NATIONAL FOREST HEALTH MONITORING PROGRAM

Monitoring Urban Forests in Indiana: Pilot Study 2002

Part 1: Analysis of Field Methods and Data Collection

United States
Department of Agriculture

Forest Service

Northeastern Area
State and Private Forestry
Newtown Square, PA

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Northeastern Area State and Private Forestry
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Preface

This report highlights findings from the first statewide urban forest health monitoring pilot study conducted in the State of Indiana in 2002. The report is in two parts—Part One summarizes analysis of the field methods and data collected on the urban nonforest plots of one panel in Indiana, and Part Two expands these data to statewide urban forest estimates with the addition of FIA forest plots within the urban boundary.

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ABSTRACT

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 to local, regional, and national societies and economies. To better understand the urban forest resource and its numerous values, the USDA Forest Service Forest Health Monitoring Program initiated a pilot program to assess urban forests in several States. State urban forest functions and values were analyzed using the Urban Forest Effects (UFORE) model (www.ufore.org). Those results are presented in *Monitoring Urban Forests in Indiana: Pilot Study 2002 Part 2: Statewide estimates using the UFORE Model*. Results from both Part 1 and Part 2 should be viewed as a demonstration of the value of collecting and analyzing urban forest data. These data can be used to advance the understanding of urban forests and their management to improve human health and environmental quality in urban areas.

INTRODUCTION

The implementation of the Forest Health Monitoring (FHM) Program by the USDA Forest Service has proven to be an effective way to assess and detect potential health issues within "traditional" forested areas. Urban forests are a key component of environmental health whose contributions are becoming increasingly vital as urban sprawl escalates and other factors impinge on urban forest health. There is minimal information available, however, to address issues regarding this valuable natural resource. Data collected from urban sampling plots could identify trends detrimental to the health of urban forest ecosystems. Indiana conducted a pilot test of urban forest health monitoring to refine sampling techniques and data collection procedures, determine the validity of data collected, and address complications encountered when using the FHM sample framework in urban environments.

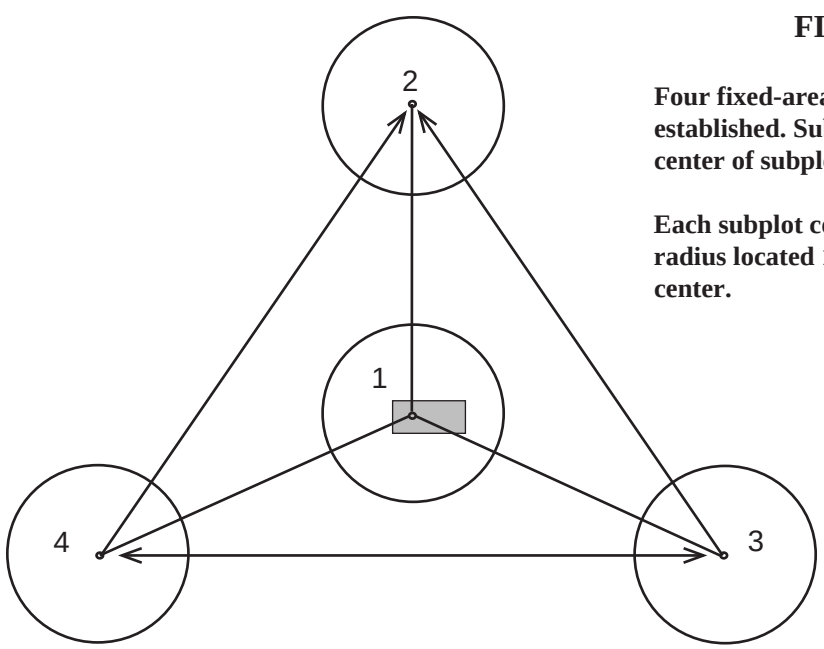
METHODS

Indiana conducted a pilot test of Urban Forest Health Monitoring (UFHM) using Forest Inventory and Analysis (FIA) survey points, the urban area defined by the 1990 U.S. census, and amended FHM data collection methods. The UFHM plots were located in 30 urban areas within 14 counties and 22 different cities. This first grouping of 30 plots is referred to as panel 1. Following initial pilot test data collection in 2001, concerns were raised about collection methods as well as other survey procedures concerning foliage density, building variables, lack of trees on plots, survey logistics, multiple landowner contacts, microplot data, and an absence of variables related to urban tree issues. As a result, changes were implemented to address these issues and plots were revisited in 2002 to incorporate refined changes.

Plot Description

Each plot consisted of four fixed-area, 24-foot radius circular subplots (figure 1). Each subplot covered one twenty-fourth of an acre. The centers of subplots 2, 3, and 4 were located 120 feet from the center of subplot 1 at fixed azimuths of 0° (360°), 120°, and 240°, respectively. A total of 30 plots were sampled for the first panel. The traditional FHM microplot was omitted after preliminary data suggested that it would not capture information relevant to urban or traditional FHM.

Figure 1. Plot layout.



FIA Plot Configuration

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.

Manual

An Urban FHM manual was drafted to define protocols for sampling. The manual is based on procedures from the National Forest Health Monitoring Field Method Guide (USDA Forest Service 1998).

Codes Used in Data Collection

Sets of codes were used to represent variables collected in the field (appendix A). Most of the codes paralleled those used for FIA with the exception of species codes. UFORE species codes were used because they were more comprehensive and included more exotic and nonnative species found within urban areas. Additional damage agents were added to capture information on issues that are more specific to urban environments.

Trees Surveyed

In order to capture data on trees <5 inches in diameter at breast height (d.b.h.) after omitting the microplot, all trees ≥ 1 inch d.b.h. became eligible for complete sampling. This also allowed capture of newly installed trees (usually 2 to 3 inches in diameter), which are commonly planted within urban areas. Naturally seeded trees would be captured within conservation or abandoned areas that allow opportunities for natural regeneration.

Variables

Data collection variables were grouped into six categories. Landowner contact data were collected first to record information about property owners because permission for access was needed. Witness data were collected to reference the locations of subplot centers. Boundary references identified condition changes within a subplot. Condition classes defined changes in the use, ownership, or status of the property that would define a potential change in management strategies. Subplot-level data measured information pertaining to characteristics of ground, tree, and shrub cover. Tree-level data recorded information about crown, size, species, damages, and proximity to buildings.

Installing Plots

Plot installation began by determining the physical location of the center of subplot 1 using fixed, definable references from scaled aerial photos. Driving directions to each location were generated using plot center latitude and longitude coordinates entered into mapping programs. Landowner permission for property access was granted through personal contacts. Plots or subplots that were nonaccessible due to property owner denial, hazards, or physical barriers were not sampled. Measurements were recorded by a single, two-person field crew. The crew was trained to make subjective measurements within an acceptable range of variability.

Duration of Sampling

The field data had to be collected within an acceptable timeframe given that data collection variables included foliage-dependent measurements. The sampling window for foliage-dependent measurements in Indiana lasts from June to August. Initial measurements for panel 1 in Indiana were collected during the summer of 2001. Based on the 2001 field sampling experience, it was recommended that the plots be revisited in the summer of 2002 to incorporate refined variables and data collection changes.

RESULTS AND DISCUSSION

Plot-Level Data

Since only one two-person crew measured data on all Indiana panel 1 plots, there is no variability between crews for subjective measurements. Plots were located in 14 different counties (22 cities) throughout Indiana (tables 1 and 2). Most of the plots (30 percent) were in Marion County, whose population of 860,454 (2000 U.S. Census) represents 14.15 percent of the State's population and contains no "rural" population as defined by the U.S. Census. Lake and Allen County both contained 13.3 percent of the plots and represent 7.97 and 5.46 percent of the population of Indiana, respectively. Eight plots were located in Indianapolis (pop. 781,870).

Table 1. Indiana plot frequency by county of one panel (20 percent) of urban nonforest plots.

County	Number of Plots	Percent of Total
Marion	9	30.0
Lake	4	13.3
Allen	4	13.3
Whitley	2	6.6
Madison	2	6.6
Wayne	1	3.3
Vanderburgh	1	3.3
Tippecanoe	1	3.3
St. Joseph	1	3.3
Parke	1	3.3
Greene	1	3.3
Elkhart	1	3.3
Delaware	1	3.3
Daviess	1	3.3

Table 2. Indiana plot frequency by city of one panel (20 percent) of urban nonforest plots.

City	Number of Plots	Percent of Total
Indianapolis	8	26.6
Columbia City	2	6.6
Beech Grove	1	3.3
Clinton	1	3.3
Elwood	1	3.3
Evansville	1	3.3
Ft. Wayne	1	3.3
Highland	1	3.3
Hobart	1	3.3
Anderson	1	3.3
Linton	1	3.3
Washington	1	3.3
Merrillville	1	3.3
Muncie	1	3.3
New Haven	1	3.3
North	1	3.3
Osceola	1	3.3
Ossian	1	3.3
Richmond	1	3.3
Schererville	1	3.3
South Bend	1	3.3
Lafayette	1	3.3

Plot Access

A total of 30 plots were assigned for panel 1. Three plots were determined to be inaccessible. Plots where access to the center of subplot 1 was denied due to hazards or lack of permission from legal property owners were not sampled. Therefore, the following results only consider data collected from 27 accessible plots (108 subplots) with the exception of contact and plot distribution data. Only two subplots were not physically accessible. Both of these subplots were entirely within buildings and thus required no witnesses or tree data collection. Neither of these were subplot 1 and ground cover was recorded as 99 percent building.

Landowner Contacts

There was an average of 1.93 landowner contacts per plot (SD=0.94). This is lower than expected given the probability of encountering subplot locations across multiple property boundaries. The number of contacts for each plot, however, can be highly variable and brought up logistical concerns. Given the preference to collect data during the day, the number of repeated attempts to request permission for property access increased, a factor that is not reflected in the average. This delayed the completion of plot data collection. Once personal contact was established and the objective explained, permission was almost always granted.

Another concern regarding contacts was providing proper responses to tree care questions from property owners. Although providing proper advice will contribute to the improvement of urban forest quality, health, and safety, it may change the management strategies of the trees within the subplots. This would then compromise the data for future analysis.

Crew Safety

The safety of the crew is also a concern when surveying any private property, and may require specialized training on dealing with dangers such as guard dogs, hazardous materials, gangs, and utility hazards. Field crews may have to be equipped with safety items such as first aid kits, pepper spray, and cell phones.

Liability

Being granted verbal permission to enter private property can have liability concerns in the event that a crew is accused of damaging property. Our crew did not experience any negative conflicts with property owners. Written permission may reduce liability, but would most likely result in more refusals. In addition, any advice given pertaining to risk tree abatement and corrective actions could become a liability concern. Strict policies should be implemented regarding proper and responsible methods of dealing with public safety issues.

Plot Installation

The use of Global Positioning System (GPS) coordinates can eliminate bias during initial subplot installation. Coordinates for subplot 1 centers were provided to crews at the beginning of the field season. Using coordinates to reference surrounding subplot centers can allow a plot to be installed if the entire area of subplot 1 is inaccessible. The relocation of subplot centers using most commercial GPS units, however, was insufficient for remeasurements due to the ± 1- to 3-meter accuracy limitations. Coordinates can also be entered into online mapping programs to locate the plot vicinity and provide travel time, directions, and mileage information.

Witness Objects

Because crews were working within urban boundaries on private property, nondestructive sampling was preferred and required the use of fixed objects to reference subplot center locations. Items used as reliable urban references included fire hydrants, electric meters, utility poles, and gas meters. Utility poles were the most frequently used nonliving witness item followed by sewer covers. Unfortunately, future construction could result in unexpected location changes or elimination of “fixed” witness items.

GPS coordinates were recorded to reference subplot centers in areas where no fixed witness items were available. Overall, the field crews recommended using fixed nonliving items or structures since they may be less subject to change when compared to living structures (i.e. trees). Many of the larger (≥ 10-inch d.b.h.) trees within the subplot boundaries, however, were used for reference due to their close proximity.

A digital photo can be taken of a crew member standing at the center of subplot 1 using a digital camera. If the photo can capture other background clues, the relocation of plot center locations can more easily be determined. The photo can then be linked to the database directly.

Overall, there were no major complications accessing or locating reliable witness items for subplot centers. Some witness objects were accessed by crossing busy

streets, which required good communication and alertness among crew members. Using measuring devices such as range finders may prove beneficial for measuring distances to trees and witness items, depending on the accuracy of the instrument.

Boundary References

Distances and azimuths were recorded to identify changes in condition status, land use, and ownership within a subplot. These boundary references were recorded from subplot centers when more than one condition class was evident. Given the apparent heterogeneous nature of the urban environment, it was predicted that condition status would be highly variable. The crews only experienced five instances where a boundary reference was required. The lower-than-expected variability may be due to questionable boundaries between different ownerships and land uses within a subplot. Although some physical clues such as fire hydrants, sidewalks, and landscape changes are sometimes available, the differences are not always apparent.

Condition Status

Most of the subplots were defined as having a nonforest land status (94.1 percent), which reflects the majority of land types within urban boundaries. Crews were denied access to two subplots and one subplot landed in census-defined water (table 3).

Table 3. Subplot frequency by condition status.

Condition Status	Number of Subplots	Percent of All Subplots
Nonforest	48	94.1
Denied Access	2	3.9
Census-defined Water	1	2.0

Ownership and Land Use

Almost three-quarters of the land ownership was categorized as private (72.55 percent) with the remainder owned by the State or local governments (27.45 percent). Capturing a large percentage of randomized data on private property should provide more accurate information that reflects the urban forest landscape. Collecting data on nonforest urban FIA plots creates an opportunity to survey a variety of land types and land uses compared to the traditional urban forestry methods of municipal inventories of public lands.

Seven distinct land use classifications were recognized. A majority of the land use was categorized as residential (29.4 percent), followed by right-of-way and transportation (23.6 percent), commercial and industrial (17.7 percent), and vacant (11.8 percent) (table 4). The vacant areas were mostly abandoned industrial sites or unmanaged lots with an abundance of sapling growth.

Table 4. Subplot frequency by land use type.

Land Use[1]	Subplot Frequency	Percent of Total
Residential	15	29.4
ROW/Transportation/ Utility	12	23.6
Commercial/Industrial	9	17.7
Vacant	6	11.8
Park	4	7.9
Agriculture	3	5.9
Water	2	4.0

[1]**Residential**: Developed land used primarily for human dwellings

ROW/Transportation/Utility: Rights-of-way and transportation corridors, limited access roadways, airports, or railways

Commercial/Industrial: Developed land used for commercial businesses or industrial purposes

Vacant: Vacant land was considered developed land for use by humans for purposes other than forestry or agriculture. Other land uses were land parcels that were greater than 1.0 acres in size and greater than 120 feet wide and did not fall into any other category (e.g., marsh or undeveloped beach).

Park: Developed land used primarily for parks, green/open space, golf courses, or cemeteries

Agriculture: Land managed for crops, pasture, or other agricultural uses

Subplot-Level Data

Tree, Seedling, and Shrub Cover

The average tree cover per plot was 12.8 percent while the combined shrub and seedling cover was only 1.97 percent (table 5). These averages are lower than the overall estimated tree cover within urban areas of both Indiana (31.2 percent) and the Nation (27.1 percent) (Dwyer and others 2000). Data from the remaining panels are needed to get a valid statistical estimate of statewide tree cover.

Table 5. Percent of total cover by subplot cover type.

Subplot Cover Type[1]	Percent of Total Cover
Tree Cover	12.8
Shrub/Seedling	1.97

[1]**Tree Cover:** Tree species greater than or equal to 1 inch d.b.h.

Shrubs: Species listed as never becoming a tree, regardless of stem diameter

Seedlings: Tree species less than 1 inch d.b.h.

Ground Cover

Most of the cover at ground level was classified as herbaceous (54.51 percent) followed by impervious (27.51 percent), permeable (8.60 percent), building (6.23 percent), and water (1.96 percent) (table 6). Most ground cover described as herbaceous was mowed and maintained grass in residential lawns and parks. A majority of the impervious ground cover was blacktop, asphalt, and cement from roads and driveways. Thus, a majority of the ground types surveyed (63.11 percent) could be considered plantable space. However, individual site restrictions may not provide an accommodating environment for trees in all areas.

Table 6. Percent of total ground cover by ground cover type.

Ground Cover[1]	Percent of Total Ground Cover
Herbaceous	54.5
Impervious	27.5
Permeable	8.6
Building	6.2
Water	1.9

[1]**Herbaceous:** Nonwoody plant material

Impervious: Nonbuilding material that does not allow water percolation

Permeable: Ground surface that allows water percolation (includes gravel and soil)

Building: Physical structures occupying the plot

Water: Water features or wetlands

Tree-Level Data

Trees Per Plot

Because the minimum diameter of sampled trees was lowered from 5 inches d.b.h. in 2001 to 1 inch d.b.h. in 2002, there was a significant increase in the number of trees recorded in 2002 (190 trees) compared to 2001 (44 trees). Of the plots surveyed, only 55.56 percent of the plots contained one or more trees ≥ 1 inch d.b.h. If only those plots that contain one or more trees are considered, the average number of trees per plot is 12.73. This is not an accurate representation of a typical occurrence for panel 1 due to the high variability in the number of trees per plot (SD=20.01); one plot actually contained 39.47 percent of the trees (table 7a). This accounts for the addition of trees less than 5 inches d.b.h. to the survey. Those plots that contained a high frequency of trees were vacant, unmanaged lots that had an abundance of saplings and trees smaller than 5 inches in diameter. Although these vacant plots were not frequently encountered, they greatly influenced the average number of trees per plot. If only trees 5 inches or greater in diameter are considered, the average number of trees per plot decreases to 2.64 (SD=1.86) (table 7b).

Table 7a. Number of trees recorded ≥ 1 inch d.b.h., by plot.

Sum= 190; SD=20.01

Plot Number	Number of trees ≥ 1 inch d.b.h.
097	75
174	36
049	25
062	17
022	9
121	6
106	4
202	3
124	3
027	3
086	3
078	2
074	2
046	1
038	1

Table 7b. Number of trees recorded ≥ 5 inches d.b.h., by plot.

Sum=44; SD=1.86

Plot Number	Number of trees ≥ 5 inches d.b.h.
174	7
049	6
106	4
202	3
086	3
124	2
027	2
078	2
121	2
074	2
097	1
046	1
062	1
038	1

Diameter

A majority of the diameter measurements were taken at 4.5 feet above the ground (162 trees), followed by alternative heights of 4 feet (12 trees) and 2 feet (7 trees). Thus, few trees were encountered that were unable to be measured as single main stems at 4.5 feet (d.b.h.). An overwhelming majority of the diameters were accurately measured (188 of 190 trees measured). This reflects both the accessibility of the trees in the field and the skills of the crew. Once permission was granted, field crews encountered few instances where trees could not be measured.

The average diameter for all trees 1 inch d.b.h. and greater recorded in panel 1 was 5.07 inches. When considering only trees greater than or equal to 5 inches d.b.h., the average diameter increases to 14.76 inches. Almost two-thirds of the trees sampled were 3 inches or less in diameter (table 8), while the largest trees (greater than 20 inches) comprised less than 8 percent of the sample.

Table 8. Number and percent of total trees sampled, by d.b.h. class.

d.b.h. Class (Inches)	Number of Trees	Percent of Total
1 – 3	119	62.6
3.1 – 5	30	15.7
5.1- 10	19	10.0
10.1 – 15	4	2.1
15.1 – 20	3	1.5
20.1 – 25	7	3.6
25.1 and greater	8	4.2

Species Composition

Twenty-six different species were encountered in this pilot study, with *Acer saccharinum* having the highest percent frequency (31.1 percent) followed by *Populus deltoides* (23.2 percent), *Ulmus pumila* (12.1 percent), and *Acer negundo* (6.8 percent) (table 9).

Table 9. Species frequency for trees ≥ 1 inch d.b.h.

Species	Frequency	Percent of Total
Acer saccharinum	59	31.1
Populus deltoides	44	23.2
Ulmus pumila	23	12.1
Acer negundo	13	6.8
Malus sp.	6	3.2
Picea abies	6	3.2
Morus rubra	5	2.6
Tsuga canadensis	5	2.6
Fraxinus americana	4	2.1
Acer rubrum	3	1.6
Ulmus americana	3	1.6
Fraxinus pennsylvanica	2	1.1
Quercus velutina	2	1.1
Salix babylonica	2	1.1
Prunus serotina	2	1.1
Acer platanoides	1	0.5
Acer saccharum	1	0.5
Ailanthus altissima	1	0.5
Cercis canadensis	1	0.5
Magnolia × soulangeana	1	0.5
Liriodendron tulipifera	1	0.5
Ulmus rubra	1	0.5
Picea pungens	1	0.5
Platanus occidentalis	1	0.5
Populus alba	1	0.5
Juglans nigra	1	0.5

Most of these were saplings less than 5 inches d.b.h. growing in vacant, unmanaged lots. If only trees 5 inches in diameter and greater are considered, species diversity is reduced by 23.08 percent (table 10).

Table 10. Species frequency for trees ≥ 5 inches d.b.h.

Species	Frequency	Percent of Total
Acer saccharinum	7	15.9
Ulmus pumila	6	13.6
Picea abies	6	13.6
Populus deltoides	4	9.1
Fraxinus americana	3	6.8
Morus rubra	2	4.6
Acer rubrum	2	4.6
Malus sp.	2	4.6
Picea pungens	1	2.3
Ulmus rubra	1	2.3
Populus alba	1	2.3
Prunus serotina	1	2.3
Liriodendron tulipifera	1	2.3
Juglans nigra	1	2.3
Fraxinus pennsylvanica	1	2.3
Salix babylonica	1	2.3
Cercis canadensis	1	2.3
Acer saccharum	1	2.3
Tsuga canadensis	1	2.3
Magnolia × soulangeana	1	2.3

Crown Dimensions

The mean height of the trees, including dieback, was 25.3 feet. The difference in total height compared to the height to the live crown top was only 0.15 feet, which reflects minimal dieback at the apex of the crown. Crown widths averaged 11.4 feet. The widths and heights were heavily influenced by the high number of trees smaller than 5 inches d.b.h. that were sampled. The average physical dimensions basically doubled if trees 5 inches d.b.h. and greater are considered. Figures 2 and 3 demonstrate the influence of the smaller trees included in the survey.

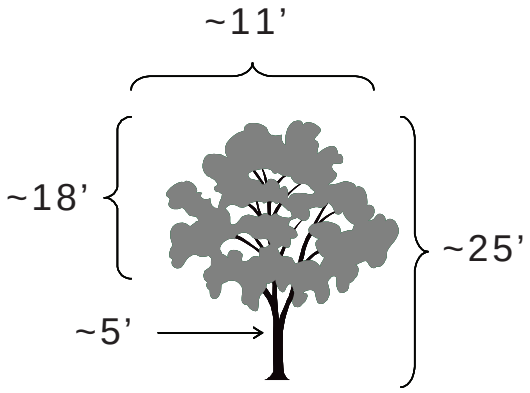


Figure 2. Average dimensions of all trees surveyed ≥ 1 inch d.b.h.

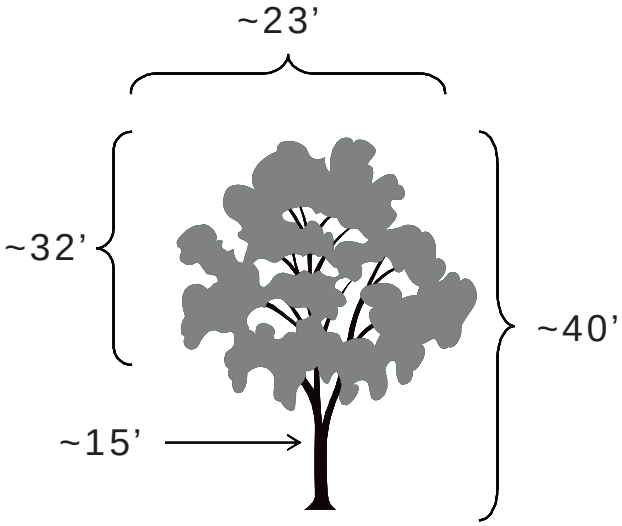


Figure 3. Average dimensions of all trees surveyed ≥ 5 inches d.b.h.

Crown Ratios

The average uncompacted live crown ratio, determined from the height measurements, was 69.7 percent. The average dieback was only 1.1 percent, which reflects the influence of young vigorous saplings and proper deadwood removal and pruning on more mature urban trees. The resulting values for foliage absent (average 1.8 percent) were similarly impacted (table 11). Other foliage-dependent crown measurement results included transparency (average 19.6 percent) and density (average 55.7 percent). Most (68.1 percent) of the larger trees (≥ 5 inches d.b.h.) were open canopy and allowed a clear line of sight to observe crown measurements.

Table 11. Average crown measurements, percent.

Foliage Absent	Transparency	Density	Dieback
1.8	19.6	55.7	1.1

Crown Positions

Crown positions were heavily influenced by the inclusion of trees 5 inches and greater d.b.h. Saplings greater than or equal to 5 inches d.b.h. accounted for most of the overstory positions (table 12). A majority of the trees surveyed were classified as overstory (47.4 percent), followed by open canopy (28.4 percent) and understory (24.2 percent). Most residential trees were classified as open canopy while trees in vacant "unmanaged" areas were classified in both overstory and understory crown positions. None of the trees surveyed for panel 1 were classified as superstory. Given that many of the large trees were open grown, crown measurements were less likely to have observer error resulting from overlapping canopies.

Table 12. Percent of total tree sample by crown position.

Crown Position	Percent of Total Tree Sample
Overstory	47.4
Understory	28.4
Open canopy	24.2

Light Exposure

Light exposure was measured using the uncompacted live crown. Each side of the crown was rated separately by dividing the crown vertically into four equal sides. Each side and top was rated for sun exposure. The percent of trees sampled was somewhat evenly distributed (table 13) among all crown exposure classifications (SD= 8.85). Exposure defined as "top + 2 sides" accounted for the majority of trees (25.8 percent) while "top + 1 side or 2 sides without top" had the least frequency of occurrence (13.7 percent).

Table 13. Percent of total tree sample by crown exposure category.

Crown Exposure to Natural Light	Percent of Trees
No full light	14.2
Top + 1 side	17.4
Top + 1 side or 2 sides without top	13.7
Top + 2 sides	25.8
Top + 3 sides	14.7
Top + 4 sides	14.2

Mortality

None of the trees surveyed were categorized as dead. Encountering dead standing trees on plots within urban boundaries may be an infrequent occurrence, especially on residential property and in public rights-of-way. Municipalities and private property owners are more actively removing dead trees for liability, safety, and aesthetic purposes. Dead trees may, most likely, be found in vacant lots and abandoned sites or along waterways.

Damage Type

Damage that met sampling thresholds was not often encountered. Only 10.5 percent of the trees surveyed were recorded as having one or more damage types. The most frequently occurring damage type was vines in the crown (45 percent), followed by open wounds (18 percent), conks and fruiting bodies (18 percent), and loss of apical dominance (9 percent) (table 14). These data were virtually unchanged with the addition of trees less than 5 inches d.b.h. due to the quality of health and vigor of the additional saplings and small trees. The damage agents recorded for this pilot study do not represent the "typical "damage (e.g. improper planting, included bark, or stem girdling roots) associated with urban environmental factors and poor arboricultural practices.

Table 14. Number and percent of damaged trees sampled by damage type.

Damage Type	Number of Damaged Trees	Percent of All Trees with Damage
Vines in crown	10	45.5
Open wounds	4	18.2
Conk/fruiting bodies	4	18.2
Loss of apical dominance	2	9.1
Broken or dead branches	1	4.6
Cracks or seams in trunk	1	4.6

Damage Location

Most of the damage was located in the branches (39.1 percent) followed by the lower bole (17.4 percent) and roots, stump, and lower bole (17.4 percent) (table 15).

Table 15. Number and percent of damaged trees sampled by damage location.

Damage Location	Number of Damaged Tree	Percent of All Trees with Damage
Branches	9	39.1
Lower bole	4	17.4
Roots, stump, lower bole	4	17.4
Lower and upper bole	3	13.0
Crown stem	2	8.7
Roots	1	4.4

Damage Agent

While the most prevalent anthropogenic urban damage agents were “other human” and “topped tree,” the most frequent damage agent was vines in the crowns of large trees in vacant, unmanaged lots (table 16). Field crews expected more human-caused urban damage agents to be encountered in the field. Future crews will have to be thoroughly trained to identify urban-specific damage agents. Only 10.5 percent of the trees that contained damage had more than one damage type.

Table 16. Number and percent of damaged trees sampled by damage agent.

Damage Agent	Number of Damaged Trees	Percent of All Trees with Damage
Vines in crown	10	45.5
Other human damages	5	22.7
Topping	1	4.6
Wind damage	1	4.6
Bole cankers	1	4.6
Unknown breakage	1	4.6
Unknown canker	1	4.6
Unknown abnormal form on bole	1	4.6
Unknown crack/seam	1	4.6

CONCLUSIONS

Several objectives were accomplished during the course of the Indiana pilot study. We improved sampling techniques; added variables applicable to urban environments; created systems for data collection, storage, and analysis; and investigated new technologies to streamline field work and reduce error. The study was conducted to determine the feasibility of this unique type of sampling with the intent of monitoring forest health within urban areas. Given the refinement process of the pilot study and the logistical challenges of making contact with landowners, we encountered some delays, but progress was steady after landowner permission was granted. Although random sampling in urban areas using a subplot cluster design offers specific challenges, it can be accomplished effectively, provided that enough time is allowed for sampling. Given the unpredictable nature of urban plots, we would conservatively estimate that 1 day be granted per plot. As more panels are completed from other States, we can more accurately assess the duration of time needed on each plot.

The addition of trees between 1 and 5 inches d.b.h. in the sample heavily influenced the data, which reflected the characteristics of young, vigorous, undamaged, and opportunistic lowland species. Although the frequency of encountering an abundance of these small trees was low in the pilot study, when they did occur on a plot, it resulted in a much higher density than in those plots with trees 5 inches and greater. This dramatically changed the whole profile of the urban forest as described by the trees sampled in this pilot study.

Most of the trees sampled were located in unmanaged, vacant land. Many of these areas are subject to development, which will have a tremendous influence on the temporal data as plots are repeatedly remeasured. Although construction changes will jeopardize some of the long-term data needed for periodic assessments, it may also provide more insight into the effects and impacts of development and urban sprawl.

Given the results, the vast potential of this type of sampling method is becoming evident. The randomized design increases the probability of capturing data from trees not routinely sampled. Since the design allows the opportunity to sample anywhere within an urban boundary, it will likely provide the most accurate representation of urban forest health and offer data that can be used to enhance the entire urban forest ecosystem. This includes the detection of invasive insects and pathogens in areas not commonly sampled in urban forestry as well as assessment of tree care needs based on species diversity, condition, and density. Data from varied demographic areas can be compared to study the impact of populations upon urban forest health. Eventually, the compilation of data from other States can provide a regional and national profile of urban forest health. In addition, if we increase the intensity of sampling within urban boundaries, substantial data can be generated to more accurately represent forest dynamics within all landscapes and demographic areas by merging traditional with urban datasets.

We have refined the survey methods and proven the feasibility of using this design within urban boundaries. The greatest concerns about continuing and expanding such a survey involve fiscal limitations, crew safety, sample size, and access to private property. As the importance of urban forest ecosystems becomes more apparent, the demand for monitoring the health of this overlooked resource will increase. With the commitment from other States to conduct urban forest health monitoring surveys, we can further assess the status of urban forests and use the data to enhance environmental health.

LITERATURE CITED

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APPENDIX A.

Urban FHM Codes - *Code list for variables. Urban Forest Effects Model (UFORE) species codes not included.*

Condition Status	
Code	**Description**
1	Accessible Forest Land
2	Nonforest Land
3	Noncensus Water
4	Census Water
5	Denied Access Area
6	Area too Hazardous

Land Use Class	
Code	**Description**
1	Agriculture
2	Cemetery
3	Comm/Ind
4	Forest
5	Golf Course
6	Institutional
7	Multi Family Residential
8	Park
9	Residential
10	Transportation
11	Utility
12	Vacant
13	Right of Way

Ownership	
Code	**Description**
10	Forest Service
20	Other Federal
30	State and Local Gov.
40	Private

Tree Status	
Code	**Description**
1	Live
2	Dead
3	Removal
4	Missed Live
5	Missed Mortality
6	Missed Dead
7	No History

Diameter Check	
Code	**Description**
0	Accurate
1	Estimated

Offset Position	
Code	**Description**
1	North Offest Point
2	East Offset Point
3	South Offset Point
4	West Offset Point

Slope	
Code	**Description**
000	0-4 % Slope
005	5 % Slope
XX	XX % Slope

Crown Light Exposure	
Code	**Description**
0	No Full Light, Shaded
1	Top or 1 Side
2	Top and 1 Side or 2 Sides
3	Top and 2 Sides
4	Top and 3 Sides
5	Top and all 4 Sides

Crown Position	
Code	**Description**
1	Superstory
2	Overstory
3	Understory
4	Open Canopy

Cause of Death	
Code	**Description**
10	Insect Damage
20	Disease Damage
30	Fire Damage
40	Animal Damage
50	Weather Damage
60	Vegetation
70	Unknown/Other (include notes)
80	Human-caused
90	Physical (hit by falling tree)

Location	
Code	**Description**
0	None
1	Roots
2	Roots, Stump and Lower Bole
3	Lower Bole
4	Lower and Upper Bole
5	Upper Bole
6	Crownstem
7	Branches
8	Buds & Shoots
9	Foliage

Common Witness Objects	
Code	**Description**
C	Corner of House/Building
E	Electric Meter
F	Fire Hydrant
G	Gas Meter
M	Mailbox
P	Fence Post
S	Street Sign
U	Utility Pole
X	Sewer Cover

Note: letter codes are used since you can reference to a tree number.

Damage Type	
Code	**Description**
01	Canker, Stem Girdling Root, Gall ≥ 20%
02	Conks, Fruiting Bodies, Sign of Advanced Decay
03	Open Wounds ≥ 20 %
04	Resinosis or Gummosis ≥ 20 %
05	Cracks & Seams > 5’ long
11	Broken Bole or Roots < 5’ from Bole
12	Brooms
13	Broken or Dead Roots >3’ from Bole ≥ 20 %
20	Vines in Crown ≥ 20 %
21	Loss of Apical Dominance ≥ 1 %
22	Broken or Dead ≥ 20 %
23	Excessive Branching or Brooms ≥ 20 %
24	Damage Buds, Shoots, or Foliage ≥ 30 %
25	Discoloration of Foliage ≥ 30 %
31	Other

Severity (Damage)	
Code	**Description**
0	1-9 %
1	10-19 %
2	20-29 %
3	30-39 %
4	40-49 %
5	50-59 %
6	60-69 %
7	70-79 %
8	80-89 %
9	90-99 %

Urban Damage Agents	
Code	**Description**
1	Stem Girdling Root
2	Chlorosis
3	Topped Tree
4	Poor Pruning
5	Dutch Elm Disease ***
6	Verticillium ***
7	Gypsy Moth ***
8	Asian Longhorned Beetle ***
9	Dogwood Anthracnose
10	Sudden Oak Death ***
11	Bacterial Leaf Scorch
12	Forest Tent Caterpillar
13	Codominant Lead w/Included Bark
14	Oak Wilt ***
15	Confined Space (at or below ground) ***
16	Object Restricting Crown Growth (Anthropogenic)
17	Girdling from Foreign Object
18	Construction Activity
19	Absent Basal Trunk Flare (for depth and grade) ***
20	Other Human (include notes)
21	Emerald Ash Beetle ***

Note: items with *** must be recorded if present others must meet threshold

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