STEM-UP COMMUNITY TREE INVENTORY INSTRUCTIONS

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This publication provides a step-by-step guide to conducting measurements for use in an urban tree inventory. In general, this guide reflects the measurements included in the U.S. Forest Service's i-Tree Eco software program; however, the measurements are fairly standard variables used in bottom-up urban forest inventories.

URBAN TREE INVENTORIES, i-TREE, AND EQUIPMENT

What is a community tree inventory?

A community tree inventory performs three primary functions:

1. As a *database* consisting of information about individual trees. This information includes tree location, diameter, height, canopy width, condition, and hazards.

2. As a *maintenance tool*, the community tree inventory enables managers to identify trees that need to be pruned, staked, fertilized, cabled, or removed. Urban forest managers use the inventory to periodically review trees that have been identified as hazards.

3. As a *management tool*, the inventory enables aggregation of individual tree data to provide information about a population of trees – also known as the urban forest. Tree population information includes species distribution and canopy cover. A tree map enables community forest managers to identify and prioritize community canopy goals (e.g., planting and maintenance), while accounting for the condition of the community forest (i.e., dead, critical, poor, fair, good, very good, or excellent). Inventories are used in risk assessment to compare pre- and post-disaster forest conditions and prioritize removals.

Creating a visual map of how urban forest benefits are distributed across the landscape is known as benefit mapping. A key aspect of benefit mapping is applying a dollar value to trees based on their individual characteristics. Using computer software, economic value can be assigned to ecosystem service benefits of urban trees such as pollution removal (e.g., ozone, sulfur dioxide, nitrogen dioxide), carbon sequestration, and energy savings.

What is a bottom-up tree inventory?

A bottom-up inventory generates primary data from on-the-ground inventory methods as opposed to aerial or satellite imagery (i.e., top-down inventory). This approach requires a process of measuring individual tree characteristics and quality assurance/control. Field data collection requires extensive planning, management, and time. Although it can be somewhat costly, the results can provide more information than possible through top-down analyses. For these reasons, it is beneficial to perform a bottom-up inventory at some stage of the community tree inventory.

## What is the scope of the bottom-up inventory (or how much is enough)?

The scope, also known as the sample, is one the most important decisions made in planning a bottom-up urban forest inventory. Determining the scope of the survey depends on available resources and goals. Inventory projects have ranged from parks to small neighborhoods to cities to counties.

A statistical representation of the urban forest requires a random sample, whereby plots are placed randomly across the landscape within the boundaries of the study area (e.g., the official city limits). A simple random sample is the most basic form of random sample. A *simple* random sample, however, may not provide a true picture of forest cover since the urban forest is usually not distributed across the landscape randomly.
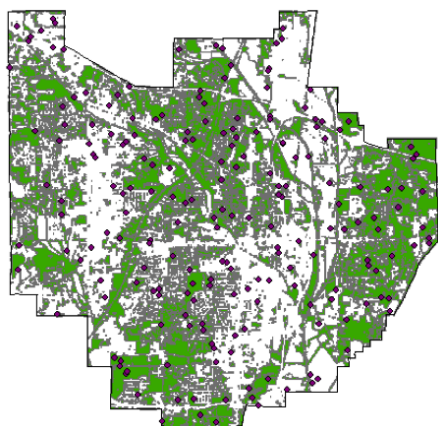
Simple random sample in (N=200). The green areas represent trees while dots are measurement plots.

A *stratified* random sample offers an alternative statistical representation with plots randomly allocated according to land use. A stratified random sample decreases the amount of plots wasted on sites with little or no trees (e.g., large commercial parking lots and agriculture fields). However, because such sites are important characteristics of any populated place, some plots will still be located there.
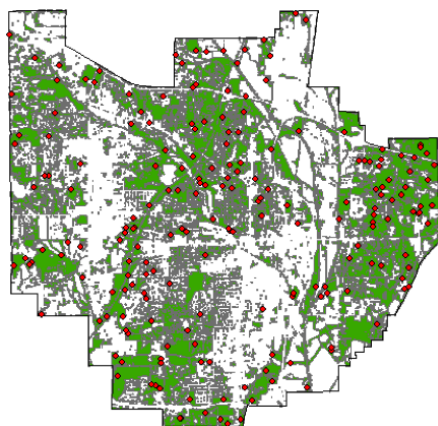
Stratified random sample (N=200). The green areas represent trees. There are more points located in areas with tree cover than in the simple random sample.

Research has found that 200 tenth-acre plots in a given area provides enough information for statistical inference and benefit mapping while also maintaining an acceptable level of costs associated with data collection (Nowak et al. 2008). Fewer points may be appropriate for a small area, but a greater number of points decrease error in the sample. A statistical sample mitigates the effects of data collection error and landscape variation. The project facilitator will add five to ten percent more plots as "extra plots" in case of some of the original 200 are inaccessible. Once the community determines the scope, the project facilitator will locate the plots on a map using Geographic Information System technology. Plot center geo-coordinates and the map will then be distributed to volunteers.

Finally, a *full inventory* (also called a 100 percent inventory) is often used to measure street trees, parks, and other public areas. This project scope measures each tree in the designated area. A full inventory is usually not a practical alternative for assessing the urban forest. Because a full inventory is unlikely to be implemented across and the entire community, it does not usually provide a true representation of the urban forest. However, a full inventory is beneficial for managing specific trees, such as those along a major thoroughfare.

What is i-Tree?

Several urban forest inventory software packages are available. Some are freeware (licensed to use free of charge), while others can be fairly expensive. Inventory software should have some basic data entry fields such as Global Positioning Systems (GPS) coordinates and tree species. Preferably, additional entry fields would include tree height, diameter, crown width, crown missing, dieback, and land use and ground cover attributes. Canopy measurements are needed to assess canopy attributes.

One of the most commonly employed programs is the USDA Forest Service's i-Tree, available online at www.itreetools.org (this is not an endorsement by the authors or the University of Georgia for this product). i-Tree is a software suite produced with the collaboration of private and public partners. Currently, there are six core applications: Eco, Hydro, Canopy, Design, Landscape, and MyTree. Each application focuses on specific objectives. For example, Eco provides a broad spectrum of data fields that, when combined with air pollution and meteorological data, quantifies community forest structure, environmental effects, and applies a monetary value to tree benefits. By contrast, Hydro simulates the effects of changes in tree and impervious cover characteristics on stream flow and water quality.

The i-Tree software suite is peer-reviewed, public domain (freeware), easy-to-use software that allows for scalable analysis. In other words, results can be generalized from individual trees to neighborhood to city levels based on a sample inventory. From this information, users can make management recommendations such as species selection, address invasive species, and perform storm damage assessment. The remainder of this article focuses on the data entry variables found within i-Tree Eco.

How is the data recorded?

Example data sheets and respective "cheat sheets" for the plot inventory (Appendices 1 and 2) and the full inventory (Appendices 3 and 4) can be found in the appendix to this document. The advantage of paper data input sheets is there is no risk of technological failure, although they may get wet while in the field. However, paper data sheets are somewhat cumbersome to use. Due to the number of variables, the data sheet must be printed on 8.5 by 11-inch paper (at least). In addition, paper requires an additional step – inputting the data into an electronic database – after measurements are taken. To address these deficiencies, and to make data processing faster, i-Tree offers a web-based mobile app. In short, the user sets up the project on the desktop computer, then can send the project data collection fields as a link to be used on a mobile device or chose to print an equivalent paper datasheet. Mobile devices provide many shortcuts, and tree inventory apps are getting better all the time, but not all inventory personnel have signal in all locations, and some do not have smartphones; therefore, alternative solutions should be known.

i-Tree offers several user-identified input categories. For example, in addition to groundcover, stem, and canopy measurements, it is often a good idea to include at least a basic (Yes/No) hazard observation measure. If desired, a positive response to this measure on the data sheet indicates the need to complete the hazard identification sheet (Appendix 5). Each of the measurements found on these data sheets will be explained in the following sections.

What equipment is needed?

We recommend four basic pieces of equipment (see illustrations below) to conduct a basic volunteer inventory: 1) diameter tape, 2) compass, 3) clinometer, and 4) GPS unit. While additional equipment or more expensive equipment could be used, we find this equipment is appropriate for limited budgets and for use with volunteers who borrow the equipment. If available, smart phone apps may be used instead of the handheld compass and GPS.


PROCEDURES

Note: We suggest urban forest inventory facilitators create an on-line public folder (e.g., Dropbox/Google Drive, etc.) where volunteers can access maps, documents, PowerPoint presentations, literature, and additional information on procedures.

Plot Information

The first measurements describe the plot, or the sample area where the tree(s) is found in a sample-based inventory (Appendix 1 and Appendix 2, page 1). Plots are typically one tenth of an acre, or 37.2 feet in radius, although project managers can decrease this area if needed (keep in mind that decreasing plot area should correspond with increasing sample size if statistical confidence is to be maintained) (Nowak et al. 2008). Once plot center is found using a GPS unit, the data collectors measure a radius of 37.2 feet from plot center using a diameter tape. Every tree with at least half the stem falling inside the radius is considered within the plot and should be measured. The following is replicated from the Sample Plot Cheat Sheet (Appendix 1). If a plot is located on private property, access must be granted by the owner (Appendices 6 and 7), otherwise the collector notes that only a portion of the plot was measured.

Plot ID: Enter plot ID

As mentioned above, plots are randomly created within the border of a given area. The plot ID is assigned by i-Tree when the project is created. Describing location is beneficial for returning to the tree during a future inventory (successive inventories monitor change) because GPS contains error. The facilitator describes the location of the plot using roads and other geographic landmarks. A copy of a large scale photo helps the volunteers get reasonably close to the plot. Then, GPS is used to get within 30 feet (about the amount of error in mobile device and handheld GPS units) of the plot center.
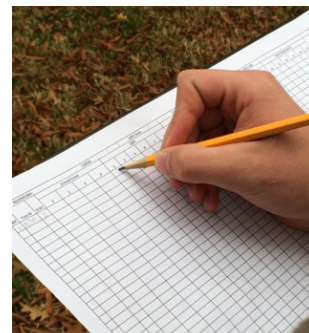
Recording data onto the data sheet. Always use a pencil.

Plot WP: Enter GPS waypoint of the plot center (not trees) (Appendix 8). The data collector attempts to arrive as close as possible to the coordinates indicated by the GPS. At this point, the volunteer marks a "Center Point" of the plot using a landscaping flag, stick, rock, or some other identifiable object. The plot is then measured using a radius of 37.2 feet (37 feet and 13/32 inches), or 1/10th acre. Again, trees are considered within the plot if at least half the stem at 4.5 ft. (known as diameter at breast height or DBH) lies within the radius measure.

DATE: Enter date of work.

CREW: Enter crew ID. A unique crew ID is assigned by the facilitator.

GPS UNIT: Enter GPS Unit ID. Crew ID and GPS Unit ID are used to trace the data back to volunteer collectors as part of quality control. If using the smart phone app, Not Applicable (NA) can be entered here.

Making a waypoint using GPS.

PLOT ADDRESS: If the plot (or any portion) is located on private property, enter the plot address, including street number, street, and zip code.
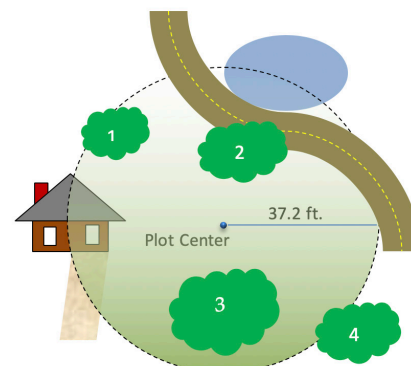
PLOT PHONE: If the plot (or any portion) is located on private property, enter the telephone number. The telephone number will be available after the property owner has consented to the procedure (Appendices 6 and 7). In some cases, special permission will need to be granted to access public property. In such cases, the same permission documentation should be used with access granted by the supervising authority.

OWNER NAME: Record the name of the owner of property (if public, note government entity).

NOTES: Record anything noteworthy here. Record lack of access (e.g., property owner refusal or environmental conditions).


This 1/10th acre plot has 3 trees. Tree #4 is more than halfway out of the plot, while Tree #1 has more than half the stem inside the plot boundary.

ACTUAL LAND USE AND PERCENT IN: The letter from the list below is recorded along with percent of each land use that falls within the plot. Proportions are recorded in increments of one to five percent, then every five percentage points. As with other qualitative estimates in the inventory, land use should be discussed and agreed upon by team members. Up to four land uses can be recorded. Below are the land uses recognized by i-Tree.

Residential (R)
Multi-family residential (M)
Commercial/Industrial (C)
Park (P)
Cemetery (E)
Golf Course (G)
Agriculture (A)
Vacant (V)
Institutional (I)
Utility (U)
Water/wetland (W)
Transportation (T)
Other (O)
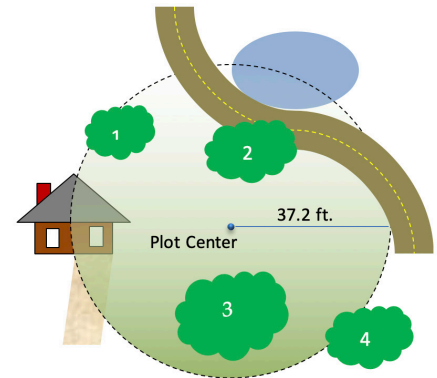
This plot has approximately: 4% T, 1% W, 95% R.

PLOT TREE COVER: Record the estimated percent of tree canopy over the plot. This is another qualitative estimate that should be discussed among team members.

SHRUB COVER: Record the estimated percent of shrub cover in the plot. The facilitator will inform the volunteers on what is classified as shrub cover.

GROUND COVER: Pervious versus impervious surface as well as soil area is important in assessing tree vigor and ecosystem services. Record the percent ground cover in plot, which must total 100 percent. The crew notes the percentage of the plot ground area that is covered by the materials below. Estimation may be facilitated by dividing the plot in halves or quarters, then summing the proportions of each section.

This 1/10th acre plot has 3 trees. Tree #4 is more than halfway out of the plot, while Tree #1 has more than half the stem inside the plot boundary.

Building (B)
Concrete (C)
Tar (T): Blacktop/asphalt
Rock (R): Pervious rock surfaces such as gravel, brick, or flagstone walkways or patios (without mortar). This category includes sand in playgrounds or added as topping to existing soil. Large solid rock outcrops should be listed as concrete.
Bare soil (S)
Duff/mulch (D)
Herbs (H): Herbaceous ground cover, other than grass, including agricultural crops
Maintained grass (MG)
Unmaintained grass (UG)
Water (W)
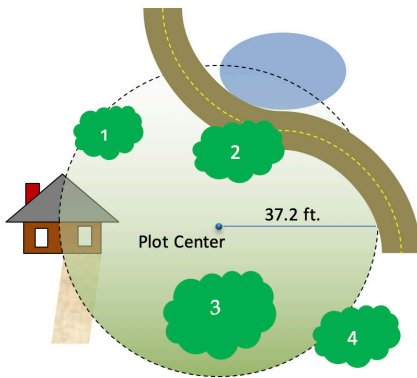
This plot has approximately: 40% tree cover, 0% shrub cover, 2% T, 1% C, 1% W, 1% B, 95% MG.

Groundcovers in this plot include: Tar, Maintained Grass, and some mulch around the tree. The land use is Institutional.

The following metrics are for individual trees within the plot (Appendix 1 and Appendix 2, page 2). Data collection for living and dead trees starts with the tree closest to due north and proceeds in a clockwise direction.

Plot ID: Enter the plot ID from page 1 (Plot Information) so that the individual tree information can be linked to the correct plot.

PLOT WP: Enter the GPS waypoint for the plot from page 1.

TREE ID: Record the tree species (U if unknown and take a photo and send to the facilitator) using the UFORE abbreviations (https://www.itreetools.org/support/resources-overview/i-tree-methods-and-files/i-tree-eco-v6-data-collection-sheets-and-species-list, last accessed August 1, 2019). i-Tree protocol recommends a relevant tree must be greater than or equal to 1 inch at 4.5 feet, although the project manager can change this protocol if needed.

STATUS: The crew should discuss and come to consensus about whether the tree was:
P: Planted—the tree was planted intentionally (often characterized by orderly patterns, e.g., rows, and landscaping);
I: Ingrowth—the tree self-seeded;
U: Unknown—planted vs. ingrowth cannot be determined.
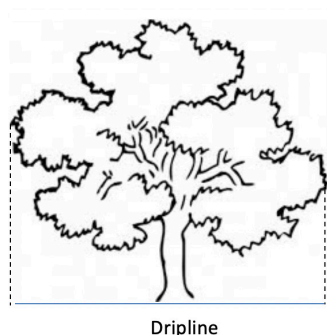Record dead trees as -1 and skip to the "Site" variable.
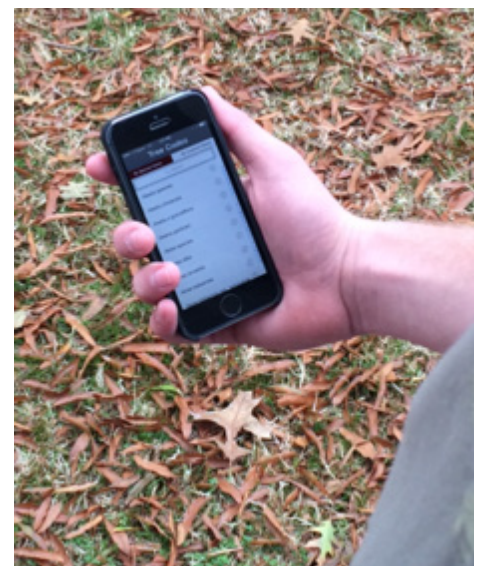
Using the tree code app to record the tree ID UFORE abbreviation.

A smartphone app makes recording direction easy.

DR: Record the direction of the tree from the center of plot using azimuth in degrees. DR and DS are used as geographic references in addition to the plot center waypoint. Again, geographic references are important for future inventory updates.

DS: Record the distance of the tree from plot center to the edge of the trunk.

LAND USE: The previous land use metric indicated land use within the entire plot; whereas, this metric records land use under individual tree canopies in the plot. Record the land use to drip line of the tree crown. The drip line is the very edge of the crown. Most of the time, this will be the same as the land use recorded for the plot. The following land uses may be recorded.


Dripline

Residential (R)
Multi-family residential (M)
Commercial/Industrial (C)
Park (P)
Cemetery (E)
Golf Course (G)
Agriculture (A)
Vacant (V)
Institutional (I)
Utility (U)
Water/wetland (W)
Transportation (T)
Other (O)

DBH: Record the tree's DBH (a relevant tree must be greater than or equal to 1 inch at 4.5 feet) on the uphill side of the tree to the nearest 0.1 inch/cm. Record up to 6 stems (≥1 in) if the pith union is below ground. If more than 6 stems, lower the measurement height to 1 foot above ground and record the DBH of the 6 largest stems. See Appendix 9 for DBH measuring procedures. On trees with swelling or other irregularities at DBH, measure the diameter immediately above the irregularity and note the height where DBH was taken.
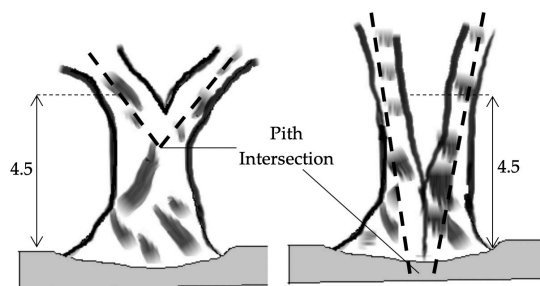
Measuring DBH in multistemmed trees.

Using the diameter tape to measure DBH. Follow the correct procedure to hold the tape (Appendix 9).

[Tree-DBH1]

TREE HEIGHT: i-Tree requires three height measurements (Appendix 10).

Total tree height: Measure the height of the tree to the highest visible branch (alive or dead).

Measuring tree height using a clinometer. Follow the correct procedure to hold the clinometer (Appendix 10).

Height to live top: Measure the height to the highest visible live branch. This height will be the same as total tree height unless the tree is alive but the top of the crown is dead.

Extent of live top
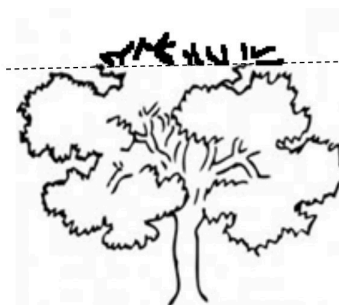
If the tree does not have any dead branches at the top, the height to live top is the same as total height. In the case of this tree, height to live top is shorter than total height.

Height to crown base: Measure the tree height to the base (the lowest live foliage) of the crown. If the base is not reachable using the measuring tape, the clinometer must be used and measured using the same procedure as measuring total height.

Measuring height to crown base using a diameter tape.

CROWN

Crown width: Measure the width of each tree's crown (to nearest foot). Two volunteers are needed to measure the crown width. Making sure the diameter tape touches the tree stem to approximate the diameter of a circle encompassing the crown, hold each end of the tape to the drip line and record the measurement. This procedure should be repeated in two perpendicular directions: north-south and east-west to account for energy savings.
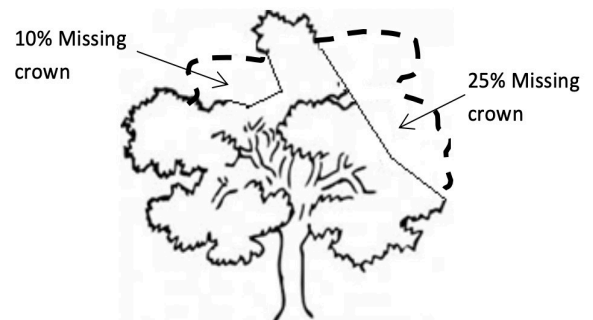

Measuring crown width East and West.

Measuring crown width North and South.

Percent canopy missing: This metric estimates the percent of branches and foliage that is absent due to pruning, defoliation, uneven crown (i.e., irregular due to damage or some other negative abiotic or biotic impact), or dwarf or sparse leaves.

10% Missing crown

25% Missing crown

*This tree has approximately 35% of its crown missing.*

Crown dieback (DB): Record percent branch dieback on each side and top of crown area. Dieback is a condition in which a tree or shrub begins to die from the tip of its leaves or shoots backward resulting from disease or an unfavorable environment.
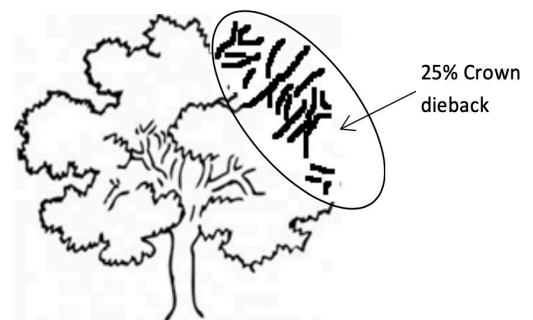
25% Crown dieback

Approximately 25% crown dieback.

Crown light exposure (CLE): Record the number of sides of the tree receiving sunlight. There is a maximum of five (four sides and top). As a rule of thumb, include each side that receives at least 50% sunlight.
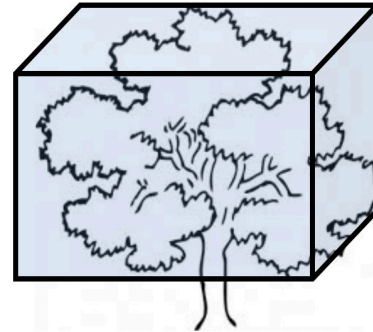
Imagine a box covering the crown to measure CLE. A tree can have up to five sides exposed to sunlight.

IMPERVIOUS SURFACE: Estimate the percent of the area beneath the dripline of the tree that is impervious to water. Often, this will reflect the single tree metric for land use (above). An impervious surface is one that does not allow water to penetrate into the soil. Greater areas of imperious surface result in increased runoff into drainages.

TREES NEAR BLDGS: Identify trees (≥20 ft. tall) that are located within 60 ft. of space-conditioned residential or commercial buildings that are three stories or fewer in height (e.g., two stories and an attic). Record the direction (D = azimuth in degrees) from the tree to the closest part of the building and the distance (S = if >60 ft., just note >60 ft.). These metrics are needed for calculating energy savings.

SITE: Indicate whether the tree is a street tree (Yes = Y) or not a street tree (No = N). A street tree is any tree or part of tree, including the canopy and root systems, that lies on or has grown onto or over public property, or in public right of way owned by a public entity.

Measuring distance to the closest building using a diameter tape.

HAZARD: In some cases, project managers might want to include some rough measure of likelihood of failure. For example, data collectors could mark (Yes = Y) or (No = N) if the overall tree, foliage, branches/bole show indications of pest, disease, or if tree/branches could be a hazard necessitating a visit by a professional. A hazard is any tree/part of tree that may cause harm to people or property (e.g., car). It is important to understand that only a Certified Arborist should conduct a complete tree risk assessment due to liability concerns. However, because they are observing many trees, volunteers are invaluable for identifying obvious, major problems. If a tree is a hazard, well-trained collectors may complete the additional hazard identification form (Appendix 5). If a hazard is indicated, arborists will return to the tree to assess it.

ADDITIONAL READING

David J. Nowak, Jeffrey T. Walton, Jack C. Stevens, Daniel E. Crane, and Robert E. Hoehn (2008) Effect of Plot and Sample Size on Timing and Precision of Urban Forest Assessments. Arboriculture & Urban Forestry, 34(6):386–390.

David J. Nowak, Daniel E. Crane, Jack C. Stevens, Robert E. Hoehn, Jeffrey T. Walton, Jerry Bond (2008) A Ground-Based Method of Assessing Urban Forest Structure and Ecosystem Services. Arboriculture and Urban Forestry, 34(6):347–358.

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US Forest Service. (n.d.) i-Tree Streets User's Manual v5.x.. Retrieved January 19, 2015, from www.itreetools.org/eco

UFORE Methods (n.d.) Retrieved January 19, 2015, from http://www.itreetools.org/eco/