NATIONAL FOREST HEALTH MONITORING PROGRAM

Urban Forests of Wisconsin: Pilot Monitoring Project 2002

United States
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Northeastern Area
State and Private Forestry
Newtown Square, PA

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Preface

Trees in cities can contribute significantly to human health and environmental quality. Unfortunately, little is known about the urban forest resource and what it contributes locally, regionally, and nationally in terms of ecology, economy, and social well-being. To better understand this resource and its values, the Forest Service, U.S. Department of Agriculture, initiated a pilot study to sample trees within all urban areas across various States. Urban forest structure, functions, health, and values in Wisconsin were analyzed using the Urban Forest Effects (UFORE) Model. Results from this report demonstrate the value of collecting and analyzing urban forest data and can be used to advance the understanding and management of urban forests to improve human health and environmental quality.

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This report highlights the findings from the first statewide urban forest health monitoring pilot study conducted in the State of Wisconsin in 2002. In addition to the authors, personnel involved in compiling this report included the following employees of the Forest Service, U.S. Department of Agriculture: Bill Smith, Jeffrey Walton, Daniel Crane, and the Information Management and Analysis Staff of the Northeastern Area State and Private Forestry, Morgantown, WV; and the Lumberjack Resource Conservation and Development Council, Inc.

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EXECUTIVE SUMMARY

Data from 139 field plots located within the urban areas (U.S. Census Bureau 1990 definition: see table 1) of Wisconsin were analyzed in this pilot project conducted by the Forest Service, U.S. Department of Agriculture, in partnership with the State of Wisconsin. Trees within the urban boundary were sampled according to modified protocols of the Forest Inventory and Analysis (FIA) and Forest Health Monitoring (FHM) Programs. Data were analyzed using the Forest Service's Urban Forest Effects (UFORE) Model to quantify and describe the benefits of the Wisconsin urban forest. The data from this project will help fill a national data gap related to trees within urban areas and help provide data on ecosystem services and values provided by urban forests.

Data were analyzed in two subsets based on how the data were collected. FIA data from plots located within the urban boundary were obtained with permission from the Forest Service's North Central Research Station. These data are part of a national system to inventory and monitor forest and timber lands. The other subset of data was collected specifically for this study on plots that were not sampled by FIA for the national inventory (see Methods for a full description). These subsets are referred to as "**$\mathbf{UFIA_F}$**" and "**$\mathbf{UFIA^+}$**", respectively, throughout the text.

In Wisconsin's urban areas there are an estimated 130.6 million trees—103.7 million in $UFIA_F$ land and 26.9 million in $UFIA^+$ areas (table 1). The most common species was *Ostrya virginiana* (Eastern hophornbeam), which is a small tree found predominantly in $UFIA_F$ areas. In $UFIA^+$ areas, the most common species was *Acer negundo* (box elder maple). $UFIA^+$ areas had a greater percentage of large trees compared with $UFIA_F$ areas.

Forest health data collected on crown condition and occurrence of damage indicated that the urban forests of Wisconsin are healthy and vigorous. The emerald ash borer poses a risk to 12.5 percent of Wisconsin's urban forest, while Asian longhorned beetle could be hosted by over 60 percent of the trees in urban areas.

The 130.6 million urban trees in Wisconsin have an estimated structural value of $17 billion, provide an annual energy saving to residents of $24.3 million, remove $36.3 million worth of pollution from the air, and store 6.1 million tons of carbon.

The statewide survey of Wisconsin's urban forest is one of a series of pilot studies initiated to determine the structure, condition, and function of forests in urban areas at a broad scale, beyond just one city or community. The Wisconsin study is the first pilot to incorporate the full panel of urban plots throughout the State and to integrate those with the corresponding FIA data. This report accomplishes several objectives:

1. *It documents the utilization of an established FIA plot system and FIA/FHM data measurement protocols to capture information about urban forests. This fills a previously identified data gap.*
2. *It demonstrates the use of the Urban Forest Effects (UFORE) Model in data analysis to quantify urban forest structure and function.*
3. *It establishes a protocol for delimiting urban boundaries.*
4. *It quantifies, for the first time, the status and condition of urban forests on a statewide basis.*
5. *It establishes a pest risk assessment for Wisconsin urban forests.*

Table 1. Wisconsin urban forest population estimates.

Measurement	Total urban	$UFIA^{+}$	$UFIA_{F}$
Area (acres)*	900,860	729,270	171,590
Estimated number of trees	130,619,000	26,934,000	103,685,000
Total biomass (tons of carbon)	6,095,000	2,021,000	4,073,000
Most common species (percent)	*Ostrya virginiana* (7.3)	*Acer negundo* (13.8)	*Ostrya virginiana* (9.0)
	Acer rubrum (6.5)	*Fraxinus americana* (13.5)	*Prunus serotina* (7.3)
	Fraxinus pennsylvanica (6.0)	*Fraxinus pennsylvanica* (5.7)	*Acer rubrum* (6.8)
	Prunus serotina (6.0)	*Pinus strobus* (5.7)	*Fraxinus pennsylvanica* (6.1)
	Pinus strobus (5.6)	*Acer rubrum* (5.2)	*Tilia americana* (5.8)
	Acer negundo (5.1)	*Picea glauca* (4.5)	*Pinus strobus* (5.6)
	Populus tremuloides (4.8)	*Ulmus rubra* (3.8)	*Populus tremuloides* (5.3)
	Tilia americana (4.6)	*Acer platanoides* (3.1)	*Ulmus americana* (4.3)
	Fraxinus americana (4.0)	*Populus tremuloides* (3.1)	*Acer spicatum* (4.2)
	Ulmus americana (3.9)	*Thuja occidentalis* (2.8)	*Carya ovata* (4.0)

*Excludes 183,846 acres of urban water

DEFINITIONS

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. These areas were recorded as "**$UFIA_F$**" throughout this report (photo below on left).
Saplings and trees	Saplings are considered woody perennials between 1 inch and 4.9 inches in diameter at breast height (d.b.h., 4.5 feet above ground). A tree is defined as a woody perennial equal to or larger than 5 inches d.b.h. For data collected on **$UFIA_F$** plots, the definition was further refined and data for trees and saplings were only collected for specific species as noted on the FIA "tally" list (U.S. Department of Agriculture, Forest Service 2003). On **$UFIA^+$** plots, all woody perennials larger than 1 inch d.b.h. were measured.
Sequestration	Sequestration is the rate at which carbon is removed from the atmosphere through biophysical processes, such as photosynthesis, and stored in a tree's biomass or tissues (wood, leaves, roots, flowers).
$UFIA^+$	These are areas that do not meet the FIA criteria for forest land. They also contain trees, but often with a lower density than $UFIA_F$ areas, or a disturbed understory, and are denoted as "**$UFIA^+$**" in this report (photo below on right).
$UFIA_F$	Designation used in this report for land that fits the definition for Forest (see above).
Urban forest	Term used for all trees within the urban boundary (both $UFIA_F$ and $UFIA^+$ lands combined).
Urban	Urban areas were classified based on the 1990 census and consisted of (1) urbanized areas with a population density of at least 1,000 people per square mile, and (2) urban places defined as a portion of places with 2,500 people or more outside the urbanized areas.
UFORE	Acronym for the Urban Forest Effects Model, which 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.

Photograph illustrating land defined as $UFIA_F$ in this report.

Photograph illustrating land defined as $UFIA^+$ in this report.

Photographs: Wisconsin Department of Natural Resources

INTRODUCTION

Urban forests are comprised of all trees (both within and outside forested stands) that occur within urban areas, as defined by the U.S. Census Bureau. These 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 this important forest resource, yet relatively little is known about it. To learn more about this resource and to aid in its management and planning, a pilot study to apply a national forest health monitoring protocol within urban areas was conducted by the Forest Service, U.S. Department of Agriculture. Based on standard Forest Health Monitoring (FHM) and Forest Inventory and Analysis (FIA) field sampling protocols, the national plot inventory grid was used to sample urban areas within the State of Wisconsin. The pilot study was developed to test the feasibility of various procedures and analysis techniques to be used in urban forest health monitoring. Similar pilot studies were and are being conducted in Indiana (2001), New Jersey (2003-2004), Tennessee (2005-2009), and Colorado (2005-2009).

Data from 139 field plots located throughout urban areas in Wisconsin were analyzed using the Forest Service's Urban Forest Effects (UFORE) Model to quantify the State's urban forest structure, health, benefits, and values (Nowak and Crane 2000). Field crews visited the plots during summer 2002.

URBAN LAND, FOREST EXTENT, AND POPULATION

The 1990 census-defined urban land area used in this study is about 3.0 percent of the total land area of Wisconsin (figure 1). Nowak and others (2005) ranked Wisconsin 26th in the United States in acreage of urban land and percent urban growth.

Forty-six percent of Wisconsin is classified as forest land. While the amount of forest land has remained relatively stable over the last 10 years (Vissage and others 2005), the amount of Wisconsin urban land area increased by 186,000 acres between 1990 and 2000. Forecasts predict urban land in the State will grow to 8.3 percent of the land area by 2050, advancing Wisconsin to the 25th rank in urban land area (Nowak and Walton 2005). Urban land area is, of course, influenced by human population. State population was 4.89 million in 1990 and increased to 5.36 million by 2000 (U.S. Census Bureau 2006a). Wisconsin's population is projected to continue to increase, with an overall State population growth of 14.7 percent by 2030 (U.S. Census Bureau 2006b).

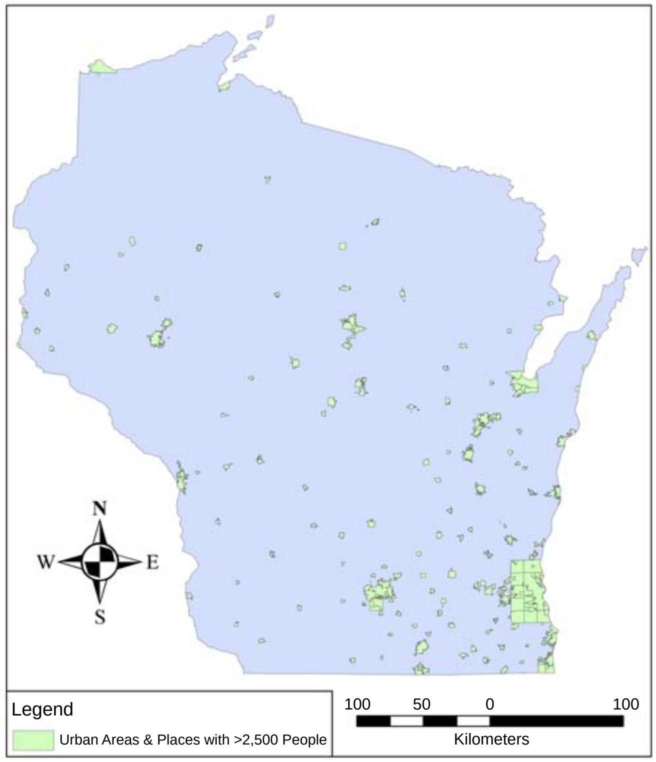


Figure 1. Urban land in Wisconsin in 1990 (using the U.S. Census Bureau's 1990 definition of urban land).

METHODS

The Forest Service's FIA Program annually assesses the Nation's forest resource on a statewide basis. Detailed tree measurements are collected on forest plots defined by FIA as areas of at least 1 acre, 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, Forest Service 2003).

In 2001, the Forest Service's FHM Program initiated an assessment of urban forest conditions. This assessment delimited urban boundaries and then collected tree information from established plots within the urban boundaries. Urban areas were classified based on the 1990 census and consisted of (1) urbanized areas with a population density of at least 1,000 people per square mile, and (2) urban places defined as a portion of places with 2,500 people or more outside the urbanized areas.

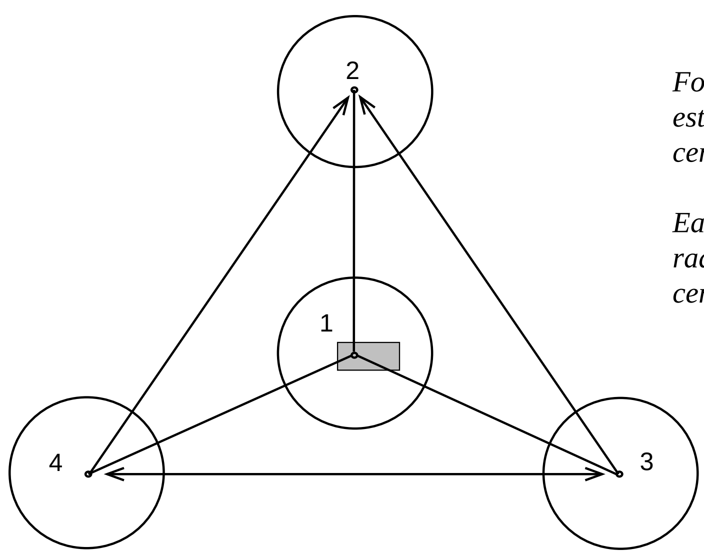
Plots were measured regardless of whether the plot met the FIA definition of forest land. Within the urban boundaries some field plots fell in areas that met the FIA definition of forest (e.g., parks, wooded areas along streambanks). Most plots, however, fell in areas considered "nonforest." While not meeting the above definition, nonforest areas do contain trees. Because trees are found in both forest and "nonforest" areas within the urban boundary, data from all plots are included in this assessment. The data from plots that meet the FIA definition of forest are segregated into the "$UFIA_F$" category. Plots not meeting the FIA definition are referred to as "$UFIA^+$".

FIA plots are measured on a panel system in which approximately one fifth of all the plots within a State are measured in a given year. This pilot study used all five panels of plots that fell within urban areas of Wisconsin ($UFIA_F$ and $UFIA^+$). A total of 180 plots landed within the urban boundary. Thirty-three plots were in water, and eight were denied access; these plots were not measured. During summer 2002, 111 permanent $UFIA^+$ field plots were established and measured. These plots were combined with 28 forested urban ($UFIA_F$) plots (already measured by FIA) (table 2).

Table 2. Urban FIA plots in Wisconsin, 2002.

Plot status	**Number of plots**
Measured	
$UFIA^+$	111
$UFIA_F$	28
Total plots measured	139
Sample intensity, non-water	1 plot/ 6,128 acres
Unmeasured	
Census-defined water	33
Denied access or problem plot	8

For each $UFIA^+$ plot, forest health monitoring data collection protocols (Conkling and Byers 1994; U.S. Department of Agriculture, Forest Service 2002a) were used on all trees larger than or equal to 1 inch in diameter at breast height (d.b.h.; 4.5 feet above ground) on each of the four 1/24-acre subplots (figure 2). Urban forest health monitoring variables



Four fixed-area 24-foot radius subplots were established. Subplots are located 120 feet from the center of subplot 1 at 360˚, 120˚, and 240˚.

Each subplot contained a microplot with a 6.8-foot radius located 12 feet at 90˚ from each subplot center.

Figure 2. FIA plot configuration.

included species, diameter, height, height-to-live-crown ratio, crown dimensions, foliage transparency, tree damage, distance from tree to buildings, ground cover, impervious surface in plot, condition class, and ownership.

For existing $UFIA_F$ plots, standard data collected by FIA crews were used for analysis, which included measurements of all trees on the tally list larger than or equal to 5 inches d.b.h. on four 1/24-acre subplots and saplings between 1 and 5 inches d.b.h. on four 1/300-acre micro-plots (U.S. Department of Agriculture, Forest Service 2003). $UFIA_F$ and $UFIA^+$ plot data were combined for the complete urban forest estimate.

RESULTS

Distribution and Characteristics of Land Use Types Within $UFIA^+$ Areas

Urban areas can be described by their land uses. Each $UFIA^+$ plot visited was given a land use designation (table 3). The predominant land use was residential (38.2 percent), followed by right-of-way (17.2 percent) and commercial/industrial land uses (12.7 percent). Tree density was highest on residential lands (63 trees/acre), followed by vacant/other (60.1 trees/acre) and park/golf (50.9 trees/acre). Land uses with trees having the highest average d.b.h. were ROW/transportation (9.2 in.), institutional (7.5 in.), and residential (5.8 in.). The highest average basal areas (BA) per acre (cross sectional area of a tree at 4.5 feet) were found on residential land (21.4 ft^2/acre), vacant/other (17.5 ft^2/acre), and park/golf (6.7 ft^2/acre) land. Appendix A illustrates species frequency by land use.

Structure and Composition

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. The current study is the first statewide inventory and forest health monitoring effort to quantify the urban forests within the State of Wisconsin. If the pilot protocol were to be implemented into a regular inventory and assessment, resource managers would be able to monitor how

Table 3. Land use characteristics in $UFIA^+$ plots.

Land use	Percentage of urban land	Trees per acre	Basal area (ft^2/acre)	Average d.b.h. (in.)	Median d.b.h. (in.)
Residential	38.2	63.0	21.4	5.8	3.0
ROW/transportation	17.2	4.9	3.2	9.2	9.0
Commercial/industrial	12.7	25.5	2.8	3.4	2.0
Institutional	8.2	0.7	0.2	7.5	7.0
Agriculture	7.9	0.0	0.0	NA	NA
Park/golf	7.9	50.9	6.7	3.7	2.0
Vacant/other	7.8	60.1	17.5	5.3	3.0

Residential—developed land used primarily for human dwellings.
ROW/transportation—rights-of-way and transportation corridors, limited access roadways, airports, or railway.
Commercial/industrial—developed land used for commercial businesses or industrial purposes.
Institutional—developed land used for schools, government or religious buildings, or hospital/medical complexes.
Agriculture—land managed for crops, pasture, or other agricultural uses.
Park/golf—developed land used primarily for parks, green/open space, or golf courses.
Vacant/other—developed land for use by humans for purposes other than forestry or agriculture but without a designated land use. Other land uses were land parcels that were larger than 1.0 acre, wider than 120 feet, and did not fall into any other category (e.g., marsh or undeveloped beach). Other also included one plot classified as $UFIA^+$ with a land use designation of forest.

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 on which species perform the best under differing urban conditions and how long various species live on average in urban areas.

There are an estimated 130.6 million trees in Wisconsin's urban areas. Of these trees, approximately 103.7 million are found in $UFIA_F$ conditions and the remaining 26.9 million are found in other urban land uses ($UFIA^+$). A total of 1,382 trees were sampled—651 trees in $UFIA^+$ plots and the remaining 731 trees in $UFIA_F$ plots. The average d.b.h. (in.) was 4.3 and the average basal area (ft^2/acre) was 26.3 for the total urban forest. The number of trees per acre in Wisconsin urban areas is 145.0, with a tree density of 36.9 trees/acre in $UFIA^+$ areas and 604.0 trees/acre in $UFIA_F$ areas (table 4).

Species frequency

One aspect of inventories is to determine the frequency, or count, of species present. Each species, and their associated families, provide specific benefits to the urban forest and may require specific management regimes. Estimates of statewide urban forest species populations give managers and policymakers baseline data to achieve desired goals. A current issue in the Midwestern United States is the expanding extent of the exotic emerald ash borer (EAB). Many States, such as Wisconsin, are preparing for EAB to invade their borders. Knowing the extent of the ash resource is essential to crafting a strategic response and action plan for EAB. This is just one example of how urban tree species frequency can be used for management and policy decisions at statewide and regional levels.

Species native to North America comprise 95 percent of trees in urban areas, while 86 percent are native to Wisconsin specifically. Most exotic species identified originated from Eurasia or Europe (3.3 percent combined).

Table 5 shows the distribution of the 10 most frequent species with percent frequency of the species in urban areas (column (a)) separated into $UFIA^+$ (column (b)) and $UFIA_F$ (column (c)). For example, *Ostrya virginiana* is estimated to comprise 7.3 percent of the entire population: 7.1 percent in $UFIA_F$ and the remaining 0.2 percent in $UFIA^+$ areas. To further describe species frequency, columns (d) and (e) show the frequency of species found only within $UFIA^+$ or $UFIA_F$ areas. For example, of all trees found on $UFIA^+$ plots, 0.8 percent were *O. virginiana*, while 9.0 percent of all $UFIA_F$ trees were *O. virginiana* (see appendix B for a listing of all species).

Ostrya virginiana was the most common tree species in Wisconsin urban areas, comprising 7.3 percent of the total population (table 5). This species was relatively uncommon in $UFIA^+$ areas, but it was the most prevailing species in $UFIA_F$ areas. In $UFIA^+$ regions, *Acer negundo* was the most common species, comprising 13.8 percent of this population. Of the 10 most common species, *Fraxinus americana* and *A. negundo* were found predominately in $UFIA^+$ areas. All of the other top 10 species were found primarily in $UFIA_F$ areas, particularly *Tilia americana* (100 percent in forest areas), *O. virginiana* (97.8 percent), and *Prunus serotina* (96.8 percent). The 10 most frequent species accounted for 53.7 percent of the total urban tree population.

Table 4. Summary of plot-level data.

Measurement	**Total**	**$UFIA^+$**	**$UFIA_F$**
Number of plots sampled in urban area	139	111	28
Number of living trees sampled	1,382.0	651.0	731.0
Median d.b.h. (in.)	2.0	3.0	2.0
Average d.b.h. (in.)	4.3	5.4	4.0
Average basal area (ft^2/acre)	26.3	11.2	90.3
Estimated number of trees per acre	145.0	36.9	604.0
Tree population estimates (millions)	130.6	26.9	103.7

A total of 80 different tree species were identified in urban areas of Wisconsin. Of these, 23 were found exclusively on $UFIA^+$ plots, 24 exclusively on urban FIA plots, and 33 species were common to both plot types (table 6). The 80 species represented 31 genera of trees and 17 plant families. Interestingly, only two plant families were found exclusively in $UFIA_F$ plots: *Tiliaceae* and *Moraceae*. Each of these families had only one species within them, *Tilia americana* and *Morus rubra,* among the trees sampled in this study.

In $UFIA^+$ plots, *Acer negundo*, *Fraxinus americana*, and *Fraxinus pennsylvanica* were the most frequent species found (table 7). The 10 most frequent species accounted for 61.1 percent of the trees found in $UFIA^+$ areas. A total of 56 different species were observed on these plots.

In forest areas, the most frequent species were *Ostrya virginiana* (9.0 percent) and *Prunus serotina* (7.3 percent). On $UFIA_F$ plots, 57 species were found, with the 10 most frequent species accounting for 58.5 percent of all trees in those areas (table 8).

Genera and family frequency

In urban areas of Wisconsin, the genus *Acer* was the most common, representing almost 18 percent of all trees, followed by *Fraxinus* (12.5 percent) and

Table 5. Species composition—percentages of top 10 species in urban areas of Wisconsin, 2002.

Species	**Percentage of total trees (a)**	**$UFIA^+$, percentage of total trees (b)**	**$UFIA_F$, percentage of total trees (c)**	**$UFIA^+$ (d)**	**$UFIA_F$ (e)**
Ostrya virginiana	7.3	0.2	7.1	0.8	9.0
Acer rubrum	6.5	1.1	5.4	5.2	6.8
Fraxinus pennsylvanica	6.0	1.2	4.9	5.7	6.1
Prunus serotina	6.0	0.2	5.8	0.9	7.3
Pinus strobus	5.6	1.2	4.5	5.7	5.6
Acer negundo	5.1	2.9	2.2	13.8	2.8
Populus tremuloides	4.8	0.6	4.2	3.1	5.3
Tilia americana	4.6	NA	4.6	NA	5.8
Fraxinus americana	4.0	2.8	1.2	13.5	1.6
Ulmus americana	3.9	0.4	3.4	2.2	4.3

(a) Species total as percentage of entire population ($UFIA^+$ and $UFIA_F$)
(b) Species total in $UFIA^+$ areas as percentage of entire population
(c) Species total in $UFIA_F$ areas as percentage of entire population
Columns (a) = (b) + (c)
(d) Species total in $UFIA^+$ areas as a percentage of $UFIA^+$ total population
(e) Species total in $UFIA_F$ areas as a percentage of $UFIA_F$ total population

Table 6. Number of unique species, genera, and families; and number common to both nonforest and forest areas, Wisconsin 2002.

Classification level	**Total**	**$UFIA^+$ only**	**$UFIA_F$ only**	**Common to both $UFIA^+$ and $UFIA_F$ plots**
Species	80	23	24	33
Genera	31	8	4	19
Families	17	4	2	11

Table 7. Species frequency—percentages of the 10 most frequent species within UFIA+ areas only.

Species	Percentage of UFIA+
Acer negundo	13.8
Fraxinus americana	13.5
Fraxinus pennsylvanica	5.7
Pinus strobus	5.7
Acer rubrum	5.2
Picea glauca	4.5
Ulmus rubra	3.8
Acer platanoides	3.1
Populus tremuloides	3.1
Thuja occidentalis	2.8
Other 46 species	38.9

Table 8. Species frequency—percentages of the 10 most frequent species in $UFIA_F$ areas only.

Species	Percentage of $UFIA_F$
Ostrya virginiana	9.0
Prunus serotina	7.3
Acer rubrum	6.8
Fraxinus pennsylvanica	6.1
Tilia americana	5.8
Pinus strobus	5.6
Populus tremuloides	5.3
Ulmus americana	4.3
Acer spicatum	4.2
Carya ovata	4.0
Other 47 species	41.5

Prunus (8.4 percent) (table 9). The 10 most frequently sampled genera represented 79.3 percent of all trees in urban areas of Wisconsin. To better understand and manage urban forest populations, it is important to assess risks from invasive insects and diseases. Asian longhorned beetle, for example, has an extensive host range including *Acer*, *Salix*, *Ulmus* ("very good hosts"), *Aesculus*, *Betula*, and *Platanus* ("good" hosts) (Raupp and others 2006). Emerald ash borer

Table 9. Genera frequency—frequency of genera, in percent, of all trees in urban areas of Wisconsin, 2002. Proportions of frequencies found in UFIA+ and $UFIA_F$ plots equal the total.

Genus	Total (percent)	UFIA+ (percentage of total)	$UFIA_F$ (percentage of total)
Acer	17.5	5.0	12.5
Fraxinus	12.5	4.0	8.5
Prunus	8.4	0.9	7.5
Ostrya	7.3	0.2	7.1
Pinus	7.2	1.6	5.6
Populus	5.9	0.7	5.2
Quercus	5.8	0.8	5.0
Ulmus	5.6	1.7	3.9
Tilia	4.6	0.0	4.6
Picea	4.5	1.5	3.0
Remaining Genera	20.7	83.6	37.1

found in the United States has been found to target only ash species (McCullough and Katovich 2004). Likewise, sudden oak death, caused by the pathogen *Phytophthora ramorum*, infects members of the red oak group and related madrone and tanoak groups (Frankel 2002).

When examined at the plant family level, *Aceraceae* was the most common plant family in urban areas of Wisconsin. Represented mostly by trees in $UFIA_F$ plot types, almost 18 percent of all trees in urban Wisconsin belonged to this plant family. *Betulaceae*, *Pinaceae*, *Oleaceae*, and *Rosaceae* were the other families that contained more than 10 percent of all trees in urban Wisconsin. A total of 17 different families were sampled (table 10). The 10 most frequent plant families represented 96.5 percent of all trees sampled in Wisconsin urban areas. In UFIA+ plots, *Aceraceae*, *Oleaceae*, and *Pinaceae* were the three most frequent families, while *Betulaceae*, *Aceraceae*, and *Rosaceae* were the three most common families on $UFIA_F$ plots (table 10). As mentioned above, species diversity at the plant family level can mitigate risk to diseases and pests.

Table 10. Family frequency—frequency of plant family, as a percentage, of all trees in urban areas of Wisconsin, 2002. Proportions of UFIA$^+$ and UFIA$_F$ together equal the total.

Plant family	Total (percent)	UFIA$^+$ (percentage of total)	UFIA$_F$ (percentage of total)
Aceraceae	17.5	5.0	12.5
Betulaceae	16.4	1.5	14.9
Pinaceae	13.4	3.4	10.0
Oleaceae	12.5	4.0	8.5
Rosaceae	11.8	1.3	10.4
Ulmaceae	7.7	2.0	5.7
Fagaceae	5.9	0.9	5.0
Tiliaceae	4.6	0.0	4.6
Juglandaceae	4.4	0.5	3.9
Cupressaceae	2.3	0.9	1.4
Remaining Families	3.5	80.5	23.1

Tree size

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 the amount of "product" or logs, urban wood volume can be translated into tons of carbon stored or 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 sawmills, and increasing demand for specialty woods are making it more common for cities and local governments to market urban wood that is scheduled for removal as a "timber" product, rather than dispose of it as a wood waste or process it 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 commercial products or the amount of waste wood that may have to be disposed.

Tree diameter measurements can assist managers in planting and removal plans. When coupled with species information, size estimates can assist managers in determining long-term patterns of tree survival, selection, and replacement (Cumming and others 2001).

Species that dominated Wisconsin's urban land in terms of overall basal area were *Pinus strobus*, *Fraxinus pennsylvanica*, and *Quercus macrocarpa*. In nonforest urban areas, species that dominated in terms of their basal area were *P. strobus*, *Acer platanoides*, and *Salix babylonica*. In the UFIA$_F$ areas, species that dominated were *Q. macrocarpa*, *F. pennsylvanica*, and *Acer negundo* (table 11 and appendix C).

Figure 3 illustrates the diameter distribution of urban trees in Wisconsin. The UFIA$^+$ trees had a greater percentage of their population in larger tree diameters than those found in UFIA$_F$ areas. On a per tree basis, larger trees can provide more services, such as air pollution removal and storm water mitigation, than smaller trees can. Understanding size distribution allows managers to account for both larger and smaller maturing trees in planting regimes.

Of the 10 most common species, *Ostrya virginiana* and *Prunus serotina* were relatively small trees in Wisconsin, with greater than 90 percent of these trees being less than 5 inches d.b.h. The species that were the largest were *Pinus strobus* and *Acer negundo*, with more than 10 percent of the trees larger than 10 inches d.b.h. and less than 70 percent of the trees smaller than 5 inches d.b.h. *Fraxinus pennsylvanica* trees were also relatively large, with about 10 percent of the trees larger than 10 inches d.b.h. and less than 50 percent of the trees smaller than 5 inches d.b.h. (figure 4).

Ground cover

Within UFIA$^+$ areas, tree cover was approximately 14 percent, and in UFIA$_F$ areas, tree cover was 80 percent. Tree cover for the entire urban area was 26.7 percent.

Shrub cover in UFIA$^+$ areas was 4.3 percent. Fifty-four percent of the ground surfaces below the trees and shrubs was dominated by maintained grass and other herbaceous cover (e.g., gardens, ivy, flowerbeds), while impervious surfaces capped 31.0 percent of the ground. The UFIA$_F$ plots did not have data on ground cover, but were most likely dominated by duff or mulch.

Table 11. Top 10 species in terms of basal area. Data include median diameter at d.b.h. (inches). (See appendix C for more information on all species).

Total urban			UFIA⁺			$UFIA_F$		
Species	**Percent-age of basal area**	**Med. d.b.h.**	**Species**	**Percent-age of basal area**	**Med. d.b.h.**	**Species**	**Percent-age of basal area**	**Med. d.b.h.**
Pinus strobus	8.4	4.0	*Pinus strobus*	11.7	7.0	*Quercus macrocarpa*	10.8	9.0
Fraxinus pennsylvanica	7.9	5.0	*Acer platanoides*	9.1	12.0	*Fraxinus pennsylvanica*	9.4	5.0
Quercus macrocarpa	7.1	9.0	*Salix babylonica*	6.7	29.0	*Acer negundo*	7.0	6.0
Acer negundo	6.1	3.0	*Fraxinus americana*	6.1	2.0	*Pinus strobus*	6.6	4.0
Quercus rubra	5.4	9.0	*Quercus rubra*	5.6	6.0	*Quercus rubra*	5.4	10.0
Pinus resinosa	3.8	10.0	*Acer saccharinum*	5.4	22.0	*Pinus resinosa*	5.3	10.0
Tilia americana	3.4	3.0	*Fraxinus pennsylvanica*	4.9	5.0	*Tilia americana*	5.2	3.0
Ulmus americana	3.2	4.0	*Acer negundo*	4.5	2.0	*Quercus ellipsoidalis*	4.7	12.0
Picea abies	3.2	6.0	*Picea alba*	4.2	13.0	*Picea abies*	3.4	6.0
Acer platanoides	3.2	12.0	*Ulmus americana*	4.1	3.0	*Quercus alba*	3.1	3.0
All other	48.3	NA	All other	37.6	NA	All other	39.1	NA

Urban Forest Health

To evaluate tree condition, we used National Forest Health Monitoring (FHM) protocols for crown and damage ratings (Conkling and Byers 1992) for all trees 1 inch d.b.h. and larger on plots within the UFIA⁺ component. Crown measurements evaluate the growth and vigor of the crown, as a whole, of 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 FHM damage ratings, crews were asked to note the presence or absence of 44 different types of damage that can occur on trees in urban areas (appendix D). These urban damage indicators are of specific interest to arborists and plant health specialists whose work is concentrated in urban areas. Knowledge of trends and emerging issues can lead to more comprehensive treatments, planning, and public outreach.

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. Two measurements of crown health were used to estimate tree condition: dieback and density (table 12).

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 tree’s crown. Both hardwood and conifer trees with crown dieback greater than 25 percent may be in decline (Steinman 2000).

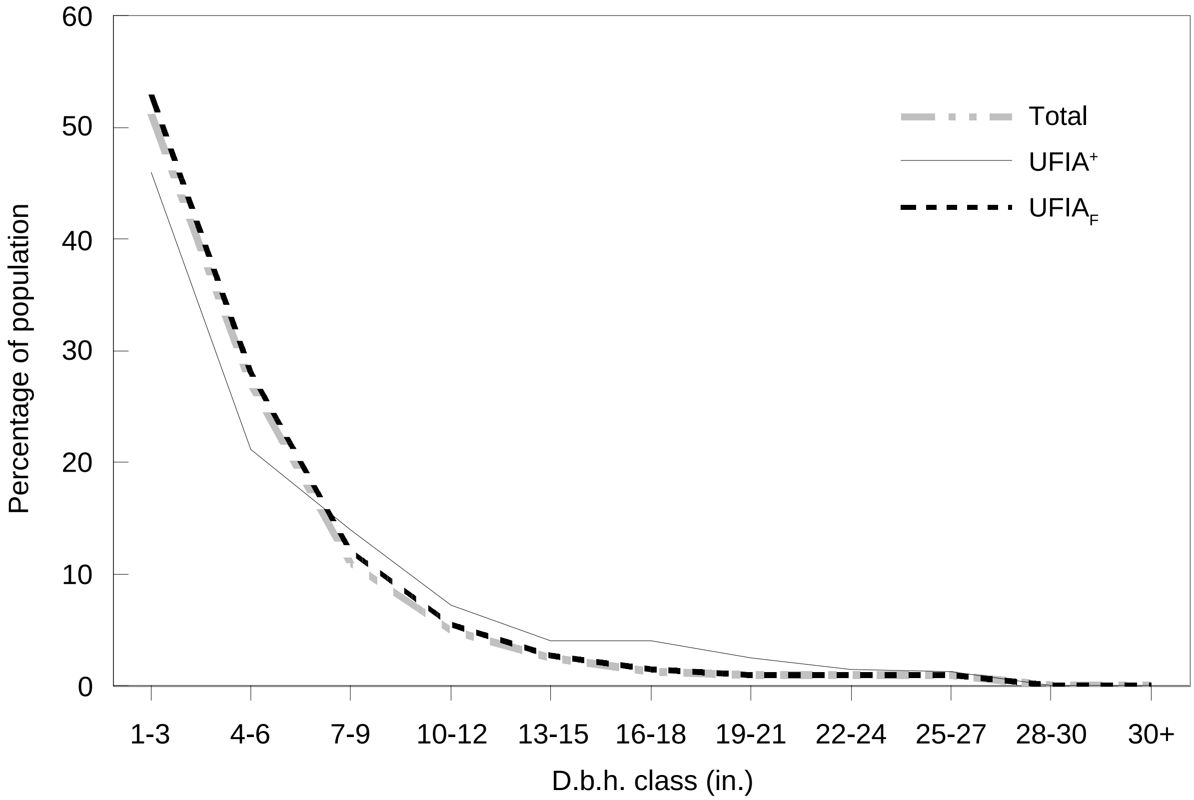


Figure 3. D.b.h. distribution of urban trees in Wisconsin.

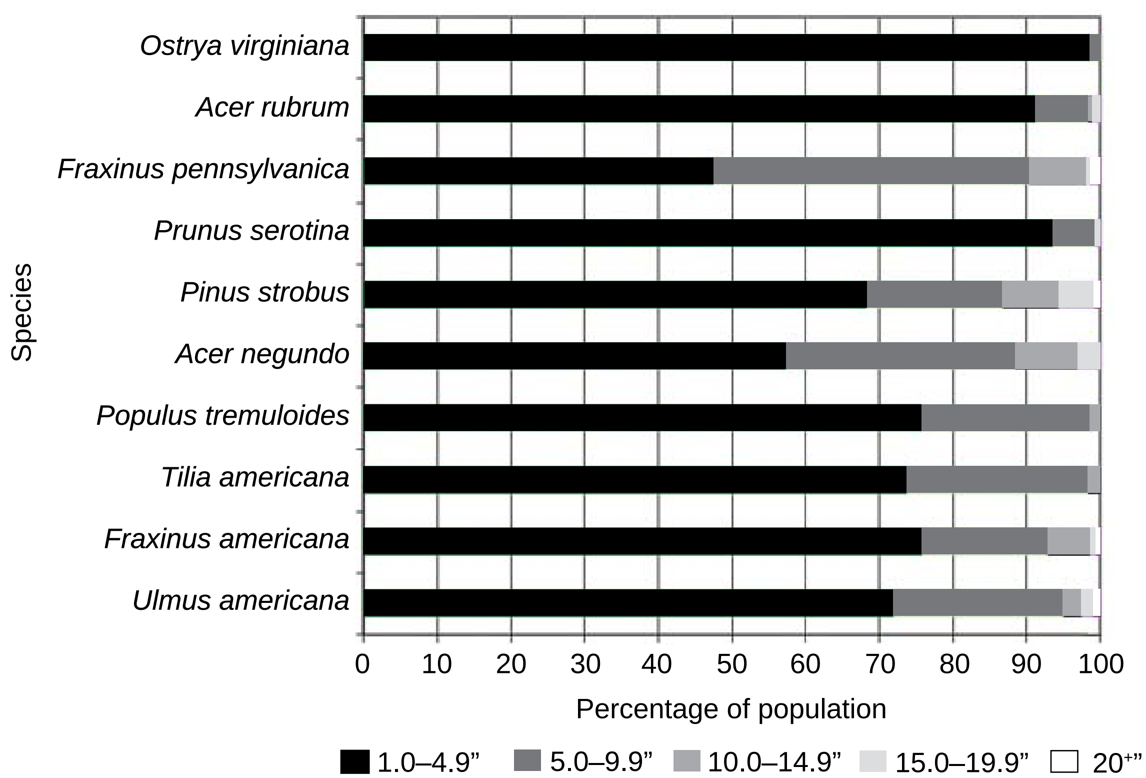


Figure 4. Distribution of trees by d.b.h. class for the 10 most common species.

Table 12. Crown measurements—values that indicate healthy trees.

Crown measure	Value threshold for healthy trees
Dieback	< 25 percent
Density	> 30 percent

Crown density is an estimate of the crown condition of each tree relative to its potential, by determining the percentage of light blocked by branches and foliage. Crown density reflects gaps in the crown that may have been caused by declining tree health. For hardwoods and conifers, density estimates less than 30 percent generally indicate the tree is in poor health (Steinman 2000).

Dieback

Very few trees in the UFIA+ plots exhibited signs of dieback. Over 96 percent of trees had dieback less than 25 percent of the crown, and the average dieback was 5 percent (table 13). None of the trees sampled in urban areas were rated as dead. Of species that did exhibit dieback, *Ulmus pumila* showed the greatest amount, with an average dieback of 46 percent for the species. *Populus tremuloides* was the only other species with an average dieback that approached the 25 percent threshold (table 14). Of the 10 most common species, 9 had an average crown dieback of 5 percent or less (table 15).

Table 13. Dieback—percentage of UFIA+ trees in each dieback class.

Dieback class	UFIA+ trees (percent)
<25 percent	96.3
≥25 percent	3.7

Table 14. Dieback—UFIA+ species showing highest average dieback.

Species (sample size)	Average dieback (percent)
Ulmus pumila (12)	46
Populus tremuloides (24)	18
Ulmus americana (14)	8

Table 15. Dieback—average dieback (percent) of the 10 species most frequently found in UFIA+ plots.

Ten most frequent species (sample size)	Average dieback (percent)
Acer negundo (89)	4.0
Fraxinus americana (90)	5.0
Fraxinus pennsylvanica (37)	3.0
Pinus strobus (39)	0.3
Acer rubrum (35)	3.0
Picea glauca (31)	3.0
Ulmus rubra (25)	5.0
Acer platanoides (22)	3.0
Populus tremuloides (24)	18.0
Thuja occidentalis (18)	1.0

Crown density

Average crown density for UFIA+ trees was 50 percent, which is within the threshold for healthy trees. Ten percent of the trees sampled had crown densities that could indicate poor health (table 16). *Ulmus pumila* showed the lowest average crown density of 31 percent for a single species (table 17). Table 18 shows a list of the most frequently encountered species and the average crown density for each species. Only *P. tremuloides* had an average crown density nearing the 30 percent threshold for declining trees.

Table 16. Density—percentage of UFIA+ trees in each foliage density class.

Density class	UFIA+ trees (percent)
≥30 percent	90
<30 percent	10

Table 17. Density—UFIA+ species showing the lowest average foliage density.

Species (sample size)	Average density (percent)
Ulmus pumila (12)	31
Morus rubra (16)	37
Populus tremuloides (24)	38
Fraxinus americana (90)	39
Ulmus americana (14)	43

Table 18. Density—average foliage density (percent) of the 10 species most frequently found in UFIA+ plots.

Ten most frequent species (sample size)	Average density (percent)
Acer negundo (89)	43
Fraxinus americana (90)	95
Fraxinus pennsylvanica (37)	50
Pinus strobes (39)	54
Acer rubrum (35)	47
Picea glauca (31)	66
Ulmus rubra (25)	45
Acer platanoides (22)	71
Populus tremuloides (24)	38
Thuja occidentalis (18)	59

Damage indicators of forest health

Signs of damage were recorded for all trees 1 inch d.b.h. and larger within the UFIA+ plots. Signs of damage were recorded 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 with damage in branches or the upper bole. The severity of the damage was also recorded. Up to three types of damage were recorded per tree, with inspections starting at the roots and bole and progressing up the tree (U.S. Department of Agriculture, Forest Service 1998).

Signs of damage used in this assessment include the following:

- Cankers and galls—may be caused by various agents but most commonly by fungi.
- Conks—fruiting bodies of fungi; are often signs of hidden decay.
- Open wounds—areas where the bark has been removed; expose the inner wood to decay.
- Resinosis—signs of resin or sap exuding from the tree bole or branches.
- Cracks and seams—separations of the bark caused by wounds, such as from lightning strikes.
- Broken bole or roots—may indicate hidden decay or, in the case of roots, previous construction damage.
- Brooms on roots or bole—clustering of foliage about a common point that may indicate the presence of disease.
- Vines in the crown—vines, such as ivy or grape, can reduce tree foliage and damage twigs and branches.
- Loss of apical dominance—death of the tree's main terminal caused by insects, disease, or frost.
- Broken or dead branches—may indicate long-term tree decline problems resulting from disease or insect defoliation over several years.
- Excessive branching or brooms within the crown—exaggerated branching or clustering of twigs, branches, or both, possibly resulting from disease or environmental changes.
- Damaged buds, foliage, or shoots—most commonly from insect feeding or the presence of disease but can also be caused by frost or the misapplication of chemicals.
- Discoloration of foliage—may indicate general tree decline resulting from disease or environmental problems.

At least one of the types of damage listed appeared on 19 percent of all trees sampled in UFIA+ plots. Table 19 shows the frequency with which damage types were encountered during the study. Conks, fruiting bodies, and other signs of decay were the most frequent types of damage recorded. Wood decay is a serious concern in urban areas, since its presence increases the potential for tree failure. Of trees with damage (19 percent of sample), 22 percent had conks, fruiting bodies, or other signs of decay. Vines in the tree crown were the second most common damage type (14 percent), followed by open wounds (14 percent), and cankers or galls (12 percent). Species showing the greatest amount of damage included *Fraxinus americana*, *Acer negundo*, *Populus tremuloides*, *Picea glauca*, and *Acer platanoides*. Table 20 illustrates the proportion of damaged trees by species. For example, of the sample's 19 percent damaged trees, 18 percent were *Fraxinus americana*.

Table 19. Damage—damage types recorded for UFIA+ trees and frequency of damage types among trees with damage.

Damage type	Frequency (percentage) of all trees	Frequency (percentage) of damaged trees
Conks, fruiting bodies	5.4	22.0
Vines in crown	3.5	14.0
Open wounds	3.4	14.0
Canker, gall	3.0	12.0
Loss apical dominance, dead terminal	2.8	11.0
Resinosis, gummosis	1.8	7.0
Other	1.0	4.0
Cracks and seams	1.0	4.0
Broken or dead branches	1.0	4.0
Damaged buds, shoots, or foliage	0.9	4.0
Discoloration of foliage	0.4	2.0
Broken bole or roots	0.1	0.6

Table 20. Damage—species showing the greatest frequency of damage, indicated by percentage of species among damaged trees.

Species (sample size)	Frequency of damaged trees (percent)
Fraxinus americana (90)	18
Acer negundo (89)	12
Populus tremuloides (24)	9
Picea glauca (31)	6
Acer platanoides (22)	5
Fraxinus pennsylvanica (37)	4
Betula papyrifera (17)	3
Quercus rubra (19)	3
Pinus strobus (36)	3

Urban damage agents

During the design phase of this study, the Wisconsin Department of Natural Resources urban forestry and plant health programs noted that the FHM damage indicators did not fully capture information about damage types and agents found in urban areas. To address this concern, crews tested field methods to collect additional data about damage agents. Unlike the FHM damage protocols that document only symptoms and not causes, "urban damage" is very specific, and crews needed only to note presence of the damage on the tree. Urban damage agents included specific insects, arboricultural issues, pathogens and diseases, and other damage from humans, weather, or animals (appendix D).

Of all the trees sampled in the UFIA+ plots in Wisconsin, 9 percent showed some type of urban damage. The most common urban damage encountered was stem decay (table 21). *Populus tremuloides* was the species most frequently seen with urban damage. Of all trees with damage, 16 percent were *P. tremuloides*, followed by *Acer negundo* and *Acer platanoides* (table 22).

Table 21. Most common types of urban damage and frequency of damage type among trees with urban damage.

Urban damage type	**Frequency (percent)**
Stem decay	23
Other human damage	11
Butt rot	10
Hypoxylon canker	10
Included bark	10
Poor pruning	10

Table 22. UFIA+ species most frequently found with urban damage.

Species (sample size)	**Percentage of trees with urban damage**
Populus tremuloides (24)	16
Acer negundo (89)	13
Acer platanoides (22)	13
Betula papyrifera (17)	6

Biomass and Carbon Cycle

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and reducing energy use in buildings, consequently reducing carbon dioxide emissions from fossil-fuel-based power plants (Abdollahi and others 2000).

Trees can reduce the amount of carbon in the atmosphere by providing a net increase in new growth (carbon) every year (i.e., growth greater than 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 the carbon cycle. The rate at which a tree removes carbon from the atmosphere is called **carbon sequestration**. The amount or weight of carbon currently accumulated by a tree is considered **carbon storage**. To estimate monetary value associated with urban tree carbon sequestration and storage, carbon values were multiplied by $20.30 per metric ton of carbon, based on the estimated marginal social costs of carbon dioxide emissions (Fankhauser 1994).

Carbon storage by Wisconsin's urban forest was estimated at 6.1 million metric tons. The species that were estimated to sequester the most carbon annually are *Acer negundo* (7.2 percent of the total annual sequestration), *Fraxinus pennsylvanica* (7.1 percent), and *Quercus macrocarpa* (5.4 percent). Sequestration estimates are based on estimates of growth, which are partially dependent upon tree condition. Annual carbon sequestration by urban trees is valued at $8.1 million per year (table 23).

Heating and Cooling

Trees affect energy use in buildings by shading houses and offices, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy use in summer and either increase or decrease building energy use in winter depending upon their

Table 23. Carbon storage, carbon sequestration, and carbon avoided, by weight (in tons) and associated value, for Wisconsin's urban forest.

Carbon status	**Total**	**UFIA+**	**UFIA$_F$**
Carbon storage (total)	6,147,000 $125 million	2,021,000 $41 million	4,126,000 $84 million
Carbon sequestration (annual)	400,000 $8.1 million	119,000 $2.4 million	280,000 $5.7 million
Carbon avoided (annual)	50,000 $1 million	50,000 $1 million	NA

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 were projected to save homeowners $24.3 million annually, with 54 percent of the savings occurring during the winter (heating) season. Of the 26.9 million nonforest urban trees ($UFIA^+$), approximately 8.3 million trees (31 percent) contributed to energy conservation of residential buildings. Because of reduced building energy use, power plants will burn less fossil fuel and, therefore, release less carbon dioxide. Energy conservation due to trees reduced carbon emissions by 50,000 metric tons in Wisconsin, with an estimated value of $1 million per year (figure 5).

Air Quality Improvement

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 energy use in buildings. Trees emit volatile organic compounds (VOCs), however, that can contribute to ground-level ozone formation. Yet integrated studies have revealed that increasing tree cover will ultimately reduce ozone formation (Nowak 2005).

Pollution removal by Wisconsin's urban forest was estimated with the use of hourly pollution data from all of the monitors in the State and weather data (Milwaukee) from the year 2000. Based on these inputs, the urban forests in Wisconsin were estimated to remove about 6,400 metric tons of pollution per year, with an associated annual value of about $36.3 million. The pollutant removal rate was greatest for ozone (O_3) followed by particulate matter less than 10 microns (PM_{10}), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) (table 24).

Value of Wisconsin's Urban Forest

Urban forests have a structural value based on the tree resource itself (e.g., the cost of having to replace a tree with a similar tree), and annually produce functional values based on the functions the tree

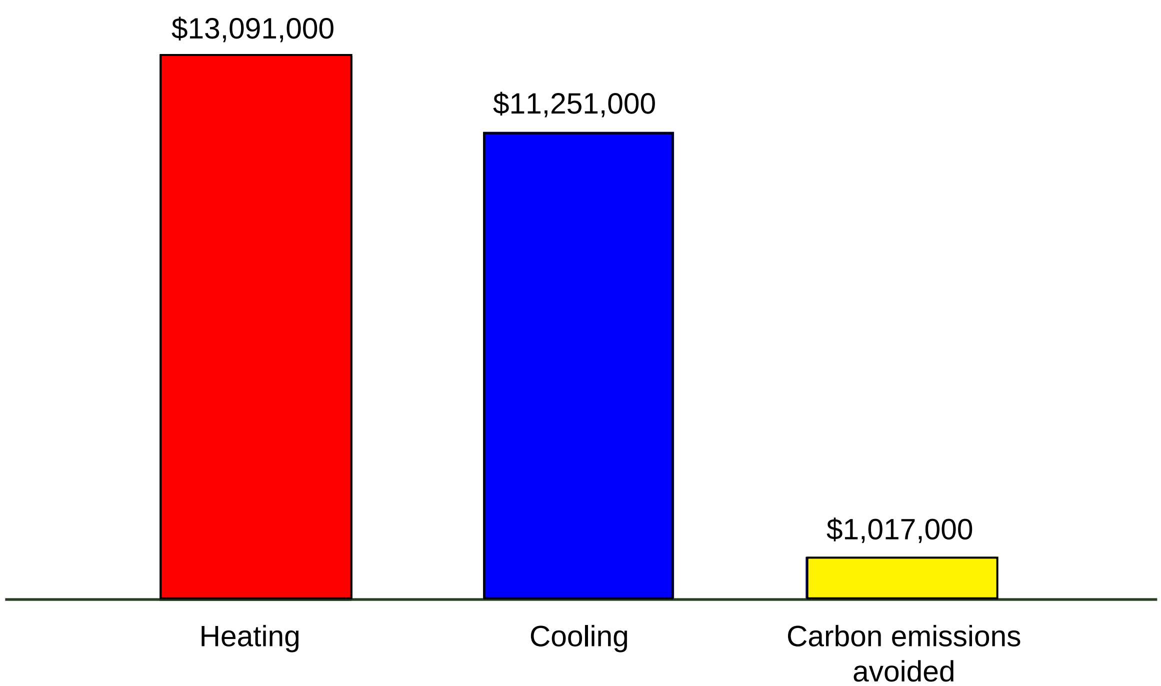


Figure 5. Estimated annual energy savings and carbon emissions avoided due to nonforest urban trees in Wisconsin.

Table 24. Annual pollution removal and value for Wisconsin's urban forest.

Pollutant	Amount removed by Wisconsin's urban forest (metric tons/year)	Value of removal ($1,000/year)
Ozone	3,310	22,370
Particulate matter	1,750	7,870
Nitrogen dioxide	760	5,130
Sulfur dioxide	520	860
Carbon monoxide	63	61

performs. These estimates of 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 or structural value of trees was developed by the Council of Tree and Landscape Appraisers (CTLA 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 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 1.37 m above the ground), species, condition, and location.

The estimated structural value of Wisconsin's urban forest was approximately $17 billion. Other estimated functional values of the urban forest included carbon storage ($125 million), annual carbon sequestration ($8.1 million), annual pollution removal ($36.3 million), and annual building energy reduction ($24.3 million) (table 25). These values tend to increase with increased size and number of healthy trees.

Table 25. Monetary value of Wisconsin's urban forest by benefit category.

Benefit	Value
Structural or replacement costs	$17 billion
Carbon storage	$125.0 million
Carbon sequestration	$8.1 million/year
Pollution removal	$36.3 million/year
Energy reduction	$24.3 million/year

Potential Economic Impacts of Pests

Based on the species distribution, the urban forest is at risk from various pests that could potentially impact its health and sustainability. The effects of three exotic insect pests—Asian longhorned beetle, gypsy moth, and emerald ash borer—were analyzed using the UFORE Model.

The Asian longhorned beetle bores into and kills a wide range of hardwood species (U.S. Department of Agriculture, Forest Service 2002b). The risk from Asian longhorned beetle to Wisconsin's urban forest is an estimated loss of $8.0 billion in structural value (replacement value) or 60.2 percent of all urban trees in the State. The gypsy moth is a defoliator that feeds on a wide variety of tree species and can cause widespread crown reduction and tree death if outbreak conditions last several years (Liebhold 2003). This pest already exists in the eastern region of Wisconsin. The risk from this pest is an estimated loss of $4.8 billion in replacement value (29.6 percent of the urban forest population). If one assumes that only about 20 percent of the tree population will be killed in a gypsy moth outbreak, the risk from this pest drops to $960 million (5.9 percent of the tree population). Finally, the emerald ash borer can kill many species of ash trees and has been detected in Michigan, Ohio, Indiana, and Maryland (McCullough and Katovich 2004). The potential urban risk from this borer in Wisconsin is $2.4 billion or 12.5 percent of the urban forest tree population (table 26).

Table 26. Total replacement value of host trees and percentage of the Wisconsin urban tree population at risk from three important insect pests.

Insect pest	Total replacement value of host trees	Percentage of urban tree population at risk
Asian longhorned beetle	$8.0 billion	60.2
Gypsy moth	$4.8 billion	29.6
Emerald ash borer	$2.4 billion	12.5

DISCUSSION

Because of the dominance of $UFIA_F$ land, forest species (*Ostrya virginiana*, *Acer rubrum*, *Fraxinus pennsylvanica*, and *Prunus serotina*) dominated the composition of the entire urban forest. Some of the common $UFIA_F$ species (*Fraxinus pennsylvanica*, *Pinus strobus*, *Acer rubrum*, and *Populus tremuloides*), however, are also common in $UFIA^+$ areas, and some predominantly nonforest species (*Acer negundo*, *Fraxinus americana*) comprise a significant component of the entire urban forest. Trees and forests in urban areas that are not currently sampled by the FIA program ($UFIA^+$) will become increasingly important because the extent of urban land is predicted to more than double in the State of Wisconsin by 2050 (Nowak and Walton 2005).

The urban forests of Wisconsin provide significant social and environmental benefits to the people of Wisconsin. The resource itself is worth billions of dollars and annually provides functional benefits to society on the order of $70 million dollars per year. These functional benefits are only for air pollution removal, carbon sequestration, and reduced building energy consumption. Many other environmental and social benefits are yet to be quantified. Sustaining forest health and longevity is critical to sustaining these benefits through time.

The species that constitute Wisconsin's urban forest are fairly diverse, with no one species comprising more than 8 percent of the existing population overall. In $UFIA^+$ areas, however, *Acer negundo* and *Fraxinus americana* each made up almost 14 percent of the nonforest population. In addition, the *Acer* and *Fraxinus* genera combined made up 30 percent of all trees in urban Wisconsin. Given the potential risk to *Acer* from the Asian longhorned beetle and to *Fraxinus* from the emerald ash borer, managers of urban tree planting efforts in Wisconsin should consider shifting to other suitable tree genera to avoid potential large-scale losses from these exotic invasive beetles.

Overall, Wisconsin's urban forests were healthy. Health indicators such as crown dieback, density, and damage revealed only a few issues of concern. *Populus tremuloides* showed a relatively high average dieback. Coupled with its borderline average crown density, it appears that the species is not doing very well in Wisconsin's urban forests. More investigation is needed to determine whether hypoxylon canker, which is caused by the fungus *Hypoxylon mammatum* and is one of the most common diseases of *P. tremuloides*, is associated with this dieback. Stressed trees are susceptible to the fungus, and disease symptoms often include dieback (Anderson and others 1979, Behrendt and Floyd 1999).

Construction and development, even within $UFIA^+$ areas, continue to threaten forest health and sustainability within urban and surrounding areas. Long-term monitoring data on rates of change in and around urban areas are critical to developing management plans to sustain urban forest health and cover at local, regional, and national scales. Health monitoring information can be used to detect or determine which factors are leading to changes in urban forests. Thus, regional and statewide management plans can be developed to help offset the undesirable forces of change. In addition, with accurate data on rates of change, accurate plans for sustaining or enhancing forest cover can be developed. Through monitoring, these plans can be continually updated to meet the needs of society and to adjust for numerous factors that affect urban forest health and sustainability.

CONCLUSIONS

With the growth of urban areas, data on urban forests are becoming more essential, particularly because urban trees can have significant impacts on numerous local to global environmental regulations (e.g., Clean Air Act, Clean Water Act, Kyoto Protocol[1]). Having data on this important resource will allow trees and forests to be assessed for their ecosystem values and how they can be incorporated into regulations set to protect human health and well-being. Not only does an urban forest monitoring program provide essential data for management and integration with local to international policies, the long-term data provide essential information for sustaining urban forest canopy cover and health.

The statewide survey of Wisconsin's urban forest reported here is one of a series of pilot studies initiated to determine the structure, condition, and function of forests in urban areas at a broad scale, beyond just one city or community. The Wisconsin study is the first pilot to incorporate the full panel of urban plots throughout the State and to integrate those with the corresponding FIA data. The series of pilots began with Indiana, using 20 percent of the State's plots (Lake and others 2006; Nowak and others 2007) and extended to data collection in New Jersey, Tennessee, and Colorado.

This report accomplishes several objectives:

1. *This report documents the utilization of an established FIA plot system and FIA/FHM data measurement protocols to capture information about urban forests. This fills a previously identified data gap.*

   Prior to this pilot project, FIA plots classified as nonforested were not measured. While estimates of the urban forest resource could be approached in a variety of ways, the approach taken in this pilot was to delimit urban boundaries and then select all FIA plots ($UFIA_F$ and $UFIA^+$) falling within those boundaries for measurement. One strong argument in favor of this approach is that the FIA plot grid is an established method of resource sampling and analysis. This project simply demonstrated how the urban forest resource data gap could be filled.

   The plot footprint itself, designed for forest sampling, did present some logistical problems with respect to the multitude of property ownerships often encountered in urban situations. Maintaining the same plot footprint for both urban and forest sampling had advantages, however, particularly with respect to future remeasurements and assessing changes in land use.

2. *This report demonstrates the use of the Urban Forest Effects (UFORE) Model in data analysis to quantify urban forest structure and function.*

   UFORE was designed to use standardized field data from randomly located plots within a single urban area. Modifications were made to the UFORE analytical code to accommodate use of the FIA/FHM plot structure and the statewide nature of the analysis. UFORE was chosen as the analytical engine for this project because of its ability to calculate urban forest values (air pollution removal, carbon storage and sequestration, effect of trees on energy consumption, and structural and replacement values).

3. *This report establishes a protocol for delimiting urban boundaries.*

   Urban boundaries were obtained by using 1990 census definitions and then overlaying these boundaries with the FIA plot grid. Plots falling within the urban boundaries were included in this analysis. The U.S. Census Bureau defined "urban" for the 1990 census as comprising all territory, population, and housing units in urbanized areas and in places of 2,500 or more persons outside urbanized areas. Use of this definition, however, eliminated the more rural communities of Wisconsin and included forested plots in areas that urban foresters may not, at first glance, consider "urban." Since the completion of this study, the U.S. Census Bureau has modified their definition of urban, resulting in a smaller urban land area, nationally (U.S. Census Bureau 2002).

[1] The United Nations Framework Convention on Climate Change approved this protocol in Kyoto, Japan, in 1997. The Kyoto Protocol is an agreement by participating countries and other government entities to reduce their emissions of six greenhouse gases, or engage in emissions trading if reductions are not possible. (http://unfccc.int/kyoto_protocol/items/2830.php)

Wisconsin's urban forest was dominated by trees within forest stands ($UFIA_F$ areas), with 79 percent of the trees found in these stands. This large proportion of trees in $UFIA_F$ areas is partially due to the definition of urban areas used. As the 1990 Census Bureau definition of urban included places with populations greater than 2,500 people, this type of political boundary definition often includes many forested areas with low population densities that are found within the political boundaries of places (cities, towns, and villages).

The new 2000 definition of urban that will be used in future analysis of plots in urban areas is population-density based (areas with population density greater than 500 people per square mile). The change in the definition of urban areas will reduce the number of traditional FIA forest plots that fall within the urban boundary. It will significantly alter the ratio of $UFIA^+$ to $UFIA_F$ trees in the statewide population estimates. It will also likely reduce the amount of urban trees as urban land area is reduced based on the new census definitions.

4. *This report quantifies, for the first time, the status and condition of urban forests on a statewide basis.*

   Prior to this pilot project, statewide estimates of urban forest and tree resources did not exist. The data collected has enabled an estimation of urban forest statistics, including biomass contributions, carbon storage, energy savings, air pollution removal, and structural value. Data collected here can be used as a baseline from which changes and trends can be evaluated if the plots are remeasured.

5. *This report establishes a pest risk assessment for Wisconsin urban forests.*

   Using UFORE, economic impacts associated with selected potential pest problems were determined. While species composition data alone could be used to describe the potential susceptibility of the Wisconsin urban forest to various pests, use of UFORE enabled an economic impact assessment that included replacement values.

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 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 assessments of the success of the plans and continual updating of plans to ensure forest sustainability. Long-term monitoring data will also reveal which factors (e.g., insects, diseases, decay, vandalism) most threaten urban forest sustainability, so corrective management actions can be taken.

Data from urban forest monitoring programs should be incorporated within State and local urban forest planning and management regimes to allow local constituents to develop canopy goals and tree planting goals to sustain or enhance urban forest canopy across the State.

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APPENDIX A. Wisconsin Urban Forest Survey, 2002. Estimates of total number of trees and standard error (S.E.) by land use in UFIA+ areas.

Land use	Species	Common name	Total number of trees	S.E.
Transportation/ Right-of-way (ROW)	*Acer platanoides*	Norway maple	331,000	150,700
	Celtis occidentalis	Northern hackberry	82,700	82,700
	Fraxinus pennsylvanica	Green ash	82,700	82,700
	Aesculus glabra	Ohio buckeye	41,400	41,400
	Betula nigra	River birch	41,400	41,400
	Quercus rubra	Northern red oak	41,400	41,400
		Total	**620,600**	**219,700**
Vacant/Other	*Acer negundo*	Boxelder	1,406,700	1,022,700
	Pinus strobus	Eastern white pine	786,100	786,100
	Fraxinus americana	White ash	372,400	372,400
	Populus tremuloides	Quaking aspen	331,000	331,000
	Fraxinus pennsylvanica	Green ash	206,900	206,900
	Quercus rubra	Northern red oak	82,700	82,700
	Ulmus americana	American elm	82,700	82,700
	Fraxinus nigra	Black ash	41,400	41,400
	Morus rubra	Red mulberry	41,400	41,400
	Picea pungens	Blue spruce	41,400	41,400
	Prunus serotina	Black cherry	41,400	41,400
		Total	**3,434,000**	**1,978,200**
Commercial/Industrial	*Acer negundo*	Boxelder	1,324,000	1,323,900
	Fraxinus americana	White ash	455,100	413,900
	Fraxinus pennsylvanica	Green ash	124,100	90,800
	Acer saccharinum	Silver maple	82,700	82,700
	Juniperus virginiana	Eastern red cedar	82,700	82,700
	Prunus pensylvanica	Pin cherry	82,700	82,700
	Gleditsia triacanthos	Honeylocust	41,400	41,400
	Malus species	Crabapple	41,400	41,400
	Other species	Other species	41,400	41,400
	Populus deltoides	Eastern cottonwood	41,400	41,400
	Thuja occidentalis	Northern white cedar	41,400	41,400
		Total	**2,358,300**	**1,430,700**
Park/Golf	*Fraxinus americana*	White ash	1,613,600	1,484,300
	Juglans nigra	Black walnut	372,400	268,100
	Picea pungens	Blue spruce	289,600	216,300
	Carya ovalis	Red hickory	206,900	206,900

APPENDIX A. Wisconsin Urban Forest Survey, 2002. Estimates of total number of trees and standard error (S.E.) by land use in UFIA+ areas (cont.).

Land use	Species	Common name	Total number of trees	S.E.
Park/Golf (cont.)	*Picea glauca*	White spruce	124,100	124,100
	Acer platanoides	Norway maple	82,700	82,700
	Pinus nigra	Austrian pine	82,700	82,700
	Acer negundo	Boxelder	41,400	41,400
	Acer saccharum	Sugar maple	41,400	41,400
	Quercus marilandica	Blackjack oak	41,400	41,400
	Quercus rubra	Northern red oak	41,400	41,400
		Total	**2,937,500**	**1,956,000**
Institutional	*Betula nigra*	River birch	41,400	41,400
		Total	**41,400**	**41,400**
Residential	*Acer rubrum*	Red maple	1,406,700	900,300
	Fraxinus americana	White ash	1,199,800	850,500
	Fraxinus pennsylvanica	Green ash	1,117,100	634,800
	Picea glauca	White spruce	1,075,700	394,700
	Ulmus rubra	Slippery elm	1,034,300	993,200
	Acer negundo	Boxelder	951,600	652,400
	Pinus strobus	Eastern white pine	744,700	320,300
	Betula papyrifera	Paper birch	703,400	296,500
	Thuja occidentalis	Northern white cedar	703,400	308,000
	Morus rubra	Red mulberry	620,600	337,500
	Prunus serrulata	Kwanzan cherry	537,900	339,800
	Populus tremuloides	Quaking aspen	496,500	353,300
	Ulmus americana	American elm	496,500	288,200
	Ulmus pumila	Siberian elm	496,500	456,300
	Quercus rubra	Northern red oak	455,100	254,100
	Acer platanoides	Norway maple	413,700	147,200
	Acer saccharum	Sugar maple	413,700	179,200
	Celtis occidentalis	Northern hackberry	413,700	374,000
	Juniperus virginiana	Eastern red cedar	413,700	334,800
	Pinus sylvestris	Scotch pine	331,000	232,200
	Quercus alba	White oak	331,000	291,900
	Malus pumila	Apple	289,600	221,600
	Picea abies	Norway spruce	248,200	128,100
	Picea pungens	Blue spruce	248,200	141,100
	Cornus florida	Flowering dogwood	206,900	206,900
	Ostrya virginiana	Eastern hophornbeam	206,900	170,000

APPENDIX A. Wisconsin Urban Forest Survey, 2002. Estimates of total number of trees and standard error (S.E.) by land use in UFIA+ areas (cont.).

Land use	Species	Common name	Total number of trees	S.E.
Residential (cont.)	*Prunus serotina*	Black cherry	206,900	148,100
	Abies balsamea	Balsam fir	124,100	124,100
	Crataegus monogyna	Oneseed hawthorn	124,100	124,100
	Fagus grandifolia	American beech	124,100	124,100
	Gleditsia triacanthos	Honeylocust	124,100	70,500
	Pinus resinosa	Red pine	124,100	91,900
	Acer saccharinum	Silver maple	82,700	58,100
	Crataegus phaenopyrum	Washington hawthorn	82,700	82,700
	Elaeagnus angustifolia	Russian olive	82,700	82,700
	Malus species	Crabapple	82,700	58,100
	Prunus species	Cherry	82,700	58,100
	Prunus virginiana	Common chokecherry	82,700	82,700
	Quercus marilandica	Blackjack oak	82,700	58,100
	Salix species	Willow	82,700	82,700
	Salix babylonica	Weeping willow	82,700	82,700
	Abies concolor	White fir	41,400	41,400
	Carpinus caroliniana	American hornbeam	41,400	41,400
	Catalpa speciosa	Northern catalpa	41,400	41,400
	Juglans nigra	Black walnut	41,400	41,400
	Other species	Other species	41,400	41,400
	Pinus banksiana	Jack pine	41,400	41,400
	Populus grandidentata	Bigtooth aspen	41,400	41,400
	Prunus maackii	Amur chokecherry	41,400	41,400
	Prunus pensylvanica	Pin cherry	41,400	41,400
	Quercus ellipsoidalis	Northern pin oak	41,400	41,400
		Total	**17,542,500**	**3,930,000**
Urban Nonforest		**Grand Total**	**26,934,300**	**4,808,400**

APPENDIX B. Wisconsin Urban Forest Survey, 2002. Percentages of species populations in urban areas. (NA = not applicable.)

Species	Common name	All trees, percent of total (a)	$UFIA^+$, percent of all trees (b)	$UFIA_F$, percent of all trees (c)	$UFIA^+$, percent (d)	$UFIA_F$, percent (e)
Ostrya virginiana	Eastern hophornbeam	7.3	0.2	7.1	0.8	9.0
Acer rubrum	Red maple	6.5	1.1	5.4	5.2	6.8
Fraxinus pennsylvanica	Green ash	6.0	1.2	4.9	5.7	6.1
Prunus serotina	Black cherry	6.0	0.2	5.8	0.9	7.4
Pinus strobus	Eastern white pine	5.6	1.2	4.5	5.6	5.6
Acer negundo	Boxelder	5.1	2.9	2.2	13.8	2.8
Populus tremuloides	Quaking aspen	4.8	0.6	4.2	3.1	5.3
Tilia americana	American basswood	4.6	NA*	4.6	NA	5.8
Fraxinus americana	White ash	4.0	2.8	1.2	13.5	1.6
Ulmus americana	American elm	3.8	0.4	3.4	2.1	4.3
Acer spicatum	Mountain maple	3.4	NA	3.4	NA	4.2
Carya ovata	Shagbark hickory	3.2	NA	3.2	NA	4.0
Betula papyrifera	Paper birch	3.0	0.5	2.4	2.6	3.1
Crataegus sp	Hawthorn	2.9	0.2	2.8	0.8	3.5
Fraxinus nigra	Black ash	2.4	0.0	2.4	0.2	3.0
Celtis occidentalis	Northern hackberry	2.2	0.4	1.8	1.8	2.3
Picea glauca	White spruce	2.2	0.9	1.3	4.4	1.6
Thuja occidentalis	Northern white cedar	1.9	0.6	1.3	2.8	1.7
Robinia pseudoacacia	Black locust	1.9	NA	1.9	NA	2.4
Picea abies	Norway spruce	1.9	0.2	1.7	0.9	2.1
Acer saccharum	Sugar maple	1.8	0.3	1.4	1.7	1.8
Abies balsamea	Balsam fir	1.5	0.1	1.4	0.5	1.8
Quercus rubra	Northern red oak	1.5	0.5	1.0	2.3	1.2
Quercus marcrocarpa	Bur oak	1.5	NA	1.5	NA	1.8
Prunus pensylvanica	Pin cherry	1.4	0.1	1.3	0.5	1.6
Quercus velutina	Black oak	1.3	NA	1.3	NA	1.7
Ulmus rubra	Slippery elm	1.3	0.8	0.5	3.8	0.7
Pinus resinosa	Red pine	1.1	0.1	1.1	0.5	1.3
Quercus alba	White oak	1.0	0.2	0.8	1.2	1.0
Morus rubra	Red mulberry	1.0	0.5	0.5	2.5	0.7
Carya cordiformis	Bitternut hickory	0.7	NA	0.7	NA	0.8
Acer platanoides	Norway maple	0.6	0.6	NA	3.1	NA
Populus deltoides	Eastern cottonwood	0.5	0.0	0.5	0.2	0.6
Prunus virginiana	Common chokecherry	0.5	0.1	0.4	0.3	0.5

APPENDIX B. Wisconsin Urban Forest Survey, 2002. Percentages of species populations in urban areas (cont.). (NA = not applicable.)

Species	Common name	All trees, percent of total (a)	UFIA+, percent of all trees (b)	$UFIA_F$, percent of all trees (c)	UFIA+, percent (d)	$UFIA_F$, percent (e)
Quercus ellipsoidalis	Northern pin oak	0.5	0.0	0.4	0.2	0.5
Picea pungens	Blue spruce	0.4	0.4	NA	2.1	NA
Populus balsamifera	Balsam poplar	0.4	NA	0.4	NA	0.5
Prunus serrulata	Kwanzan cherry	0.4	0.4	NA	2.0	NA
Juniperus virginiana	Eastern red cedar	0.4	0.4	NA	1.8	NA
Ulmus pumila	Siberian elm	0.4	0.4	NA	1.8	NA
Juglans nigra	Black walnut	0.4	0.3	0.0	1.5	0.0
Pinus sylvestris	Scotch pine	0.3	0.3	NA	1.2	NA
Malus pumila	Apple	0.2	0.2	NA	1.1	NA
Acer saccharinum	Silver maple	0.2	0.1	0.1	0.7	0.1
Malus species	Crabapple	0.2	0.1	0.1	0.5	0.1
Cornus florida	Flowering dogwood	0.2	0.2	NA	0.8	NA
Carya ovalis	Red hickory	0.2	0.2	NA	0.8	NA
Tsuga canadensis	Eastern hemlock	0.1	NA	0.1	NA	0.2
Populus grandidentata	Bigtooth aspen	0.1	0.0	0.1	0.2	0.1
Gleditsia triacanthos	Honeylocust	0.1	0.1	NA	0.6	NA
Betula alleghaniensis	Yellow birch	0.1	NA	0.1	NA	0.1
Quercus marilandica	Blackjack oak	0.1	0.1	NA	0.5	NA
Fagus grandifolia	American beech	0.1	0.1	NA	0.5	NA
Salix babylonica	Weeping willow	0.1	0.1	NA	0.4	NA
Pinus banksiana	Jack pine	0.1	0.0	0.0	0.2	0.0
Betula nigra	River birch	0.1	0.1	NA	0.3	NA
Other species	Other species	0.1	0.1	NA	0.3	NA
Elaeagnus angustifolia	Russian olive	0.1	0.1	NA	0.3	NA
Pinus nigra	Austrian pine	0.1	0.1	NA	0.3	NA
Prunus species	Cherry	0.1	0.1	NA	0.3	NA
Salix species	Willow	0.1	0.1	NA	0.3	NA
Salix nigra	Black willow	0.0	NA	0.0	NA	0.0
Larix laricina	Tamarack	0.0	NA	0.0	NA	0.0
Catalpa speciosa	Catalpa	0.0	0.0	NA	0.2	NA
Aesculus glabra	Ohio buckeye	0.0	0.0	NA	0.2	NA
Carpinus caroliniana	American hornbeam	0.0	0.0	NA	0.2	NA
Prunus maackii	Amur chokecherry	0.0	0.0	NA	0.2	NA
Abies concolor	White fir	0.0	0.0	NA	0.2	NA

APPENDIX C. Wisconsin Urban Forest Survey, 2002. Estimates of number of trees, percentage of basal area (BA), average d.b.h., and median d.b.h. by species for the total urban forest population, trees in $UFIA^+$ areas, and trees in FIA forest areas ($UFIA_F$). (NA = not applicable.)

			Total population				$UFIA^+$				$UFIA_F$			
Genus	Species	Common name	Number of trees	% BA	Avg. d.b.h.	Med. d.b.h.	Number of trees	% BA	Avg. d.b.h.	Med. d.b.h.	Number of trees	% BA	Avg. d.b.h.	Med. d.b.h.
Abies	*balsamea*	Balsam fir	1,946,600	0.6	3.3	3.0	124,100	0.0	1.5	1.0	1,822,400	0.9	3.4	3.0
Abies	*concolor*	White fir	41,400	0.0	3.5	3.0	41,400	0.0	3.5	3.0	0	0.0	NA*	NA
Acer	*negundo*	Boxelder	6,648,400	6.1	4.9	3.0	3,723,600	4.5	3.0	2.0	2,924,800	7.0	7.4	6.0
Acer	*platanoides*	Norway maple	827,500	3.2	11.4	12.0	827,500	9.1	11.4	12.0	0	0.0	NA	NA
Acer	*rubrum*	Red maple	8,427,400	2.5	2.8	1.0	1,406,700	3.0	4.1	2.0	7,020,700	2.2	2.5	1.0
Acer	*saccharinum*	Silver maple	255,200	2.3	17.6	16.0	165,500	5.4	20.2	22.0	89,700	0.6	12.8	16.0
Acer	*saccharum*	Sugar maple	2,322,400	1.9	4.5	3.0	455,100	2.9	8.0	6.0	1,867,300	1.3	3.6	3.0
Acer	*spicatum*	Mountain maple	4,381,400	0.3	1.6	1.0	0	0.0	NA	NA	4,381,400	0.4	1.6	1.0
Aesculus	*glabra*	Ohio buckeye	41,400	0.0	1.5	1.0	41,400	0.0	1.5	1.0	0	0.0	NA	NA
Betula	*alleghaniensis*	Yellow birch	134,600	0.3	9.8	9.0	0	0.0	NA	NA	134,600	0.5	9.8	9.0
Betula	*nigra*	River birch	82,700	0.1	5.0	7.0	82,700	0.2	5.0	7.0	0	0.0	NA	NA
Betula	*papyrifera*	Paper birch	3,890,300	1.9	4.0	3.0	703,300	1.9	5.7	5.0	3,186,900	1.9	3.6	2.0
Carpinus	*caroliniana*	American hornbeam	41,400	0.0	1.5	1.0	41,400	0.0	1.5	1.0	0	0.0	NA	NA
Carya	*cordiformis*	Bitternut hickory	861,600	0.6	3.5	0.0	0	0.0	NA	NA	861,600	0.8	3.5	0.0
Carya	*ovalis*	Red hickory	206,900	0.0	2.0	2.0	206,900	0.1	2.0	2.0	0	0.0	NA	NA
Carya	*ovata*	Shagbark hickory	4,192,600	1.1	2.5	1.0	0	0.0	NA	NA	4,192,600	1.6	2.5	1.0
Catalpa	*speciosa*	Northern catalpa	41,400	0.5	22.5	22.0	41,400	1.5	22.5	22.0	0	0.0	NA	NA
Celtis	*occidentalis*	Northern hackberry	2,866,600	0.8	3.0	2.0	496,500	0.7	4.2	5.0	2,370,100	0.8	2.7	2.0
Cornus	*florida*	Flowering dogwood	206,900	0.0	1.7	1.0	206,900	0.0	1.7	1.0	0	0.0	NA	NA
Crataegus	*sp*	Hawthorn	3,851,800	0.8	2.4	2.0	206,900	0.4	4.3	2.0	3,644,900	1.0	2.3	2.0
Elaeagnus	*angustifolia*	Russian olive	82,700	0.3	12.0	11.0	82,700	0.8	12.0	11.0	0	0.0	NA	NA
Fagus	*grandifolia*	American beech	124,100	0.1	5.5	5.0	124,100	0.3	5.5	5.0	0	0.0	NA	NA
Fraxinus	*americana*	White ash	5,274,400	3.1	3.5	1.0	3,640,800	6.1	3.5	2.0	1,633,600	1.6	3.6	1.0
Fraxinus	*nigra*	Black ash	3,174,000	2.0	3.8	1.0	41,400	0.0	1.5	1.0	3,132,600	3.0	3.8	1.0
Fraxinus	*pennsylvanica*	Green ash	7,902,200	7.9	5.3	5.0	1,530,800	4.9	5.6	5.0	6,371,400	9.4	5.2	5.0
Gleditsia	*triacanthos*	Honeylocust	165,500	0.8	12.1	13.0	165,500	2.3	12.1	13.0	0	0.0	NA	NA
Juglans	*nigra*	Black walnut	458,600	0.4	5.4	5.0	413,700	0.9	5.1	5.0	44,900	0.1	8.5	8.0
Juniperus	*virginiana*	Eastern red cedar	496,500	0.5	5.6	5.0	496,500	1.3	5.6	5.0	0	0.0	NA	NA

APPENDIX C. Wisconsin Urban Forest Survey, 2002. Estimates of number of trees, percentage of basal area (BA), average d.b.h., and median d.b.h. by species for the total urban forest population, trees in UFIA+ areas, and trees in FIA forest areas ($UFIA_F$) (cont.). (NA = not applicable.)

			Total population				UFIA+				$UFIA_F$			
Genus	Species	Common name	Number of trees	% BA	Avg. d.b.h.	Med. d.b.h.	Number of trees	% BA	Avg. d.b.h.	Med. d.b.h.	Number of trees	% BA	Avg. d.b.h.	Med. d.b.h.
Larix	*laricina*	Tamarack	44,900	0.0	5.5	5.0	0	0.0	NA	NA	44,900	0.0	5.5	5.0
Malus	*pumila*	Apple	289,600	0.3	5.4	3.0	289,600	0.8	5.4	3.0	0	0.0	NA	NA
Malus	*species*	Crabapple	258,700	0.5	8.2	6.0	124,100	1.1	10.1	10.0	134,600	0.2	6.5	6.0
Morus	*rubra*	Red mulberry	1,344,200	0.3	2.4	1.0	662,000	0.5	2.4	1.0	682,200	0.2	2.4	1.0
Ostrya	*virginiana*	Eastern hophornbeam	9,517,400	1.3	2.2	2.0	206,900	0.4	5.1	5.0	9,310,600	1.7	2.1	2.0
Other	*species*	Other species	82,700	0.1	5.0	6.0	82,700	0.2	5.0	6.0	0	0.0	NA	NA
Picea	*abies*	Norway spruce	2,455,400	3.2	7.0	6.0	248,200	2.8	12.6	13.0	2,207,200	3.4	6.4	6.0
Picea	*glauca*	White spruce	2,842,900	1.5	3.3	1.0	1,199,800	4.2	5.8	5.0	1,643,000	0.1	1.5	1.0
Picea	*pungens*	Blue spruce	579,200	0.7	6.8	6.0	579,200	2.2	6.8	6.0	0	0.0	NA	NA
Pinus	*banksiana*	Jack pine	86,200	0.1	4.6	7.0	41,400	0.0	1.5	1.0	44,900	0.1	7.5	7.0
Pinus	*nigra*	Austrian pine	82,700	0.0	3.5	3.0	82,700	0.1	3.5	3.0	0	0.0	NA	NA
Pinus	*resinosa*	Red pine	1,514,500	3.8	10.2	10.0	124,100	0.8	8.5	11.0	1,390,400	5.3	10.3	10.0
Pinus	*strobus*	Eastern white pine	7,347,500	8.4	5.6	4.0	1,530,800	11.7	8.8	7.0	5,816,700	6.6	4.7	4.0
Pinus	*sylvestris*	Scotch pine	331,000	0.4	6.3	6.0	331,000	1.0	6.3	6.0	0	0.0	NA	NA
Populus	*balsamifera*	Balsam poplar	547,700	0.1	2.5	2.0	0	0.0	NA	NA	547,700	0.1	2.5	2.0
Populus	*deltoides*	Eastern cottonwood	678,800	1.2	5.5	2.0	41,400	0.0	3.5	3.0	637,400	1.9	5.6	2.0
Populus	*grandidentata*	Bigtooth aspen	175,900	0.3	8.3	10.0	41,400	0.1	5.5	5.0	134,600	0.4	9.1	10.0
Populus	*tremuloides*	Quaking aspen	6,330,200	2.7	3.6	3.0	827,500	2.1	5.5	5.0	5,502,700	3.0	3.4	3.0
Prunus	*maackii*	Amur chokecherry	41,400	0.0	2.5	2.0	41,400	0.0	2.5	2.0	0	0.0	NA	NA
Prunus	*pensylvanica*	Pin cherry	1,812,000	0.4	2.9	2.0	124,100	0.0	1.8	1.0	1,687,900	0.6	3.0	2.0
Prunus	*serotina*	Black cherry	7,861,500	1.8	2.6	2.0	248,200	0.2	3.2	2.0	7,613,200	2.6	2.6	2.0
Prunus	*serrulata*	Kwanzan cherry	537,900	0.2	3.1	2.0	537,900	0.5	3.1	2.0	0	0.0	NA	NA
Prunus	*species*	Cherry	82,700	0.0	2.2	3.0	82,700	0.0	2.2	3.0	0	0.0	NA	NA
Prunus	*virginiana*	Common chokecherry	630,400	0.0	1.5	1.0	82,700	0.0	1.2	1.0	547,700	0.0	1.5	1.0
Quercus	*alba*	White oak	1,372,000	2.6	6.9	3.0	331,000	1.7	6.0	3.0	1,041,000	3.1	7.2	3.0
Quercus	*ellipsoidalis*	Northern pin oak	579,600	3.1	13.2	11.0	41,400	0.0	1.5	1.0	538,200	4.7	14.0	12.0
Quercus	*marcrocarpa*	Bur oak	1,883,800	7.1	11.1	9.0	0	0.0	NA	NA	1,883,800	10.8	11.1	9.0

APPENDIX C. Wisconsin Urban Forest Survey, 2002. Estimates of number of trees, percentage of basal area (BA), average d.b.h., and median d.b.h. by species for the total urban forest population, trees in $UFIA^{+}$ areas, and trees in FIA forest areas ($UFIA_{F}$) (cont.). (NA = not applicable.)

			Total population				$UFIA^{+}$				$UFIA_{F}$			
Genus	**Species**	**Common name**	**Number of trees**	**% BA**	**Avg. d.b.h.**	**Med. d.b.h.**	**Number of trees**	**% BA**	**Avg. d.b.h.**	**Med. d.b.h.**	**Number of trees**	**% BA**	**Avg. d.b.h.**	**Med. d.b.h.**
Quercus	*marilandica*	Blackjack oak	124,100	0.6	13.0	16.0	124,100	1.8	13.0	16.0	0	0.0	NA	NA
Quercus	*rubra*	Northern red oak	1,921,300	5.4	10.1	9.0	620,600	5.6	9.4	6.0	1,300,700	5.4	10.5	10.0
Quercus	*velutina*	Black oak	1,732,700	0.3	2.4	2.0	0	0.0	NA	NA	1,732,700	0.4	2.4	2.0
Robinia	*pseudoacacia*	Black locust	2,450,400	1.5	5.0	4.0	0	0.0	NA	NA	2,450,400	2.3	5.0	4.0
Salix	*babylonica*	Weeping willow	82,700	2.3	30.5	29.0	82,700	6.7	30.5	29.0	0	0.0	NA	NA
Salix	*nigra*	Black willow	44,900	1.1	30.5	30.0	0	0.0	NA	NA	44,900	1.7	30.5	30.0
Salix	*species*	Willow	82,700	0.4	14.0	12.0	82,700	1.1	14.0	12.0	0	0.0	NA	NA
Thuja	*occidentalis*	Northern white cedar	2,503,400	2.4	6.0	5.0	744,700	1.9	4.9	3.0	1,758,700	2.7	6.4	6.0
Tilia	*americana*	American basswood	5,996,100	3.4	4.5	3.0	0	0.0	NA	NA	5,996,100	5.2	4.5	3.0
Tsuga	*canadensis*	Eastern hemlock	179,400	0.6	12.3	13.0	0	0.0	NA	NA	179,400	0.9	12.3	13.0
Ulmus	*americana*	American elm	5,031,400	3.2	4.0	3.0	579,200	4.1	7.7	3.0	4,452,200	2.8	3.6	3.0
Ulmus	*pumila*	Siberian elm	496,500	0.3	4.3	3.0	496,500	0.9	4.3	3.0	0	0.0	NA	NA
Ulmus	*rubra*	Slippery elm	1,716,600	0.5	3.0	2.0	1,034,300	0.9	3.4	3.0	682,200	0.3	2.5	1.0

APPENDIX D. Wisconsin Urban Forest Survey, 2002. Urban damage agents.

Insect pests	Arboriculture issues	Pathogens and diseases	Other
• Gypsy moth • Asian longhorned beetle • Insect defoliators—general • Forest tent caterpillar • Shoot and branch insects—general • Branch gall insects • Bole borers—general • Bark beetles—general • Root/root collar insects	• Stem girdling roots • Topped tree • Poor pruning • Included bark/ codominant leader • Confined space above or below ground • Object restricting root growth • Girdling from foreign object • Construction activity • Absent basal trunk flare	• Dutch elm disease • *Verticillium* • Dogwood anthracnose • Sudden oak death • Bacterial leaf scorch • Oak wilt • Foliage diseases • Shoot blights • Bole rusts • Bole cankers • *Eutypella* canker • *Hypoxylon* canker • *Nectria* canker • Butternut canker • *Annosus* root rot • Ash yellows • *Armillaria* root rot	• Chlorosis • Other human disturbance to tree • Stem decay • Rot/butt rot • Weather • Animal damage • Fire • Chemical