

## Key Findings from iTree Report City of Winooski, Vermont

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February 2015  
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### Summary

Data was collected in 2014 and 2015 from 63 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, such as rainfall infiltration, carbon storage and annual sequestration, and pollution abatement. The overall goal of this assessment was to specifically 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: 56,400
- Tree cover: 35.8%
- Most common species: Boxelder, Red maple, American elm
- Percentage of trees less than 6" diameter: 54.6%
- Estimated air pollution removal: 12 metric tons/yr (\$394,000/yr)
- Estimated carbon storage: 11,700 metric tons (\$919,000-1,832,200)
- Estimated carbon sequestration: 387 metric tons/yr (\$30,400/yr-\$60,600/yr)
- Estimated oxygen production: 855 metric tons/yr
- Estimated avoided runoff: 29,100 cubic meters/yr (1,028,000 ft<sup>3</sup>/yr) (\$68,400/yr)
- Estimated structural value: \$62 million-\$62.9 million
- Estimated functional value: \$492,800-\$523,000

### Tree Characteristics

The urban forest of Winooski has an estimated 56,400 trees with a tree cover of 35.8%. Trees that have diameters less than 6" make up 54.6% of the population (Figure 1), indicating a relatively young forest in the city. The three most common species are Boxelder (14.7%), Red maple (12.2%), and American elm (10.8%) (Figure 2).

Both Norway maple and buckthorn (two common invasive species) are widespread throughout the city.

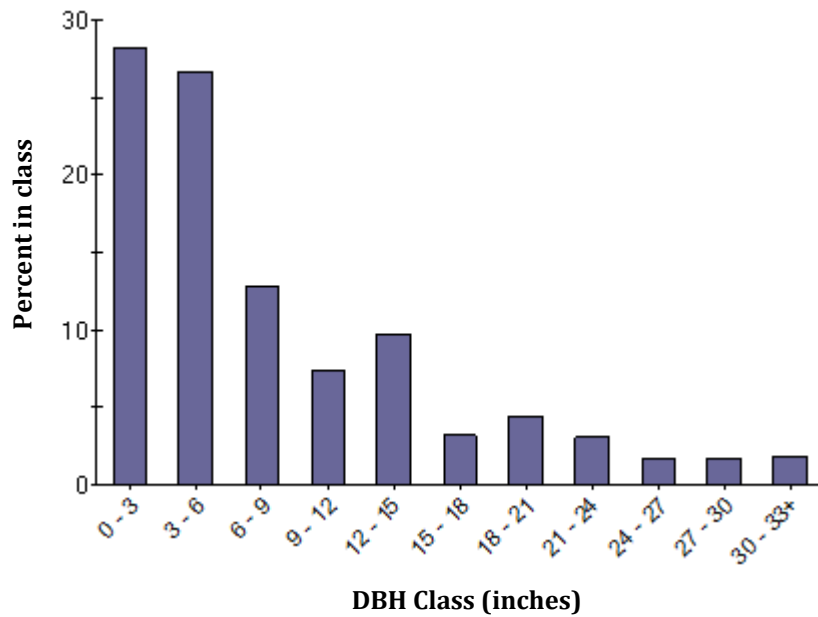


Figure 1: Percent of tree population in Winooski by diameter class (cm) (DBH = diameter at breast height [1.37 m]). From i-Tree Eco Report.

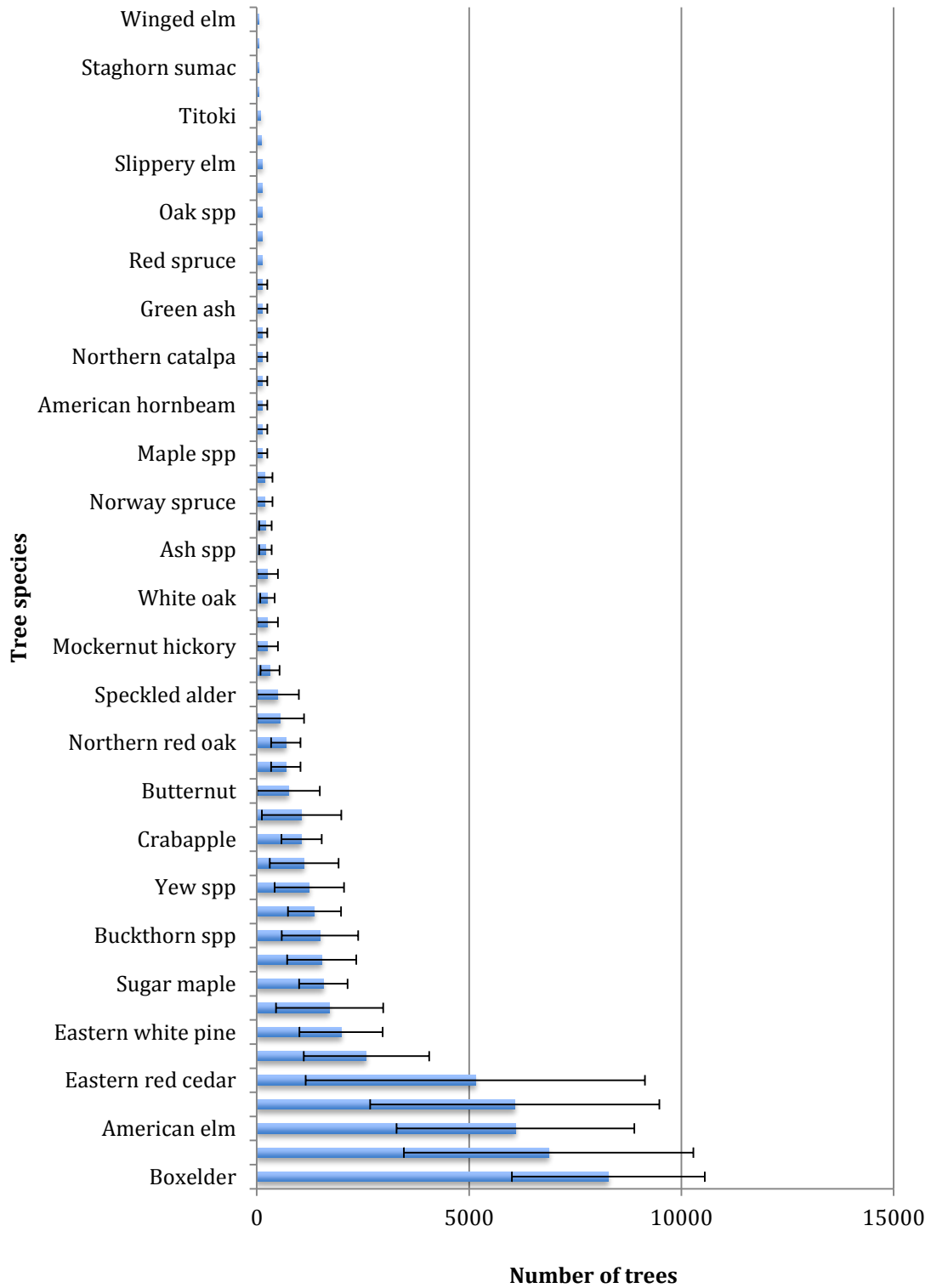


Figure 2: Estimated number of trees ( $\pm$  standard error) per species for the city of Winooski based on 63 sample plots. SE bars a large in magnitude due to low number of sample plots.

# Tree Health

Overall, about 77% of Winooski’s trees are classified as being in excellent or good health (Figure 3). Higher levels of poor tree health are found in the commercial-industrial land use group (Figure 4). While over a third of trees in residential areas are found to be in excellent health, very few trees on public or commercial-industrial lands are. This indicates that different land uses in the city support trees differently. This can be expected due to differing management priorities and provides the City with information regarding areas for targeted improvements.

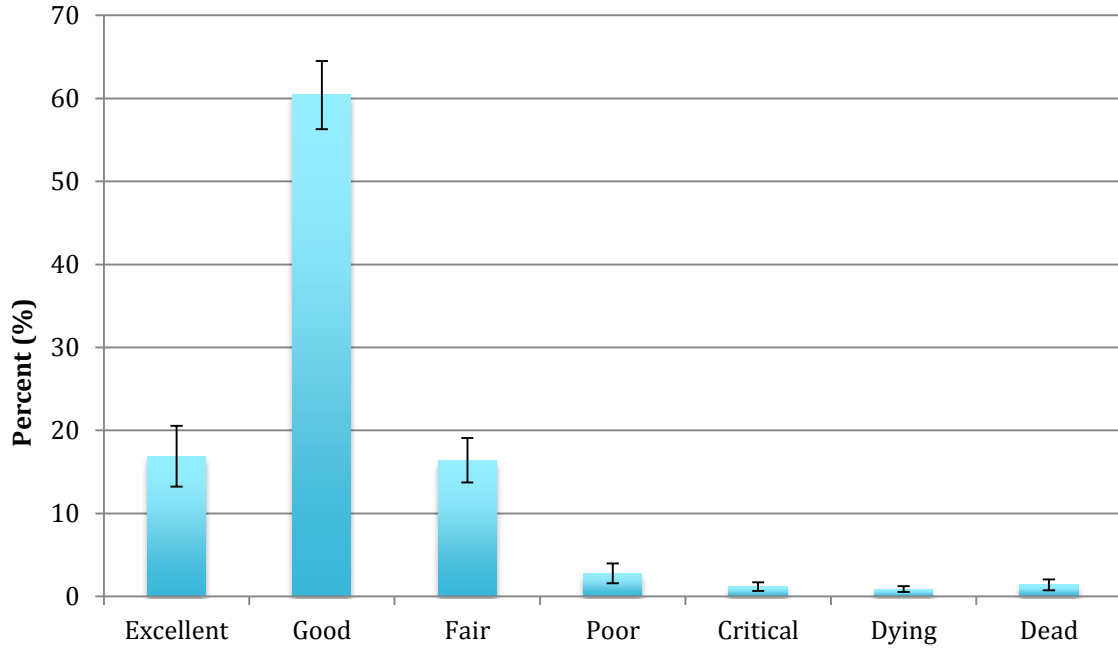


Figure 3. Percent of trees by assessed crown condition city wide.

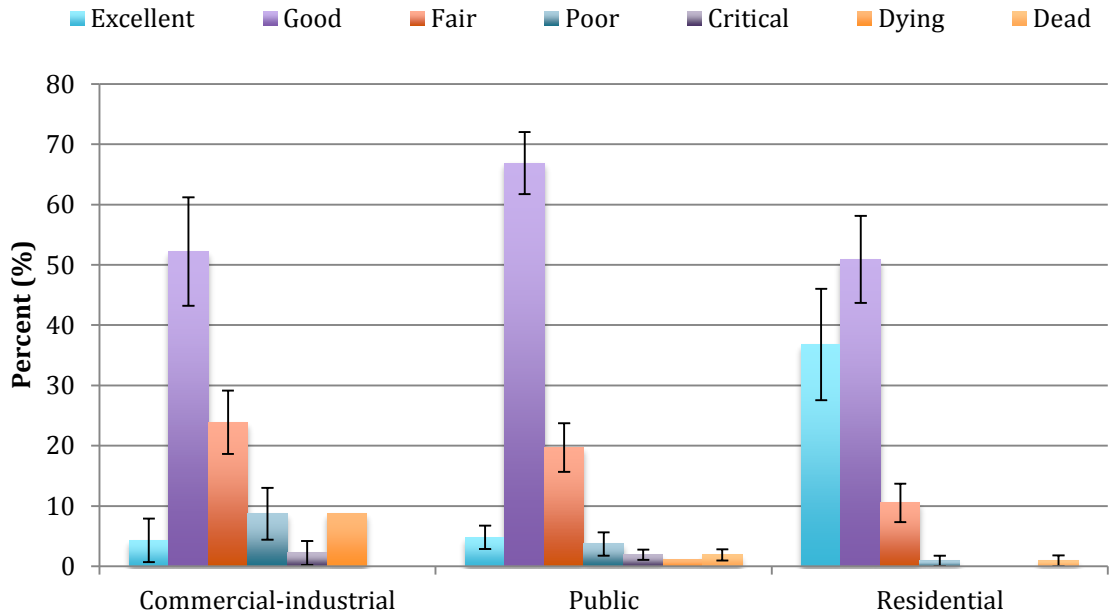
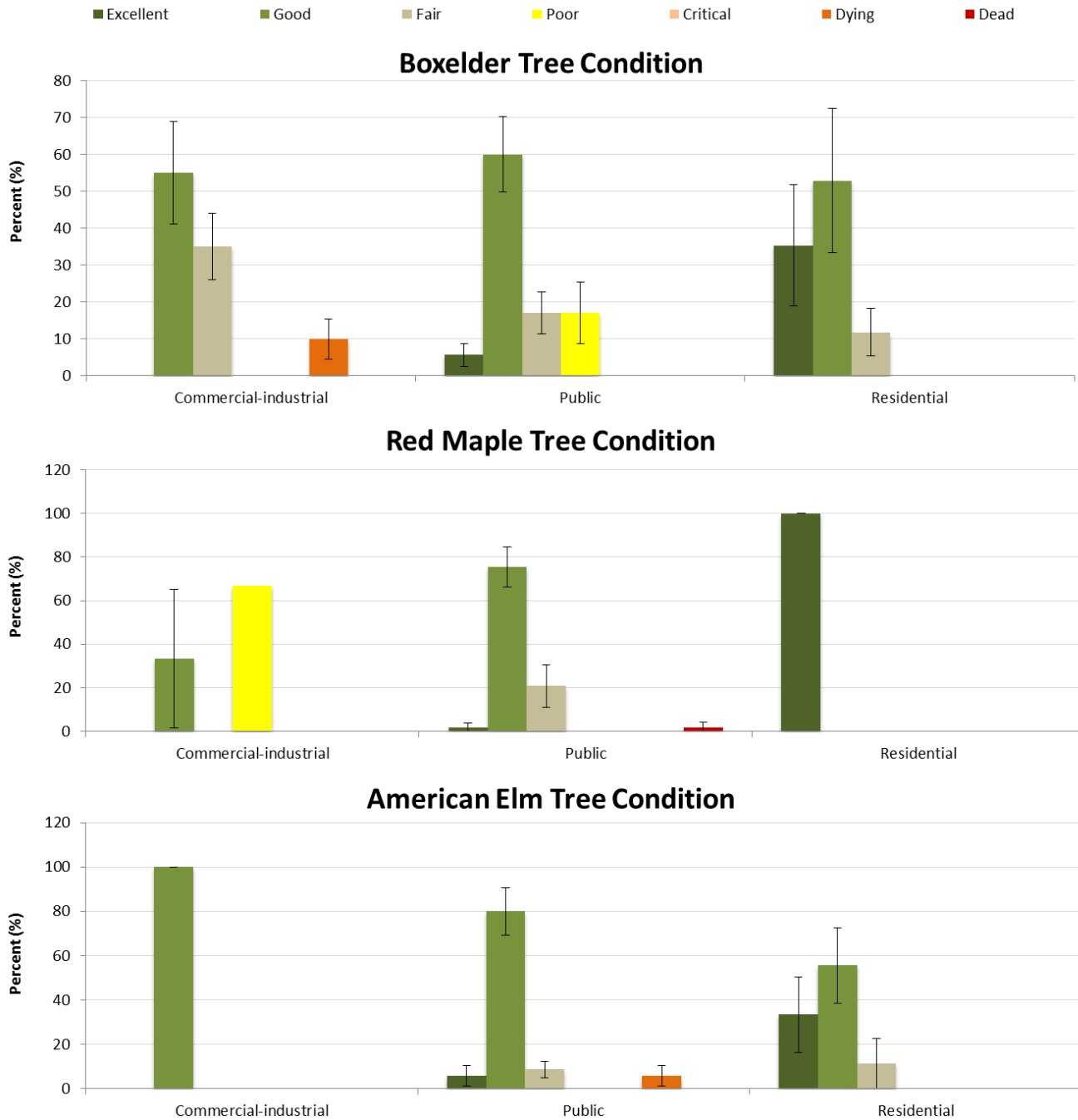


Figure 4. Percent of trees assessed by crown condition and land use type

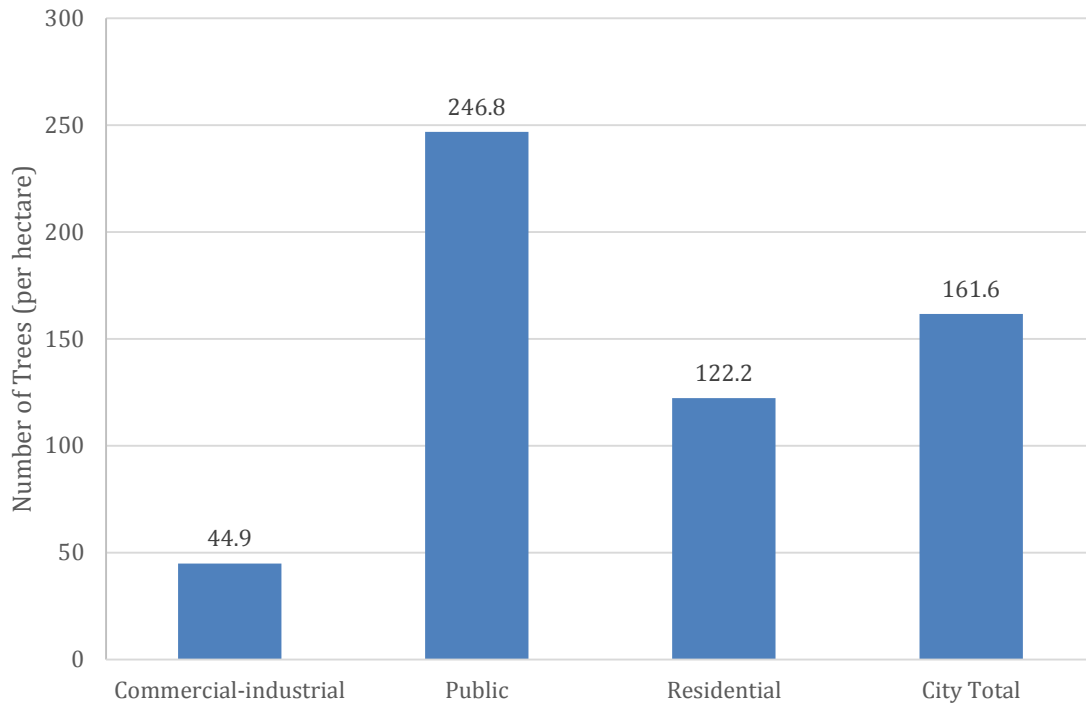
Taking a closer look at the top three species in terms of leaf area, and percent of population, there are marked differences between how each species fares by land use. Boxelder does best in residential land and worst in public areas, though a number of trees with substantial decline are found in commercial areas. Red maple, a late-successional species in the northeast, was found to do very well in residential and public land uses, while a number of red maples in poor health were observed in commercial-industrial uses. Surprisingly, the condition of American elm trees surveyed shows that most are in good condition across all land uses, with the exception of some severely declining specimens in public land use (Figure 5).



**Figure 5: Tree condition for the top three most prevalent species in Winooski, Boxelder (top), Red maple (middle) and American elm (bottom).**

## Tree Density

Trees cover approximately 35.8% of the city of Winooski. The overall tree density in Winooski is 161.6 trees/hectare. The highest tree densities in Winooski occur in public areas (246.8 trees/ha) followed by residential (122.2 trees/ha) and commercial-industrial (44.9 trees/ha) (Figure 6). Public areas include the Gilbrook and Casavant Natural areas, which are likely elevating the overall representation of density in that land use category.



**Figure 6: Estimated tree density (number of trees per hectare) by land use classification and averaged for the city.**

## Leaf Cover

Many benefits provided by trees correspond directly to the amount of healthy leaf surface area. Currently, in Winooski, the most dominant species in terms of leaf area are Boxelder, Red maple and American elm (Figure 7). 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.

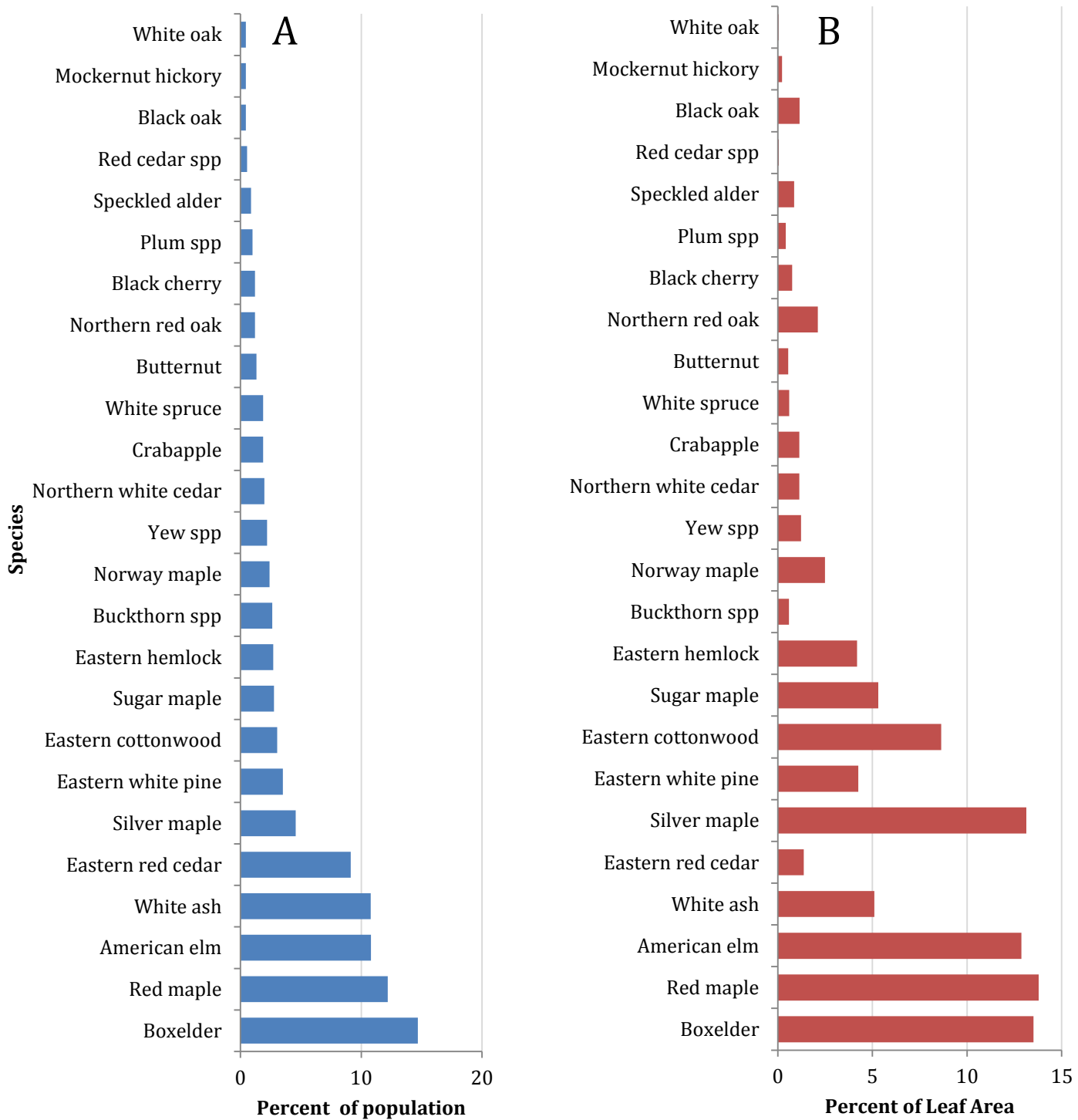


Figure 7: Estimated percent of the (A) total tree population and (B) total leaf area of the tree and shrub species in Winooski.



## Avoided Stormwater Runoff

Surface runoff is a cause for concern in many urban areas due to its ability to transport pollutants, sediment and elevated flow volumes to streams, wetlands, rivers, and lakes. During precipitation events, a 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 increases the amount of surface runoff due to lack of infiltration and water storage opportunities. 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 in Winooski help to reduce runoff by an estimated 7,689,974 gallons a year (1,028,000 ft<sup>3</sup>/yr), with an associated value of \$68,409 per year (Figure 8). This monetary value represents the cost to treat this additional runoff in the absence of these trees. By land use type, this equates to \$1,719 (19,3184 gallons) for commercial-industrial land, \$41,367 (4,648,024 gallons) for public land, and \$25,322 (2,845,179 gallons) for residential land. The tree species that currently provide the most stormwater infiltration benefit (per tree) for Winooski are depicted in Figure 9.

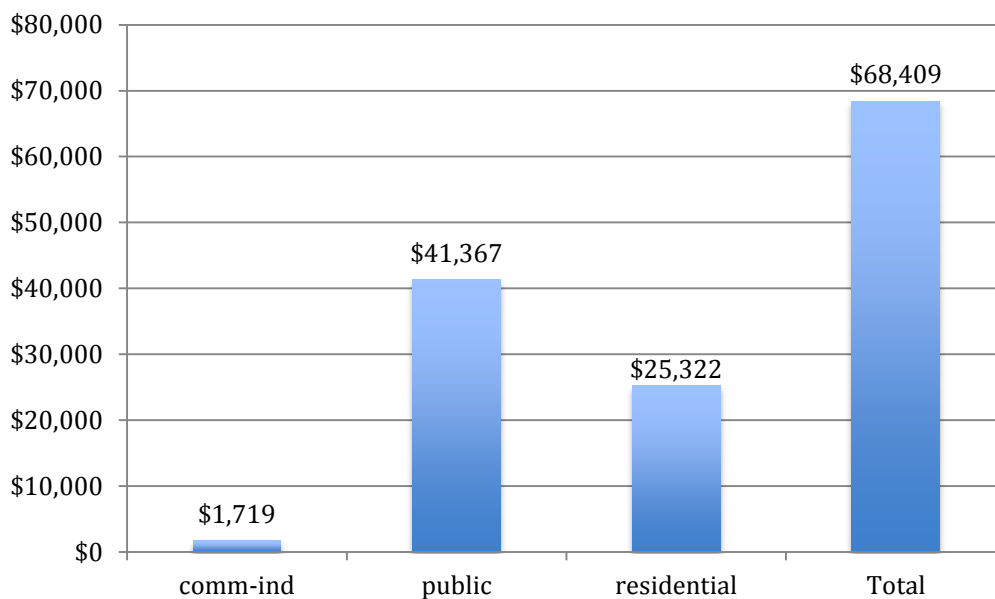


Figure 8: Estimated value provided by trees to treat stormwater runoff in the City.

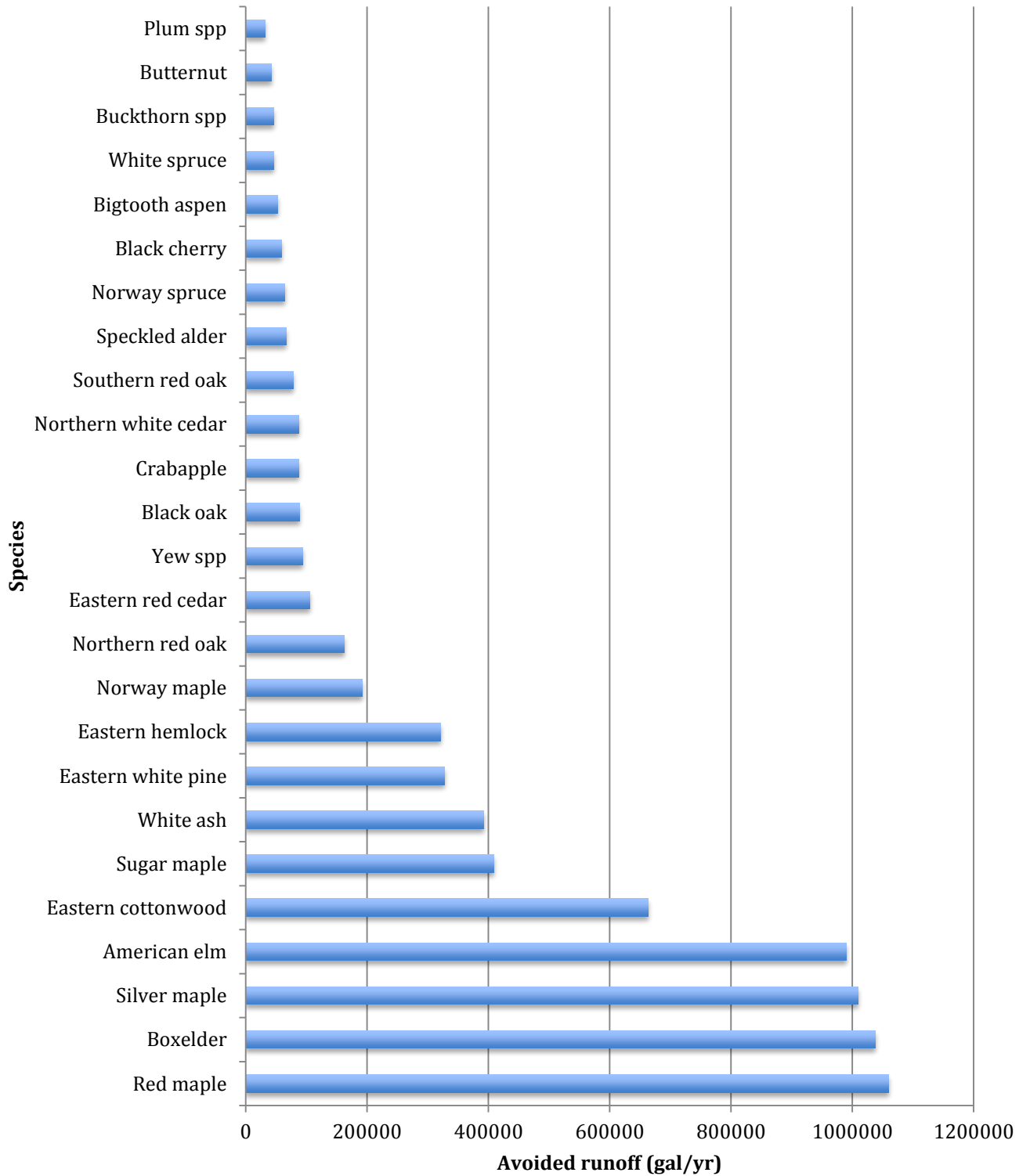
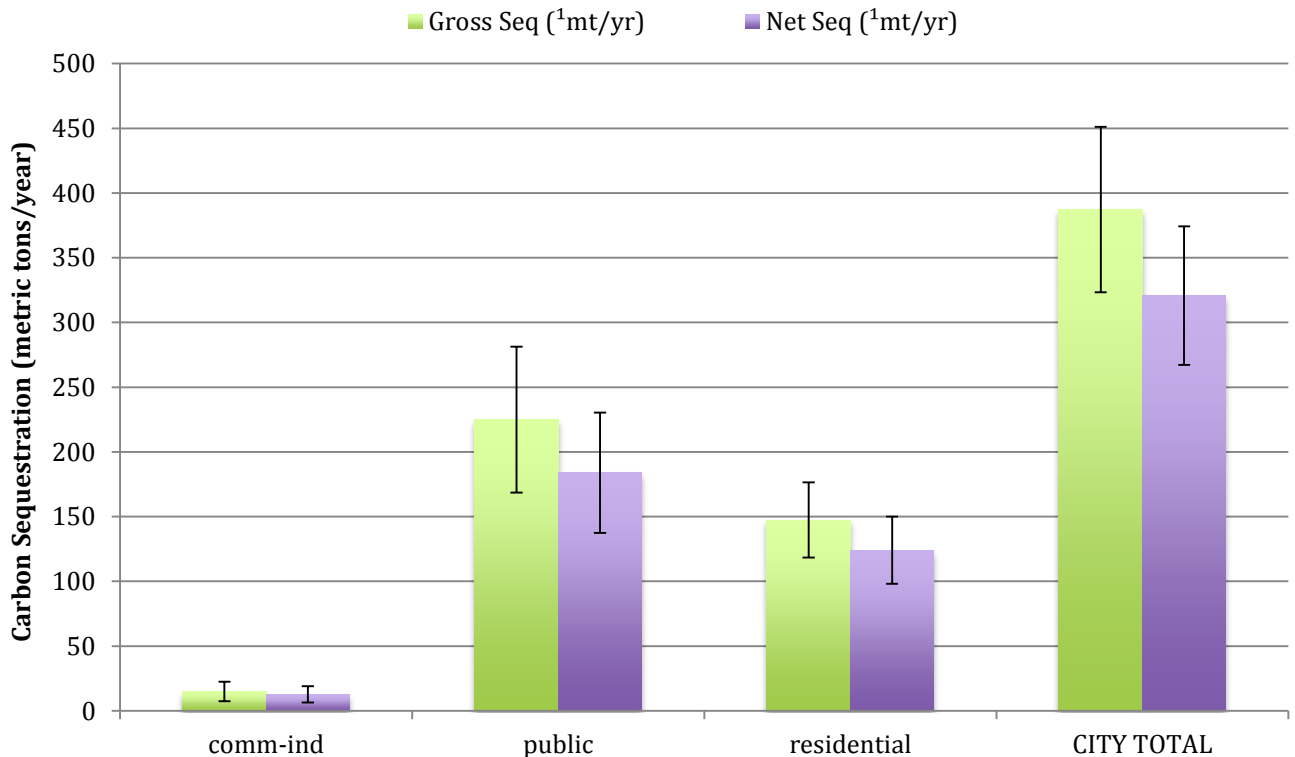


Figure 9: Estimated runoff avoided per species for in gallons per year (showing the 25 species intercepting the most runoff).

## 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 \$78.50/metric ton) and with an updated value in 2015 US dollars (valued at \$156.60/metric ton C).

The gross sequestration of Winooski trees is about 387 metric tons of carbon per year with an associated value of \$30,400/year (using default value) or \$60,600/year (using current costs of carbon). Net carbon sequestration is slightly lower, about 320 metric tons, which accounts for estimated mortality and decline of trees (Figure 10).



**Figure 10: Estimated gross carbon sequestration and net carbon sequestration per land use type and for the entire city, in metric tons per year.**

Trees in Winooski are estimated to store 11,700 metric tons of carbon, estimated to be worth \$919,000 (default carbon valuation) to \$1,832,000 (updated valuation). Of the trees sampled, Boxelder, Red maple and Silver maple currently store the most carbon in Winooski, likely due to the fact that these are often large trees (Figure 11). 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 11: Estimated average (A) gross carbon sequestration (metric tons per year) and (B) carbon storage (metric tons) per species in Winooski. Showing only the 25 species currently storing the most carbon.

## 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 the power plants.

Pollution removal by trees and shrubs in Winooski was estimated using field data and recent available pollution and weather data. Pollution removal performance by trees was greatest for ozone (O<sub>3</sub>). It is estimated that trees and shrubs remove 12 metric tons of air pollution (ozone (O<sub>3</sub>), carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>), particulate matter less than 10 microns and greater than 2.5 microns (PM<sub>10</sub>), particulate matter less than 2.5 microns (PM<sub>2.5</sub>), and sulfur dioxide (SO<sub>2</sub>)) per year with an associated value of \$394,000 (Figure 12). Reductions in levels of PM<sub>10</sub> and PM<sub>2.5</sub> in the urban environment are particularly important, as both can cause serious respiratory illnesses, especially in elderly and young people.

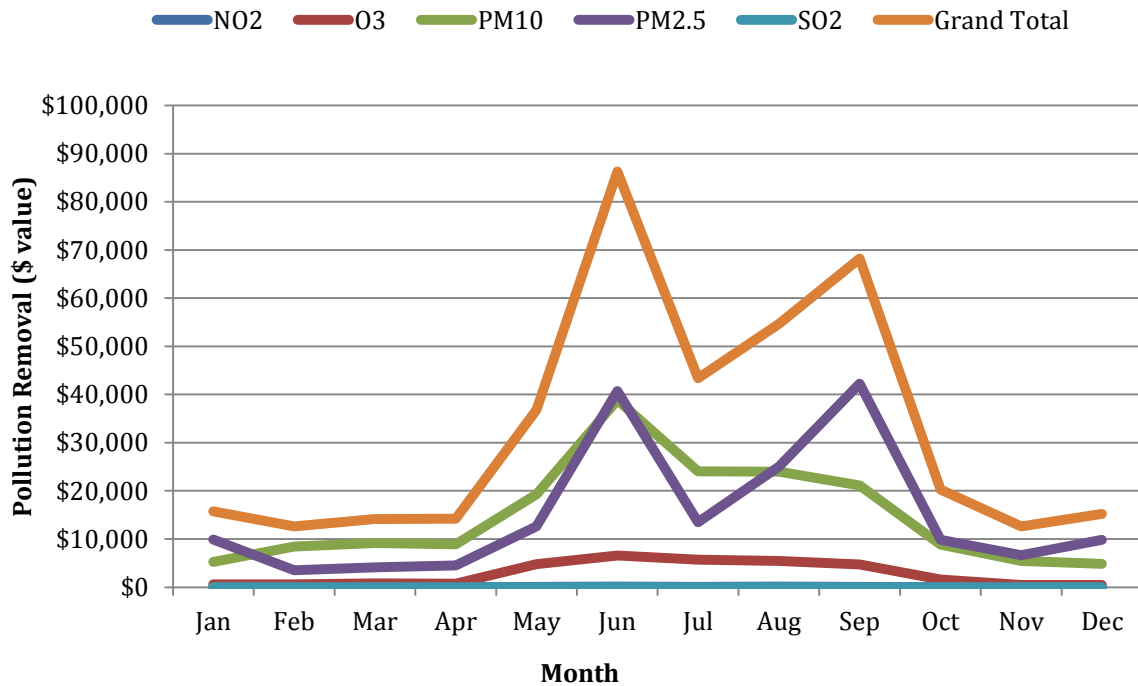


Figure 12: Value of monthly pollution removal estimates by woody vegetation in the city of Winooski for: ozone (O<sub>3</sub>), carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>), particulate matter less than 10 microns and greater than 2.5 microns (PM<sub>10</sub>), particulate matter less than 2.5 microns (PM<sub>2.5</sub>), and sulfur dioxide (SO<sub>2</sub>).

## 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 (in terms of tree replacement) of Winooski's urban forests is estimated to be \$61,100,000. Because the trees provide an estimated \$919,000-1,832,200 in carbon storage, the structural value can be reflected as: \$62,019,000-62,932,200.

Functionally, each year Winooski's trees provide \$394,000 in pollution removal, \$30,400/yr to \$60,600/yr in carbon sequestration and \$68,409 in avoided runoff costs, providing between \$492,800-\$523,000 in annual functional values for the City.

## 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 107 days
  - Annual emissions from 7,750 automobiles
  - Annual emissions from 3,890 single-family houses
- Annual carbon sequestration is equivalent to:
  - Amount of carbon emitted in Winooski in 3.5 days
  - Annual emissions from 300 automobiles
  - Annual emissions from 100 single-family houses
- Carbon monoxide removal is equivalent to:
  - Annual emissions from 1 automobile
  - Annual emissions from 3 single-family houses
- Nitrogen dioxide removal is equivalent to:
  - Annual emissions from 85 automobiles
  - Annual emissions from 57 single-family houses
- Sulfur dioxide removal is equivalent to:
  - Annual emissions from 267 automobiles
  - Annual emissions from 4 single-family houses
- Particulate matter less than 10 micron (PM<sub>10</sub>) removal is equivalent to:
  - Annual emissions from 13,000 automobiles
  - Annual emissions from 1,250 single-family houses

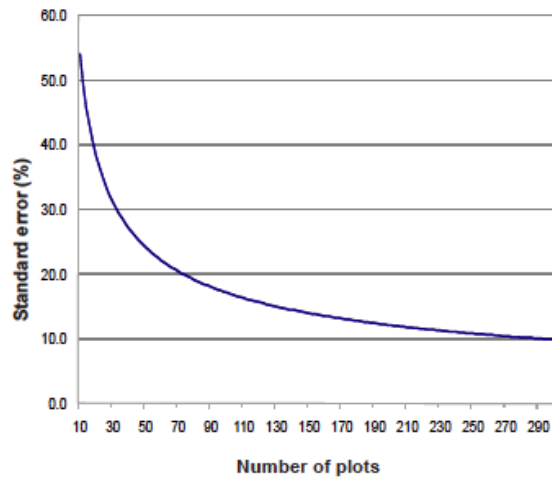
## Uncertainty in Results

Sixty-three plots were surveyed for this study. i-Tree Eco recommends at least 200 plots for a robust sample, therefore results should be interpreted with caution. However, it is worth noting that since Winooski is approximately one square mile in size; it is much smaller than the cities targeted for this recommendation. The recommendation for a 200-plot sample size remains the same for a city the size of Chicago or Atlanta as it does for Winooski. Since i-Tree Eco utilizes the sample plot inputs to extrapolate to city as a whole, estimates carry uncertainty. Figure 12 depicts the 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 63, the standard error of the mean is about 20%. Increasing the number of plots to 100 would reduce that value to ~15%. Equal stratification of plots within land use type helps reduce uncertainty. In total, 21 plots were measured in the commercial-industrial land-use category, 22 plots in public and 20 plots in residential, providing an equal distribution.

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 or in species identification) 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 can provide some meaningful opportunities to enhance and support future tree management decisions.

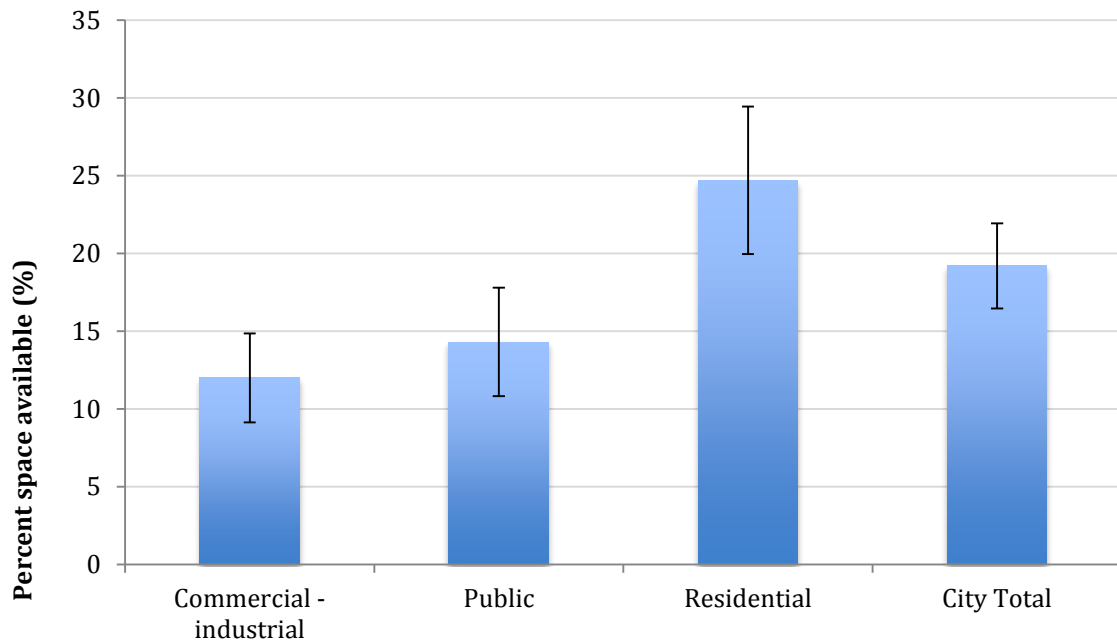


**Figure 12: Relationship between the number of sampled plots and the associated percent standard error. From i-Tree Eco Users Manual.**

## Conclusions

Based on these results, it is clear that the City of Winooski could increase the size of 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 \$62,511,800-63,455,200 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. However, in this land use type, it has the lowest available planting space of the three land use types (Figure 13) because impervious surfaces cover an estimated 74% of the land (Figure 14).



**Figure 13: Estimated percent of space available for planting within each land use classification type and for the city as a whole.**



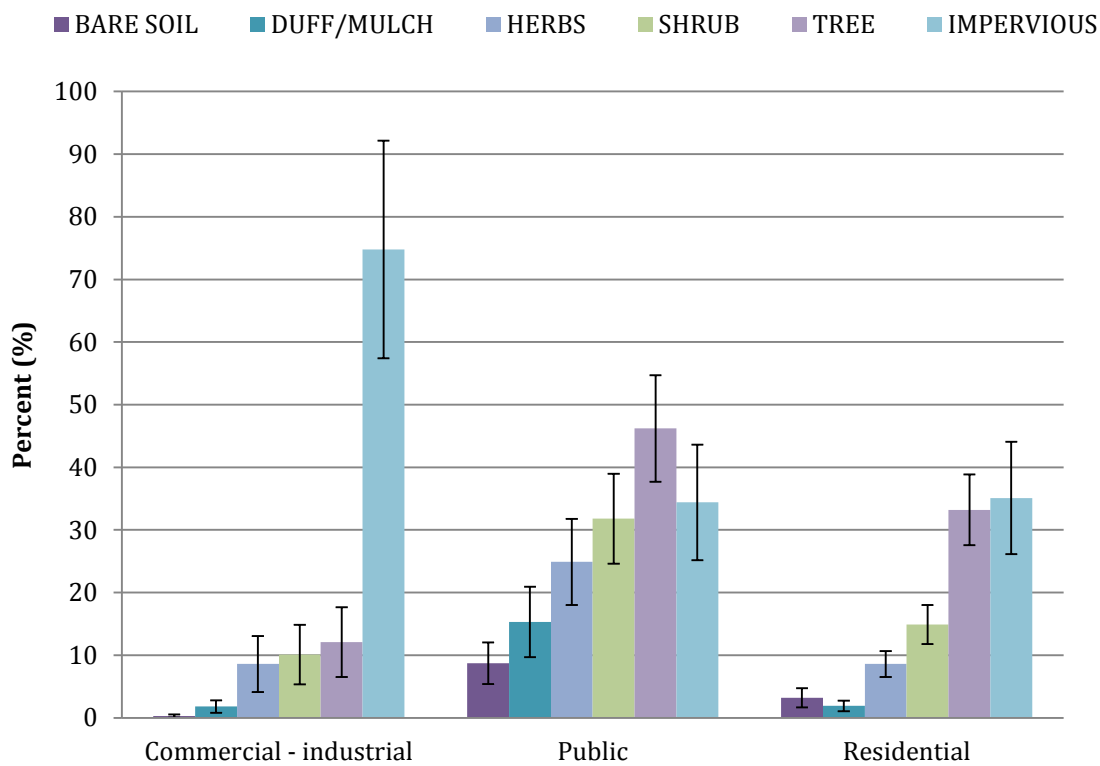


Figure 14: Estimated percent of each type of groundcover per land use classification type. Rock, cement, tar and buildings were grouped into “impervious surfaces”.