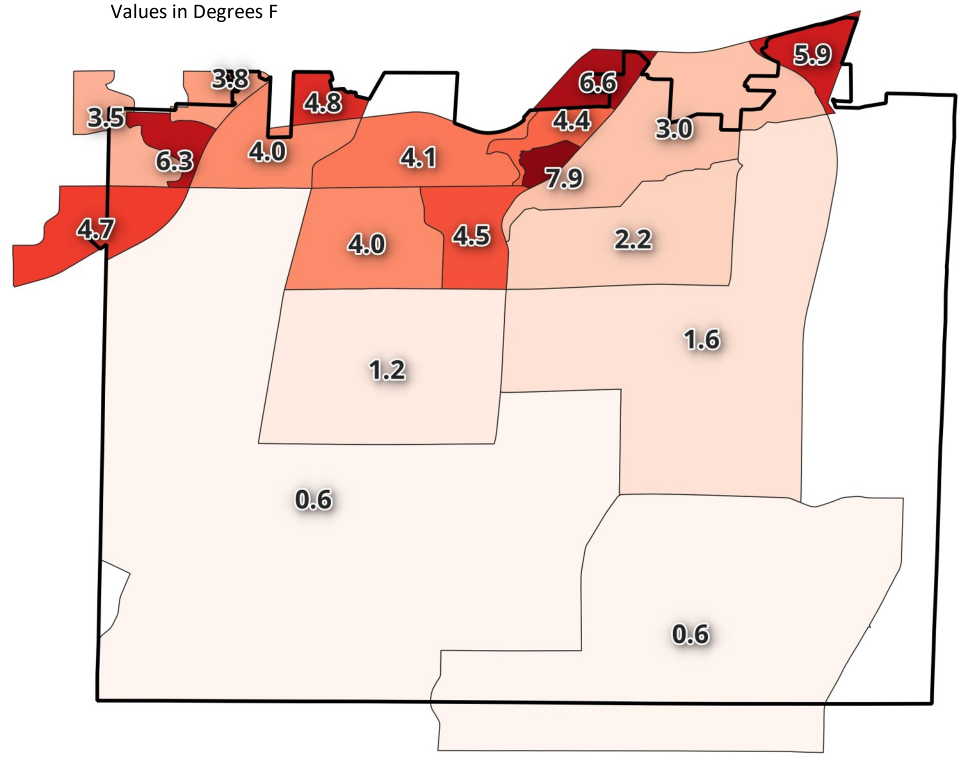
City Average: **1.7°F**

City High: **7.9°F**
Tract 14.05 bg3

City Low: **0.6°F**
Tracts 107.02 bg1
Tracts 125.02 bg1

Note: values are City-wide averages. Portions of the City with higher impervious surface coverage will have much higher values

Values in Degrees F



Land Cover Impacts and Benefits

Stormwater Runoff and Management by Green Infrastructure

Increases in impervious cover can dramatically increase the impact of so-called 100-year flood events. Typically, floods in areas of high impervious surfaces are short-lived, however, they do carry risks to infrastructure and vulnerable populations. Extended flooding can stress trees, leading to leaf yellowing, defoliation, and crown dieback. If damage is severe, tree mortality can occur. In addition, flooding can lead to secondary attacks by insect pests and diseases. Some species are more tolerant of flooding than others.

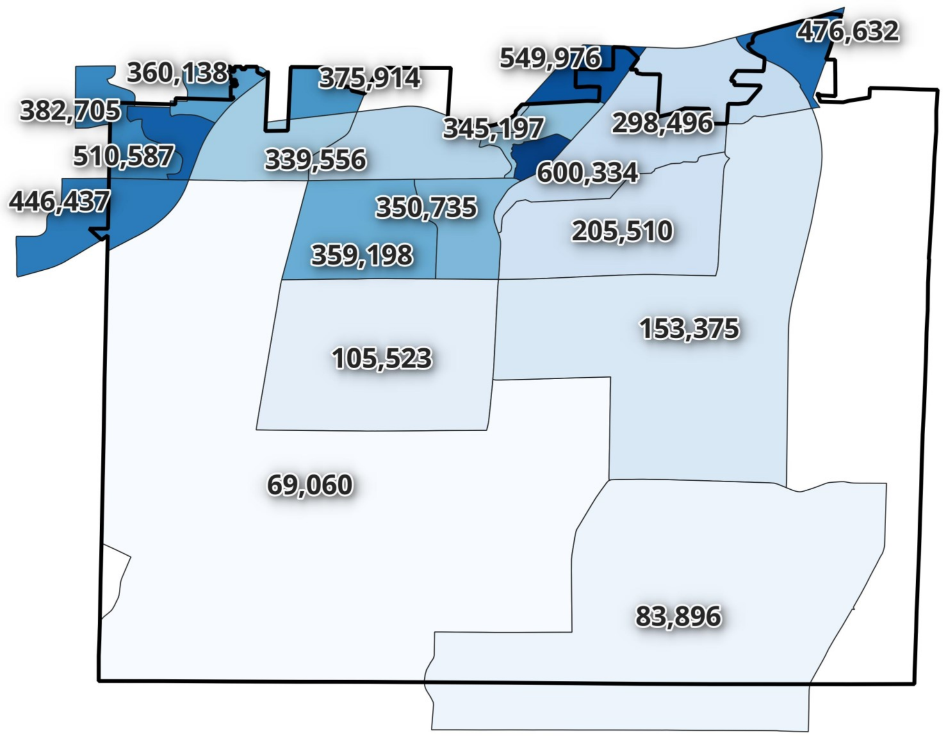
According to data from National Climatic Data Center and NOAA, Fitchburg receives 40.3” of precipitation annually. That total precipitation level and the impervious surface coverages can then be used to estimate the total potential stormwater runoff values by census area (rainfall x area) as indicated on the map on this page.

Stormwater Runoff Generated City of Fitchburg’s Impervious Surfaces Annually

City Total: **3.36 B** Gallons

City Average: **158,733** Gallons / Acre

Values in Gallons/Acre



Land Cover Impacts and Benefits

Stormwater Runoff and Management by Green Infrastructure

Green Infrastructure like native grasses, wetlands, and trees play a vital role in stormwater management. They help maintain and mimic the natural water cycle, often disrupted by urban development.

To gauge stormwater uptake by census tract, we used data from studies on urban tree canopy and grass water uptake.[4, 5, 6, 7, 8] Accurate values require detailed soil hydrology and runoff curve numbers. This study serves as a comparative tool between census tracts.

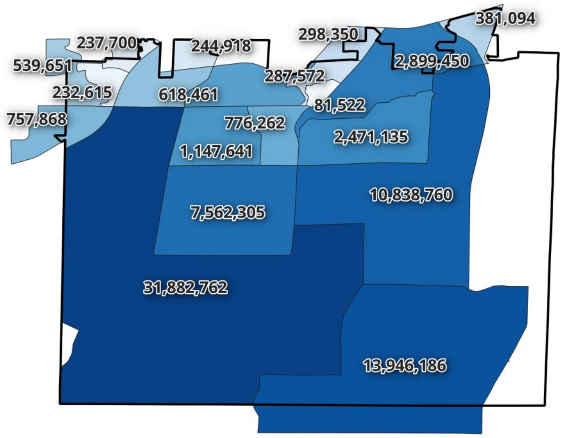
4: Yeganeh Asadian; Markus Weiler “A New Approach in Measuring Rainfall Interception by Urban Trees in Coastal British Columbia”; https://doi.org/10.2166/wqrj.2009.003

5: A. Guevara-Escobar, et al “Rainfall interception and distribution patterns of gross precipitation around an isolated Ficus benjamina tree in an urban area”; https://doi.org/10.1016/j.jhydrol.2006.09.017

6: USGS, Evaluation of Turf-Grass and Prairie-Vegetated Rain Gardens in a Clay and Sand Soil, Madison, Wisconsin, Water Years 2004–08, https://pubs.usgs.gov/sir/2010/5077/pdf/sir20105077.pdf

7: K. O'Costa, For Water Quality: Creating Woods Instead of Lawns, Penn State; https://ecosystems.psu.edu/research/centers/private-forests/news/for-water-quality-creating-woods-instead-of-lawns

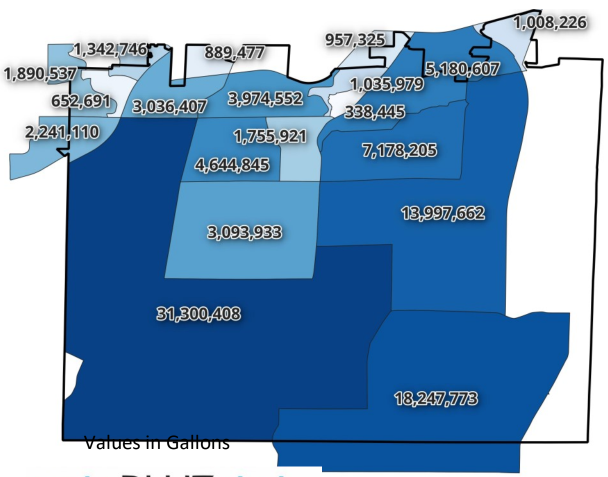
8: Clean Lakes Alliance, Prairies and Our Lakes; https://www.cleanlakesalliance.org/prairies-and-our-lakes/



Values in Gallons

Total Stormwater Uptake by Grasses and Agriculture Land

76.2 Million Gallons



Values in Gallons

Total Stormwater Uptake by Trees

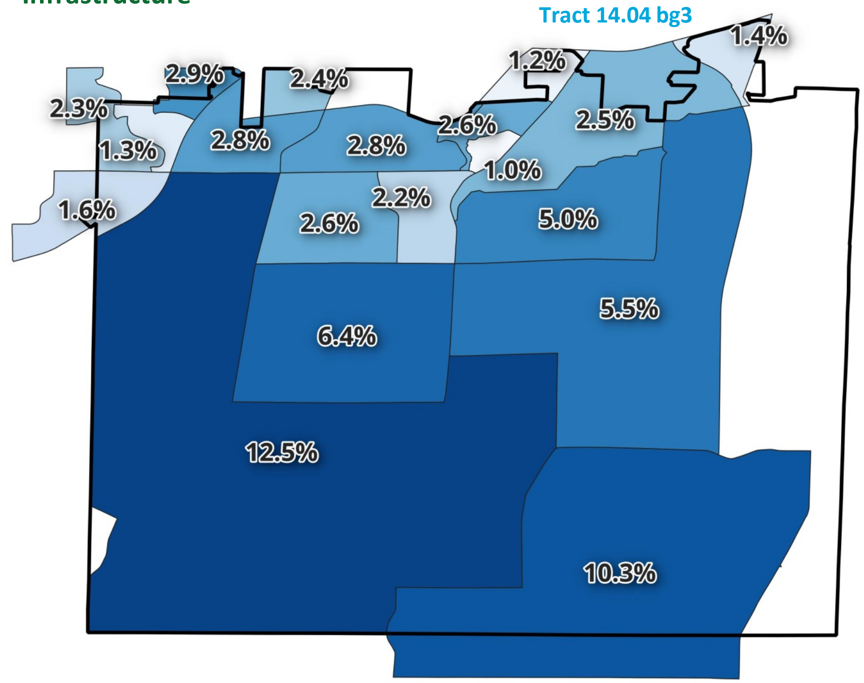
102.8 Million Gallons

Estimated Percentage of Stormwater Runoff Uptake by Green Infrastructure

City Average: **5.3%**

City High: **12.5%**
Tract 107.02 bg1

City Low: **1.0%**
Tract 14.04 bg3

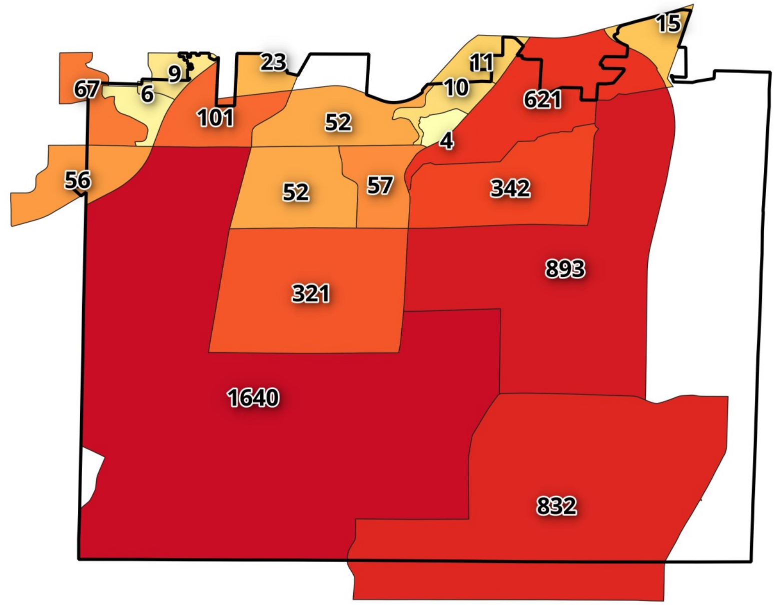


Land Cover Impacts and Benefits

Pollution Absorption - Carbon

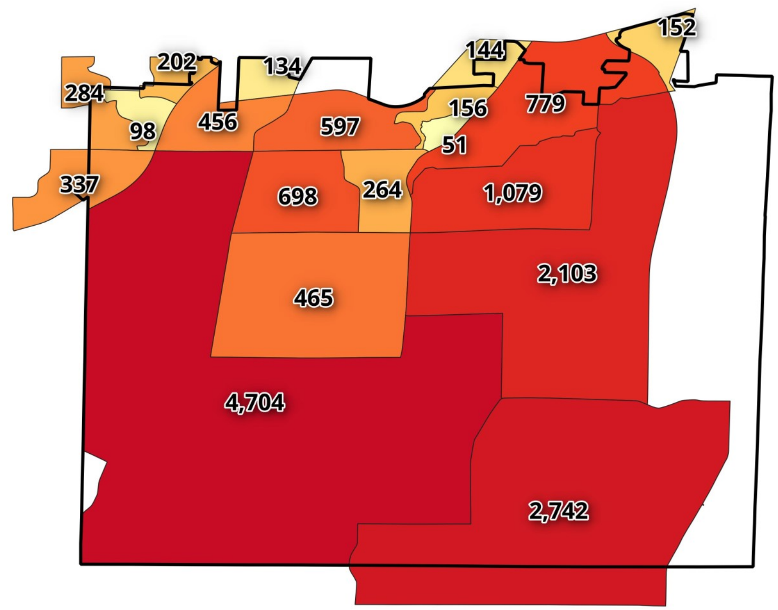
By volume, Carbon Dioxide pollution is the largest man-made emission contributing to Global Warming. Throughout the City of Fitchburg, 4 billion cubic feet of CO2 pollution is produced annually by vehicles alone. Carbon Sequestration occurs throughout the growing season of all plants. Long-term carbon storage occurs within the tree/plant structure in the form of the plant material as well as below-grade in the form of soil carbon. 3.663 pounds of CO2 sequestered produces 1 pound of

Annual Carbon Sequestration by Lawns and Grasses (metric tons)



Values in Metric Tons

Annual Carbon Sequestration by Trees (metric tons)



Values in Metric Tons

Land Cover Impacts and Benefits

Pollution Absorption - Carbon

The combined carbon sequestration services of grasses and trees throughout the community can be seen as a measure of equity of green infrastructure when viewed on a per-acre basis. Higher per-acre carbon sequestration rates reflect combined higher rates of per-acre green infrastructure (trees and grasses). In addition, these per-acre values can help guide future tree canopy increase goals by focusing on portions of the community with lower per-acre baselines while including consideration for other ground cover aspects which may be important to the community such as retention of existing agricultural land.

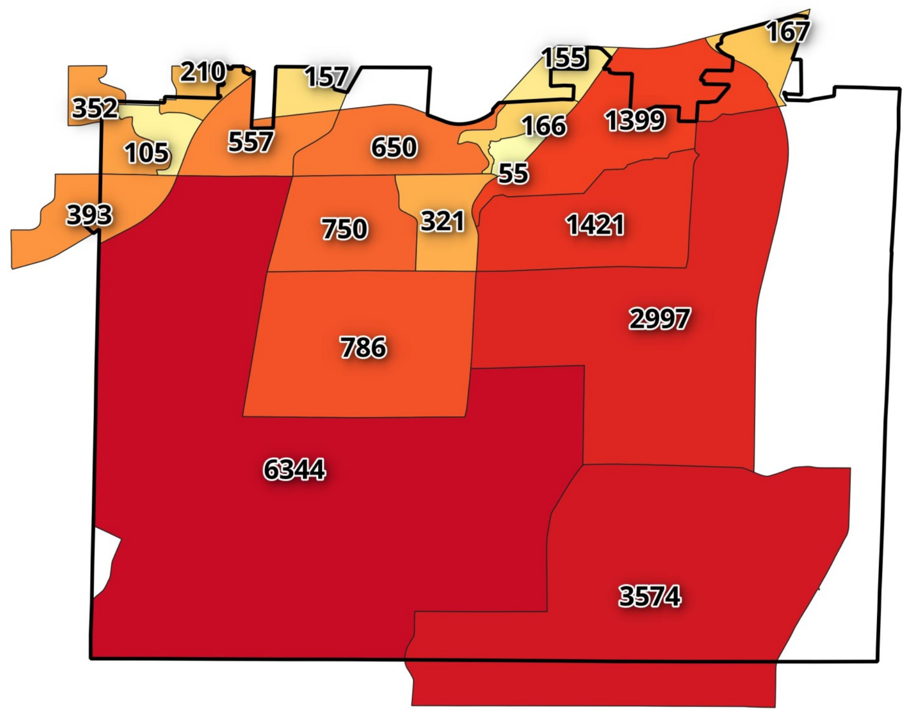
Annual Carbon Sequestration of Green Infrastructure Per Acre (metric tons)

City Total: **20,557**

City High: **6,344** **Tract 107.02 bg1**

City Low: **55** **Tract 14.04 bg3**

Values in Pounds



(Note: Sequestration rates used are rule-of-thumb values; actual rates can vary widely based on factors including land management practices, soil types, and topography)

Section 04

Tree Canopy Economic Value

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Recently, the USDA Forest Service developed models with partners to help cities evaluate their tree resources' economic and environmental worth. Benefits in Section 3 have both economic and environmental value.

Air Pollution Removal Values

Section 3 mentions six pollutants as defined by the U.S. EPA: carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), sulfur dioxide (SO2), particulate matter (PM), PM less than 2.5 microns (PM2.5), and PM between 2.5 and 10 microns (PM10).

Estimates for pollution removal come from the USDA iTree Canopy tool and are based on EPA's BenMAP.[1] Using various data, it gauges pollution removal and values in urban/rural areas. Values per ton removed are: CO at $0.05 | NO2 at $0.03, O3 at $0.19, SO2 at $0.01, PM2.5 at $8.84, PM10 at $0.51, and CO2 sequestration at $46.51 per ton.

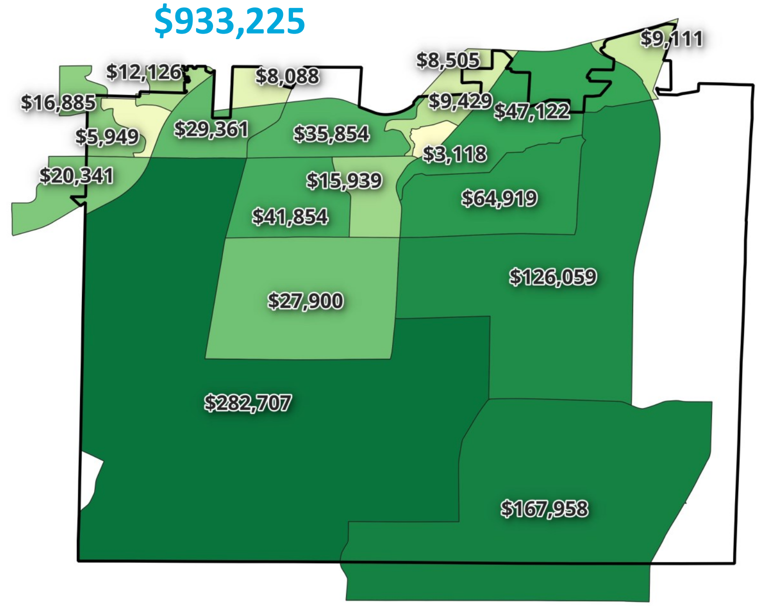
Building Energy Savings Values

Section 3 explains how to estimate energy savings using tree counts per acre based on a study. With these averages, we can calculate the electrical and gas savings from the City's tree canopy using average costs for electricity and natural gas.

1: USDA iTree Methods: https://www.itreetools.org/support/resources-overview/i-tree-methods-and-files

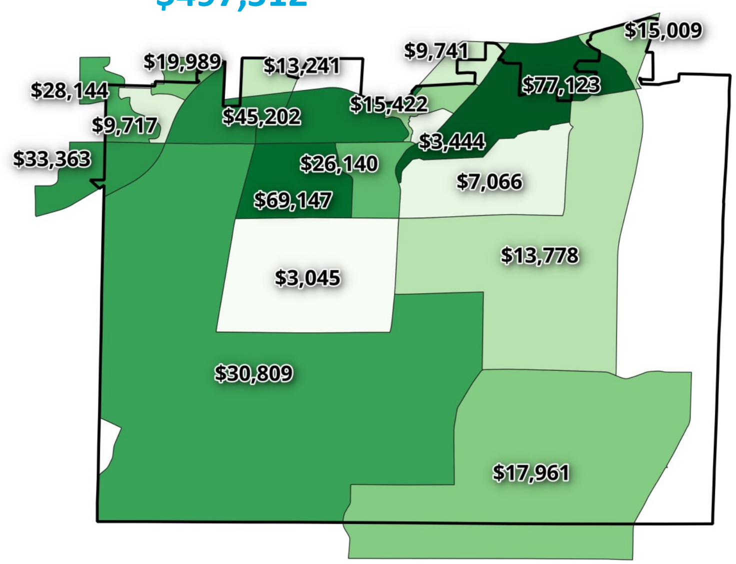
Annual Pollution and Carbon Benefit Value of Trees

$933,225



Annual Energy Savings Value of Trees

$497,512



Tree Canopy Economic Value

Equity in Tree Value

The economic benefits outlined on the previous page can be viewed on the basis of value-per-acre and value-per-household to establish an understanding of tree benefit equity throughout the City.

Tree Canopy Benefit Per Acre

City Average:

$67.64

City High:

$209.08 **Tract 5.01 bg2**

City Low:

$19.58 **Tract 107.01 bg3**

Tree Canopy Benefit Per Household

City Average:

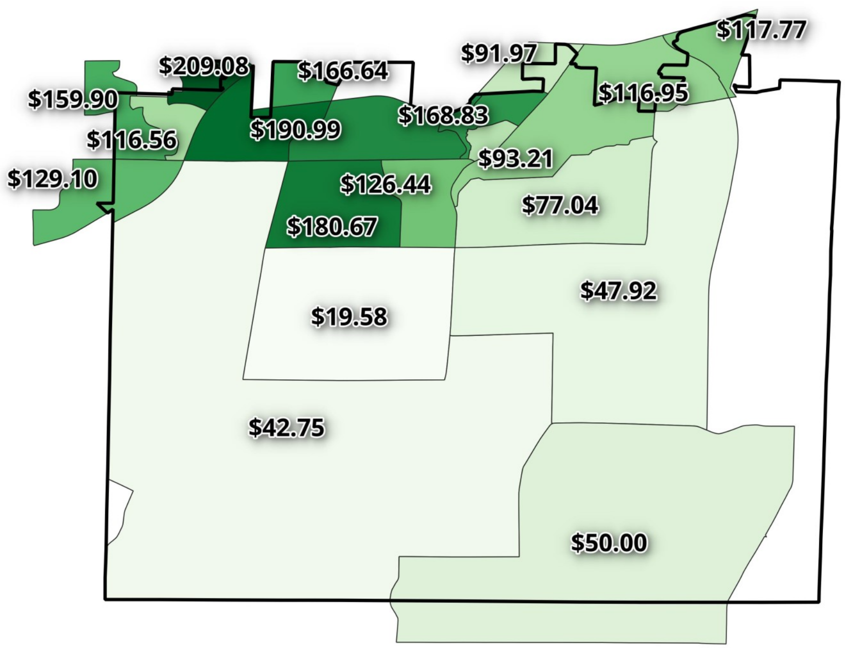
$92.32

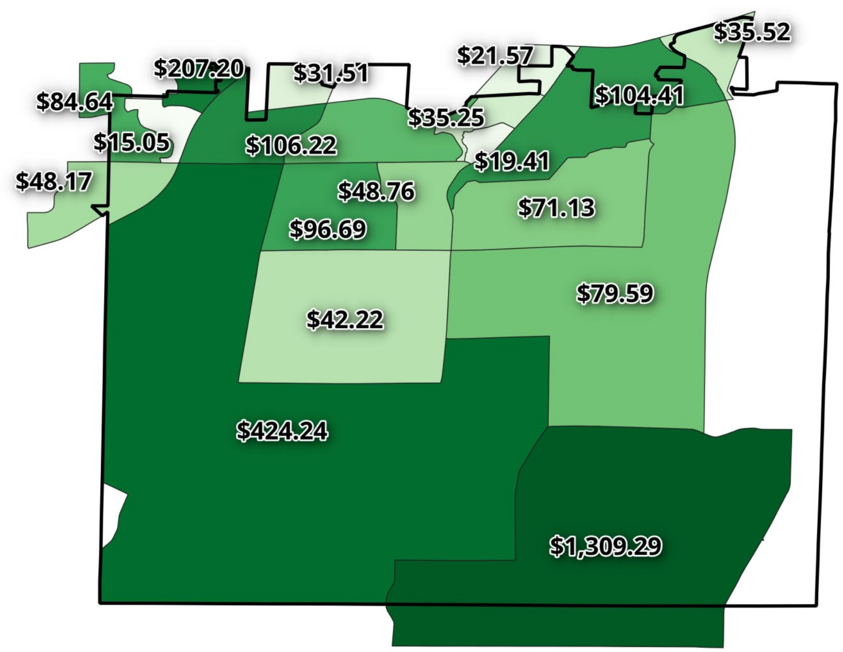
City High:

$1,309.29 **Tract 125.02 bg1**

City Low:

$15.05 **Tract 5.06 bg2**





Section 05 Findings

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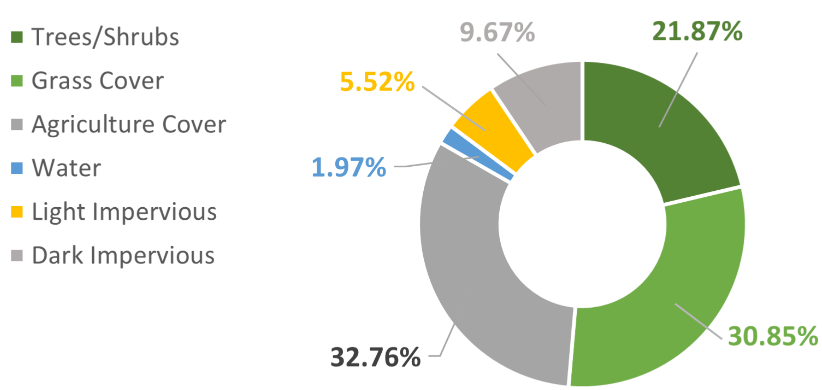
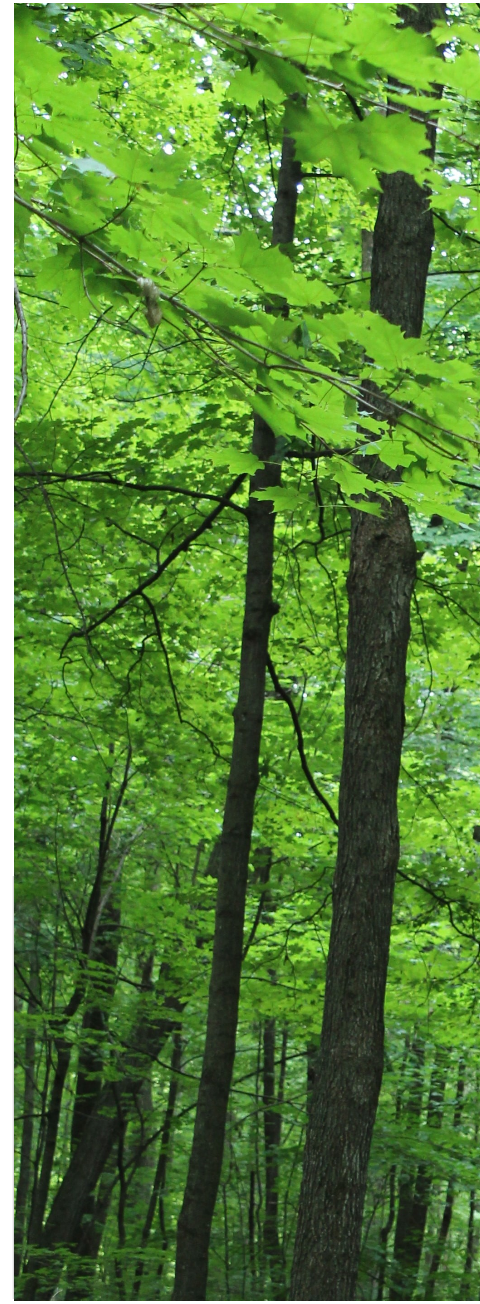
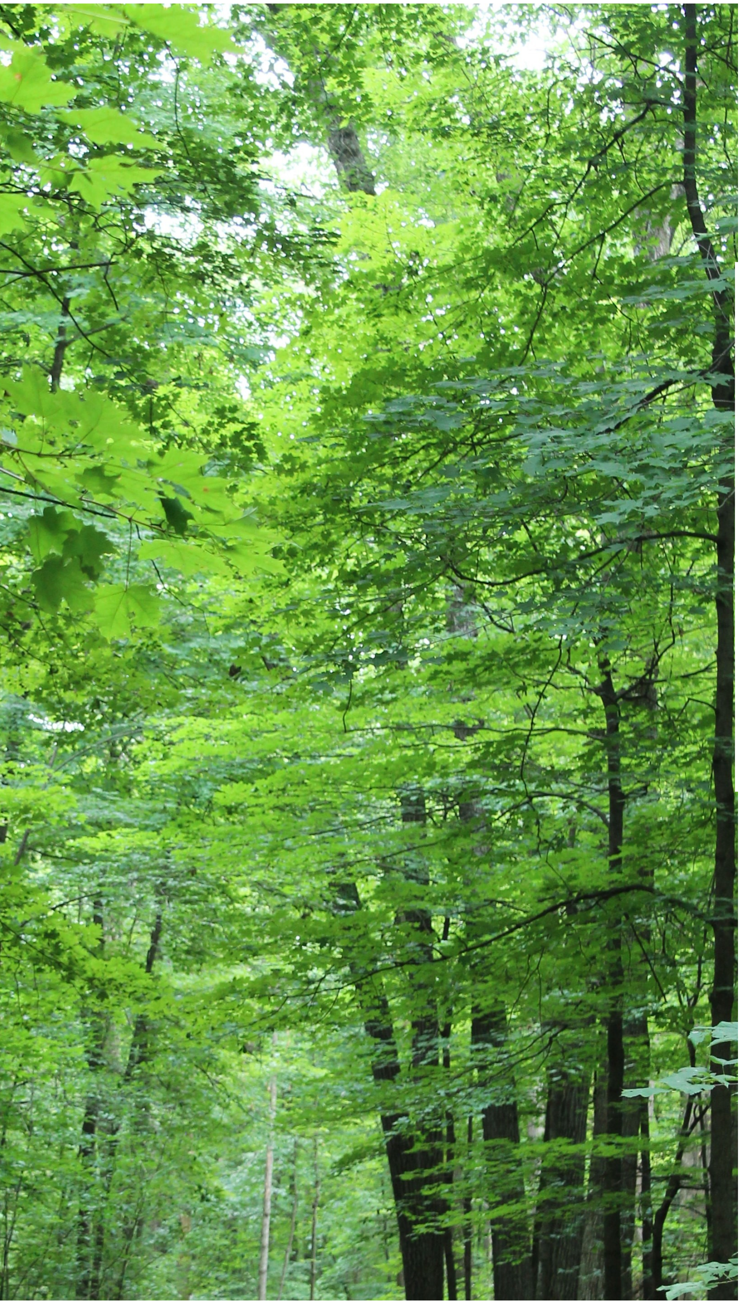
The health of the City's green infrastructure and the impacts of impervious land cover affect everyone in the community and City policies and actions should consider needs of the entire community. As with all planning efforts landcover planning benefits from analysis in order to assist in establishing priorities for efforts. An effort to structure a prioritization should not be seen as an attempt to discard the need to address or improve land cover impacts for any census area of the City - whether or not it is defined as one of the "priority" census areas. Prioritization, however, is necessary to ensure the greatest impact and effectiveness of limited City resources.

To assist in prioritization, in the following pages, this report reviews the community Green Infrastructure and Impervious Surface data through "filters" in order to arrive at a recommended prioritization of census areas for policy action. These "filters" are based on the land coverage information detailed in Section 2 of this report.

Ground Cover Breakdown by Type



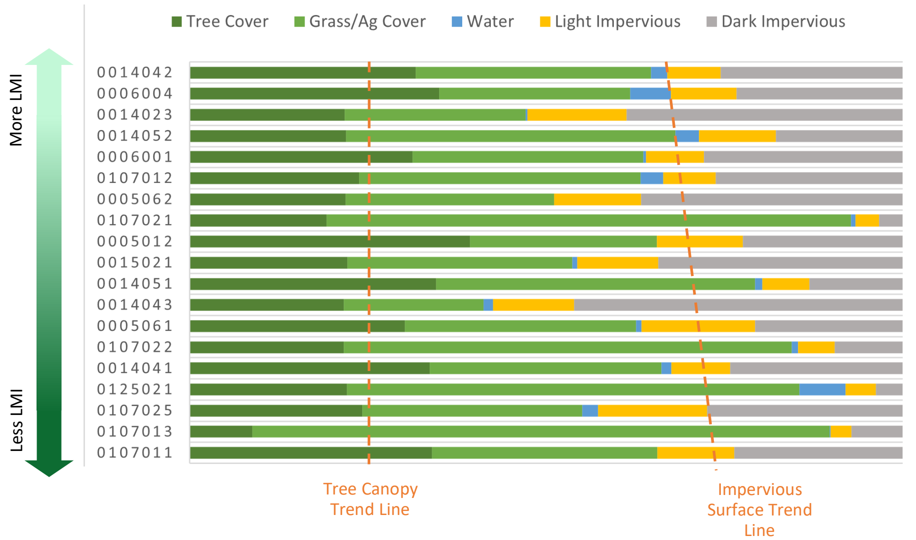




Ground Cover Characteristics by Census Tract

Organized by Share of Low Income Population (LMI)

The bar chart compares land cover data from Section 2 by Census Tract. Tracts with the most low to moderate-income (LMI) households are at the top and those with the least at the bottom. The chart doesn't show a consistent link between LMI populations and tree canopy coverage. There is, however, some indication of a potential link between LMI populations and dark impervious surface



coverage.

The Importance of Ground Cover and Heat Island Mitigation

A recent study found that the warming effect of impervious surfaces within developed areas was effectively countered by the cooling effect of trees, especially when tree canopy coverage was 40% or greater.[1] The same study found that reducing overall coverage of impervious surfaces is critical for the reduction of night-time summer temperatures.

1: Ziter CD, Pedersen EJ, Kucharik CJ, Turner MG. "Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer." Proc Natl Acad Sci U S A. 2019; https://pubmed.ncbi.nlm.nih.gov/30910972/


Pick 'n Save

Review Criteria - Green Infrastructure

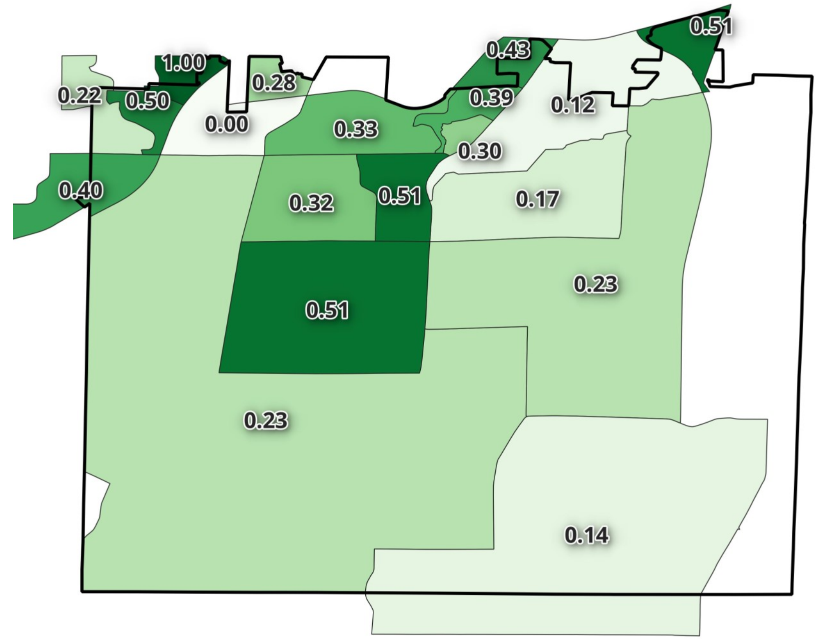
Prioritization of locations for increased green infrastructure included in this report is based on an equity approach. This approach reviews a range of land cover and demographic characteristics of each census tract in an "environmental equity index".

To determine the best locations to plant trees, tree canopy and impervious cover maps developed for this report's Section 2 were used in conjunction with U.S. Census data to produce an index of priority planting areas by census area. Index values were produced for each census area, with higher index values relating to higher priority of the area for tree planting. This index is a type of "environmental equity" index with areas with higher human population density, higher economic stress, lower existing tree cover, and higher total tree canopy potential receiving the higher index value. The criteria used to make the index were:

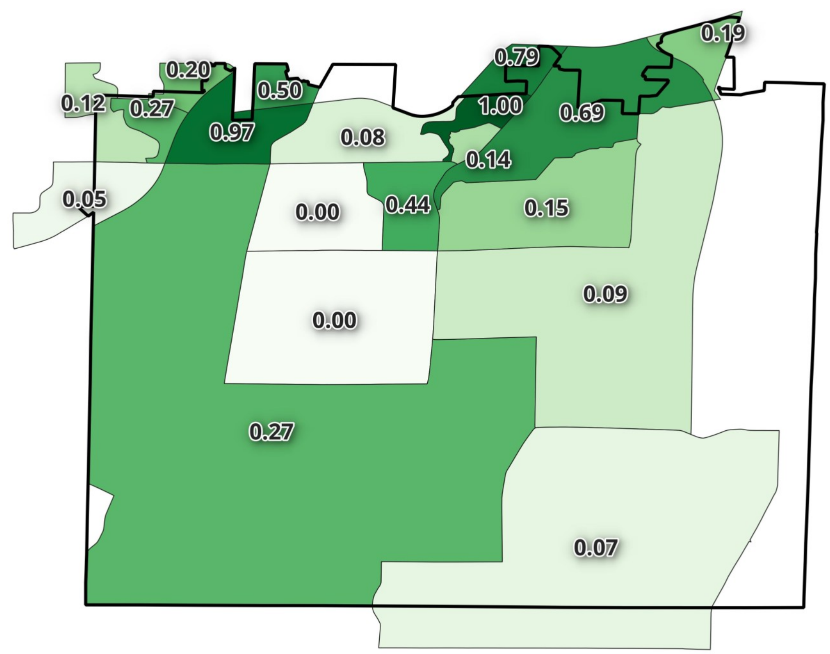
- Potential for New Trees
- Low Income Density
- Population Density
- Heat Island Reduction Need

These criteria are then combined to establish a "Weighted Priority Tree Canopy Increase."

Prioritization based on
Potential for New Trees
Higher values represent increased potential for tree planting based on physical capacity (available open space, open lawn areas, etc excluding land used as agriculture)



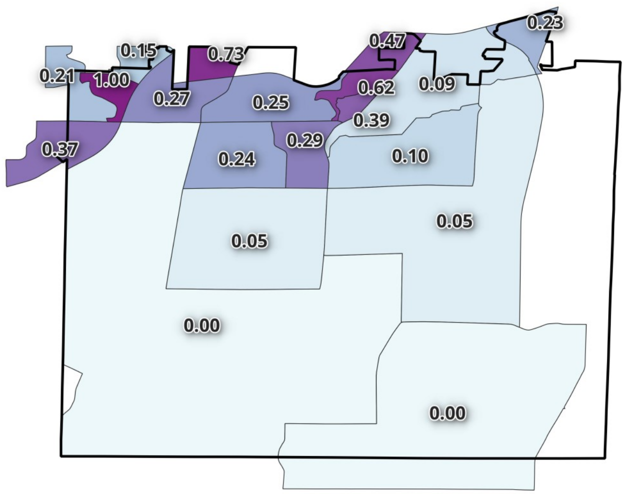
Prioritization based on
Low Income Density
(equity adjustment)
Higher low income density values represent higher potential for increasing environmental equity of tree canopy cover and benefits.



Findings

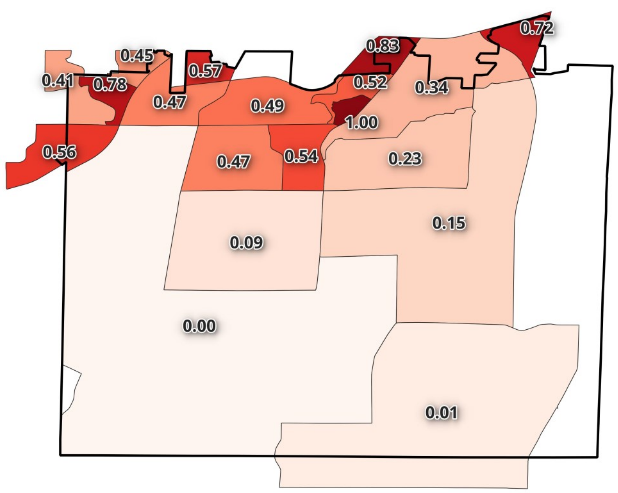
Prioritization based on Total Population Density

The greater the population density, the greater the opportunity for tree planting to impact community members. Population densities shown are estimates based on US Census data by tract. Higher numbers represent higher prioritization based on this category.



Prioritization based on Heat Island Reduction Need

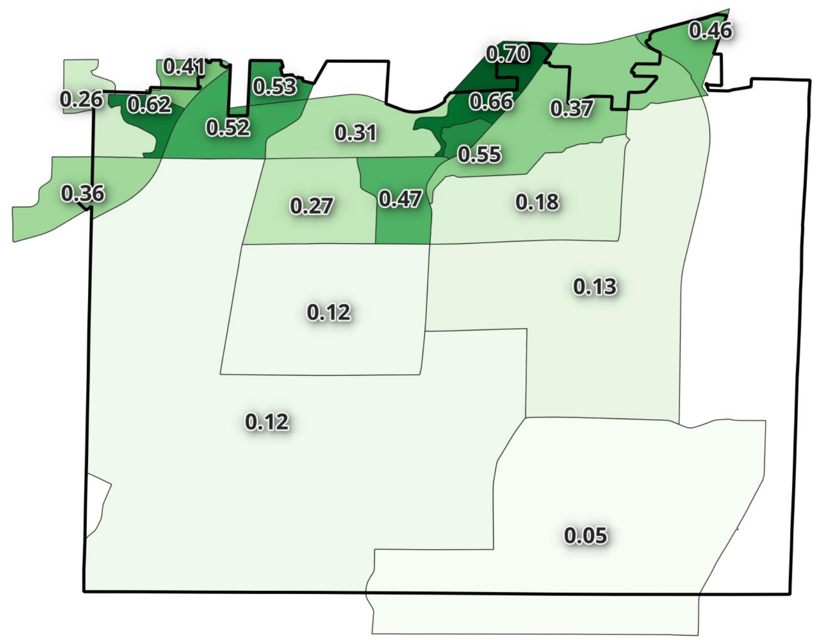
Higher heat island reduction need values represent increased potential for reducing current and future heat island impacts through tree planting.

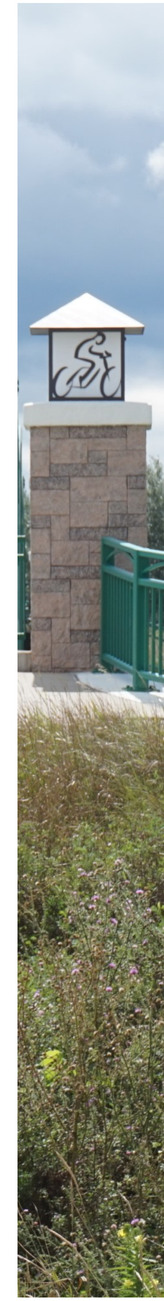


Weighted Priority Tree Canopy Increase

The weighted prioritization for tree canopy increase looks to balance the potential for increased tree canopy with the opportunity to improve tree canopy benefit equity, potential to positively impact as many households as possible, and the need for mitigation of heat island impacts. Higher numbers represent higher prioritization. The priorities above are weighted as follows:

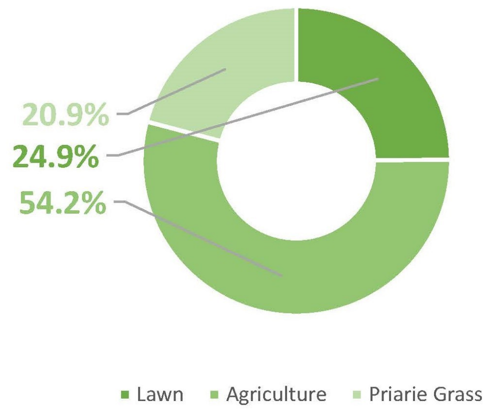
- Potential for New Trees: 15%
- Low Income Density: 30%
- Population Density: 15%
- Heat Island Reduction Need: 40%





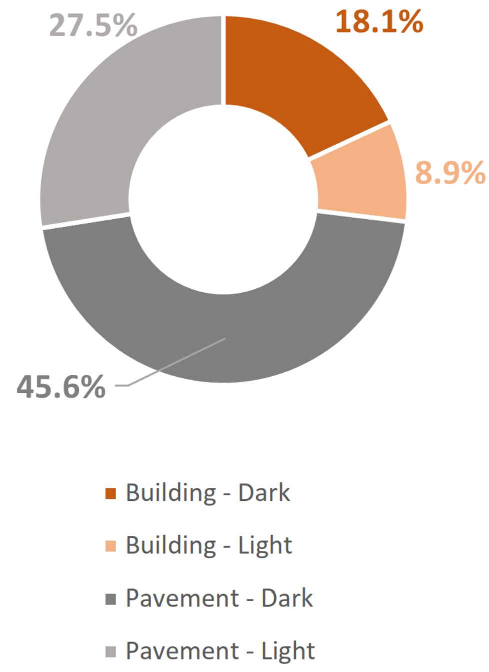
Findings

In addition to opportunities to expand and improve the City's tree canopy, the findings of the ground cover study as outlined in Section 2 may be used to identify additional opportunities for increased heat island mitigation and increased native grass installations.



Turf Reduction Potential

As illustrated in the chart to the right, 54.2% of all grasslands in City of Fitchburg are agricultural and crop lands. An estimated 24.9% are native prairie and wildflower grasses. The remaining 20.9% are manicured lawns—representing a great opportunity for turf reduction. Turf reduction can increase stormwater uptake, reduce potable water use, and increase soil carbon.



Impervious Surface Characteristic

As outlined in Section 3, the City's experiences of heat island are directly impacted by the level of impervious surface coverage—particularly dark roofs and pavement. As the diagram to the right illustrates, dark pavements make up 45.6% of City impervious surfaces while dark roof structures make up 18.1%, totaling 63.7% of all impervious surfaces classified as 'dark'. This data indicates significant potential for decreasing heat island impacts in the community through "cool" and "green" roof and pavement strategies.

Section 06

Calculating Potential Goals

Click here to return to TOC

Calculating Tree Canopy Coverage Goal for 2040

Total tree canopy coverage goals are central to long-range land cover goal recommendations for the City. In support of an "Environmental Equity" approach to tree canopy goalsetting, as outlined in the Findings Section of this report, identification of long-term tree canopy coverage goals includes consideration of each census area's Tree Stock value (the amount of existing tree canopy compared to available land for tree canopy coverage), population densities, economic stress densities, and heat island mitigation need.

The City of Fitchburg's Comprehensive Plan established a goal of 30% tree canopy coverage for the Urban Service Area (Policy 1.3.6). This study builds on this goal, illustrating potential ground cover goals covering the entire city.

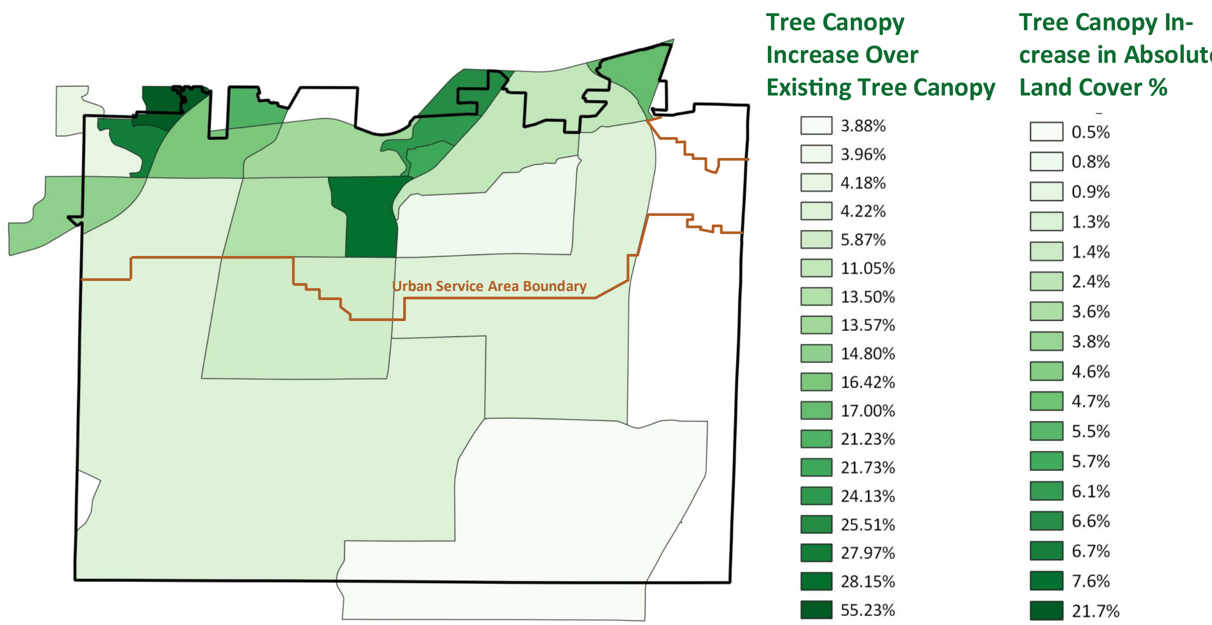
An "Environmental Equity" approach from Section 05 shapes the 2040 goal. This method evaluates census tracts based on potential for new trees, low income density, population density, and heat island reduction need. The proposed framework does not include land in use as agriculture in calculations of potential tree canopy increases.

The recommended Tree Stock increase goals are:

For areas in the top 1/3rd Census area Priority Ranking:	12%
For areas in middle 1/3rd Census area Priority Ranking:	7.25%
For areas in bottom 1/3rd Census area Priority Ranking:	2.5%

Resulting 2040 Tree Canopy Coverage Goal:

Citywide Average:	23.5%
Urban Service Area Average:	32%



New Tree Plantings Needed to Achieve Tree Canopy Coverage Goal for 2040

While it is easy to think of the long range Tree Canopy coverage goals for each neighborhood in terms of planting trees, it is critical that tree canopy enhancement goals include a combination of tree protection, tree maintenance, and tree planting in order to be fully realized and efficiently implemented.

A common calculation used to determine the new tree planting requirements is based on a report by the USDA Forest Service.[1] That report offers the following conceptual analysis for increasing tree canopy coverage:

CB + CG - CM + CN = CT
Where:
CB= the existing Tree Canopy;
CG= the growth of existing Tree Canopy (protection and maintenance);
CM= Tree Canopy mortality or loss due to natural and human-induced causes (including removal of invasive species).
CN= Tree Canopy increase from new trees (planting); and
CT= total Tree Canopy Result (or goal)

The maps on the following pages illustrate these calculations for the example 2040 goal for the City of Fitchburg.

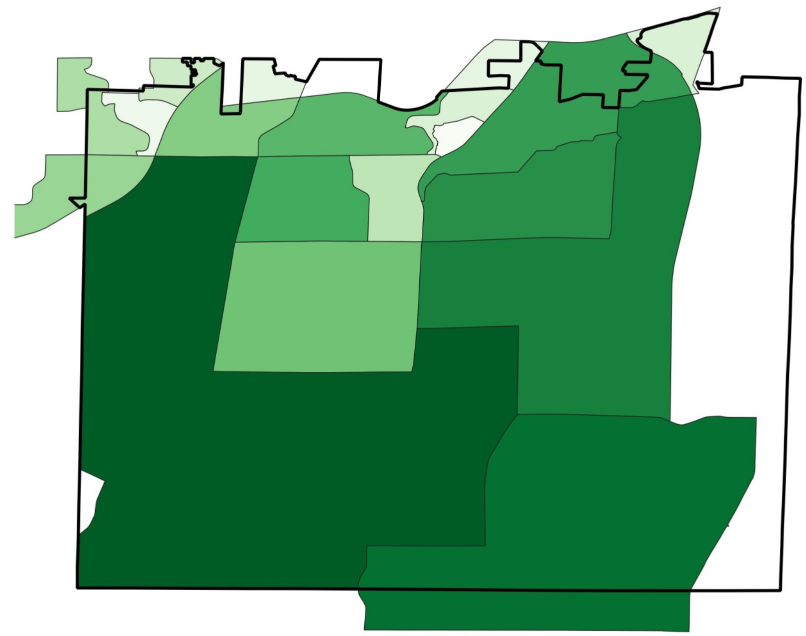
1: J. Morgan Grove, et al, A Report on New York City's Present and Possible Urban Tree Canopy; https://www.fs.usda.gov/nrs/utc/reports/UTC_NYC_Report_2006.pdf

2: E. Gregory McPherson and Paula J. Peper, Urban Tree Growth Modeling; https://www.fs.usda.gov/psw/publications/mcpherson/psw_2012_mcpherson001.pdf

3: Jason S. Lyle, How Fast Do Trees Grow; http://qualityforest.com/forester-notes/how-fast-do-trees-grow.pdf

Translating Tree Canopy Coverage Goal To New Tree Planting - Growth Rates (CG)

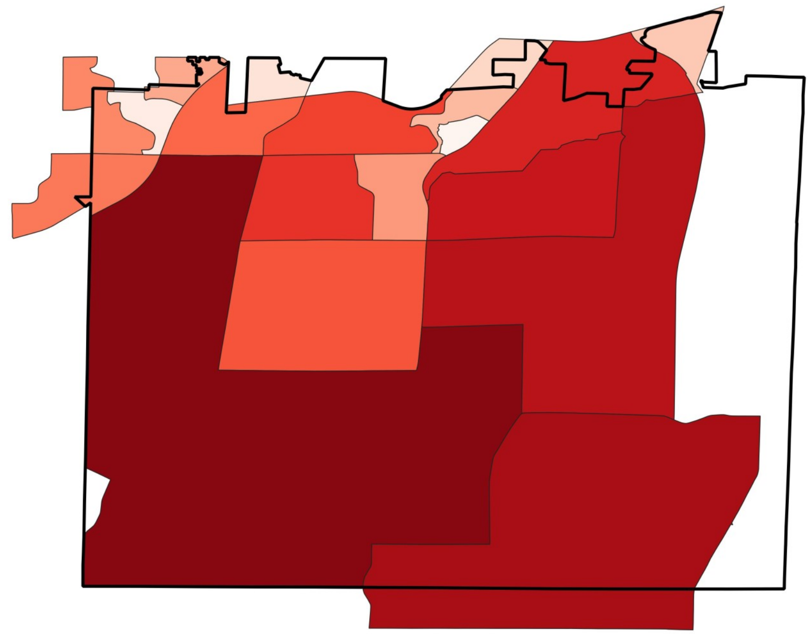
Consideration of tree canopy growth rate is important in anticipating long-range tree canopy goals and annual new planting needs. Though there are studies on urban tree canopy growth rates, the methodologies, studied species, and results vary. Due to the high variability of information and results, this report uses the blended annual growth rate of 4.36% found in the most prevalent studies.[2, 3]



Calculating Potential Goals

Translating Tree Canopy Coverage Goal To New Tree Planting - Mortality Rates (CM)

Consideration of tree canopy growth rate is important in anticipating long-range tree canopy goals and annual new planting needs. As with urban tree growth rates, existing studies and results vary. Due to the high variability of information and results, this report uses the mixed urban tree mean mortality of 4.3% from "Urban Tree Mortality: A Literature Review."[4]



Ash Tree Mortality and Invasive Species Removal

The USDA Forest Service approximates that Ash trees make up about 7% of forest trees in the Eastern U.S. and might constitute up to 50% of urban street trees.[5] Unfortunately, the Emerald Ash Borer insect poses a significant threat to Ash trees. City's long-term tree canopy strategies should expect major Ash tree losses in the upcoming 10-15 years (all non-treated trees included). Besides unwanted tree deaths, invasive species removal could be a necessary management strategy.

This study uses 9% as the assumed Ash tree share of the existing urban tree canopy, with an assumed 50% loss occurring over the next 15 years. These losses are included in the total tree mortality rates (TM) illustrated.

4: Deborah R. Hilbert, et al, Urban Tree Mortality: A Literature Review; https://www.fs.usda.gov/nrs/pubs/jrnl/2019/nrs_2019_hilbert_001.pdf

5: Devin J. Wanner, Virgina Tech Demonstrates New Method To Treat Ash Firewood; https://www.fs.usda.gov/features/virginia-tech-demonstrates-new-method-treat-ash-firewood

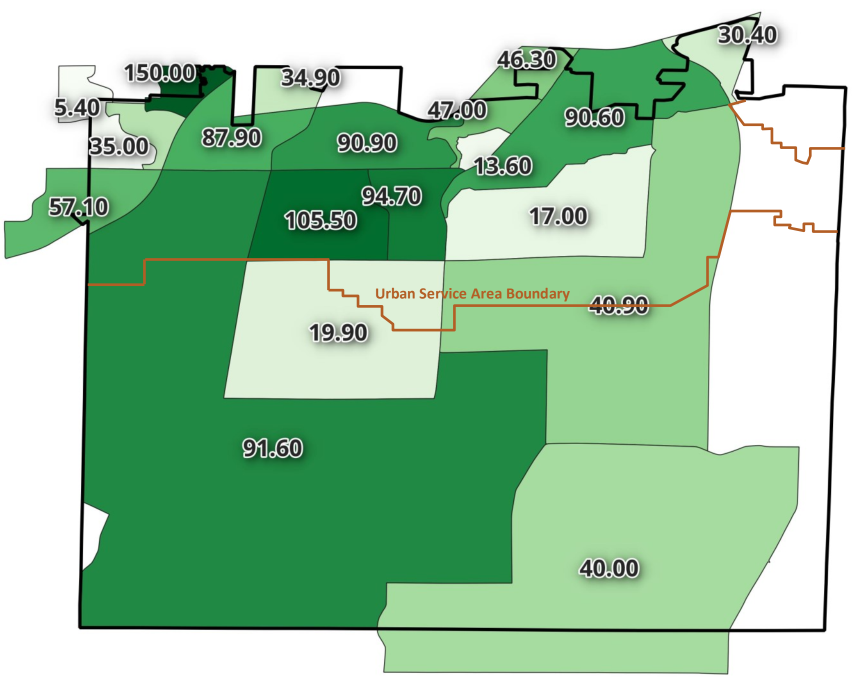
Translating Tree Canopy Coverage Goal To New Tree Planting - New Tree Planting Annual Target (CN)

Using the new planting requirement calculation method (CB + CG - CM + CN = CT) with the previously defined values for existing tree canopy (CB), growth rates (CG), mortality rates (CM), and the 2040 Tree Canopy (CT) goals by census area the required number of new trees to be planted to meet that goal can be identified. The map below shows the annual new tree count required to meet the 2040 tree canopy goals for each census area.

New Tree Planting Annual Target to Meet 2040 Tree Canopy Goal (CN)

Community-Wide Total (Note, Acreage represents the canopy coverage at year of planting, with an assumed new tree crown radius of 5' planted no more than 22' apart):

2,800 New Trees **31 Acres**



Annual Path to 2040 Tree Canopy Cover Goal

The chart below shows the community wide average values for year beginning canopy cover (CB), annual growth rate (CG), mortality rate (CM), the new tree planting targets (CN) and the year end tree canopy goal (CT) for each year through the 2040 goal.

Resulting Tree Canopy Coverage:	2030	2040
Citywide Average:	22.5%	23.5%
Urban Service Area Average:	30%	32%

Note, the proposed framework does not include land in use as agriculture in calculations of potential tree canopy increases.

	CB (existing)		CG (growth)		CM (loss)		CN (new)		CT (year goal)	UTC (year end coverage %)
2024	4626	+	202	-	-213	+	31	=	4646	22.0%
2025	4646	+	203	-	-214	+	31	=	4666	22.1%
2026	4666	+	204	-	-215	+	31	=	4686	22.2%
2027	4686	+	204	-	-216	+	31	=	4706	22.3%
2028	4706	+	205	-	-216	+	31	=	4727	22.3%
2029	4727	+	206	-	-217	+	31	=	4747	22.4%
2030	4747	+	207	-	-218	+	31	=	4767	22.5%
2031	4767	+	208	-	-219	+	31	=	4787	22.6%
2032	4787	+	209	-	-220	+	31	=	4807	22.7%
2033	4807	+	210	-	-221	+	32	=	4827	22.8%
2034	4827	+	211	-	-222	+	32	=	4847	22.9%
2035	4847	+	211	-	-223	+	32	=	4867	23.0%
2036	4867	+	212	-	-224	+	32	=	4887	23.1%
2037	4887	+	213	-	-225	+	32	=	4908	23.2%
2038	4908	+	214	-	-226	+	32	=	4928	23.3%
2039	4928	+	215	-	-227	+	32	=	4948	23.4%
2040	4948	+	216	-	-228	+	32	=	4968	23.5%

Section 07
Recommendations

Click here to return to TOC

Conclusions

Even with a strong existing green infrastructure, the City has the potential for more. As this report outlines, tree canopy cover in the City provides a number of benefits including pollution absorption, energy consumption savings, carbon sequestration, micro heat island mitigation, and economic benefit. Consequently, increases in green infrastructure offer significant reward potential for the City.

Preliminary Strategic Goal Recommendations

Section 6 of this report provided a range of recommended goals for the City of Fitchburg. The recommendations included in this document should be understood as preliminary illustrations only and created solely for the purpose of supporting a fully collaborative planning team process. The potential goals are:

1. To increase the tree canopy coverage throughout the City, particularly in areas with increased vulnerable population shares (see the City's Climate Vulnerability Assessment for more information), an average of at least 1.7% of total City-wide land area by 2040 (equal to an increase of 7% over total existing tree canopy coverage).
2. Decrease the quantity of "dark" impervious surfaces throughout the City, particularly in census areas identified with higher heat island contributions in Section 3, by an average of 10% of existing dark impervious surface coverage by 2040 (approximately 15 acres annually).
3. Increase pollinator supportiveness of lawns and non-agricultural grasslands in City of Omaha and achieve a 10% turf replacement with native grasses and wildflowers by 2030 (approximately 45 acres annually).

Section

A1

i-Tree Technical Notes

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i-Tree Canopy Technical Notes

This tool is designed to allow users to easily and accurately estimate tree and other cover classes (e.g., grass, building, roads, etc.) within their city or any area they like. This tool randomly lays points (number determined by the user) onto Google Earth imagery and the user then classifies what cover class each point falls upon. The user can define any cover classes that they like and the program will show estimation results throughout the interpretation process. Point data and results can be exported for use in other programs if desired.

There are three steps to this analysis:

1) Import a file that delimits the boundary of your area of analysis (e.g., city boundary). Some standard boundary files for the US can be located on the US Census website. Data from these sites will require some minor processing in GIS software to select and export a specific boundary area polygon.
2) Name the cover classes you want to classify (e.g., tree, grass, building). Tree and Non-Tree are the default classes given, but can be easily changed.
3) Start classifying each point: points will be located randomly within your boundary file. For each point, the user selects from a dropdown list the class from step 2 that the point falls upon.

The more points that are interpreted, the more accurate the estimate.

Credits

The concept and prototype of this program were developed by David J. Nowak, Jeffrey T. Walton and Eric J. Greenfield (USDA Forest Service). The current version of this program was developed and adapted to i-Tree by David Ellingsworth, Mike Binkley, and Scott Maco (The Davey Tree Expert Company).

Limitations

The accuracy of the analysis depends upon the ability of the user to correctly classify each point into its correct class. Thus the classes that are chosen for analysis must be able to be interpreted from an aerial image. As the number of points increase, the precision of the estimate will increase as the standard error of the estimate will decrease. If too few points are classified, the standard error will be too high to have any real certainty of the estimate. Information on calculating standard errors can be found below. Another limitation of this process is that the Google imagery may be difficult to interpret in all areas due to relatively poor image resolution (e.g., image pixel size), environmental factors, or poor image quality.

Calculating Standard Error and Confidence Intervals from Photo-Interpreted Estimates of Tree Cover
In photo-interpretation, randomly selected points are laid over aerial imagery and an interpreter classifies each point into a cover class (e.g., tree, building, water).

From this classification of points, a statistical estimate of the amount or percent cover in each cover class can be calculated along with an estimate of uncertainty of the estimate (standard error (SE)). To illustrate how this is done, let us assume 1,000 points have been interpreted and classified within a city as either "tree" or "non-tree" as a means to ascertain the tree cover within that city, and 330 points were classified as "tree".

To calculate the percent tree cover and SE, let:

N = total number of sampled points (i.e, 1,000)
n = total number of points classified as tree (i.e., 330), and
p = n/N (i.e., 330/1,000 = 0.33)
q = 1 – p (i.e., 1 - 0.33 = 0.67)
SE = √ (pq/N) (i.e., √ (0.33 x 0.67 / 1,000) = 0.0149)

Thus in this example, tree cover in the city is estimated at 33% with a SE of 1.5%. Based on the SE formula, SE is greatest when p=0.5 and least when p is very small or very large (Table 1).

Table 1. Estimate of SE (N = 1000) with varying p.

p	SE
0.01	0.0031
0.1	0.0095
0.3	0.0145
0.5	0.0158
0.7	0.0145
0.9	0.0095
0.99	0.0031

Confidence Interval
In the case above, a 95% confidence interval can be calculated. "Under simple random sampling, a 95% confidence interval procedure has the interpretation that for 95% of the possible samples of size *n*, the interval covers the true value of the population mean" (Thompson 2002). The 95% confidence interval for the above example is between 30.1% and 35.9%. To calculate a 95% confidence interval (if N>=30) the SE x 1.96 (i.e., 0.0149 x 1.96 = 0.029) is added to and subtracted from the estimate (i.e., 0.33) to obtain the confidence interval.

SE if n < 10

If the number of points classified in a category (n) is less than 10, a different SE formula (Poisson) should be used as the normal approximation cannot be relied upon with a small sample size (<10) (Hodges and Lehmann, 1964). In this case:

$SE = (\sqrt{n}) / N$

For example, if n = 5 and N = 1000, p = n/N (i.e., 5/1,000 = 0.005) and SE = $\sqrt{5}$ / 1000 = 0.0022. Thus the tree cover estimate would be 0.5% with a SE of 0.22%.

References

Lindgren, BW and GW McElrath. 1969. Introduction to Probability and Statistics. Macmillan Co. London
Hodges, JL and EL Lehmann. 1964. Basic Concepts of Probability and Statistics. Holden-Day, Inc. San Francisco.
Thompson, S. K. 2002. Sampling, second edition. John Wiley and Sons, Inc., New York, New York.

Section A2

Climate Adaptive Tree Species

(Northern Institute of Applied Climate Science)

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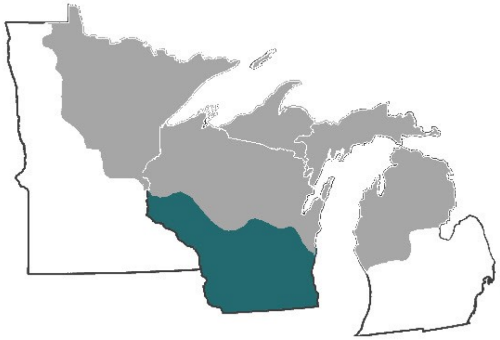
CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

SOUTHERN WISCONSIN



This region's forests will be affected by a changing climate and other stressors during this century. A team of managers and researchers created a field guide that includes information on the vulnerability of forests in the region (Handler et al. 2021). The Landscape Change Research Group recently updated the Climate Change Tree Atlas, and this handout summarizes that information. Full Tree Atlas results are available online at www.fs.fed.us/nrs/atlas/. Two climate scenarios are presented to "bracket" a range of possible futures. These future climate projections (2070 to 2099) provide information about how individual tree species may respond to a changing climate. Results for "low" and "high" emissions scenarios can be compared on the reverse side of this handout.

The updated Tree Atlas presents additional information helpful to interpret tree species changes:

- Suitable habitat - calculated based on 39 variables that explain where optimum conditions exist for a species, including soils, landforms, and climate variables.
- Adaptability - based on life-history traits that might increase or decrease tolerance of expected changes, such as the ability to withstand different forms of disturbance.
- Capability - a rating of the species' ability to cope or persist with climate change in this region based on suitable habitat change (statistical modeling), adaptability (literature review and expert opinion), and abundance (FIA data). The capability rating is modified by abundance information; ratings are downgraded for rare species and upgraded for abundant species.
- Migration Potential Model - when combined with habitat suitability, an estimate of a species' colonization likelihood for new habitats. This rating can be helpful for assisted migration or focused management (see the table section: "New Habitat with Migration Potential").

Remember that models are just tools, and they're not perfect. Model projections can't account for all factors that influence future species success. If a species is rare or confined to a small area, model results may be less reliable. These factors, and others, could cause a particular species to perform better or worse than a model projects. Human choices will also continue to influence forest distribution, especially for tree species that are projected to increase. Planting programs may assist the movement of future-adapted species, but this will depend on management decisions. Despite these limits, models provide useful information about future expectations. It's perhaps best to think of these projections as indicators of possibility and potential change.

SOURCES: *This handout summarizes the full model results for Southern Wisconsin, available at www.fs.fed.us/nrs/atlas/combined/resources/summaries. More information on vulnerability and adaptation in the Northwoods region can be found at www.forestadaptation.org/northwoods. A full description of the models and variables are provided in Iverson et al. 2019 (www.nrs.fs.fed.us/pubs/57857 and www.nrs.fs.fed.us/pubs/59105) and Peters et al. 2019 (www.nrs.fs.fed.us/pubs/58353).*

CLIMATE CHANGE CAPABILITY

POOR CAPABILITY	
American hornbeam	Paper birch
Balsam fir	Pin cherry
Balsam poplar	Quaking aspen
Bigtooth aspen	Red mulberry
Black ash	Red pine
Black maple	River birch
Black spruce	Serviceberry
Black willow	Swamp white oak
Eastern hemlock	Tamarack
Eastern white pine	White spruce
Flowering dogwood	Yellow birch
Northern white-cedar	

FAIR CAPABILITY	
American basswood	Northern pin oak
Chinkapin oak	Slippery elm
Jack pine	White ash

GOOD CAPABILITY	
American elm	Hackberry
Bitternut hickory	Honeylocust
Black oak	Northern red oak
Black walnut	Red maple
Bur oak	Silver maple
Ironwood	Sugar maple
Eastern redcedar	White oak
Green ash	

MIXED RESULTS	
Black cherry	Eastern cottonwood
Box elder	Shagbark hickory

NEW HABITAT WITH MIGRATION POTENTIAL	
Black hickory	Pin oak
Blackgum	Post oak
Common persimmon	Sassafras
Eastern redbud	Scarlet oak
Mockernut hickory	Shingle oak
Osage-orange	Sycamore
Pignut hickory	Yellow-poplar

NIACS
Northern Institute of Applied Climate Science

www.forestadaptation.org

ADAPTABILITY: Life-history factors, such as the ability to respond favorably to disturbance, that are not included in the Tree Atlas model and may make a species more or less able to adapt to future stressors.

- \+ HIGH *Species may perform better than modeled*
- • MEDIUM
- – LOW *Species may perform worse than modeled*

HABITAT CHANGE: Projected change in suitable habitat between current and potential future conditions.

- ▲ INCREASE *Projected increase of >20% by 2100*
- ▼ DECREASE *Projected decrease of >20% by 2100*
- ● NO CHANGE *Projected change of <20% by 2100*
- ★ NEW HABITAT *Tree Atlas projects new habitat for species not currently present*

ABUNDANCE: Based on Forest Inventory Analysis (FIA) summed Importance Value data, calibrated to a standard geographic area.

- \+ ABUNDANT
- • COMMON
- – RARE

CAPABILITY: An overall rating that describes a species' ability to cope or persist with climate change based on suitable habitat change class (statistical modeling), adaptability (literature review and expert opinion), and abundance within this region.

- △ GOOD *Increasing suitable habitat, medium or high adaptability, and common or abundant*
- ○ FAIR *Mixed combinations, such as a rare species with increasing suitable habitat and medium adaptability*
- ▽ POOR *Decreasing suitable habitat, medium or low adaptability, and uncommon or rare*

SPECIES	ADAPT	ABUN	LOW CLIMATE CHANGE (RCP 4.5) HABITAT CHANGE	CAPABILITY	HIGH CLIMATE CHANGE (RCP 8.5) HABITAT CHANGE	CAPABILITY
American basswood	•	•	●	○	●	○
American beech	•	–	●	▽	●	▽
American elm	•	+	●	△	●	△
Balsam fir	–	–	●	▽	▼	▽
Bigtooth aspen	•	•	▼	▽	▼	▽
Bitternut hickory*	+	•	●	△	▲	△
Black ash	–	•	▼	▽	▼	▽
Black cherry	–	•	▲	○	●	▽
Black hickory	•		★		★	
Black oak	•	•	▲	△	▲	△
Black spruce	•	–	▼	▽	▼	▽
Black walnut*	•	•	▲	△	▲	△
Black willow*	–	•	▼	▽	●	▽
Blackgum	+		★		★	
Blackjack oak	+		★		★	
Boxelder*	+	•	●	△	▼	○
Bur oak	+	•	▲	△	▲	△
Chinkapin oak	•	–	▲	○	▲	○
Common persimmon*	+		★		★	
Eastern cottonwood*	•	–	●	▽	▲	○
Eastern hemlock	–	–	●	▽	▼	▽
Eastern redbud*	•		★		★	
Eastern redcedar	•	•	▲	△	▲	△
Eastern white pine	–	•	▼	▽	▼	▽
Flowering dogwood	•	–	▼	▽	●	▽
Green ash*	•	•	▲	△	▲	△
Hackberry	+	•	▲	△	▲	△
Honeylocust*	+	–	▲	△	▲	△
Ironwood*	+	•	▲	△	▲	△
Jack pine	+	•	▼	○	▼	○
Loblolly pine	•		★		★	
Mockernut hickory	+		★		★	
Northern pin oak	+	•	▼	○	▼	○
Northern red oak	+	•	●	△	●	△
Northern white-cedar	•	–	●	▽	●	▽
Ohio buckeye*	•		★		★	
Osage-orange	+		★		★	
Paper birch	•	•	▼	▽	▼	▽
Pecan*	–		★		★	
Pignut hickory	•		★		★	
Pin cherry*	•	–	▼	▽	▼	▽
Pin oak*	–		★		★	
Post oak	+		★		★	
Quaking aspen	•	•	▼	▽	▼	▽
Red maple	+	+	▼	△	▼	△
Red mulberry*	•	–	●	▽	●	▽
Red pine	–	•	▼	▽	▼	▽
River birch*	•	–	▼	▽	▼	▽
Sassafras*	•		★		★	
Scarlet oak	•		★		★	
Serviceberry*	•	–	▼	▽	▼	▽
Shagbark hickory	•	•	●	○	▼	▽
Shingle oak	•		★		★	
Shortleaf pine	•		★		★	
Shumard oak*	+		★		★	
Silver maple*	+	•	▲	△	▲	△
Sugar maple	+	•	▲	△	▲	△
Sugarberry	•		★		★	
Swamp white oak*	•	–	●	▽	●	▽
Sweetgum	•		★		★	
Sycamore*	•		★		★	
Tamarack (native)	–	•	▼	▽	▼	▽
Virginia pine	•		★		★	
White ash	–	•	▲	○	▲	○
White oak	+	•	▲	△	●	△
White spruce	•	•	▼	▽	▼	▽
Winged elm	•		★		★	
Yellow birch	•	–	▼	▽	▼	▽
Yellow-poplar	+		★		★	

**Species with low model reliability based on five statistical metrics of the habitat models that affect change class. See maps and tables for more information (www.fs.fed.us/nrs/atlas/combined/resources/sum)*

Updated November 2021.

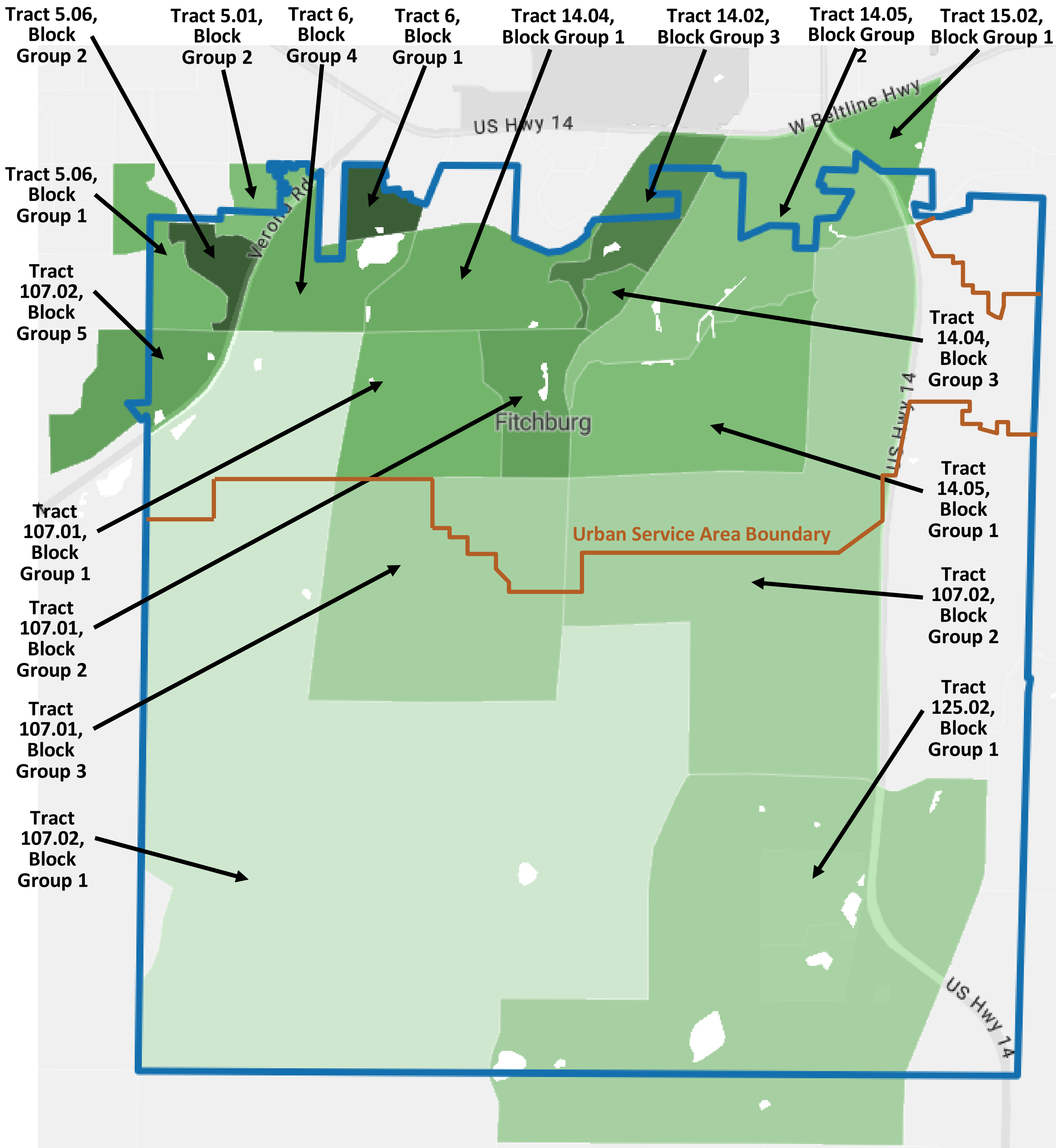
Section A3

Reference Map

Click here to return to TOC

This assessment includes population data or maps at the Census Tract or Block Group level, as needed to relate to relevant US Census Bureau data. Census boundaries may differ from actual community boundaries. All areas within the official community boundaries are included in the plan this Baseline Document supports, even if not shown on a map. Other assessments might use data at the Census "Place" or city boundary level, leading to differences in reported population counts due to Census boundary variations.

The map on the following page indicates census areas which may be referenced in this report. City boundary and census area boundaries are based on 2020 US Census.


Tract 5.06, Block Group 2
Tract 5.01, Block Group 2
Tract 6, Block Group 4
Tract 6, Block Group 1
Tract 14.04, Block Group 1
Tract 14.02, Block Group 3
Tract 14.05, Block Group 2
Tract 15.02, Block Group 1
US Hwy 14
W Beltline Hwy
Verona Rd
Tract 5.06, Block Group 1
Tract 107.02, Block Group 5
Tract 14.04, Block Group 3
Fitchburg
Tract 14.05, Block Group 1
Tract 107.01, Block Group 1
Urban Service Area Boundary
Tract 107.01, Block Group 2
Tract 107.02, Block Group 2
Tract 107.01, Block Group 3
Tract 125.02, Block Group 1
Tract 107.02, Block Group 1
US Hwy 14

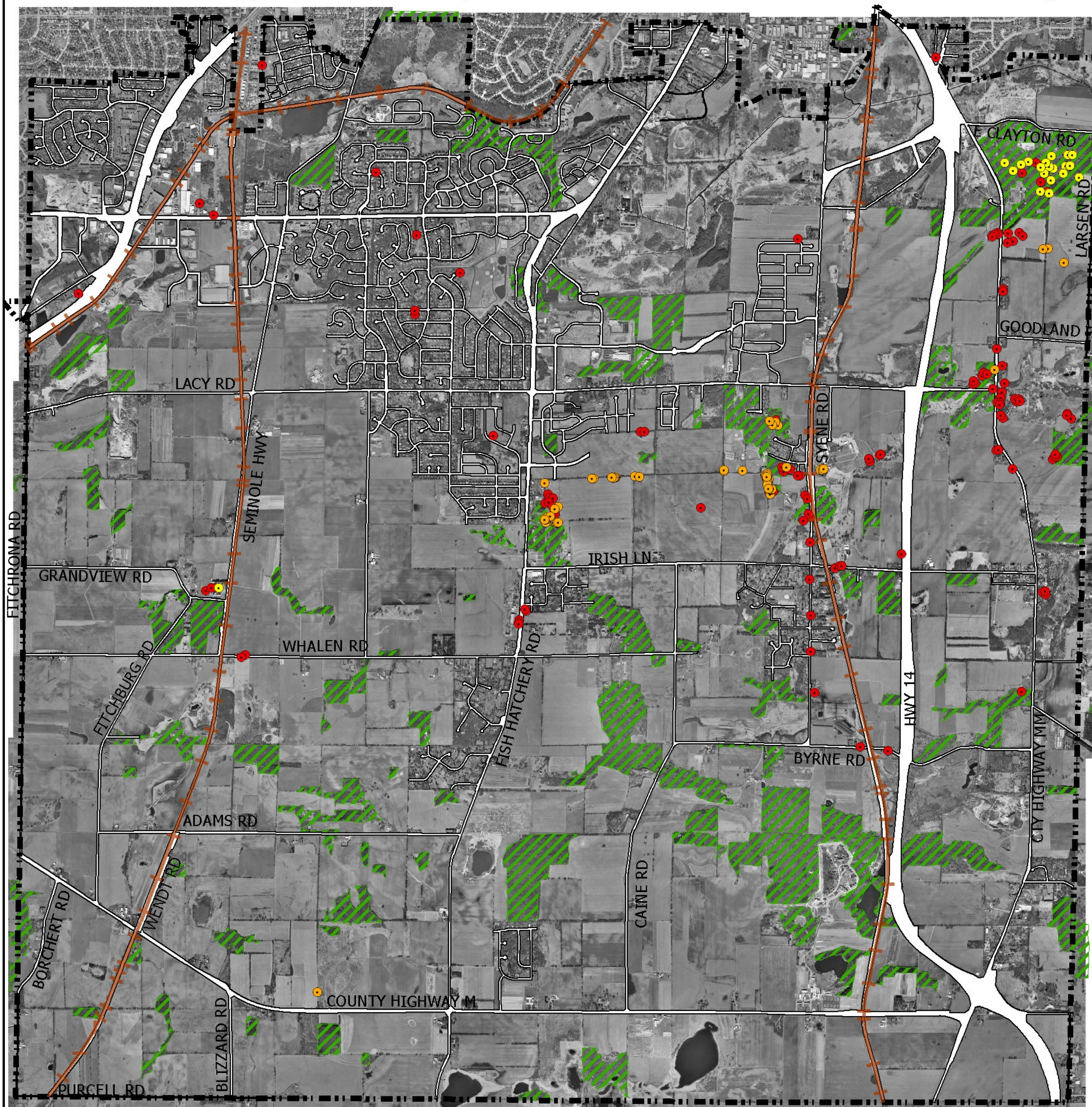
Section

A4

2010 Heritage and Specimen Tree Inventory Map

Click here to return to TOC

Heritage and Specimen Tree Inventory



Legend

- Forest
- Heritage Tree (+200 yrs)
- Specimen Tree (Tree greater than 15" diameter, displaying superior quality compared to trees of same species)
- Potential Specimen Tree
- City Limits
- Railroad Corridor
- Right of Way

Data Sources:
Capital Area Regional Planning Commission, Feb. 2008 (data derived from 1990 aerial photography). Natural Resources Consulting, 2008. Fitchburg Parks Department, 2010. Scott, 1976; Alison, 2001.

Map prepared by Fitchburg Parks, Recreation & Forestry Department, July 30, 2010

Prepared by:

making change personal
paleBLUEdot LLC

2515 White Bear Ave, A8
Suite 177
Maplewood, MN 55109

Contact:
Ted Redmond
tredmond@paleBLUEdot.llc