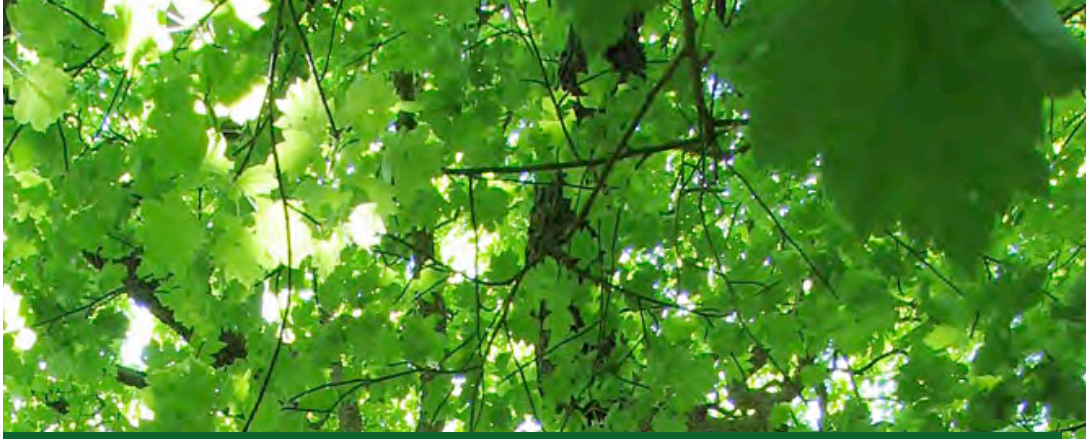
i-Tree Canopy



Urban Tree Canopy (UTC) Assessment for Massachusetts 10 Largest Communities

September 2014

Boston
Worcester
Springfield
Lowell
Cambridge
New Bedford
Brockton
Quincy
Lynn
Fall River

Prepared using i-Tree Canopy, a state –of-the-art analysis tool, developed by the US Forest Service and its key research partners.

Prepared by:
Department of Environmental Conservation, UMass/Amherst
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www.unri.org/utc

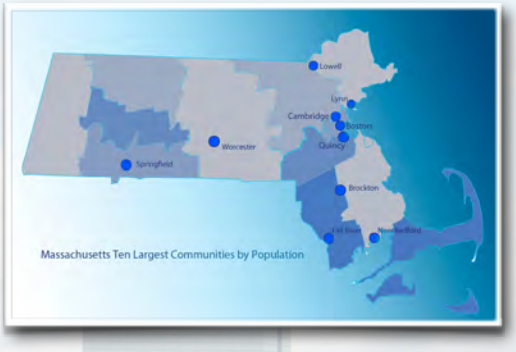
University of Massachusetts Amherst

Urban Tree Canopy (UTC) Assessment for Massachusetts Ten Largest Communities using i-Tree Canopy

About this Report

This report provides the results of an i-Tree Canopy study of the ten most populated communities in Massachusetts, in an effort to better understand the Urban Tree Canopy (UTC) that shades each community. The following communities were used in developing this report:

- Boston
- Worcester
- Springfield
- Lowell
- Cambridge
- New Bedford
- Brockton
- Quincy
- Lynn
- Fall River



i-Tree Canopy offers a quick and easy way to produce a statistically valid estimate of land cover types (e.g., tree cover) using aerial images available in Google Maps. The latest version of Canopy also estimates values for air pollution reduction and capturing atmospheric carbon. Canopy can be used by urban forest managers to estimate tree canopy cover, set canopy goals and monitor canopy change over time.

i-Tree Canopy 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. In this report, the following landscape features were identified: Trees, Shrubs and other Vegetation, Impervious Surfaces and Other (i.e.: water bodies, streams, etc.).

The report provides findings on the Percent Tree Canopy Cover in each community, a calculation of the Area of Tree Canopy Cover in Square Miles, and Amount and Value of various ecosystem benefits provided by the tree canopy in each community.

The i-Tree Canopy software provides reports for each analysis that is performed, and those reports are contained in this document. Additionally, some key findings, comparing each city, are outlined in this report. Finally, the report outlines the importance of urban forests and begins with an overview of tree benefits in the urban landscape.

This study was completed in 2014 by US Forest researchers and students from the University of Massachusetts at Amherst Department of Environmental Conservation. Additional assistance was provided by interns from Regreen Springfield, a local non-profit located in Springfield, MA. The following students from the University of Massachusetts contributed to the i-Tree Canopy air photo interpretation for this project: Todd Beals, Vincent Buiso, Monica Davis, Jarrod Fowler, Justin Gonzalez, and Rebecca Jordan. David Bloniarz, of the Forest Service Northern Research Station, coordinated the data collection and interpretation of the i-Tree Canopy results, and edited the report.

To obtain an electronic copy of this report, please visit http://www.unri.org/research-documents

Urban Tree Benefits

General Introduction

Trees in urban and suburban areas are municipal assets that often appreciate in value over time because they are living and growing, increasing the ecosystem services and benefits that they provide as they mature. Urban trees and forests provide many environmental, social and economic benefits to the local community. Because of their significant contribution to the well-being of urbanized landscapes, trees and the urban forest should be professionally managed and protected to preserve them now for all residents to benefit, and increase the canopy for future generations to enjoy. Aside from the obvious aesthetic benefits, trees within our urban forest improve our air, protect our water, save energy, and improve economic sustainability.

Specific Benefits

The following outlines several of the most significant ecosystem services and benefits, as well as the associated financial values that trees provide a local community:

Filter Stormwater Runoff - Trees are frequently cited as the best stormwater management tool because of their ability to slow and filter stormwater runoff. Through their root systems and leaves, branches, and stems, trees intercept rainfall and release it slowly, reducing runoff and helping to maintain water quality. For every 5% of tree cover added to the an urban neighborhood, stormwater runoff is reduced by approximately 2%. Trees work in combination with conventional stormwater controls to produce a comprehensive solution to the stormwater dilemma.

It is important to note that research shows that trees store more water during a 1-inch rainfall event that lasts two days versus one that lasts only two hours. Therefore, urban forests are more likely to produce more benefits through water quality protection than flood control.

Improve Water Quality and Reduce Soil Erosion - Trees act as natural pollution filters. Their canopies, trunks, roots and associated soil along with other natural elements of the landscape filter polluted particulate matter out of the flow toward the storm sewers. Tree roots remove nutrients such as nitrogen and phosphorus, both byproducts of urban living, which can pollute local streams and rivers. These root systems also help to hold the soil in place, decreasing the amount of sediment that enters local streams and rivers.

Riparian, or “streamside” forests are of particular importance because they can slow the flow of stormwater runoff and capture up to 95% of the sediment before it enters local waterways. In a medium sized city, the amount of soil saved annually can be as much as 10,886 tons.

Energy Savings

Trees properly placed in the landscape (south and west exposure for deciduous trees) shade a community’s homes, offices, streets, parking lots, and other pavement that surrounds them. They cool the air as their leaves evaporate water. Homeowners can save up to 58% on daytime air conditioning costs. If applied nationwide to buildings not now benefiting from trees, the shade could reduce our nation’s consumption of oil by 500,000 barrels of oil/day. Projections suggest that 100 million additional mature trees in US cities (3 trees for every unshaded single family home) could save over $2 billion in energy costs per year.

Overall, trees can help reduce the heat island effect that is created in urban and suburban areas. Human dwellings and associated activities generate heat resulting in a 3 to 10 degree F rise in temperature from surrounding countryside. Trees reduce temperatures by shading surfaces, dissipating heat through evaporation, and increasing air movement.

Offset the Greenhouse Effect

Trees fight the atmospheric greenhouse effect The greenhouse effect is created when heat from the sun enters the atmosphere and is prevented from radiating back into space by air-polluting gasses. The buildup of about 40 heat-trapping gasses is created mostly by human activities. Heat buildup threatens to raise global temperatures to levels unprecedented in human history. About half of the greenhouse effect is caused by CO2. Trees act as a carbon sink by removing the carbon from CO2 and storing it as cellulose in the trunk while releasing the oxygen back into the air. A healthy tree stores about 13 pounds of carbon annually-or 2.6 tons per acre per year.

Trees also reduce the greenhouse effect by shading our homes and office buildings. This reduces air conditioning needs up to 30 percent, thereby reducing the amount of fossil fuel burned to produce electricity. This combination to CO2 removal from the atmosphere, carbon storage in wood, and the cooling effect makes trees a very efficient tool in fighting the greenhouse effect.

Improved Air Quality

Trees and other plants make their own food from carbon dioxide (CO2) in the atmosphere, water, sunlight and a small amount of soil elements. In the process, they release oxygen (O2) for us to breathe. Trees growing in urban landscapes help to settle out, trap and hold particle pollutants (dust, ash, pollen and smoke) that can damage human lungs. They absorb CO2 and other dangerous gasses and, in turn, replenish the atmosphere with oxygen. Estimates project that trees produce enough oxygen on each acre for 18 people every day, and absorb enough CO2 on each acre, over a year's time, to equal the amount you produce when you drive your car 26,000 miles. Trees remove gaseous pollutants by absorbing them through the pores in the leaf surface. Particulates are trapped and filtered by leaves, stems and twigs, and washed to the ground by rainfall.

i-Tree Canopy

Background

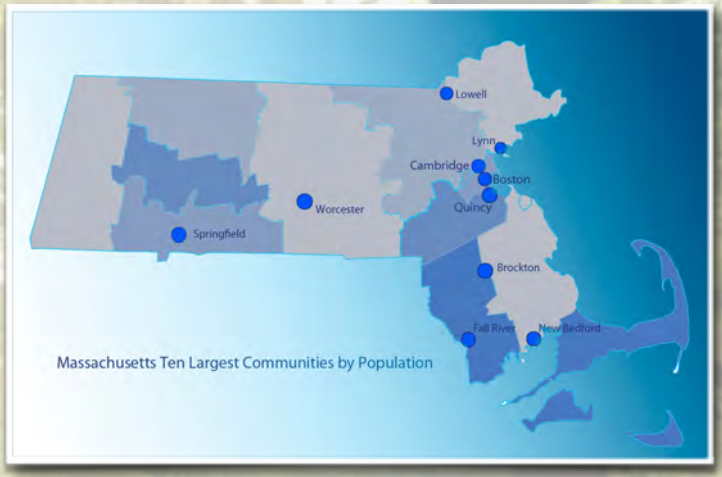
i-Tree Canopy is an analysis software tool developed by the USDA Forest Service that allows users to analyze the benefits of the urban forests surrounding them. The software includes several components that give users the ability to calculate tree canopy cover, and other landscape attributes, that can be used to develop more effective urban forest management plans. Not only can the user determine the structure of the urban forest, they can also quantify the environmental benefits the tree canopy tree cover provide within selected communities.

i-Tree Canopy uses aerial images available in Google Maps to enable users to produce a statistically valid estimate of specific land cover types in order to evaluate different potential economical values and environmental benefits within a community. Urban forest managers, landscape designers, and other planners are able to calculate percentage and area of tree canopy coverage. These calculated reports can be used to set tree canopy goals, and monitor vegetation and canopy change over time. Aerial imagery provided by Google Maps allows the user to survey points to classify specific types of coverage found at selected points within a city, town, or geographically defined area.

Coverage types can be precise; not only including tree canopy, but also grasses and shrubs, water, impervious surfaces, such as concrete and buildings, or anything else the user desires. The i-Tree report allows for an accurate representation of what percentage and area is not only covered by vegetation, but also of how much area is paved with roadways or impervious areas that could be potential areas to expand a city's urban tree canopy. In this study, tree canopy, shrub layers, and impervious surfaces were examined and calculated. The findings outlined here report on the function and value of the tree canopy that was calculated in each community.

Key Findings

This study utilized i-Tree Canopy to asses the tree canopy cover in the 10 most populated cities in Massachusetts (Map A., Table 1.). Canopy cover percentages were calculated for each community, as well as the approximate size of the area covered by tree canopy. This information was modeled using the i-Tree Canopy toolkit, and included the classification of 500 sample point locations in each community.



Map A. Area and Population of 10 Largest Communities

In addition to determining tree cover percentage and size, shrub and grass areas, and impervious surfaces were also calculated, as well as an estimation of areas considered "other". This allowed for examination tree of canopy coverage, in terms of percent tree cover and area, in square miles, for each community. Additionally, the three largest cities in Massachusetts — Boston, Worcester, and Springfield — were examined more closely with subsequent studies using i-Tree Design and i-Tree Streets. The Urban Tree Canopy in each of the ten largest Massachusetts cities is reported in Table 2. Closer examination of the three largest cities, Boston, Worcester and Springfield, report 27.9%, 39.3% and 36.7% canopy coverage respectively. Although Boston and Worcester differ by over ten percent in terms of percent coverage, they show 13.9 square miles and 14.1 square miles in total tree canopy coverage area. Springfield's tree canopy covers 5.89 square miles of the total area of the city.

City Size Rank	City	Total Area (Sq. Mi.)	Population
1	Boston	48.26	645,966
2	Worcester	37.37	182,544
3	Springfield	31.87	153,703
4	Lowell	13.58	108,861
5	Cambridge	6.39	107,289
6	New Bedford	20	95,078
7	Brockton	21.33	94,089
8	Qunicy	16.57	93,494
9	Lynn	10.74	91,589
10	Fall River	33.13	88,697

Table 1. Area and Population of 10 Largest Communities

Comparing these three cities with three other large cities on the east coast provides a gauge of how Massachusetts' largest communities compare with other large cities. The urban tree canopy percentage for Baltimore, New York City and Philadelphia are 20%, 24% and 20% respectively. Comparatively speaking, Massachusetts's largest cities are already slightly ahead of the curve in terms of canopy percentage. Interesting. as well, is the fact that Philadelphia, New York City and Baltimore, are all similar in landscape type to Boston in landscape type, yet the Commonwealth's largest city has almost 5% more coverage than the closest competitor — New York City. All of the other cities studied had over 30% canopy coverage, with Fall River with the the highest percentages of 59.3%.

Another key finding that the i-Tree Canopy analysis provided was the value, in dollars, of the ecosystem services and benefits provided by the tree canopy in each city and is seen in Table 3. It was found that the total value of the tree cover in Massachusetts' ten largest communities was over $197,350,000. Fall River had the highest dollar value of benefits at over $35,900,000, while Worcester had over $27,000,000 in benefits.

These dollar estimates were determined by first calculating the following ecosystem services provided by the trees growing in each city: Carbon Monoxide removed annually, NO2 Nitrogen Dioxide removed annually, O3 Ozone removed annually, Particulate Matter less than 2.5 microns removed annually, Sulfur Dioxide removed annually, Particulate Matter greater than 2.5 microns and less than 10 microns removed annually, Carbon Dioxide sequestered annually in trees, and Carbon Dioxide stored in trees.

Following the determination of ecosystem services provided, the following monetary values were used to calculate the dollar values of these benefits: i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and $/T/yr: CO 0.902 @ $85.08 | NO2 4.917 @ $26.86 | O3 48.968 @ $140.47 | PM2.5 2.379 @ $5,975.67 | SO2 3.098 @ $7.45 | PM10* 16.403 @ $304.43 | CO2seq 9,807.385 @ $19.43 | CO2stor is a total biomass amount of 297,489.961 @ $19.43.

City Size Rank	City	% Canopy Cover	Report by Area (mi
1	Boston	27.9	13.9
2	Worcester	39.3	14.1
3	Springfield	36.7	11.8
4	Lowell	31	4.59
5	Cambridge	34	2.08
6	New Bedford	32.8	6.58
7	Brockton	45.9	9.88
8	Qunicy	43.1	7.21
9	Lynn	40.5	4.58
10	Fall River	59.3	18.7

Table 2. Percent Canopy Cover and Area

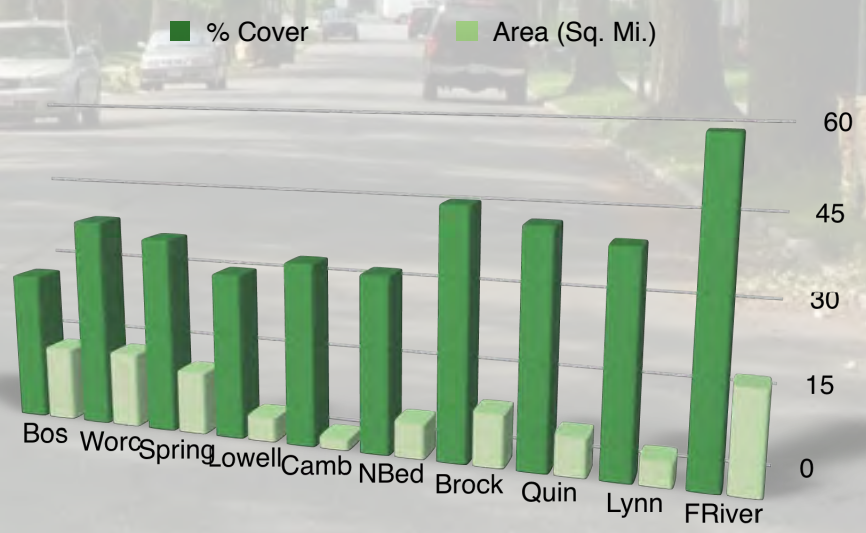


Chart 1. Percent Canopy Cover and Area

City Size Rank	City	Total Tree Benefits ($)
1	Boston	$26,587,698
2	Worcester	$27,026,730
3	Springfield	$22,642,221
4	Lowell	$8,808,327
5	Cambridge	$3,984,187
6	New Bedford	$12,623,867
7	Brockton	$18,965,875
8	Qunicy	$13,837,228
9	Lynn	$8,790,730
10	Fall River	$35,983,596

Table 3. Total Value of Tree Canopy Benefits

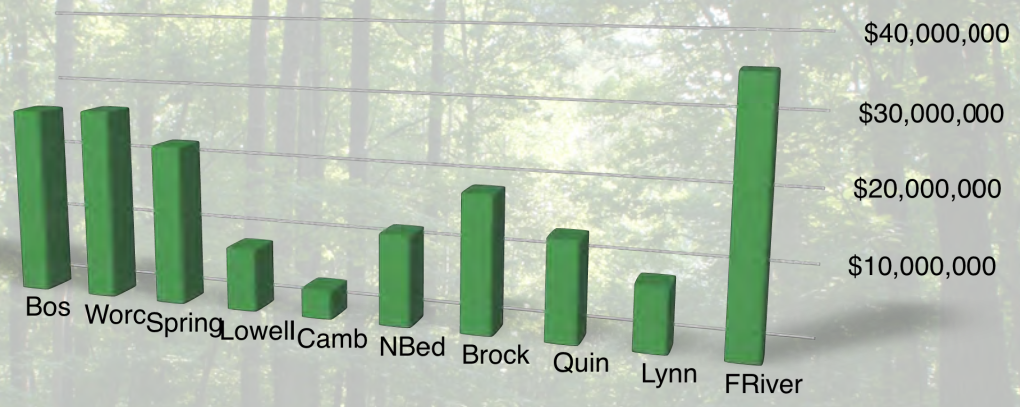


Chart 2. Total Value of Tree Canopy Benefits

Map B. Summary of Tree Canopy Cover and Value in Massachusetts Ten Most Populated Communities

Setting Urban Tree Canopy (UTC) Goals

Why Communities Should Set UTC Goals

As urban development expands, it is increasingly important to balance growth with environmental wellbeing. Researchers estimate that tree canopy cover in urban and metropolitan areas across the U.S. averages only 27% and 33% respectively. Additionally, the trees that are present are subject to a wide variety of stressors, which significantly shortens their lifespan. As such, it is important for urban communities to take steps to protect and enhance their urban forests through UTC goal setting processes. Few communities have developed land cover strategies such as UTC that mitigate urbanization effects regardless of land use type. Several recent efforts have explicitly included UTC in planning efforts to address community, environmental and human health concerns:To maximize Urban Tree Canopy benefits, communities should set goals to protect, maintain and enhance their entire urban forest. Careful planning and goal setting are necessary to retain as much mature tree canopy as possible in areas with development pressure and to expand and sustain canopy in already urbanized areas. UTC goals can emphasize environmental quality (stormwater, air quality, carbon offsets), livability and economic vitality. Though many communities have adopted land use strategies to mitigate sprawl, few have developed land cover strategies like UTC to mitigate urbanization effects.

How to Set UTC Goals

In order to set UTC goals, communities must first have an idea of how much current canopy is present. The process for conducting UTC assessments and goal setting generally includes the following steps

1. ***Measure current UTC*** *- This was completed in this study*

2. ***Estimate potential UTC*** *- Use remote sensing imagery and Geographic Information Systems analyses to identify locations with potential for UTC. Identify priority locations where UTC increases will support identified community priorities (e.g., water quality, wildlife).*

3. ***Adopt a UTC Goal for the Community*** *- Determine a goal based on the results of the assessments and specify a timeframe. Formal adoption of the goal is preferable to ensure that the goal comes to fruition (e.g., institutionalize UTC goals in local ordinance, regulations and comprehensive planning efforts).*

Once the assessment and goal setting process is complete, the next logical step is to develop an implementation plan that summarizes the approaches the community will take to achieve their UTC goals. In general, a UTC plan identifies the UTC goal and timeline, describes the relationship of canopy goals to local ordinances, regulations, and the community's comprehensive plan, and outlines the specific strategies for achieving UTC goals, including identifying a timeline and responsible party.

References and Resources

Community Tree Management Plan and Canopy Goals , Borough of Columbia, Pennsylvania. 2008 http://www.forestsforwatersheds.org/storage/Columbia%20Tree%20Mgmt%20Plan.FinalApproved.June08.pdf

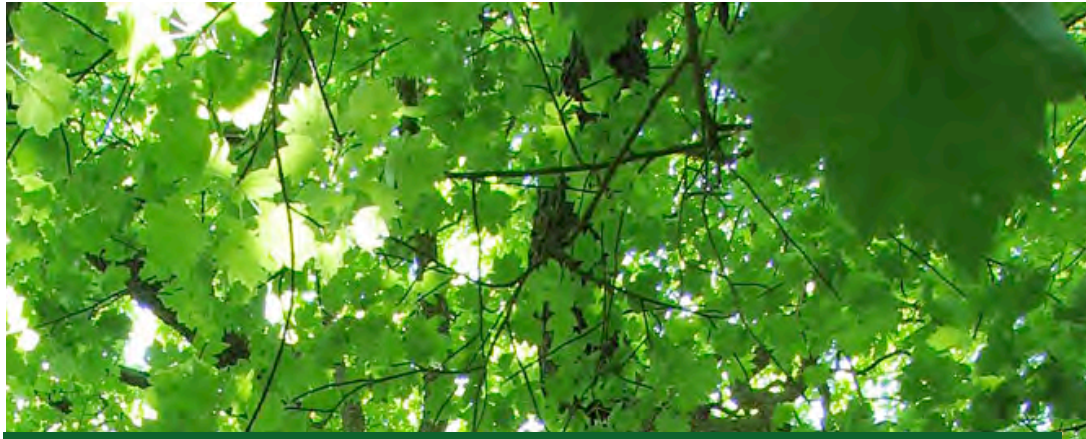
i-Tree Canopy Software. http://www.itreetools.org/canopy/index.php

Society of Municipal Arborists, Urban Forestry BMPs, http://www.urban-forestry.com/sma-urban-forestry-bmps

Urban Tree Canopy Assessment, Northern Research Station, USDA Forest Service, http://nrs.fs.fed.us/urban/utc/

Watershed Forestry Resource Guide, Urban Tree Canopy, http://www.forestsforwatersheds.org/urban-tree-canopy/

Urban Tree Canopy Assessment, Northern Research Station, USDA Forest Service, http://nrs.fs.fed.us/urban/utc/



Boston
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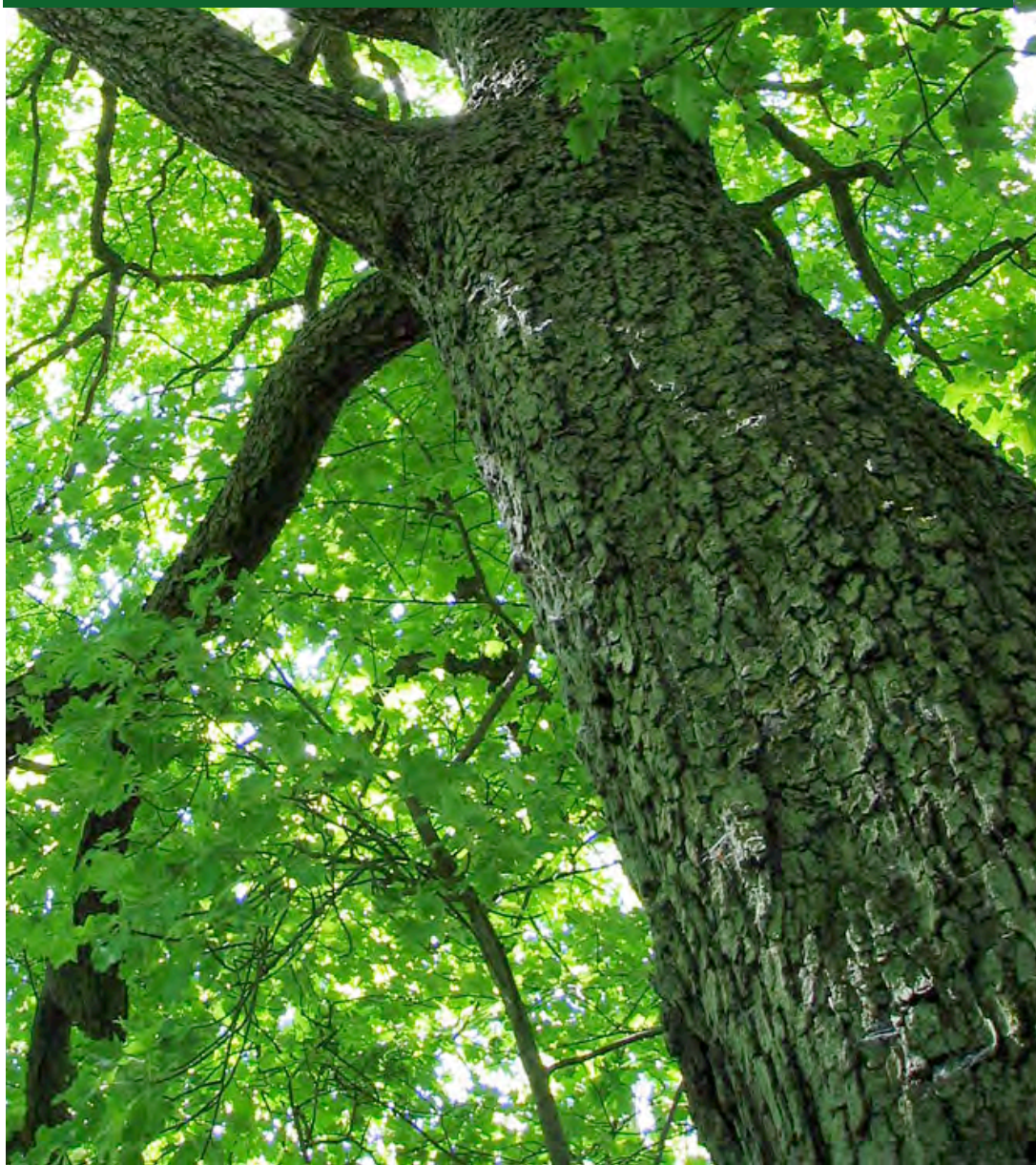
COMMUNITY SUMMARY REPORTS



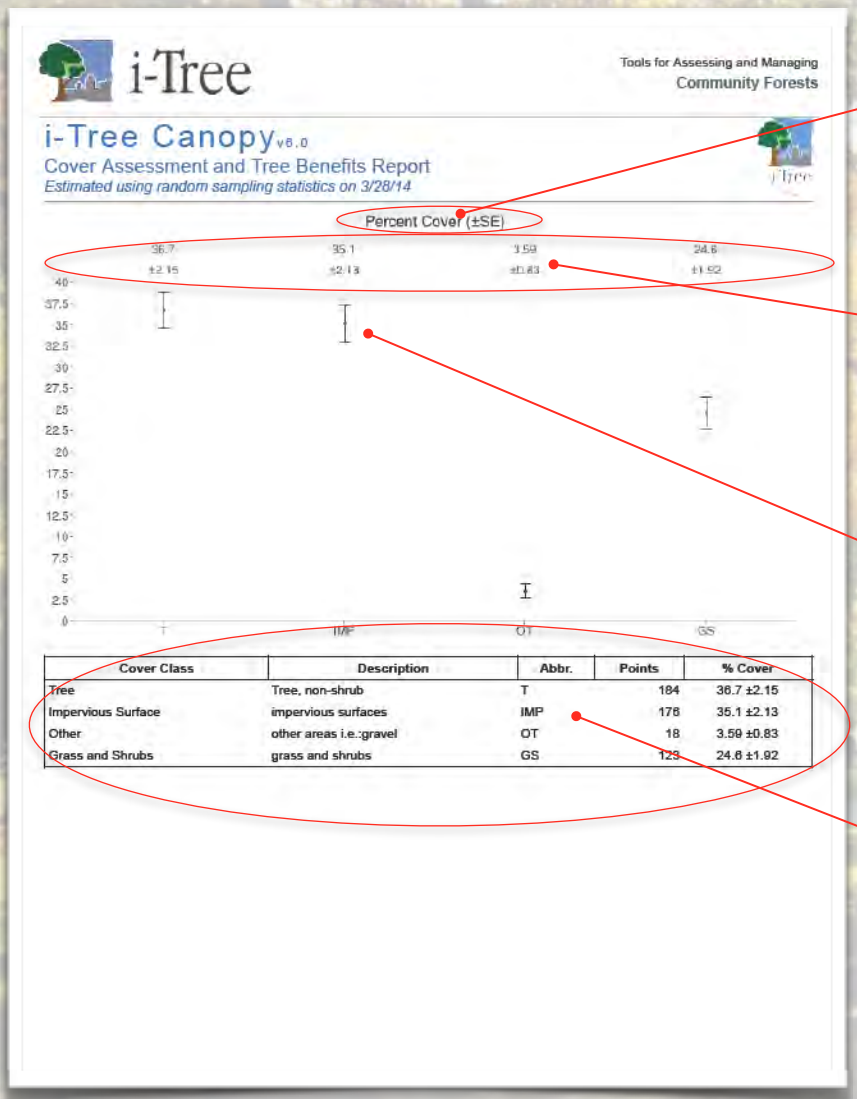
Community Summary Reports

About the Reports

The reports that i-Tree Canopy generates estimate pollution removal, carbon sequestration, and carbon storage based on local benefit values and the estimated tree canopy of the tree cover area for the areas in which the study is completed. In this study, the reports for each of the 10 largest population centers of Massachusetts were prepared. In the reports that follow in this report, the Percent Tree Canopy Cover, Area (sq. mi.) of Tree Canopy Cover, Value ($) of the benefits provided by the Tree Canopy Cover. Additionally, the following ecosystem services are calculated: Carbon Monoxide removed annually, NO2 Nitrogen Dioxide removed annually, O3 Ozone removed annually, Particulate Matter less than 2.5 microns removed annually, Sulfur Dioxide removed annually, Particulate Matter greater than 2.5 microns and less than 10 microns removed annually, Carbon Dioxide sequestered annually in trees, and Carbon Dioxide stored in trees.

Interpreting the Reports

The reports for each community contain details on the statistical accuracy of the i-Tree Canopy analysis as well as providing values on the ecosystem services and value of the benefits provided by each community's tree canopy cover. The key statistical and monetary components of the reports are noted in the samples below.



i-Tree

Tools for Assessing and Managing Community Forests

i-Tree Canopy v6.0

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 3/28/14

Percent Cover (±SE)

Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	184	36.7 ±2.15
Impervious Surface	impervious surfaces	IMP	176	35.1 ±2.13
Other	other areas i.e.:gravel	OT	18	3.59 ±0.83
Grass and Shrubs	grass and shrubs	GS	123	24.6 ±1.92

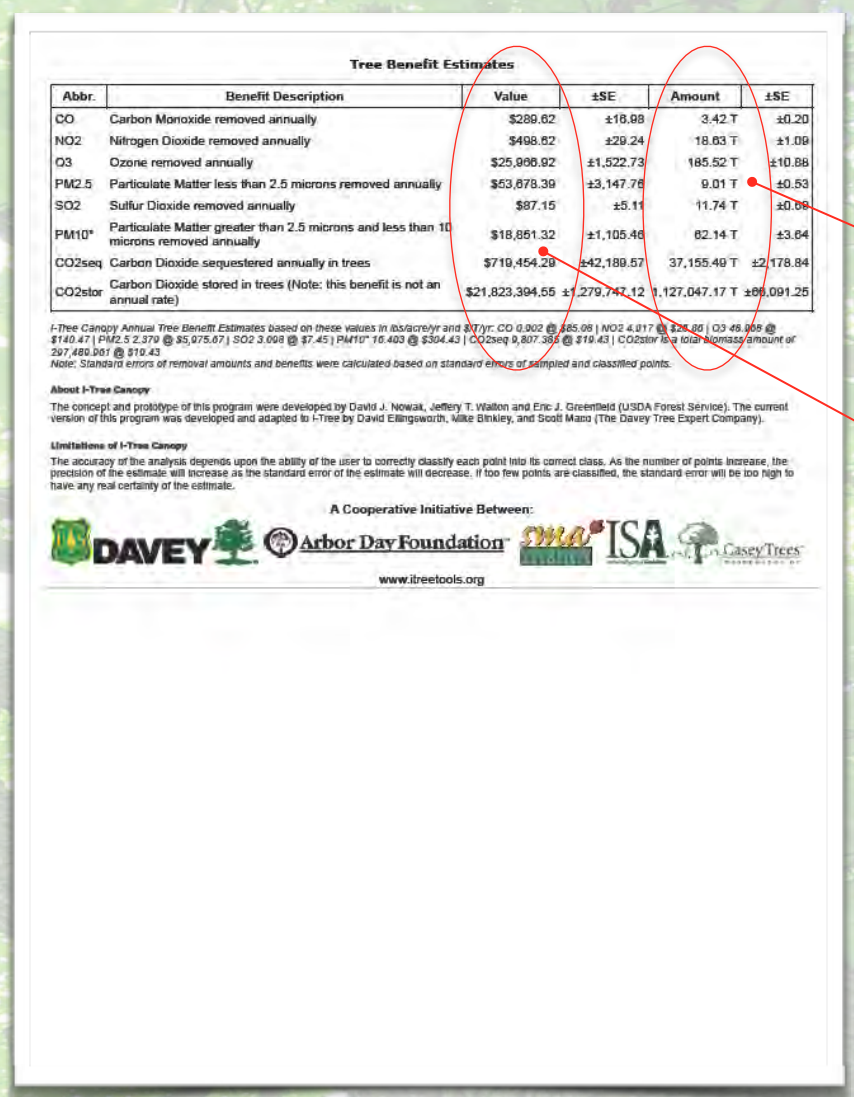
Reporting Value - % or Area

Standard Error

Confidence Intervals

Cover Class Reporting

Sample Report - Page 1



Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$289.62	±16.98	3.42 T	±0.20
NO2	Nitrogen Dioxide removed annually	$498.62	±29.24	18.63 T	±1.09
O3	Ozone removed annually	$25,966.92	±1,522.73	185.52 T	±10.88
PM2.5	Particulate Matter less than 2.5 microns removed annually	$53,678.39	±3,147.76	9.01 T	±0.53
SO2	Sulfur Dioxide removed annually	$87.15	±5.11	11.74 T	±0.69
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$18,851.32	±1,105.46	62.14 T	±3.64
CO2seq	Carbon Dioxide sequestered annually in trees	$719,454.29	±42,189.57	37,155.49 T	±2,178.84
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$21,823,394.55	±1,279,747.12	1,127,047.17 T	±66,091.25

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and $/T/yr: CO 0.902 @ $385.08 | NO2 4.017 @ $26.86 | O3 46.008 @ $140.47 | PM2.5 2.379 @ $5,075.67 | SO2 3.098 @ $7.45 | PM10 16.403 @ $304.43 | CO2seq 9,807.385 @ $19.43 | CO2stor is a total biomass amount of 297,480.061 @ $19.43*
Note: Standard errors of removal amounts and benefits were calculated based on standard errors of sampled and classified points.

About i-Tree Canopy

The concept and prototype of this program were developed by David J. Nowak, Jeffery 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 of i-Tree Canopy

The accuracy of the analysis depends upon the ability of the user to correctly classify each point into its correct class. 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.

A Cooperative Initiative Between:

DAVEY Arbor Day Foundation SMA ISA Casey Trees

www.itreetools.org

Amount (Tons)

Dollar Value of Benefits ($)

Sample Report - Page 2

Accuracy

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

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)).

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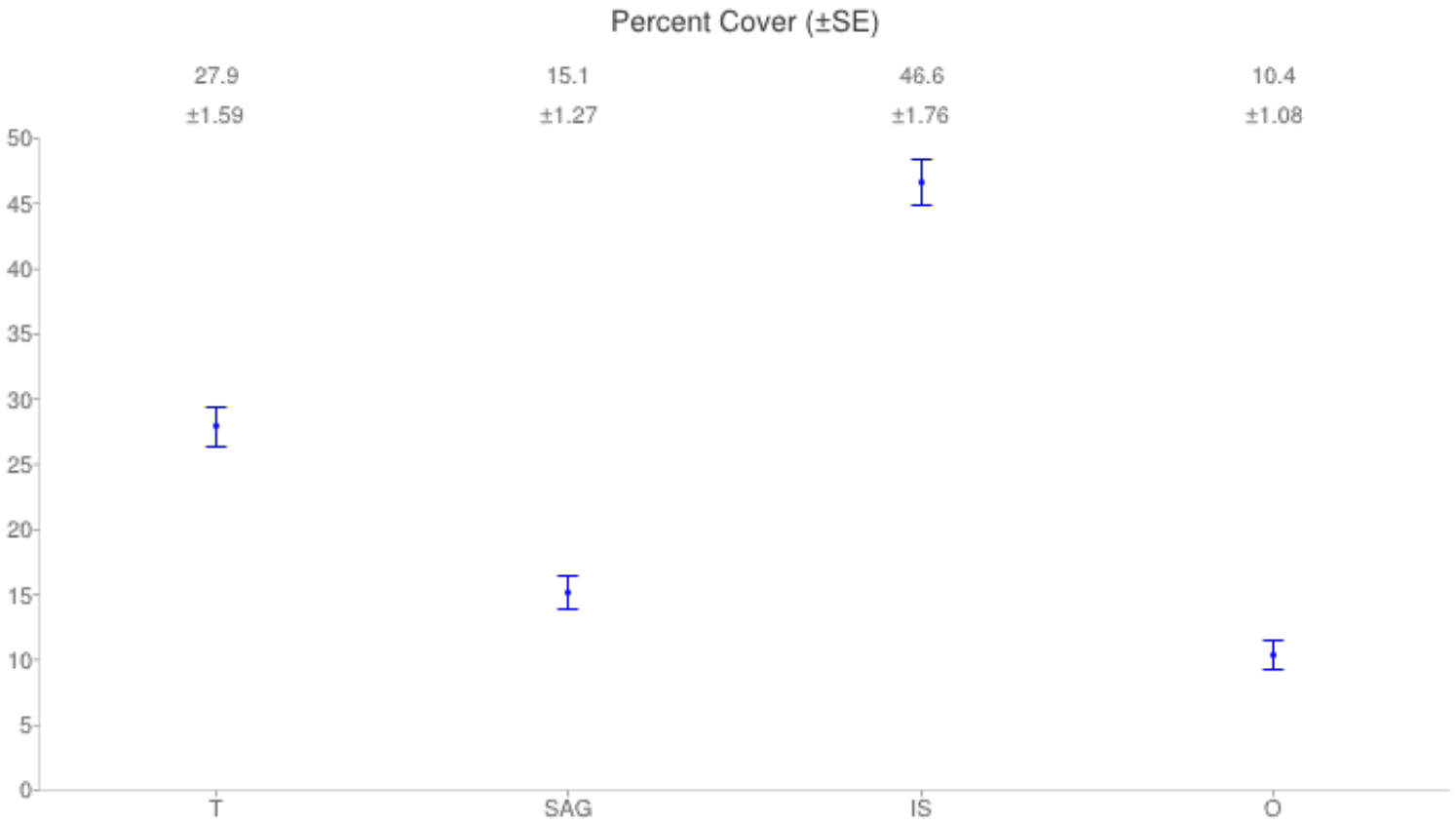
i-Tree Canopy v6.0

Cover Assessment and Tree Benefits Report - Boston, MA

Estimated using random sampling statistics on 3/28/14

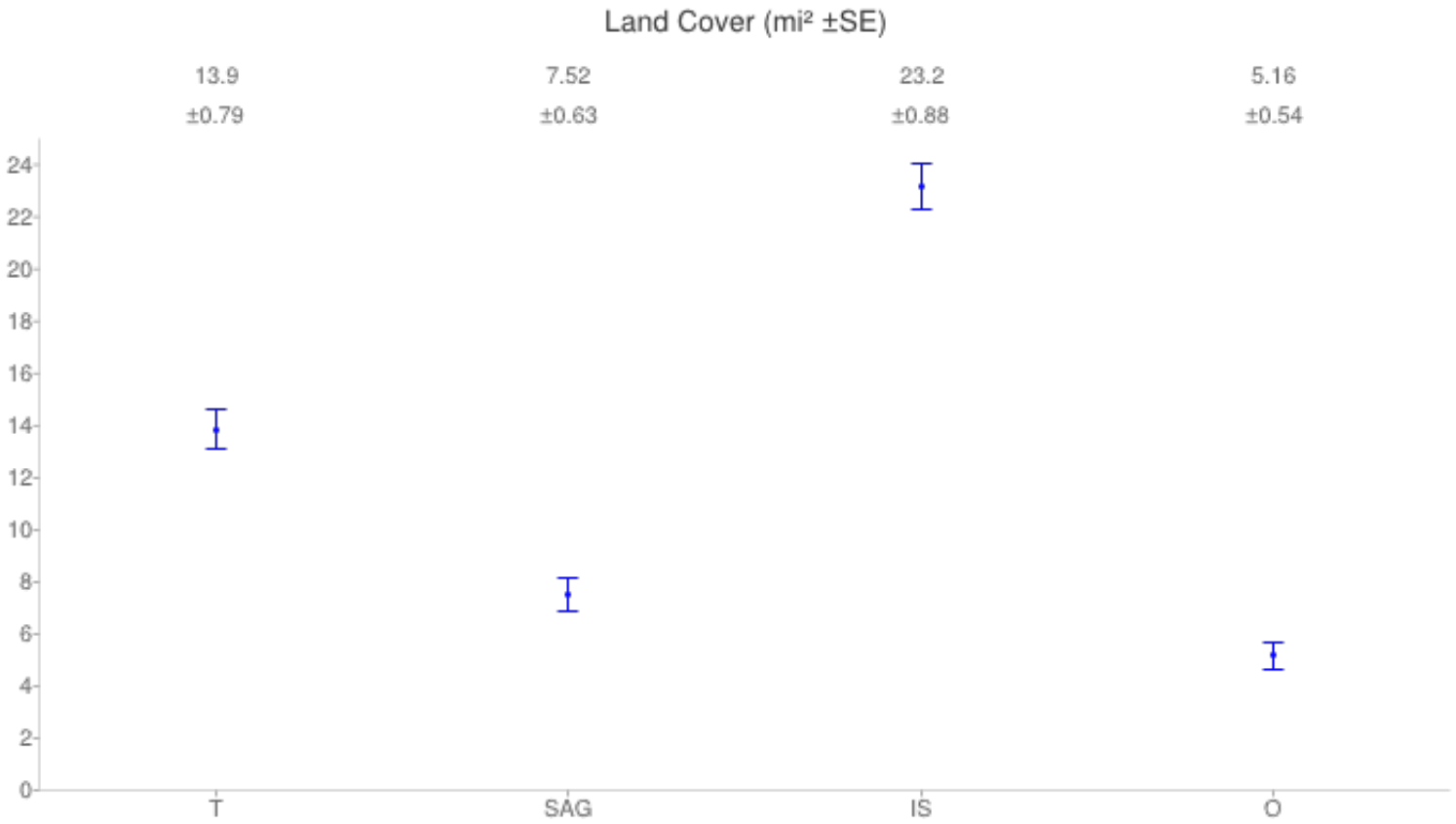


Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	223	27.9 ±1.59
Shrub and Grass		SAG	121	15.1 ±1.27
Impervious Surfaces		IS	373	46.6 ±1.76
Other		O	83	10.4 ±1.08

i-Tree Canopy v6.0

Cover Assessment and Tree Benefits Report - Boston, MA

Estimated using random sampling statistics on 3/28/14



Cover Class	Description	Abbr.	Points	Land Cover
Tree	Tree, non-shrub	T	223	13.9 ±0.79
Shrub and Grass		SAG	121	7.52 ±0.63
Impervious Surfaces		IS	373	23.2 ±0.88
Other		O	83	5.16 ±0.54

Tree Benefit Estimates - Boston, MA

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$340.09	±19.34	4.01 T	±0.23
NO2	Nitrogen Dioxide removed annually	$585.50	±33.30	21.87 T	±1.24
O3	Ozone removed annually	$30,491.74	±1,734.09	217.84 T	±12.39
PM2.5	Particulate Matter less than 2.5 microns removed annually	$63,032.01	±3,584.69	10.59 T	±0.60
SO2	Sulfur Dioxide removed annually	$102.33	±5.82	13.78 T	±0.78
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$22,136.22	±1,258.91	72.97 T	±4.15
CO2seq	Carbon Dioxide sequestered annually in trees	$844,821.44	±48,045.80	43,629.95 T	±2,481.28
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$25,626,188.94	±1,457,385.70	1,323,438.65 T	±75,265.21

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and $/T/yr: CO 0.902 @ $85.08 | NO2 4.917 @ $26.86 | O3 48.968 @ $140.47 | PM2.5 2.379 @ $5,975.67 | SO2 3.098 @ $7.45 | PM10 16.403 @ $304.43 | CO2seq 9,807.385 @ $19.43 | CO2stor is a total biomass amount of 297,489.961 @ $19.43*
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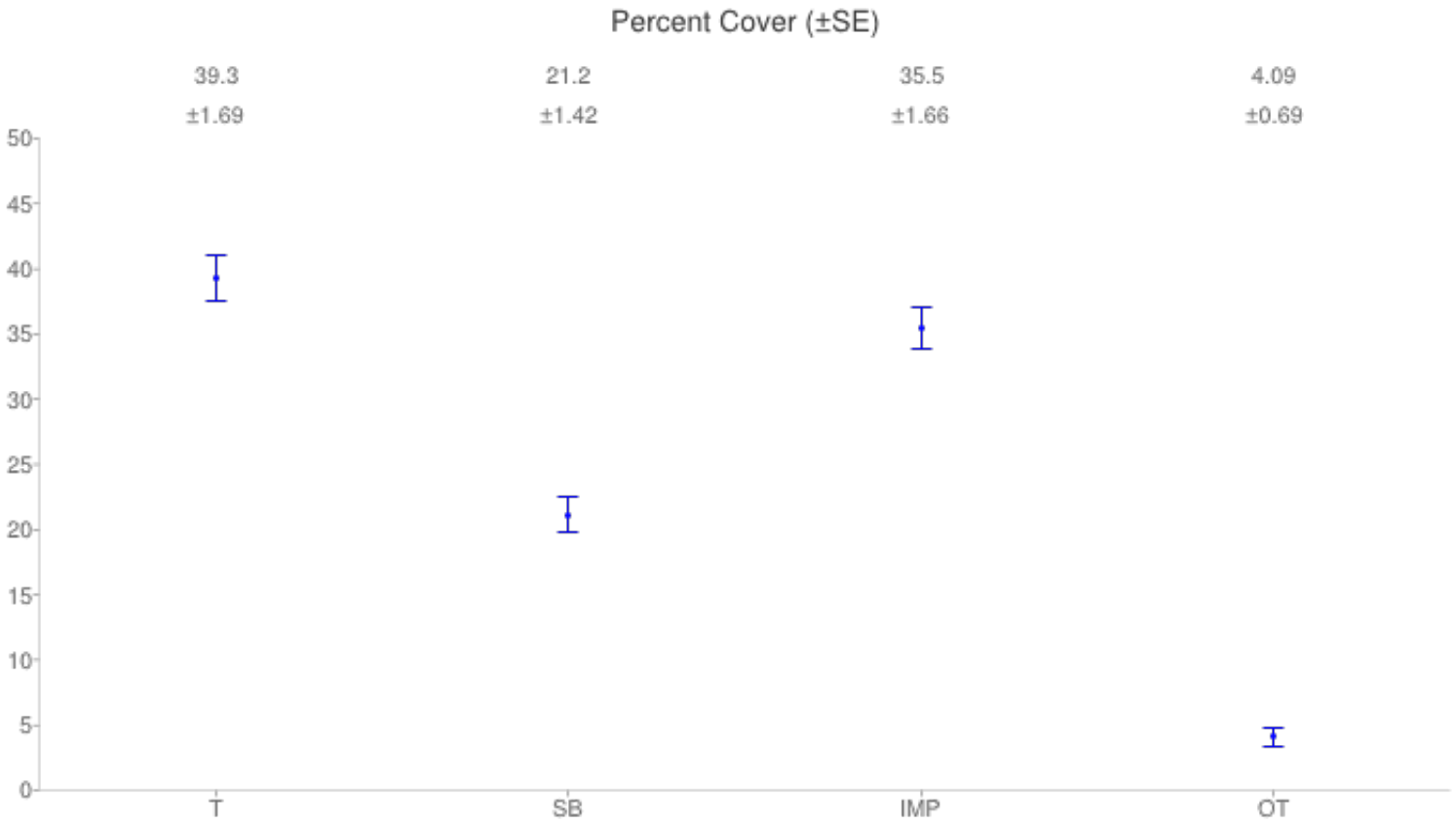
i-Tree Canopy v6.0

Cover Assessment and Tree Benefits Report - Worcester, MA

Estimated using random sampling statistics on 3/28/14



Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	327	39.3 ±1.69
Shrubs and Grass	Shrubs and Grass areas	SB	176	21.2 ±1.42
Impervious Surfaces	Impervious Surfaces	IMP	295	35.5 ±1.66
Other	Other areas, water, bare soil, etc.	OT	34	4.09 ±0.69

Tools for Assessing and Managing
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i-Tree Canopy v6.0

Cover Assessment and Tree Benefits Report - Worcester

Estimated using random sampling statistics on 3/28/14

Cover Class	Description	Abbr.	Points	Land Cover
Tree	Tree, non-shrub	T	327	14.1 ±0.61
Shrubs and Grass	Shrubs and Grass areas	SB	176	7.58 ±0.51
Impervious Surfaces	Impervious Surfaces	IMP	295	12.7 ±0.59
Other	Other areas, water, bare soil, etc.	OT	34	1.46 ±0.25

Tree Benefit Estimates - Worcester, MA

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$345.70	±14.89	4.08 T	±0.18
NO2	Nitrogen Dioxide removed annually	$595.17	±25.64	22.23 T	±0.96
O3	Ozone removed annually	$30,995.24	±1,335.38	221.44 T	±9.54
PM2.5	Particulate Matter less than 2.5 microns removed annually	$64,072.83	±2,760.48	10.76 T	±0.46
SO2	Sulfur Dioxide removed annually	$104.02	±4.48	14.01 T	±0.60
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$22,501.74	±969.45	74.17 T	±3.20
CO2seq	Carbon Dioxide sequestered annually in trees	$858,771.64	±36,998.82	44,350.39 T	±1,910.77
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$26,049,343.82	±1,122,294.77	1,345,292.06 T	±57,959.78

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and $/T/yr: CO 0.902 @ $85.08 | NO2 4.917 @ $26.86 | O3 48.968 @ $140.47 | PM2.5 2.379 @ $5,975.67 | SO2 3.098 @ $7.45 | PM10 16.403 @ $304.43 | CO2seq 9,807.385 @ $19.43 | CO2stor is a total biomass amount of 297,489.961 @ $19.43*
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Cover Assessment and Tree Benefits Report - Springfield, MA

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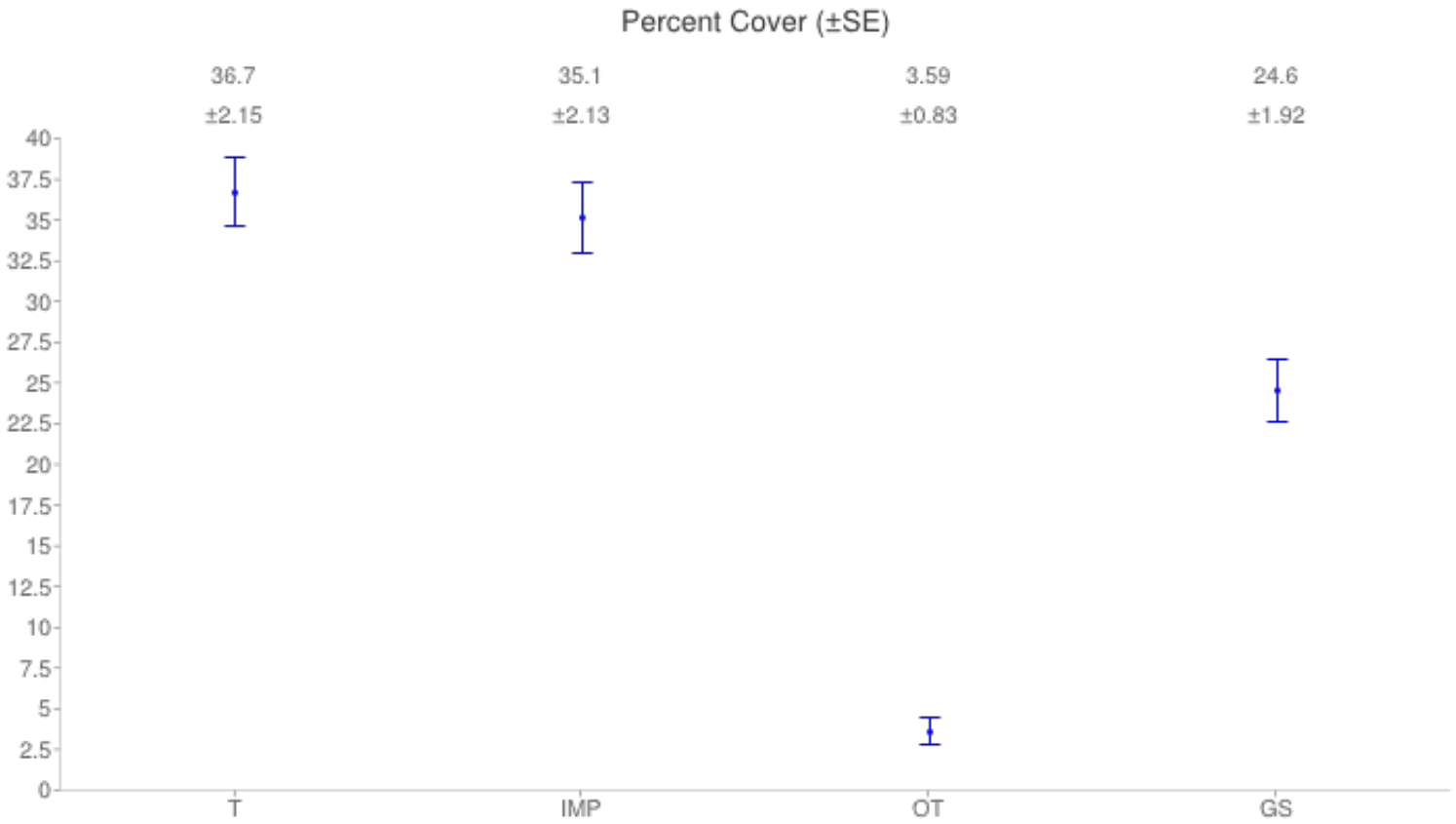

Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	184	36.7 ±2.15
Impervious Surface	impervious surfaces	IMP	176	35.1 ±2.13
Other	other areas i.e.:gravel	OT	18	3.59 ±0.83
Grass and Shrubs	grass and shrubs	GS	123	24.6 ±1.92

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Cover Assessment and Tree Benefits Report - Springfield, MA

Estimated using random sampling statistics on 3/28/14

Cover Class	Description	Abbr.	Points	Land Cover
Tree	Tree, non-shrub	T	184	11.8 ±0.69
Impervious Surface	impervious surfaces	IMP	176	11.3 ±0.69
Other	other areas i.e.:gravel	OT	18	1.15 ±0.27
Grass and Shrubs	grass and shrubs	GS	123	7.89 ±0.62

Tree Benefit Estimates - Springfield, MA

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$289.62	±16.98	3.42 T	±0.20
NO2	Nitrogen Dioxide removed annually	$498.62	±29.24	18.63 T	±1.09
O3	Ozone removed annually	$25,966.92	±1,522.73	185.52 T	±10.88
PM2.5	Particulate Matter less than 2.5 microns removed annually	$53,678.39	±3,147.76	9.01 T	±0.53
SO2	Sulfur Dioxide removed annually	$87.15	±5.11	11.74 T	±0.69
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$18,851.32	±1,105.46	62.14 T	±3.64
CO2seq	Carbon Dioxide sequestered annually in trees	$719,454.29	±42,189.57	37,155.49 T	±2,178.84
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$21,823,394.55	±1,279,747.12	1,127,047.17 T	±66,091.25

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and $/T/yr: CO 0.902 @ $85.08 | NO2 4.917 @ $26.86 | O3 48.968 @ $140.47 | PM2.5 2.379 @ $5,975.67 | SO2 3.098 @ $7.45 | PM10 16.403 @ $304.43 | CO2seq 9,807.385 @ $19.43 | CO2stor is a total biomass amount of 297,489.961 @ $19.43*
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Cover Assessment and Tree Benefits Report - Lowell, MA

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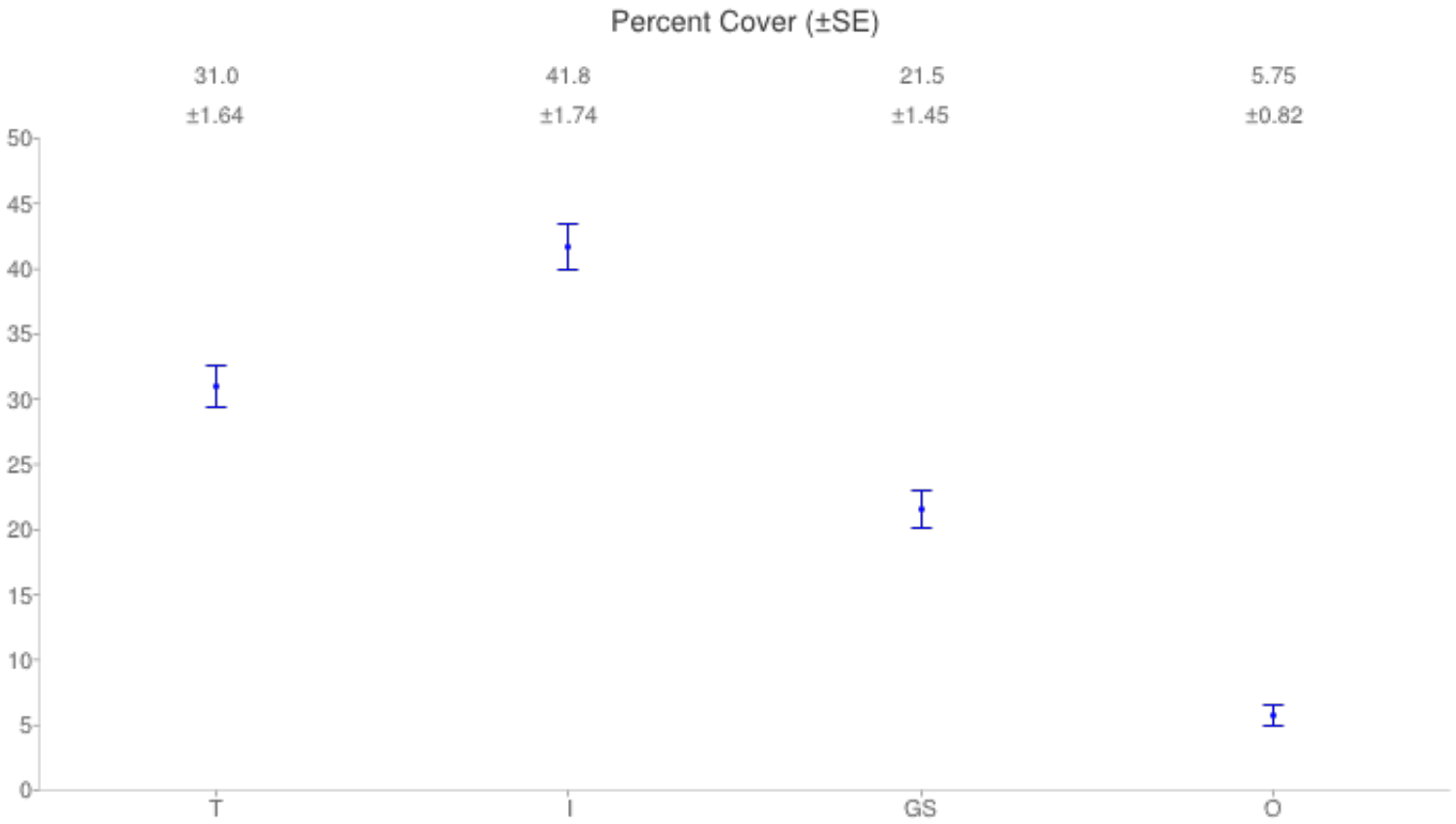

Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	248	31.0 ±1.64
Impervious	solid surface	I	334	41.8 ±1.74
Grass/Shrubs	Grass land	GS	172	21.5 ±1.45
Other	Nont any of the other stuff	O	46	5.75 ±0.82

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i-Tree Canopy v6.0

Cover Assessment and Tree Benefits Report - Lowell, MA

Estimated using random sampling statistics on 3/28/14

Cover Class	Description	Abbr.	Points	Land Cover
Tree	Tree, non-shrub	T	248	4.59 ±0.24
Impervious	solid surface	I	334	6.18 ±0.26
Grass/Shrubs	Grass land	GS	172	3.18 ±0.22
Other	Nont any of the other stuff	O	46	0.85 ±0.12

Tree Benefit Estimates - Lowell, MA

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$112.67	±5.94	1.33 T	±0.07
NO2	Nitrogen Dioxide removed annually	$193.97	±10.23	7.25 T	±0.38
O3	Ozone removed annually	$10,101.71	±532.84	72.17 T	±3.81
PM2.5	Particulate Matter less than 2.5 microns removed annually	$20,882.08	±1,101.47	3.51 T	±0.18
SO2	Sulfur Dioxide removed annually	$33.90	±1.79	4.57 T	±0.24
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$7,333.58	±386.83	24.17 T	±1.28
CO2seq	Carbon Dioxide sequestered annually in trees	$279,883.71	±14,763.06	14,454.31 T	±762.42
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$8,489,785.37	±447,811.68	438,446.39 T	±23,126.78

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and $/T/yr: CO 0.902 @ $85.08 | NO2 4.917 @ $26.86 | O3 48.968 @ $140.47 | PM2.5 2.379 @ $5,975.67 | SO2 3.098 @ $7.45 | PM10 16.403 @ $304.43 | CO2seq 9,807.385 @ $19.43 | CO2stor is a total biomass amount of 297,489.961 @ $19.43*
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Cover Assessment and Tree Benefits Report - Cambridge, MA

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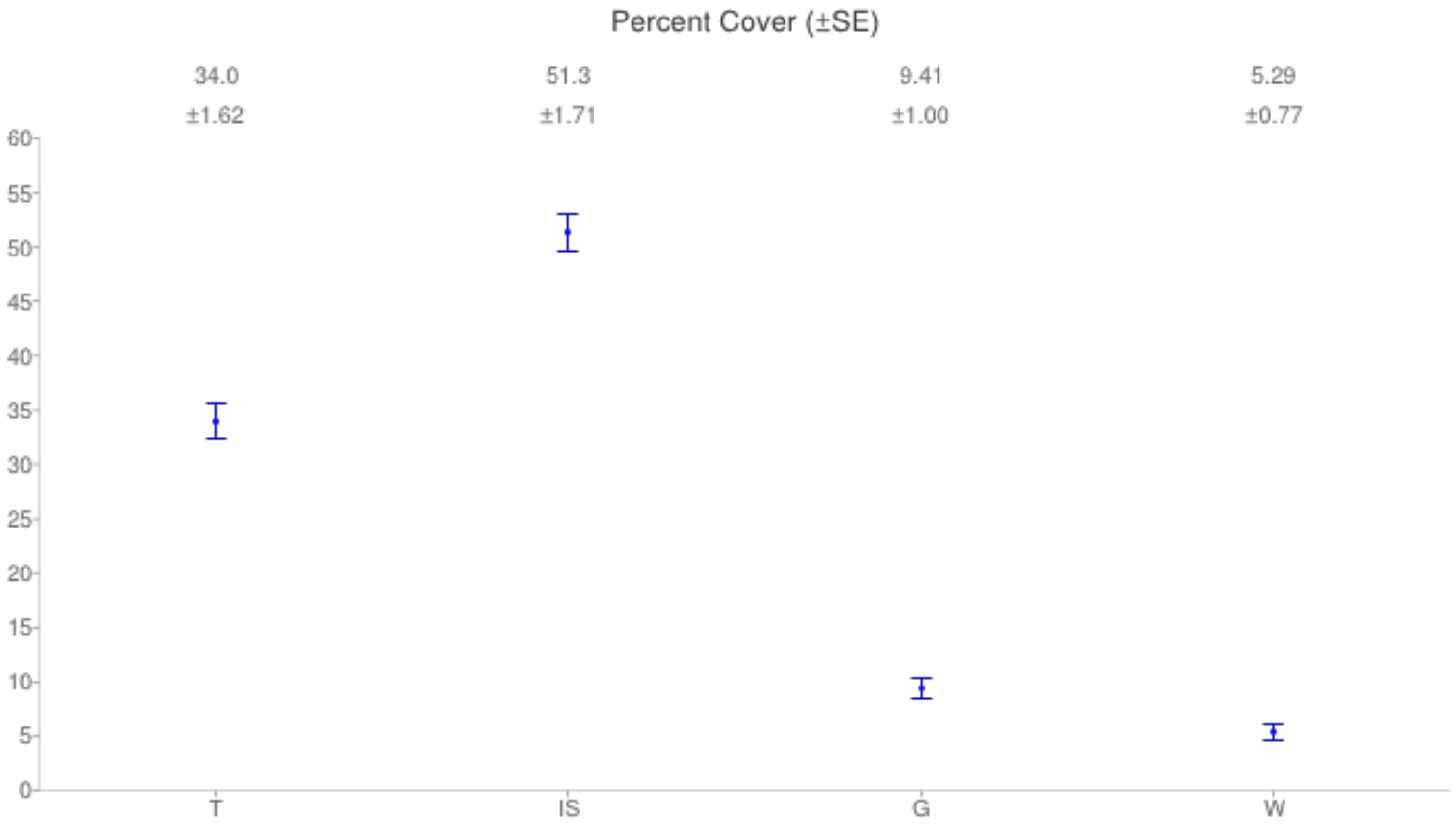

Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	289	34.0 ±1.62
Impervious Surfaces	Hardscape	IS	436	51.3 ±1.71
Grass	Grassy areas	G	80	9.41 ±1.00
Water	Lakes, rivers, streams, etc	W	45	5.29 ±0.77

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Cover Assessment and Tree Benefits Report - Cambridge, MA

Estimated using random sampling statistics on 3/28/14

Cover Class	Description	Abbr.	Points	Land Cover
Tree	Tree, non-shrub	T	289	2.08 ±0.10
Impervious Surfaces	Hardscape	IS	436	3.13 ±0.10
Grass	Grassy areas	G	80	0.57 ±0.06
Water	Lakes, rivers, streams, etc	W	45	0.32 ±0.05

Tree Benefit Estimates - Cambridge, MA

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$50.96	±2.44	1,202.21 lb	±57.45
NO2	Nitrogen Dioxide removed annually	$87.74	±4.19	3.28 T	±0.16
O3	Ozone removed annually	$4,569.21	±218.36	32.64 T	±1.56
PM2.5	Particulate Matter less than 2.5 microns removed annually	$9,445.40	±451.38	1.59 T	±0.08
SO2	Sulfur Dioxide removed annually	$15.33	±0.73	2.07 T	±0.10
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$3,317.13	±158.52	10.93 T	±0.52
CO2seq	Carbon Dioxide sequestered annually in trees	$126,597.15	±6,049.88	6,537.98 T	±312.44
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$3,840,104.49	±183,512.68	198,318.32 T	±9,477.33

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and $/T/yr: CO 0.902 @ $85.08 | NO2 4.917 @ $26.86 | O3 48.968 @ $140.47 | PM2.5 2.379 @ $5,975.67 | SO2 3.098 @ $7.45 | PM10 16.403 @ $304.43 | CO2seq 9,807.385 @ $19.43 | CO2stor is a total biomass amount of 297,489.961 @ $19.43*
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Cover Assessment and Tree Benefits Report - New Bedford, MA

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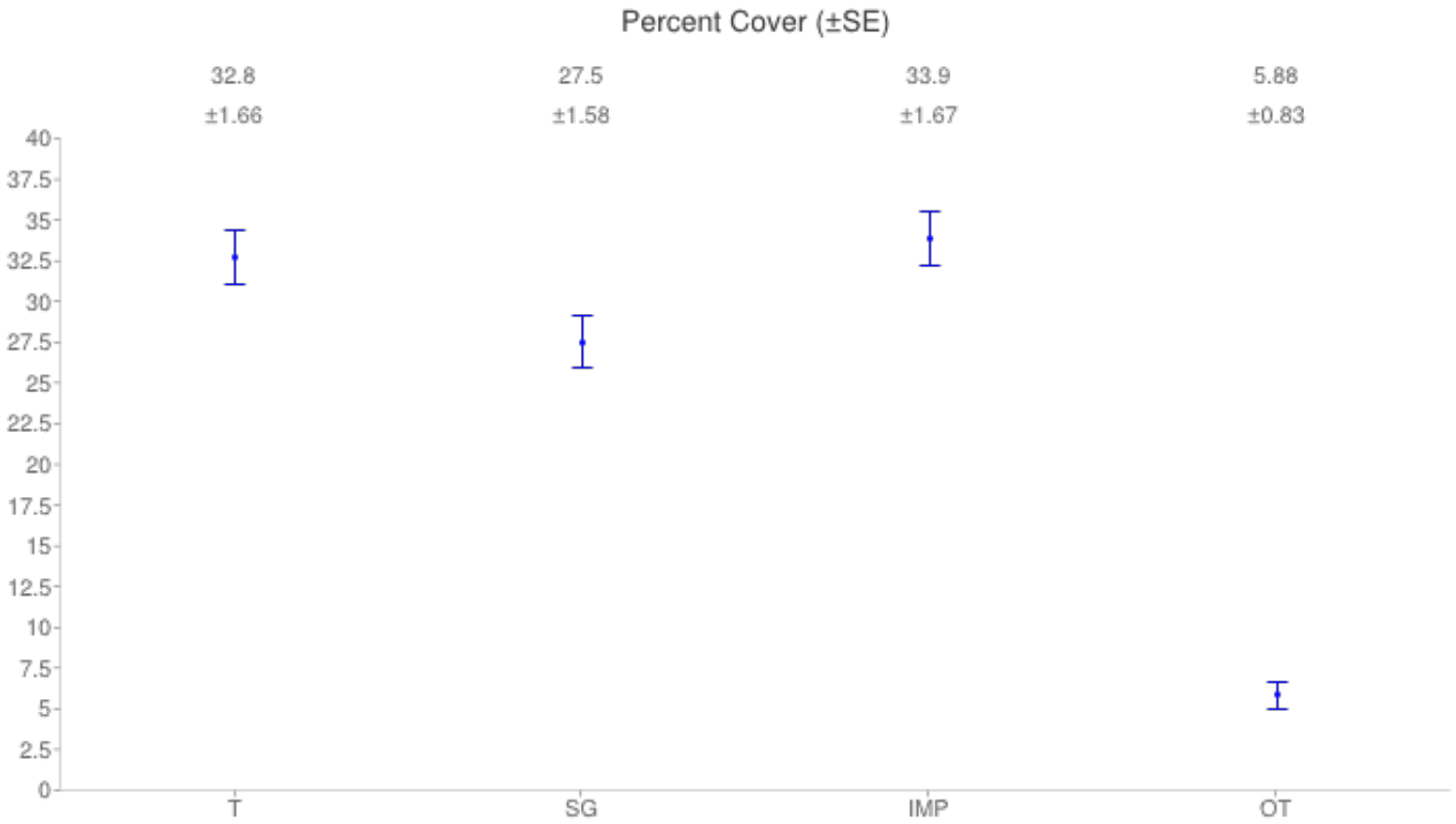

Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	262	32.8 ±1.66
Shrub & Grass	Shrubs and grass areas	SG	220	27.5 ±1.58
Impervious Surfaces	Impervious surfaces	IMP	271	33.9 ±1.67
Other	Other areas, water, bare soil, etc.	OT	47	5.88 ±0.83

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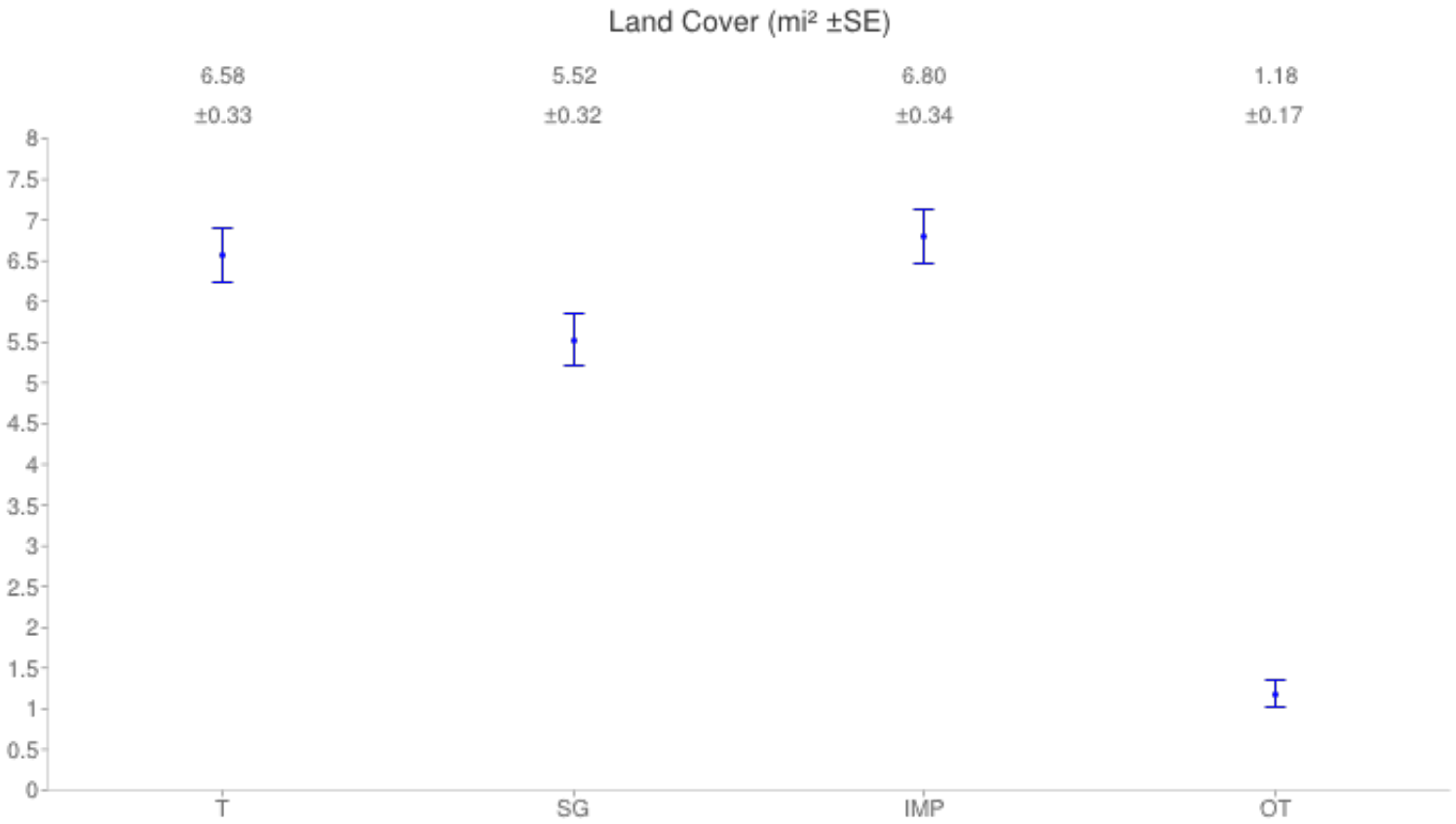

Cover Class	Description	Abbr.	Points	Land Cover
Tree	Tree, non-shrub	T	262	6.58 ±0.33
Shrub & Grass	Shrubs and grass areas	SG	220	5.52 ±0.32
Impervious Surfaces	Impervious surfaces	IMP	271	6.80 ±0.34
Other	Other areas, water, bare soil, etc.	OT	47	1.18 ±0.17

Tree Benefit Estimates - New Bedford, MA

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$161.47	±8.18	1.90 T	±0.10
NO2	Nitrogen Dioxide removed annually	$278.00	±14.08	10.39 T	±0.53
O3	Ozone removed annually	$14,477.51	±733.48	103.43 T	±5.24
PM2.5	Particulate Matter less than 2.5 microns removed annually	$29,927.67	±1,516.24	5.03 T	±0.25
SO2	Sulfur Dioxide removed annually	$48.59	±2.46	6.54 T	±0.33
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$10,510.30	±532.49	34.65 T	±1.76
CO2seq	Carbon Dioxide sequestered annually in trees	$401,122.11	±20,322.26	20,715.55 T	±1,049.52
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$12,167,341.39	±616,440.54	628,370.06 T	±31,835.45

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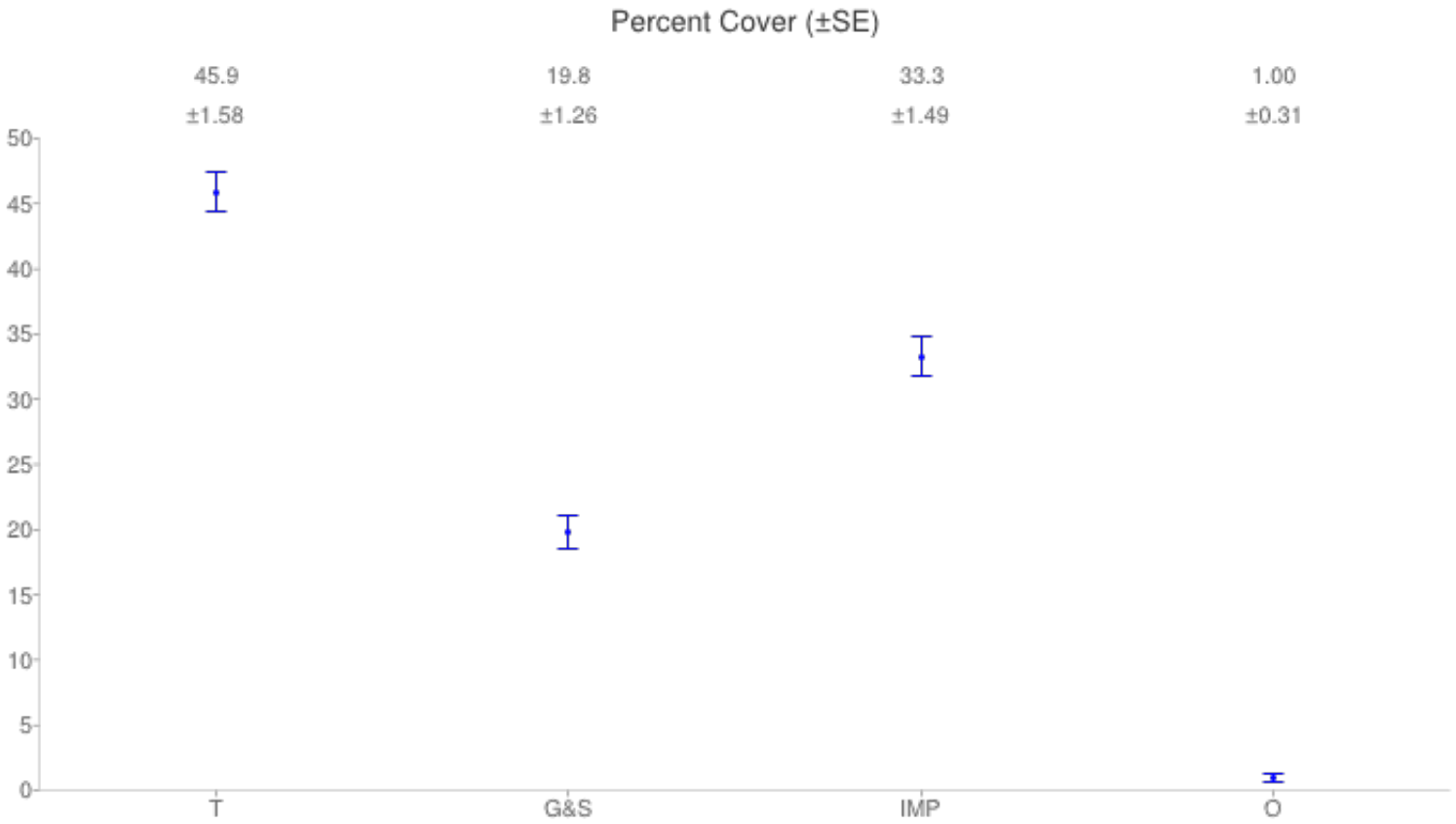

Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	459	45.9 ±1.58
Grass & Shrubs	Grasses and Shrubs	G&S	198	19.8 ±1.26
Impervious	Impervious Surface	IMP	333	33.3 ±1.49
Other	Other	O	10	1.00 ±0.31

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Cover Class	Description	Abbr.	Points	Land Cover
Tree	Tree, non-shrub	T	459	9.88 ±0.34
Grass & Shrubs	Grasses and Shrubs	G&S	198	4.26 ±0.27
Impervious	Impervious Surface	IMP	333	7.17 ±0.32
Other	Other	O	10	0.22 ±0.07

Tree Benefit Estimates - Brockton, MA

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$242.59	±8.33	2.86 T	±0.10
NO2	Nitrogen Dioxide removed annually	$417.66	±14.34	15.60 T	±0.54
O3	Ozone removed annually	$21,750.76	±746.74	155.40 T	±5.33
PM2.5	Particulate Matter less than 2.5 microns removed annually	$44,962.80	±1,543.64	7.55 T	±0.26
SO2	Sulfur Dioxide removed annually	$73.00	±2.51	9.83 T	±0.34
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$15,790.49	±542.11	52.05 T	±1.79
CO2seq	Carbon Dioxide sequestered annually in trees	$602,638.78	±20,689.47	31,122.67 T	±1,068.49
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$18,279,999.25	±627,579.09	944,052.10 T	±32,410.69

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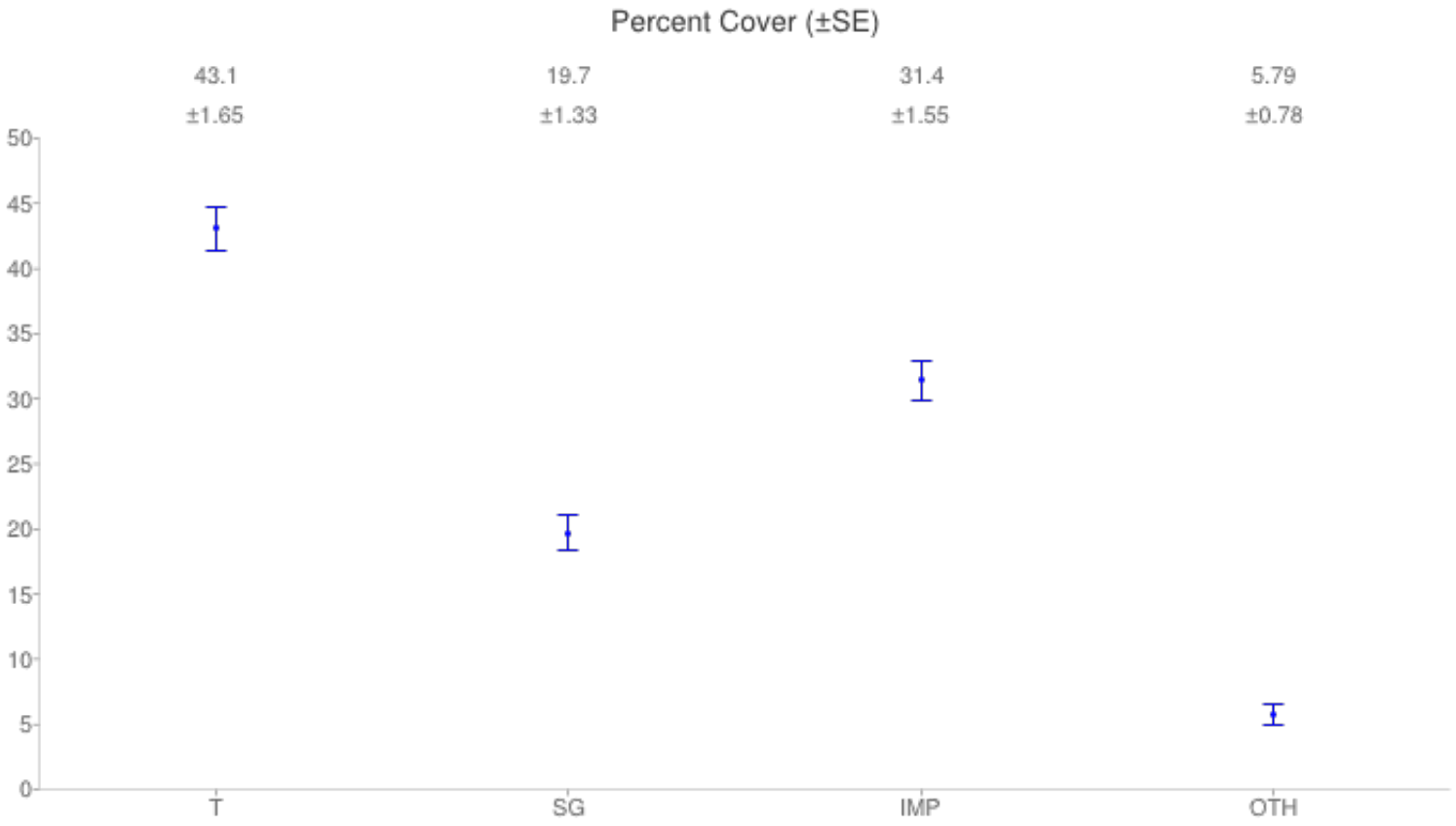

Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	387	43.1 ±1.65
Shrubs/Grassland	Shrubs and Grass	SG	177	19.7 ±1.33
Impervious	Impervious Surfaces	IMP	282	31.4 ±1.55
Other	Other areas, Sand, Water, etc	OTH	52	5.79 ±0.78

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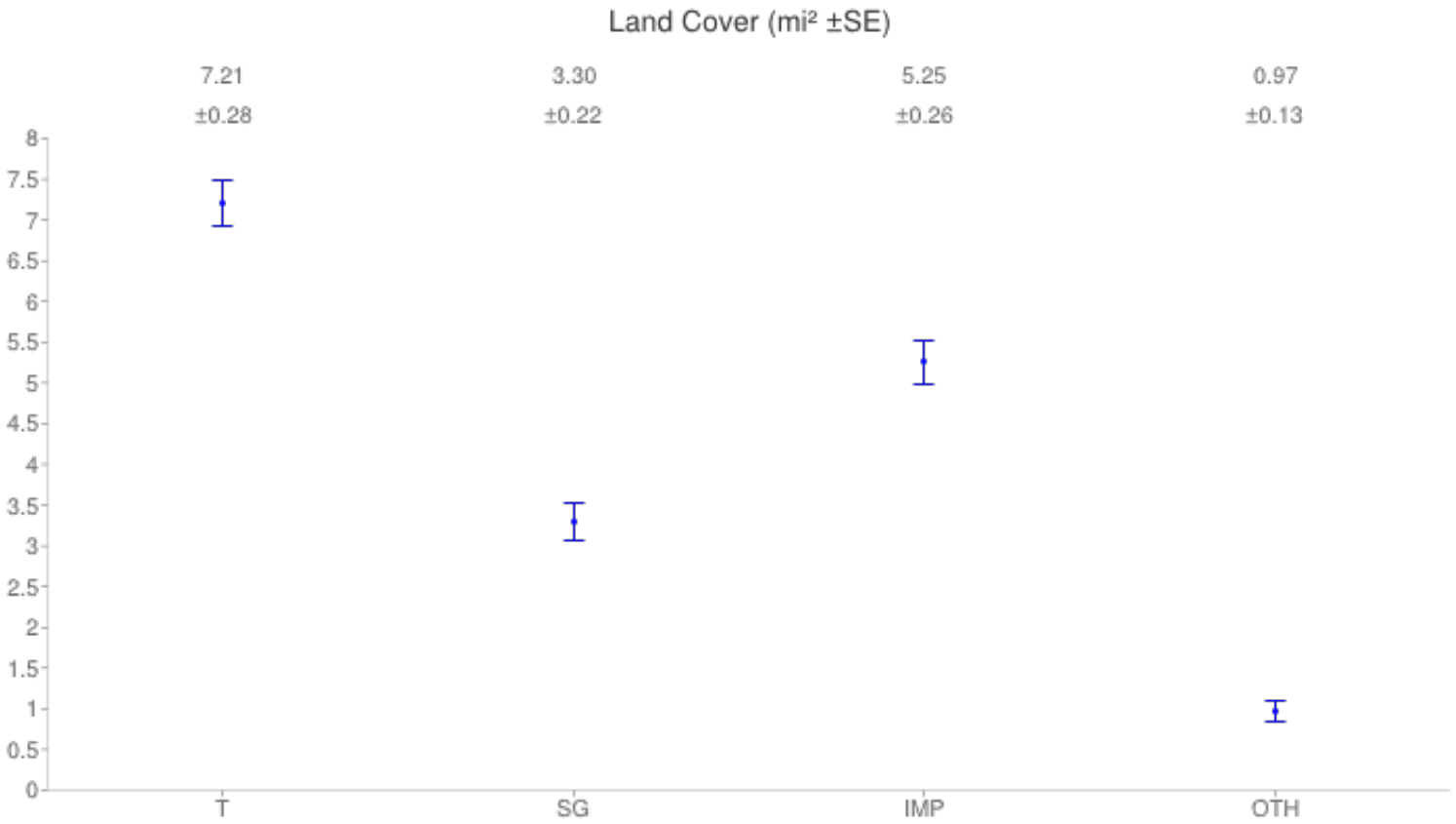

Cover Class	Description	Abbr.	Points	Land Cover
Tree	Tree, non-shrub	T	387	7.21 ±0.28
Shrubs/Grassland	Shrubs and Grass	SG	177	3.30 ±0.22
Impervious	Impervious Surfaces	IMP	282	5.25 ±0.26
Other	Other areas, Sand, Water, etc	OTH	52	0.97 ±0.13

Tree Benefit Estimates - Quincy, MA

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$176.99	±6.79	2.09 T	±0.08
NO2	Nitrogen Dioxide removed annually	$304.72	±11.68	11.38 T	±0.44
O3	Ozone removed annually	$15,869.04	±608.51	113.37 T	±4.35
PM2.5	Particulate Matter less than 2.5 microns removed annually	$32,804.21	±1,257.90	5.51 T	±0.21
SO2	Sulfur Dioxide removed annually	$53.26	±2.04	7.17 T	±0.28
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$11,520.51	±441.76	37.98 T	±1.46
CO2seq	Carbon Dioxide sequestered annually in trees	$439,676.54	±16,859.71	22,706.65 T	±870.70
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$13,336,823.04	±511,409.97	688,766.76 T	±26,411.25

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About i-Tree Canopy

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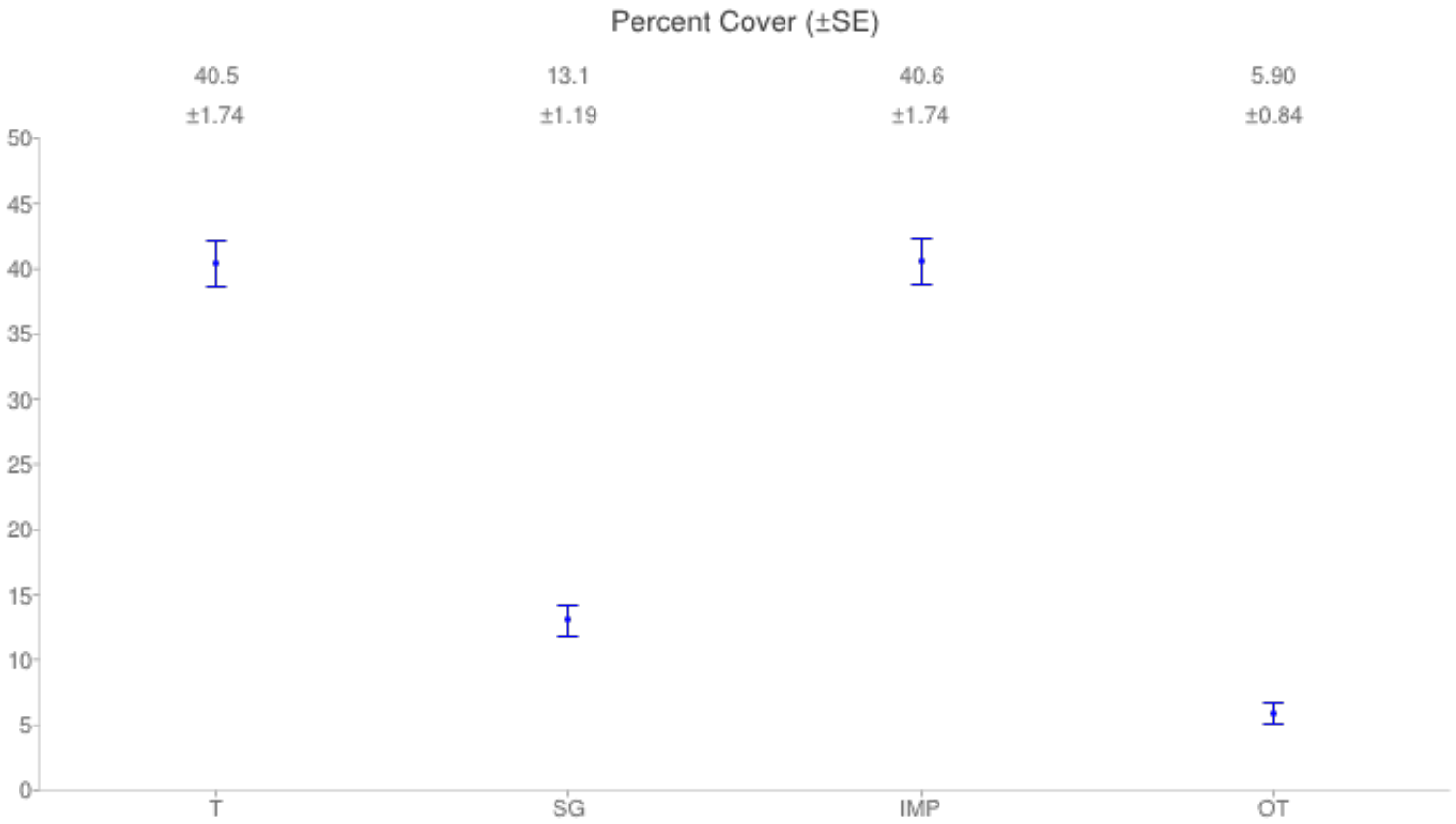
i-Tree Canopy v6.0

Cover Assessment and Tree Benefits Report - Lynn, MA

Estimated using random sampling statistics on 3/28/14



Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	322	40.5 ±1.74
Shrub & Grass	Shrubs and grass areas	SG	104	13.1 ±1.19
Impervious Surfaces	Impervious surfaces	IMP	323	40.6 ±1.74
Other	Other areas water, bare soil, etc.	OT	47	5.90 ±0.84

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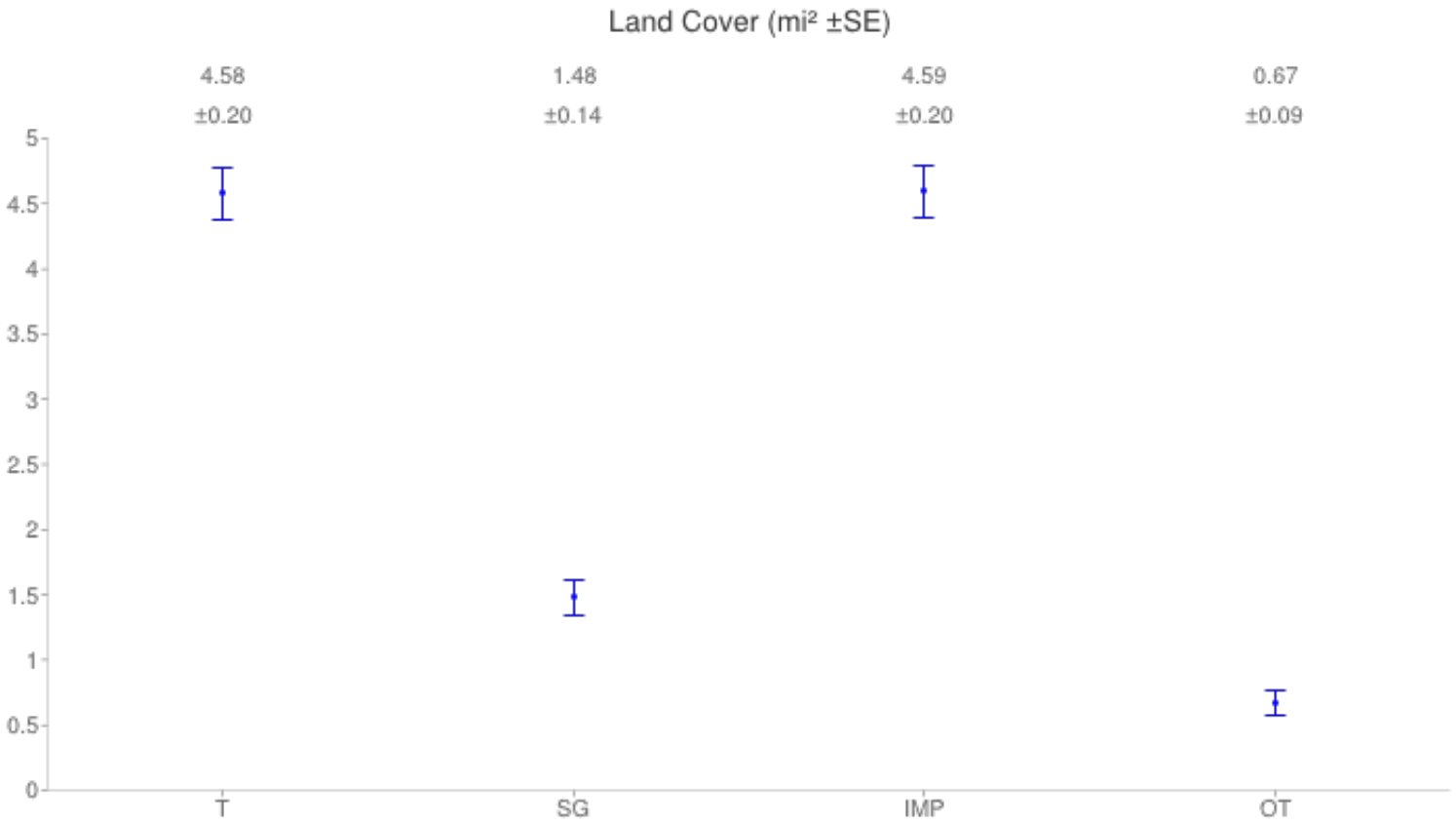

Cover Class	Description	Abbr.	Points	Land Cover
Tree	Tree, non-shrub	T	322	4.58 ±0.20
Shrub & Grass	Shrubs and grass areas	SG	104	1.48 ±0.14
Impervious Surfaces	Impervious surfaces	IMP	323	4.59 ±0.20
Other	Other areas water, bare soil, etc.	OT	47	0.67 ±0.09

Tree Benefit Estimates - Lynn, MA

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$112.44	±4.84	1.33 T	±0.06
NO2	Nitrogen Dioxide removed annually	$193.59	±8.32	7.23 T	±0.31
O3	Ozone removed annually	$10,081.53	±433.54	72.03 T	±3.10
PM2.5	Particulate Matter less than 2.5 microns removed annually	$20,840.37	±896.21	3.50 T	±0.15
SO2	Sulfur Dioxide removed annually	$33.83	±1.46	4.56 T	±0.20
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$7,318.93	±314.74	24.13 T	±1.04
CO2seq	Carbon Dioxide sequestered annually in trees	$279,324.57	±12,011.96	14,425.44 T	±620.35
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$8,472,824.85	±364,361.88	437,570.48 T	±18,817.10

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Cover Assessment and Tree Benefits Report - Fall River, MA

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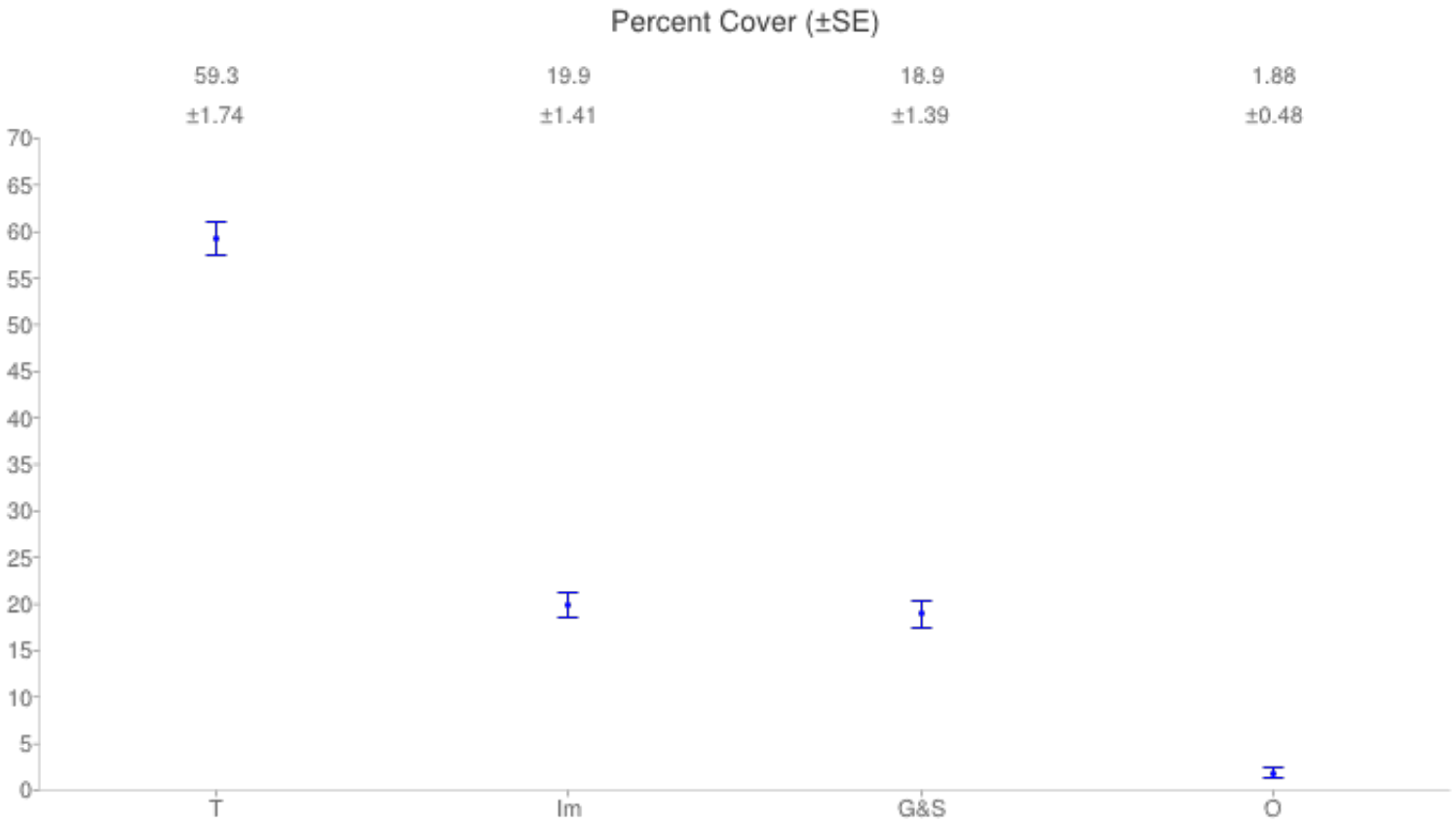

Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	473	59.3 ±1.74
Impervious	Paving/concrete	Im	159	19.9 ±1.41
Grass and/or Shrub	Grass and Shrub	G&S	151	18.9 ±1.39
Other	Water	O	15	1.88 ±0.48

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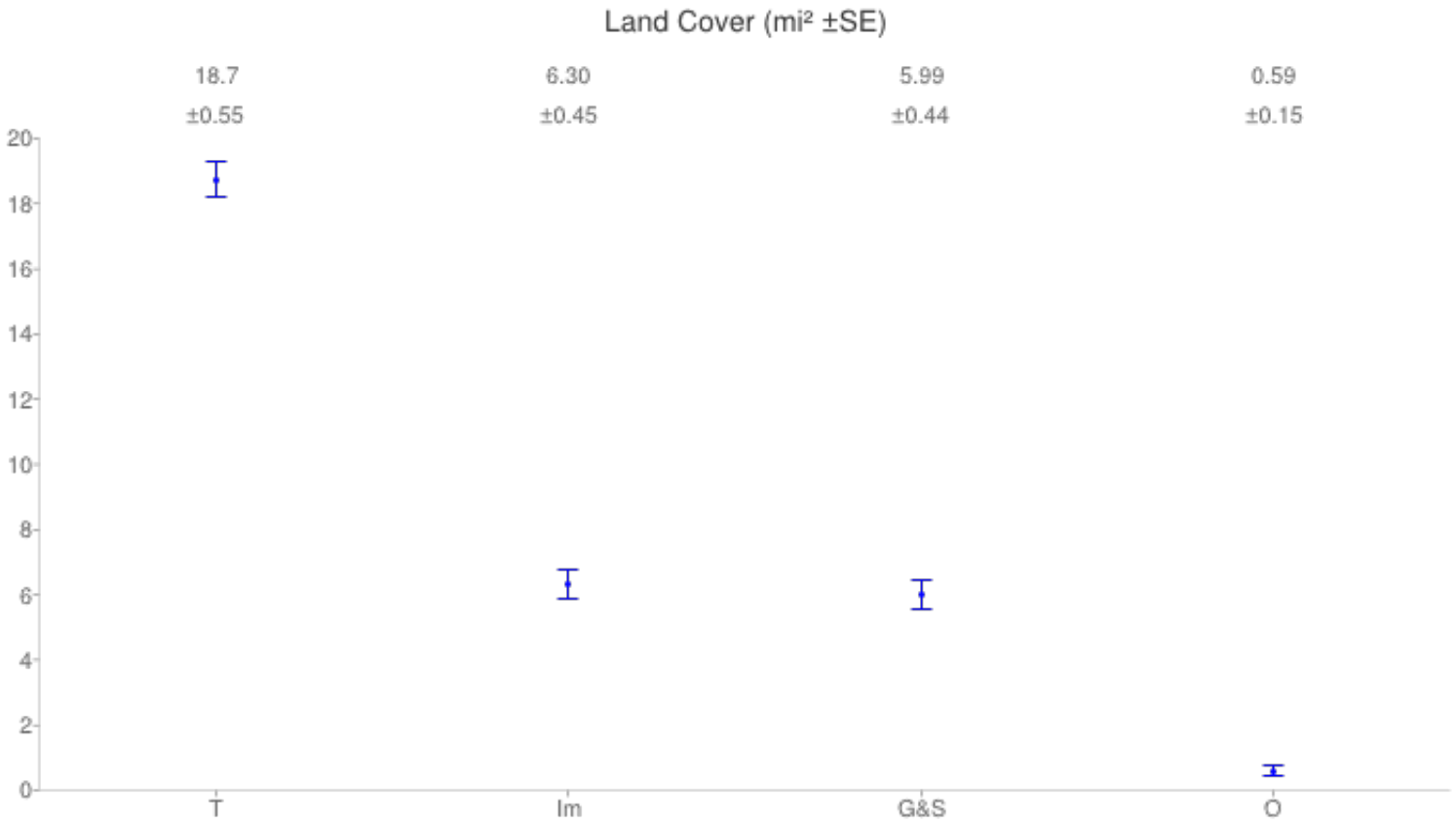

Cover Class	Description	Abbr.	Points	Land Cover
Tree	Tree, non-shrub	T	473	18.7 ±0.55
Impervious	Paving/concrete	Im	159	6.30 ±0.45
Grass and/or Shrub	Grass and Shrub	G&S	151	5.99 ±0.44
Other	Water	O	15	0.59 ±0.15

Tree Benefit Estimates - Fall River, MA

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$460.27	±13.51	5.43 T	±0.16
NO2	Nitrogen Dioxide removed annually	$792.41	±23.25	29.60 T	±0.87
O3	Ozone removed annually	$41,267.30	±1,210.92	294.83 T	±8.65
PM2.5	Particulate Matter less than 2.5 microns removed annually	$85,307.06	±2,503.19	14.33 T	±0.42
SO2	Sulfur Dioxide removed annually	$138.50	±4.06	18.65 T	±0.55
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$29,959.00	±879.10	98.76 T	±2.90
CO2seq	Carbon Dioxide sequestered annually in trees	$1,143,375.16	±33,550.46	59,048.46 T	±1,732.68
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$34,682,296.66	±1,017,694.70	1,791,132.19 T	±52,557.82

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