

# URBAN FORESTS OF WISCONSIN, 2012

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Wisconsin Department of Natural Resources  
Forestry Division  
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## ABSTRACT

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Trees in cities can contribute significantly to human health and environmental quality. In 2002, there were an estimated 26.9 million trees (36.9 trees / acre) within non-forested urban areas in Wisconsin. In 2012, the non-forest urban areas were reassessed based on 185 field plots. Urban forest attributes changed between 2002 and 2012 due, in part, to the expansion of urban areas, but also tree planting and natural regeneration, tree growth and tree mortality. Based on the 2012 data, urban forest structure, functions, health, and values in non-forest urban areas in Wisconsin (i.e., hereafter referred to as urban forests) were analyzed using the i-Tree Eco model. In addition, changes in tree populations greater than 5 inches d.b.h. were assessed (2002-2012). Results reveal that urban forests in 2012 have an estimated 42.8 million trees (45.9 trees / acre). Trees are considered as any woody plant with a d.b.h.  $\geq 1$  inch. Most trees are found in residential areas (69.2 percent). The most common species are common lilac (*Syringa vulgaris*), Northern white cedar (*Thuja occidentalis*), and apple species (*Malus spp.*). Wisconsin's urban forest currently stores about 4.0 million tons of carbon valued at \$507 million. In addition, these trees remove about 212 thousand tons of carbon per year (\$26.8 million per year) and about 7,030 tons of air pollution per year (\$47.7 million per year). Trees in non-forest urban Wisconsin are estimated to decrease annual residential energy costs by \$78.9 million per year. The compensatory value is estimated at \$19.3 billion. In Wisconsin, 64 percent of the trees were within maintained areas with residential land uses containing the highest proportion of maintained trees. Overall, 1.1 percent of trees were recorded as standing dead. Between 2002 and 2012, one species that had a statistically significant increase in trees greater than 5 inches was silver maple (*Acer saccharinum*). Species with statistically significant decreases were white ash (*Fraxinus americana*) and sugar maple (*Acer saccharum*). Strengths and weaknesses of the national urban forest inventory and analysis protocol were identified and recommendations for intensification are made. Information in this report can be used to advance the understanding and management of urban forests to improve human health and environmental quality in Wisconsin.

**Keywords:** Air pollution removal, carbon sequestration, ecosystem services, FIA, i-Tree, tree value, urban forestry.



## HIGHLIGHTS

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### Value

- Urban vegetation, particularly trees, provides numerous benefits that can improve environmental quality and human health in and around urban areas.
- The structural value of Wisconsin's urban forests is valued at about \$19.8 billion, including \$507 million in carbon storage value.
- Urban forests in Wisconsin currently provide annual functional values greater than \$150 million: \$26.8 million in carbon sequestration, \$47.7 million in pollution removal and \$78.9 million in reduced building energy use.

### Area

- There were a total of 933,000 acres of urban forests in Wisconsin.
- The land use that covered the largest area within the urban boundary of Wisconsin was residential at 432,000 acres.

### Trees

- An estimated 42.8 million trees were found in urban areas of Wisconsin with 69.2 percent of them located on residential areas.
- A total of 65 species were encountered within urban areas of Wisconsin.
- The most common species in Wisconsin urban areas were common lilac (11.4 percent of the population), Northern white cedar (10.7 percent), and apple species (7.6 percent).
- Of the 42.8 million trees found in Wisconsin urban areas, 67.6 percent were < 6 inches d.b.h. One hundred percent of common lilac, winged burning bush, American plum, and common chokecherry were < 3 inches d.b.h.

### Urban Forest Health

- In Wisconsin, American elm was the tree species with the highest average percent crown dieback.
- The most common damages on trees were tree bark inclusion.
- Potential risks of exotic pests include gypsy moth, emerald ash borer and pine shoot beetle, which can all be found in Wisconsin. Asian longhorned beetle poses a threat to more than a quarter of the tree population.

### Protocol Evaluation

- A ten-year interval between data set samples created significant limitations on trend analysis.
- Traditional FIA sample density of one plot per 6,000 acres is insufficient to capture the high species diversity and low tree stem count in urban forests.

## EXECUTIVE SUMMARY

Data from 185 field plots located within non-forest urban areas (U.S. Department of Commerce 2000 definition) of Wisconsin were measured in 2012. Land classified as forest based on the Forest Service Forest Inventory and Analysis (FIA) were excluded from the sample. Thus, this assessment analyzes non-forest urban areas in Wisconsin, hereafter referred to as “urban forests”. Trees within the urban boundary were sampled according to the U.S. Department of Agriculture (USDA) Forest Service, FIA and Forest Health Monitoring programs’ protocols. Data were analyzed using the Forest Service’s i-Tree Eco model to quantify and describe the benefits of Wisconsin’s urban forest. The data from this project updated values from a 2002 urban forest assessment in Wisconsin on ecosystem services and values provided by urban forests, and analyze change for species greater than 5 inches in diameter. This project also evaluated the sampling protocols’ value as a component of Wisconsin’s developing statewide continuous urban forest assessment program.

In Wisconsin’s urban forest there are an estimated 42.8 million trees with 29.6 million in residential areas (69.2 percent of trees), 6.4 million within institutional / park areas (15.0 percent), 5.3 million on commercial / transportation lands (12.4 percent), 650,000 in wooded areas (1.5 percent), 560,000 on agricultural and other lands (1.3 percent) and 225,000 on wetland areas (0.5 percent) (Table 1). The most common species were common lilac (11.4 percent of the population), Northern white cedar (10.7 percent), apple species (7.6 percent), European buckthorn (5.9 percent) and Eastern red cedar (5.6 percent). Species that dominated in terms of leaf area were silver maple (10.6 percent), Norway maple (8.4 percent), Northern red oak (5.9 percent), green ash (5.4 percent) and Eastern red cedar (4.9 percent).

**Table 1—Summary of urban forest populations estimates**

| Land use                        | Area    | Trees      | Three most common species |      |                      |      |                    |      |
|---------------------------------|---------|------------|---------------------------|------|----------------------|------|--------------------|------|
|                                 |         |            | 1                         | 2    |                      | 3    |                    |      |
|                                 | acres   | number     |                           | %    |                      | %    |                    | %    |
| Residential                     | 431,600 | 29,610,000 | Common lilac              | 16.4 | Apple                | 10.7 | European buckthorn | 8.2  |
| Institutional/Park              | 137,200 | 6,435,000  | Winged burning bush       | 34.5 | Scotch pine          | 11.1 | Silver maple       | 9.9  |
| Commercial/trans.               | 169,800 | 5,314,000  | Northern white cedar      | 62.5 | Eastern red cedar    | 14.6 | Siberian elm       | 10.4 |
| Partially Forested <sup>a</sup> | 73,900  | 648,700    | Green ash                 | 19.0 | Apple                | 14.3 | Black locust       | 14.3 |
| Agriculture / other             | 88,300  | 559,400    | Norway maple              | 25.0 | Green ash            | 18.7 | White ash          | 18.7 |
| Wetland                         | 32,200  | 225,800    | Green ash                 | 71.4 | Alder                | 28.6 |                    |      |
| Total urban                     | 932,900 | 42,800,000 | Common lilac              | 11.4 | Northern white cedar | 10.7 | Apple              | 7.6  |

1,2,3 = first-, second-, and third-most common tree within each land use or total urban area, respectively.

<sup>a</sup> plots with a portion of its area meeting the FIA definition of forest

Forest health data collected on crown conditions and occurrence of damage indicates that the urban forests of Wisconsin are healthy and vigorous with 1.1 percent of trees classified as dead. However, risks to the urban forest exist. The greatest potential risks from insect and diseases in

Wisconsin are from gypsy moth (5.8 million trees at risk; 13.6 percent of live tree population), emerald ash borer (3.2 million trees; 7.6 percent) and pine shoot beetle (2.7 million trees; 6.4 percent). The greatest risk from insects and diseases outside of Wisconsin come from Asian longhorned beetle (11.0 million trees; 26.0 percent), southern pine beetle (3.7 million trees; 8.7 percent), and sirex wood wasp (2.5 million trees; 5.9 percent).

The 42.8 million urban trees in Wisconsin have a compensatory value of \$19.3 billion, provide an annual energy saving to residents of \$78.9 million, remove \$47.7 million worth of pollution from the air annually, and store 4.0 million tons of carbon valued at \$507 million.

## INTRODUCTION

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Urban vegetation, particularly trees, provides numerous benefits that can improve environmental quality and human health in and around urban areas. Urban trees in particular make significant contributions to improve air and water quality, reduce energy used for heating and cooling buildings, cool air temperatures, reduce ultraviolet radiation, and many other environmental and social benefits (Nowak and Dwyer 2007). Structural data about these trees and forests (e.g., number of trees, species composition, tree size, health, and tree location) provide the basis to estimate numerous ecosystem services and values derived from these natural resources, and establish the foundation to improve management to enhance these services for future generations.

Urban forests are comprised of all trees (both within and outside forested stands) that occur within the U.S. Census Bureau definition of urban areas. Urban areas are defined as all territory, population, and housing units located within urbanized areas or urban clusters, which are based on population density (areas with core population density of 1,000 people per square mile), but includes surrounding areas with lesser population density (see U.S. Department of Commerce 2007 for definitions).

Urban forests provide a multitude of benefits to society, such as recreational opportunities, aesthetics, and cleaner air and water. Millions of dollars are spent annually to maintain them, yet relatively little is known about this important resource. Management of any natural resource requires knowledge of type, size, and quantity of the resource. Inventories and assessments to monitor composition, size, and health provide information about the current status of urban forests, and, if compiled periodically, information about how the forest changes over time.

In 2002, an assessment of Wisconsin's urban forest was conducted and found a total of 130.6 million trees—103.7 million in forests within urban areas and 26.9 million in non-forest urban areas (Cumming et al. 2007). In 2012, the urban forest was reassessed, but the study boundary was modified. The area changed as 1) urban area increased between 2002 and 2012, thus more urban land was included and 2) the 2012 study focused only on the urban plots that did not meet the traditional FIA definition of “forest.” In the 2002 study, these urban forest plots were segregated out and referred to as “UFIA<sup>+</sup>” to allow urban foresters to distinguish between “natural forest” land, referred to in the report as “UFIA<sub>f</sub>”, which they typically are not responsible for managing (i.e. urban woodlots) and the “urban forest” land which they traditionally do manage (i.e. street, park and yard trees).

This report details information on a) the extent and distribution of the urban forest, b) the characteristics of the urban tree population, c) the health of the urban trees, d) ecosystem services and values provided by the urban trees, e) change in tree populations for trees greater than 5 inches in diameter and f) an evaluation of the USDA Forest Service's Urban Forest Inventory and Analysis methodology for Wisconsin's statewide urban forest assessment program. Methods used in gathering these data are given in Appendix A.

## RESULTS

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### Extent and Land Use Distribution of Wisconsin's Urban Forest

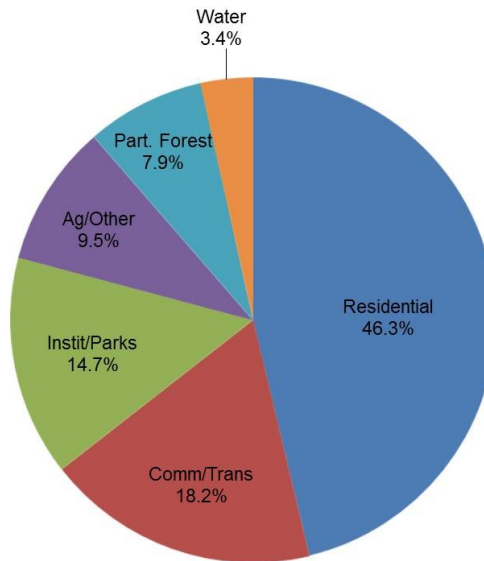
The 2000 census-defined urban land area used in this study is about 3.0 percent of the total land area of Wisconsin. This is an increase from 2.4 percent in 1990. Wisconsin ranked 26<sup>th</sup> in the coterminous United States for amount of urban land in 2000 and 26<sup>th</sup> in percent urban growth between 1990 and 2000 (Nowak et al. 2005). Forecasts predict urban land in the State will grow from 3.0 percent in 2000 to 8.3 percent of the land area by 2050, holding Wisconsin at 25<sup>th</sup> in the State ranking of percent urban land (Nowak and Walton 2005). Urban land area is, of course, influenced by the human population. State population was 4.89 million in 1990 and increased to 5.36 million in 2000 and 5.69 million in 2010 (U.S. Department of Commerce 1999; U.S. Department of Commerce 2000; U.S. Department of Commerce 2010). Wisconsin's population is projected to continue to increase between 2000 and 2030 by 14.7 percent or 0.79 million people to 6.15 million in 2030 (U.S. Department of Commerce 2013).

There were a total of 933 thousand acres of urban areas assessed in the 2012 study (Table 2). This land was selected for sampling based on the 2000 Census Urban Areas with sampling limited to only plots that were not fully forested as defined by FIA. Urban areas were classified by their principal land use in the field. The land uses designated for this study were residential, commercial/transportation, institutional/parks, agriculture/other, partially forested (i.e., plots with a portion of its area meeting the FIA definition of forest), and wetland. The distribution of urban land uses are residential (46.3 percent), followed by commercial/transportation (18.2 percent), institution/parks (14.7 percent), agriculture/other (9.5 percent), partially forested (7.9 percent), and wetland (3.4 percent) (Figure 1).

**Table 2—Area of land within urban areas by land use, Wisconsin, 2012**

| <b>Land use*</b>          | <b>Area</b>  |
|---------------------------|--------------|
|                           | <i>acres</i> |
| Residential               | 432,000      |
| Commercial/transportation | 170,000      |
| Institutional/parks       | 137,000      |
| Agriculture/other         | 88,000       |
| Partially forested        | 74,000       |
| Wetland                   | 32,000       |
| Total Urban               | 933,000      |

\*see Glossary for definitions



**Figure 1—Land distribution based on urban plots, Wisconsin, 2012.**

There are an estimated 42.8 million trees in Wisconsin's urban areas. Of these urban trees, about 29.6 million (69.2 percent) are found in the residential land use. There were a total of 597 live trees sampled. The average diameter at breast height (d.b.h.) was 5.4 inches, with a median d.b.h. of 2.9 inches. The average basal area (stem cross sectional area of a tree at 4.5 feet) was 16.4 square feet per acre. The average number of trees per acre in Wisconsin urban areas is 45.9 (Table 3). Tree density was highest on residential land (68.6 trees per acre), followed by institutional/parks (46.9 trees per acre), commercial/transportation (31.3 trees per acre), partially forested (8.8 trees per acre), wetland (7.0 trees per acre) and agriculture/other (6.3 trees per acre) (Figure 2). The average tree d.b.h. by land use was 10.4 inches on wetlands, 9.6 inches on partially forested, 7.9 inches on agriculture/other, 6.1 inches on institutions/parks, 5.6 inches on residential and 2.8 inches on commercial/transportation. Average basal area per acre by land use was 26.2 square feet per acre on residential, 18.8 square feet per acre on institutional/parks, 6.3 square feet per acre on partially forested, 5.3 square feet per acre on wetland, 3.4 square feet per acre on commercial/transportation and 2.6 square feet per acre on agriculture/other land.

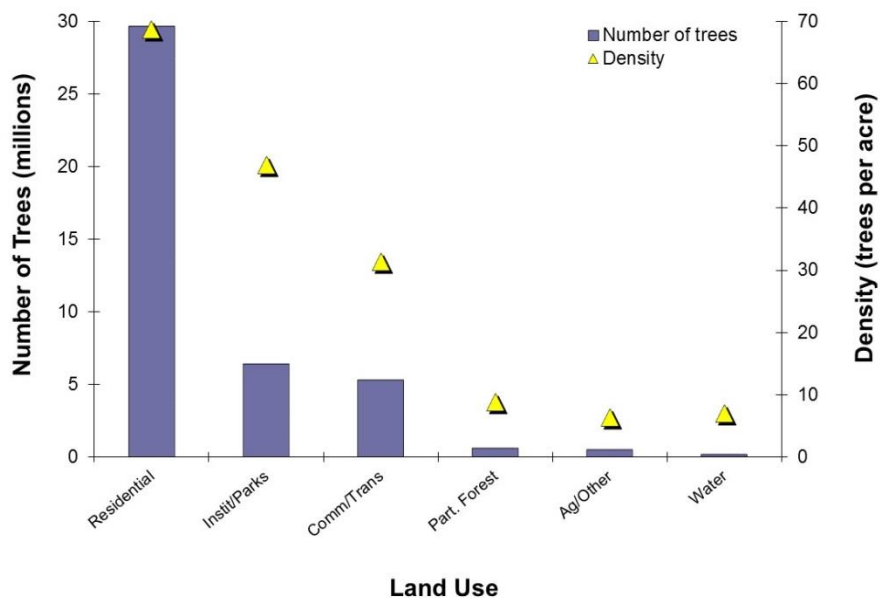
**Table 3—Forest and tree characteristics by land use type, Wisconsin, 2012**

| Land use                        | Urban land<br>percent | Trees    |            |                     | D.b.h. |        |
|---------------------------------|-----------------------|----------|------------|---------------------|--------|--------|
|                                 |                       | Number   | Density    | Basal area          | Avg    | Median |
|                                 |                       | millions | trees/acre | ft <sup>2</sup> /ac | inches |        |
| Residential                     | 46.3                  | 29.6     | 68.6       | 26.2                | 5.6    | 3.1    |
| Commercial/transportation       | 18.2                  | 5.3      | 31.3       | 3.4                 | 2.8    | 1.6    |
| Institutions/parks              | 14.7                  | 6.4      | 46.9       | 18.8                | 6.1    | 4.6    |
| Agriculture/other               | 9.5                   | 0.56     | 6.3        | 2.6                 | 7.9    | 7.7    |
| Partially forested <sup>a</sup> | 7.9                   | 0.65     | 8.8        | 6.3                 | 9.6    | 7.9    |
| Wetland                         | 3.4                   | 0.23     | 7.0        | 5.3                 | 10.4   | 10.5   |
| Total urban                     | 100.0                 | 42.8     | 45.9       | 16.4                | 5.4    | 2.9    |

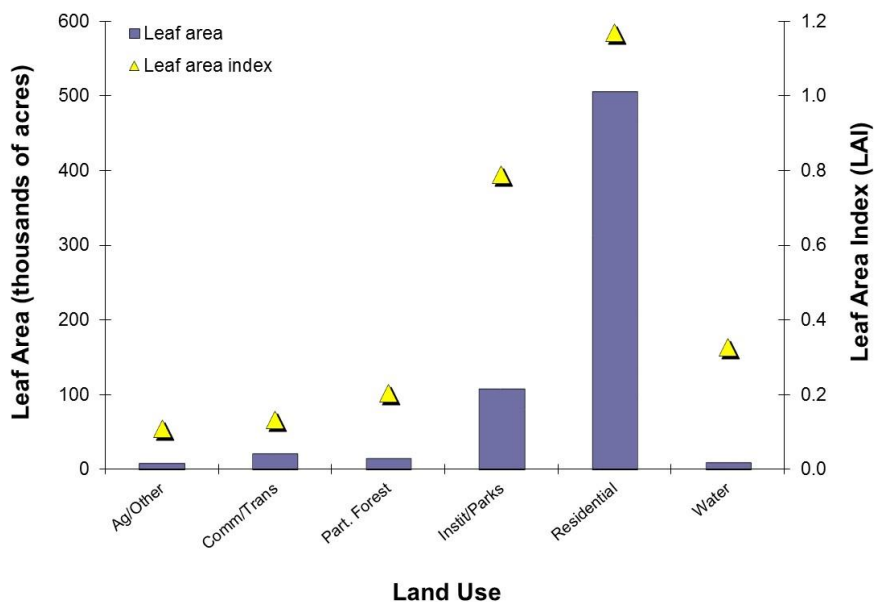
D.b.h. = Diameter at breast height

<sup>a</sup> plots with a portion of its area meeting the FIA definition of forest





**Figure 2—Tree population and density by land use type, Wisconsin, 2012.**



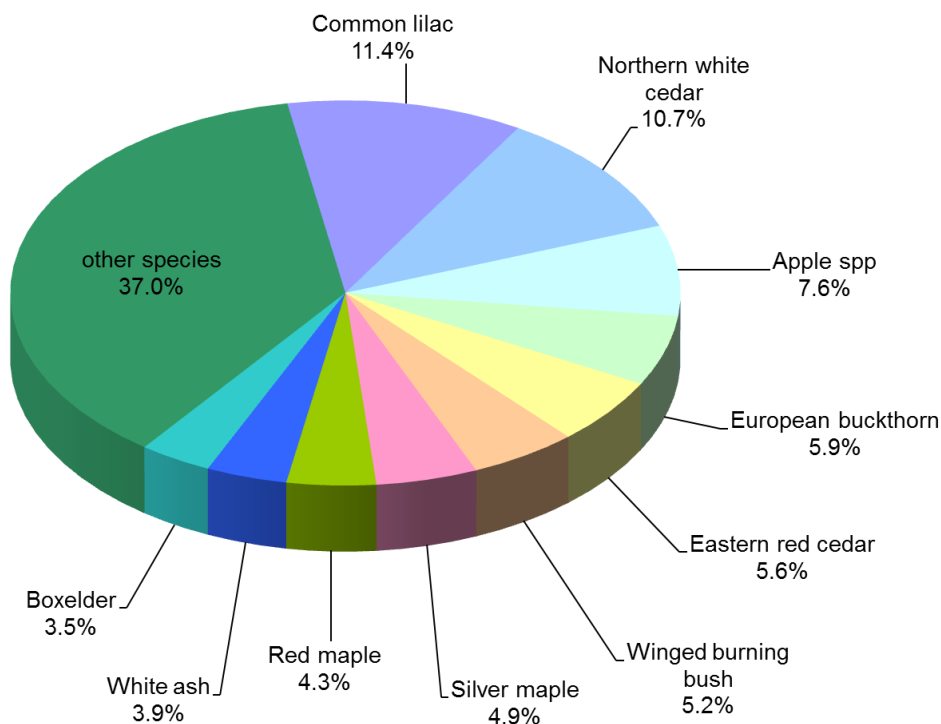
**Figure 3—Total leaf area and leaf area index by land use, Wisconsin, 2012.**

Total leaf area is greatest in residential land uses (75.3 percent of total tree leaf area) (Figure 3). Leaf area is a measure of leaf surface area (one side). Leaf area index (LAI) is a measure of the total leaf surface area (one side) divided by land area. As each land use has a different land area, LAI standardizes the canopy depth on an equal area basis. Higher LAIs indicate a greater leaf surface area per acre of land. The land use that has the highest LAI is residential (1.2) (Figure 3).

# The Tree Population and Species Characteristics of Wisconsin's Urban Forest

## Species Composition

The most common species observed in Wisconsin urban areas are common lilac (11.4 percent of the population), Northern white cedar (10.7 percent), and apple species (7.6 percent) (Figure 4-5). The 10 most frequent species account for 63.0 percent of the total urban tree population.

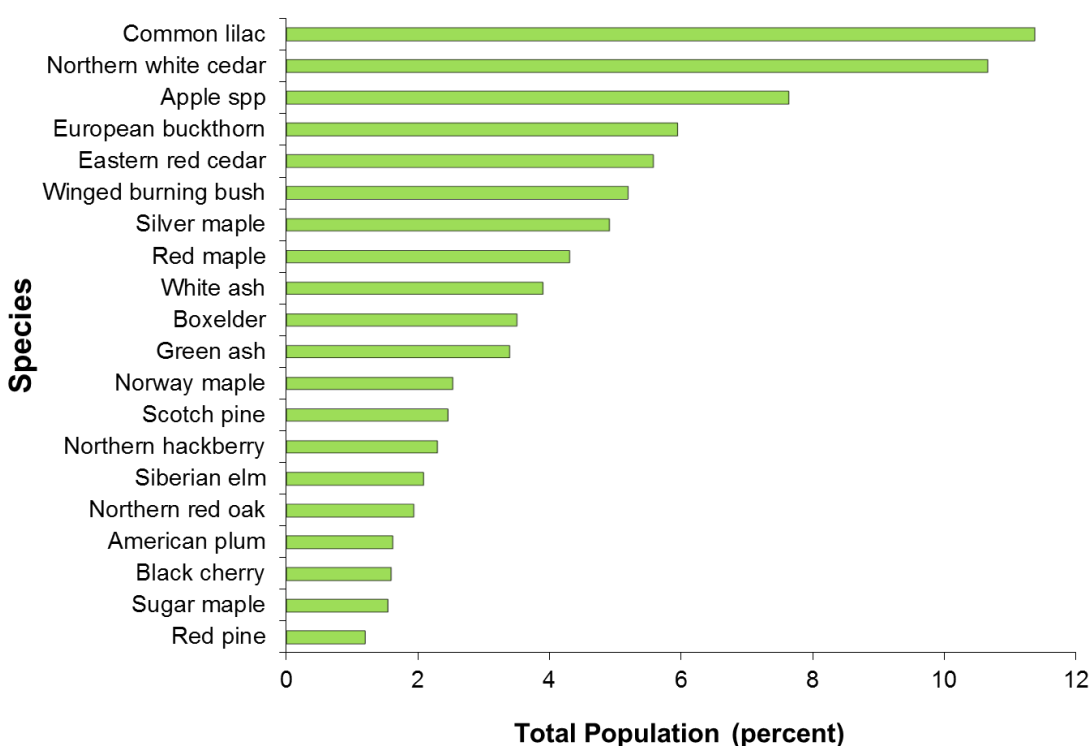


**Figure 4—Urban tree species composition, Wisconsin, 2012.**

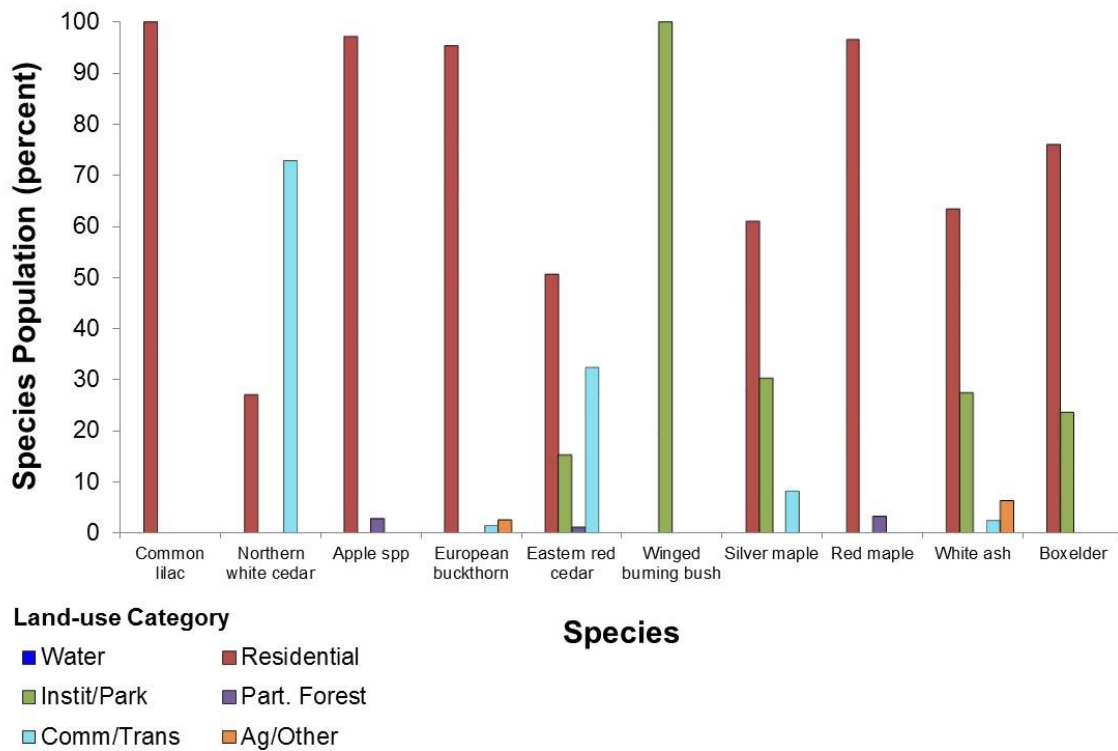
The distribution of the top 10 species in urban areas varied by land use (Figure 6). The greatest proportion of many of the top 10 species is found in residential lands. For example, over 90 percent of all common lilac, apple species, European buckthorn, and red maple are found on residential lands. Also, various species tend to be more dominant in certain land uses (Figure 7). For example, Northern white cedar comprises 62.5 percent of the commercial/transportation tree population, while winged burning bush comprises 34.6 percent of institutional/parks land use. Species composition also varied by tree size. For trees < 5 inches d.b.h. (trees measured on microplots), the common species were common lilac (19.6 percent), Northern white cedar (17.6 percent), and European buckthorn (9.8 percent) (Figure 8). For trees > 5 inches d.b.h., the common species were green ash (8.1 percent), silver maple (7.7 percent), and apple species (6.5 percent) (Figure 9). A total of 65 species were encountered within Wisconsin's urban forests. The scientific names of the species sampled are found in Appendix B. Total species summary information is provided in Appendix C.

Species composition varies by land use. The most common species on residential lands were common lilac (16.4 percent), apple species (10.7 percent), and European buckthorn (8.2 percent)

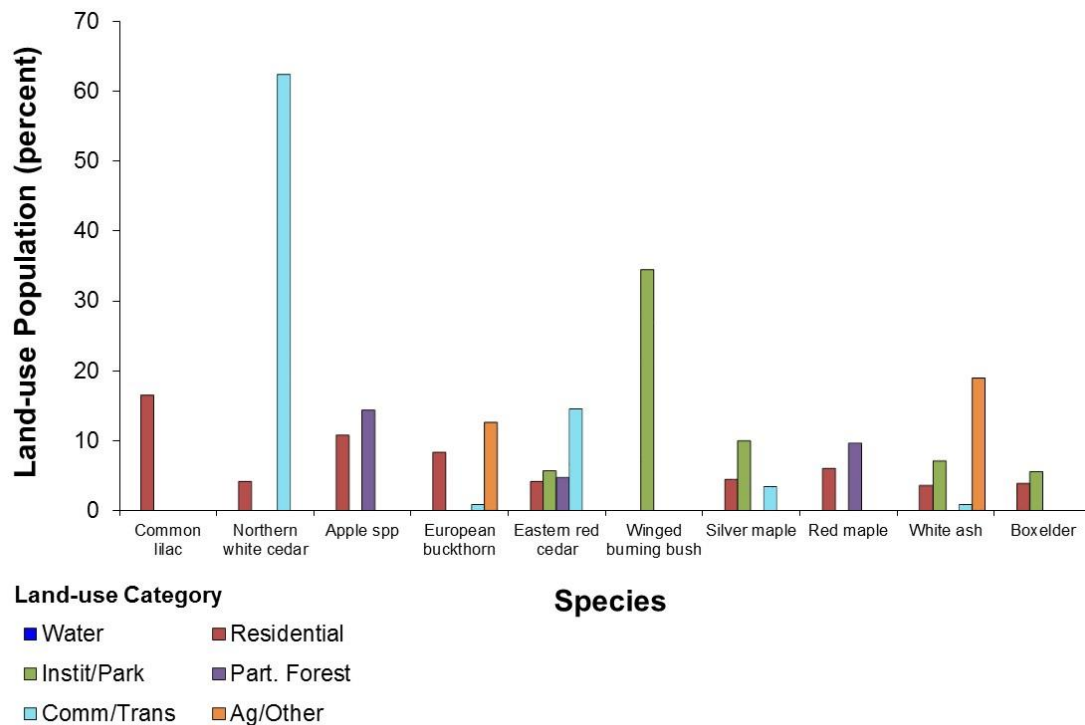
(Figure 10). The most common species on institutional/park lands were winged burning bush (34.6 percent), Scotch pine (11.1 percent), and silver maple (9.9 percent) (Figure 11). The most common species on commercial/transportation lands were Northern white cedar (62.3 percent), Eastern red cedar (14.6 percent), and Siberian elm (10.4 percent) (Figure 12). The most common species on partially forested lands were green ash (19.1 percent), black locust (14.3 percent), and apple species (14.3 percent) (Figure 13). The most common species on wetland land use were green ash (71.4 percent) and alder (28.6 percent) (Figure 15). The most common species on agriculture/other lands were Norway maple (25.0 percent), white ash (18.8 percent), and green ash (18.8 percent) (Figure 15). Total species summary information by land use type is provided in Appendix D.



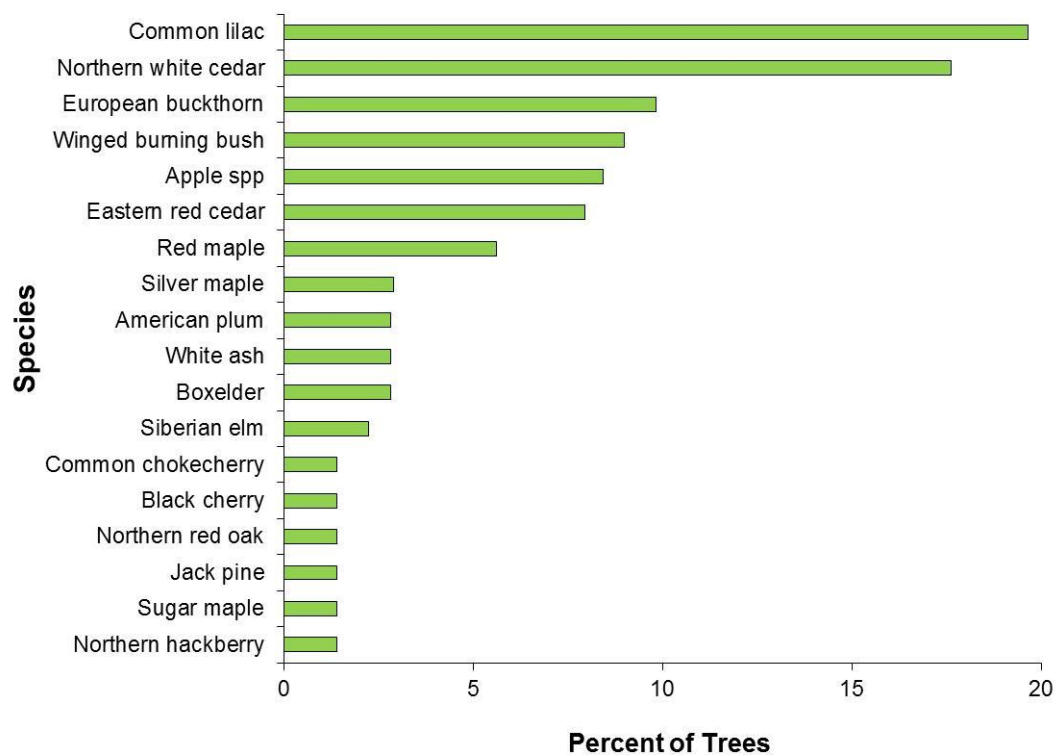
**Figure 5—Percent of total urban tree population for 20 most common tree species, Wisconsin, 2012.**



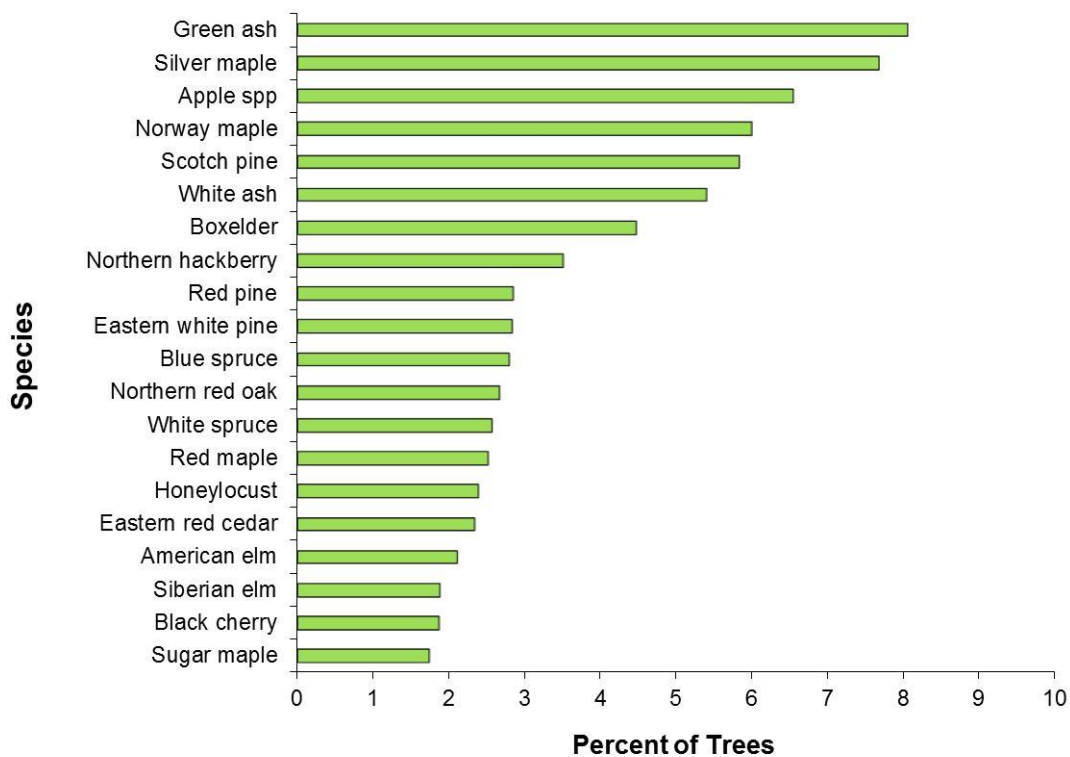
**Figure 6—Distribution (percent of species population) of top 10 species by land use type, Wisconsin, 2012.** For example, 100 percent of common lilac is found in residential areas.



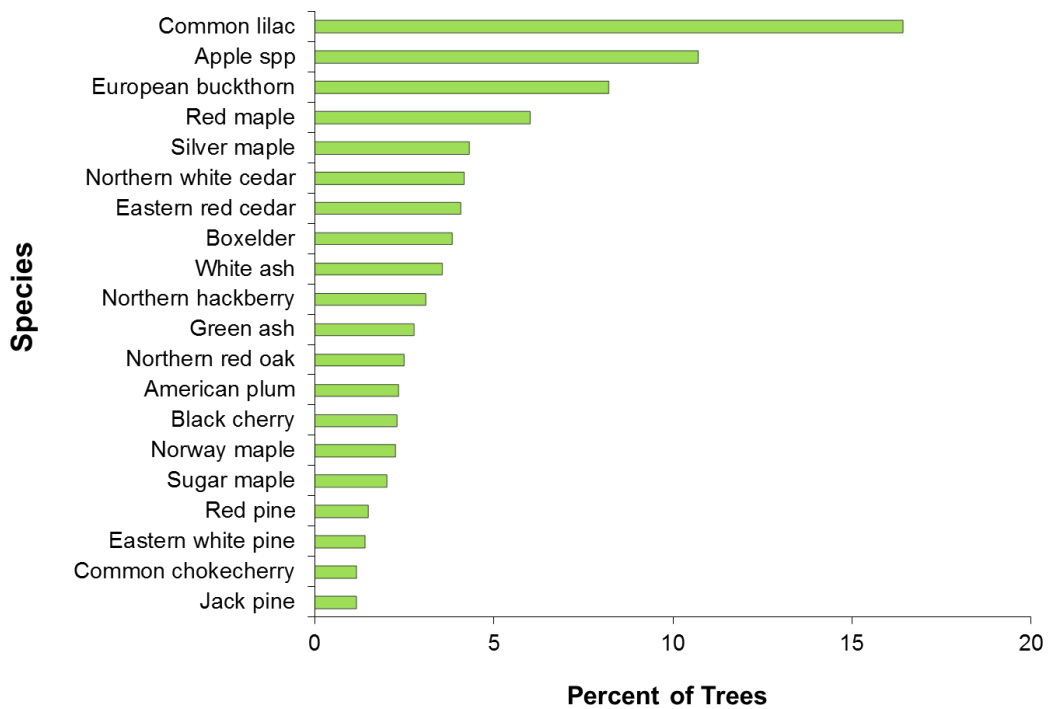
**Figure 7—Percent of land use occupied by top 10 tree species, Wisconsin, 2012.** For example, 62.5 percent of commercial/transportation trees are Northern white cedar.



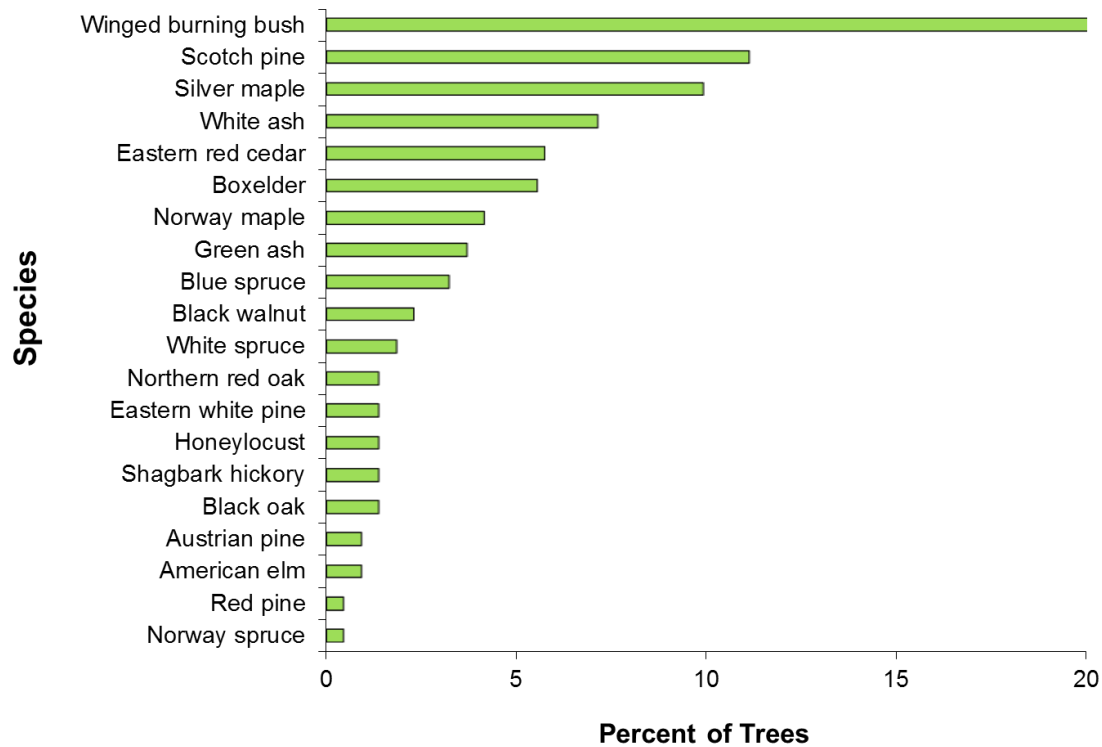
**Figure 8—Percent of urban tree population < 5 inches diameter at breast height (d.b.h.) for the 18 species less than 5 inches d.b.h., Wisconsin, 2012.**



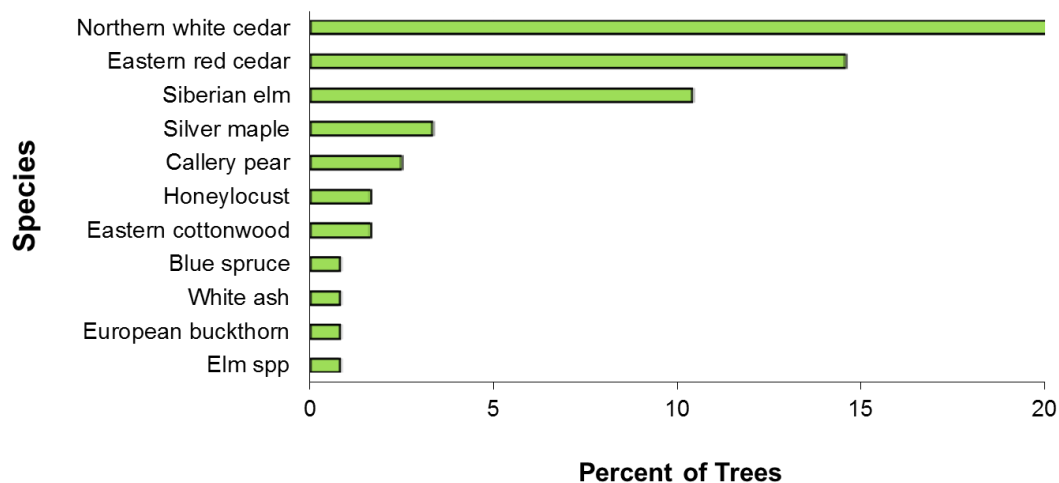
**Figure 9—Percent of urban tree population > 5 inches diameter at breast height (d.b.h.) for 20 most common species greater than 5 inches d.b.h., Wisconsin, 2012.**



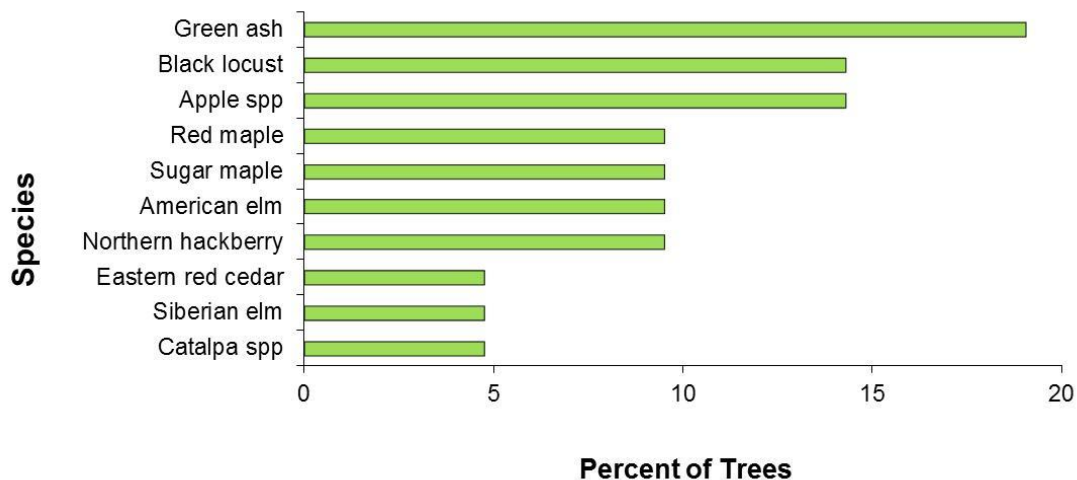
**Figure 10—Percent of total tree population for 20 most common tree species in residential urban land use, Wisconsin, 2012.**



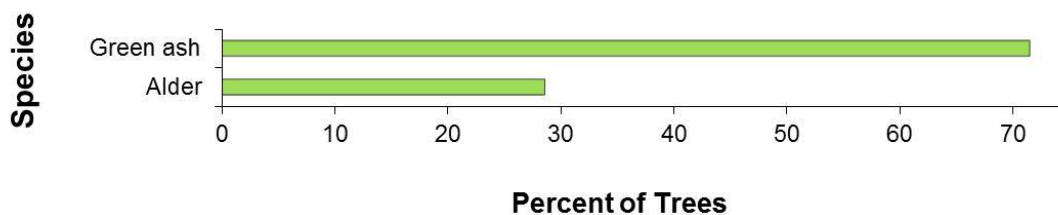
**Figure 11—Percent of total tree population for 20 most common tree species in institution/parks land use, Wisconsin, 2012.**



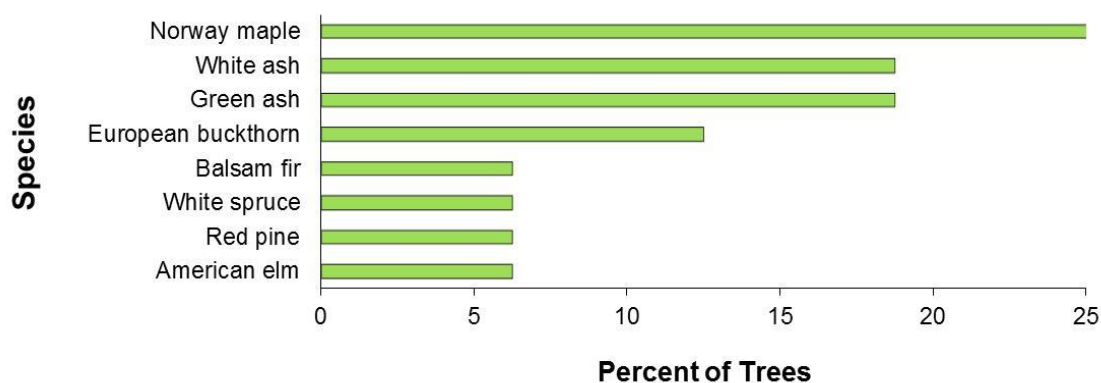
**Figure 12—Percent of total tree population for 11 tree species in commercial/transportation land use, Wisconsin, 2012.**



**Figure 13—Percent of total tree population for 10 tree species in partially forested lands, Wisconsin, 2012.**



**Figure 14—Percent of total tree population for 2 tree species in wetland land use, Wisconsin, 2012.**



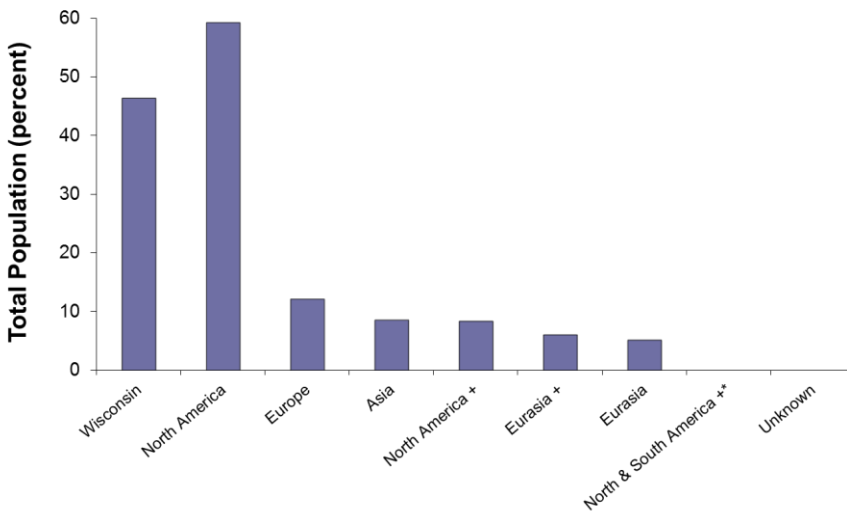
**Figure 15—Percent of total tree population for 8 species in agriculture/other land use, Wisconsin, 2012.**

Urban forests are a mix of native tree species that were planted, seeded in or existed prior to the development of the city and exotic species that were introduced by residents or other means. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but the increase in the number of exotic plants can also pose a risk to native plants if some of the exotics species are invasive plants that can potentially out-compete and displace native species. Nine tree species found in this survey are classified as invasive in Wisconsin (Wisconsin Department of Natural Resources 2015; Table 4). These species comprise about 20 percent of the population (8.4 million trees) and about 17 percent of the total leaf area. Species native to North America comprise 59.2 percent of trees in urban areas in Wisconsin, while 46.3 percent are native to Wisconsin specifically. Most of the exotic species identified originated from Europe (12.1 percent) (Figure 16).

**Table 4—Invasive urban tree species, Wisconsin, 2012**

| Scientific name               | Common name         | % Population | % Leaf area | Number of Trees |
|-------------------------------|---------------------|--------------|-------------|-----------------|
| <i>Rhamnus cathartica</i>     | European buckthorn  | 5.9          | 2.4         | 2,545,755       |
| <i>Euonymus alata</i>         | Winged burning bush | 5.2          | 0.2         | 2,223,535       |
| <i>Acer platanoides</i>       | Norway maple        | 2.5          | 8.4         | 1,082,477       |
| <i>Pinus sylvestris</i>       | Scotch pine         | 2.5          | 2.1         | 1,052,645       |
| <i>Ulmus pumila</i>           | Siberian elm        | 2.1          | 1.6         | 893,236         |
| <i>Morus alba</i>             | White mulberry      | 0.7          | 1.6         | 309,064         |
| <i>Pyrus calleryana</i>       | Callery pear        | 0.4          | 0.2         | 189,442         |
| <i>Robinia pseudoacacia</i>   | Black locust        | 0.2          | 0.4         | 92,667          |
| <i>Elaeagnus angustifolia</i> | Russian olive       | 0.1          | 0.2         | 56,193          |
|                               |                     | 19.6         | 17.1        | 8,445,014       |





(+) indicates native to the continent(s) listed and one other continent

**Figure 16—Native range distribution of urban trees in Wisconsin, 2012.**

## Tree Size Distribution

Tree stem diameter is used to estimate wood volume and mass. Unlike commercial forestry, where trees are harvested as a crop and volumes are used to estimate amount of timber products, urban wood volume can be translated into tons of carbon stored or carbon sequestered per year. As States and local units of government become more interested in environmental services provided by “green infrastructure,” estimates of carbon storage and sequestration rates by trees will become increasingly more important.

That is not to say, however, that urban wood is not a commodity in its own right. Development of technologies, like portable saw mills, and increasing demand for specialty woods are making it more common for cities and local governments to market urban wood that is scheduled for removals as a timber or fuel product, rather than disposing as a wood waste or processing for mulch. In this case, knowledge of wood volumes for marketing plans and management is crucial (Bratkovich 2001). Thus, estimates of urban tree mass can provide information related to wood used for timber products or the amount of waste wood that may have to be disposed. In addition to basal area, tree leaf surface area is an important measure for determining the species effects on many ecosystem services (e.g., air temperature cooling, pollution removal), as many services are directly related to leaf surface area.

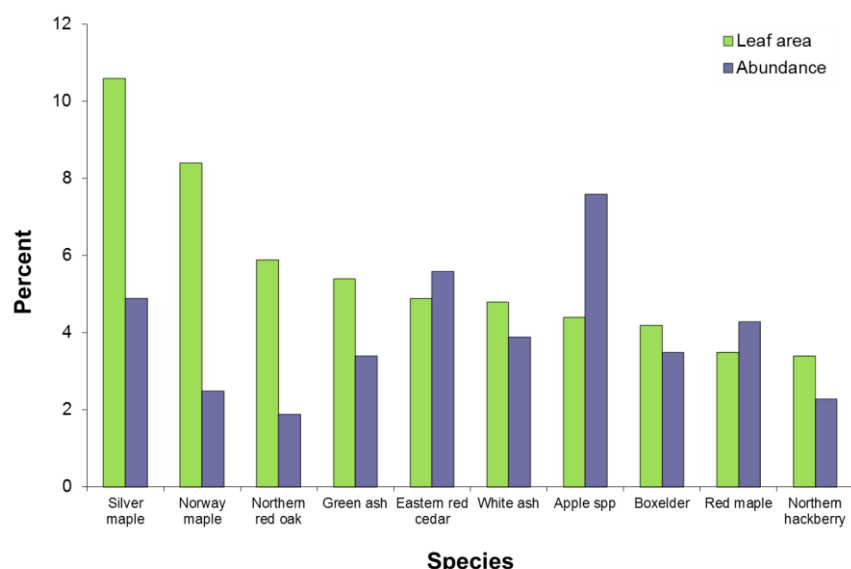
Tree diameter measurements are used by managers when creating plans for tree maintenance, removals and planting. When coupled with species information, size estimates can assist managers to determine long-term patterns of tree survival, selection and replacement (Cumming et al. 2001).

Species that dominate Wisconsin’s urban land in terms of overall basal area are silver maple, Norway maple, and green ash (Table 5). Trees that dominate in terms of leaf surface area are

silver maple (10.6 percent), Norway maple (8.4 percent), Northern red oak (5.9 percent), green ash (5.4 percent), and Eastern red cedar (4.9 percent) (Figure 17). Leaf area estimates are likely a better indication of ecosystem services derived from trees than basal area as the leaf area estimates are directly related to the parts of the trees where most of the services are derived. Species with percent leaf area much greater than percent total population tend to be relatively large, healthy trees on average. Species with percent of total population much greater than percent total leaf area tend to be relatively small and/or unhealthy trees on average. While most of the trees are found in the 1-3 inch diameter class, most of the leaf area is within the 6-9 inch diameter class (Figure 18).

Tree diameter distribution provides information related to tree size and approximate age distribution, which are important for understanding population dynamics. For example, for a sustainable population, more small trees are typically required than larger trees, as the smaller tree population eventually will fill the larger diameter population classes through time. However, some small-statured species (e.g., crabapple) will not attain a large diameter or stature. The diameter distribution for Wisconsin's urban forest displays the typical inverse-J shape distribution (Figure 19). On a per tree basis, larger trees can provide more services, such as air pollution removal and storm water mitigation, than smaller trees.

Of the 10 most common species, common lilac, Northern white cedar, Eastern red cedar, red maple and winged burning bush each have more than 75 percent of their trees in the 1-3 inch d.b.h. class (Figure 20). The three species with the largest average diameters were black willow (28.8 in.), weeping willow (22.0 in.) and Eastern cottonwood (21.6 in.). Diameter distribution patterns among the land use classes are given in Figure 21. Detailed statistics (e.g., average d.b.h. and basal area) on urban trees can be found in Appendix B. Detailed tree statistics by land use type are given in Appendix D.

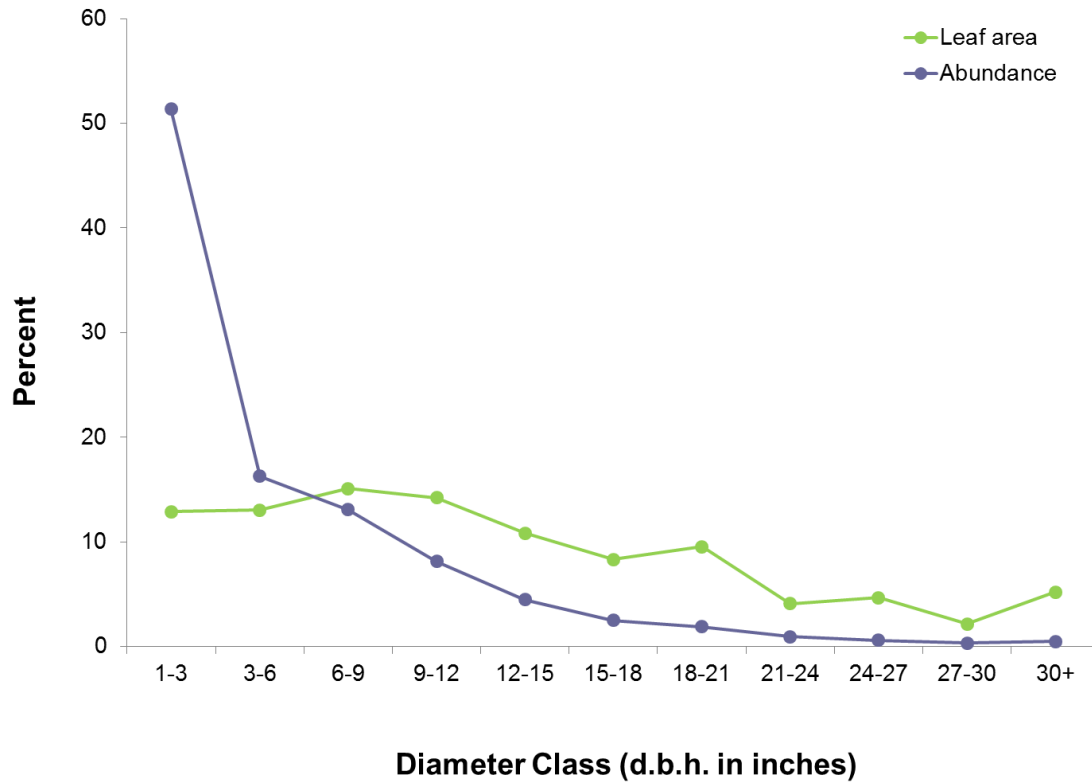


**Figure 17—Percent of total tree population (abundance) and total leaf area for 10 most dominant species in terms of leaf area, Wisconsin, 2012.**

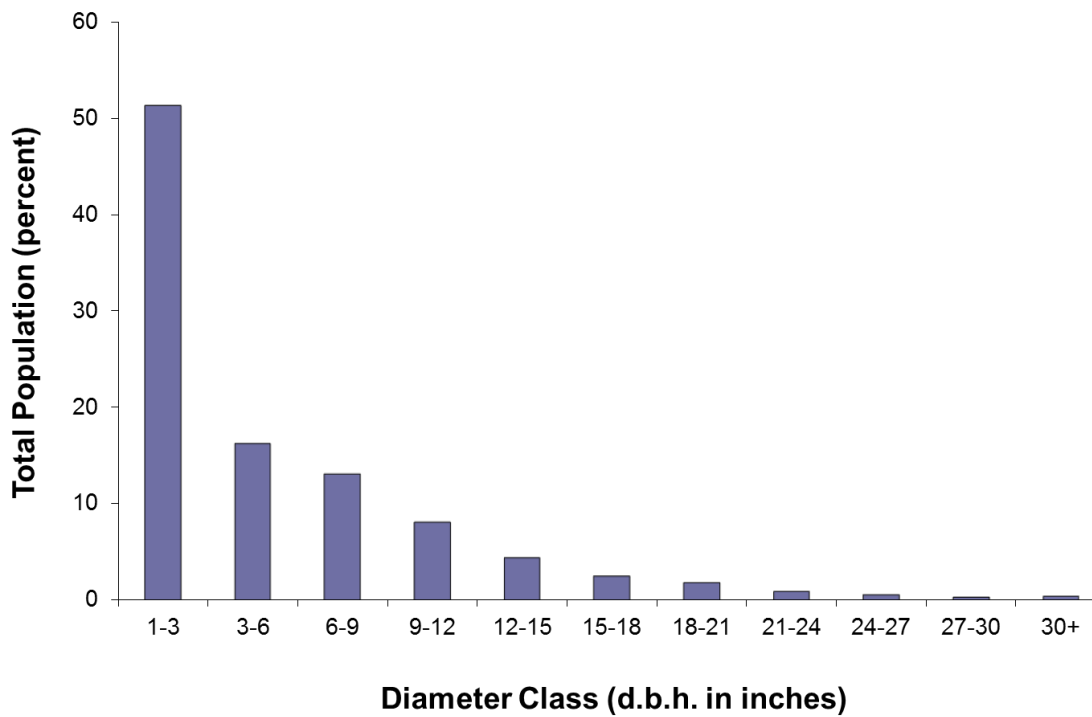
**Table 5—Top 20 urban tree species in terms of basal area, Wisconsin, 2012.**

| <b>Species</b>       | <b>Population</b> | <b>Basal area</b>        |                | <b>D.b.h.</b> |               |
|----------------------|-------------------|--------------------------|----------------|---------------|---------------|
|                      |                   |                          |                | <b>Avg</b>    | <b>Median</b> |
|                      | <i>percent</i>    | <i>ft<sup>2</sup>/ac</i> | <i>percent</i> | <i>inches</i> |               |
| Silver maple         | 4.9               | 1.79                     | 10.9           | 9.1           | 5.0           |
| Norway maple         | 2.5               | 1.32                     | 8.1            | 13.1          | 13.5          |
| Green ash            | 3.4               | 1.04                     | 6.3            | 9.3           | 7.8           |
| Northern red oak     | 1.9               | 1.03                     | 6.3            | 11.2          | 8.7           |
| Eastern white pine   | 1.2               | 0.89                     | 5.4            | 15.9          | 15.5          |
| White ash            | 3.9               | 0.65                     | 4.0            | 6.2           | 4.4           |
| Eastern cottonwood   | 0.4               | 0.60                     | 3.7            | 21.6          | 13.9          |
| Honeylocust          | 1.0               | 0.60                     | 3.6            | 13.9          | 13.3          |
| Scotch pine          | 2.5               | 0.59                     | 3.6            | 9.2           | 9.2           |
| Boxelder             | 3.5               | 0.48                     | 2.9            | 5.8           | 5.2           |
| Black willow         | 0.2               | 0.46                     | 2.8            | 28.8          | 23.5          |
| American elm         | 0.9               | 0.44                     | 2.7            | 10.9          | 7.4           |
| Red maple            | 4.3               | 0.43                     | 2.6            | 4.1           | 2.3           |
| Apple spp            | 7.6               | 0.40                     | 2.5            | 3.7           | 2.9           |
| Red pine             | 1.2               | 0.37                     | 2.2            | 10.0          | 9.9           |
| White oak            | 0.5               | 0.36                     | 2.2            | 14.4          | 10.0          |
| Blue spruce          | 1.2               | 0.34                     | 2.1            | 9.9           | 9.8           |
| White spruce         | 1.1               | 0.33                     | 2.0            | 9.7           | 8.0           |
| Northern white cedar | 10.7              | 0.28                     | 1.7            | 2.1           | 1.6           |
| Norway spruce        | 0.5               | 0.27                     | 1.7            | 14.3          | 12.5          |

D.b.h. = Diameter at breast height.



**Figure 18—Comparison of proportion of tree abundance with leaf area by diameter class, Wisconsin, 2012.**



**Figure 19—Proportion of urban tree population by diameter class, Wisconsin, 2012.**

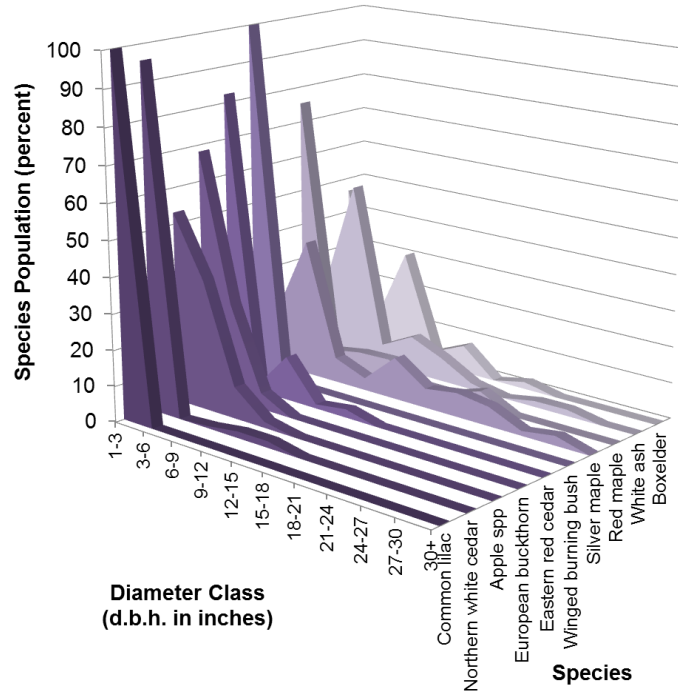


Figure 20—Proportion of top 10 species populations by diameter class, Wisconsin, 2012.

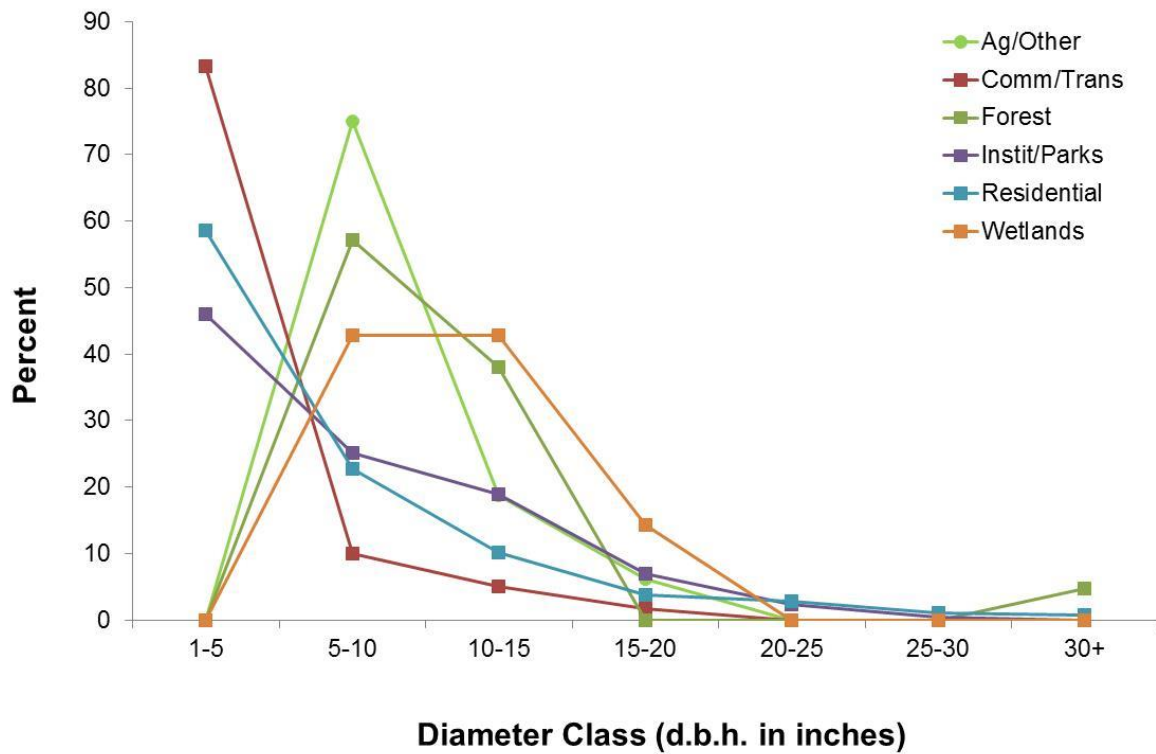
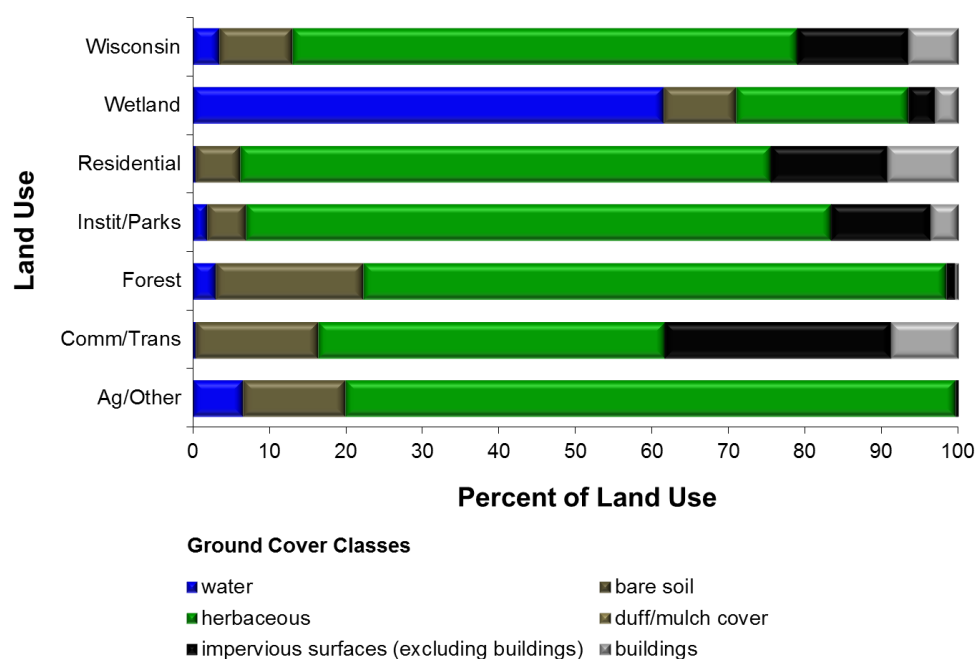


Figure 21—Diameter distribution by land use class, Wisconsin, 2012.

## Tree and Ground Cover

Tree cover in urban areas in Wisconsin was interpreted using Google Earth imagery circa 2012. Five hundred points were randomly located within the urban areas of Wisconsin and interpreted as either tree/shrub cover, impervious surfaces (concrete, asphalt, etc.), water, or other. Urban tree/shrub cover in Wisconsin is estimated at 29.4 percent (standard error – 2.0 percent). Based on field crew estimates of tree and shrub cover, it is estimated that trees cover is 20.8 percent and shrub cover is 5.8 percent. However, the field plots only estimated non-forested urban areas, whereas the photo-interpreted estimates are for the entire urban area.

The ground cover in urban Wisconsin is dominated by herbaceous (grass and other nonwoody plants) cover (65.9 percent) (Figure 22). Herbaceous cover is also most common in all land uses except wetland. The wetland land use is dominated by water (61.5 percent).



**Figure 22—Ground cover distribution by land use type and for entire urban area, Wisconsin, 2012.**

## Trees in Maintained and Nonmaintained Urban Areas

Each tree was classified as to whether it was found in a maintained or nonmaintained area. Maintained areas are defined as those which are regularly impacted by mowing, weeding, herbicide applications, etc. Trees found in a maintained area do not imply each tree had maintenance. Examples of maintained areas include lawns, rights-of-way, and parks. Of the 65 tree species sampled on urban lands in Wisconsin, 58 species were classified as being found in maintained areas. Overall, 64 percent of the trees (27.4 million) were classified as growing in maintained areas (Table 6).

Most of the maintained trees (69.5 percent) were found on residential land (Table 6). Most of the sampled species (61.5 percent) had at least 80 percent of their sampled trees in maintained areas (Table 7). The proportion of species in maintained areas can be highly uncertain with low sample sizes (e.g.,  $n < 10$ ). Of the maintained tree population, the most common species were apple (10.3 percent of the total maintained tree population), winged burning bush (8.1 percent), and Eastern red cedar (8.0 percent) (Table 8).

**Table 6—Number and percent of maintained trees by species within land use classes, Wisconsin, 2012**

| Land use    | Species              | Total trees      |                  | Maintained trees |                |             |
|-------------|----------------------|------------------|------------------|------------------|----------------|-------------|
|             |                      | number           | SE               | number           | SE             | %           |
| Ag/Other    | American elm         | 34,962           | 34,962           | 0                | 0              | 0.0         |
|             | Balsam fir           | 34,962           | 34,962           | 34,962           | 34,962         | 100.0       |
|             | European buckthorn   | 69,924           | 69,923           | 0                | 0              | 0.0         |
|             | Green ash            | 104,886          | 76,063           | 69,924           | 69,923         | 66.7        |
|             | Norway maple         | 139,848          | 139,846          | 139,848          | 139,846        | 100.0       |
|             | Red pine             | 34,962           | 34,962           | 0                | 0              | 0.0         |
|             | White ash            | 104,886          | 104,885          | 0                | 0              | 0.0         |
|             | White spruce         | 34,962           | 34,962           | 34,962           | 34,962         | 100.0       |
|             | <b>Total</b>         | <b>559,394</b>   | <b>250,165</b>   | <b>279,697</b>   | <b>184,116</b> | <b>50.0</b> |
| Comm/Trans  | Blue spruce          | 44,416           | 44,416           | 0                | 0              | 0.0         |
|             | Callery pear         | 133,249          | 133,247          | 133,249          | 133,247        | 100.0       |
|             | Eastern cottonwood   | 88,833           | 88,832           | 88,833           | 88,832         | 100.0       |
|             | Eastern red cedar    | 775,365          | 582,186          | 597,699          | 555,062        | 77.1        |
|             | Elm spp              | 44,416           | 44,416           | 0                | 0              | 0.0         |
|             | European buckthorn   | 44,416           | 44,416           | 44,416           | 44,416         | 100.0       |
|             | Honeylocust          | 88,833           | 61,369           | 44,416           | 44,416         | 50.0        |
|             | Northern white cedar | 3,319,696        | 3,319,693        | 0                | 0              | 0.0         |
|             | Siberian elm         | 553,283          | 553,282          | 553,283          | 553,282        | 100.0       |
|             | Silver maple         | 177,665          | 177,663          | 177,665          | 177,663        | 100.0       |
|             | White ash            | 44,416           | 44,416           | 44,416           | 44,416         | 100.0       |
|             | <b>Total</b>         | <b>5,314,587</b> | <b>3,374,548</b> | <b>1,683,977</b> | <b>816,206</b> | <b>31.7</b> |
| Forest      | American elm         | 61,778           | 42,202           | 0                | 0              | 0.0         |
|             | Black locust         | 92,667           | 92,665           | 92,667           | 92,665         | 100.0       |
|             | Catalpa spp          | 30,889           | 30,888           | 0                | 0              | 0.0         |
|             | Eastern red cedar    | 30,889           | 30,888           | 0                | 0              | 0.0         |
|             | Green ash            | 123,556          | 123,554          | 123,556          | 123,554        | 100.0       |
|             | Apple spp            | 92,667           | 92,665           | 0                | 0              | 0.0         |
|             | Northern hackberry   | 61,778           | 61,777           | 0                | 0              | 0.0         |
|             | Red maple            | 61,778           | 61,777           | 0                | 0              | 0.0         |
|             | Siberian elm         | 30,889           | 30,888           | 0                | 0              | 0.0         |
|             | Sugar maple          | 61,778           | 61,777           | 0                | 0              | 0.0         |
|             | <b>Total</b>         | <b>648,667</b>   | <b>273,381</b>   | <b>216,222</b>   | <b>216,219</b> | <b>33.3</b> |
| Instit/Park | American elm         | 59,624           | 41,372           | 59,624           | 41,372         | 100.0       |
|             | Austrian pine        | 59,624           | 59,623           | 0                | 0              | 0.0         |
|             | Black oak            | 89,436           | 89,434           | 89,436           | 89,434         | 100.0       |
|             | Black walnut         | 149,059          | 105,633          | 149,059          | 105,633        | 100.0       |
|             | Blue spruce          | 208,683          | 133,197          | 29,812           | 29,811         | 14.3        |
|             | Boxelder             | 357,742          | 228,913          | 357,742          | 228,913        | 100.0       |
|             |                      |                  |                  |                  |                |             |

*continued*

| Land use             | Species              | Total trees      |                  | Maintained trees |                  |             |
|----------------------|----------------------|------------------|------------------|------------------|------------------|-------------|
|                      |                      | number           | SE               | number           | SE               | %           |
| Instit/Park<br>cont. | Eastern red cedar    | 370,589          | 370,589          | 370,589          | 370,589          | 100.0       |
|                      | Eastern white pine   | 89,436           | 89,434           | 89,436           | 89,434           | 100.0       |
|                      | Green ash            | 238,495          | 112,426          | 149,059          | 75,024           | 62.5        |
|                      | Honeylocust          | 89,436           | 65,665           | 89,436           | 65,665           | 100.0       |
|                      | Jack pine            | 29,812           | 29,811           | 29,812           | 29,811           | 100.0       |
|                      | Mountain ash spp     | 29,812           | 29,811           | 29,812           | 29,811           | 100.0       |
|                      | Northern red oak     | 89,436           | 89,434           | 89,436           | 89,434           | 100.0       |
|                      | Norway maple         | 268,307          | 136,130          | 268,307          | 136,130          | 100.0       |
|                      | Norway spruce        | 29,812           | 29,811           | 0                | 0                | 0.0         |
|                      | Red pine             | 29,812           | 29,811           | 29,812           | 29,811           | 100.0       |
|                      | Scotch pine          | 715,484          | 715,472          | 715,484          | 715,472          | 100.0       |
|                      | Shagbark hickory     | 89,436           | 89,434           | 89,436           | 89,434           | 100.0       |
|                      | Silver maple         | 638,896          | 428,388          | 638,896          | 428,388          | 100.0       |
|                      | White ash            | 460,025          | 376,362          | 460,025          | 376,362          | 100.0       |
|                      | White spruce         | 119,247          | 82,743           | 0                | 0                | 0.0         |
|                      | Winged burning bush  | 2,223,535        | 2,223,532        | 2,223,535        | 2,223,532        | 100.0       |
|                      | <b>Total</b>         | <b>6,435,735</b> | <b>2,586,443</b> | <b>5,958,746</b> | <b>2,583,183</b> | <b>92.6</b> |
| Residential          | American basswood    | 56,193           | 39,524           | 28,097           | 28,096           | 50.0        |
|                      | American beech       | 56,193           | 56,192           | 56,193           | 56,192           | 100.0       |
|                      | American elm         | 224,774          | 147,662          | 224,774          | 147,662          | 100.0       |
|                      | American plum        | 694,690          | 694,689          | 694,690          | 694,689          | 100.0       |
|                      | Ash spp              | 112,387          | 88,567           | 112,387          | 88,567           | 100.0       |
|                      | Bigtooth aspen       | 28,097           | 28,096           | 28,097           | 28,096           | 100.0       |
|                      | Bitternut hickory    | 56,193           | 39,524           | 0                | 0                | 0.0         |
|                      | Black cherry         | 684,506          | 374,422          | 196,677          | 82,293           | 28.7        |
|                      | Black oak            | 56,193           | 56,192           | 56,193           | 56,192           | 100.0       |
|                      | Black willow         | 84,290           | 84,289           | 84,290           | 84,289           | 100.0       |
|                      | Blue spruce          | 252,871          | 126,802          | 224,774          | 124,187          | 88.9        |
|                      | Boxelder             | 1,144,238        | 716,916          | 1,088,044        | 716,151          | 95.1        |
|                      | Bur oak              | 28,097           | 28,096           | 28,097           | 28,096           | 100.0       |
|                      | Callery pear         | 56,193           | 56,192           | 0                | 0                | 0.0         |
|                      | Common chokecherry   | 347,345          | 347,344          | 0                | 0                | 0.0         |
|                      | Common lilac         | 4,862,830        | 3,161,046        | 0                | 0                | 0.0         |
|                      | Common pear          | 28,097           | 28,096           | 28,097           | 28,096           | 100.0       |
|                      | Downy hawthorn       | 28,097           | 28,096           | 28,097           | 28,096           | 100.0       |
|                      | Eastern cottonwood   | 84,290           | 62,560           | 84,290           | 62,560           | 100.0       |
|                      | Eastern hophornbeam  | 84,290           | 62,560           | 56,193           | 56,192           | 66.7        |
|                      | Eastern red cedar    | 1,210,615        | 791,568          | 1,210,615        | 791,568          | 100.0       |
|                      | Eastern white pine   | 421,451          | 219,968          | 309,064          | 191,015          | 73.3        |
|                      | European buckthorn   | 2,431,415        | 1,501,405        | 1,389,380        | 1,094,926        | 57.1        |
|                      | Green ash            | 824,990          | 390,574          | 768,796          | 389,210          | 93.2        |
|                      | Honeylocust          | 252,871          | 106,266          | 140,484          | 61,488           | 55.6        |
|                      | Jack pine            | 347,345          | 347,344          | 347,345          | 347,344          | 100.0       |
|                      | Littleleaf linden    | 56,193           | 56,192           | 56,193           | 56,192           | 100.0       |
|                      | Apple spp            | 3,172,114        | 2,463,501        | 2,824,769        | 2,442,534        | 89.1        |
|                      | Northern catalpa     | 56,193           | 56,192           | 56,193           | 56,192           | 100.0       |
|                      | Northern hackberry   | 919,464          | 705,702          | 919,464          | 705,702          | 100.0       |
|                      | Northern pin oak     | 196,677          | 127,846          | 196,677          | 127,846          | 100.0       |
|                      | Northern red oak     | 740,699          | 394,606          | 572,119          | 368,877          | 77.2        |
|                      | Northern white cedar | 1,238,712        | 1,049,846        | 1,238,712        | 1,049,846        | 100.0       |
|                      | Norway maple         | 674,322          | 164,688          | 505,741          | 145,736          | 75.0        |
|                      | Norway spruce        | 168,580          | 77,991           | 140,484          | 73,323           | 83.3        |

*continued*



| Land use                        | Species          | Total trees       |                  | Maintained trees  |                  |              |
|---------------------------------|------------------|-------------------|------------------|-------------------|------------------|--------------|
|                                 |                  | <i>number</i>     | <i>SE</i>        | <i>number</i>     | <i>SE</i>        | <i>%</i>     |
| Residential<br>cont.            | Paper birch      | 309,064           | 118,958          | 309,064           | 118,958          | 100.0        |
|                                 | Pin cherry       | 28,097            | 28,096           | 28,097            | 28,096           | 100.0        |
|                                 | Plum spp         | 84,290            | 62,560           | 0                 | 0                | 0.0          |
|                                 | Quaking aspen    | 140,484           | 61,488           | 112,387           | 55,298           | 80.0         |
|                                 | Red maple        | 1,782,734         | 857,372          | 947,561           | 506,390          | 53.2         |
|                                 | Red mulberry     | 28,097            | 28,096           | 28,097            | 28,096           | 100.0        |
|                                 | Red pine         | 449,548           | 213,858          | 196,677           | 170,611          | 43.8         |
|                                 | Russian olive    | 56,193            | 56,192           | 56,193            | 56,192           | 100.0        |
|                                 | Scotch pine      | 337,161           | 240,487          | 252,871           | 226,226          | 75.0         |
|                                 | Shagbark hickory | 224,774           | 177,134          | 168,580           | 168,577          | 75.0         |
|                                 | Siberian elm     | 309,064           | 131,688          | 224,774           | 103,132          | 72.7         |
|                                 | Silver maple     | 1,284,722         | 720,841          | 1,144,238         | 716,916          | 89.1         |
|                                 | Slippery elm     | 252,871           | 252,866          | 252,871           | 252,866          | 100.0        |
|                                 | Sugar maple      | 600,216           | 361,033          | 56,193            | 39,524           | 9.4          |
|                                 | Weeping willow   | 56,193            | 39,524           | 28,097            | 28,096           | 50.0         |
|                                 | White ash        | 1,059,948         | 711,279          | 891,367           | 700,686          | 84.1         |
|                                 | White fir        | 56,193            | 56,192           | 56,193            | 56,192           | 100.0        |
|                                 | White mulberry   | 309,064           | 214,614          | 309,064           | 214,614          | 100.0        |
|                                 | White oak        | 224,774           | 130,452          | 56,193            | 56,192           | 25.0         |
|                                 | White spruce     | 309,064           | 118,958          | 196,677           | 107,510          | 63.6         |
|                                 | Willow spp       | 28,097            | 28,096           | 28,097            | 28,096           | 100.0        |
|                                 | <b>Total</b>     | <b>29,612,158</b> | <b>5,990,106</b> | <b>19,038,322</b> | <b>4,474,507</b> | <b>64.3</b>  |
| Wetland                         | Alder            | 64,511            | 64,510           | 64,511            | 64,510           | 100.0        |
|                                 | Green ash        | 161,277           | 105,014          | 161,277           | 105,014          | 100.0        |
|                                 | <b>Total</b>     | <b>225,787</b>    | <b>144,967</b>   | <b>225,787</b>    | <b>144,967</b>   | <b>100.0</b> |
| <b>State Urban Forest Total</b> |                  | <b>42,796,328</b> | <b>7,356,423</b> | <b>27,402,751</b> | <b>5,240,411</b> | <b>64.0</b>  |

**Table 7—Species by percent of sampled trees in maintained areas, Wisconsin, 2012**

| Species             | Trees          | Sample size   |
|---------------------|----------------|---------------|
|                     | <i>percent</i> | <i>number</i> |
| Winged burning bush | 100.0          | 6             |
| American plum       | 100.0          | 2             |
| Jack pine           | 100.0          | 2             |
| Paper birch         | 100.0          | 11            |
| White mulberry      | 100.0          | 11            |
| Slippery elm        | 100.0          | 9             |
| Northern pin oak    | 100.0          | 7             |
| Eastern cottonwood  | 100.0          | 5             |
| Black walnut        | 100.0          | 5             |
| Black oak           | 100.0          | 5             |
| Ash spp             | 100.0          | 4             |
| Black locust        | 100.0          | 3             |
| Black willow        | 100.0          | 3             |

*continued*

| Species             | Trees          | Sample size   |
|---------------------|----------------|---------------|
|                     | <i>percent</i> | <i>number</i> |
| Alder               | 100.0          | 2             |
| White fir           | 100.0          | 2             |
| Northern catalpa    | 100.0          | 2             |
| Russian olive       | 100.0          | 2             |
| American beech      | 100.0          | 2             |
| Littleleaf linden   | 100.0          | 2             |
| Balsam fir          | 100.0          | 1             |
| Mountain ash spp    | 100.0          | 1             |
| Downy hawthorn      | 100.0          | 1             |
| Red mulberry        | 100.0          | 1             |
| Bigtooth aspen      | 100.0          | 1             |
| Pin cherry          | 100.0          | 1             |
| Common pear         | 100.0          | 1             |
| Bur oak             | 100.0          | 1             |
| Willow spp          | 100.0          | 1             |
| Boxelder            | 96.3           | 30            |
| Northern hackberry  | 93.7           | 12            |
| Silver maple        | 93.3           | 37            |
| Scotch pine         | 92.0           | 36            |
| Eastern red cedar   | 91.3           | 17            |
| Green ash           | 87.6           | 38            |
| Siberian elm        | 87.1           | 13            |
| Apple spp           | 86.5           | 25            |
| Norway maple        | 84.4           | 37            |
| White ash           | 83.6           | 23            |
| Shagbark hickory    | 82.1           | 11            |
| Quaking aspen       | 80.0           | 5             |
| Northern red oak    | 79.7           | 18            |
| Eastern white pine  | 78.0           | 18            |
| American elm        | 74.6           | 13            |
| Norway spruce       | 70.8           | 7             |
| Callery pear        | 70.3           | 5             |
| Eastern hophornbeam | 66.7           | 3             |
| Honeylocust         | 63.6           | 14            |
| European buckthorn  | 56.3           | 10            |
| Red maple           | 51.4           | 20            |
| Blue spruce         | 50.3           | 17            |
| Weeping willow      | 50.0           | 2             |
| American basswood   | 50.0           | 2             |
| White spruce        | 50.0           | 16            |

*continued*

| <b>Species</b>       | <b>Trees</b>   | <b>Sample size</b> |
|----------------------|----------------|--------------------|
|                      | <i>percent</i> | <i>number</i>      |
| Red pine             | 44.0           | 18                 |
| Black cherry         | 28.7           | 13                 |
| Northern white cedar | 27.2           | 16                 |
| White oak            | 25.0           | 8                  |
| Sugar maple          | 8.5            | 12                 |
| Common lilac         | 0.0            | 14                 |
| Common chokecherry   | 0.0            | 1                  |
| Plum spp             | 0.0            | 3                  |
| Austrian pine        | 0.0            | 2                  |
| Bitternut hickory    | 0.0            | 2                  |
| Elm spp              | 0.0            | 1                  |
| Catalpa spp          | 0.0            | 1                  |

**Table 8—Species composition in maintained areas, Wisconsin, 2012**

| <b>Species</b>       | <b>Trees</b>   |
|----------------------|----------------|
|                      | <i>percent</i> |
| Apple spp            | 10.3           |
| Winged burning bush  | 8.1            |
| Eastern red cedar    | 8.0            |
| Silver maple         | 7.2            |
| Boxelder             | 5.3            |
| European buckthorn   | 5.2            |
| White ash            | 5.1            |
| Green ash            | 4.6            |
| Northern white cedar | 4.5            |
| Scotch pine          | 3.5            |
| Red maple            | 3.5            |
| Northern hackberry   | 3.4            |
| Norway maple         | 3.3            |
| Siberian elm         | 2.8            |
| American plum        | 2.5            |
| Northern red oak     | 2.4            |
| Eastern white pine   | 1.5            |
| Jack pine            | 1.4            |
| Paper birch          | 1.1            |
| White mulberry       | 1.1            |
| American elm         | 1.0            |
| Honeylocust          | 1.0            |
| Shagbark hickory     | 0.9            |
| Blue spruce          | 0.9            |

*continued*

| <b>Species</b>      | <b>Trees</b>   |
|---------------------|----------------|
|                     | <i>percent</i> |
| Slippery elm        | 0.9            |
| White spruce        | 0.8            |
| Red pine            | 0.8            |
| Black cherry        | 0.7            |
| Northern pin oak    | 0.7            |
| Eastern cottonwood  | 0.6            |
| Black walnut        | 0.5            |
| Black oak           | 0.5            |
| Norway spruce       | 0.5            |
| Callery pear        | 0.5            |
| Quaking aspen       | 0.4            |
| Ash spp             | 0.4            |
| Black locust        | 0.3            |
| Black willow        | 0.3            |
| Alder               | 0.2            |
| Sugar maple         | 0.2            |
| White oak           | 0.2            |
| Eastern hophornbeam | 0.2            |
| White fir           | 0.2            |
| Northern catalpa    | 0.2            |
| Russian olive       | 0.2            |
| American beech      | 0.2            |
| Littleleaf linden   | 0.2            |
| Balsam fir          | 0.1            |
| Mountain ash spp    | 0.1            |
| Weeping willow      | 0.1            |
| American basswood   | 0.1            |
| Downy hawthorn      | 0.1            |
| Red mulberry        | 0.1            |
| Bigtooth aspen      | 0.1            |
| Pin cherry          | 0.1            |
| Common pear         | 0.1            |
| Bur oak             | 0.1            |
| Willow spp          | 0.1            |
| Common lilac        | 0.0            |
| Common chokecherry  | 0.0            |
| Plum spp            | 0.0            |
| Austrian pine       | 0.0            |
| Bitternut hickory   | 0.0            |
| Elm spp             | 0.0            |
| Catalpa spp         | 0.0            |

## Urban Forest Health

To evaluate tree condition, we used national FIA protocols for crown and damage ratings (Conkling and Byers 1992) for all trees  $\geq 1$  inch (see U.S. Department of Agriculture 2007 for details). Crown measurements evaluate the growth and vigor of the crown, as a whole, for each tree. Damage ratings describe symptoms on a tree where there are abnormalities in the visible roots, bark, branches and leaves. Taken together, crown and damage ratings give an overall description of tree health. In addition to damage ratings, crews were asked to note the presence or absence of 10 different damages that can occur on trees in urban areas. These urban damage indicators are of specific interest to arborists and plant health specialists, and included signs of trunk/bark inclusions, cankers/decay, wounds/cracks, root/stem girdling, chlorotic/necrotic foliage, dead/dying crowns, borers/bark beetles, vines in crown, dead tree top and defoliation.

### Tree Mortality

Overall, 1.1 percent of the total urban tree population was standing dead. The species with the highest percent of its total urban population in standing dead trees were American elm, Russian olive, slippery elm, Eastern hophornbeam, and quaking aspen (Table 9).

Higher proportions of standing dead trees coupled with large tree populations may indicate potential insect, disease or environmental problems. Further evaluation and monitoring of these species is warranted. A high percent of dead trees does not necessarily indicate a health problem with the species, but could be due to the fact that some trees will naturally remain standing as dead trees for longer periods, or that they might be left standing dead depending upon the land use, risk associated with dead trees, and maintenance activities related to their removal. Thus, some species may have a higher proportion of dead trees as they are in locations where they are not immediately removed and therefore have a higher probability of being sampled as dead. Long-term monitoring of plots can help determine actual species mortality rates.

Land uses with the highest proportion of trees sampled as dead trees were agriculture/other and partially forested (Table 10).

**Table 9—Species with the largest proportion of their total population classified as dead, Wisconsin, 2012**

| <b>Species</b>      | <b>Population</b> | <b>Dead</b>    |
|---------------------|-------------------|----------------|
|                     | <i>number</i>     | <i>percent</i> |
| American elm        | 381,138           | 54.1           |
| Russian olive       | 56,193            | 50.0           |
| Slippery elm        | 252,871           | 44.4           |
| Eastern hophornbeam | 84,290            | 33.3           |
| Quaking aspen       | 140,484           | 20.0           |
| Black cherry        | 684,506           | 4.1            |
| Siberian elm        | 893,236           | 3.1            |
| Scotch pine         | 1,052,645         | 2.8            |

**Table 10—Percent of tree population classified as dead by land use, Wisconsin, 2012**

| <b>Land use</b>    | <b>Dead</b>    |
|--------------------|----------------|
|                    | <i>percent</i> |
| Agriculture/Other  | 6.3            |
| Partially forested | 4.8            |
| Residential        | 1.3            |
| Instit/Parks       | 0.5            |
| Comm/Trans         | 0.0            |
| Wetland            | 0.0            |

### **Crown Indicators of Forest Health**

Measurement of tree crowns can be used as an indicator of tree health. Large dense crowns are often indicative of vigorously growing trees, while small, sparsely foliated crowns signal trees with little or no growth and possibly in a state of decline. One measurement of crown health used to estimate tree condition is dieback (Table 11).

Crown dieback is demonstrative of tree health and is defined as recent mortality of small branches and twigs in the upper and outer portion of the trees' crown. Trees with crown dieback > 25 percent may be in decline, for both hardwoods and conifers (Steinman 1998).

**Table 11—Average percent crown dieback and percent of population for 20 most common species, Wisconsin, 2012**

| <b>Species</b>       | <b>Dieback</b> | <b>Population</b> |
|----------------------|----------------|-------------------|
|                      | <i>percent</i> |                   |
| Common lilac         | 5.0            | 11.4              |
| Northern white cedar | 4.5            | 10.7              |
| Apple spp            | 4.4            | 7.6               |
| European buckthorn   | 5.0            | 5.9               |
| Eastern red cedar    | 4.2            | 5.6               |
| Winged burning bush  | 5.0            | 5.2               |
| Silver maple         | 3.9            | 4.9               |
| Red maple            | 4.2            | 4.3               |
| White ash            | 5.0            | 3.9               |
| Boxelder             | 4.0            | 3.5               |
| Green ash            | 2.5            | 3.4               |
| Norway maple         | 1.3            | 2.5               |
| Scotch pine          | 1.6            | 2.5               |
| Northern hackberry   | 4.2            | 2.3               |
| Siberian elm         | 8.1            | 2.1               |
| Northern red oak     | 3.0            | 1.9               |
| American plum        | 5.0            | 1.6               |
| Black cherry         | 8.1            | 1.6               |
| Sugar maple          | 3.1            | 1.5               |
| Red pine             | 0.6            | 1.2               |

## Dieback

Based on the live tree population with a minimum sample size of 10, species with highest percent crown dieback were American elm and paper birch (Table 12). Higher levels of dieback may indicate a potential insect, disease, or environmental problem associated with this species and further evaluation is warranted.

**Table 12—Species with highest average percent dieback (minimum sample size = 10), Wisconsin, 2012**

| Species              | Sample        | Dieback        |
|----------------------|---------------|----------------|
|                      | <i>number</i> | <i>percent</i> |
| American elm         | 13            | 58.8           |
| Paper birch          | 11            | 15.0           |
| Black cherry         | 13            | 8.1            |
| Siberian elm         | 13            | 8.1            |
| White ash            | 23            | 5.0            |
| European buckthorn   | 10            | 5.0            |
| Common lilac         | 14            | 5.0            |
| Northern white cedar | 16            | 4.5            |
| Apple spp            | 25            | 4.4            |
| Red maple            | 20            | 4.2            |

## Damage Indicators of Forest Health

Signs of damage were recorded for all trees  $\geq 1$  inch d.b.h. and based upon the location of the damage. Damage at the root level or tree bole can potentially be more significant in terms of tree health as compared to damages in branches or upper bole. Up to three damages (see Glossary) were recorded per tree, with inspections starting at the roots and bole and progressing up the tree (U.S. Department of Agriculture 2005a).

The most common damage on trees was trunk/bark inclusion (32.8 percent of all trees) (Table 13). Trunk bark inclusions are places where branches are not strongly attached to the tree. A weak union occurs when two or more branches grow so closely together that bark grows between the branches and inside the union. This ingrown, or included, bark does not have the structural strength of wood and the union can become very weak. The inside bark may also act as a wedge and force the branch union to split apart. The land use with the greatest proportion of trees with trunk/bark inclusion was commercial/transportation (Table 13). Species with the highest percent of its population with trunk/bark inclusion were Northern white cedar and apple species (Table 14). Poor pruning practices can result in the formation of included trunk bark.

Cankers or signs of decay were the second most common damage (19.5 percent). Cankers or signs of decay are a serious concern in urban areas since the presence of wood decay increases the potential for tree failure. Apple species, common lilac, and silver maple had the highest proportions of their populations with cankers and signs of decay (Table 14).

Wounds or cracks were the third most common damage (5.3 percent), with green ash, Norway maple, and Northern red oak having the highest percent of its population exhibiting this damage (Table 14). A wound or crack is typically an area where bark is visibly damaged or absent on the stem of a tree, oftentimes resulting from an incident such as a lightning strike or lawn mower impacts.

The diameter distribution of trees with damage differed greatly between the damage classes (Figure 23). Damages that tended to occur more on larger trees (trees with a d.b.h. greater than 18 inches) were root/stem girdling and wounds or cracks. Damage that was most frequent on smaller trees (trees with a d.b.h. less than 3 inches) was trunk/bark inclusion and canker/decay.

In addition to the tree damages in Table 13, 2.1 percent of trees had overhead wire conflicts, 1.1 percent had issues with excess mulch, and 0.6 percent of the trees were noted as having topping and pruning damage (Table 15). Residential trees had the highest percent of its population with these maintenance and site issues.

**Table 13—Percent of trees with various types of damage by land use, Wisconsin, 2012.**

| Damage Type                | Ag/Other       | Comm/Trans | Part. Forest | Instit/Parks | Residential | Wetland | Total |
|----------------------------|----------------|------------|--------------|--------------|-------------|---------|-------|
|                            | <i>percent</i> |            |              |              |             |         |       |
| Trunk/bark inclusion       | 62.5           | 65.0       | 47.6         | 11.6         | 31.0        | 0.0     | 32.8  |
| Canker/decay               | 12.5           | 2.5        | 33.3         | 7.9          | 25.0        | 0.0     | 19.5  |
| Wound/crack                | 18.7           | 0.8        | 14.3         | 8.3          | 4.7         | 42.9    | 5.3   |
| Root/stem girdling         | 18.7           | 0.8        | 0.0          | 4.6          | 1.4         | 14.3    | 2.1   |
| Chlorotic/necrotic foliage | 0.0            | 0.0        | 0.0          | 0.0          | 1.1         | 0.0     | 0.8   |
| Dead/dying crown           | 0.0            | 0.0        | 0.0          | 0.9          | 0.8         | 0.0     | 0.7   |
| Borers/bark beetles        | 0.0            | 0.0        | 0.0          | 0.0          | 0.7         | 0.0     | 0.5   |
| Vines in crown             | 6.2            | 0.0        | 0.0          | 0.9          | 0.3         | 0.0     | 0.4   |
| Dead top                   | 0.0            | 0.0        | 0.0          | 0.0          | 0.4         | 0.0     | 0.3   |
| Defoliation                | 0.0            | 0.0        | 0.0          | 0.0          | 0.3         | 0.0     | 0.2   |

**Table 14—Species with greatest proportion of their population having the specific damage class, Wisconsin, 2012.** For example, 32.3 percent of apples had canker/decay

| Damage Class and Species          | Damage Class   | Damage Class and Species    | Damage Class   |
|-----------------------------------|----------------|-----------------------------|----------------|
|                                   | <i>percent</i> |                             | <i>percent</i> |
| <b>Canker/decay</b>               |                | <b>Root/stem girdling</b>   |                |
| Apple spp                         | 32.3           | Norway maple                | 27.8           |
| Common lilac                      | 8.3            | Silver maple                | 14.3           |
| Silver maple                      | 6.4            | Green ash                   | 13.3           |
| Eastern red cedar                 | 6.2            | Eastern white pine          | 12.5           |
| Red maple                         | 5.5            | Northern red oak            | 9.9            |
| <b>Chlorotic/necrotic foliage</b> |                | <b>Trunk/bark inclusion</b> |                |
| Silver maple                      | 70.0           | Northern white cedar        | 31.7           |
| Norway maple                      | 13.6           | Apple spp                   | 19.8           |
| Paper birch                       | 5.4            | Common lilac                | 9.9            |
| Boxelder                          | 2.7            | Silver maple                | 6.4            |
| Red maple                         | 2.7            | Eastern red cedar           | 4.3            |

*continued*



| Damage Class and Species | Damage Class   | Damage Class and Species | Damage Class   |
|--------------------------|----------------|--------------------------|----------------|
|                          | <i>percent</i> |                          | <i>percent</i> |
| <b>Dead/dying crown</b>  |                | <b>Vines in crown</b>    |                |
| Boxelder                 | 30.8           | Boxelder                 | 48.1           |
| Paper birch              | 19.8           | White ash                | 19.5           |
| Norway maple             | 9.9            | Shagbark hickory         | 16.7           |
| Red maple                | 9.9            | Red maple                | 15.7           |
| White ash                | 9.9            |                          |                |
| <b>Dead top</b>          |                | <b>Wound/crack</b>       |                |
| Boxelder                 | 33.5           | Green ash                | 25.6           |
| Paper birch              | 32.5           | Norway maple             | 11.6           |
| Red maple                | 16.2           | Northern red oak         | 7.7            |
|                          |                | Red maple                | 6.2            |
| <b>Defoliation</b>       |                | Honeylocust              | 5.8            |
| Paper birch              | 66.7           |                          |                |
| Norway maple             | 33.3           |                          |                |

Note: Only species with minimum sample size of 10 trees are included in this analysis to minimize effect of small sample size on percentage estimates. All species values are given in appendices E and F.

There were not 5 species having the specific damage class borers/bark beetles, dead top, defoliation, or vines in crown with a minimum sample size of 10 trees

**Table 15—Percent of trees with site or maintenance issue by land use, Wisconsin, 2012.**

| Site or Maintenance Issue | Ag/Other       | Comm/Trans | Part. Forest | Instit/Parks | Residential | Wetland | Total |
|---------------------------|----------------|------------|--------------|--------------|-------------|---------|-------|
|                           | <i>percent</i> |            |              |              |             |         |       |
| Overhead wires            | 0.0            | 0.0        | 0.0          | 0.0          | 3.0         | 0.0     | 2.1   |
| Excess mulch              | 0.0            | 0.0        | 0.0          | 0.0          | 1.6         | 0.0     | 1.1   |
| Topping/pruning           | 0.0            | 0.0        | 0.0          | 2.3          | 0.4         | 0.0     | 0.6   |
| Sidewalk-root conflict    | 0.0            | 0.0        | 0.0          | 0.0          | 0.4         | 0.0     | 0.3   |
| Improper planting         | 0.0            | 0.0        | 0.0          | 0.0          | 0.0         | 0.0     | 0.0   |

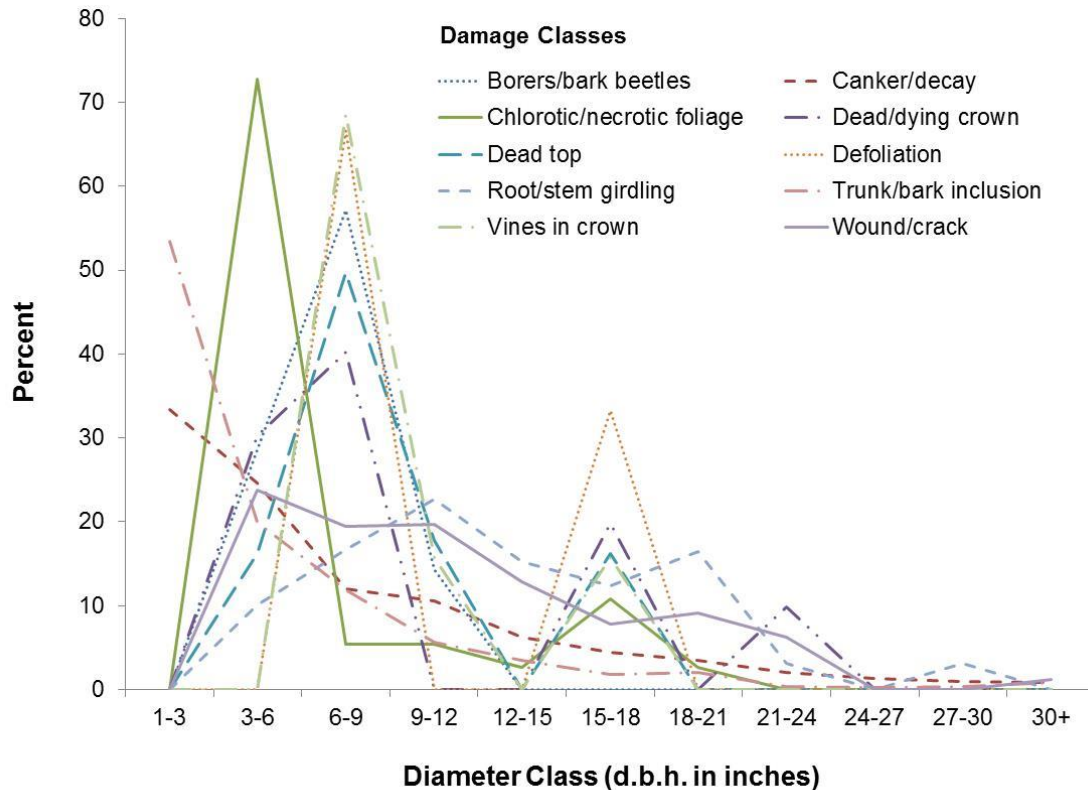


Figure 23—Diameter distribution of trees with various damage classes, Wisconsin, 2012.

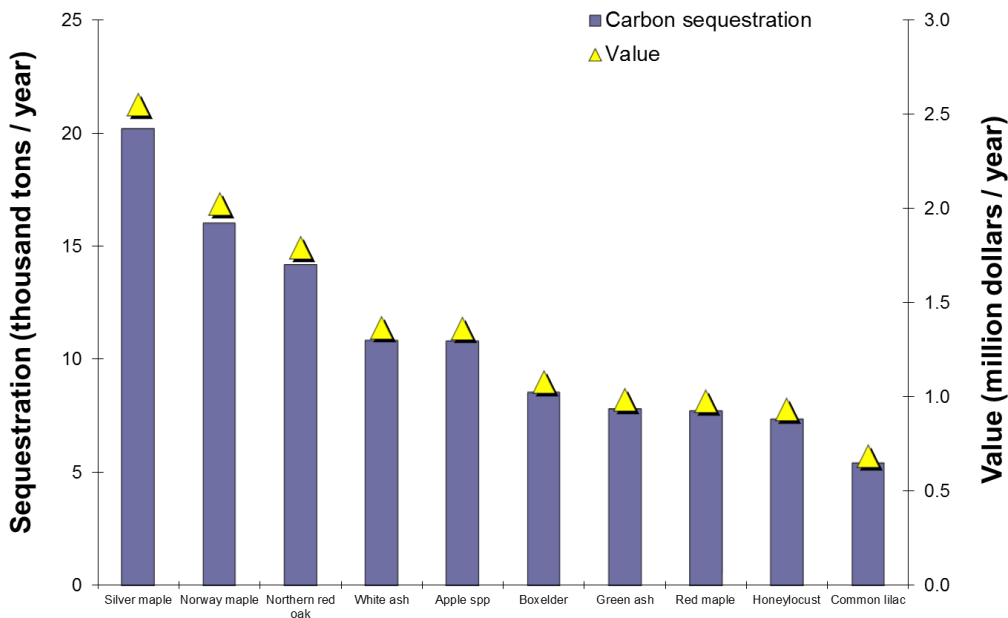
## Ecosystem Services and Values

### Carbon Storage by Urban Trees

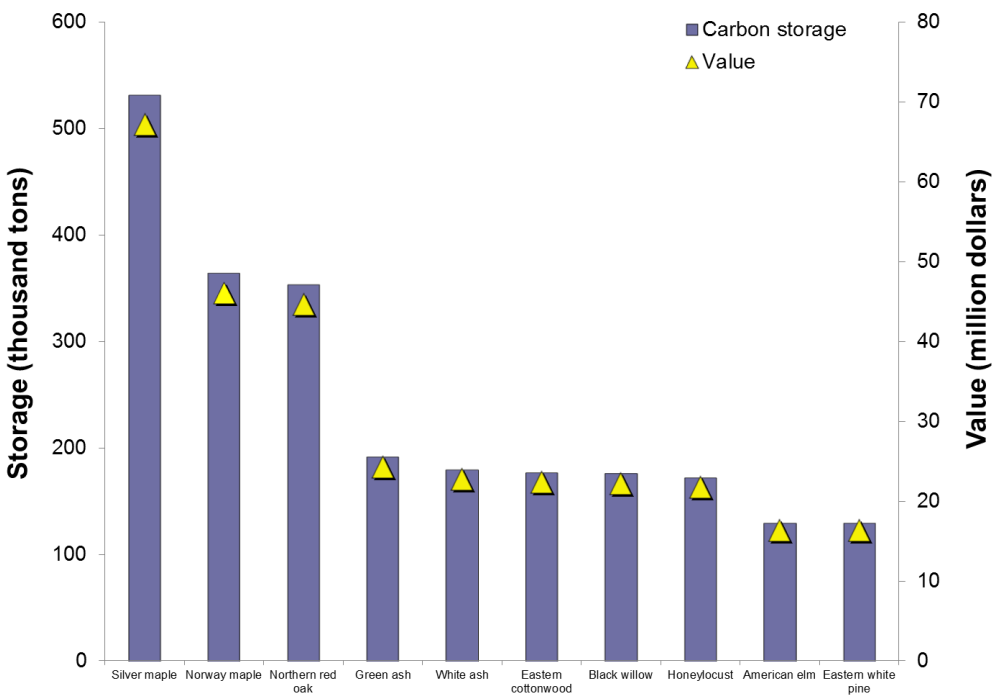
Trees can reduce the amount of carbon in the atmosphere by providing a net increase in new growth (carbon) every year (i.e., growth > decomposition). The amount of carbon annually sequestered is typically greatest in large healthy trees. Trees and forests are considered a significant sink of carbon within terrestrial ecosystems. The process by which a tree annually removes carbon from the atmosphere is called carbon sequestration. The amount or weight of carbon currently stored in a tree is considered carbon storage. To estimate monetary value associated with urban tree carbon storage and sequestration, carbon values were multiplied by \$139.33 per metric ton of carbon (range = \$44.00 -212.67 per tC) based on the estimated social costs of carbon for 2015 with a 3% discount rate (Interagency Working Group 2013).

The species that are estimated to sequester the most carbon annually are silver maple (9.5 percent of the total annual sequestration), Norway maple (7.6 percent), and Northern red oak (6.7 percent) (Figure 24). Sequestration estimates are based on estimates of growth, which are partially dependent upon tree condition. Annual carbon sequestration by urban trees is valued at \$26.8 million per year (Table 16). Carbon storage by Wisconsin's urban forest is estimated at 4.0 million tons (\$507 million). The species that are estimated to store the most carbon are silver

maple (13.3 percent of the total storage), Norway maple (9.1 percent), and Northern red oak (8.8 percent) (Figure 25).



**Figure 24—Annual carbon sequestration by top 10 species in terms of estimated annual gross carbon sequestration, Wisconsin, 2012.**



**Figure 25—Cumulative carbon storage by top 10 species, Wisconsin, 2012.**

**Table 16—Carbon storage and annual sequestration by land use, Wisconsin, 2012.**

| Land use                  | Carbon storage  |                 | Carbon sequestration |                  |
|---------------------------|-----------------|-----------------|----------------------|------------------|
|                           | tons            | dollars         | tons per year        | dollars per year |
|                           | <i>millions</i> | <i>millions</i> | <i>thousands</i>     | <i>millions</i>  |
| Wetland                   | 0.04            | 5.7             | 1.0                  | 0.1              |
| Residential               | 3.01            | 381.0           | 167.5                | 21.2             |
| Institution/Parks         | 0.63            | 79.7            | 27.3                 | 3.4              |
| Partially forested        | 0.16            | 19.9            | 3.1                  | 0.4              |
| Commercial/Transportation | 0.11            | 13.8            | 9.7                  | 1.2              |
| Agriculture/Other         | 0.05            | 6.5             | 3.4                  | 0.4              |
| Total urban               | 4.01            | 506.6           | 212.0                | 26.8             |

### Heating and Cooling Effects of Urban Trees

Trees affect energy consumption of buildings by shading buildings, providing evaporative cooling, and by blocking winter winds. Trees tend to reduce energy use in the summer and either increase or decrease the building energy use in the winter depending upon their location around the building. Tree effects on building energy use were based on field measurements of tree distance and direction to residential buildings.

In Wisconsin, interactions between trees and buildings are projected to decrease energy costs by \$78.9 million annually, based on 2012 energy costs (Table 17). Because of reduced building energy use, power plants will burn less fossil fuel and, therefore, release less carbon dioxide. Changes in energy use will lead to reduced emission of carbon of about 102,000 tons per year (375,000 tons of carbon dioxide per year) in Wisconsin (Table 18).

**Table 17—Annual monetary savings (\$) in residential energy expenditures during heating and cooling seasons, Wisconsin, 2012.**

|                   | Heating <sup>a</sup> | Cooling <sup>a</sup> | Total      |
|-------------------|----------------------|----------------------|------------|
| MBTU <sup>b</sup> | 47,862,000           | n/a                  | 47,862,000 |
| MWH <sup>c</sup>  | 3,666,000            | 27,356,000           | 31,022,000 |
| Carbon avoided    | 7,929,000            | 4,983,000            | 12,912,000 |

<sup>a</sup> Based on 2012 statewide energy costs (Energy Information Administration 2012a, 2012b, 2014a, 2014b) and 2013 social cost of carbon (Interagency Working Group 2013)

<sup>b</sup> MBTU – Million British Thermal Units (not used for cooling)

<sup>c</sup> MWH – Megawatt-hour

**Table 18—Annual energy savings (MBTU, MWH, or tons) due to trees near residential buildings, Wisconsin, 2012.**

|                                 | Heating   | Cooling | Total     |
|---------------------------------|-----------|---------|-----------|
| MBTU <sup>a</sup>               | 3,440,000 | n/a     | 3,440,000 |
| MWH <sup>b</sup>                | 28,000    | 206,000 | 234,000   |
| Carbon avoided (t) <sup>c</sup> | 63,000    | 39,000  | 102,000   |

<sup>a</sup> MBTU – Million British Thermal Units (not used for cooling)

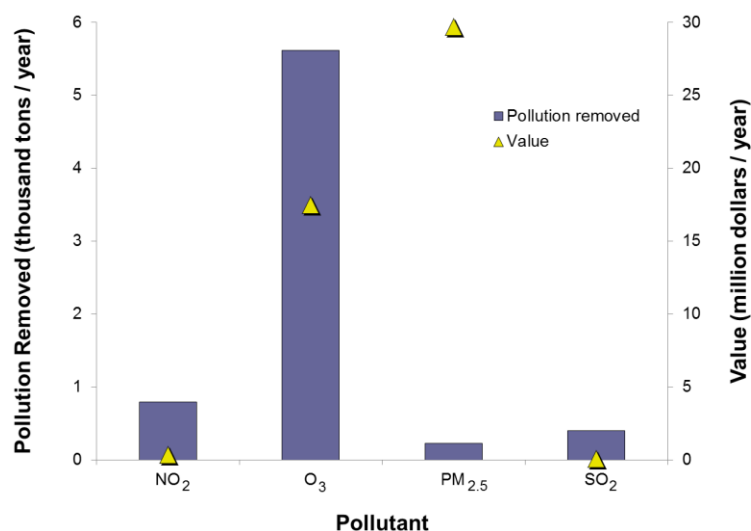
<sup>b</sup> MWH – Megawatt-hour

<sup>c</sup> To convert carbon estimates to carbon dioxide, multiply carbon value by 3.667

### Air Pollution Removal by Urban Trees

Poor air quality is a common problem in urban areas and leads to human health problems, ecosystem damage and reduced visibility. The urban forest can improve air quality by reducing ambient air temperatures, removing pollutants directly from the air, and reducing the energy use in buildings. However, trees emit volatile organic compounds (VOCs) that can contribute to ground level ozone formation. Yet, integrated studies have revealed that increasing tree cover will ultimately reduce ozone formation (Nowak 2005).

Air pollution removal by Wisconsin's urban forest is estimated for each county using the hourly pollution data from the monitors within the county, or nearest to the county, and weather data from the year 2010 (Nowak et al. 2014). Based on these inputs, the urban forests in Wisconsin are estimated to remove about 7,030 tons of pollution per year, with an associated annual value of about \$47.7 million. Pollutant removal rate was greatest for ozone (O<sub>3</sub>), followed by nitrogen dioxide (NO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>), and particulate matter < 2.5 microns (PM<sub>10</sub>) (Figure 26, Table 20). Health effect values were greatest for reduction in mortality in relation to reduced ozone and particulate matter concentrations (Table 20). Over 5,300 of acute respiratory symptoms were reduced to trees reducing pollution concentrations (Table 20).



**Figure 26—Annual pollution removal and value from the urban trees, Wisconsin, 2010.**

NO<sub>2</sub> = nitrogen dioxide, O<sub>3</sub> = ozone, PM<sub>2.5</sub> = fine particulate matter, SO<sub>2</sub> = sulfur dioxide

**Table 19—Annual pollution removal and value from the urban trees, Wisconsin, 2010.**NO<sub>2</sub> = nitrogen dioxide, O<sub>3</sub> = ozone, PM<sub>2.5</sub> = fine particulate matter, SO<sub>2</sub> = sulfur dioxide

| Pollutant         | Removal (t/yr) | Value (\$/yr) |
|-------------------|----------------|---------------|
| NO <sub>2</sub>   | 790            | 348,000       |
| O <sub>3</sub>    | 5,613          | 17,469,000    |
| PM <sub>2.5</sub> | 226            | 29,826,000    |
| SO <sub>2</sub>   | 402            | 52,000        |
| Total             | 7,030          | 47,695,000    |

**Table 20—Reduction in number of incidences and associated monetary value (\$) for various health effects due to pollutant reduction from urban forests, Wisconsin, 2010.**

| Pollutant         | Adverse Health Effect               | No. Inc <sup>a</sup> | Value      |
|-------------------|-------------------------------------|----------------------|------------|
| NO <sub>2</sub>   | Asthma Exacerbation                 | 2,534                | 212,400    |
|                   | Hospital Admissions                 | 4.3                  | 128,800    |
|                   | Acute Respiratory Symptoms          | 178                  | 5,600      |
|                   | Emergency Room Visits               | 1.8                  | 800        |
|                   | Total                               |                      | 347,600    |
| O <sub>3</sub>    | Mortality                           | 2.2                  | 16,855,400 |
|                   | Acute Respiratory Symptoms          | 3,780                | 323,200    |
|                   | School Loss Days                    | 1,613                | 158,300    |
|                   | Hospital Admissions                 | 4.3                  | 131,800    |
|                   | Emergency Room Visits               | 1.6                  | 700        |
|                   | Total                               |                      | 17,469,500 |
| PM <sub>2.5</sub> | Mortality                           | 3.8                  | 29,173,000 |
|                   | Chronic Bronchitis                  | 1.0                  | 285,200    |
|                   | Acute Respiratory Symptoms          | 1,318                | 129,200    |
|                   | Asthma Exacerbation                 | 1,170                | 95,100     |
|                   | Acute Myocardial Infarction         | 0.9                  | 79,400     |
|                   | Work Loss Days                      | 213                  | 35,100     |
|                   | Hospital Admissions, Cardiovascular | 0.4                  | 15,600     |
|                   | Hospital Admissions, Respiratory    | 0.3                  | 9,500      |
|                   | Lower Respiratory Symptoms          | 37                   | 1,900      |
|                   | Upper Respiratory Symptoms          | 22                   | 1,000      |
|                   | Emergency Room Visits               | 1.6                  | 700        |
|                   | Acute Bronchitis                    | 2.3                  | 200        |
|                   | Total                               |                      | 29,825,800 |
| SO <sub>2</sub>   | Hospital Admissions                 | 1.1                  | 33,200     |
|                   | Asthma Exacerbation                 | 224                  | 17,600     |
|                   | Acute Respiratory Symptoms          | 26                   | 800        |
|                   | Emergency Room Visits               | 0.7                  | 300        |
|                   |                                     |                      | 52,000     |

<sup>a</sup> reduction in number of incidences

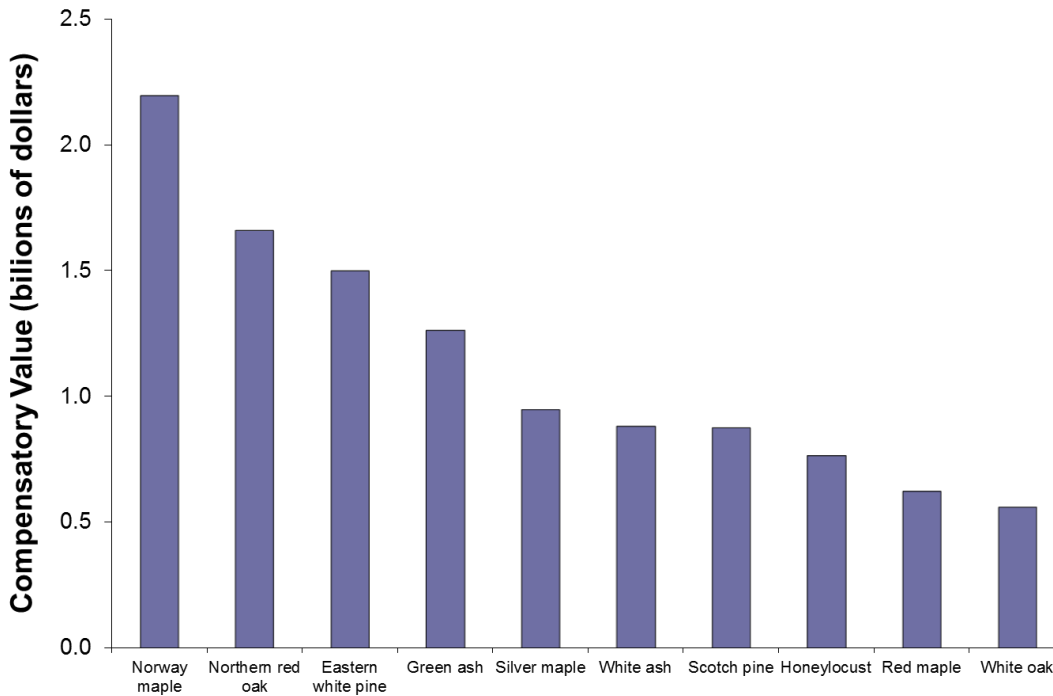
## Value of Wisconsin's Urban Forest

Urban forests have a structural value based on the tree resource itself, which includes compensatory value and carbon storage value. The compensatory value is an estimate of the value of the forest as a structural asset (e.g., how much should one be compensated for the loss of the physical structure of the tree). The urban forest also annually produces functional values based on the functions the tree performs. These estimated annual values can be either positive (e.g., air pollution removal, reduced building energy use) or negative (volatile organic compound emissions, increased building energy use) depending upon species and tree location. In North America, the most widely used method for estimating the compensatory value of trees was developed by the Council of Tree and Landscape Appraisers (CTLA) (Council of Tree and Landscape Appraisers 2000). Compensatory values represent compensation to owners for the loss of an individual tree. Compensatory values can be used for estimating compensation for tree losses, justifying and managing resources, and/or setting policies related to the management of urban trees. CTLA compensatory value calculations are based on tree and site characteristics, specifically tree trunk area (cross-sectional area at 4.5 feet above the ground), species, condition and location (Nowak et al., 2002, 2008).

The estimated compensatory value of Wisconsin's urban forest is about \$19.3 billion (Figure 27). The other estimated structural value of the urban forest is carbon storage (\$507 million). Estimated functional values include annual carbon sequestration (\$26.8 million per year), annual air pollution removal (\$47.7 million per year), and reduced annual building energy use (\$78.9 million per year) (Table 21). These values tend to increase with increased size and numbers of healthy trees.

**Table 21—Monetary value of urban forest structure and annual functions, Wisconsin, 2012**

| <b>Benefit</b>           | <b>Value</b>   |
|--------------------------|----------------|
|                          | <i>dollars</i> |
| Structural Values        |                |
| Compensatory value       | 19.3 billion   |
| Carbon storage           | 507 million    |
| Annual Functional Values |                |
| Carbon sequestration     | 26.8 million   |
| Pollution removal        | 47.7 million   |
| Energy reduction         | 78.9 million   |

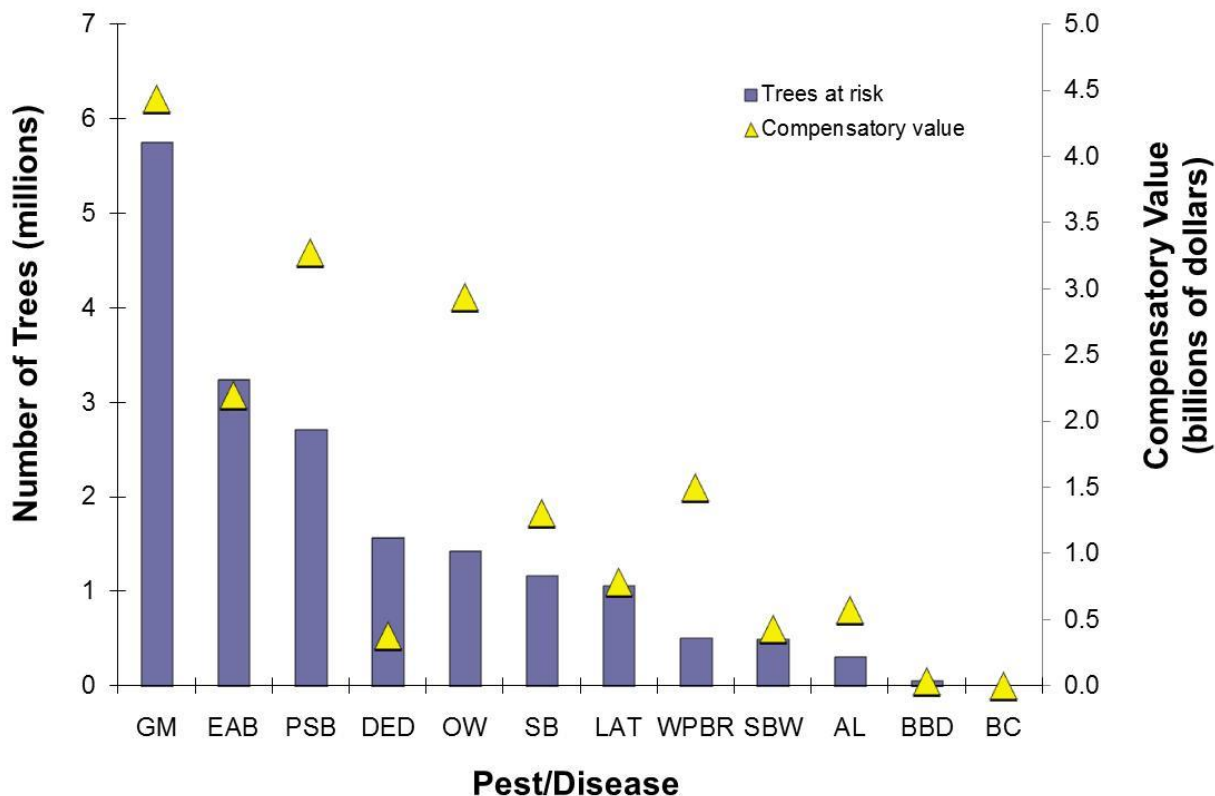


**Figure 27—Tree species with the greatest compensatory value, Wisconsin, 2012.**

### Potential Risk from Pests

Based on the species distribution, the urban forest is at risk from various pests that could potentially impact the health and sustainability of the urban forest resource (Table 22). Thirty-one native or exotic pests and diseases were analyzed using the i-Tree Eco model (Appendix F). Of these pests, only 12 occur within Wisconsin (Figure 28). The greatest potential risks from insect and diseases in Wisconsin are from gypsy moth (5.8 million trees at risk; 13.6 percent of live tree population), emerald ash borer (3.2 million trees; 7.6 percent) and pine shoot beetle (2.7 million trees; 6.4 percent). The greatest risk from insects and diseases outside of Wisconsin come from Asian longhorned beetle (11.0 million trees; 26.0 percent), southern pine beetle (3.7 million trees; 8.7 percent), and sirex wood wasp (2.5 million trees; 5.9 percent). Trees species sampled that are susceptible to pests in Wisconsin are given in Appendix F.





**Figure 28—Potential risk (number of trees) and compensatory value of the 12 pests/diseases found in the state, Wisconsin, 2012.**

As each pest/disease is likely to attack different host tree species, the implications for Wisconsin will vary. In Table 23, the number of trees at risk reflects only the known host species that are likely to experience mortality. The species host lists used for these pests/diseases can be found at [https://www.itreetools.org/eco/resources/iTreeEco\\_pest\\_host\\_list\\_06292016.xlsx](https://www.itreetools.org/eco/resources/iTreeEco_pest_host_list_06292016.xlsx).

**Table 22—Potential risk to urban trees by pests/diseases, Wisconsin, 2012**

| Abbreviation | Common Name             | Trees at Risk<br><i>number</i> | Compensatory Value<br><i>\$ millions</i> |
|--------------|-------------------------|--------------------------------|------------------------------------------|
| AL*          | Aspen Leafminer         | 309,000                        | 573                                      |
| ALB          | Asian Longhorned Beetle | 11,008,000                     | 6,940                                    |
| BBD*         | Beech Bark Disease      | 56,000                         | 37                                       |
| BC*          | Butternut Canker        | -                              | -                                        |
| CB           | Chestnut Blight         | -                              | -                                        |
| DA           | Dogwood Anthracnose     | -                              | -                                        |
| DED*         | Dutch Elm Disease       | 1,572,000                      | 380                                      |
| DFB          | Douglas-Fir Beetle      | -                              | -                                        |
| EAB*         | Emerald Ash Borer       | 3,235,000                      | 2,203                                    |

*continued*

| <b>Abbreviation</b> | <b>Common Name</b>                     | <b>Trees at Risk</b> | <b>Compensatory Value</b> |
|---------------------|----------------------------------------|----------------------|---------------------------|
|                     |                                        | <i>number</i>        | <i>\$ millions</i>        |
| FE                  | Fir Engraver                           | 56,000               | 19                        |
| FR                  | Fusiform Rust                          | -                    | -                         |
| GM*                 | Gypsy Moth                             | 5,751,000            | 4,442                     |
| GSOB                | Goldspotted Oak Borer                  | -                    | -                         |
| HWA                 | Hemlock Woolly Adelgid                 | -                    | -                         |
| JPB                 | Jeffrey Pine Beetle                    | -                    | -                         |
| LAT*                | Large Aspen Tortrix                    | 1,058,000            | 789                       |
| LWD                 | Laurel Wilt                            | -                    | -                         |
| MPB                 | Mountain Pine Beetle                   | 1,251,000            | 1,213                     |
| NSE                 | Northern Spruce Engraver               | 463,000              | 410                       |
| OW*                 | Oak Wilt                               | 1,425,000            | 2,941                     |
| POCRD               | Port-Orford-Cedar Root Disease         | -                    | -                         |
| PSB*                | Pine Shoot Beetle                      | 2,713,000            | 3,278                     |
| SB*                 | Spruce Beetle                          | 1,168,000            | 1,306                     |
| SBW*                | Spruce Budworm                         | 498,000              | 434                       |
| SOD                 | Sudden Oak Death                       | 830,000              | 1,659                     |
| SPB                 | Southern Pine Beetle                   | 3,682,000            | 4,245                     |
| SW                  | Sirex Wood Wasp                        | 2,515,000            | 2,939                     |
| TCD                 | Thousand Canker Disease                | 149,000              | 142                       |
| WPB                 | Western Pine Beetle                    | -                    | -                         |
| WPBR*               | White Pine Blister Rust (Eastern U.S.) | 511,000              | 1,501                     |
| WSB                 | Western Spruce Budworm                 | 2,276,000            | 2,200                     |

\* found in Wisconsin

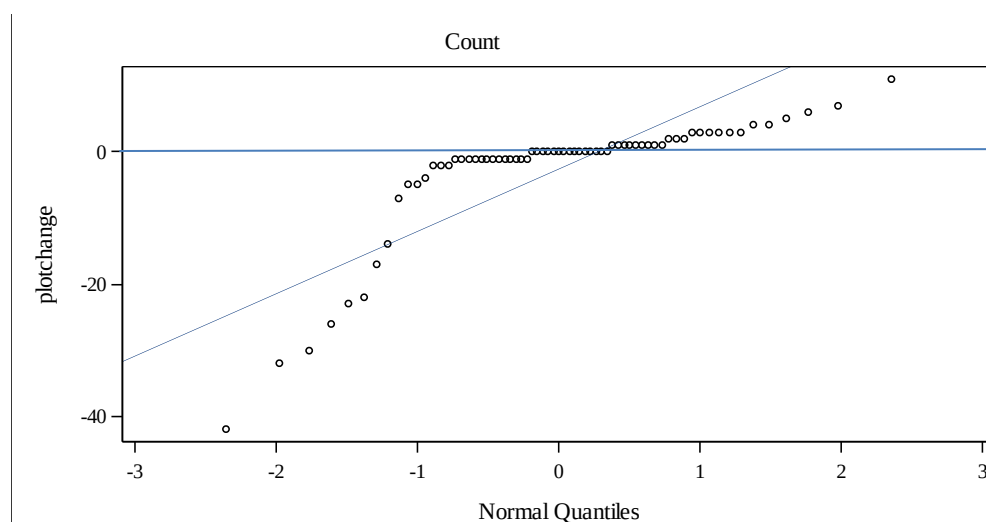
## Wisconsin Change Analysis

To estimate change in urban trees between 2002 and 2012, tree data that were measured in both years were assessed. This change analysis was only conducted on urban plots for trees greater than 5 inches d.b.h. that were collected on entire plots in both years. Only trees greater than 5 inches in d.b.h. could be analyzed because while the 2002 data had data on all trees sizes within the entire plot (28 forest plots and 111 urban plots), the 2012 data had 185 urban plots that used microplots to sample trees <5" d.b.h. Thus, in the end, there were only 91 urban plots that had remeasurement data, but only for trees greater than 5 inches d.b.h.

Overall the total tree population grew from 26.9 million trees in 2002 to 42.8 million in 2012, but the amount of urban land increased and the number and location of plots were different, except for the 91 remeasured plots. In addition, two tree species classified as trees in 2002 were not classified as trees in 2012 and were subsequently removed from the change analysis. Thus, the 91 plots are used to assess if there were statistically significant differences in the number of trees greater than 5 inches between 2002 and 2012.

To estimate changes in the Wisconsin urban tree population greater than 5 inches d.b.h., plot data were compared among the sampled years (2002, 2012). As the data were usually not normally distributed (Shapiro-Wilk test;  $\alpha = 0.05$ ), the Wilcoxon signed rank test ( $\alpha = 0.1$ ) was used on the paired plots to test for statistically significant differences in total population and species population totals between years. A minimum of 5 plots was used to test for statistical change.

Of the 91 plots, only 67 plots had trees greater than 5 inches in 2002. While the average number of trees greater than 5 inches d.b.h. dropped by 2.6 trees per plot, there was no statistically significant change in number of trees. As illustrated in Figure 29, 15 plots had no net change in number of trees greater than 5 inches, 24 plots had net increases (maximum increase = 11 trees) and 28 plots had a net decrease (maximum decrease = 42 trees).



**Figure 29—Distribution of change in trees greater than 5 inches d.b.h. Plot change = difference in number of trees greater than 5 inches between 2002 and 2012 on a plot.**

Analyzing change by species was hampered by a limited sample size for individual species (e.g., many species were only measured on one plot). One species that had a statistically significant increase in trees greater than 5 inches was silver maple (*Acer saccharinum*). Species with statistically significant decreases were white ash (*Fraxinus americana*) and sugar maple (*Acer saccharum*) (Table 23).

**Table 23—Average change in number of trees per plot by species.**

| Scientific name               | Common name          | n  | Change <sup>a</sup> | p value <sup>b</sup> |
|-------------------------------|----------------------|----|---------------------|----------------------|
| <i>Malus spp.</i>             | Crabapple            | 2  | 8.00                | .                    |
| <i>Euonymus alata</i>         | Winged burning bush  | 1  | 6.00                | .                    |
| <i>Syringa vulgaris</i>       | Common lilac         | 1  | 4.00                | .                    |
| <i>Acer saccharinum</i>       | Silver maple         | 9  | 2.22                | 0.008*               |
| <i>Crataegus mollis</i>       | Downy hawthorn       | 1  | 2.00                | .                    |
| <i>Pinus sylvestris</i>       | Scotch pine          | 2  | 2.00                | .                    |
| <i>Prunus americana</i>       | American plum        | 1  | 2.00                | .                    |
| <i>Rhamnus cathartica</i>     | European buckthorn   | 3  | 1.67                | .                    |
| <i>Abies concolor</i>         | White fir            | 1  | 1.00                | .                    |
| <i>Catalpa speciosa</i>       | Northern catalpa     | 1  | 1.00                | .                    |
| <i>Fraxinus spp.</i>          | Ash                  | 1  | 1.00                | .                    |
| <i>Morus alba</i>             | White mulberry       | 1  | 1.00                | .                    |
| <i>Populus deltoides</i>      | Eastern cottonwood   | 1  | 1.00                | .                    |
| <i>Quercus macrocarpa</i>     | Bur oak              | 2  | 1.00                | .                    |
| <i>Sorbus spp.</i>            | Mountain ash         | 1  | 1.00                | .                    |
| <i>Ulmus spp.</i>             | Elm                  | 1  | 1.00                | .                    |
| <i>Pinus banksiana</i>        | Jack pine            | 2  | 0.50                | .                    |
| <i>Pinus resinosa</i>         | Red pine             | 4  | 0.50                | .                    |
| <i>Quercus ellipsoidalis</i>  | Northern pin oak     | 2  | 0.50                | .                    |
| <i>Gleditsia triacanthos</i>  | Honeylocust          | 7  | 0.43                | 0.250                |
| <i>Juniperus virginiana</i>   | Eastern red cedar    | 5  | 0.20                | 1.000                |
| <i>Picea abies</i>            | Norway spruce        | 5  | 0.20                | 1.000                |
| <i>Picea pungens</i>          | Blue spruce          | 8  | 0.13                | 1.000                |
| <i>Acer platanoides</i>       | Norway maple         | 16 | 0.00                | 1.000                |
| <i>Aesculus glabra</i>        | Ohio buckeye         | 1  | 0.00                | .                    |
| <i>Cornus florida</i>         | Flowering dogwood    | 1  | 0.00                | .                    |
| <i>Elaeagnus angustifolia</i> | Russian olive        | 1  | 0.00                | .                    |
| <i>Pinus nigra</i>            | Austrian pine        | 1  | 0.00                | .                    |
| <i>Pinus strobus</i>          | Eastern white pine   | 7  | 0.00                | 1.000                |
| <i>Populus grandidentata</i>  | Bigtooth aspen       | 1  | 0.00                | .                    |
| <i>Prunus spp.</i>            | Cherry               | 3  | 0.00                | .                    |
| <i>Prunus serotina</i>        | Black cherry         | 4  | 0.00                | .                    |
| <i>Quercus rubra</i>          | Northern red oak     | 9  | 0.00                | 1.000                |
| <i>Salix spp.</i>             | Willow               | 1  | 0.00                | .                    |
| <i>Salix babylonica</i>       | Weeping willow       | 1  | 0.00                | .                    |
| <i>Picea glauca</i>           | White spruce         | 16 | -0.13               | 1.000                |
| <i>Populus tremuloides</i>    | Quaking aspen        | 3  | -0.33               | .                    |
| <i>Prunus pensylvanica</i>    | Pin cherry           | 2  | -0.50               | .                    |
| <i>Thuja occidentalis</i>     | Northern white cedar | 7  | -0.57               | 0.469                |
| <i>Betula papyrifera</i>      | Paper birch          | 7  | -0.71               | 0.500                |

*continued*

| Scientific name               | Common name         | n  | Change <sup>a</sup> | p value <sup>b</sup> |
|-------------------------------|---------------------|----|---------------------|----------------------|
| <i>Betula nigra</i>           | River birch         | 1  | -1.00               | .                    |
| <i>Carpinus caroliniana</i>   | American hornbeam   | 1  | -1.00               | .                    |
| <i>Fagus grandifolia</i>      | American beech      | 1  | -1.00               | .                    |
| <i>Fraxinus nigra</i>         | Black ash           | 1  | -1.00               | .                    |
| <i>Ostrya virginiana</i>      | Eastern hophornbeam | 2  | -1.00               | .                    |
| <i>Quercus marilandica</i>    | Blackjack oak       | 3  | -1.00               | .                    |
| <i>Ulmus americana</i>        | American elm        | 5  | -1.20               | 0.250                |
| <i>Ulmus pumila</i>           | Siberian elm        | 4  | -1.25               | .                    |
| <i>Fraxinus pennsylvanica</i> | Green ash           | 10 | -1.40               | 0.547                |
| <i>Acer saccharum</i>         | Sugar maple         | 7  | -1.43               | 0.031*               |
| <i>Celtis occidentalis</i>    | Northern hackberry  | 3  | -1.67               | .                    |
| <i>Crataegus phaenopyrum</i>  | Washington hawthorn | 1  | -2.00               | .                    |
| <i>Juglans nigra</i>          | Black walnut        | 2  | -2.00               | .                    |
| <i>Prunus virginiana</i>      | Common chokecherry  | 1  | -2.00               | .                    |
| <i>Quercus alba</i>           | White oak           | 2  | -2.50               | .                    |
| <i>Morus rubra</i>            | Red mulberry        | 5  | -2.60               | 0.125                |
| <i>Abies balsamea</i>         | Balsam fir          | 1  | -3.00               | .                    |
| <i>Crataegus monogyna</i>     | Oneseed hawthorn    | 1  | -3.00               | .                    |
| <i>Malus pumila</i>           | Apple               | 2  | -3.50               | .                    |
| <i>Acer rubrum</i>            | Red maple           | 6  | -3.67               | 0.375                |
| <i>Prunus serrulata</i>       | Kwanzan cherry      | 3  | -4.33               | .                    |
| <i>Carya ovalis</i>           | Red hickory         | 1  | -5.00               | .                    |
| <i>Fraxinus americana</i>     | White ash           | 10 | -5.40               | 0.062*               |
| <i>Acer negundo</i>           | Boxelder            | 10 | -5.80               | 0.191                |
| <i>Ulmus rubra</i>            | Slippery elm        | 2  | -7.50               | .                    |

n = number of plots with given species (sample size)

. = sample did not meet selected minimum sample size of 5 plots for statistical analysis

na – not applicable

<sup>a</sup> average change in number of trees per plot

<sup>b</sup> Wilcoxon signed rank test

\* statistically significant difference at alpha = 0.10

## DISCUSSION

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### 2012 Results

Trees in Wisconsin's urban forest are mostly found within residential areas. Residential areas account of 46.3 percent of the area and 69 percent of the tree population. Thus residential lands are providing essential forest services to the people of Wisconsin. As this study focused predominantly on the non-forested urban areas, it is also important to note that forest lands within urban areas also contributed substantial services to urban populations. In the 2002 assessments, forests in urban areas contributed about 79% of the total number of urban trees in Wisconsin. As urban lands and urban populations increase, urban trees, particularly in forests and on residential lands will be essential to sustain as these trees provide the greatest amount of services and values to urban residents.

The urban forests of Wisconsin are fairly rich in terms of species, with 65 species being sampled. However, in terms of size distribution, the top 6 species in terms of number of trees are all small trees / large shrubs; none of these species reaching over 15 inches in diameter. The top six species in terms of numbers are: common lilac (all less than 3 inches d.b.h.), Northern white cedar, apples (all less than 12 inches d.b.h.); European buckthorn (invasive species, all less than 9 inches d.b.h.), Eastern red cedar and winged burning bush (all less than 3 inches d.b.h.). These six species comprise 46.4 percent of the total tree population, but only 14.2 percent of the leaf area. Thus these trees are important in terms of number of stems to manage, but relatively unimportant in terms of impact or benefits provided to the local residents.

The more important trees in terms of benefits are the large tree species. Only 25 of the 65 species encountered reached at least 15 inches in diameter, and these 25 species only accounted for 37.8 percent of the tree population, but 70 percent of the total leaf area. The most dominant of the species are silver maple, Norway maple (non-regulated invasive species), green ash, Northern red oak and Eastern white pine, which account for 13.9 percent of the population, but 37 percent of total basal area and 33 percent of total leaf area. One of these species, green ash, is likely to decline significantly in the coming years due to the emerald ash borer. Two other species, Norway maple and Eastern white pine, are likely to decline due to limited recent planting or natural regeneration. Norway maple only has 5.8 percent of its population less than 6 inches in diameter and over 34 percent greater than 18 inches in diameter. Eastern white pine has 0 percent of its population less than 6 inches in diameter and over 36 percent greater than 18 inches in diameter. There likely are not enough small trees currently to sustain these species' populations at current levels and these populations will likely decline as the older and larger trees pass away. With regards to Norway maple, which is classified as a non-regulated invasive species, it is either not invading many urban areas or there are controls to keep regeneration in check as there were not many small Norway maples encountered in the sample. Thus three of the five most important urban species in Wisconsin are likely to decline in importance and impact in the coming years. The question for the residents of Wisconsin is – what species, if any, will take their place in providing benefits to society. If not replaced, or replaced with smaller, more common species, then urban forest benefits to society will decline.

The urban forests of Wisconsin provide significant social and environmental benefits to the people of Wisconsin. The resource itself is worth about 20 billion dollars and provides annual benefits of more than \$150 million per year. These annual benefits are only based on three benefits that were quantified: air pollution removal, carbon sequestration and building energy effects. Urban forests provide numerous other benefits (e.g., air temperature reduction, aesthetics, improved human health wildlife habitat, improved water quality, reduced flooding, etc.) yet to be valued. However, urban forest management comes with direct costs of maintenance and indirect costs associated with negative services (e.g., tree pollen). By understanding the urban forests and its impacts, urban forest management plans can be developed to optimize the benefits and minimize costs in developing sustainable and healthy urban forests for both current and future generations.

There are four dominant threats that are likely to affect Wisconsin's urban forests in the coming years. These threats are:

1) Development – as evidenced by the expansion of urban land in the state, this impact also includes perpetual development or redevelopment within existing urban areas. This development often either removes existing trees, or limits the expansion or regeneration of trees through the development of hardscapes that prohibit trees, or mowing that prevents regeneration of trees.

2) Insects and diseases – new insects and diseases, particularly potentially devastating ones like emerald ash borer, Asian longhorned beetle and sudden oak death have the potential to create large changes in urban forests in a relative short period of time. Management to limit the introduction and/or impact of the pests is critical to sustaining forest health. Emerald ash borer is already in Wisconsin as are other insects and diseases, but additional pests that are not within the state could have a substantial impact if introduced into Wisconsin's urban forest. Millions of trees are currently at risk to emerald ash borer and gypsy moth, the two most potentially devastating pests that already exist within Wisconsin's urban forest.

3) Invasive species – invasive species are an issue in Wisconsin's urban forest with about 20 percent of the trees classified as invasive. Nine species encountered are classified as invasive, with two invasive species (European buckthorn and winged burning bush) in the top 10 species in terms of total numbers and one species (Norway maple) providing the second most leaf area of any species (8.4 percent of total leaf area). While Norway maple appears to be heading for a decline in population due to the limited number of small diameter trees encountered, the other invasive plants could have an increasing influence on Wisconsin's urban forest (particularly buckthorn and winged burning bush).

4) Environmental change – though not directly addressed in this assessment, environmental change will likely influence the composition of Wisconsin's urban forest in the years to come. As temperature and rainfall patterns change, some species will perform better, and some worse, under the new environmental conditions. Thus species composition will change as some species will decline and others perform better, or possibly new species are introduced that will perform well in the altered environment. In addition to potential species shifts, severe environmental extremes could substantially impact forest structure and composition. Extreme wind, heat, rain or drought events could lead to significant losses in tree population in a relative short period of

time. Forest management to compensate for these extreme events (e.g., watering, pruning) may be needed to sustain urban forest health through these extreme events.

## **2002-2012 Change Analysis**

Urban forest change is a certainty. Forests always change and always will change. Data on tree change in the last 10 years reveals that one species had a significant increase: silver maple and two species had significant declines: white ash (likely an artifact of emerald ash borer) and sugar maple. These changes could be due to many factors, including changes in planting or natural regeneration rates of these species. As emerald ash borer (EAB) continues to spread in Wisconsin, management decisions and activities of communities and the public are changing due to the actual or anticipated arrival of EAB. While the insect itself likely contributed to the observed decrease in the average number of white ash trees greater than 5 inches d.b.h., pre-emptive removals of ash by municipalities and private homeowners may have contributed as well.

While not statistically significant, the overall trend in the last 10 years has been a decline in the density of trees greater than 5 inches in diameter. More long-term monitoring of urban forests will help reveal patterns and possible reasons for change. Through better understanding of the amounts and types of changes that are occurring, forest management plans can be developed to better direct urban forests to a more sustainable and desirable future.

## **Methodology Evaluation**

A major purpose of the 2012 study was to evaluate the Forest Service's Urban Forest Inventory and Analysis protocol as a means of characterizing and monitoring the state's urban forest resource over time. The comparison of the 2002 protocol and the 2012 protocol provide key insights into the opportunities and challenges of long-term urban forest monitoring at the statewide scale.

The first challenge was due to changes in data acquisition protocols between the years. While changes can occur due to procedural improvements, consistency in plot locations and remeasurement are essential. Some new plots are expected through time as urban areas expand; and some plots are expected to be lost through time due to loss of access permission. However, the lack of 2012 remeasurements of FIA forested plots limited the ability to assess change through time.

Plot measurements also changed between years. In 2002, all trees greater than one-inch d.b.h. were measured on the entire plot, regardless of species. In 2012, only trees greater than 5 inches d.b.h. were measured on the plot and trees less than 5 inches d.b.h. measured on microplots. This change negated the ability to assess change for trees less than 5 inches d.b.h. Also in 2012, tree species measured only included species on the USFS FIA tally-list, so some species were dropped from the original 2002 tally, which did not use a tally-list, but rather included all woody species greater than one-inch d.b.h.



One of the most significant observations from the two studies was that the traditional FIA plot density of 1 plot per 6,000 acres is insufficient to capture enough urban trees to produce statistically comparable results. There is a greater species diversity and lower tree density in the urban forest than in rural forests, so smaller sample sizes limits the ability to detect change and lowers the precision of the estimates related to the diverse tree population.

The plot-based Urban FIA program provides forest composition and characterization across all urban forest ownerships using a nationally standardized data gathering protocol and consistently trained and certified crews. It is now designed to be a continuous inventory, sampling a portion of all plots every year. Analysis is also nationally standardized and supported by the Forest Service. It combines both urban ecosystem services model outputs through i-Tree tools and traditional FIA timberland data outputs. Analysis and data tables from these analyses will be publically available online. No other inventory program exists that provides this level of urban forest resource information.

The urban FIA program has established urban forest monitoring programs in Austin, TX (Nowak et al. 2016); Baltimore, MD; Houston, TX; Providence, RI; Madison and Milwaukee, WI; St. Louis, MO; and Des Moines IA. Planned future program areas include San Antonio, TX; Springfield and Kansas City, MO; Denver and Fort Collins, CO; Burlington, VT; Rochester, NY; Pittsburgh and Philadelphia, PA; Detroit, MI; Minneapolis and St. Paul, MN; Cleveland, OH; Chicago, IL; Lincoln, NE; Wichita, KS; and San Diego, CA.

## **CONCLUSION**

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With the growth of urban areas and high concentration of human populations in urban areas, data on urban forests are becoming more essential, particularly as urban trees can have significant impacts on numerous local to global environmental issues and regulations (e.g., Clean Air Act, Clean Water Act). Having long-term data on this important resource will allow assessing changes in forest composition and associated ecosystem values. In addition, monitoring can provide essential data in relation to the potential use of urban forests within regulations set to protect human health and well-being. Not only does an urban forest monitoring program provide essential data for management and integration within local to international policies, the long-term data provide essential information for sustaining urban forest canopy cover and health.

Management of any natural resource requires knowledge of type, size and quantity of the resource. Inventories and assessments to monitor composition, size and health provide information about the current status of urban forests, and, if compiled periodically, information about how the forest changes over time. This current study is the first statewide assessment of urban forest change. Continued measurements could monitor how urban forests change over time due to urbanization pressures, management techniques, and the influence of stresses, such as invasive pests or extreme weather events. In addition, information could be compiled regarding which species perform the best under differing urban conditions and how long various species live on average in urban areas.

The results of the 2002 pilot demonstrated how a statewide urban forest inventory and analysis can be used to show the value of the resource, and to establish goals for its sustainable management. The 2012 remeasurement not only provided more current information, but identified gaps in desired analyses. Insights gained from this comparison will refine protocols to improve the precision of the estimates of the current urban forest status and its future trends. While plot-based inventories have certain inherent limitations, they are a critical component of a complete urban forest resource analysis because they characterize all urban forest land both public and private. With a plot sample intensification to improve precision, the USDA Forest Service's new continuous UFIA protocol will help meet Wisconsin's need for an all-lands component of its statewide urban forest assessment program.

Statewide estimates of urban forest and tree resources only exist for a few States in addition to Wisconsin (Indiana and Tennessee) (Nowak et al. 2007, Nowak et al. 2012), but only Wisconsin is implementing a statewide, long-term urban forest monitoring program. Additionally, long-term monitoring of metropolitan areas by the Forest Service FIA program began in 2014 with many cities currently being monitored, or to be monitored in the near future.

To sustain the health, environmental and social benefits received from urban forests, specific urban forest management plans and goals need to be developed. These plans also need to be dynamic due to the continuous forces of change that alter urban forest environments. Long-term urban forest monitoring data will provide the information necessary to make these specific, goal-oriented management plans. In addition, the monitoring data will allow for continual updating of plans to ensure that plan goals are met to facilitate forest sustainability. Long-term monitoring data will also reveal what factors (e.g., insects, diseases, decay, etc.) most threaten urban forest sustainability so that corrective management actions can be taken. Data from urban forest monitoring programs could be incorporated within State and local urban forest planning and management regimes to allow local constituents to develop canopy goals and/or tree planting goals to sustain or enhance urban forest canopy across the State.

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## GLOSSARY

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**Biomass**—The aboveground weight of wood and bark in measured live trees. Biomass is expressed as oven-dry weight and the units are tons.

**Crown**—The part of a tree or woody plant bearing live branches or foliage.

**Crown dieback**—Recent mortality of branches with fine twigs, which begins at the terminal portion of a branch and proceeds toward the trunk. Dieback is only considered when it occurs in the upper and outer portions of the tree. Dead branches in the lower live crown are not considered as part of crown dieback, unless there is continuous dieback from the upper and outer crown down to those branches.

### **Damage/causal agents:**

- Trunk (canker or decay)—Presence of decay fungi; hollow areas or weak, rotten wood.
- Trunk (wound or crack)—Physical damage to the main stem or stems of a tree. Bark is visibly damaged or absent. This includes: lightning strikes, lawn mower and line trimmer damage. Wound or crack must be at least 25 percent of circumference or over a 3 foot vertical section.
- Roots (stem girdling)—Roots that encircle the trunk of tree may cause bark and wood tissue compression. Roots stem girdling must be at least 25 percent of circumference of stem at base.
- Trunk/branches (bark inclusion)—“V” branching pattern. Signs of bark inclusion are evident. Bark inclusion is bark enclosed between branches with narrow angles of attachment, forming a wedge between the branches.
- Trunk (severe topping or poor pruning)—Tree has been reduced to a single “pole” due to severe overpruning and branch removal. Poor pruning techniques include leaving stubs outside the branch collar, cutting into the branch collar. Severe topping or poor pruning must be  $\geq 30$  percent of crown.
- Trunk (excessive mulch)—Mulch piled around the tree trunk. Root flare is not visible at base of trunk. Mulch piled high around stem and mulch depth  $> 8$  inches.
- Branches (dead or dying crown)—Dead branches in crown. Dead or dying crown must be  $\geq 30$  percent of crown.
- Leaves (chlorotic/necrotic)—Leaves are chlorotic, necrotic, wilted, abnormal size/shape or have been defoliated from branches. Chlorotic/necrotic foliage must be  $\geq 30$  percent of crown.

- **Branches (vines in crown)**—Vines present in tree. Vines in crown must be  $\geq 30$  percent of crown volume.
- **Main stem (dead top)**—Main stem dead or missing. Main stem dead top must be at least 30 percent of tree height.
- **Sidewalk (conflict with roots)**—Damage to sidewalk directly caused by roots.
- **Overhead wires (conflict with tree crown)**—Tree crown (branches or leaves) are within 5 feet of utility wires.
- **Improper planting (trees  $\leq 10$  inches d.b.h.)**—Evidence that burlap, twine, or root ball wire was not removed prior to planting. Any of the following are visible at the soil surface: burlap, twine, or cage/wire.

**Diameter at breast height (d.b.h.)**—The diameter for tree stem, located at 4.5 feet above the ground (breast height) on the uphill side of a tree. The point of diameter measurement may vary on abnormally formed trees.

**Foliage transparency**—The amount of skylight visible through microholes in the live portion of the crown, i.e. where you see foliage, normal or damaged, or remnants of its recent presence. Recently defoliated branches are included in foliage transparency measurements. Macroholes are excluded unless they are the result of recent defoliation. Dieback and dead branches are always excluded from the estimate. Foliage transparency is different from crown density because it emphasizes foliage and ignores stems, branches, fruits, and holes in the crown.

**Forest** — The standard definition of forest land, used by the Forest Inventory and Analysis (FIA) Program, is an area at least 1 acre in size, at least 120 feet wide, at least 10 percent stocked with trees, and with an understory undisturbed by another nonforest land use.

**i-Tree Eco**—An i-Tree model formerly known as the Urban Forest Effects (UFORE) model that uses field data in conjunction with air pollution and meteorological inputs to quantify urban forest structure (such as species composition, tree density, tree health, leaf area, and biomass), environmental services (such as air pollution removal, carbon storage and sequestration, effects of trees on energy use), and potential pest impacts.

**Land use**—The purpose of human activity on the land; it is usually, but not always, related to land cover. Land use categories used were:

- **Agriculture/other** - land managed for crops, pasture, or other agricultural uses and land not classified within any of the other land use categories.
- **Commercial/transportation** - developed land used for commercial businesses or industrial purposes and transportation corridors, limited access roadways, airports, or railway. Trees along arterial streets were included as part of the adjacent land use (e.g., a street tree in front of a residence was classified as residential).

- Partially forested - plots with a portion of its area meeting the FIA definition of forest.
- Institutional/park - developed land used for schools, government or religious buildings, or hospital/medical complexes and land used primarily for parks, green/open space, or golf courses.
- Residential - developed land used primarily for human dwellings.
- Wetland - areas where water covers soil all or part of the time

**Maintained**—The maintained classification was applied to each tree in our sample. It designates the surrounding area in which the tree is located. Maintained areas are regularly impacted by mowing, mulching, or other types of landscape care. It does not imply that the tree is maintained.

**Tree**—A woody perennial plant, typically large, with a single well-defined stem carrying a more or less definite crown; sometimes defined as attaining a minimum diameter of 3 inches and a minimum height of 15 feet at maturity. For FIA, any plant on the tree list in the current field manual is measured as a tree.

**Urban**—Urban areas were classified based on the 2000 census and consisted of: all territory, population, and housing units located within either urbanized areas or urban clusters (U.S. Department of Commerce 2011). Urbanized area and urban cluster boundaries encompass densely settled territories, which generally consist of: (a) cluster of one or more block groups or census blocks with a population density of at least 1,000 people per square mile, (b) surrounding block groups and census blocks with a population density of 500 people per square mile, and (c) less densely settled blocks that form enclaves or indentations, or are used to connect discontinuous areas. Urbanized areas consist of densely settled territory that has  $\geq 50,000$  people; urban clusters consist of densely settled territory that has  $\geq 2,500$  people but  $< 50,000$  people.

**Urban forest**—Term used for all trees within nonforested urban land.

#### **Metric equivalents**

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1 acre = 4,046.87 m<sup>2</sup> or 0.404687 ha

1 cubic foot = 0.028317 m<sup>3</sup>

1 inch = 2.54 cm or 0.0254 m

Breast height (4.5 feet) = 1.374 m above the ground

1 square foot = 929.03 cm<sup>2</sup> or 0.0929 m<sup>2</sup>

1 square foot of basal area per acre = 0.229568 m<sup>2</sup>/ha

1 cubic foot per acre = 0.0699722 m<sup>3</sup>/ha

1 pound = 0.454 kg

1 ton = 0.908 metric ton

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## APPENDIX A—METHODS

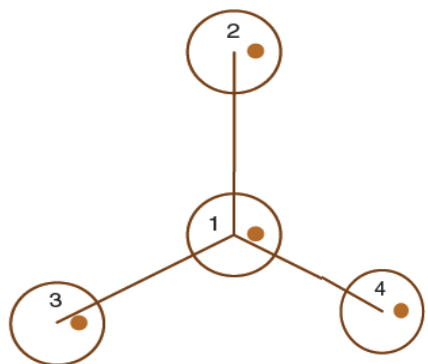
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Urban areas were classified based on the 2000 census and consisted of: (all territory, population, and housing units located within either urbanized areas or urban clusters (U.S. Department of Commerce 2011). Urbanized area and urban cluster boundaries encompass densely settled territories, which generally consist of (a) a cluster of one or more block groups or census blocks with a population density of at least 1,000 people per square mile, (b) surrounding block groups and census blocks with a population density of 500 people per square mile, and (c) less densely settled blocks that form enclaves or indentations, or are used to connect discontinuous areas. Urbanized areas consist of densely settled territory that contains  $\geq 50,000$  people; urban clusters consist of densely settled territory that has  $\geq 2,500$  people but  $< 50,000$  people.

Within the urban areas, forest land exists. The U.S. Department of Agriculture (USDA) Forest Service's Forest Inventory and Analysis (FIA) program define forests as areas at least 1 acre in size, at least 120 feet wide, and at least 10 percent stocked. Forested plots must also have an understory that is undisturbed by another land use (U.S. Department of Agriculture 2010). For the 2012 assessment, plots falling with forested land were excluded and only non-forested ("urban forest") plots were measured (Table A.1).

On each plot, trees and saplings were measured. Variables measured on the trees and the plot included species, diameter, height, height to live crown, crown dimensions, foliage transparency, tree damage, distance of tree to buildings, ground cover, impervious surface on plot, condition class, and ownership. Each plot consisted of four subplots with microplots contained within the subplot (Figure A.1). Data were collected on all trees  $\geq 5$  inches d.b.h. on four  $1/24^{\text{th}}$  acre subplots and on saplings between 1 and 4.9 inches d.b.h. on four  $1/300^{\text{th}}$  acre microplots (data collection methods are described in detail in U.S. Department of Agriculture 2005a, 2006).

Methods of the assessment of ecosystem services using the i-Tree model are detailed in Nowak et al. (2008). Additional forest health data were collected on urban trees, including estimates of tree crown condition (U.S. Department of Agriculture 2007) and tree damage (U.S. Department of Agriculture 2006).



**Figure A.1—FIA plot configuration.**

**Table A.1—Urban plots by land use / plot status in Wisconsin, 2012**

| Land use/ plot status     | Sampled       |            |
|---------------------------|---------------|------------|
|                           | Plots         | Live trees |
|                           | <i>number</i> |            |
| Agriculture/Other         | 16            | 15         |
| Commercial/Transportation | 23            | 28         |
| Partially forested        | 16            | 20         |
| Institutional/Parks       | 28            | 112        |
| Residential               | 96            | 415        |
| Wetland                   | 6             | 7          |
| Total                     | 185           | 597        |

Sample intensity = 1 plot per 5,043 acres

n/a = not applicable

## APPENDIX B—STATISTICS ON TREE SPECIES

**Table B.1—Statistics of tree species by common and scientific name, Wisconsin, 2012**

| Common name         | Scientific name        | Trees     |     | Basal area      |                     |      | D.b.h. |        |
|---------------------|------------------------|-----------|-----|-----------------|---------------------|------|--------|--------|
|                     |                        | number    | %   | ft <sup>2</sup> | ft <sup>2</sup> /ac | %    | Avg    | Median |
|                     |                        |           |     |                 |                     |      | inches |        |
| Balsam fir          | Abies balsamea         | 34,962    | 0.1 | 15,446          | 0                   | 0.1  | 8.5    | 8.5    |
| White fir           | Abies concolor         | 56,193    | 0.1 | 15,324          | 0                   | 0.1  | 6.5    | 6.0    |
| Boxelder            | Acer negundo           | 1,501,980 | 3.5 | 450,981         | 0.5                 | 2.9  | 5.8    | 5.2    |
| Norway maple        | Acer platanoides       | 1,082,477 | 2.5 | 1,234,761       | 1.3                 | 8.1  | 13.1   | 13.5   |
| Red maple           | Acer rubrum            | 1,844,512 | 4.3 | 405,872         | 0.4                 | 2.6  | 4.1    | 2.3    |
| Silver maple        | Acer saccharinum       | 2,101,283 | 4.9 | 1,668,417       | 1.8                 | 10.9 | 9.1    | 5.0    |
| Sugar maple         | Acer saccharum         | 661,994   | 1.5 | 207,828         | 0.2                 | 1.4  | 6.3    | 4.0    |
| Alder               | Alnus x fallacina      | 64,511    | 0.2 | 12,667          | 0                   | 0.1  | 5.5    | 5.5    |
| Paper birch         | Betula papyrifera      | 309,064   | 0.7 | 144,816         | 0.2                 | 0.9  | 8.5    | 8.2    |
| Bitternut hickory   | Carya cordiformis      | 56,193    | 0.1 | 31,415          | 0                   | 0.2  | 9.0    | 6.0    |
| Shagbark hickory    | Carya ovata            | 314,210   | 0.7 | 130,854         | 0.1                 | 0.9  | 7.9    | 6.9    |
| Catalpa species     | Catalpa spp.           | 30,889    | 0.1 | 24,260          | 0                   | 0.2  | 11.5   | 11.5   |
| Northern catalpa    | Catalpa speciosa       | 56,193    | 0.1 | 76,621          | 0.1                 | 0.5  | 14.5   | 10.0   |
| Northern hackberry  | Celtis occidentalis    | 981,242   | 2.3 | 215,499         | 0.2                 | 1.4  | 5.3    | 4.4    |
| Downy hawthorn      | Crataegus mollis       | 28,097    | 0.1 | 25,899          | 0                   | 0.2  | 12.5   | 12.5   |
| Russian olive       | Elaeagnus angustifolia | 56,193    | 0.1 | 48,578          | 0.1                 | 0.3  | 12.0   | 11.0   |
| Winged burning bush | Euonymus alata         | 2,223,535 | 5.2 | 36,395          | 0                   | 0.2  | 1.3    | 1.3    |
| American beech      | Fagus grandifolia      | 56,193    | 0.1 | 26,051          | 0                   | 0.2  | 8.5    | 7.0    |
| White ash           | Fraxinus americana     | 1,669,275 | 3.9 | 610,211         | 0.7                 | 4.0  | 6.2    | 4.4    |
| Green ash           | Fraxinus pennsylvanica | 1,453,204 | 3.4 | 968,281         | 1                   | 6.3  | 9.3    | 7.8    |
| Ash species         | Fraxinus spp.          | 112,387   | 0.3 | 41,989          | 0                   | 0.3  | 7.5    | 6.0    |
| Honeylocust         | Gleditsia triacanthos  | 431,140   | 1   | 556,890         | 0.6                 | 3.6  | 13.9   | 13.2   |
| Black walnut        | Juglans nigra          | 149,059   | 0.3 | 101,787         | 0.1                 | 0.7  | 10.3   | 9.8    |
| Eastern red cedar   | Juniperus virginiana   | 2,387,458 | 5.6 | 213,907         | 0.2                 | 1.4  | 2.6    | 1.6    |
| Apple species       | Malus spp.             | 3,264,781 | 7.6 | 376,008         | 0.4                 | 2.5  | 3.7    | 2.9    |
| White mulberry      | Morus alba             | 309,064   | 0.7 | 157,535         | 0.2                 | 1.0  | 8.6    | 6.8    |
| Red mulberry        | Morus rubra            | 28,097    | 0.1 | 9,808           | 0                   | 0.1  | 7.5    | 7.5    |
| Eastern hophornbeam | Ostrya virginiana      | 84,290    | 0.2 | 31,568          | 0                   | 0.2  | 7.5    | 6.5    |
| Norway spruce       | Picea abies            | 198,392   | 0.5 | 253,519         | 0.3                 | 1.7  | 14.3   | 12.5   |
| White spruce        | Picea glauca           | 463,273   | 1.1 | 308,097         | 0.3                 | 2.0  | 9.7    | 8.0    |
| Blue spruce         | Picea pungens          | 505,970   | 1.2 | 320,018         | 0.3                 | 2.1  | 9.9    | 9.8    |
| Jack pine           | Pinus banksiana        | 377,157   | 0.9 | 15,545          | 0                   | 0.1  | 1.9    | 1.5    |
| Austrian pine       | Pinus nigra            | 59,624    | 0.1 | 29,431          | 0                   | 0.2  | 9.0    | 9.0    |
| Red pine            | Pinus resinosa         | 514,322   | 1.2 | 340,531         | 0.4                 | 2.2  | 10.0   | 9.9    |
| Eastern white pine  | Pinus strobus          | 510,887   | 1.2 | 828,233         | 0.9                 | 5.4  | 15.9   | 15.5   |
| Scotch pine         | Pinus sylvestris       | 1,052,645 | 2.5 | 552,792         | 0.6                 | 3.6  | 9.2    | 9.2    |
| Eastern cottonwood  | Populus deltoides      | 173,123   | 0.4 | 560,947         | 0.6                 | 3.7  | 21.6   | 13.9   |

*continued*

| Common name          | Scientific name            | Trees         |          | Basal area            |                          |          | D.b.h.        |        |
|----------------------|----------------------------|---------------|----------|-----------------------|--------------------------|----------|---------------|--------|
|                      |                            |               |          |                       |                          |          | Avg           | Median |
|                      |                            | <i>number</i> | <i>%</i> | <i>ft<sup>2</sup></i> | <i>ft<sup>2</sup>/ac</i> | <i>%</i> | <i>inches</i> |        |
| Bigtooth aspen       | Populus grandidentata      | 28,097        | 0.1      | 9,808                 | 0                        | 0.1      | 7.5           | 7.5    |
| Quaking aspen        | Populus tremuloides        | 140,484       | 0.3      | 93,326                | 0.1                      | 0.6      | 10.1          | 9.5    |
| American plum        | Prunus americana           | 694,690       | 1.6      | 24,628                | 0                        | 0.2      | 2.0           | 2.0    |
| Pin cherry           | Prunus pensylvanica        | 28,097        | 0.1      | 12,413                | 0                        | 0.1      | 8.5           | 8.5    |
| Black cherry         | Prunus serotina            | 684,506       | 1.6      | 158,120               | 0.2                      | 1.0      | 5.2           | 3.0    |
| Plum species         | Prunus spp.                | 84,290        | 0.2      | 21,761                | 0                        | 0.1      | 6.2           | 5.5    |
| Common chokecherry   | Prunus virginiana          | 347,345       | 0.8      | 7,578                 | 0                        | 0.0      | 1.5           | 1.5    |
| Callery pear         | Pyrus calleryana           | 189,442       | 0.4      | 40,343                | 0                        | 0.3      | 5.7           | 5.7    |
| Common pear          | Pyrus communis             | 28,097        | 0.1      | 5,517                 | 0                        | 0.0      | 5.5           | 5.5    |
| White oak            | Quercus alba               | 224,774       | 0.5      | 334,226               | 0.4                      | 2.2      | 14.4          | 10.0   |
| Northern pin oak     | Quercus ellipsoidalis      | 196,677       | 0.5      | 176,844               | 0.2                      | 1.2      | 9.8           | 7.2    |
| Bur oak              | Quercus macrocarpa         | 28,097        | 0.1      | 61,298                | 0.1                      | 0.4      | 19.5          | 19.5   |
| Northern red oak     | Quercus rubra              | 830,135       | 1.9      | 964,256               | 1                        | 6.3      | 11.2          | 8.7    |
| Black oak            | Quercus velutina           | 145,629       | 0.3      | 169,538               | 0.2                      | 1.1      | 13.7          | 14.5   |
| European buckthorn   | Rhamnus cathartica         | 2,545,755     | 5.9      | 147,560               | 0.2                      | 1.0      | 2.4           | 1.9    |
| Black locust         | Robinia pseudoacacia       | 92,667        | 0.2      | 65,027                | 0.1                      | 0.4      | 10.8          | 10.7   |
| Black willow         | Salix nigra                | 84,290        | 0.2      | 432,761               | 0.5                      | 2.8      | 28.8          | 23.5   |
| Willow species       | Salix spp.                 | 28,097        | 0.1      | 34,480                | 0                        | 0.2      | 14.5          | 14.5   |
| Weeping willow       | Salix x sepulcralis simonk | 56,193        | 0.1      | 211,016               | 0.2                      | 1.4      | 22.0          | 9.0    |
| Mountain ash species | Sorbus spp.                | 29,812        | 0.1      | 16,260                | 0                        | 0.1      | 9.5           | 9.5    |
| Common lilac         | Syringa vulgaris           | 4,862,830     | 11.4     | 144,018               | 0.2                      | 0.9      | 1.8           | 1.7    |
| Northern white cedar | Thuja occidentalis         | 4,558,408     | 10.7     | 264,445               | 0.3                      | 1.7      | 2.1           | 1.6    |
| American basswood    | Tilia americana            | 56,193        | 0.1      | 147,726               | 0.2                      | 1.0      | 18.5          | 8.0    |
| Littleleaf linden    | Tilia cordata              | 56,193        | 0.1      | 19,615                | 0                        | 0.1      | 7.5           | 7.5    |
| American elm         | Ulmus Americana            | 381,138       | 0.9      | 413,604               | 0.4                      | 2.7      | 10.9          | 7.4    |
| Siberian elm         | Ulmus pumila               | 893,236       | 2.1      | 210,341               | 0.2                      | 1.4      | 4.9           | 2.8    |
| Slippery elm         | Ulmus rubra                | 252,871       | 0.6      | 75,243                | 0.1                      | 0.5      | 6.7           | 6.2    |
| Elm spp              | Ulmus species              | 44,416        | 0.1      | 11,870                | 0                        | 0.1      | 6.5           | 6.5    |

D.b.h. = diameter at breast height



APPENDIX C—TOTAL SPECIES SUMMARY

Table C.1— Total species summary, Wisconsin, 2012

| Species              | Trees |           |           | Carbon storage |         |         | Carbon sequestration |        |       | Net carbon sequestration |       |      | Leaf area            |      | Leaf biomass |        |        | Compensatory value |             |     |
|----------------------|-------|-----------|-----------|----------------|---------|---------|----------------------|--------|-------|--------------------------|-------|------|----------------------|------|--------------|--------|--------|--------------------|-------------|-----|
|                      | %     | number    | SE        | %              | tons    | SE      | %                    | tons   | SE    | tons                     | SE    |      | acres<br>(thousands) | SE   | %            | tons   | SE     | %                  | \$ millions | SE  |
| Common lilac         | 11.4  | 4,862,830 | 3,161,046 | 0.3            | 12,198  | 7,971   | 2.6                  | 5,437  | 3,533 | 5,344                    | 3,473 | 1.0  | 6.5                  | 3.9  | 1.1          | 2,783  | 1,666  | 1.2                | 226         | 147 |
| Northern white cedar | 10.7  | 4,558,408 | 3,481,744 | 0.6            | 22,690  | 12,161  | 1.6                  | 3,395  | 2,075 | 3,279                    | 2,023 | 1.3  | 8.9                  | 4.8  | 3.0          | 7,667  | 4,132  | 2.8                | 531         | 301 |
| Apple spp            | 7.6   | 3,264,781 | 2,465,244 | 1.6            | 63,277  | 31,768  | 5.1                  | 10,791 | 7,058 | 10,523                   | 6,907 | 4.4  | 29.3                 | 19.3 | 4.4          | 11,277 | 7,424  | 2.0                | 381         | 202 |
| European buckthorn   | 5.9   | 2,545,755 | 1,503,688 | 0.5            | 18,567  | 9,042   | 2.1                  | 4,454  | 2,252 | 4,381                    | 2,216 | 2.4  | 15.9                 | 8.1  | 1.2          | 3,149  | 1,607  | 0.9                | 183         | 87  |
| Eastern red cedar    | 5.6   | 2,387,458 | 1,050,624 | 1.0            | 40,622  | 20,042  | 1.4                  | 2,937  | 1,280 | 2,754                    | 1,201 | 4.9  | 32.8                 | 20.7 | 15.7         | 40,626 | 25,645 | 2.0                | 376         | 183 |
| Winged burning bush  | 5.2   | 2,223,535 | 2,223,532 | 0.1            | 2,313   | 2,313   | 0.5                  | 1,071  | 1,071 | 1,053                    | 1,053 | 0.2  | 1.5                  | 1.5  | 0.2          | 508    | 507    | 0.7                | 129         | 129 |
| Silver maple         | 4.9   | 2,101,283 | 857,142   | 13.3           | 531,591 | 165,158 | 9.5                  | 20,184 | 5,952 | 17,796                   | 5,312 | 10.6 | 71.3                 | 19.7 | 6.5          | 16,730 | 4,626  | 4.9                | 948         | 291 |
| Red maple            | 4.3   | 1,844,512 | 859,595   | 2.8            | 110,568 | 44,181  | 3.6                  | 7,722  | 2,522 | 7,305                    | 2,369 | 3.5  | 23.6                 | 9.0  | 2.7          | 7,089  | 2,695  | 3.2                | 623         | 237 |
| White ash            | 3.9   | 1,669,275 | 812,735   | 4.5            | 179,862 | 66,642  | 5.1                  | 10,830 | 3,559 | 9,205                    | 3,438 | 4.8  | 32.5                 | 11.3 | 3.2          | 8,227  | 2,873  | 4.6                | 884         | 321 |
| Boxelder             | 3.5   | 1,501,980 | 752,576   | 2.9            | 117,187 | 42,717  | 4.0                  | 8,533  | 2,751 | 8,023                    | 2,604 | 4.2  | 28.0                 | 9.1  | 4.4          | 11,435 | 3,707  | 1.7                | 320         | 117 |
| Green ash            | 3.4   | 1,453,203 | 444,147   | 4.8            | 192,242 | 49,414  | 3.7                  | 7,807  | 1,890 | 7,295                    | 1,775 | 5.4  | 36.4                 | 10.2 | 4.1          | 10,577 | 2,956  | 6.6                | 1,262       | 337 |
| Norway maple         | 2.5   | 1,082,477 | 255,363   | 9.1            | 364,684 | 101,885 | 7.6                  | 16,015 | 3,973 | 14,610                   | 3,605 | 8.4  | 56.6                 | 16.1 | 5.3          | 13,623 | 3,884  | 11.4               | 2,196       | 599 |
| Scotch pine          | 2.5   | 1,052,645 | 754,808   | 1.7            | 67,762  | 51,062  | 1.9                  | 3,925  | 2,645 | 2,903                    | 1,768 | 2.1  | 14.1                 | 8.9  | 2.3          | 6,070  | 3,844  | 4.5                | 874         | 676 |
| Northern hackberry   | 2.3   | 981,242   | 708,401   | 1.1            | 43,765  | 20,862  | 2.4                  | 5,049  | 2,868 | 4,895                    | 2,799 | 3.4  | 23.1                 | 15.5 | 2.1          | 5,353  | 3,596  | 1.1                | 215         | 105 |
| Siberian elm         | 2.1   | 893,236   | 569,576   | 1.0            | 39,336  | 15,779  | 1.4                  | 3,073  | 1,231 | 350                      | 2,895 | 1.6  | 10.5                 | 4.0  | 1.2          | 3,191  | 1,229  | 0.5                | 89          | 40  |
| Northern red oak     | 1.9   | 830,135   | 404,614   | 8.8            | 353,610 | 160,651 | 6.7                  | 14,175 | 5,788 | 12,829                   | 5,194 | 5.9  | 39.5                 | 17.1 | 5.4          | 14,037 | 6,090  | 8.6                | 1,659       | 727 |
| American plum        | 1.6   | 694,690   | 694,689   | 0.1            | 2,333   | 2,333   | 0.5                  | 993    | 993   | 976                      | 976   | 0.4  | 2.7                  | 2.7  | 0.4          | 932    | 932    | 0.1                | 20          | 20  |
| Black cherry         | 1.6   | 684,506   | 374,422   | 1.0            | 39,178  | 15,248  | 1.8                  | 3,821  | 1,464 | 2,362                    | 1,949 | 1.0  | 6.8                  | 3.1  | 0.9          | 2,344  | 1,061  | 0.7                | 141         | 57  |
| Sugar maple          | 1.5   | 661,994   | 366,281   | 1.5            | 60,314  | 26,202  | 2.4                  | 5,181  | 2,027 | 4,974                    | 1,949 | 2.1  | 14.4                 | 5.8  | 1.5          | 3,864  | 1,556  | 1.4                | 267         | 115 |
| Red pine             | 1.2   | 514,322   | 218,738   | 1.7            | 67,371  | 36,038  | 2.0                  | 4,309  | 2,092 | 4,045                    | 1,952 | 1.7  | 11.4                 | 5.6  | 2.9          | 7,476  | 3,705  | 2.5                | 483         | 253 |
| Eastern white pine   | 1.2   | 510,887   | 237,454   | 3.2            | 129,480 | 67,056  | 2.5                  | 5,244  | 2,520 | 4,742                    | 2,269 | 2.8  | 18.7                 | 8.8  | 2.1          | 5,374  | 2,537  | 7.8                | 1,501       | 738 |

| Species             | Trees |         |         | Carbon storage |         |         | Carbon sequestration |       |       | Net carbon sequestration |       | Leaf area |                      |      | Leaf biomass |        |       | Compensatory value |             |     |
|---------------------|-------|---------|---------|----------------|---------|---------|----------------------|-------|-------|--------------------------|-------|-----------|----------------------|------|--------------|--------|-------|--------------------|-------------|-----|
|                     | %     | number  | SE      | %              | tons    | SE      | %                    | tons  | SE    | tons                     | SE    | %         | acres<br>(thousands) | SE   | %            | tons   | SE    | %                  | \$ millions | SE  |
| Blue spruce         | 1.2   | 505,970 | 189,190 | 1.6            | 64,074  | 25,162  | 1.8                  | 3,825 | 1,447 | 3,589                    | 1,353 | 1.4       | 9.5                  | 3.7  | 2.8          | 7,162  | 2,827 | 2.9                | 557         | 226 |
| White spruce        | 1.1   | 463,274 | 149,063 | 1.6            | 63,273  | 23,831  | 1.6                  | 3,457 | 1,123 | 3,219                    | 1,039 | 1.8       | 12.0                 | 4.3  | 3.3          | 8,629  | 3,050 | 2.1                | 410         | 148 |
| Honeylocust         | 1.0   | 431,139 | 139,179 | 4.3            | 172,110 | 71,374  | 3.5                  | 7,378 | 2,671 | 6,775                    | 2,436 | 1.9       | 12.5                 | 5.1  | 2.3          | 5,839  | 2,388 | 4.0                | 765         | 294 |
| American elm        | 0.9   | 381,138 | 162,846 | 3.2            | 129,525 | 82,378  | 0.8                  | 1,711 | 1,071 | (5,611)                  | 5,134 | 1.4       | 9.1                  | 5.0  | 1.1          | 2,942  | 1,635 | 1.2                | 226         | 166 |
| Jack pine           | 0.9   | 377,157 | 348,621 | <0.1           | 1,848   | 1,333   | 0.1                  | 293   | 236   | 286                      | 230   | 0.2       | 1.1                  | 0.9  | 0.2          | 413    | 332   | 0.1                | 24          | 17  |
| Common chokecherry  | 0.8   | 347,345 | 347,344 | <0.1           | 457     | 457     | 0.1                  | 308   | 308   | 304                      | 304   | 0.1       | 0.5                  | 0.5  | 0.1          | 181    | 181   | 0.1                | 10          | 10  |
| Shagbark hickory    | 0.7   | 314,210 | 198,431 | 0.7            | 29,928  | 18,087  | 1.3                  | 2,761 | 1,694 | 2,639                    | 1,624 | 1.0       | 6.9                  | 4.4  | 0.9          | 2,247  | 1,439 | 0.9                | 166         | 96  |
| Paper birch         | 0.7   | 309,064 | 118,958 | 1.0            | 41,429  | 17,529  | 1.6                  | 3,361 | 1,361 | 2,601                    | 1,364 | 1.0       | 6.6                  | 3.1  | 0.8          | 2,057  | 958   | 1.0                | 191         | 81  |
| White mulberry      | 0.7   | 309,064 | 214,614 | 0.9            | 37,474  | 33,365  | 1.4                  | 3,053 | 2,425 | 2,902                    | 2,293 | 1.6       | 10.6                 | 9.1  | 1.3          | 3,449  | 2,959 | 1.0                | 200         | 174 |
| Slippery elm        | 0.6   | 252,871 | 252,866 | 0.3            | 11,921  | 11,921  | 0.4                  | 837   | 837   | (691)                    | 691   | 0.3       | 1.8                  | 1.8  | 0.1          | 357    | 357   | 0.3                | 50          | 50  |
| White oak           | 0.5   | 224,774 | 130,452 | 3.0            | 119,514 | 63,574  | 2.4                  | 5,082 | 2,583 | 4,618                    | 2,347 | 1.5       | 10.3                 | 5.1  | 1.3          | 3,347  | 1,662 | 2.9                | 562         | 288 |
| Norway spruce       | 0.5   | 198,392 | 83,494  | 1.5            | 59,674  | 32,114  | 1.2                  | 2,506 | 1,199 | 2,283                    | 1,078 | 2.0       | 13.7                 | 7.7  | 3.9          | 10,210 | 5,710 | 1.8                | 339         | 177 |
| Northern pin oak    | 0.5   | 196,677 | 127,846 | 1.7            | 66,802  | 57,332  | 1.4                  | 3,001 | 1,924 | 2,740                    | 1,723 | 1.3       | 8.5                  | 5.5  | 1.5          | 3,904  | 2,522 | 1.5                | 284         | 220 |
| Callery pear        | 0.4   | 189,442 | 144,611 | 0.2            | 7,000   | 5,512   | 0.5                  | 1,157 | 892   | 1,126                    | 868   | 0.2       | 1.4                  | 1.2  | 0.2          | 481    | 405   | 0.2                | 46          | 38  |
| Eastern cottonwood  | 0.4   | 173,123 | 108,650 | 4.4            | 177,088 | 142,417 | 2.6                  | 5,414 | 3,834 | 4,734                    | 3,299 | 3.2       | 21.6                 | 16.5 | 2.7          | 6,965  | 5,320 | 0.9                | 179         | 115 |
| Black walnut        | 0.3   | 149,059 | 105,633 | 0.6            | 25,561  | 18,998  | 0.6                  | 1,290 | 928   | 1,203                    | 860   | 1.0       | 6.8                  | 4.9  | 0.9          | 2,416  | 1,755 | 0.7                | 142         | 108 |
| Black oak           | 0.3   | 145,629 | 105,622 | 1.7            | 66,673  | 49,179  | 1.5                  | 3,121 | 2,239 | 2,861                    | 2,049 | 0.8       | 5.1                  | 3.6  | 0.6          | 1,604  | 1,141 | 1.7                | 331         | 252 |
| Quaking aspen       | 0.3   | 140,484 | 61,488  | 0.4            | 17,793  | 9,281   | 0.5                  | 1,094 | 569   | 520                      | 746   | 0.4       | 2.7                  | 1.8  | 0.4          | 955    | 619   | 0.2                | 43          | 24  |
| Ash spp             | 0.3   | 112,387 | 88,567  | 0.2            | 7,618   | 5,364   | 0.4                  | 785   | 574   | 754                      | 553   | 0.3       | 1.8                  | 1.5  | 0.3          | 723    | 621   | 0.3                | 57          | 41  |
| Black locust        | 0.2   | 92,667  | 92,665  | 0.5            | 21,509  | 21,509  | 0.3                  | 691   | 691   | 676                      | 676   | 0.4       | 2.5                  | 2.5  | 0.2          | 610    | 610   | 0.1                | 18          | 18  |
| Eastern hophornbeam | 0.2   | 84,290  | 62,560  | 0.2            | 6,230   | 4,638   | 0.2                  | 500   | 371   | 187                      | 344   | 0.2       | 1.5                  | 1.0  | 0.2          | 424    | 302   | 0.2                | 33          | 27  |
| Plum spp            | 0.2   | 84,290  | 62,560  | 0.1            | 4,596   | 3,348   | 0.3                  | 648   | 457   | 629                      | 443   | 0.2       | 1.3                  | 1.0  | 0.2          | 440    | 341   | 0.1                | 19          | 15  |
| Black willow        | 0.2   | 84,290  | 84,289  | 4.4            | 176,131 | 176,128 | 2.0                  | 4,298 | 4,298 | 3,626                    | 3,626 | 1.3       | 8.5                  | 8.5  | 0.9          | 2,404  | 2,404 | 1.7                | 326         | 326 |
| Alder               | 0.2   | 64,511  | 64,510  | 0.1            | 2,712   | 2,712   | 0.1                  | 177   | 177   | 175                      | 175   | 0.1       | 0.4                  | 0.4  | 0.1          | 142    | 142   | <0.1               | 4           | 4   |

| Species           | Trees |            |           | Carbon storage |           |         | Carbon sequestration |         |        | Net carbon sequestration |        | Leaf area |                      | Leaf biomass |      |         | Compensatory value |      |             |       |
|-------------------|-------|------------|-----------|----------------|-----------|---------|----------------------|---------|--------|--------------------------|--------|-----------|----------------------|--------------|------|---------|--------------------|------|-------------|-------|
|                   | %     | number     | SE        | %              | tons      | SE      | %                    | tons    | SE     | tons                     | SE     | %         | acres<br>(thousands) | SE           | %    | tons    | SE                 | %    | \$ millions | SE    |
| Austrian pine     | 0.1   | 59,624     | 59,623    | 0.1            | 2,878     | 2,878   | 0.1                  | 160     | 160    | 149                      | 149    | 0.2       | 1.4                  | 1.4          | 0.2  | 603     | 603                | 0.3  | 56          | 56    |
| White fir         | 0.1   | 56,193     | 56,192    | 0.1            | 2,205     | 2,205   | 0.1                  | 244     | 244    | 235                      | 235    | 0.1       | 0.9                  | 0.9          | 0.2  | 567     | 567                | 0.1  | 19          | 19    |
| Bitternut hickory | 0.1   | 56,193     | 39,524    | 0.2            | 8,252     | 7,460   | 0.3                  | 638     | 498    | 605                      | 469    | 0.4       | 2.5                  | 2.1          | 0.3  | 692     | 590                | 0.2  | 38          | 33    |
| Northern catalpa  | 0.1   | 56,193     | 56,192    | 0.6            | 22,119    | 22,119  | 0.5                  | 1,054   | 1,054  | 968                      | 968    | 0.1       | 0.7                  | 0.7          | 0.1  | 203     | 203                | 0.5  | 94          | 94    |
| Russian olive     | 0.1   | 56,193     | 56,192    | 0.3            | 12,707    | 12,707  | 0.2                  | 466     | 466    | (694)                    | 694    | 0.2       | 1.3                  | 1.3          | 0.2  | 428     | 428                | 0.2  | 41          | 41    |
| American beech    | 0.1   | 56,193     | 56,192    | 0.2            | 7,410     | 7,410   | 0.3                  | 669     | 669    | 639                      | 639    | 0.6       | 4.0                  | 4.0          | 0.3  | 757     | 757                | 0.2  | 37          | 37    |
| Weeping willow    | 0.1   | 56,193     | 39,524    | 2.2            | 88,729    | 85,946  | 1.1                  | 2,438   | 2,178  | 2,098                    | 1,851  | 0.8       | 5.2                  | 4.4          | 0.6  | 1,483   | 1,249              | 0.9  | 178         | 163   |
| American basswood | 0.1   | 56,193     | 39,524    | 0.9            | 35,213    | 34,044  | 0.5                  | 1,029   | 899    | 894                      | 770    | 0.7       | 4.4                  | 3.7          | 0.2  | 571     | 485                | 1.0  | 201         | 188   |
| Littleleaf linden | 0.1   | 56,193     | 56,192    | 0.1            | 2,723     | 2,723   | 0.1                  | 302     | 302    | 291                      | 291    | 0.2       | 1.5                  | 1.5          | 0.2  | 511     | 511                | 0.2  | 31          | 31    |
| Elm spp           | 0.1   | 44,416     | 44,416    | <0.1           | 1,683     | 1,683   | 0.1                  | 233     | 233    | 226                      | 226    | 0.1       | 0.4                  | 0.4          | <0.1 | 125     | 125                | 0.1  | 14          | 14    |
| Balsam fir        | 0.1   | 34,962     | 34,962    | 0.1            | 2,183     | 2,183   | 0.1                  | 188     | 188    | 179                      | 179    | 0.1       | 0.6                  | 0.6          | 0.1  | 260     | 260                | 0.1  | 24          | 24    |
| Catalpa spp       | 0.1   | 30,889     | 30,888    | 0.2            | 6,645     | 6,645   | 0.1                  | 218     | 218    | 213                      | 213    | <0.1      | 0.2                  | 0.2          | <0.1 | 66      | 66                 | <0.1 | 9           | 9     |
| Mountain ash spp  | 0.1   | 29,812     | 29,811    | 0.1            | 3,607     | 3,607   | 0.1                  | 222     | 222    | 213                      | 213    | 0.1       | 0.6                  | 0.6          | 0.1  | 219     | 219                | 0.1  | 22          | 22    |
| Downy hawthorn    | 0.1   | 28,097     | 28,096    | 0.2            | 6,229     | 6,229   | 0.2                  | 387     | 386    | 362                      | 362    | 0.2       | 1.4                  | 1.4          | 0.2  | 471     | 471                | 0.2  | 33          | 33    |
| Red mulberry      | 0.1   | 28,097     | 28,096    | <0.1           | 1,796     | 1,796   | 0.1                  | 212     | 212    | 205                      | 205    | 0.1       | 0.7                  | 0.7          | 0.1  | 325     | 325                | 0.1  | 13          | 13    |
| Bigtooth aspen    | 0.1   | 28,097     | 28,096    | <0.1           | 1,601     | 1,601   | 0.1                  | 186     | 186    | 179                      | 179    | 0.1       | 0.5                  | 0.5          | <0.1 | 120     | 120                | 0.1  | 12          | 12    |
| Pin cherry        | 0.1   | 28,097     | 28,096    | 0.1            | 2,778     | 2,778   | 0.1                  | 289     | 289    | 278                      | 278    | 0.1       | 0.4                  | 0.4          | <0.1 | 90      | 90                 | 0.1  | 15          | 15    |
| Common pear       | 0.1   | 28,097     | 28,096    | <0.1           | 904       | 904     | 0.1                  | 165     | 165    | 161                      | 161    | <0.1      | 0.3                  | 0.3          | <0.1 | 87      | 87                 | <0.1 | 5           | 5     |
| Bur oak           | 0.1   | 28,097     | 28,096    | 0.5            | 18,983    | 18,983  | 0.4                  | 773     | 773    | 700                      | 700    | 0.3       | 2.1                  | 2.1          | 0.4  | 919     | 919                | 0.5  | 104         | 104   |
| Willow spp        | 0.1   | 28,097     | 28,096    | 0.2            | 9,108     | 9,108   | 0.2                  | 482     | 482    | 395                      | 395    | <0.1      | 0.2                  | 0.2          | <0.1 | 63      | 63                 | 0.1  | 26          | 26    |
| Total             |       | 42,796,327 | 7,356,424 |                | 4,007,641 | 503,730 |                      | 212,050 | 23,083 | 180,084                  | 21,837 |           | 670.5                | 74.9         |      | 258,792 | 34,808             |      | 19,265      | 2,389 |

## APPENDIX D—TREE SPECIES STATISTICS BY LAND USE

**Table D.1—Tree statistics by land use and species, Wisconsin, 2012**

| Land use and species | Trees         | Basal<br>area            | D.b.h. |               | Land use and species | Trees         | Basal<br>area            | D.b.h. |               |
|----------------------|---------------|--------------------------|--------|---------------|----------------------|---------------|--------------------------|--------|---------------|
|                      |               |                          | Avg    | Median        |                      |               |                          | Avg    | Median        |
|                      | <i>number</i> | <i>ft<sup>2</sup>/ac</i> |        | <i>inches</i> |                      | <i>number</i> | <i>ft<sup>2</sup>/ac</i> |        | <i>inches</i> |
| Ag/Other             |               |                          |        |               | Residential          |               |                          |        |               |
| Norway maple         | 139,848       | 82,187                   | 9.3    | 7.0           | Common lilac         | 4,862,830     | 144,018                  | 1.8    | 1.7           |
| Green ash            | 104,886       | 38,138                   | 7.5    | 7.5           | Apple spp            | 3,172,114     | 343,324                  | 3.6    | 2.9           |
| White ash            | 104,886       | 46,719                   | 8.5    | 8.5           | European buckthorn   | 2,431,415     | 108,040                  | 2.2    | 1.9           |
| European buckthorn   | 69,924        | 27,650                   | 8.0    | 8.0           | Red maple            | 1,782,734     | 372,177                  | 3.9    | 2.3           |
| American elm         | 34,962        | 6,865                    | 5.5    | 5.5           | Silver maple         | 1,284,722     | 1,202,299                | 9.9    | 4.8           |
| Balsam fir           | 34,962        | 15,446                   | 8.5    | 8.5           | Northern white cedar | 1,238,712     | 192,021                  | 3.6    | 2.4           |
| White spruce         | 34,962        | 6,865                    | 5.5    | 5.5           | Eastern red cedar    | 1,210,615     | 135,819                  | 2.9    | 1.9           |
| Red pine             | 34,962        | 6,865                    | 5.5    | 5.5           | Boxelder             | 1,144,238     | 217,500                  | 4.6    | 2.8           |
| Comm/Trans           |               |                          |        |               | White ash            | 1,059,948     | 370,095                  | 5.9    | 3.5           |
| Northern white cedar | 3,319,696     | 72,425                   | 1.5    | 1.5           | Northern hackberry   | 919,464       | 184,332                  | 5.1    | 4.3           |
| Eastern red cedar    | 775,365       | 59,221                   | 2.4    | 0.0           | Green ash            | 824,990       | 543,874                  | 8.9    | 7.3           |
| Siberian elm         | 553,283       | 27,159                   | 2.5    | 2.5           | Northern red oak     | 740,699       | 909,444                  | 11.3   | 8.4           |
| Silver maple         | 177,665       | 160,614                  | 12.3   | 12.5          | American plum        | 694,690       | 24,628                   | 2.0    | 2.0           |
| Callery pear         | 133,249       | 29,310                   | 5.8    | 5.7           | Black cherry         | 684,506       | 158,120                  | 5.2    | 3.0           |
| Eastern cottonwood   | 88,833        | 82,367                   | 12.5   | 12.0          | Norway maple         | 674,322       | 793,393                  | 13.2   | 12.0          |
| Honeylocust          | 88,833        | 49,662                   | 9.0    | 6.0           | Sugar maple          | 600,216       | 176,660                  | 6.0    | 3.9           |
| White ash            | 44,416        | 8,721                    | 5.5    | 5.5           | Red pine             | 449,548       | 325,699                  | 10.6   | 10.5          |
| European buckthorn   | 44,416        | 11,870                   | 6.5    | 6.5           | Eastern white pine   | 421,451       | 703,357                  | 16.0   | 15.5          |
| Blue spruce          | 44,416        | 70,011                   | 16.5   | 16.5          | Jack pine            | 347,345       | 7,578                    | 1.5    | 1.5           |
| Elm spp              | 44,416        | 11,870                   | 6.5    | 6.5           | Common chokecherry   | 347,345       | 7,578                    | 1.5    | 1.5           |
| Wetland              |               |                          |        |               | Scotch pine          | 337,161       | 154,766                  | 8.5    | 8.5           |
| Green ash            | 161,277       | 157,630                  | 12.3   | 12.5          | White mulberry       | 309,064       | 157,535                  | 8.6    | 6.8           |
| Alder                | 64,511        | 12,667                   | 5.5    | 5.5           | White spruce         | 309,064       | 254,079                  | 10.8   | 9.5           |
|                      |               |                          |        |               | Siberian elm         | 309,064       | 172,400                  | 9.0    | 8.5           |
|                      |               |                          |        |               | Paper birch          | 309,064       | 144,816                  | 8.5    | 8.2           |
|                      |               |                          |        |               | Slippery elm         | 252,871       | 75,243                   | 6.7    | 6.2           |

*continued*

| Land use and species | Trees     | Basal         | D.b.h.                   |               | Land use and species  | Trees   | Basal         | D.b.h.                   |               |
|----------------------|-----------|---------------|--------------------------|---------------|-----------------------|---------|---------------|--------------------------|---------------|
|                      |           | Area          | Avg                      | Median        |                       |         | Area          | Avg                      | Median        |
|                      |           | <i>number</i> | <i>ft<sup>2</sup>/ac</i> | <i>inches</i> |                       |         | <i>number</i> | <i>ft<sup>2</sup>/ac</i> | <i>inches</i> |
| Partially forested   |           |               |                          |               | Residential continued |         |               |                          |               |
| Green ash            | 123,556   | 33,358        | 6.5                      | 6.5           | Honeylocust           | 252,871 | 344,953       | 14.3                     | 13.5          |
| Apple spp            | 92,667    | 32,684        | 7.5                      | 7.5           | Blue spruce           | 252,871 | 137,001       | 9.3                      | 8.8           |
| Black locust         | 92,667    | 65,027        | 10.8                     | 10.7          | American elm          | 224,774 | 190,789       | 10.1                     | 8.0           |
| American elm         | 61,778    | 191,723       | 19.5                     | 7.0           | Shagbark hickory      | 224,774 | 101,754       | 8.3                      | 7.0           |
| Northern hackberry   | 61,778    | 31,168        | 9.0                      | 8.0           | White oak             | 224,774 | 334,226       | 14.4                     | 10.0          |
| Red maple            | 61,778    | 33,695        | 9.5                      | 9.5           | Northern pin oak      | 196,677 | 176,844       | 9.8                      | 7.2           |
| Sugar maple          | 61,778    | 31,168        | 9.0                      | 8.0           | Norway spruce         | 168,580 | 230,105       | 14.8                     | 13.0          |
| Eastern red cedar    | 30,889    | 10,782        | 7.5                      | 7.5           | Quaking aspen         | 140,484 | 93,326        | 10.1                     | 9.5           |
| Siberian elm         | 30,889    | 10,782        | 7.5                      | 7.5           | Ash spp               | 112,387 | 41,989        | 7.5                      | 6.0           |
| Catalpa spp          | 30,889    | 24,260        | 11.5                     | 11.5          | Plum spp              | 84,290  | 21,761        | 6.2                      | 5.5           |
|                      |           |               |                          |               | Eastern cottonwood    | 84,290  | 478,581       | 31.2                     | 34.5          |
| Instit/Parks         |           |               |                          |               | Eastern hophornbeam   | 84,290  | 31,568        | 7.5                      | 6.5           |
| Winged burning bush  | 2,223,535 | 36,395        | 1.3                      | 1.3           | Black willow          | 84,290  | 432,761       | 28.8                     | 23.5          |
| Scotch pine          | 715,484   | 398,026       | 9.5                      | 9.4           | Callery pear          | 56,193  | 11,034        | 5.5                      | 5.5           |
| Silver maple         | 638,896   | 305,504       | 6.5                      | 2.9           | Black oak             | 56,193  | 59,458        | 12.5                     | 8.0           |
| White ash            | 460,025   | 184,676       | 6.3                      | 4.6           | White fir             | 56,193  | 15,324        | 6.5                      | 6.0           |
| Eastern red cedar    | 370,589   | 8,085         | 1.5                      | 1.5           | Bitternut hickory     | 56,193  | 31,415        | 9.0                      | 6.0           |
| Boxelder             | 357,742   | 233,481       | 9.6                      | 8.0           | Northern catalpa      | 56,193  | 76,622        | 14.5                     | 10.0          |
| Norway maple         | 268,307   | 359,181       | 14.9                     | 14.3          | Russian olive         | 56,193  | 48,578        | 12.0                     | 11.0          |
| Green ash            | 238,495   | 195,281       | 11.1                     | 9.5           | American beech        | 56,193  | 26,051        | 8.5                      | 7.0           |
| Blue spruce          | 208,683   | 113,006       | 9.4                      | 9.5           | Weeping willow        | 56,193  | 211,016       | 22.0                     | 9.0           |
| Black walnut         | 149,059   | 101,787       | 10.3                     | 9.8           | American basswood     | 56,193  | 147,726       | 18.5                     | 8.0           |
| White spruce         | 119,247   | 47,154        | 8.0                      | 8.0           | Littleleaf linden     | 56,193  | 19,615        | 7.5                      | 7.5           |
| Honeylocust          | 89,436    | 162,274       | 17.5                     | 18.5          | Red mulberry          | 28,097  | 9,808         | 7.5                      | 7.5           |
| Shagbark hickory     | 89,436    | 29,100        | 7.2                      | 6.7           | Bur oak               | 28,097  | 61,298        | 19.5                     | 19.5          |
| Eastern white pine   | 89,436    | 124,877       | 15.5                     | 15.5          | Downy hawthorn        | 28,097  | 25,899        | 12.5                     | 12.5          |
| Northern red oak     | 89,436    | 54,812        | 9.8                      | 11.3          | Bigtooth aspen        | 28,097  | 9,808         | 7.5                      | 7.5           |
| Black oak            | 89,436    | 110,080       | 14.5                     | 14.5          | Pin cherry            | 28,097  | 12,413        | 8.5                      | 8.5           |
| American elm         | 59,624    | 24,227        | 8.0                      | 7.0           | Common pear           | 28,097  | 5,517         | 5.5                      | 5.5           |
| Austrian pine        | 59,624    | 29,431        | 9.0                      | 9.0           | Willow spp            | 28,097  | 34,480        | 14.5                     | 14.5          |

*continued*

| Land use and species   | Trees  | Basal<br>Area | D.b.h.        |               | Land use and species | Trees | Basal<br>Area | D.b.h.        |               |
|------------------------|--------|---------------|---------------|---------------|----------------------|-------|---------------|---------------|---------------|
|                        |        |               | Avg           | Median        |                      |       |               | Avg           | Median        |
|                        |        | <i>number</i> | <i>ft²/ac</i> | <i>inches</i> |                      |       | <i>number</i> | <i>ft²/ac</i> | <i>inches</i> |
| Instit/Parks continued |        |               |               |               |                      |       |               |               |               |
| Red pine               | 29,812 | 7,967         | 6.5           | 6.5           |                      |       |               |               |               |
| Norway spruce          | 29,812 | 23,414        | 11.5          | 11.5          |                      |       |               |               |               |
| Jack pine              | 29,812 | 7,967         | 6.5           | 6.5           |                      |       |               |               |               |
| Mountain ash spp       | 29,812 | 16,260        | 9.5           | 9.5           |                      |       |               |               |               |

## APPENDIX E—DAMAGE TYPE OR MAINTENANCE OR SITE ISSUE STATISTICS

**Table E.1—Percent of Trees Identified with Damage or Maintenance or Site Issues, Wisconsin, 2012**

| Species           | Sample   | Damage type                |                  |                                   |             |             |                         |                           |                             |                      |                 | Maintenance or site issue |                 |                   |                              |                     |
|-------------------|----------|----------------------------|------------------|-----------------------------------|-------------|-------------|-------------------------|---------------------------|-----------------------------|----------------------|-----------------|---------------------------|-----------------|-------------------|------------------------------|---------------------|
|                   |          | Borers/<br>bark<br>beetles | Canker/<br>decay | Chlorotic/<br>necrotic<br>foliage | Dead<br>top | Defoliation | Dead/<br>dying<br>crown | Root/<br>stem<br>girdling | Trunk/<br>bark<br>inclusion | Vines<br>in<br>crown | Wound/<br>crack | Improper<br>planting      | Excess<br>mulch | Overhead<br>wires | Sidewalk<br>root<br>conflict | Topping/<br>pruning |
|                   | <i>n</i> | <i>percent</i>             |                  |                                   |             |             |                         |                           |                             |                      |                 |                           |                 |                   |                              |                     |
| Alder             | 2        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| American basswood | 2        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 50.0                        | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| American beech    | 2        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| American elm      | 13       | 0.0                        | 7.4              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 7.8                         | 0.0                  | 0.0             | 0.0                       | 0.0             | 7.4               | 0.0                          | 0.0                 |
| American plum     | 2        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Apple spp         | 25       | 0.0                        | 82.5             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 85.0                        | 0.0                  | 2.7             | 0.0                       | 10.6            | 0.0               | 0.0                          | 0.0                 |
| Ash spp           | 4        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Austrian pine     | 2        | 0.0                        | 50.0             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Balsam fir        | 1        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Bigtooth aspen    | 1        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Bitternut hickory | 2        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Black cherry      | 13       | 0.0                        | 8.2              | 4.1                               | 0.0         | 0.0         | 4.1                     | 4.1                       | 8.2                         | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Black locust      | 3        | 0.0                        | 66.7             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 33.3                        | 0.0                  | 33.3            | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Black oak         | 5        | 0.0                        | 39.8             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 20.5                        | 0.0                  | 20.5            | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Black walnut      | 5        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 20.0                        | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Black willow      | 3        | 0.0                        | 100.0            | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 33.3                        | 0.0                  | 33.3            | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Blue spruce       | 17       | 0.0                        | 5.6              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                  | 11.4            | 0.0                       | 5.6             | 0.0               | 0.0                          | 11.8                |
| Boxelder          | 30       | 0.0                        | 17.0             | 1.9                               | 3.9         | 0.0         | 5.8                     | 0.0                       | 9.6                         | 5.7                  | 7.6             | 0.0                       | 0.0             | 1.9               | 0.0                          | 0.0                 |
| Bur oak           | 1        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Callery pear      | 5        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 29.7                        | 0.0                  | 0.0             | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Catalpa spp       | 1        | 0.0                        | 100.0            | 0.0                               | 100.0       | 0.0         | 0.0                     | 0.0                       | 100.0                       | 0.0                  | 100.0           | 0.0                       | 0.0             | 0.0               | 0.0                          | 0.0                 |

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| Species              | Sample   | Damage type                |                  |                                   |             |             |                         |                           |                             | Maintenance or site issue |                 |                      |                 |                   |                              |                     |
|----------------------|----------|----------------------------|------------------|-----------------------------------|-------------|-------------|-------------------------|---------------------------|-----------------------------|---------------------------|-----------------|----------------------|-----------------|-------------------|------------------------------|---------------------|
|                      |          | Borers/<br>bark<br>beetles | Canker/<br>decay | Chlorotic/<br>necrotic<br>foliage | Dead<br>top | Defoliation | Dead/<br>dying<br>crown | Root/<br>stem<br>girdling | Trunk/<br>bark<br>inclusion | Vines<br>in<br>crown      | Wound/<br>crack | Improper<br>planting | Excess<br>mulch | Overhead<br>wires | Sidewalk<br>root<br>conflict | Topping/<br>pruning |
|                      | <i>n</i> |                            |                  |                                   |             |             |                         |                           |                             |                           |                 |                      |                 |                   |                              |                     |
| Common chokecherry   | 1        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Common lilac         | 14       | 0.0                        | 14.3             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 28.6                        | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Common pear          | 1        | 0.0                        | 100.0            | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 100.0                       | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Downy hawthorn       | 1        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 100.0                       | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Eastern cottonwood   | 5        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 16.2                        | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Eastern hophornbeam  | 3        | 0.0                        | 33.3             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Eastern red cedar    | 17       | 0.0                        | 21.6             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 25.3                        | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Eastern white pine   | 18       | 0.0                        | 5.5              | 5.5                               | 0.0         | 0.0         | 0.0                     | 22.0                      | 16.5                        | 0.0                       | 0.0             | 0.0                  | 0.0             | 5.5               | 0.0                          | 0.0                 |
| Elm spp              | 1        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| European buckthorn   | 10       | 0.0                        | 13.6             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 4.5                         | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Green ash            | 38       | 0.0                        | 6.3              | 0.0                               | 0.0         | 0.0         | 0.0                     | 8.3                       | 28.8                        | 0.0                       | 39.8            | 0.0                  | 0.0             | 7.7               | 0.0                          | 5.8                 |
| Honeylocust          | 14       | 0.0                        | 19.9             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 19.6                        | 0.0                       | 30.3            | 0.0                  | 0.0             | 6.5               | 0.0                          | 0.0                 |
| Jack pine            | 2        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 7.9             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Littleleaf linden    | 2        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 100.0                       | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Mountain ash spp     | 1        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Northern catalpa     | 2        | 0.0                        | 100.0            | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 100.0                       | 0.0                       | 100.0           | 0.0                  | 0.0             | 100.0             | 0.0                          | 0.0                 |
| Northern hackberry   | 12       | 0.0                        | 2.9              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 0.0             | 0.0                  | 0.0             | 5.7               | 0.0                          | 0.0                 |
| Northern pin oak     | 7        | 14.3                       | 28.6             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 28.6                        | 0.0                       | 14.3            | 0.0                  | 0.0             | 14.3              | 0.0                          | 0.0                 |
| Northern red oak     | 18       | 0.0                        | 14.2             | 0.0                               | 0.0         | 0.0         | 0.0                     | 10.8                      | 59.4                        | 0.0                       | 20.9            | 0.0                  | 0.0             | 3.4               | 0.0                          | 0.0                 |
| Northern white cedar | 16       | 0.0                        | 0.6              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 97.5                        | 0.0                       | 0.6             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Norway maple         | 37       | 0.0                        | 35.3             | 13.0                              | 0.0         | 2.6         | 2.6                     | 23.1                      | 50.2                        | 0.0                       | 24.3            | 0.0                  | 0.0             | 2.6               | 2.6                          | 0.0                 |
| Norway spruce        | 7        | 0.0                        | 14.2             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 0.0             | 0.0                  | 0.0             | 14.2              | 0.0                          | 15.0                |

continued



| Species             | Sample   | Damage type                |                  |                                   |             |             |                         |                           |                             | Maintenance or site issue |                 |                      |                 |                   |                              |                     |
|---------------------|----------|----------------------------|------------------|-----------------------------------|-------------|-------------|-------------------------|---------------------------|-----------------------------|---------------------------|-----------------|----------------------|-----------------|-------------------|------------------------------|---------------------|
|                     |          | Borers/<br>bark<br>beetles | Canker/<br>decay | Chlorotic/<br>necrotic<br>foliage | Dead<br>top | Defoliation | Dead/<br>dying<br>crown | Root/<br>stem<br>girdling | Trunk/<br>bark<br>inclusion | Vines<br>in<br>crown      | Wound/<br>crack | Improper<br>planting | Excess<br>mulch | Overhead<br>wires | Sidewalk<br>root<br>conflict | Topping/<br>pruning |
|                     | <i>n</i> | <i>percent</i>             |                  |                                   |             |             |                         |                           |                             |                           |                 |                      |                 |                   |                              |                     |
| Paper birch         | 11       | 0.0                        | 45.5             | 18.2                              | 18.2        | 18.2        | 18.2                    | 0.0                       | 27.3                        | 0.0                       | 9.1             | 0.0                  | 0.0             | 9.1               | 0.0                          | 0.0                 |
| Pin cherry          | 1        | 100.0                      | 100.0            | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 100.0                       | 0.0                       | 100.0           | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Plum spp            | 3        | 0.0                        | 33.3             | 0.0                               | 0.0         | 0.0         | 0.0                     | 66.7                      | 66.7                        | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Quaking aspen       | 5        | 0.0                        | 60.0             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 20.0            | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Red maple           | 20       | 0.0                        | 25.1             | 1.5                               | 1.5         | 0.0         | 1.5                     | 3.0                       | 12.2                        | 1.5                       | 7.6             | 1.5                  | 0.0             | 3.0               | 1.5                          | 0.0                 |
| Red mulberry        | 1        | 0.0                        | 100.0            | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 100.0           | 0.0                  | 0.0             | 100.0             | 0.0                          | 0.0                 |
| Red pine            | 18       | 0.0                        | 5.8              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 18.1                        | 0.0                       | 10.9            | 0.0                  | 16.4            | 0.0               | 0.0                          | 0.0                 |
| Russian olive       | 2        | 0.0                        | 50.0             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 0.0             | 0.0                  | 0.0             | 50.0              | 0.0                          | 0.0                 |
| Scotch pine         | 36       | 0.0                        | 8.2              | 0.0                               | 0.0         | 0.0         | 0.0                     | 5.7                       | 11.3                        | 0.0                       | 0.0             | 0.0                  | 2.7             | 0.0               | 0.0                          | 0.0                 |
| Shagbark hickory    | 11       | 0.0                        | 8.9              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 17.9                        | 9.5                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Siberian elm        | 13       | 0.0                        | 12.6             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 16.0                        | 0.0                       | 3.1             | 0.0                  | 0.0             | 6.3               | 0.0                          | 0.0                 |
| Silver maple        | 37       | 0.0                        | 25.2             | 34.4                              | 0.0         | 0.0         | 0.0                     | 6.1                       | 42.6                        | 0.0                       | 2.8             | 0.0                  | 0.0             | 6.7               | 1.3                          | 0.0                 |
| Slippery elm        | 9        | 55.6                       | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 33.3                        | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Sugar maple         | 12       | 0.0                        | 4.2              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 13.2                        | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Weeping willow      | 2        | 0.0                        | 100.0            | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 100.0                       | 0.0                       | 50.0            | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| White ash           | 23       | 0.0                        | 27.5             | 0.0                               | 0.0         | 0.0         | 1.7                     | 0.0                       | 3.8                         | 2.1                       | 5.2             | 0.0                  | 0.0             | 5.2               | 1.7                          | 0.0                 |
| White fir           | 2        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 100.0                       | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| White mulberry      | 11       | 0.0                        | 90.9             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 81.8                        | 0.0                       | 9.1             | 0.0                  | 0.0             | 9.1               | 0.0                          | 9.1                 |
| White oak           | 8        | 0.0                        | 12.5             | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| White spruce        | 16       | 0.0                        | 6.1              | 0.0                               | 0.0         | 0.0         | 6.1                     | 0.0                       | 13.6                        | 0.0                       | 6.1             | 0.0                  | 0.0             | 6.1               | 0.0                          | 12.9                |
| Willow spp          | 1        | 0.0                        | 100.0            | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 100.0           | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| Winged burning bush | 6        | 0.0                        | 0.0              | 0.0                               | 0.0         | 0.0         | 0.0                     | 0.0                       | 0.0                         | 0.0                       | 0.0             | 0.0                  | 0.0             | 0.0               | 0.0                          | 0.0                 |
| All Trees           |          | 0.5                        | 19.5             | 2.4                               | 0.4         | 0.2         | 0.7                     | 2.1                       | 32.8                        | 0.4                       | 5.3             | 0.0                  | 1.1             | 2.2               | 0.3                          | 0.6                 |

## APPENDIX F—POTENTIAL INSECT AND DISEASE IMPACT

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The following insects and diseases were analyzed to quantify their potential impact on the urban forests of Wisconsin.

- **AL:** Aspen Leafminer (*Phyllocnistis populiella*) - AL is an insect that causes damage primarily to trembling or small tooth aspen by larval feeding of leaf tissue. While outbreaks of the aspen leafminer have been recorded throughout parts of Alaska, Canada, and the western United States, the pest is relatively uncommon in eastern North America (Kruse et al. 2007).
- **ALB:** Asian Longhorned Beetle (*Anoplophora glabripennis*) - The Asian longhorned beetle (USDA Animal and Plant Health Inspection Service 2010, U.S. Department of Agriculture 2002) is an insect that bores into and kills a wide range of hardwood species. This beetle was discovered in 1996 in Brooklyn, NY and has subsequently spread to Long Island, Queens and Manhattan. In 1998, the beetle was discovered in the suburbs of Chicago, IL and successfully declared eradicated in 2006. Beetles have also been found in Jersey City, NY (2002), Toronto/Vaughan, Ontario (2003) and Middlesex/Union counties, NJ (2004). In 2007, the beetle was found on Staten and Prall's Island, NY. Most recently, beetles were detected in Worcester, MA (2008) and Bethel, OH (2011). In addition to the eradication in Chicago, successful eradication has since occurred in Hudson County, NJ (2008) and Islip, NY (2011).
- **BBD:** Beech Bark Disease (*Cryptococcus fagisuga*) - Beech bark disease is an insect-disease complex that primarily impacts American beech. It is caused by the infestation of several different species. First, the insect, *Cryptococcus fagisuga*, feeds on the sap of the beech trees. These affected trees can become hosts to the necrotic fungi. The two primary species of necrotic fungi in North America are *N. coccinea* var. *faginata* and *N. galligena* (Houston and O'Brien 1983).
- **BC:** Butternut Canker (*Sirococcus clavigignenti-juglandacearum*) - Butternut canker is caused by a fungus that infects butternut trees. The disease was first discovered in 1967 in Wisconsin and has since caused significant declines in butternut populations in the United States (Ostry et al. 1996).
- **CB:** Chestnut Blight (*Cryphonectria parasitica*) - The most common hosts of the fungus that cause chestnut blight are American and European chestnut. This disease causes canker formation in host trees resulting in dead limbs, brown or yellowing leaves, or mortality (Diller 1965).
- **DA:** Dogwood Anthracnose (*Discula destructiva*) - Dogwood anthracnose is a disease that affects dogwood species, specifically flowering and Pacific dogwood. It is caused by a fungus that produces leaf spots and necrotic blotches and canker formation on twigs, branches, and the main stem of infected trees (Mielke and Daughtrey no date)

- **DED:** Dutch Elm Disease (*Ophiostoma novo-ulmi*) - American elm, one of the most important street trees in the 20<sup>th</sup> century, has been devastated by the Dutch elm disease. Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States (Stack et al. 1996).
- **DFB:** Douglas-Fir Beetle (*Dendroctonus pseudotsugae*) - The Douglas-fir beetle is a bark beetle that infests Douglas-fir trees. Infestations of DFB have been seen throughout the western United States, British Columbia, and Mexico often resulting in tree mortality (Schmitz and Gibson 1996).
- **EAB:** Emerald Ash Borer (*Agrilus planipennis*) - Since being discovered in Detroit in 2002, emerald ash borer (U.S. Department of Agriculture et al. 2010) has killed millions of ash trees in Illinois, Indiana, Kentucky, Maryland, Michigan, Minnesota, Missouri, New York, Ohio, Ontario, Pennsylvania, Quebec, Virginia, West Virginia, and Wisconsin.
- **FE:** Fir Engraver (*Scotylus ventralis*) - One common pest of white fir, grand fir, and red fir trees is the fir engraver. This bark beetle is distributed primarily in the western United States (Ferrell 1986).
- **FR:** Fusiform Rust (*Cronartium fusiforme*) – Fusiform rust is a fungal disease that is distributed in the southern United States. It is particularly damaging to slash pine and loblolly pine because it infects the living tissue of the host's stems and branches. Pine trees affected by the fungus can develop fatal galls and cankers (Phelps and Czabator 1978).
- **GM:** Gypsy Moth (*Lymantria dispar*) - The gypsy moth (U.S. Department of Agriculture 2005c) is a defoliator that feeds on many species causing widespread defoliation and tree death if outbreak conditions last several years.
- **GSOB:** Goldspotted Oak Borer (*Agrilus auroguttatus*) - Infestations of the goldspotted oak borer have been a growing problem in southern California. This forest pest is native to southeastern Arizona and Mexico and believed to have been transported to California by the movement of firewood. The three known host species for GOB are coast live oaks, California black oaks, and canyon live oaks (Society of American Foresters 2011).
- **HWA:** Hemlock Woolly Adelgid (*Adelges tsugae*) – As one of the most damaging pests to Eastern hemlock and Carolina hemlock, HWA has played a large role in hemlock mortality in the United States. Since the pest was first discovered in 1951, infestations have expanded to cover about half of the range of hemlock in the Eastern United States (U.S. Department of Agriculture 2005b).
- **JPB:** Jeffrey Pine Beetle (*Dendroctonus jeffreyi*) - The Jeffrey pine beetle is native to North America and is distributed across California, Nevada, and Oregon where its only host, Jeffrey pine, also occurs (Smith et al. 2009).

- **LAT:** Large Aspen Tortrix (*Choristoneura conflictana*) – Quaking aspen is a principal host for the defoliator, large aspen tortrix. The insect has been found across much of the northeastern, north central, and western United States, as well as Alaska and Canada. LAT can reach outbreak levels where quaking aspen are abundant and will potentially strip hosts of all of their foliage (Ciesla and Kruse 2009).
- **LWD:** Laurel Wilt (*Raffaelea lauricola*) - Laurel wilt is a fungus-caused disease that is introduced to host trees by the redbay ambrosia beetle. Redbay, as well as other tree species in the Laurel family, are common hosts for laurel wilt which has been observed in North Carolina, South Carolina, Georgia, Alabama, Mississippi, and Florida (U.S. Department of Agriculture no date).
- **MPB:** Mountain Pine Beetle (*Dendroctonus ponderosae*) - Mountain pine beetle is a bark beetle that primarily attacks pine species in the western United States. The major host species of MPB, lodgepole pine, ponderosa pine, western white pine, sugar pine, limber pine, and whitebark pine, have a similar distribution as this pest (Gibson et al. 2009).
- **NSE:** Northern Spruce Engraver (*Ips pertubatus*) - This insect has had a significant impact on the boreal and sub-boreal forests of North America where the pest's distribution overlaps with the range of its major hosts, white spruce, Englemann spruce, and Lutz's spruce. This forest pest has been found in Alaska, Maine, Michigan, Minnesota, and Montana within the United States and in most of the provinces of Canada (Burnside et al. 2011).
- **OW:** Oak Wilt (*Ceratocystis fagacearum*) - Oak wilt, which is caused by a fungus, is a prominent disease among oak trees producing leaf wilting and discoloration, heavy defoliation, or fungal mats beneath the bark. The disease has been found in 21 states throughout most of the Midwestern United States and it is still unknown whether any species of oak are immune to it (Rexrode and Brown 1983).
- **POCRD:** Port-Orford-Cedar Root Disease (*Phytophthora lateralis*) - Port-Orford-cedar root disease is a root disease that is caused by a fungus. This fungus is most damaging to Port-Orford cedar and Pacific yew species (Liebhold 2010).
- **PSB:** Pine Shoot Beetle (*Tomicus piniperda*) - The pine shoot beetle is a wood borer that attacks various pine species, though Scotch pine is the preferred host in North America. The beetle has an international geographic distribution. In the United States it has been discovered in Illinois, Indiana, Maine, Maryland, Michigan, New Hampshire, New York, Ohio, Pennsylvania, Vermont, West Virginia, and Wisconsin, as well as in Ontario and Quebec in Canada (Ciesla 2001).
- **SB:** Spruce Beetle (*Dendroctonus rufipennis*) - All species of spruce that fall within the spruce beetle's range are suitable hosts for attack. This bark beetle causes significant

mortality and covers large areas of Alaska, Canada, and the northern United States, as well as some patches through the Rocky Mountain range (Holsten et al. 1999).

- **SBW:** Spruce Budworm (*Choristoneura fumiferana*) - Spruce budworm is an insect that causes severe damage to balsam fir. During the larval stage of the budworm's life, it feeds primarily on the needles or expanding buds of its hosts. Years of heavy defoliation can ultimately lead to tree mortality. Other hosts for the spruce budworm include white, red, and black spruce (Kucera and Orr 1981).
- **SOD:** Sudden Oak Death (*Phytophthora ramorum*) - Sudden oak death is a disease that is caused by a fungus. It is most common in British Columbia, Washington, Oregon, and California and impacts many different species including southern red oak, California black oak, Northern red oak, pacific madrone, tanoak, and coastal live oak (Kliejunas 2005).
- **SPB:** Southern Pine Beetle (*Dendroctonus frontalis*) - Although the southern pine beetle will attack most pine species, its preferred hosts are loblolly, Virginia, pond, spruce, shortleaf, and sand pines. The range of this particular bark beetle covers much of the southeastern United States (Clarke and Nowak 2009).
- **SW:** Sirex Woodwasp (*Sirex noctilio*) - The sirex woodwasp is a wood borer that primarily attacks pine species. It is not native to the United States, but is known to cause a high percentage of tree mortality among North American species that have been planted in countries of the southern hemisphere (Haugen and Hoebeke 2005).
- **TCD:** Thousand Cankers Disease (*Pityophthorus juglandis* & *Geosmithia* spp.) - Thousand cankers disease is an insect-disease complex that kills several species of walnuts, including black walnut. It is known to occur primarily in the western states of Washington, Oregon, California, Idaho, Utah, Arizona, New Mexico, and Colorado. Tennessee is the first state in the east where thousand cankers disease has been found. Tree mortality is the result of attacks by the walnut twig beetle and subsequent canker development caused by associated fungi (Cranshaw and Tisserat 2009; Seybold et al. 2010, U.S. Department of Agriculture 2011).
- **WPB:** Western Pine Beetle (*Dendroctonus brevicomis*) - The western pine beetle is an aggressive attacker of ponderosa and Coulter pines. This bark beetle has caused significant swaths of damage in California, Oregon, Washington, Idaho, British Columbia, Montana, Nevada, Utah, Colorado, Arizona, New Mexico, Texas, and parts of northern Mexico (DeMars and Roettgering 1982).
- **WPBR:** White Pine Blister Rust (*Cronartium ribicola*) - Since its introduction to the United States in 1900, white pine blister rust has had a detrimental effect on white pines, particularly in the Lake States (Nicholls and Anderson 1977).

- WSB:** Western Spruce Budworm (*Choristoneura occidentalis*) - Western spruce budworm is an insect that causes defoliation in western conifers. It has been found in Arizona, New Mexico, Colorado, Utah, Wyoming, Montana, Idaho, Oregon, and Washington in the United States and British Columbia and Alberta in Canada. The western spruce budworm feeds on new foliage of its hosts. Common host species include Douglas-fir, grand fir, white fir, subalpine fir, corkbark fir, blue spruce, Engelmann spruce, white spruce, and western larch (Fellin and Dewey 1986).

The following table displays which sampled tree species are susceptible to various insects and diseases found in Wisconsin.

|                     |                 | Pests <sup>a</sup> |     |     |     |    |    |     |      |     |    |     |                 |
|---------------------|-----------------|--------------------|-----|-----|-----|----|----|-----|------|-----|----|-----|-----------------|
| Common Name         | Number of Trees | GM                 | EAB | PSB | DED | OW | SB | LAT | WPBR | SBW | AL | BBD | BC <sup>b</sup> |
| Apple spp.          | 3,265,000       | x                  |     |     |     |    |    |     |      |     |    |     |                 |
| White ash           | 1,669,000       |                    | x   |     |     |    |    |     |      |     |    |     |                 |
| Green ash           | 1,453,000       |                    | x   |     |     |    |    |     |      |     |    |     |                 |
| Scotch pine         | 1,053,000       |                    |     | x   |     |    |    |     |      |     |    |     |                 |
| Siberian elm        | 893,000         |                    |     |     | x   |    |    |     |      |     |    |     |                 |
| Northern red oak    | 830,000         | x                  |     |     |     | x  |    |     |      |     |    |     |                 |
| Red pine            | 514,000         |                    |     | x   |     |    |    |     |      |     |    |     |                 |
| Eastern white pine  | 511,000         |                    |     | x   |     |    |    |     | x    |     |    |     |                 |
| Blue spruce         | 506,000         |                    |     |     |     |    | x  |     |      |     |    |     |                 |
| White spruce        | 463,000         |                    |     |     |     |    | x  |     |      | x   |    |     |                 |
| American elm        | 381,000         |                    |     |     | x   |    |    |     |      |     |    |     |                 |
| Jack pine           | 377,000         |                    |     | x   |     |    |    |     |      |     |    |     |                 |
| Common chokecherry  | 347,000         |                    |     |     |     |    |    | x   |      |     |    |     |                 |
| Paper birch         | 309,000         | x                  |     |     |     |    |    | x   |      |     |    |     |                 |
| Slippery elm        | 253,000         |                    |     |     | x   |    |    |     |      |     |    |     |                 |
| White oak           | 225,000         | x                  |     |     |     | x  |    |     |      |     |    |     |                 |
| Norway spruce       | 198,000         |                    |     | x   |     |    | x  |     |      |     |    |     |                 |
| Northern pin oak    | 197,000         | x                  |     |     |     | x  |    |     |      |     |    |     |                 |
| Callery pear        | 189,000         | x                  |     |     |     |    |    |     |      |     |    |     |                 |
| Black oak           | 146,000         | x                  |     |     |     | x  |    |     |      |     |    |     |                 |
| Quaking aspen       | 140,000         | x                  |     |     |     |    |    | x   |      |     | x  |     |                 |
| Ash spp.            | 112,000         |                    | x   |     |     |    |    |     |      |     |    |     |                 |
| Eastern hophornbeam | 84,000          | x                  |     |     |     |    |    |     |      |     |    |     |                 |
| Black willow        | 84,000          | x                  |     |     |     |    |    | x   |      |     | x  |     |                 |
| Alder               | 65,000          |                    |     |     |     |    |    | x   |      |     |    |     |                 |
| Austrian pine       | 60,000          |                    |     | x   |     |    |    |     |      |     |    |     |                 |
| American beech      | 56,000          |                    |     |     |     |    |    |     |      |     |    | x   |                 |

*continued*

|                   |                 | Pests <sup>a</sup> |     |     |     |    |    |     |      |     |    |     |                 |
|-------------------|-----------------|--------------------|-----|-----|-----|----|----|-----|------|-----|----|-----|-----------------|
| Common Name       | Number of Trees | GM                 | EAB | PSB | DED | OW | SB | LAT | WPBR | SBW | AL | BBD | BC <sup>b</sup> |
| Weeping willow    | 56,000          | x                  |     |     |     |    |    | x   |      |     | x  |     |                 |
| American basswood | 56,000          | x                  |     |     |     |    |    |     |      |     |    |     |                 |
| Littleleaf linden | 56,000          | x                  |     |     |     |    |    |     |      |     |    |     |                 |
| Elm spp.          | 44,000          |                    |     |     | x   |    |    |     |      |     |    |     |                 |
| Balsam fir        | 35,000          |                    |     |     |     |    |    |     |      | x   |    |     |                 |
| Downy hawthorn    | 28,000          | x                  |     |     |     |    |    |     |      |     |    |     |                 |
| Bigtooth aspen    | 28,000          | x                  |     |     |     |    |    | x   |      |     |    |     |                 |
| Bur oak           | 28,000          | x                  |     |     |     | x  |    |     |      |     |    |     |                 |
| Willow spp.       | 28,000          | x                  |     |     |     |    |    | x   |      |     | x  |     |                 |

‘x’ indicates tree species is a host to the pest

<sup>a</sup> Includes only pests found in Wisconsin

<sup>b</sup> Butternut canker (BC) is found in Wisconsin, but no host species were sampled

