Key Findings from i-Tree Report
City of Winooski, Vermont

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for
Winooski Natural Resources Conservation District
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i-Tree Inventory Summary

Data was collected in 2014 from 39 field plots (0.05 hectare) located throughout Winooski, Vermont and were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station. Plots were stratified by land use type: residential, commercial-industrial, or public. Within each plot, data on ground and tree cover, available planting space, and individual tree and shrub attributes – such as: species, stem diameter, height, crown width, dieback, and proximity to residential buildings – were collected.

The i-Tree Eco program uses the quantified plot data to estimate the city-wide number of trees per species and land use type, plot characteristics, and ecosystem services provided by the woody vegetation, including rainfall infiltration, carbon storage and annual sequestration, and pollution abatement. The overall goal of this assessment was to quantify the carbon sequestration and rainfall infiltration (avoided runoff) by the urban forest and use these results to recommend future plantings to maximize these two services.

Key Findings & Estimates:

- Estimated number of urban trees: 58,600
- Tree cover: 30.9%
- Most common species: white ash, eastern red cedar, american elm
- Percentage of trees less than 6"diameter: 62.6%
- Estimated pollution removal: 11 metric tons/yr ($419,000/yr)
- Estimated carbon storage: 10,600 metric tons ($836, 000 to $1,040,000/yr)
- Estimated carbon sequestration: 325 metric tons/yr ($25,500/yr to $31, 700/yr)
- Estimated oxygen production: 705 metric tons/yr
- Estimated avoided runoff: 29,200 m^3/yr ($68,700/yr)
- Estimated structural value: $56,000,000
- Total estimated valuation of urban forest: $57,349,200 to $57,559,400

Tree Characteristics

The urban forest of Winooski has an estimated 58,600 trees with a tree cover of 30.9%. Trees that have diameters less than 6" make up 62.6% of the population (Figure 1). The three most common species are white ash (13.5%), eastern red cedar (13.2%), and american elm (11.8%) (Figure 2).

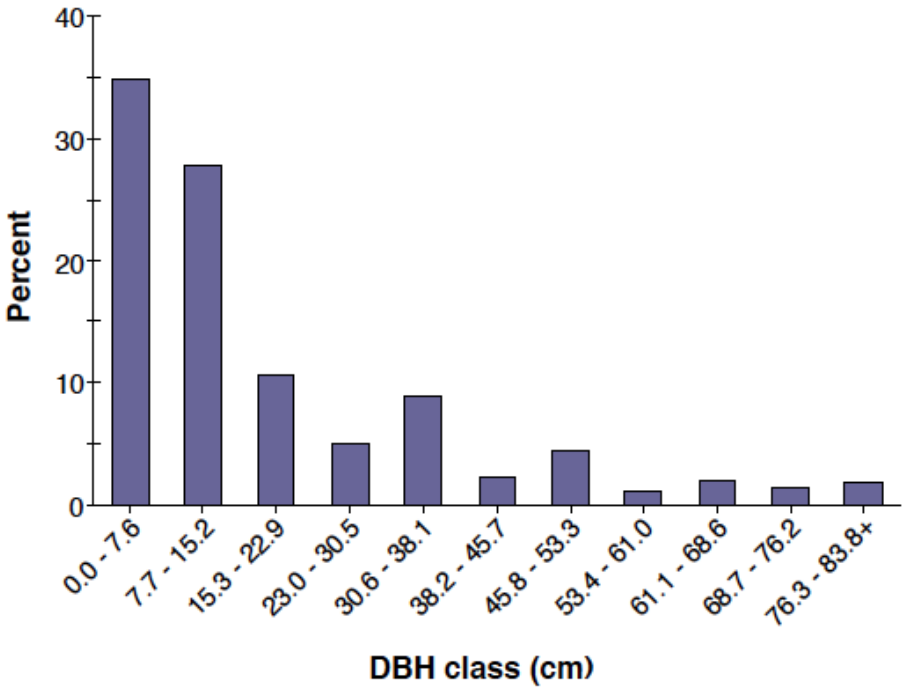

Figure 1: Percent of tree population in Winooski by diameter class (cm) (DBH = diameter at breast height [1.37 m]). From i-Tree Eco Report.

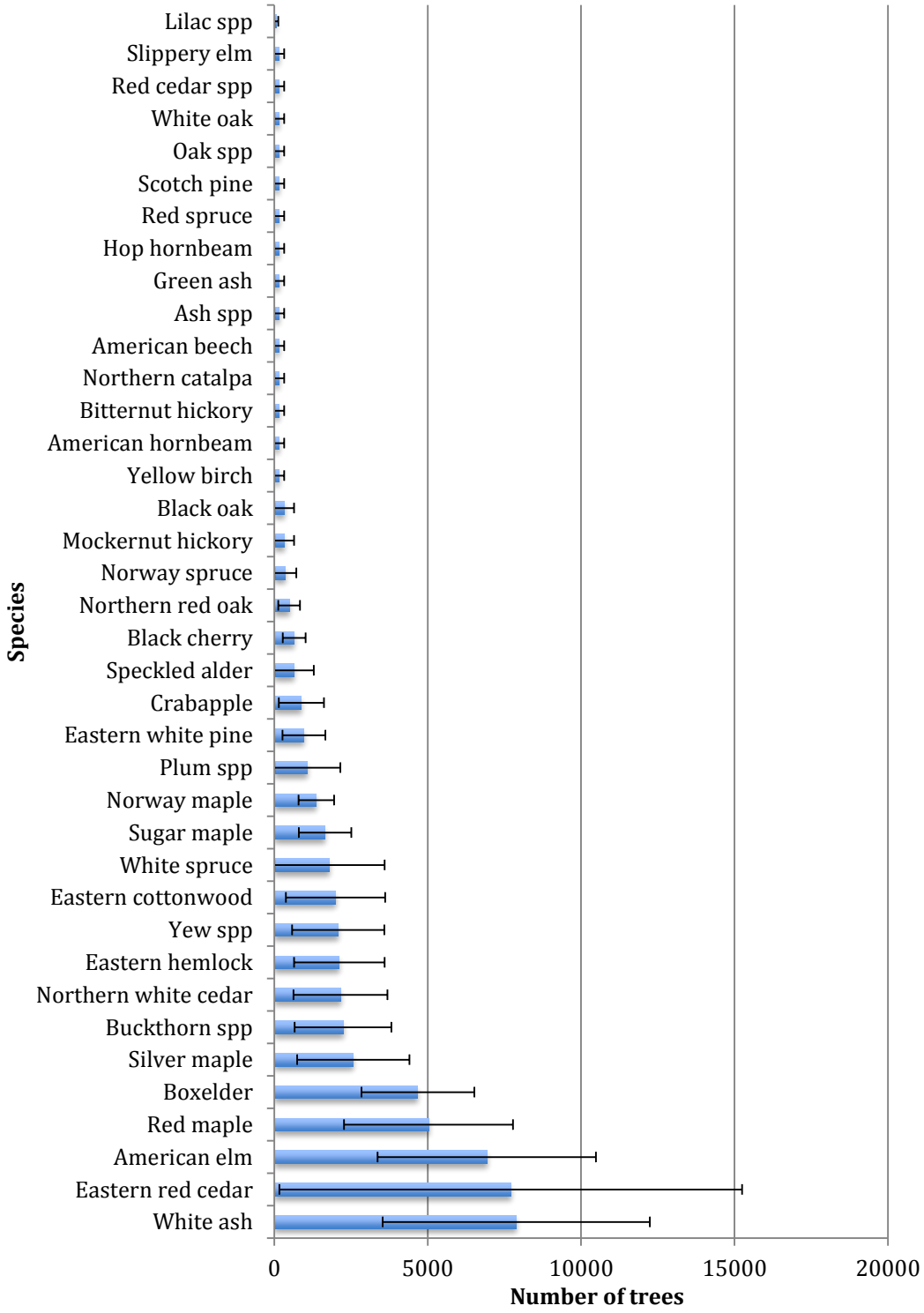

Figure 2: Estimated number of trees (± standard error) per species for the city of Winooski based on 39 sample plots. SE bars a large in magnitude due to low number of sample plots.

Tree Health

Overall, about 80% of the total trees assessed in Winooski (Figure 3) are classified at excellent or good health (Figure 4).

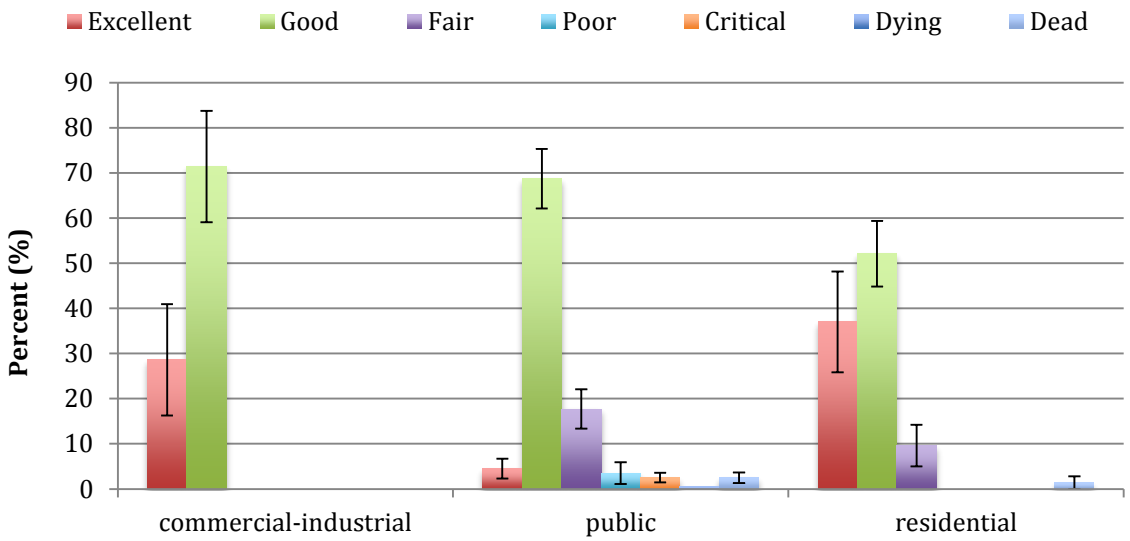

Figure 3: Percent of trees by assessed crown condition and land use type

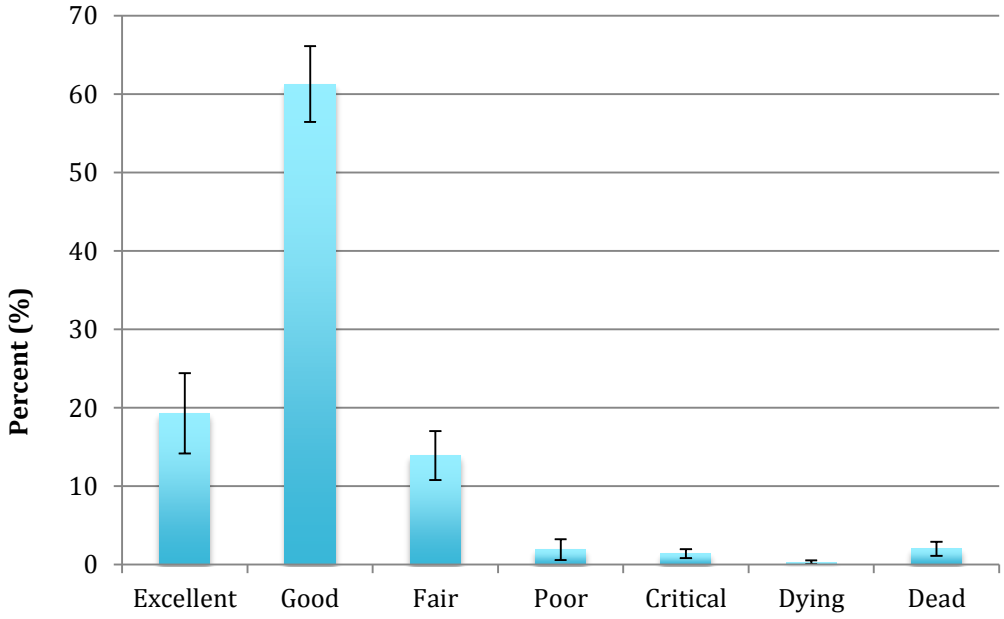

Figure 4: Percent of trees by assessed crown condition city wide

Tree Density

Trees cover approximately 30.9% of the city of Winooski. The overall tree density in Winooski is 168 trees/hectare. The highest tree densities in Winooski occur in public places (235.7 trees/ha) followed by residential areas (151.1 trees/ha) and commercial-industrial area (11.7 trees/ha) (Figure 5).

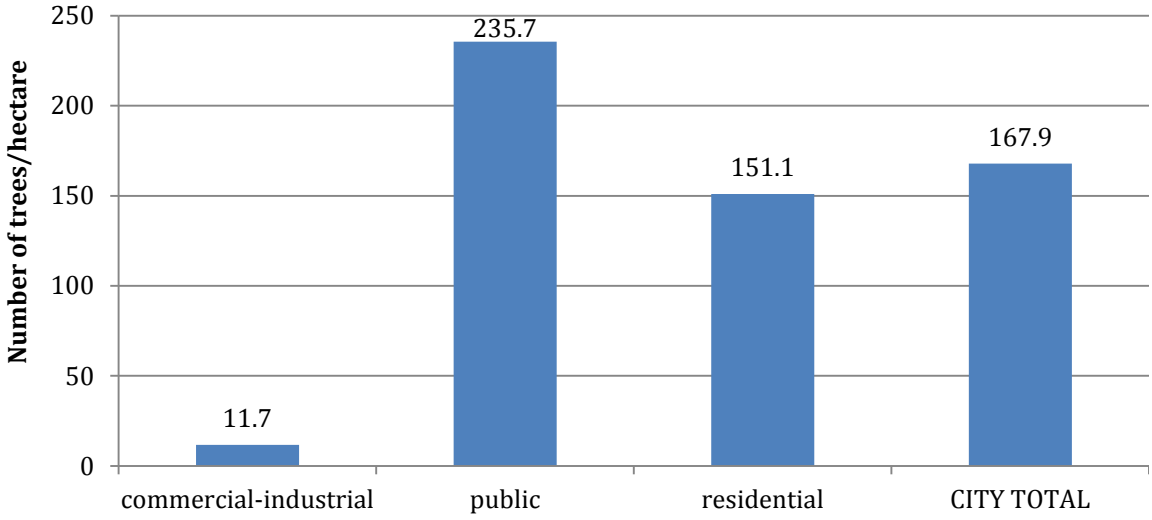

Figure 5: Estimated tree density (number of trees per hectare) by land use classification and averaged for the city.

Leaf Cover

Many tree benefits equate directly to the amount of healthy leaf surface area. Currently, in Winooski, the most dominant species in terms of leaf area are: american elm, silver maple, and boxelder (Figure 6). Leaf area also equates to the amount of rainfall intercepted by the tree and thus, factors into calculations of avoided runoff attributable to woody vegetation.

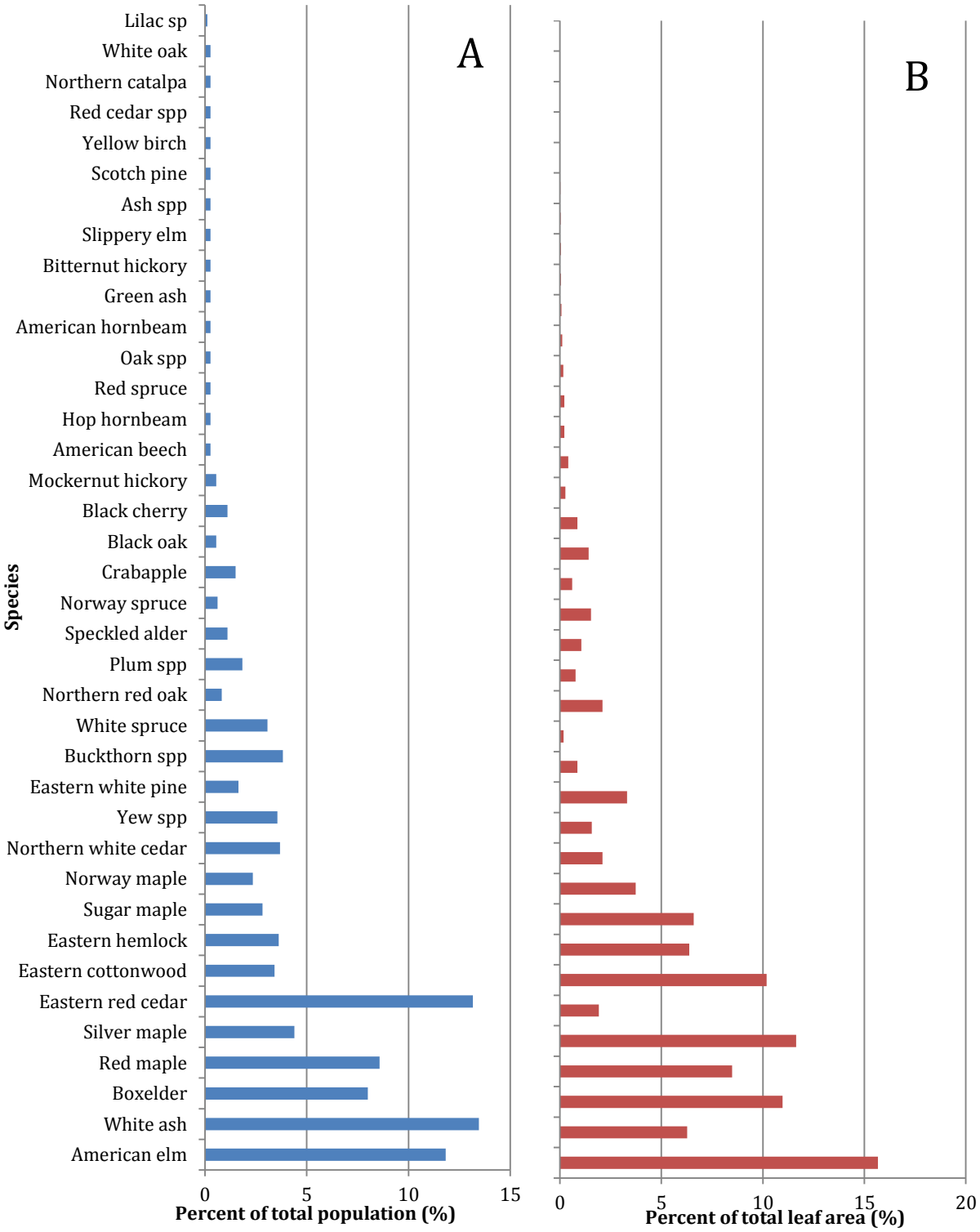

Figure 6: Estimated percent of the (A) total tree population and (B) total leaf area of the tree and shrub species in Winooski.

Surface Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution accumulation in streams, wetlands, rivers, and lakes. During precipitation events, some portion of the precipitation is intercepted by vegetation; the remaining portion that reaches the ground and does not infiltrate into the soil becomes surface runoff. The extent of impervious surface in Winooski also increases the amount of surface runoff. Urban trees, however, are beneficial in reducing surface runoff by intercepting precipitation at the canopy level (e.g., leaves), while root systems promote soil infiltration and storage.

Annual avoided surface runoff is calculated based on rainfall interception by vegetation – specifically the difference between annual runoff with and without vegetation. While a tree's branches and bark may also intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The national default value for the cost of stormwater was used in this analysis since a local cost could not be quantified at this time due to limitations of partitioning costs at local water treatment facilities. In i-Tree Eco, The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series ($0.0089/gal).

The trees of Winooski help to reduce runoff by an estimated 7,716,100 gallons a year with an associated value of $68,700 (Figure 7). By land use type, this equates to $627 for commercial-industrial land, $38,665 for public land, and $29,381 for residential land. The tree species that currently provide the most stormwater infiltration benefit (per tree) for Winooski are depicted in Figure 8.

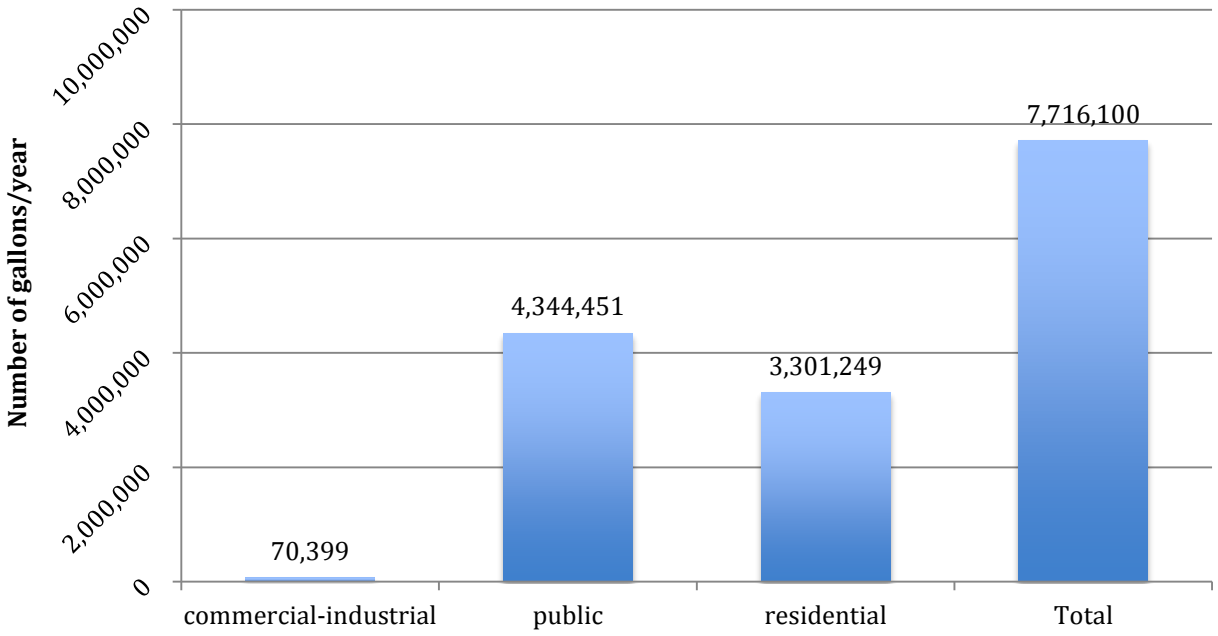

Figure 7: Estimated number of gallons of rainfall intercepted by woody vegetation by land use type and averaged by the city.

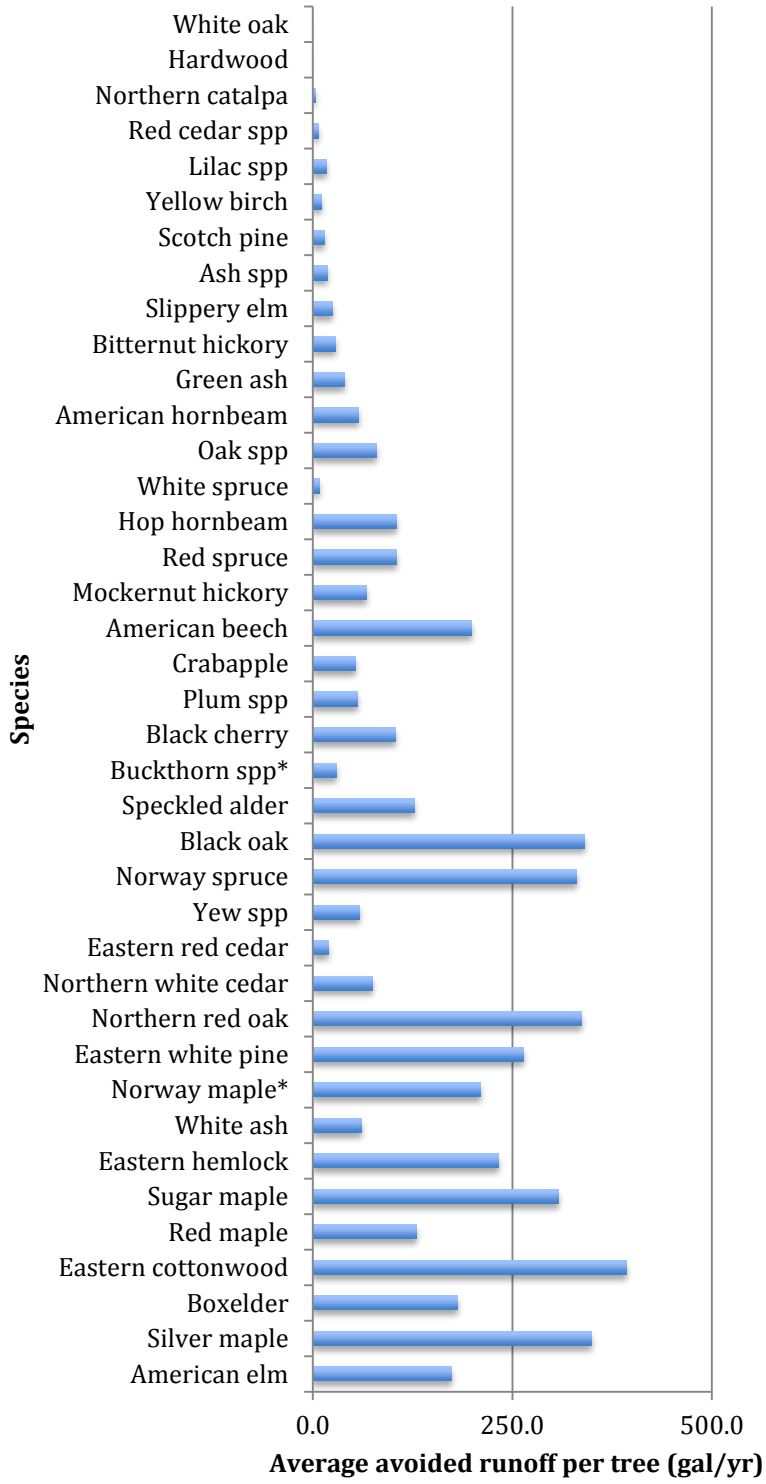

Figure 8: Estimated current average avoided runoff per tree per species (gallons per year).

Carbon Storage and Sequestration

Urban trees can help mitigate climate change by sequestering atmospheric carbon; this amount increases with the size and health of the trees. To calculate current carbon storage, biomass for each tree was calculated using allometric equations and measured tree data. Analysis was done using the default parameters for the social cost of carbon (valued at $21.4/metric ton CO_2) and with an updated value in 2014 US dollars (valued at $25.89/metric ton CO_2).

The gross sequestration of Winooski trees is about 325 metric tons of carbon per year with an associated value of $25,500/year (using default value) or $31,700/year (using current costs of carbon). Net carbon sequestration is slightly lowed, about 264 metric tons, which accounts for estimated mortality and decline of trees.

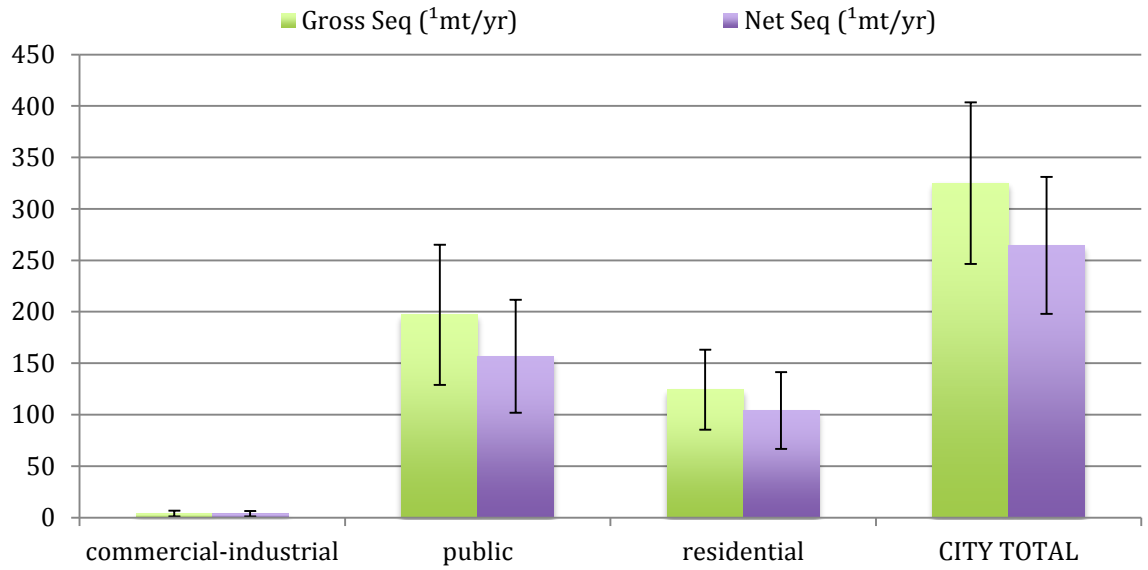

Figure 9: Estimated gross carbon sequestration and net carbon sequestration per land use type and for the entire city.

Trees in Winooski are estimated to store 10,600 metric tons of carbon, estimated to be worth $836,000 (default carbon valuation) to $1,040,000 (updated valuation). Of the trees sampled, black oak, eastern cottonwood, and silver maple currently store the most carbon in Winooski, likely due to the fact that these are often large trees. Black oak, northern red oak and silver maple currently sequester the most carbon annually. However, this is only an indication of the existing trees that store and sequester the most carbon, which is contingent on diameter, crown condition and size, as well as species.

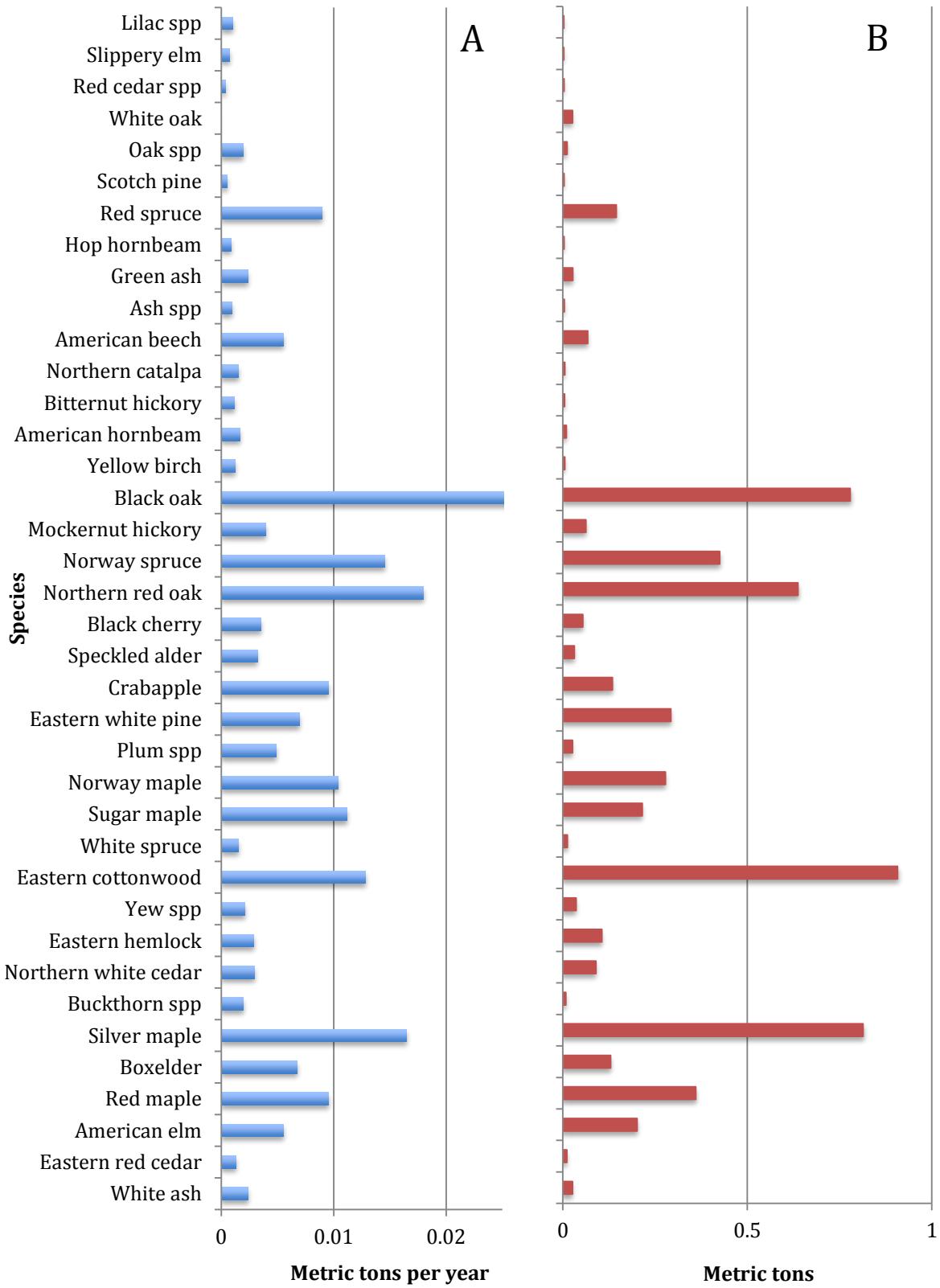

Figure 10: Estimated average (A) gross carbon sequestration and (B) carbon storage per species in sample plots.

Air Pollution Removal

The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from power plants.

Pollution removal by trees and shrubs in Winooski was estimated using field data and recent available pollution and weather data (Figure 11). Pollution removal was greatest for ozone. It is estimated that trees and shrubs remove 11 metric tons of air pollution (ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter less than 10 microns and greater than 2.5 microns (PM_{10}), particulate matter less than 2.5 microns ($PM_{2.5}$), and sulfur dioxide (SO_2) per year with an associated value of $419,000.

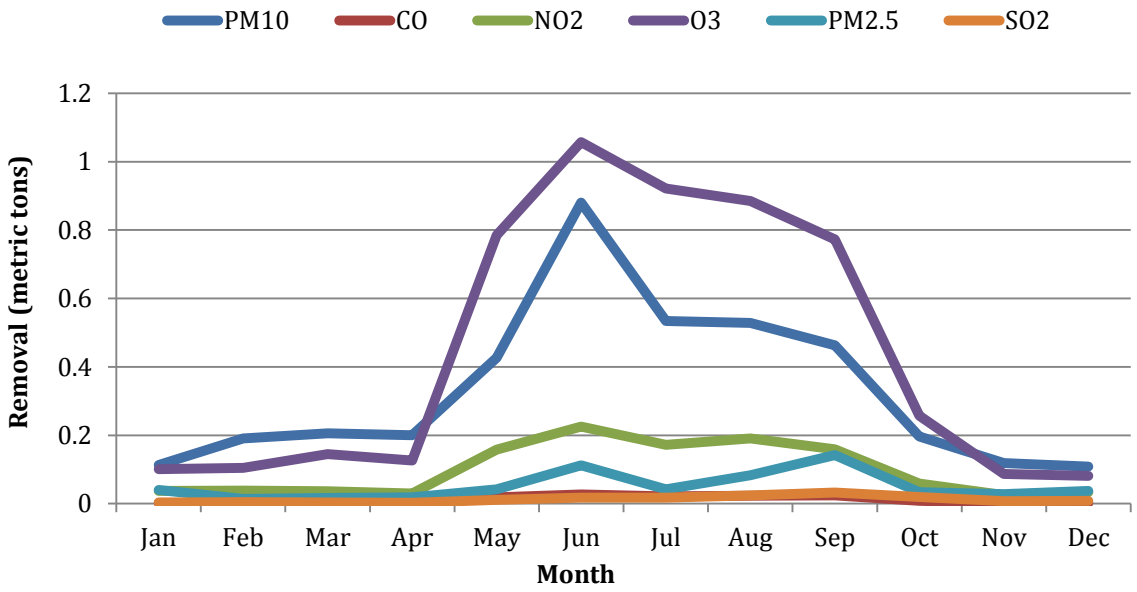

Figure 11: Monthly pollution removal estimates for the city of Winooski by woody vegetation: ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter less than 10 microns and greater than 2.5 microns (PM_{10}), particulate matter less than 2.5 microns ($PM_{2.5}$), and sulfur dioxide (SO_2).

Structural and Functional Values

Urban forests have a structural value based on the individual trees (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform. The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees. Annual functional values also tend to increase with increased number and size of healthy trees, and are usually on the order of several million dollars per year. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines. The structural value of Winooski's urban forests is estimated to be $56,000,000.

Relative Tree Effects

The urban forest in Winooski provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, i-Tree Eco also contrasts tree benefits to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions.

- Total carbon storage is equivalent to:
  - Amount of carbon emitted in Winooski in 98 days
  - Annual emissions from 7,040 automobiles
  - Annual emissions from 3,540 single-family houses
- Annual carbon sequestration is equivalent to:
  - Amount of carbon emitted in Winooski in 3.0 days
  - Annual emissions from 200 automobiles
  - Annual emissions from 100 single-family houses
- Carbon monoxide removal is equivalent to:
  - Annual emissions from 1 automobile
  - Annual emissions from 2 single-family houses
- Nitrogen dioxide removal is equivalent to:
  - Annual emissions from 81 automobiles
  - Annual emissions from 54 single-family houses
- Sulfur dioxide removal is equivalent to:
  - Annual emissions from 252 automobiles
  - Annual emissions from 4 single-family houses
- Particulate matter less than 10 micron (PM_{10}) removal is equivalent to:
  - Annual emissions from 13,400 automobiles
  - Annual emissions from 1,300 single-family houses

Uncertainty in Results

Only 39 plots were surveyed for this study; therefore results should be interpreted with caution – this is fewer plots than i-Tree Eco suggests for a robust sample. Since i-Tree Eco utilizes the sample plot inputs to extrapolate thecity as a whole, estimates carry uncertainty. Figure 2 depicts the large uncertainty around the estimations of number of trees per species in Winooski. As these values are used to estimate ecosystem services, the uncertainty carries over to those metrics as well. Figure 12 shows that with a sample size of 39, the standard error of the mean is about 25%. Increasing the number of plots to 100 would reduce that value to ~15%. Equal stratification of plots within land use type should also be a goal.

Uncertainty in the ecosystem valuation of the urban trees is also a concern. Allometric equations are utilized by i-Tree Eco to calculate the amount of carbon storage and annual sequestration, leaf area index, and pollution abatement. While the allometric equations are based on scientific studies, error could occur due to human error in field measurements (e.g., error in measuring tree metrics) as well as tree-to-tree deviations from standard growth curves.

Obtaining a local cost of stormwater treatment would also help limit uncertainty in the avoided runoff calculation. While this value may be a hurdle to quantify, climate models projected increasing severe weather events in the future, with heavy rainfall events becoming increasingly common.

Regardless, the estimates by i-Tree Eco do provide an approximation of the ecosystem services provided by Winooski's urban trees and incentivizes the completion of a larger survey.

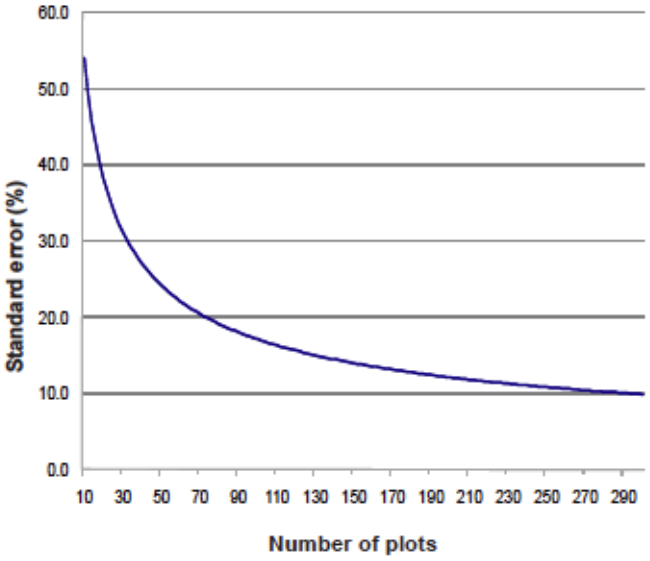

Figure 12: Relationship between the number of sampled plots and the associated percent standard error. From i-Tree Eco Users Manual.

Conclusions

Based on these results, it is clear that the City of Winooski could increase its urban forest to increase the benefits of the ecosystem services the trees provide. Carbon sequestration and storage, avoided runoff, and pollution abatement, and structure values of the urban forest are not inconsequential and carry a high monetary valuation, with a total valuation of $57,349,200 to $57,559,400 depending on the cost of carbon. Using these data can help incentivize increasing the cover, diversity, and health of the trees and shrubs in Winooski.

Recommendations to increase carbon storage and sequestration, rainfall infiltration, and pollution abatement, are made in a separate document, but this analysis suggests increasing the number, size, and variety of trees in Winooski, especially focusing on commercial-industrial areas where tree and shrub density is low (Figure 5). However, in this land use type, impervious surfaces cover an estimated 83% of the land (Figure 14) and consequentially it has the lowest available planting space of the three land use types (Figure 13).

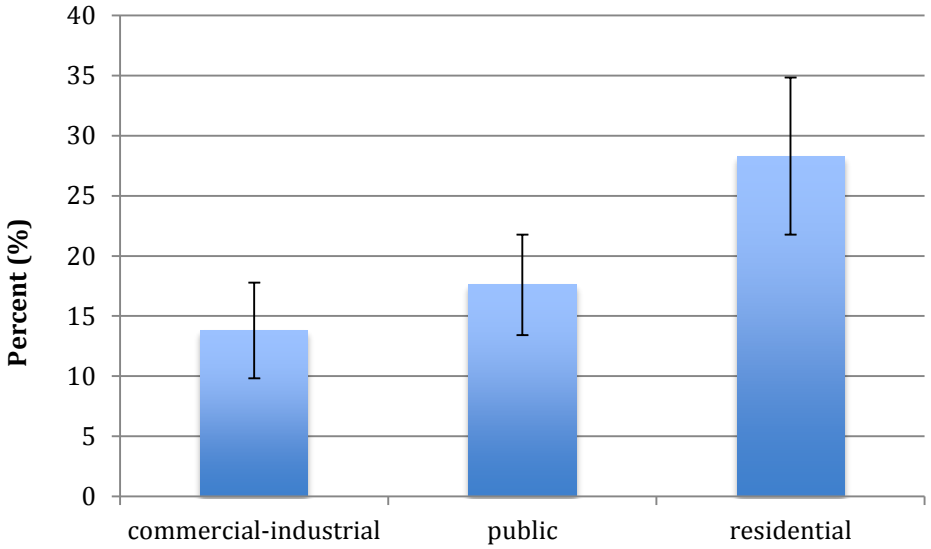

Figure 13: Estimated percent of space available for planting within each land use classification type.

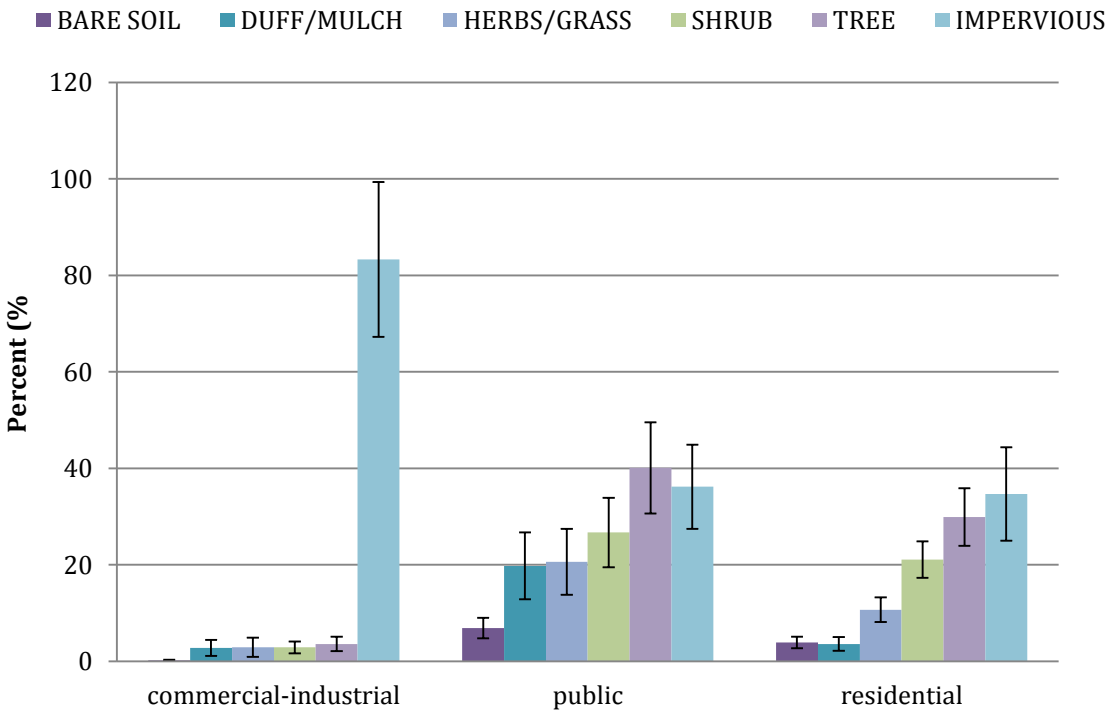

Figure 14: Estimated percent of each type of groundcover per land use classification type. Rock, concrete, tar and buildings were grouped into "impervious surfaces".