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# Urban Tree Monitoring: A Field Guide


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## Abstract

This report provides detailed protocols for urban tree monitoring data collection. Specifically, we discuss the core variables necessary for field-based monitoring projects, including field crew identification, field crew experience level, tree record identifier, location, site type, land use, species, mortality status, crown vigor, and trunk diameter. The intent of this Field Guide is to serve urban forest managers and researchers who collect longitudinal field data on urban trees, as well as interns and citizen scientists. This report is a companion document to *Urban Tree Monitoring: A Resource Guide*.

### Cover photo

Trees in Rittenhouse Square, Philadelphia, PA. Photo by L.A. Roman, USDA Forest Service.



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# Contents

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# 1. Introduction

Long-term collection of urban tree data can provide valuable information for urban forest managers and researchers interested in tree mortality and growth rates, performance of planting programs, changes in species composition, and identifying dead and declining trees (Clark et al. 1997; Dawson and Khawaja 1985; Hallett et al. 2018; Hilbert et al. 2019; Ko et al. 2015a, 2015b; Koeser et al. 2014; Martin et al. 2016; Roman et al. 2013, 2014a, 2014b, 2016; Vogt et al. 2015). This report, *Urban Tree Monitoring: A Field Guide* (hereafter referred to as the Field Guide), has been designed to support long-term, repeated monitoring of individual trees (i.e., longitudinal data collection) in the urban landscape (Roman et al. 2016). In contrast to a one-time inventory, longitudinal data collection enables analysis of change over time, such as analyses of mortality and growth as well as shifts in health. Certain aspects of data collection—for instance, the reliable relocation of individual trees, clear delineation of which site types are included or excluded from a study, consistency in recording tree mortality status, and precise remeasurement of trunk diameter—are of great importance to longitudinal studies. To achieve both the precision and accuracy needed to evaluate long-term changes in urban forests, we propose here the Minimum Data Set: the core variables necessary for monitoring projects, including field crew identification and experience level, tree record identifier, location, site type, land use, species, mortality status, crown vigor, and trunk diameter. The methods described in the Field Guide focus primarily on monitoring trees along streets, in lawns, and other maintained or landscaped areas. We do not cover methods for monitoring trees in wooded or natural areas within cities because those areas require a different approach. We provide protocol descriptions that are accessible to urban forest managers, interns, and citizen scientists, as these are the individuals often responsible for urban tree monitoring (Roman et al. 2013).

A companion report, *Urban Tree Monitoring: A Resource Guide* (hereafter referred to as the Resource Guide; van Doorn et al. 2020), provides additional information about the following topics:

- Common goals for urban tree monitoring
- Matching monitoring goals to data collection plans
- Background about the development of the monitoring guidelines and connections to other tree inventory protocols
- Planning ahead for data collection and analysis
- Longitudinal database considerations
- Training and managing field crews

- Detailed discussion about components of the Minimum Data Set (in particular, crown vigor and trunk diameter)
- Supplemental data sets related to tree health, site, management, and the human community surrounding trees

The Resource Guide also provides more citations and links to other resources, including urban tree species identification references. The Field Guide and the Resource Guide complement each other, and readers designing a monitoring program are advised to read both. In particular, before launching a monitoring study, project supervisors are encouraged to review guidelines for tree location methods in the Resource Guide (section 2.3), where we discuss advantages and limitations for various location techniques. Furthermore, to determine which trees are included or excluded from a particular study, project supervisors should choose an option for how to define what counts as a "tree" (Resource Guide, section 2.2).

This Field Guide has a modular design, which allows for customization of a local monitoring project. Users of this Field Guide may wish to apply only part of these methods, such as the mortality status categories, street tree location techniques, or trunk diameter protocols. For projects that apply the full Minimum Data Set, a cheat sheet, data collection sheet, and equipment list are provided (appendixes 1, 2, 3).

This Field Guide does not include safety procedures and guidelines for interacting with the public, which should be provided to field crews by project supervisors. Such procedures and guidelines will vary among projects and cities depending on local risks and other circumstances. See Resource Guide sections 3.1 and 3.2 for additional suggestions regarding training and managing field crews.

# 2. Minimum Data Set

The Minimum Data Set includes the core variables necessary for urban tree monitoring projects. We describe each variable, explain why each is included in the Minimum Data Set, and when that variable should be recorded. More details regarding the development of the Minimum Data Set are found in the Resource Guide (sections 1.4 and 6), including detailed discussion of crown vigor and trunk diameter.

A summary of the Minimum Data Set variables is provided in Table 1. Nominal variables are categorical without a presumed ordering, whereas ordinal variables are categorical with an implied ordering, continuous variables can take on any number in a range of values, and binary variables have only two values.

**Table 1.—Summary of variables included in the Minimum Data Set for urban tree monitoring**

| Variable | Description | Variable Type | Values or Units |
|---|---|---|---|
| Field crew identification | Information about the individual(s) who collected field data on this tree | Text | n/a |
| Field crew experience level | Experience level of the most experienced individual on the field crew | Nominal | Novice, intermediate, expert |
| Date of observation | Year, month, and day of field data collection | Date | n/a |
| Tree record identifier | Unique identifier that remains connected to the tree during future monitoring | Text | n/a |
| Location | Information about the tree's geographic position in the landscape; several protocols available | Different variables and/or images depending on method selected | n/a |
| Tree photo | A photograph taken to include the entire tree in the context of its immediate location and showing nearby built infrastructure objects | Image | n/a |
| Site type | A description of the tree's immediate location | Nominal | Sidewalk cutout, sidewalk planting strip, median, planter box, other hardscape, front yard, side yard, back yard, maintained park, other landscapes area, natural area |

(continued on next page)

**Table 1 (continued).—Summary of variables included in the Minimum Data Set for urban tree monitoring**

| Variable | Description | Variable Type | Values or Units |
|---|---|---|---|
| Land use | A description of the way the property around or adjacent to the tree is used by humans | Nominal | Single-family residential – detached, single-family residential – attached, multi-family residential, mixed use, industrial, institutional, maintained park, natural area, cemetery, golf course, agricultural, utility, water / wetland, transportation, vacant lot, other |
| Species | The species of the tree being monitored | Text | n/a |
| Mortality status | A record of whether the tree is alive, standing dead, removed, or in some other state | Nominal | Alive, standing dead, stump, removed, never planted |
| Basal sprouts | Growths from the base of the trunk or in the roots (record only for standing dead trees and stumps) | Binary | Present, absent |
| Crown vigor | A holistic assessment of overall crown health which reflects the proportion of the crown with foliage problems and major branch loss | Ordinal | 5 classes ranging from 1 (healthy) to 5 (dead) |
| Trunk diameter | Diameter of the tree's trunk recorded at either 4.5 ft (1.37 m) or 1 ft (30.5 cm) depending on tree form, with many special rules | Continuous | cm or in |
| Height of trunk diameter | The exact height at which trunk diameter was recorded | Continuous | m or ft |
| Notes for supervisory review | Issues that cannot be resolved in the field; entering a note flags the tree for review by the project supervisor | Text | n/a |

## 2.1. Field Crew

### 2.1.1. Field Crew Identification

**Description:** Field crew identification is information about the individual(s) who collected field data on this tree. Crew names, initials, or team numbers may be used, but should be consistent within a given project. If using team numbers or initials, record information about the names of individuals on each team in the data dictionary (or metadata) for the project (see Resource Guide sections 2.1.18 and Glossary).

**Justification:** Field crew identification is necessary to facilitate future analysis, data cleaning (e.g., resolving issues with handwriting and questionable species identification), and to determine whether a particular crew had biased observations.

**Recorded for:** All trees. Record once for a given team each day in the field. For example, with paper data collection, record field crew identification at the top of a data sheet. If using a mobile data collection system (e.g., mobile app or website accessed via smartphone or tablet), confirm that the software can track relevant user information to identify the user who gathered the data. The user information should be exported with the other data collected for each tree or contained in the metadata. If the mobile data collection platform has all users signing in under the same user name, then the crews will need to enter their field crew identification for every tree. See the Resource Guide (section 2.6) for more discussion about different data collection systems.

### 2.1.2. Field Crew Experience Level

**Description:** The experience level of the most experienced individual on the field crew team that collected data about this tree (Table 2). Record once for a given team, e.g., at the top of a data sheet, with the user information for a mobile data collection tool, or in a separate metadata file.

**Justification:** Field crew experience level is helpful to understand how much prior expertise the crew members have. Expert crews (i.e., those with extensive prior experience and knowledge) are presumably very good at species identification and adherence to tree measurement protocols. For other crews, while it might seem that experience level would relate to data accuracy, the pilot study for the Field Guide demonstrated that volunteer crews with novice and intermediate levels of experience had similar data quality for genus and trunk diameter after a 6-hour training (Roman et al. 2017). Those data quality results are discussed in more depth in the Resource Guide (section 1.4.3, 6.5, and 6.6). Additional guidance regarding the use of novice citizen scientists for urban tree monitoring is also found in the Resource Guide (section 3.2)

**Recorded for:** All trees.

**Table 2.—Categories of field crew experience level**

| Category | Description |
| --- | --- |
| Expert | Researchers and professionals from urban forestry, forestry, or arboriculture with extensive prior field experience with tree inventories and extensive knowledge of essential skills (e.g., species identification, trunk diameter measurements). |
| Intermediate | Program staff, students, volunteers and interns with relevant past experience in urban forestry, forestry, or arboriculture fieldwork (at least 1-3 years) and some prior knowledge of essential skills (e.g., species identification, trunk diameter measurements). |
| Novice | Program staff, students, volunteers and interns with little to no prior urban forestry, forestry, or arboriculture fieldwork experience (1 year or less) and little prior knowledge of essential skills (e.g., species identification, trunk diameter measurements). |

## 2.2. Date of Observation

**Description:** Date (year, month, day) of the field data collection.

**Justification:** Date of observation is necessary to calculate rates of change over time. It is important to have the actual day of observation, rather than a coarser indication of data collection timing, such as season or year, to enable more precise calculations of mortality and growth rates or detect changes in health.

**Recorded for:** All trees. Record at the top of a data sheet or automatically through a digital data collection platform.

## 2.3. Tree Record Identifier

**Description:** Each tree record should have a unique identifier that remains connected to the tree during future monitoring. For projects that track recently planted trees, the identifier should connect to planting records. Project supervisors should instruct crews in using identifiers that are appropriate for the project's design. Examples are illustrated in Figure 1.

Whenever possible, we encourage the use of identification tags affixed to the tree, which can include the unique tree record identifier, as this facilitates future crews reliably finding the right tree (Resource Guide, section 2.3.4).

The tree record identifier can be obtained from a tree tag (when present), planting records (for projects that monitor a planting project), generated within a database after the first data collection (e.g., record numbers produced automatically within a database associated with a mobile app), or constructed to represent plots (e.g., coding reflects plot number and tree number within the plot).

The unique record identifier for a given tree should only be used for that specific tree. When a tree is dead or removed, that unique identifier should be retired to avoid future confusion with a new tree in the same location. Some projects may choose to keep track of both trees and locations, especially for street tree monitoring. For guidance about other strategies to monitor planting locations themselves (e.g., a street tree sidewalk cutout that has different trees over time, or may be temporarily vacant) and tracking replacement plantings, see the Resource Guide (section 2.5). That section also discusses broader considerations for designing and managing longitudinal databases, and the distinction between tree record identifiers, primary keys, and unique keys.

**Justification:** Tree record identifier is unique for every tree and is used to connect the same individual tree over successive monitoring visits. It is critical to have observations linked at the level of individual trees to facilitate analysis of mortality, growth, and health over time. Unique identifiers for every tree are therefore central to both data collection and database management (Boyer et al. 2016).

**Recorded for:** All trees.


**Figure 1.**—(A) Tree tag at the University of Pennsylvania in Philadelphia, PA. The lower right corner has a tree record identifier that reflects a grid cell that corresponds to a campus map and tree number within the grid cell. Photo by J.P. Fristensky, used with permission. (B) Street tree with affixed tag, planted by University City Green, Philadelphia, PA. The tree record identifier here is the identification number used in the nursery. Photo by L.A. Roman, USDA Forest Service. (C) Inventory site map for Casey Trees in Washington, D.C. The tree record identifier is a numerical sequence of trees in this specific area. Image by J.R. Sanders, used with permission.

## 2.4. Location

**Description:** Location is information about the tree's geographic position in the landscape. Project supervisors should specify what method to use based on guidelines in section 2.3 of the Resource Guide. We describe protocols for three methods in detail below, but other methods may also be appropriate for some projects.

Two of the protocols described here are specifically for street trees: the address and site code method, and the block edge distance method. These methods are best suited to gridded street patterns but can also work reasonably well in other street designs (e.g., curving streets, urban roads with no sidewalks). The third protocol described in this section—digitizing locations on satellite imagery—works well in many street tree and lawn situations (e.g., residential yards, landscaped neighborhood parks), but may be challenging on densely planted lawns where canopies overlap.

Note that recording latitude and longitude in the field with GPS equipment by itself (i.e., without matching to satellite imagery) may be appropriate for some projects, but such GPS equipment should have high resolution (sub-meter accuracy). Even with such sophisticated equipment, there are challenges getting a signal in urban areas with tall buildings due to a "canyon effect" (Silva et al. 2013). More discussion about location method options is provided in the Resource Guide (section 2.3).

**Justification:** Location is essential for field monitoring because it enables field crews to reliably find the same tree again. Locational information can also be used to connect tree data to other geospatial datasets, such as socioeconomic data.

**Recorded for:** All trees. Trees in different site types will require different location methods (Resource Guide, section 2.3).

### 2.4.1. Address and Site Code Method

For this location technique, six pieces of information are recorded for each tree: address; site code; on, from, and to streets; and side of street.

Tree site codes describe where a tree is located in relation to a specific property. The property is specified with a street address so the site code is in reference to that address. There are five site codes for street trees: front, side, rear, adjacent, and median (Table 3). Multiple trees and site codes can exist at each address, and the number sequence of the site codes starts over with each address (Table 4, Figure 2A). For example, a given address could have trees 1F and 2F, representing two trees in front of that property, and the next property would begin anew with 1F but with a different address (e.g., see tree numbers 6, 7, and 30 in Table 4 and Figure 2). Within each property, the numbering system for site codes goes in order of ascending addresses on the street where the tree is located (e.g., see 208 Pear St. and tree numbers 9, 10, 46, 4, 20, and 88 in Table 4 and Figure 2B). In other words, site code numbers go up as address numbers go up. A separate sequence of tree site code numbers exists for each side of a property (e.g., 1F, 2F, 1S, 2S, instead of 1F, 2F, 3S, 4S).

**Table 3.—Tree site codes and their descriptions for use with the address and site code method of recording tree location**

| Tree Site Codes | Description |
|---|---|
| F | Trees in front of the property |
| S | Trees on the side of the property; this is used for corner properties |
| R | Trees at the rear of the property; this is used for properties that span the entire block, e.g., schools, hospitals |
| A | Trees next to an adjacent property without an address, e.g., vacant lots, small parks/gardens |
| M | Trees on a median, including traffic circles and triangle cutouts or road verges |

Regarding the “on”, “from”, and “to” street information: The “on” street is referring to which street the tree is actually on (this can be different than the parcel street address). The “from” street is the street closest to the lowest address on that block, while the “to” street is the next encountered street (when traveling along the ascending addresses). Side of street should be recorded as odd versus even address numbers, north versus south, or east versus west, depending on the structure of the gridded street system in the monitoring project (or n/a for median trees and street trees in cul de sacs).

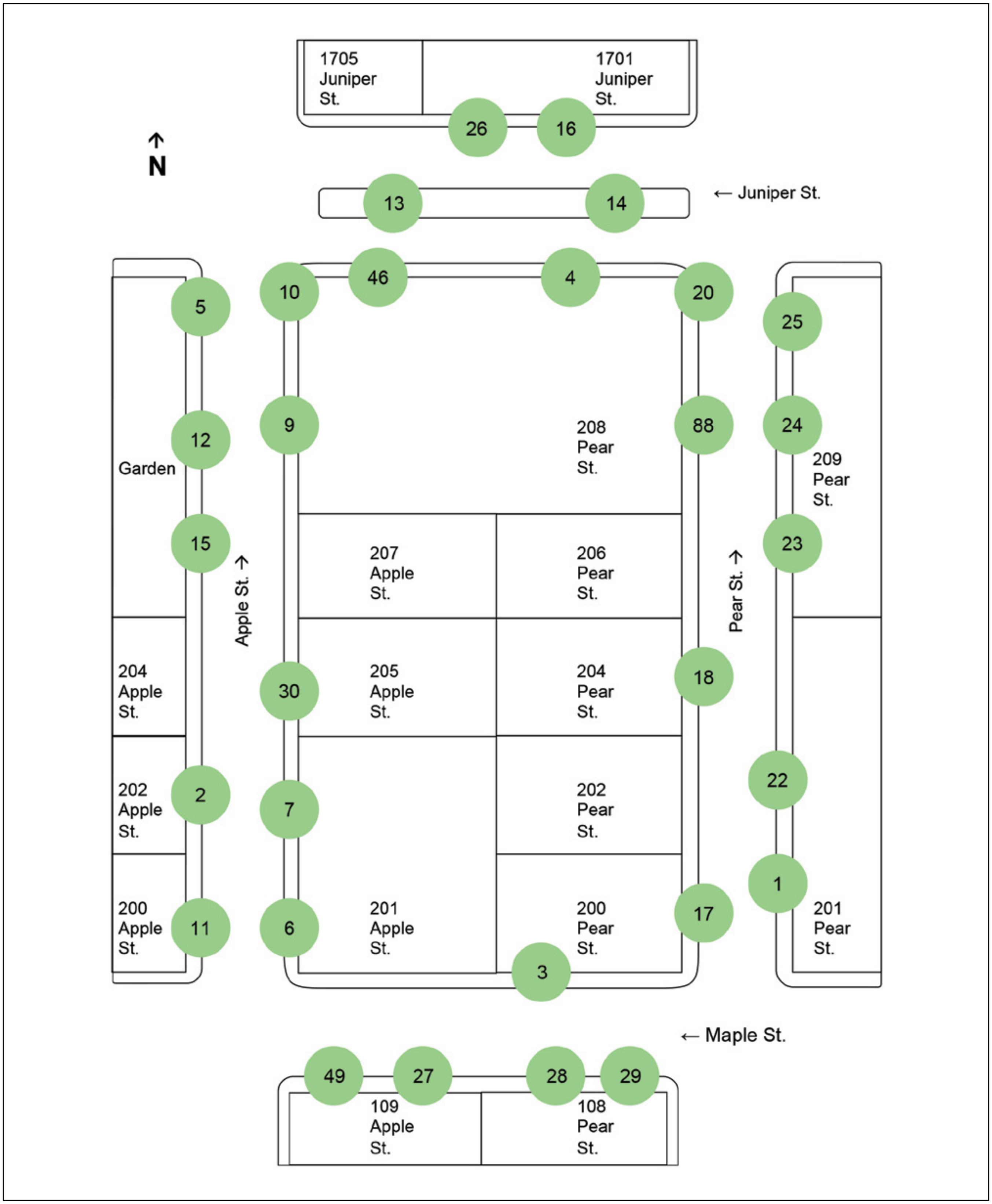


**Figure 2A.**—Address and site code map of an imaginary block which corresponds to Table 4. Arrows with the street names indicate ascending order of address numbers on that street. Note that tree numbers are not placed in any particular order and are merely used to help the reader connect the table to the figure.

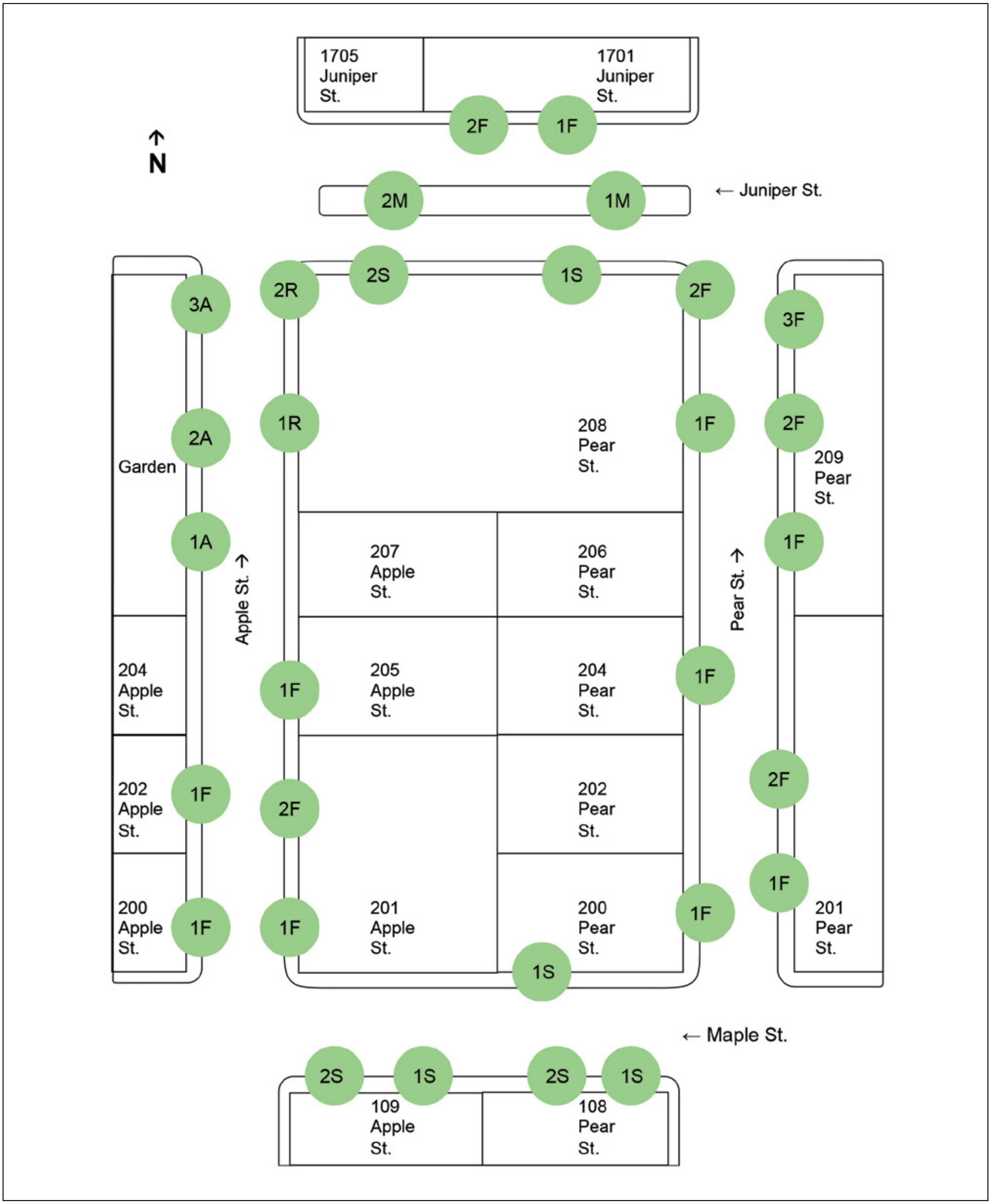


**Figure 2B.**—Address and site code map of an imaginary block which corresponds to Table 3. Arrows with the street names indicate ascending order of address numbers on that street. Whereas Figure 2A had tree numbers to designate each tree, this figure shows the site codes for each tree.

**Table 4.—Example location data: address and site code method for an imaginary block (Figure 2A). The site code numbering sequence corresponds with the ascending order of the addresses on the street (i.e., site code numbers go up as address numbers go up). For trees in the median, address and side of street are not applicable, so record n/a in those spaces. For trees located next to a property without an address, record the nearest property address and use site code A for adjacent. Note that tree numbers are not placed in any particular order and are merely used to help the reader connect the table to Figure 2A.**

| Tree Number | Site Code | Address # and Street Name | Block Information | | | |
|---|---|---|---|---|---|---|
| | | | On Street | From Street | To Street | Side of Street |
| 11 | 1F | 200 Apple St. | Apple St. | Maple St. | Juniper St. | W |
| 2 | 1F | 202 Apple St. | Apple St. | Maple St. | Juniper St. | W |
| 15 | 1A | 204 Apple St. | Apple St. | Maple St. | Juniper St. | W |
| 12 | 2A | 204 Apple St. | Apple St. | Maple St. | Juniper St. | W |
| 5 | 3A | 204 Apple St. | Apple St. | Maple St. | Juniper St. | W |
| 6 | 1F | 201 Apple St. | Apple St. | Maple St. | Juniper St. | E |
| 7 | 2F | 201 Apple St. | Apple St. | Maple St. | Juniper St. | E |
| 30 | 1F | 205 Apple St. | Apple St. | Maple St. | Juniper St. | E |
| 9 | 1R | 208 Pear St. | Apple St. | Maple St. | Juniper St. | E |
| 10 | 2R | 208 Pear St. | Apple St. | Maple St. | Juniper St. | E |
| 46 | 2S | 208 Pear St. | Juniper St. | Pear St. | Apple St. | S |
| 4 | 1S | 208 Pear St. | Juniper St. | Pear St. | Apple St. | S |
| 13 | 2M | n/a | Juniper St. | Pear St. | Apple St. | n/a |
| 14 | 1M | n/a | Juniper St. | Pear St. | Apple St. | n/a |
| 26 | 2F | 1701 Juniper St. | Juniper St. | Pear St. | Apple St. | N |
| 16 | 1F | 1701 Juniper St. | Juniper St. | Pear St. | Apple St. | N |
| 17 | 1F | 200 Pear St. | Pear St. | Maple St. | Juniper St. | W |
| 18 | 1F | 204 Pear St. | Pear St. | Maple St. | Juniper St. | W |
| 88 | 1F | 208 Pear St. | Pear St. | Maple St. | Juniper St. | W |
| 20 | 2F | 208 Pear St. | Pear St. | Maple St. | Juniper St. | W |
| 1 | 1F | 201 Pear St. | Pear St. | Maple St. | Juniper St. | E |
| 22 | 2F | 201 Pear St. | Pear St. | Maple St. | Juniper St. | E |
| 23 | 1F | 209 Pear St. | Pear St. | Maple St. | Juniper St. | E |
| 24 | 2F | 209 Pear St. | Pear St. | Maple St. | Juniper St. | E |
| 25 | 3F | 209 Pear St. | Pear St. | Maple St. | Juniper St. | E |
| 49 | 2S | 109 Apple St. | Maple St. | Pear St. | Apple St. | S |
| 27 | 1S | 109 Apple St. | Maple St. | Pear St. | Apple St. | S |
| 28 | 2S | 108 Pear St. | Maple St. | Pear St. | Apple St. | S |
| 29 | 1S | 108 Pear St. | Maple St. | Pear St. | Apple St. | S |
| 3 | 1S | 200 Pear St. | Maple St. | Pear St. | Apple St. | N |

### 2.4.2. Block Edge Distance Method

The block edge distance method involves measuring the distance in a straight line from the sidewalk corner at the street intersection to each tree. This method is most efficient when using a measuring wheel but can also be done with a transect measuring tape. This technique is best suited to gridded street systems with sidewalks but can be used in other circumstances as well. Measurements start at the point beyond the sidewalk corner where the two curb lines would intersect (Table 5, Figure 3). Measurements are made in a straight line from the starting point to the point where two curb lines would meet at the next intersection. The first measurement is made by recording the distance between the starting point and the center of the first tree (i.e., center of the tree trunk where it meets the ground). The second measurement is taken by measuring from the starting point to the center of the second tree. This procedure is repeated for subsequent trees on the block.

In addition to the distance measurements, field crews must record the street intersections used as start and end points and which side of the street they are measuring in relation to the road's centerline (right or left). In theory, crews should be able to place the start point at either end of the block, but supervisors may choose to follow a consistent pattern, e.g., always going north to south or always going in the direction of ascending addresses.

This technique is adapted from the TreeKIT method developed for New York City, NY (Silva et al. 2013). However, in the original TreeKIT method, distances were measured between trees instead of in relation to the starting point. As long as field crews are careful to avoid "wobble" in the measuring wheel (i.e., crews need to walk in a very straight line, and not shift the measuring wheel side-to-side as they walk down the street), either way of measuring distance should work well. The original TreeKIT method also called for recording the distance from the last tree to the end point of the block edge. (i.e., the point beyond the sidewalk corner where the two curb lines would intersect). This final measurement gives the length of the entire block edge and can be useful to confirm that the total length of the block edge recorded in the field matches distances recorded in shapefiles in geographic information system (GIS) software. Currently, a system for automatically mapping trees in GIS using the block edge distance method has only been developed for New York City. Therefore, project supervisors in other cities using this method would have to manually map tree locations in a GIS shapefile using the data produced by the block edge distance method. However, this method can still be incredibly valuable for highly accurate street tree locations where reliable re-location of individual street trees is paramount.

While the address and site code method can have difficulties with long-term monitoring as trees are added to and removed from the street each year, making the site code numbering system shift, the distances measured using the block edge distance method should stay fixed year after year. Further discussion about pros and cons of the different location methods is found in the Resource Guide (section 2.3).

**Table 5.—Example location data: block edge distance method for an imaginary block (Figure 3)**

| Tree Number | Distance from Start (m) | Address # and Street Name | Block Information | | | | |
|---|---|---|---|---|---|---|---|
| | | | On Street | From Street | To Street | Side of Street | Side of Centerline |
| 1 | 12 | 200 Rose St. | Blossom St. | Rose St. | Petal St. | N | right |
| 2 | 23 | 200 Rose St. | Blossom St. | Rose St. | Petal St. | N | right |
| 3 | 55 | 200 Rose St. | Blossom St. | Rose St. | Petal St. | N | right |
| 4 | 73 | 201 Petal St. | Blossom St. | Rose St. | Petal St. | N | right |

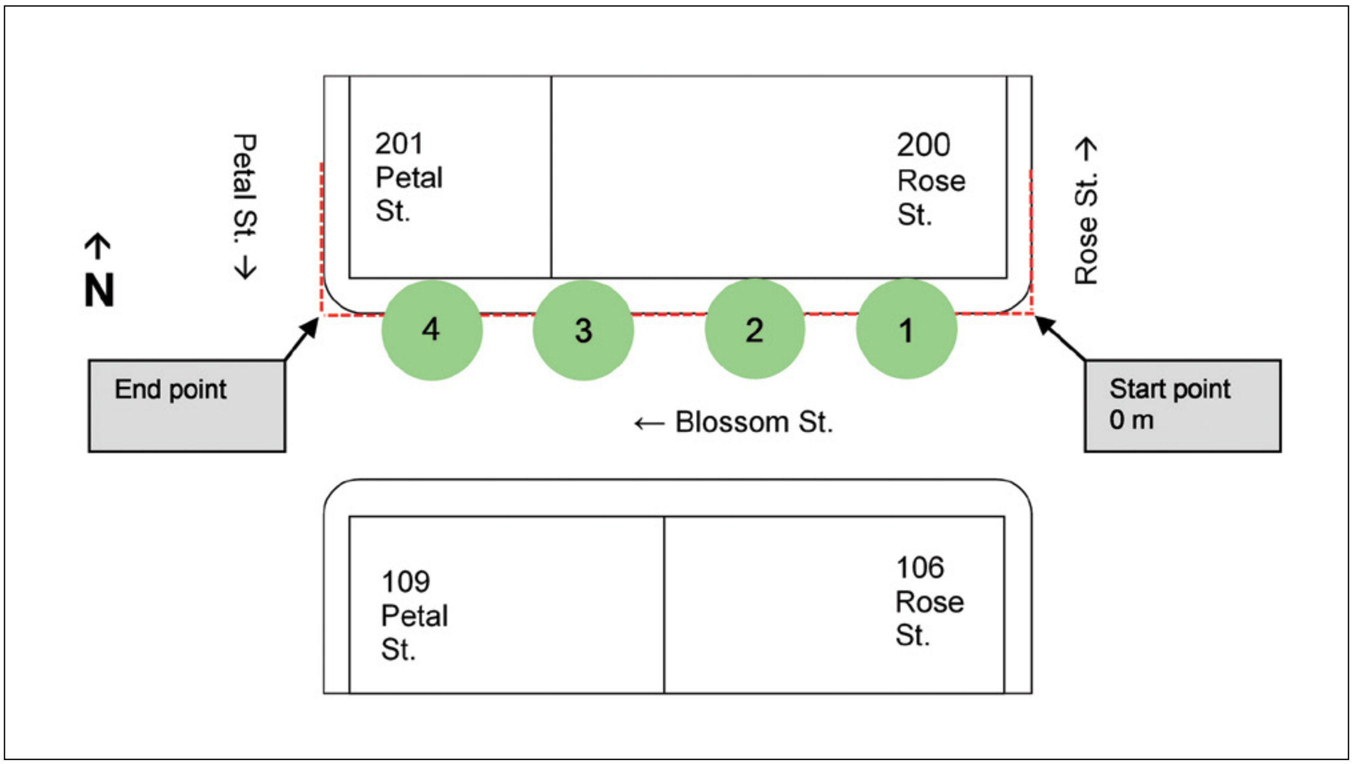


**Figure 3.**—Block edge distance method for recording location. The start point is the projected curb edge. The first measurement is taken from the start point to the center of the first tree. The second measurement is taken from the start point to the center of the second tree. This process continues for all trees on the block.

### 2.4.3. Digitizing Locations on Satellite Imagery Method

The digitizing locations on satellite imagery method involves referencing a printed satellite image of the study area in the field or viewing such an image in a mobile data collection system in a smartphone or tablet. These images show overhead outlines of tree canopies, streets, and buildings. Using these objects as references, the location of each individual tree is marked on the image (with a pen or marker, if using paper). If using the "low tech" paper method, when field crews return to the office, the location is converted to digital format in software such as ArcGIS, Google Maps, or Google Earth. The more direct "high tech" method involves bringing a mobile device into the field loaded with an appropriate app that provides satellite imagery (e.g., ESRI Collector, Google My Maps) that allows dropping points on the image while standing in the field (Figure 4). This reduces data processing time in the office.

## 2.5. Tree Photo

**Description:** A photograph taken to include the entire tree (when possible) in the context of its immediate location and showing nearby built infrastructure objects in the landscape (e.g., buildings, light posts), in order to help future field crews reliably find the same tree. For street trees and front yard trees, the best view is often from across the street, as long as cars are not blocking the view.

Examples of tree photos in context are shown in Figure 5. This also can serve a dual purpose of species identification if needed (see section 2.8 for additional tips about photos for species identification). When taking a photograph in the field within a mobile data collection system on a smartphone or tablet, the photo should be tied to a particular tree's record. When taking a photograph in the field with a camera or smartphone that is not tied to data collection software, the tree record identifier should be included with the picture, and ideally used as part of the photo file name.

**Figure 4.**—Screen shot of street tree locations in Boston, MA, that were inventoried in the field by placing dots using satellite imagery. The inventory is accessible via the Boston Tree Map at https://opentreemap.org/boston. The satellite imagery and map are provided by Google®. Image courtesy of Azavea, used with permission.

**Justification:** Tree photo is a visual documentation of the tree that serves as a check to confirm that future field crews are indeed looking at the same tree. Tree photo may also enable expert validation of field data, such as species.

**Recorded for:** All trees.

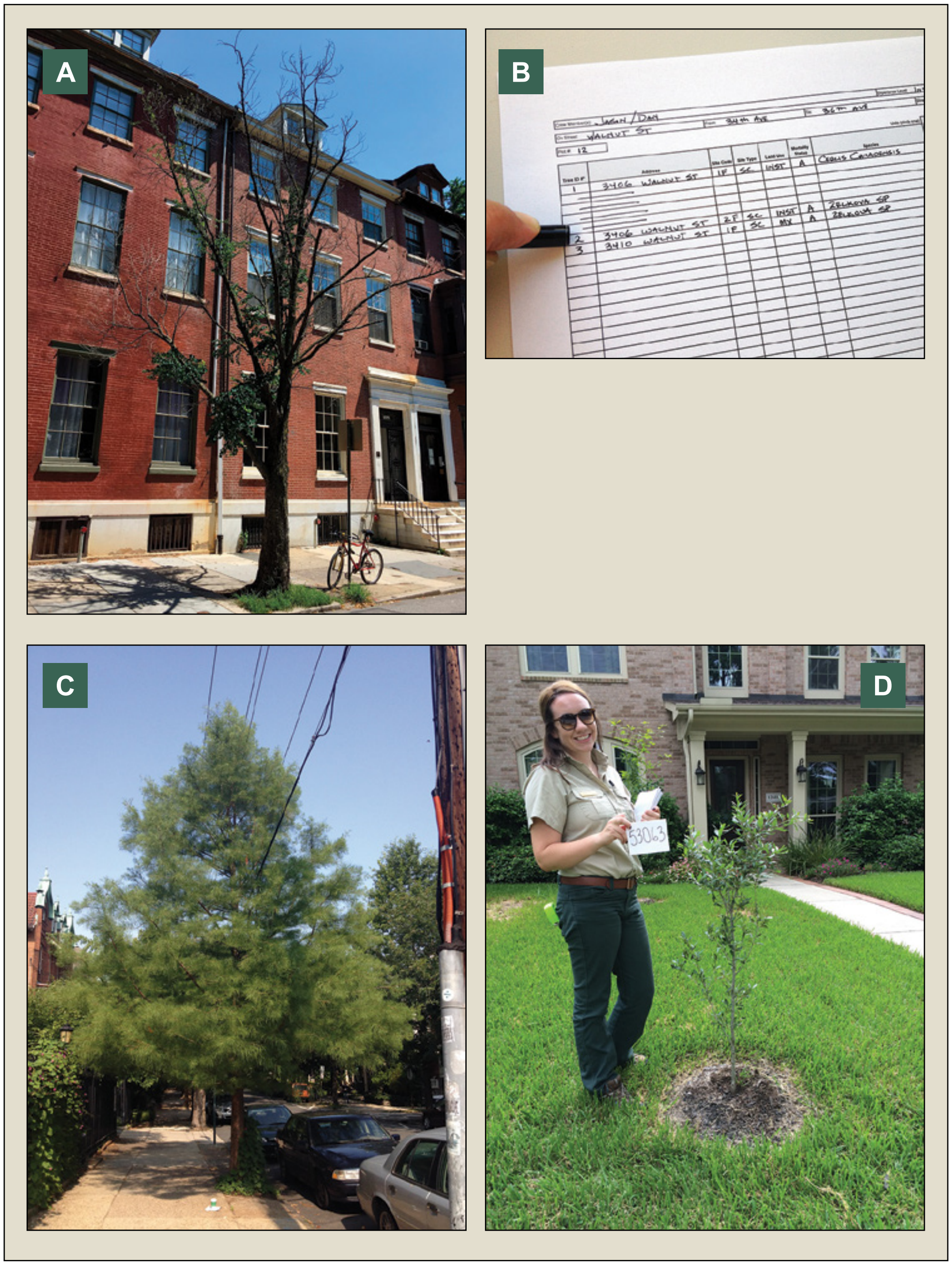


**Figure 5.**—Examples of tree photos. (A) Photos can be taken from across the street. (C) Photos can be taken looking down the sidewalk. (D). Another option is a photo with field crew personnel in the image. (B) If the photo is taken outside of a mobile data collection system, one option is to take tree photos by first drawing attention to a specific tree on the data sheet and then taking a full photo (C) of the tree in context. (D) An alternate option is to take the full photo of the tree in context while someone holds a sign with the tree record identifier. Photo A by L.A. Roman, USDA Forest Service; photos B and C by J.P. Fristensky, used with permission; photo D by Texas A&M Forest Service, used with permission.

## 2.6. Site Type

**Description:** Site type is a description of the tree's immediate location. The site type categories indicate broad information about the immediate area surrounding the tree and controls on tree inputs and removals (human dominated versus natural). We distinguish between trees in a hardscape environments (i.e., the tree is surrounded by concrete or other hard surfaces), trees in a non-hardscape maintained landscapes (i.e., the tree is surrounded by pervious ground cover like lawn or mulch), and natural areas (Table 6). The former two environments have human-dominated tree plantings and removals, whereas natural areas generally have natural seedling recruitment and tree death-in-place. Note that site type is not synonymous with ground cover. See the Resource Guide (section 2.4 and appendix 1) for more information about site type, including photo examples.

**Justification:** Site type provides information about the tree's placement in the urban context. Mortality, growth, and health may vary by site type and land use. Knowing a tree's site type can also help project managers and crews decide which location methods to use (see Resource Guide section 2.3 for guidance regarding appropriate location methods for various site types).

**Recorded for:** All trees.

**Important Note:** "Natural area" and "maintained park" are both site types and land uses. A tree located on one of these site types will not automatically have the same land use, and vice versa. See Table 8 for examples of situations when site type is natural area but land use is something else.

**Table 6.—Site type categories and associated codes for trees in hardscapes, maintained landscapes (non-hardscape), and natural areas**

| Category | Code | Description |
|---|---|---|
| | | **Trees in hardscape environments**<br>Tree plantings and removals for these site types are human dominated. |
| Sidewalk cutout | SC | Tree is located in a soil pit in the sidewalk (also sometimes call tree pit). The cutout can be anywhere in the sidewalk space (adjacent to the curb, adjacent to a building, etc.). This kind of site type is usually intended to fit just one tree. The dimensions are square or close to square. |
| Sidewalk planting strip | SP | Tree is located in a planting strip next to the sidewalk. This planting strip can be anywhere in the sidewalk space (between the sidewalk and curb, between the sidewalk and building, etc.). Planting strips can fit multiple trees planted in a row (even if only one tree present). The length of a planting strip is generally at least 10 ft (3.05 m). |
| Median | M | Tree is located in a planting space surrounded by traffic lanes. Includes center medians, traffic circles, triangular planting spaces near turning lanes, and road verges. |
| Planter box | PB | Tree is located in a raised planter box with a solid base (i.e., the tree roots are not connected to ground soil). The planter box could be anywhere on or adjacent to a property (e.g., sidewalk, yard). |
| Other hardscape | OH | Tree is located in a hardscape other than a sidewalk or median, such as cutouts or narrow planting strips in a plaza or parking lot. Please enter description in section 2.13, notes for supervisory review. |

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**Table 6 (continued).—Site type categories and associated codes for trees in hardscapes, maintained landscapes (non-hardscape), and natural areas**

| Category | Code | Description |
|---|---|---|
| **Trees in maintained landscapes, non-hardscape** Tree plantings and removals for these site types are human-dominated. | | |
| Front yard | FY | Tree is located in the yard in front of a building (i.e., on the street side of the building). Front yards are typically associated with residential properties but may also be associated with other land use types. With a corner residence, consider the “front” where the front door is located. |
| Side yard | SY | Tree is located in the yard on the side of a building. Side yard is a category that applies only to corner properties. Side yards are typically associated with residential properties but may also be on the side of corner properties for other land use types. For non-corner properties, trees located in between houses should be assigned to either front yard or back yard (Figure 6). |
| Back yard (BY) | BY | Tree is located in the yard behind a building. Back yards are typically associated with residential properties but may also be in back of other land use types. |
| Maintained park | MP | Tree is located in a maintained park or park-like setting, such as a city park, school campus, or cemetery. This category is specifically for trees in lawns and other landscaped areas with pervious ground cover. Park trees located in hardscapes such as plazas belong in the other hardscape category. Note: maintained park is both a site type and land use. |
| Other maintained landscaped area | OM | Tree is located in a landscaped area not described by the yard and maintained park categories. Please enter description in the notes for supervisory review (see section 2.13). For vacant lots with land use category vacant, field crews need to use their own judgment in the field to classify a tree as located in site type other maintained landscapes area (e.g., if the lot appears mowed and nominally maintained) or natural area (e.g., if the lot appears to have no maintenance and is overgrown). |
| **Trees in natural areas** Tree additions and removals for this site type are generally natural (e.g., natural regeneration and death-in-place). | | |
| Natural area | NAT | Tree is located in a natural park, open space area, afforested area, vacant lot with no maintenance, or residential property that has minimal human intervention (i.e., trees are not planted in this landscape and when trees die, it is death-in-place, not human removal). This includes remnant forest patches and other natural or relatively unmaintained areas, regardless of property type. For example, forest patches on a residential property or institutional property should be categorized as natural area. Natural areas include forests, prairies, woodlands, and other natural or minimally managed habitats. Note: natural area is both a land use and site type. |

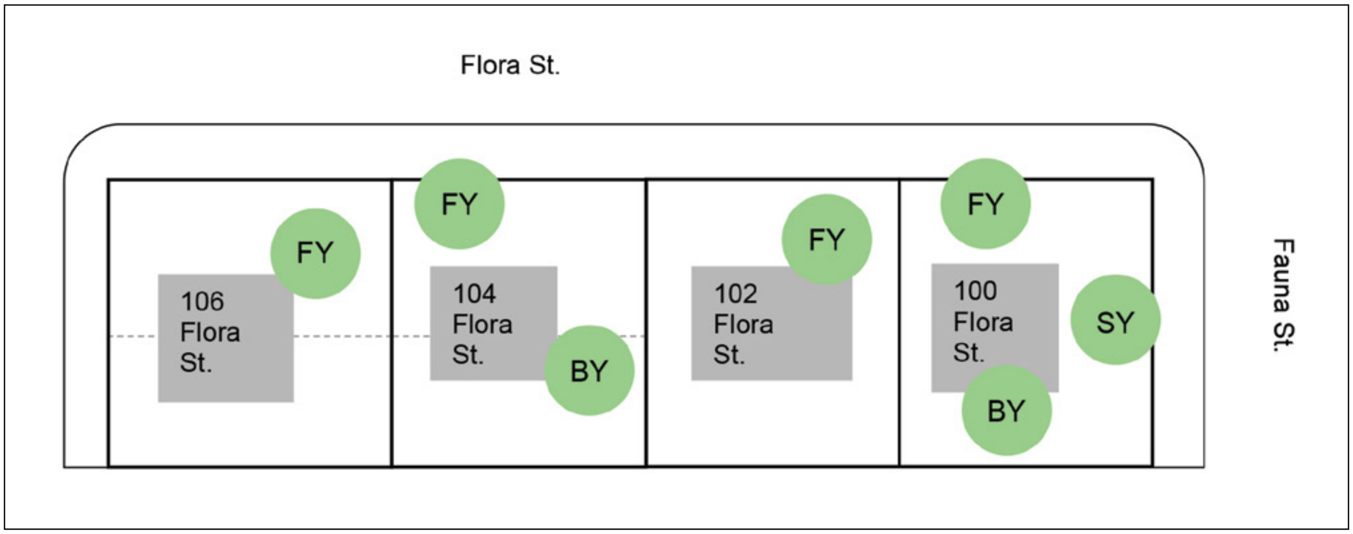



**Figure 6.**—Trees in yards under the maintained landscape, non-hardscape category. Grey boxes represent houses. Front yard (FY) and back yard (BY) can sometimes be distinguished based on the presence of a fence (dashed line), as with 104 and 106 Flora St. FY trees are between the front entrance of the house and Flora Street, and BY trees are behind the houses. The BY tree at 104 Flora St. has a crown that crosses over the fence, but the tree's trunk is actually behind the fence. At 102 Flora St., field crews should imagine where a fence would likely be located. Note that side yard (SY) is only used for corner properties, where the meaning of "front" and "back" can be ambiguous. At the corner property, 100 Flora St., a SY tree is located between the side of the house and Fauna Street. The front door of 100 Flora St. faces Flora Street, therefore the tree on the Flora Street part of the house is designated as FY.

## 2.7. Land Use

**Description:** Land use is a description of the way the property around or adjacent to the tree is used by humans (Table 7). Land use is distinct from site type, although the two variables are related and there is some overlap in their definitions, particularly with parks and natural areas. Land use refers to land use at the property level, while site type refers to the area immediately surrounding a particular tree. Examples are provided in Table 8. See the Resource Guide (section 2.4 and appendix 1) for more information about land use, including photo examples.

**Justification:** Land use provides information about the tree's placement in the urban context. Mortality, growth, and health may vary by site type and land use.

**Recorded for:** All trees.

**Important Note:** The land use categories should be classified as the current existing use and function (as opposed to original structure use, if different), as best as can be determined in the field. For example, an industrial building that has been converted to apartments would be classified as multifamily residential, and a single-family home that has been converted to an office would be classified as commercial. Furthermore, some urban tree monitoring projects may wish to collapse or omit some of the land use categories offered here, or to align their land use classes with local city planning classifications. See section 2.4 of the Resource Guide for more discussion about recording land use. Many (although not all) of the land use categories below correspond to categories used in i-Tree Eco (i-Tree 2017).

**Table 7.—Land use categories and associated codes**

| Category | Code | Description |
|---|---|---|
| Single-family residential – detached | SFR-D | Detached residential structures intended for one family. |
| Single-family residential – attached | SFR-A | Attached single-family structures, such as twins, town homes, row homes, and duplexes. Includes multiplexes with up to four units. |
| Multi-family residential | MFR | Structures containing more than four residential units (includes apartment complexes with greater than four units). |
| Mixed use | MIX | Single structure that has multiple uses, typically differentiated by floor. The common instance of this category is a commercial, civic, or retail use on main floor with multifamily residential units on floors above. |
| Commercial | COMM | Downtown commercial districts, malls, strip malls, and shopping plazas. This category also includes stand-alone parking lots in downtown areas that are not associated with institutional or residential use. |
| Industrial | IND | Factories, warehouses, and trucking businesses. |
| Institutional | INST | Schools, colleges, hospital complexes, religious buildings, and government buildings (specifically, government buildings that are not themselves part of a park or recreation center space). |
| Maintained park | MP | Maintained or landscaped public or private parks, including arboretums, botanical gardens, pocket parks, landscaped park plazas, and recreation centers. Includes trees near buildings in neighborhood parks and recreation centers. Note: maintained park is both a site type and land use. |
| Natural area | NAT | Natural park or open space area that has minimal human intervention. Natural areas include forests, prairies, woodlands, and other natural or minimally managed habitats. Note: natural area is both a site type and land use. |
| Cemetery | CEM | Self-explanatory |
| Golf course | GC | Self-explanatory |
| Agricultural | AG | Crop land, pasture, orchards, vineyards, nurseries. Farm land that is fallow when doing the fieldwork should still be classified as agricultural. |
| Utility | UT | Power-generating facilities, sewage treatment plants, covered and uncovered reservoirs, empty stormwater runoff retention areas, flood control channels, and conduits. Does not include power lines over sidewalks and yards (trees under such power lines should be classified by the land use of the adjacent property). |
| Water/wetland | W | Streams, rivers, lakes, and other water bodies (natural or manmade). Recreational pools, lakes, and fountains should be classified based on the adjacent land use. |
| Transportation | TR | Includes limited access roadways and related greenspaces (such as interstate highways with on and off ramps); railroad stations, tracks and yards; shipyards; airports. If a tree falls on any other type of road or associated median strip, classify according to the nearest adjacent land use. |

(continued on next page)

**Table 7 (continued).—Land use categories and associated codes**

| Category | Code | Description |
|---|---|---|
| Vacant lot | V | Parcel with no obvious current human use. The common instances of this are land which has yet to be developed, or land that was developed and the building has since been demolished. A standing building that is unoccupied/abandoned should be categorized by its most recent apparent use. For example, an abandoned factory would be industrial, and an abandoned retail store would be commercial. |
| Other | O | Land use does not fit the categories provided. Please enter description in the notes for supervisory review (see section 2.13). |

**Table 8.—Examples of tree site types and land uses. For additional examples with photos, see appendix 1 in the Resource Guide**

| Example | Land Use (property level) | Site Type (tree level) |
|---|---|---|
| Tree in a maintained cemetery lawn | Cemetery | Maintained park |
| Tree in the narrow planting strips of a parking lot in a cemetery | Cemetery | Other hardscape |
| Tree in a cutout in a stand-alone parking lot in a downtown area | Commercial | Other hardscape |
| Tree in a cutout in the sidewalk in front of a store | Commercial | Sidewalk cutout |
| Tree in a wooded forest fragment within a golf course | Golf course | Natural area |
| Tree in the lawn in front of an elementary school | Institutional | Front yard |
| Tree in a landscaped lawn within a hospital complex | Institutional | Maintained park |
| Tree in a landscaped park-like area of a college campus | Institutional | Maintained park |
| Tree in a wooded forest fragment of a botanical garden | Maintained park | Natural area |
| Tree in a high school parking lot (within the parking lot itself, not in sidewalk) | Institutional | Other hardscape |
| Tree in a cutout in the sidewalk in front of a municipal court house | Institutional | Sidewalk cutout |
| Tree in a landscaped lawn of a municipal recreation center | Maintained park | Maintained park |
| Tree in a public park wooded forest fragment | Natural area | Natural area |
| Tree in the front lawn of an attached townhome | Single family residential – attached | Front yard |
| Tree in the road median on a street with detached single family homes | Single family residential – detached | Median |
| Tree in an overgrown vacant lot with no apparent maintenance | Vacant | Natural area |
| Tree in a vacant lot that appears to be regularly mowed | Vacant | Other maintained landscaped area |

## 2.8. Species

**Description:** Record tree species using standard botanical names, with both genus and species, or species codes. For example, red maple should be recorded as *Acer rubrum* or species code ACRU (using the first two letters of the genus and species). When using species codes, we recommend the codes from the Urban Forest Inventory and Analysis program of the USDA Forest Service (USDA Forest Service 2017a). These codes consist of the first two letters of the genus and species and when necessary, a number that distinguishes between species. For example, sugar maple is recorded as *Acer saccharum* or species code ACSA3.

If only the common name for the tree is known, enter that in the field and then confirm the botanical name after the day's fieldwork is completed and before submitting to the project supervisor. When entering data through a mobile data collection system, there should be a drop-down menu of species to select, often prepopulated with species relevant to a particular region. Project supervisors should ensure there is an option for "unknown species" and/or "other species" as not all species are likely to be included in the prepopulated list.

Enter cultivar only if known from a list of planted trees or if the field crew doing species identification is extremely knowledgeable about cultivars.

Further guidance for urban tree species identification is provided in section 3.1.2 and appendix 2 of the Resource Guide.

If the monitoring project is tracking trees planted from a particular program or from a prior inventory where the species is known, the recorded species identification should be verified for accuracy. In such situations, field crews are doing species confirmation based on existing data, not species identification from scratch. If the species record contains errors, add a comment in the notes for supervisory review (section 2.13); do not change species in the master database without conferring with the project supervisor.

If there is a replacement tree in the same location as a prior tree record, do not change the species for that record, but rather consult with the project supervisor as to how replacements are handled (for more information about replacement trees, see Resource Guide section 2.5.3). If the information is recorded improperly, a replacement planting could appear to be the same tree with a species correction, not an entirely new tree, which would result in inaccurate data with regard to growth rate, mortality, or vigor.

**Justification:** Species is one of the most essential pieces of data for urban tree inventories and monitoring because mortality, growth, and health may differ by species or species groups. We offer general recommendations about how to record species in this Field Guide, with more information and references in appendix 2 of the Resource Guide.

**Recorded for:** All trees.

### Procedures for Unknown Species

If the crew has a "best guess" as to genus and/or species identification, enter that information but use the notes for supervisory review (see section 2.13) to indicate that assistance is needed to confirm the species.

If the crew is confident about genus but uncertain about species, record only genus information. For example, record an unknown maple species as Acer sp. (code ACER). Note that mobile data collection platforms should include an option for genus-only identification. Genus-only identification may also be acceptable for some genera that are particularly difficult to identify, as some urban trees have many hybrids and cultivars that are challenging even for experts to tell apart. Supervisors should decide ahead of time which genera should be recorded with genus-only information (see Resource Guide, section 2.1.11).

If the species and genus are completely unknown, record as "unknown broadleaf," "unknown conifer," or "unknown."

For unknown genus and/or species, take pictures of the following: leaves; fruit, nut or flower; bark; and whole-tree profile. Pictures of leaves and flowers are clearer when taken on a white background (i.e., blank note paper or mini white board). Label all photos with the tree's location and tree record identifier. For example, take a picture of the field data collection sheet followed by pictures of the tree in question (see section 2.5, Figure 5). Field crews needing assistance with species identification should show the pictures to the project supervisor and/or use tree identification books or websites (see Resource Guide, section 2.1.12 and appendix 2). Do not consider the observations for this tree complete until the species identification problem is resolved, even if that resolution is simply leaving the species as unknown after consulting with the supervisor or other resources. An example of pictures for an unknown species is found in section 2.13, Figure 15C.

**Important Note:** The field crews should be familiar with the most common species in the study city before fieldwork begins, but trees may be encountered that crews do not recognize. Bring tree identification resources into the field. Tree identification fact sheets customized to the project's city or region are especially helpful, and tree identification handbooks are available with dichotomous keys for experienced users (although such books are usually focused on native species). The project supervisor should suggest resources appropriate to the project. For additional resources and guidance related to species identification, see section 3.1 and appendix 2 of the Resource Guide.

## 2.9. Mortality Status

**Description:** Mortality status is a record of whether the tree is alive, standing dead, removed, or in some other status (Table 9, Figure 7). If there is ever difficulty deciding how to classify a tree's mortality status, those details should be recorded in notes for supervisory review (section 2.13).

**Justification:** Mortality status is an essential outcome of many monitoring studies, to report on mortality and survival rates as performance metrics, and to understand population change. Although this is a categorical variable (to enable clarity about tree status during data collection), it also can be recoded as binary (survived/died) for data analysis, such as calculating the mortality rate. The combination of trees recorded as standing dead, stump, and removed would count toward mortality, whereas trees recorded as alive would count toward survival, and trees never planted do not count toward the mortality rate calculations. See section 1.1.1 of the Resource Guide regarding mortality and survival terms, and section 6.4 of the Resource Guide for background about the mortality status categories.

**Recorded for:** All trees.

**Important Note:** Throughout this protocol, we define "mortality" to include trees that die in place and those that are removed while still alive. This is consistent with recent urban tree mortality research (Hilbert et al. 2019, Roman et al. 2016). Trees classified as standing dead, stump, and removed will all be included when calculating mortality rates. Furthermore, it is generally difficult, or even impossible, for field crews to infer whether trees observed as removed were dead or alive at the time they were removed. Additionally, we have not included a category for "replacement" trees (i.e., a tree planted as a replacement for a removed tree, in the same location); although some programs may find that information to be useful (see Resource Guide, sections 2.1.15 and 2.5.3).

For repeat monitoring, field crews should confirm that the tree is indeed the same tree from prior data (i.e., not a replacement planting). If a given tree is removed and replaced, then mark that tree's mortality status "removed." Field crews should check with the project supervisor whether or not replacement trees are being tracked in this project. If replacement trees are being tracked, supervisors should select from various options for tracking the replacement tree information within the database structure (Resource Guide section 2.5).

**Table 9.—Mortality status categories**

| Category | Code | Description |
| --- | --- | --- |
| Alive | A | The tree has green leaves and/or live buds and green tissue under the bark. Extremely unhealthy trees, such as those with no leaves but live buds, are included in this category. |
| Standing dead | SD | Tree is dead and above 12 inches (30.5 cm) in height. Trees classified as standing dead must be completely dead above-ground, with no green leaves, no live buds, and no green tissue under the bark. Trees that have the trunk and branches dead but have live basal sprouts should be recorded as standing dead (see section 2.10 about recording basal sprouts). |
| Stump | S | Tree is dead and under 12 inches in height. This includes stumps with basal sprouts (see section 2.10 about recording basal sprouts). |
| Removed | R | Tree has been removed since the previous observation. No sign of a stump. This category is not relevant for a baseline inventory of trees (e.g., for a repeated street tree inventory the “removed” category does not apply to the very first inventory, but would be relevant in future years). |
| Never planted | NP | Tree was never planted. This category is only relevant to monitoring planting programs and giveaway programs in circumstances for which the program staff cannot be certain that every tree distributed was actually planted. When this category is relevant, be very careful in distinguishing “removed” from “never planted” trees. Confirm with the resident or planting program manager as to whether the tree was indeed planted. |
| Unknown | U | Tree has unknown status (possibly due to issues in accessing the property or confusion about tree location). Note: If unknown status, explain the situation in the notes for supervisory review (see section 2.13). |


**Figure 7.**—Mortality status examples. (A) Alive. Photo by B.C. Scharenbroch, used with permission. (B) Alive. Photo by Sacramento Tree Foundation, used with permission. (C) Alive. Photo by L.A. Roman, USDA Forest Service. (D) Alive. Photo by J. Bond, used with permission. (continued on next page)


**Figure 7 (continued).**—Mortality status examples. (E) Standing dead. Photo by J. Bond, used with permission. (F) Standing dead. Photo by L.A. Roman, USDA Forest Service. (G) Stump. Photo by L.A. Roman, USDA Forest Service. (H) Removed. Photo by J.P. Fristensky, used with permission.

## 2.10. Basal Sprouts

**Description:** Basal sprouts, sometimes called suckers or water sprouts, grow from buds at the base of the stem or in the roots of a tree. Basal sprouts can indicate that the root system is still alive in a stump or standing dead tree or that the tree is under stress from a variety of factors. Record as present (P) if basal sprouts are present, or absent (A) if basal sprouts are not present.

**Justification:** Basal sprouts is recorded to complement mortality status. Trees that are dead in the main trunk may still have basal sprouts, and if such trees are not removed, they may regrow from the sprouts. While rare, this situation does occasionally occur in urban areas and is relevant to calculating mortality rates.

**Recorded for:** Trees with mortality status: standing dead or stump.

**Important Note:** If the basal sprout from a dead stump has grown back into a tree (i.e., it has reached several feet tall), then start recording d.b.h. (see section 2.12). For considerations as to whether such a tree growing from a basal sprout should be counted as a replacement tree or the same original tree, see the section 2.1.16 in the Resource Guide.

## 2.11. Crown Vigor

**Description:** Crown vigor consists of five classes based on visual examination of crown health (Table 10). It is a holistic assessment of overall crown health and reflects the proportion of the crown with foliage problems and major branch loss. Note that crown vigor does not involve evaluation of trunk condition or structural stability (Figures 8 and 9).

**Justification:** Crown vigor is a holistic visual assessment of tree health that can predict future mortality, growth, and health declines. Many other systems for observing tree health, condition, and vitality exist, which are discussed in the section 6.5 of the Resource Guide.

**Recorded for:** Trees with mortality status alive or standing dead.

**Table 10.—Descriptions of crown vigor classes. Class 5 (dead) in crown vigor aligns with "dead" as mortality status category standing (see Table 9).**

| Crown Vigor | Description |
|---|---|
| 1 | Healthy; tree appears to be in reasonably good health; no major branch mortality or large broken branches; less than 10 percent cumulative fine twig dieback, foliage discoloration, and/or defoliation present. |
| 2 | Slightly unhealthy; fine twig dieback, foliage discoloration, and/or defoliation present in 10 to 25 percent of the crown; broken branches or crown area missing based on visual evidence of large broken (not pruned) or dead branches 25 percent or less. |
| 3 | Moderately unhealthy; fine twig dieback, foliage discoloration, and/or defoliation present in 26 to 50 percent of the crown; broken branches or crown area missing based on visual evidence of large broken (not pruned) or dead branches 50 percent or less. |
| 4 | Severely unhealthy; fine twig dieback, foliage discoloration, and/or defoliation present in more than 50 percent of the crown, but foliage is still present to indicate the tree is alive, broken branches or crown area missing based on visual evidence of large broken (not pruned) or dead branches more than 50 percent. |
| 5 | Dead; trees classified as dead must be completely dead above ground, with no green leaves, no live buds, and no green tissue under the bark. |

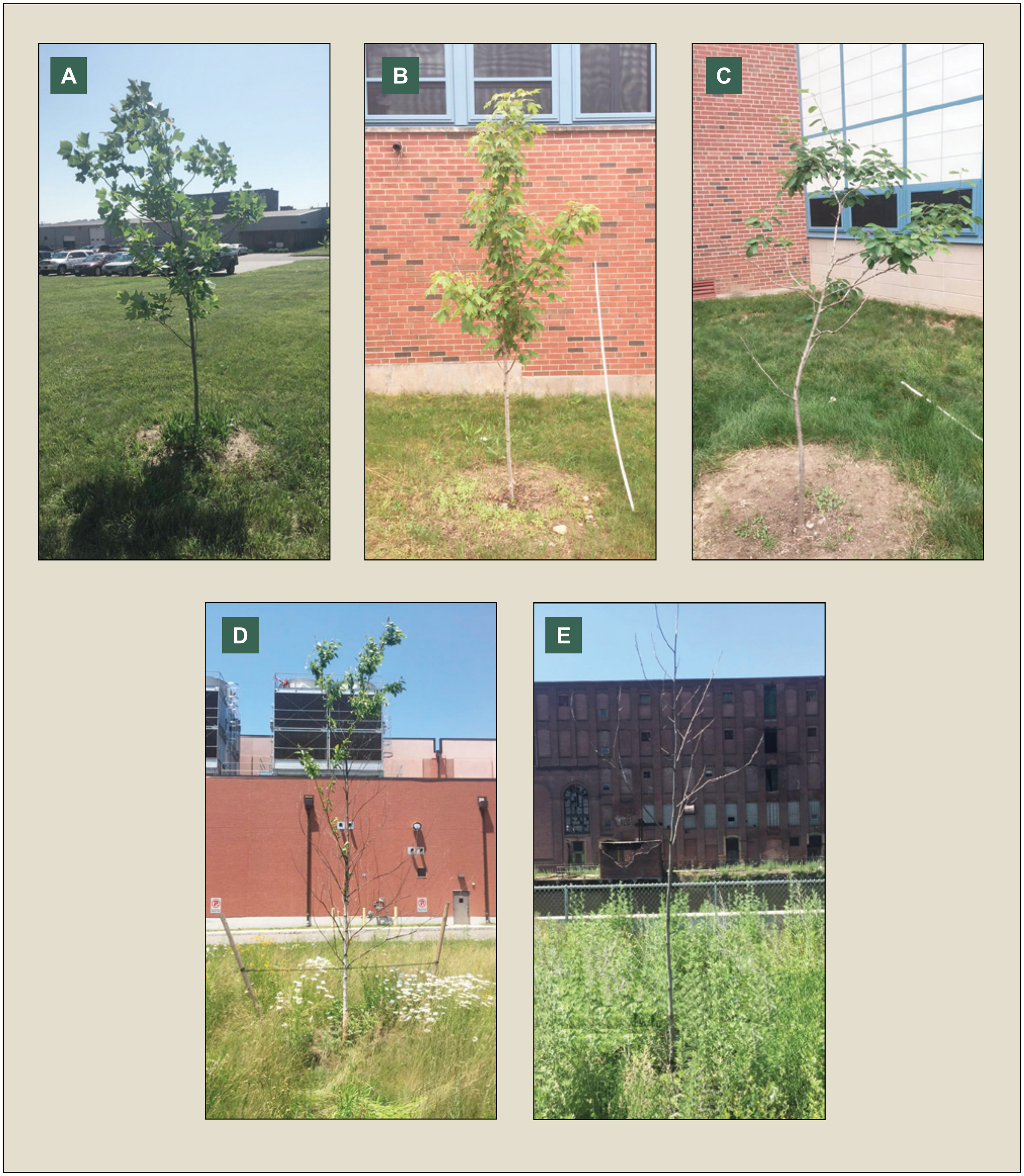



**Figure 8.**—Crown vigor examples for young, recently planted trees. (A) Crown vigor class 1, healthy. (B) Crown vigor class 2, slightly unhealthy. (C) Crown vigor class 3, moderately unhealthy. (D) Crown vigor class 4, severely unhealthy. (E) Crown vigor class 5, standing dead. All photos by B.S. Breger, used with permission.


**Figure 9.**—Crown vigor examples for mature street trees. (A) Crown vigor class 1, healthy. (B) Crown vigor class 2, slightly unhealthy. (C) Crown vigor class 3, moderately unhealthy. (D) Crown vigor class 4, severely unhealthy. All photos by R.A. Hallett, USDA Forest Service.

## 2.12. Trunk Diameter

**Description:** Trunk diameter is recorded either as diameter at breast height (d.b.h.) or as diameter at caliper height (d.c.h.), depending on the tree's characteristics. D.b.h. is the diameter at 4.5 ft (1.37 m) above the ground; d.c.h. is the diameter at 1 ft (30.5 cm) above the ground. While d.b.h. is the standard way that forest ecologists and most urban foresters measure trunk size, d.c.h. is a common way to report sizes of nursery stock and newly planted trees. Branching and foliage at 4.5 ft (1.37 m) and other practical problems often cause challenges when measuring d.b.h. on very small trees. Throughout this protocol, the word "stem" means the same as "trunk," following convention from forestry and arboriculture.

Record d.b.h. for trees of at least 1 inch (2.5 cm) diameter at 4.5 ft. For trees with stem diameter smaller than 1 inch at 4.5 ft, measure d.c.h. at 1 ft above the ground instead. Diameter is also sometimes recorded lower than 4.5 ft due to forked structure and other special considerations.

For further discussion about other ways of measuring trunk diameter and issues regarding data quality, consistency, and intended use of trunk diameter data, see the section 6.6 in the Resource Guide.

**Justification:** Trunk diameter is the only variable which requires a measuring device in this Minimum Data Set (i.e., the other variables are categorical). Both the diameter and the height at which diameter was measured should be recorded to facilitate remeasurement at the exact same point on the tree in the future. Trunk diameter is used to understand the size class distribution of the urban forest and to predict risk of mortality. Diameter remeasurements enable analysis of growth rates. See section 6.6 of the Resource Guide for background as to why these protocols recommend recording multi-stemmed trees in a particular way.

**Recorded for:** All live trees and standing dead trees.

**Trunk Diameter – What to Record**

1. Height at which trunk diameter is taken
    - This should be recorded for EVERY TREE that has a trunk diameter measurement. Do not leave blank assuming that 4.5 ft is the default. Knowing the exact height of measurement is essential to accurate remeasurements for growth.
    - Measure up from the trunk base (where it meets the ground). Field crews can use a stick that has been marked at exactly 4.5 ft as an efficient method for consistent field measurements. If measuring recently planted street trees, the height measurement could be taken from the sidewalk rather than against the trunk at soil level, as soil and mulching levels can vary over time. If measuring older street trees, the height measurement could be taken from the trunk base. The decision as to where to measure height to d.b.h. point should be recorded at the start of the project and followed consistently across crews.

2. Trunk diameter
3. Units of measurements (record only once per field crew)
    - The supervisor should determine a preferred unit of measurement for all crews as well as the level of precision (e.g., 1/10th inch, mm), which is often related to available equipment on hand. See the Resource Guide (section 6.6) for a discussion about units of measurement and precision related to tree monitoring.
    - If this is a follow-up (or re-inventory) measurement, use the same units of measure and the same device (e.g., cloth versus metal measuring tapes) as the initial measurement and record diameter at the same height. If diameter cannot be recorded at the same height (e.g., major wound where diameter was last recorded), explain why in the notes for supervisory review (see section 2.13) and record the new height.

### 2.12.1. Best Practices for Trunk Diameter Measurement

The next several pages provide a quick overview of best practices for measuring d.b.h. and d.c.h. For a list of field equipment, see appendix 3.

**The precision of trunk diameter measurements has implications for data analysis.** For studies of tree growth, we recommend using nearest 1/10 inch (0.25 cm) or nearest mm (depending whether the field crews use English of metric units). Check with the project supervisor about which level of precision is required in the project, and be consistent in all of the field measurements, including future repeated measurements of the same trees. See the section 2.1.10 of the Resource Guide for a discussion of other options for measurement precision and implications.

**Diameter tape (d-tape) is the best piece of equipment for measuring d.b.h. in most circumstances.** This specialized tool has the circumference-to-diameter conversion on one side of the tape (Figure 10A). Make sure that the d-tape being used has the appropriate units and graduations (e.g., nearest 1/10 inch or mm). However, d-tape may be cost-prohibitive for some projects. See the section 3.3 of the Resource Guide (section 3.3) for a discussion of other measuring tools for d.b.h.

**Use custom walking sticks, survey rods, or household tape for measuring height to diameter point.** A walking stick which has been marked at exactly 4.5 ft can provide an efficient method for consistent field measurements and is applicable to any trees that do not have special considerations (see section 2.12.3) or are multi-stemmed (see section 2.12.4) where the d.b.h. height would need to be adjusted and recorded. Survey poles with height measurements marked (often made of PVC pipe, typically 1 to 2 inches diameter) can also be used to record the exact measurement point. Lastly, a stiff household measuring tape (sometimes called engineer's tape) can also be used to measure the height to the measurement point. While a d-tape could potentially be used for this, soft d-tape can be challenging to use for measuring height. If two individuals are measuring the tree, it is helpful for one person to measure height to the d.b.h. point and the other to measure the diameter itself.

**Caliper tools are appropriate for small diameter trees** <1 inch diameter at 4.5 ft above ground (Figure 10B). Such trees can be impractical to measure with d-tape. When using caliper tools, take two perpendicular measurements and write down the average. Caliper tools may also be needed if d-tape is very difficult to wrap around the trunk, due to, for example, old pruning scars.

**There are a variety of special considerations and many common mistakes when recording d.b.h.** (Table 11). The field crew should be familiar with the instructions on the next few pages before beginning fieldwork.

**Important Notes:**

- Caliper refers to both a measurement (diameter at 1 ft [30.5 cm]) and a piece of equipment used to measure diameter. We refer to the equipment in this protocol as "caliper tool," whereas d.c.h. refers to the measurement height.
- Always record the exact height of diameter measurement. Most commonly, trunk diameter will be recorded at 4.5 ft (d.b.h.), but sometimes other heights will be used due to the following special considerations. The height of measurement must be recorded to allow future field crews to record diameter at the same spot on the tree in order to calculate diameter growth (or crews could make a mark on the tree, see Resource Guide, section 6.6).
- Do not record "eyeballed" or visually estimated trunk diameter. Measurements must be precise since the focus of these protocols is monitoring change over time. The only appropriate reason for eyeballed diameter is when an obstruction, denied access, or safety concern prevents physical measurement of the tree. Record in the notes for supervisory review that a visual estimate was taken.

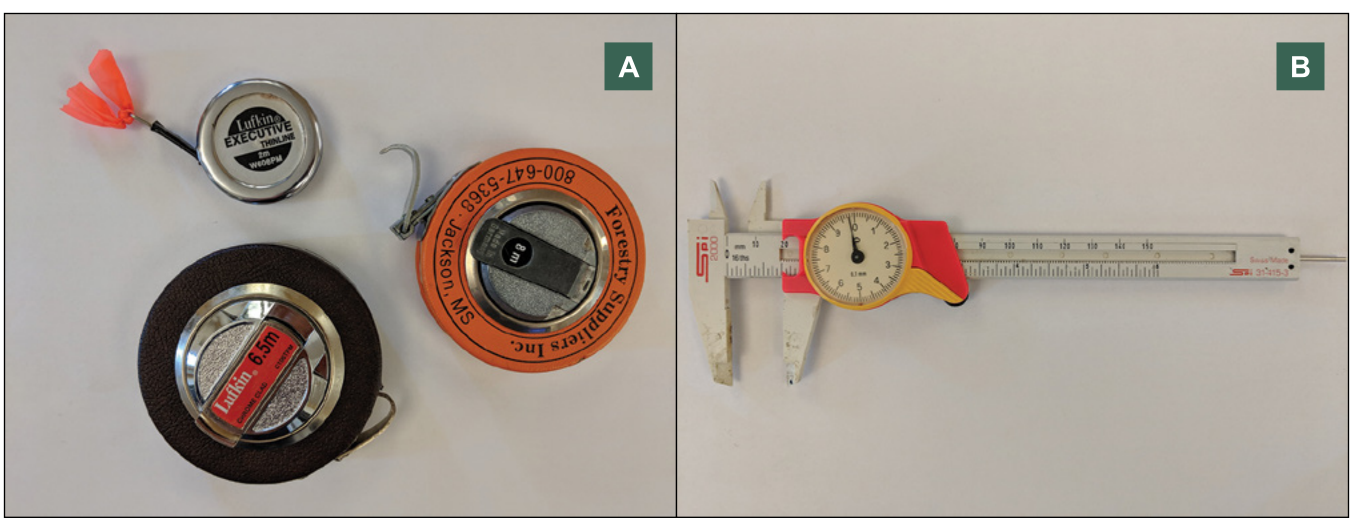



**Figure 10.**—Equipment for measuring trunk diameter: (A) d-tapes; (B) caliper tool. Photos by N.S. van Doorn, USDA Forest Service.

### 2.12.2. How to use a d-tape

The special measuring tape for d.b.h. (d-tape) is easy to use but takes practice. Below are some tips to avoid common mistakes with d-tape.

**Measure diameter, not circumference.** D-tape typically has two sides: (1) a regular side with graduated units used for measuring the circumference of the trunk, and (2) a specially calibrated side with graduated units used for measuring diameter (diameter = circumference/$\pi$). Confirm that the correct side of the tape is used prior to measuring the tree.

**Confirm that the tape is perpendicular to the trunk.** Tape can get caught on bark or become lopsided around large trunks. The tape should be perpendicular to the trunk (see section 2.12.3 for instructions about leaning trees).

**Confirm that the tape is pulled snug.** The d-tape should lay flat and be pulled snugly around the trunk without over-stretching the tape. This is especially important if there is any loose bark. Note that fabric tapes can stretch with repeated use and excess pulling, so be careful not to pull too hard.

**If vines are present, position tape under the vines (if possible).** D.b.h. should measure the diameter of the trunk, not diameter of the trunk and vines combined. If vines prevent proper recording of trunk diameter, note this in the notes for supervisory review (see section 2.13).

**When in doubt, contact the supervisor and take notes.** Diameter at breast height is one of the most important pieces of data in this protocol. If there are difficulties obtaining d.b.h. for a particular tree, take notes (see section 2.13, notes for supervisory review), and contact the supervisor for advice.

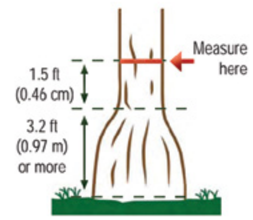
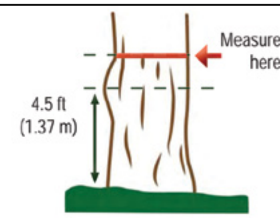
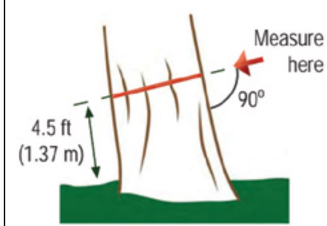
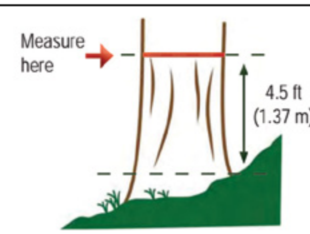
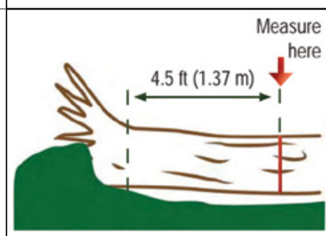
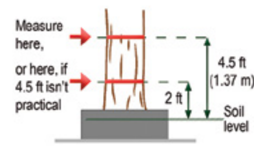
**Make sure the numbers are being read in the proper direction** (Figures 11 and 12). A common mistake when using the d-tape is reading the numbers from left to right, when the numbers should be read from right to left. There are, however, different styles of d-tape, so confirm the proper way to use the d-tape at hand.


**Figure 11.**— The d-tape pictured above is wrapped clockwise around the trunk. The correct diameter measurement is 4.3 inches, when reading from right to left. Record the d-tape reading where the zero mark overlaps. Some field crews new to measuring with d-tape could have erroneously recorded this tree as 5.7 inches. Photo by E. Desotelle, used with permission.


**Figure 12.**—Examples of d.b.h. measurements done correctly and incorrectly. (A) Correct: d-tape is perpendicular to trunk and positioned under the branching flare. Photo by J.P. Fristensky, used with permission. (B) Correct: d-tape height adjusted to avoid branching flare and trunk irregularity. Photo by J.P. Fristensky, used with permission. (C) Incorrect: d-tape should be placed under any sprouting and also placed to avoid any irregularities. Photo by J.P. Fristensky, used with permission. (D) Incorrect: d-tape placement is too loose and should be perpendicular to trunk. Photo by E. Desotelle, used with permission.

### 2.12.3. Special considerations for d.b.h.

**Table 11.—Special considerations for measuring d.b.h.**

| Situation | Instruction | Example |
|---|---|---|
| Tree with buttswell or bottleneck | Measure trees 1.5 ft (0.46 m) above the end of the swell or bottleneck if the swell or bottleneck extends 3.0 ft (0.91 m) or more above the ground. |   |
| Tree with irregularities at d.b.h. | On trees with swellings, bumps, depressions, or branches at 4.5 ft, measure immediately above the irregularity at the place the irregularity ceases to affect normal stem form. |   |
| Leaning tree | Measure diameter at 4.5 ft from the ground. The 4.5 ft distance is measured along the underside face of the trunk. Measure diameter perpendicular to the trunk. |   |
| Tree on slope | Measure diameter at 4.5 ft from the ground along the trunk on the uphill side of the tree. If the tree is leaning on the slope, measure diameter as noted under “Leaning Tree”. |   |
| Live windthrown tree | Measure from the top of the root collar along the length to 4.5 ft. |   |
| Tree in raised planter | Measure at 4.5 ft above the soil level, unless that height is impractical in which case the tree should be measured at 2 ft above the soil level. |   |

### 2.12.4. Multi-stemmed trees

Multi-stemmed trees, also called forked trees, can be challenging to measure and often require extra time and attention to detail. In order to qualify as an additional stem, the stem in question must be at least 1/3 the diameter of the main stem and must branch out from the main stem at an angle of 45 degrees or less. In other words, one should not record diameter of a low horizontal branch.

For consistency across field crews and to enable remeasurement for d.b.h. growth, we recommend the guidelines below. However, we recognize that there are different approaches to dealing with multi-stemmed trees, which we discuss in the section 6.6 in the Resource Guide.

**Scenario 1:** If the tree forks at or below 1 ft, record as separate stems. Start with the largest stem and record in a clockwise direction. If there are many stems, measure up to six (the six largest). For each stem, follow d.b.h. rules for special consideration regarding height of measurements. Record the height of d.b.h. measurement point separately for each stem.

**Scenario 2:** If the tree forks between 1.0 ft (30.5 cm) and 4.5 ft (1.37 m), record as a single trunk. Record as close to 4.5 ft as is reasonable given any swelling near the fork. Measurement height can be as low as 1 ft. See section 6.6 of the Resource Guide for additional discussion about this scenario, as some project supervisors may wish to use d.c.h. at 1 ft as the default measurement height.

This instruction is appropriate for the genera listed in Figure 13. This scenario may apply to other genera as well. This is not an exhaustive list and the supervisor can point out other relevant genera for the study area.

**Scenario 3:** If the tree forks at or above 4.5 ft, record as a single trunk. Record at 4.5 ft, paying attention to all the other special considerations (Figure 14).


**Figure 13.**—Record d.b.h. for a single stem for trees that fork between 1.0 ft and 4.5 ft, such as the examples shown here: (A) *Pyrus* sp., (B) *Prunus* sp., (C) *Malus* sp., (D) *Zelkova serata*, and (E) *Crataegus* sp. For trees that fork below 1.0 ft, record d.b.h. of multiple stems at 4.5 ft, as in example (F) *Arbutus* sp. Photos A through E by J.P. Fristensky, used with permission. Photo F by Natalie van Doorn, USDA Forest Service.


**Figure 14.**—Examples of d.b.h. measurements for trees with irregularities. Use the instructions in section 2.12.3 of this Field Guide for the rules regarding special circumstances. (A) D.b.h. for a single-stem tree measured at height of 4.0 ft (1.22 m) to avoid swelling (branching flare). (B) To record d.b.h. for single-stem tree that has irregularities, measure above bulge and record height of measurement. Photos by J.P. Fristensky, used with permission.

## 2.13. Notes for Supervisory Review

**Description:** Whenever encountering a challenge with a tree that cannot be resolved in the field, take notes for the supervisor. Notes may include difficulties with species identification, mortality status, trunk diameter measurements, or other variables. Entering a note flags the tree for review by the project supervisor.

**Justification:** Notes for supervisory review can help the project supervisor or data analyst understand peculiarities with a specific record.

**Categories for Review**

On the field data collection sheet or in a mobile data collection platform, check one or more of the items in the following list to alert the supervisor to the potential issue. Flagging a variable enables supervisors and researchers to identify and resolve common problems across the project.

- Tree record identifier
- Location
- Site type
- Land use
- Species
- Crown vigor
- Trunk diameter
- Mortality status
- Basal sprouts

**Recorded for:** Any trees that have special issues that require a supervisor's feedback or consultation, would be helpful for data analysts to review, or would be useful for future field crews. However, this does not mean that crews should record every detail; only record issues that seem especially noteworthy or unusual, and whenever possible, resolve issues in the field (Figure 15).


**Figure 15.**—Examples of notes for supervisory review. (A) Mortality status: Alive. Notes for supervisory review: Cut back to 2 ft tall, main trunk still alive but no d.b.h. was recorded. Photo by L.A. Roman, USDA Forest Service. (B) Mortality status: Standing dead. Basal sprouts: Present. Notes for supervisory review: Dead main stem with basal sprouts, no crown. Photo by L.A. Roman, USDA Forest Service. (C) Species: Unknown. Notes for supervisory review: Need help with species ID, pictures of characteristics taken. Photo by J.P. Fristensky, used with permission.

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# Appendix 1: Field Data Collection Cheat Sheet

## Site Type

**Trees in hardscape**

| | |
|---|---|
| SC | sidewalk cutout |
| SP | sidewalk planting strip |
| M | median |
| OH | other hardscape |

**Trees in maintained landscape (non-hardscape)**

| | |
|---|---|
| FY | front yard |
| SY | side yard |
| BY | back yard |
| MP | maintained park |
| OM | other maintained landscaped area |

**Trees in natural areas**

| | |
|---|---|
| NAT | natural area |

## Basal Sprouts

Recorded for trees with mortality status of: standing dead or stump

Record P for "present" if basal sprouts are present or A for "absent" if basal sprouts are not present.

If the basal sprout has grown back into a tree (reached several feet tall) then start recording d.b.h.

## Land Use

| | |
|---|---|
| **SFR-D** | single-family residential-detached |
| **SFR-A** | single-family residential-attached |
| **MFR** | multi-family residential |
| **MX** | mixed use |
| **COMM** | commercial |
| **IND** | industrial |
| **INST** | institutional |
| **MP** | maintained park |
| **NAT** | natural area |
| **CEM** | cemetery |
| **GC** | golf course |
| **AG** | agricultural |
| **UT** | utility |
| **W** | water/wetland |
| **TR** | transportation |
| **V** | vacant lot |
| **O** | other |

## Trunk Diameter

- Use the precision provided by the project supervisor
- Measure at 4.5 ft (1.37m) above ground, but follow rules to adjust height.
- Use correct side of tape to measure diameter (not circumference).
- Keep tape perpendicular to the trunk
- Make sure tape is pulled snug.
- Position under vines, if present
- When in doubt: take notes and contact supervisor.
- For special cases and multi-stemmed trees refer to Field Guide, section 2.12.

Note: Always record exact height of diameter measurement whether at 4.5 ft or if different due to special considerations.

## Mortality Status

| | |
|---|---|
| **A** | alive |
| **SD** | standing dead |
| **S** | stump |
| **R** | removed |
| **NP** | never planted |
| **U** | unknown |

## Crown Vigor

| | |
|---|---|
| **1** | healthy |
| **2** | slightly unhealthy |
| **3** | moderately unhealthy |
| **4** | severely unhealthy |
| **5** | dead |

## Notes for Supervisory Review

Make notes to flag a tree for review by project supervisor. Be sure to include relevant variable:

- Tree record identifier
- Location
- Tree photo
- Site type
- Land use
- Species
- Mortality status
- Basal sprouts
- Crown vigor
- Trunk diameter

# Appendix 2: Field Data Collection Sheet

The data sheet on the following page is intended for block-level street tree data collecting using the block edge distance method for location. When recording more than one d.b.h. value for a tree using this data sheet, write it on subsequent rows. When there are notes for supervisory review, put them in at the bottom, using the tree record identifier to denote which tree and the “For Variable(s)” area to denote the variables(s) to which the comment pertains.

| On Street: | From: | To: |
|---|---|---|

| Crew: | Date: |
|---|---|

| Tree Record Identifier | Dist from Corner | Street Side | Site Type | Land Use | Mort. Status | Basal Spr. | Crown Vigor | Species | d.b.h.* | d.b.h. Height* |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ev odd | | | | | | | | |
| | | ev odd | | | | | | | | |
| | | ev odd | | | | | | | | |
| | | ev odd | | | | | | | | |
| | | ev odd | | | | | | | | |
| | | ev odd | | | | | | | | |
| | | ev odd | | | | | | | | |
| | | ev odd | | | | | | | | |
| | | ev odd | | | | | | | | |
| | | ev odd | | | | | | | | |

* record multi-stemmed d.b.h. & d.b.h. height on subsequent rows

| Tree Record Identifier | For Variable(s) | Notes for Supervisory Review |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

# Appendix 3: Field Equipment

The following is a list of equipment that should be taken into the field for the Minimum Data Set outlined in this Field Guide. The project supervisor may add to or reduce the items listed here:

- Field guide and cheat sheet (appendix 1)
- Species ID resources (see Resource Guide, appendix 2)
- Clipboard, pencil and eraser, data collection sheets, camera or tablet or smartphone
- D-tape (with appropriate units) and/or other equipment to measure the trunk, as determined by the project supervisor
- Contractor-grade stiff measuring tape (to use when measuring height to d.b.h. point) or custom-cut 4.5 ft pole or survey rod
- Safety equipment, as determined by the project supervisor

Roman, Lara A.; van Doorn, Natalie S.; McPherson, E. Gregory; Scharenbroch, Bryant C.; Henning, Jason G.; Östberg, Johan P.A.; Mueller, Lee S.; Koeser, Andrew K.; Mills, John R.; Hallett, Richard A.; Sanders, John E.; Battles, John J.; Boyer, Deborah J.; Fristensky, Jason P.; Mincey, Sarah K.; Peper, Paula J.; Vogt, Jess. 2020. **Urban tree monitoring: A field guide.** Gen. Tech. Rep. NRS-194. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station. 48 p. https://doi.org/10.2737/NRS-GTR-194.

This report provides detailed protocols for urban tree monitoring data collection. Specifically, we discuss the core variables necessary for field-based monitoring projects, including field crew identification, field crew experience level, tree record identifier, location, site type, land use, species, mortality status, crown vigor, and trunk diameter. The intent of this Field Guide is to serve urban forest managers and researchers who collect longitudinal field data on urban trees, as well as interns and citizen scientists. This report is a companion document to *Urban Tree Monitoring: A Resource Guide*.

KEY WORDS: urban forest, street tree, tree mortality, tree growth, tree monitoring, yard tree