New USDA Forest Service Monitoring Guides Emphasize Tracking Individual Trees to Assess Change Over Time

By Natalie S. van Doorn and Lara A. Roman

Field monitoring of urban trees is essential to learning how urban forests change over time. Many arborists and urban forest managers worldwide seek to understand how their tree systems are faring in terms of growth, health, and mortality. How successful is an urban tree planting program with respect to mortality and survival? Has the tree species composition or total number of trees changed across a city or neighborhood? How much have the trees themselves grown? Long-term data collection can provide valuable information for urban forestry practitioners and researchers interested in these questions. To date, on-the-ground resource assessments have often taken the form of tree inventories, which generally capture a static snapshot of the resource. Existing inventory methods can generally work well to manage crew workflows, describe species diversity and structure of the tree system, manage tree risk, and map tree locations. Yet a single inventory can only capture a snapshot in time. If the intent is to track changes through time, an added level of detail and preparation is needed to assess change in a rigorous, meaningful way (Table 1). The new USDA Forest Service monitoring guides described here provide the means to move past a static snapshot of the urban forest and generate a dynamic look at tree populations in relation to mortality, growth, health, and population size.

These London planetrees (*Platanus × hispanica*) were measured in 2015 as part of a repeated, multi-age inventory project in Philadelphia, PA. Monitoring will enable the assessment of mortality and growth rates going forward, as well as changes in total tree counts and species composition. Photograph courtesy of LA Roman.

Tracking the fate of individual trees produces longitudinal data—meaning repeated observations of the same individuals—but also introduces unique challenges with data collection and management in contrast to inventories that were not designed to be repeated. For instance, even something as simple as reporting on the change in the number of trees over time is complicated by unclear definitions of "tree" (e.g., are large shrubs included? or palms?), requiring forethought for monitoring projects regarding which plants are "in" and "out" of the study. Inventory data is of course useful for a variety of urban forestry management applications, but inventories typically have a different purpose and may not be conducive to assessing change metrics. For example, both inventory collection and monitoring projects generally record the locations of individual trees. In a typical tree inventory, location can be used to map trees and inform work crews where to do maintenance, whereas for a monitoring project, location is needed to find the same individual tree in the field in future years. A property address as a location descriptor may be enough information for one use

Table 1. Key differences between typical urban tree inventories and the new monitoring guides. For more details comparing the monitoring guides to existing inventory systems, see section 1.4.2 in van Doorn et al. (2020) and citations therein.

	Typical urban tree inventory	New monitoring guidelines
Purpose	Tree risk and asset management	Assess change over time: mortality, growth, health, population size
	Manage tree crew workflow	
	Understand current species and size distribution	
Trunk diameter	Recorded to nearest inch or cm	Recorded to nearest 1/10 inch or mm
	Height at which trunk diameter is measured *is not* noted	Height at which trunk diameter is measured *is* noted
Mortality	Recorded as part of condition rating	Recorded separately, dead and removed trees distinguished
Location	Used to map trees and inform work crews where to do maintenance	Needed to find the same individual tree in the field in future years
Data structure	Static snapshot	Dynamic, with repeated observations
		Longitudinal database

(inventory) but not for the other (monitoring to report change metrics). Since many trees can exist at the same parcel, detailed tree location protocols are needed for monitoring to reliably relocate the same tree in future years. To be clear, monitoring projects are not inherently better than inventories, but rather these two ways of collecting urban tree data serve different purposes (Table 1).

The Development of the Urban Tree Monitoring Guides

In 2020, a team led by USDA Forest Service scientists produced a suite of resources to help urban forest professionals track their trees: a Field Guide (Roman et al. 2020) with detailed protocols, a Resource Guide (van Doorn et al. 2020) with tips, strategies, and training videos, and an archived webinar (see Literature Cited below for links). Together, these resources give detailed instructions regarding how to record a small set of variables consistently over time that will support adaptive management. The Field Guide has protocols for remeasuring trunk diameter to evaluate growth, mortality status, and tracking tree locations. The Resource Guide provides guidelines and best practices, everything from what to consider before starting a project, to managing field crews and keeping data in longitudinal databases.

These efforts were the culmination of a multi-year process, starting with listening to professionals to hear what was needed and would be the most useful, followed by consensus-building on best practices across a range of experts from academia, agencies, and other organizations, culminating in delivery through multi-media avenues. The final products represent the coproduction of knowledge across the interface of research and practice (Campbell et al. 2016). To further broaden the applicability of these monitoring resources, there is a Spanish translation in the works.

Taking a step back, the inception of the monitoring standards project is traced back to a survey (Roman et al. 2013) of municipal arborists, nonprofit urban foresters, and others who were already engaged in practitioner-driven monitoring (i.e., not monitoring instigated or led by researchers). Organizations wanted to be able to back up anecdotal observations about tree survivorship, removals outpacing plantings, and other aspects of program evaluation with empirical data. The importance of field-based monitoring was already clear to these urban forest professionals, but what was missing was a guide on how to do it, one focused on longitudinal tree data. Since that initial call to action, the development of the Field Guide was facilitated through the Urban Tree Growth and Longevity (UTGL) working group, an affiliate of the Arboriculture Research and Education Academy of the International Society of Arboriculture, and finalized by a team of 17 coauthors. Input from UTGL members was invaluable because it provided the perspectives of urban forestry professionals, where emphasis was placed on having the standards be flexible enough to accommodate needs from different programs with varying degrees of resources. For example, instead of promoting a particular trunk diameter measurement tool or location method, a range of tools (in cost and access) is presented with a discussion of each one's benefits and shortcomings. Likewise, because we recognize that urban forestry professionals already use a wide array of proprietary software for their tree data, we do not prescribe any particular software tool or mobile application, but do discuss monitoring-related issues to consider in any data collection platform.

A non-profit urban greening organization in Sacramento, CA tracks trees distributed through their shade tree program. Monitoring will enable the assessment of mortality and growth rates and associated ecosystem services, such as energy savings from shade and carbon sequestration, as well as the influence of stewardship actions. Photograph courtesy of the Sacramento Tree Foundation.

How Are These Resources Different from Other Efforts?

There are, of course, already different tree inventory protocols and systems available. Even just within the USDA Forest Service, there are protocols for the Forest Inventory and Analysis program and the *i-Tree* suite of tools related to ecosystem services, not to mention a plethora of proprietary tree inventory systems. However, the main point of difference is that the urban tree monitoring protocols exclusively focus on longitudinal tree data and enabling the assessment of change over time. For example, our specific protocols about measuring diameter at breast height (DBH) are geared towards remeasurement to assess DBH growth. This means recording DBH at the exact same height point on a tree over successive remeasurements and ideally measuring it to the nearest tenth-inch or mm. In addition to how to take measurements, these resources provide strategies for dealing with longitudinal data issues, such as how to structure longitudinal databases, something that is not needed in a one-time inventory. Our resources also adapt decades of best practices for tree monitoring, established in rural forest systems by academics and the USDA Forest Service, to urban settings and especially to urban forestry management applications.

Just as every organization or entity that works with trees is different, so are the needs and requirements of their monitoring programs. Every monitoring goal, whether it is detecting threats from pests or determining mortality and growth rates, has data needs. The intended objectives should be decided at the beginning of the project so that each monitoring goal can be linked to specific variables collected. There is no need to collect all possible data under the sun, because most of the time such efforts lead to extra variables that never get used (and thus wasted effort in field work). Our approach in developing the monitoring resources has been to follow a modular design, allowing for customization of a local monitoring project. An organization with very limited resources and whose goal is to only track survivorship may wish to apply only part of these methods, such as the mortality status categories and tree location techniques. An organization with more resources and a more complex set of goals, such as tracking tree health or monitoring the presence of an invasive pest, may want to include the full Minimum Data Set—these are the core variables for monitoring projects, including field crew identification and experience level, tree record identifier, location, site type, land use, species, mortality status, trunk diameter, and crown vigor. In addition, they would add fields specific to detecting pests. In the Resource Guide, we provide examples of pest detection protocols that users could adapt to their projects. The Field Guide also presents a spectrum of diagrams and images to assist with field work. For projects that apply the full Minimum Data Set, the Field Guide comes ready with an example data collection sheet, a cheat sheet to take out in the field, and a field equipment list. The Resource Guide also includes materials helpful for field crew training, such as a list of species identification resources and training activity plans.

Broadly, there are two types of monitoring projects: planting cohort monitoring and multi-age inventory monitoring. A planting cohort is a group of trees of a similar age planted around the same time. Monitoring of cohorts typically entails tracking planted trees within the same program. As time goes on, the total number of originally planted trees decreases as trees die or are removed. In contrast, a multi-age inventory monitoring program tracks trees within a given geographic area, whether streets in a city, or yards in a neighborhood, or all the trees on a college campus, regardless of when or by whom they were planted. Repeated data collection for these multi-age inventories may cut across different planting efforts, management actions, and disturbance impacts. Since urban forests are dynamic, and trees are planted and removed over time, new trees may be added to the inventory. These types of datasets can be analyzed for species composition change and population growth rate (i.e., how the total number of trees is changing, not to be confused with tree growth rates like DBH growth).

Each project, regardless of type, starts chronologically with baseline records. Baseline records are tree records from the first point in time for a particular monitoring project. In a planting project, the planting records are the baseline data, and for multi-age inventory projects, the first inventory or census is the baseline. To monitor for changes through time, it is crucial that these baseline records are designed for monitoring. For instance, if the height at which trunk diameter was measured was not recorded in the baseline data, a subsequent trunk diameter measurement may not be measured at the same spot on the trunk. Therefore, any differences in measurements between the two survey periods may reflect not actual growth of the tree, but rather, trunk taper or irregularities on the trunk (such as a bump or wound). In other words, without advanced planning for careful monitoring techniques, assessing DBH growth and how it varies by species becomes impractical. Similarly, advanced planning might also be necessary regarding how to measure low-forking multi-stemmed trees, such as ornamental cherries and crabapples, to assess trunk growth (Magarik et al. 2020). Likewise, if monitoring is taking place in a city with many palms, then special protocols are needed to assess palm health (Blair et al. 2019).

Monitoring Guides in Action

Urban forestry researchers, professionals, and educators have started using and adapting the urban tree monitoring guides to their programs. Here are some examples:

- *Repeated street tree census.* To track changes over time in street tree population composition, as well as growth and mortality rates and health changes, street tree plots were established in Philadelphia, PA and New York City, NY. Each plot consisted of 0.5 miles of road, representing several adjacent block segments. The project, a collaboration between the USDA Forest Service, The Nature Conservancy, the University of Connecticut, and Rutgers University, was established with longitudinal data in mind. Baseline data was collected in 2015, and repeat measurements will be taken in 2021.
- *Yard and community tree performance outcomes.* The Sacramento Tree Foundation (STF), a non-profit urban greening organization, sought to evaluate the performance of different cohorts of shade trees planted across Sacramento County, CA. The organization, in partnership with Sacramento Municipal Utility District, gives away approximately 10,000 trees per year to residents, schools, and parks to increase canopy and benefit the community. Tree mortality and growth data can serve as metrics of program success and improve estimates of associated ecosystem services. A monitoring program based on our guides was set up with the goal of tracking tree survivorship over longer time periods, tree health, stewardship context, and species-specific growth rates, in collaboration with researchers at the USDA Forest Service and several universities. Similarly, our guides have been used to monitor residential and park trees distributed through the Arbor Day Foundation in Houston, TX, in partnership with the Texas Forest Service, and through the MA Department of Conservation and Recreation, in partnership with students and faculty from Clark University and the University of Massachusetts Amherst (Breger et al. 2019).

Students from the University of Massachusetts Amherst receive training on how to carefully measure DBH on a tree in Holyoke, MA. Photograph courtesy of LA Roman.

- *Citizen science monitoring of young street trees.* Many urban forestry non-profit programs use volunteers to monitor recently planted trees. One example of this is the Tree Checkers program at the Pennsylvania Horticultural Society in Philadelphia (Roman et al. 2018). This monitoring project produced tree mortality rates to evaluate program performance while simultaneously spurring volunteers to engage with residents and encourage stewardship. This monitoring program has incorporated methods from our guides for both data collection and training with the USDA Forest Service Philadelphia Field Station.
- *Climate-ready trees evaluation.* The climate-ready trees study evaluates the tolerance of underutilized tree species to stressors associated with climate change, such as drought and more extreme storms (McPherson et al. 2018). Tree species were selected for three climate zones in California. Young trees were planted in reference sites on university experimental stations as well as urban parks, allowing for direct comparisons of growth and survival under a range of site conditions. Trees have been monitored annually for mortality, growth, health, and suitability as urban trees (e.g., arboricultural/structural characteristics and maintenance needs) for five years, and moving forward will be visited every other year for a total of twenty years by the USDA Forest Service Pacific Southwest Research Station.
- *Undergraduate education.* Our Field Guide has been used to teach undergraduates about urban tree data collection and monitoring techniques at universities such as the University of Wisconsin Stevens Point and the University of California Davis. Faculty may find different components of the Field Guide relevant to their courses, such as the sections on evaluating crown vigor or measuring trunk diameter.

A desert museum palo verde (*Parkinsonia* × 'Desert Museum') is checked for presence of pests and disease as well as structural characteristics in an urban park in Sacramento, CA as part of the climate-ready trees project. Photograph courtesy of EG McPherson.

Conclusion

Tree monitoring is increasingly recognized as an important component of urban forest management. Moving from planting records and static inventories towards longitudinal data tracking for individual trees requires advanced planning and special considerations for long-term repeated observations. While inventories are extremely useful on their own, only monitoring can produce metrics of change. Our new resources help urban forestry and urban greening professionals to track the trees that they plant and manage by adapting best practices and field protocols from forest ecology to urban settings.

Literature Cited

Blair SA, Koeser AK, Knox GW, Roman LA, Thetford M. 2019. Visual health assessments for palms. *Urban Forestry & Urban Greening*. 41:195-200. https://doi.org/10.1016/j.ufug.2019.03.017

Breger BS, Eisenman TS, Kremer ME, Roman LA, Martin DG, Rogan J. 2019. Urban tree survival and stewardship in a state-managed planting initiative: A case study in Holyoke, Massachusetts. *Urban Forestry & Urban Greening*. 43:126382. https://doi.org/10.1016/j.ufug.2019.126382

Campbell LK, Svendsen ES, Roman LA. 2016. Knowledge co-production at the research-practice interface: Embedded case studies from urban forestry. *Environmental Management*. 57:1262-1280. https://doi.org/10.1007/s00267-016-0680-8

Magarik YAS, Roman LA, Henning JG. 2020. How should we measure the DBH of multi-stemmed urban trees? *Urban Forestry & Urban Greening*. 47:126481. https://doi.org/10.1016/j.ufug.2019.126481

McPherson EG, Berry AM, van Doorn NS. 2018. Performance testing to identify climate-ready trees. *Urban Forestry & Urban Greening*. 29:28-39. https://doi.org/10.1016/j.ufug.2017.09.003

Roman LA, McPherson EG, Scharenbroch BC, Bartens J. 2013. Identifying common practices and challenges for local urban tree monitoring programs across the United States. *Arboriculture & Urban Forestry*. 39(6):292-299.

Roman LA, Smith BC, Dentice D, Maslin M, Abrams G. 2018. Monitoring young tree survival with citizen scientists: The evolving Tree Checkers program in Philadelphia, PA. *Arboriculture & Urban Forestry*. 44(6):255-265. https://doi.org/10.48044/jauf.2018.023

Roman LA, van Doorn NS, Dentice D. 2020. New guidance for tracking long-term tree survival, growth, and health. Urban Forest Connections Webinar, USDA Forest Service, 2020 Sep 9. https://www.fs.fed.us/research/urban-webinars/tracking-tree-survival-growth-health.php

Roman LA, van Doorn NS, McPherson EG, Scharenbroch BC, Henning JG, Östberg JPA, Mueller LS, Koeser AK, Mills JR, Hallett RA, Sanders JE, Battles JJ, Boyer DJ, Fristensky JP, Mincey SK, Peper PJ, Vogt J. 2020. Urban tree monitoring: A field guide. Madison (WI, USA): US Department of Agriculture Forest Service, Northern Research Station. General Technical Report NRS-194. 48 p. https://doi.org/10.2737/NRS-GTR-194

USDA Forest Service. 2020. Urban tree monitoring: A 5-part training series. Washington (DC, USA): USDA Forest Service. https://www.youtube.com/playlist?list=PLNsZX2SBTlVne-C52PUv-eewpu4vWXCAN

van Doorn NS, Roman LA, McPherson EG, Scharenbroch BC, Henning JG, Östberg JPA, Mueller LS, Koeser AK, Mills JR, Hallet RA, Sanders JE, Battles JJ, Boyer DJ, Fristensky JP, Mincey SK, Peper PJ, Vogt JM. 2020. Urban tree monitoring: A resource guide. Albany (CA, USA): US Department of Agriculture Forest Service, Pacific Southwest Research Station. General Technical Report PSW-GTR-266. 132 p. https://doi.org/10.2737/PSW-GTR-266

Natalie S. van Doorn, USDA Forest Service, Pacific Southwest Research Station, Albany, CA, USA

Lara A. Roman, USDA Forest Service, Northern Research Station, Philadelphia, PA, USA

MULTIMEDIA SPOTLIGHT

The Climbing Arborist Podcast

Hosted by Dan Holliday, an ISA Certified Arborist® with over 13 years in the industry, The Climbing Arborist podcast invites guests to talk about all things arboriculture, their stories, experiences, successes, and lessons learned. Topics frequently discussed on these podcasts include equipment, techniques, safety, training, and much more.

Media type: podcast

Cost: none / free

Where to watch: https://www.climbingarborist.com/podcasts

More information: https://www.climbingarborist.com