Arboriculture & Urban Forestry 2026. 52(2):186–202
https://doi.org/10.48044/jauf.2026.007

Virtually Tracking Planted Urban Tree Survival with Street-Level Imagery

By Lara A. Roman, Adam Berland, Sabine Nix, and Dana Dentice

Abstract. Background: Street tree plantings are common in urban greening programs, and these trees provide important ecosystem services that increase as trees survive to maturity. Field-based monitoring to understand mortality rates and causes is valuable for urban forest management but very time-consuming. Methods: We used street-level imagery to virtually monitor survival for 2,884 street trees over several years postplanting in Philadelphia, Pennsylvania, United States. Results: We observed similar mortality rates to other studies, with 7.5% of trees dead or removed by the first summer after planting and the mortality rate dropping to 3.5% between the third and fourth summers postplanting. Logistic regression models were constructed over various time horizons to understand which site, neighborhood, and species characteristics related to survival outcomes. These models showed that higher tree survival was associated with less impervious surface surrounding the tree; lower social vulnerability in the neighborhood; and tree planting in the fall season as opposed to spring. Conclusions: Our results point to management activities that could improve survival outcomes, such as planting site enhancements and establishment maintenance, as well as the use of monitoring data to drive decisions regarding planting season. This study demonstrates the value of street-level imagery interpretations to provide mortality data on a large number of street trees planted over multiple years.

Keywords. Civic Science; Street Tree; Street View; Tree Mortality; Tree Planting Initiative; Urban Forest Management.

INTRODUCTION

Urban tree planting initiatives have become a widespread form of urban greening in cities around the world (Eisenman et al. 2022; UNECE 2024), with planting campaigns motivated by the ecosystem services provided by urban canopy (Silvera Seamens 2013). Street trees generally comprise a small fraction of overall urban canopy cover—which can be dominated by trees in parks and private properties—but street tree planting and stewardship are often the front lines of engagement for urban tree programs (Roy 2017; Elton et al. 2023). Additionally, trees are an essential component of street design to enhance urban livability (Coleman et al. 2022). In cities and towns around the globe, streetscapes can be the primary opportunity for tree planting in neighborhoods with high building density where houses do not have yards (Hall et al. 2012), including low-income and low-canopy communities (Riedman et al. 2022), making street tree planting and care critical to advancing environmental justice (Grant et al. 2024). Street trees are particularly important for mitigating urban heat islands and providing pedestrian thermal comfort (Ettinger et al. 2024; Jayasingh et al. 2024), and they are also central to green stormwater infrastructure systems in aging neighborhoods facing flooding challenges (Berland et al. 2017). Furthermore, the planting, maintenance, and removal of trees along streets dominate municipal tree management budgets (Hauer and Peterson 2016). The survival of planted street trees is therefore vital for the sustained benefits of this public resource, with a pronounced relevance in low-canopy neighborhoods.

Urban tree monitoring for mortality and survival enables urban forestry professionals and researchers to understand the performance of planting programs (Wattenhofer and Johnson 2021). A literature review revealed that typical annual mortality during the first 5 years after planting was 6.6% to 7.0%, with post-establishment annual mortality dropping to 2.8% to 3.8% (Hilbert et al. 2019). Based on those annual mortality rates, the typical population half-life for a planted tree cohort is 13 to 18 years; in other words, half the trees are dead or removed by about 15 years after planting. Improved long-term survival would yield greater ecosystem services (Widney et al. 2016). It is therefore imperative to understand the factors associated with mortality to enable realistic performance expectations and targeted program interventions (Wattenhofer and Johnson 2021; Moore 2022). With recent massive investments in urban tree planting initiatives in countries around the world, coproduced monitoring efforts across research and practice present an opportunity for learning and adaptive management (Campbell et al. 2016; Eisenman et al. 2025). Knowledge coproduction is a collaborative process to bring together different types and sources of knowledge for problem solving (Armitage et al. 2011). In the context of evaluating tree planting projects, such coproduction typically involves collaboration between researchers in government or academia and urban forestry professionals working for municipalities, states, nonprofits, or private companies (Campbell et al. 2016; Roman et al. 2018a; Vogt and Abood 2020).

Factors associated with urban tree mortality include taxonomic groups, site characteristics, planting technique and season, nursery stock, maintenance levels, construction, and socioeconomic characteristics (Cregg and Ellison 2018; Breger et al. 2019; Hilbert et al. 2019; Roman et al. 2022). Tree age and size are often related to mortality, with younger or smaller trees having higher mortality rates, reflecting vulnerabilities during early establishment (Hilbert et al. 2019; Bigelow et al. 2024). With respect to socioeconomic characteristics, there can be higher mortality in neighborhoods with lower socioeconomic status, but results are sometimes contradictory (Hilbert et al. 2019). Tree growth, health, and mortality are impacted by characteristics of planting sites, including soil condition and the extent of nearby impervious surfaces (Sanders and Grabosky 2014; Scharenbroch et al. 2017; Bigelow et al. 2024). For recently planted trees, there is a strong association between mortality outcomes and poor planting technique or inadequate maintenance (Yang and McBride 2003; Breger et al. 2019), and high survival has been found where there are professional expertise and consistent maintenance, including irrigation (Koeser et al. 2014; Roman et al. 2014; Roman et al. 2015). When residents are responsible for irrigation, tree survival can be enhanced through collective watering strategies or signed watering agreements (Mincey and Vogt 2014). More broadly, failure to maintain trees (including irrigation, mulching, and pruning) results in lower tree health and survival, as well as higher costs for replacement plantings and structural challenges as trees mature (Vogt et al. 2015a). The many factors related to urban tree mortality also vary by local ecological, institutional, and social context, making investigations into local planting initiatives critical to understand mortality patterns at scales relevant to program management.

Past mortality studies of planted urban trees have been carried out through field work, often representing a sample of the trees planted through a given program (e.g., Koeser et al. 2014; Vogt et al. 2015b; Elmes et al. 2018; Salisbury et al. 2022). However, recent research has illustrated the feasibility of virtual data collection through street view (SV) imagery, which has the potential to expand the temporal and geographical scale of monitoring. SV imagery, which is generally captured by cameras mounted on vehicles, offers a ground-level panoramic view along streets. In comparison to field work, SV manual data collection can be faster and less expensive, especially since there are no transportation costs (Berland and Roman 2020). However, there are limitations: tree diameter, species identification, health evaluations, and risk assessment can be challenging or impractical for SV interpretation (Berland and Lange 2017; Berland et al. 2019; Meunpong et al. 2019). Therefore, depending on data quality needs, SV imagery is not appropriate for all urban forestry research and management applications. However, SV is especially well-suited to tracking the mortality of recently planted trees for which there are already baseline records with accurate species and location (Berland and Roman 2020). Although the aforementioned studies involved manual inspection of SV imagery, there have been advances in using machine learning to conduct automated inventories (Branson et al. 2018; Laumer et al. 2020; Beery et al. 2022; Choi et al. 2022) and quantify streetscape tree cover or green view index (Li et al. 2015; Seiferling et al. 2017). Given the proliferation of tree planting initiatives in cities around the world, monitoring through SV is a promising avenue to evaluate planting performance.

Another strategy for young tree monitoring that has gained prominence in recent years is volunteer-based data collection, sometimes called citizen science or civic science (Roman et al. 2018a). Across the

United States of America (USA), volunteers have been utilized for tree inventories (Boukili et al. 2017; Bancks et al. 2018; Crown et al. 2018; Johnson et al. 2018) and monitoring recently planted trees (Roman et al. 2018b). Such civic science programs engage local communities and are part of larger trends of extensive volunteer engagement in urban forestry in the USA (Hauer et al. 2018). Additionally, for both field and virtual data collection, volunteer data quality is high for simple tasks like determining mortality status and tree counts (Roman et al. 2017; Berland et al. 2019).

In this study, we tracked recently planted street tree survival and mortality from a planting program in Philadelphia, Pennsylvania, USA. We generated data using manual interpretation of SV imagery, complemented by civic science monitoring records, to demonstrate the application of virtual monitoring to local program assessment. We asked the following questions: (1) how do survival rates in this local program compare to typical rates from a literature review (Hilbert et al. 2019); and (2) how is establishment survival of these street trees related to site, neighborhood, and species characteristics? We then situate these findings with a reflection on the potential for large-scale virtual monitoring of tree planting initiatives.

METHODS

We used virtual monitoring of street tree survival following pilot testing by Berland et al. (2019) and a coproduced transdisciplinary research approach (Campbell et al. 2016; Vogt and Abood 2020) involving research scientists, planting program staff, and students codeveloping the methods and interpreting the findings. Research scientists conceptualized the study and analyzed the data, while an undergraduate student devised the data collection protocol, and a planting manager advised on conceptualization, data collection, and interpretation.

Study System

Located in the mid-Atlantic region of the USA, Philadelphia's natural ecosystems are mainly deciduous forests. The city typically has steady precipitation throughout the year (1,120 mm/yr)(NOAA 2021). Summers are humid and hot (average July temperature 25.9 °C), winters are cold (average January temperature 0.9 °C), and spring and fall are mild (NOAA 2021). In this region, spring and fall are considered the best times of year for tree planting (Jackson 2023; Miklas 2023).

Philadelphia had 1.6 million people as of 2020, making it the sixth-largest city in the USA. The city's diverse human population is 38.3% Black, 34.3% White, 8.3% Asian, and 14.9% Hispanic/Latino (The Pew Charitable Trusts 2022). Philadelphia is the poorest of the 10 largest cities in the USA, with 23% of residents living in poverty (The Pew Charitable Trusts 2021). As a postindustrial city whose population peaked at 2 million in the 1950s, Philadelphia has experienced challenges common to postindustrial cities in the USA and globally, including depopulation, reduced tax base for city services, and land vacancy, with accompanying steep declines in staffing and resources for municipal tree management (Roman et al. 2021).

Many Philadelphia neighborhoods have older housing stock (41% built prior to 1939)(The Pew Charitable Trusts 2021) and small residential lots with little to no yard space (Riedman et al. 2022). Common housing types in the city include attached units known as rowhomes (i.e., entire city blocks of relatively narrow attached houses) and twins (i.e., two homes sharing a single wall). Philadelphia's streets generally have sidewalks, and many neighborhoods have substantial pedestrian traffic, as 29% of the city's households do not have cars (The Pew Charitable Trusts 2021). Street trees are therefore a critical part of urban greening strategies in this city. Philadelphia's overall tree cover was 20% as of 2018, with considerably lower canopy in low-income neighborhoods (O'Neil-Dunne 2019). Municipal leaders set a goal to achieve 30% canopy in every neighborhood (City of Philadelphia 2009) and Philadelphia Parks and Recreation released an urban forest strategic plan in 2022 centered around environmental justice (PPR 2023). Street trees are also integral to city plans and initiatives regarding mitigation of urban heat islands (Jaramillo 2020) and stormwater runoff (PWD 2011).

The Tree Tenders program at the nonprofit Pennsylvania Horticultural Society (PHS) was founded in 1993 for community-based urban tree education, planting, and care. This program began at a time when Philadelphia's park agency, which has legal jurisdiction over street tree management, had undergone severe cuts in budget and personnel (66% staff reduction between 1970 and 2000)(Roman et al. 2021). Residents that have taken an 8 hour to 9 hour course on tree planting, care, advocacy, and community organizing are considered official Tree Tenders, and trained individuals partner with their neighbors to create geographically based Tree Tenders groups. Volunteer Tree Tenders group leaders take on substantial labor for tree planting and associated tasks (Riedman et al. 2024). These groups gather requests for free trees from neighborhood residents and property owners. PHS facilitates volunteer plantings each fall (mid-November) and spring (late April, coinciding with Arbor Day celebrations in Pennsylvania). Over the past decade, 800 to 1,300 trees have been planted annually through Tree Tenders in Philadelphia, mostly street trees. PHS began offering Tree Tenders training in Spanish in 2018, and in recent years staff have been prioritizing equity and environmental justice, including plantings in low-income areas and communities of color (Grant et al. 2024).

The Tree Tenders plantings are bare root stock, following previous investigations which found that bare root is a viable alternative to balled-and-burlapped stock (Jack-Scott 2011; Roman et al. 2018b). Trees are purchased from a nursery in upstate New York and shipped on climate-controlled tractor trailers, with roots dipped in hydrogel and encased in large plastic bags. When received by PHS, the trees are inspected by staff and stored in a warehouse with appropriate climate for bare root trees for up to 3.5 days before pickup by neighborhood TT groups. Planting group leaders are advised on the proper way to store bare root trees for several more days before planting, particularly with respect to temperature and protecting roots.

In Philadelphia, property owners formally own the street trees in front of their properties, while the municipal department Philadelphia Parks and Recreation maintains jurisdiction, requiring permits for planting and removal (PPR 2023). Municipal arborists are responsible for approving proposed Tree Tenders planting sites and selecting species. Residents and property owners receiving trees through Tree Tenders are responsible for establishment tree maintenance (e.g., irrigation, adjusting stakes, reapplying mulch), but neighborhood Tree Tenders groups may also help with pruning and pit care, although such group assistance to residents varies tremendously across neighborhoods. Tree Tenders volunteer groups operate semi-autonomously, providing labor for recruitment, event coordination, monitoring, and sometimes maintenance (Riedman et al. 2024). The Tree Tenders handbook calls for irrigating trees 57 L to 75 L/week during the growing season in the early establishment years (Maslin 2005). Establishment maintenance is done by a mix of property owners, tenants, and neighbors. During the first summer after planting, a visit by Tree Checkers volunteers involves talking to residents or leaving a note with reminders about young tree maintenance needs, especially irrigation (Tree Checkers is explained more in the Methods).

For purposes of this research, we considered street trees to be trees located in sidewalks (e.g., in cut-outs or planting strips) or medians, following Bigelow et al. (2024). A tree in a private yard within the roadside right-of-way where there is no sidewalk was not a street tree for this study. We do not have measurements for individual street tree sites, but in general, Philadelphia is an older city with narrow sidewalks, with relatively small planting sites.

Data Collection

We used Tree Tenders planting data from Fall 2015 through Spring 2019 (Table 1), monitoring all planted street trees from these several years of planting. As described below, methods were adapted from Berland et al. (2019) and Roman et al. (2020).

Virtual Monitoring

Virtual data collection involved Google SV, as well as the Philadelphia Atlas (an online tool for parcel-level municipal data)(Eaton 2019) and the PHS Urban Forest Cloud (an online tree inventory software from

Table 1. Street trees planted in Philadelphia through the Tree Tenders program that were monitored for this study.

Planting season	Year	Number planted
Fall	2015	374
Spring	2016	349
Fall	2016	371
Spring	2017	272
Fall	2017	300
Spring	2018	333
Fall	2018	523
Spring	2019	362
	Total	**2,884**

PlanIT Geo, customized for PHS planting records) (Roman et al. 2018b). The data collection workflow proceeded as follows. A given tree's address was entered into Google SV, as well as Philadelphia Atlas and PHS Urban Forest Cloud, to aid in confirming that the correct tree in front of the correct property parcel was being evaluated. Once the tree identity, species, and location were confirmed, mortality status was recorded for each time that SV imagery was available, relying on imagery from the growing season when trees are expected to be leafed out (May through September, i.e., when trees lacking leaves can be interpreted as dead). Notably, Google SV provides month and year of imagery, not exact dates.

For relatively narrow rowhomes with only a single tree in front, latitude and longitude coordinates were generally precise, as PHS tree geocoding involves automatically "pushing" trees to the sidewalk. However, for corner properties or larger properties, tree locations sometimes appeared as "stacked points" on the sidewalk. In such situations, individual tree locations were triangulated from multiple SV angles (Leatherbarrow 2019).

For each time that imagery was available, trees were categorized as alive, dead, or removed. A street tree considered to be alive possessed green leaves (or other appropriate color, depending on cultivar); even severely unhealthy trees were considered to be living. Trees were also categorized as alive when an obstruction prevented full visibility or when SV was not available for a given year yet subsequent imagery revealed the tree to be alive. Trees were categorized as dead when they did not possess any leaves in May to September imagery. Both trees observed dead and those observed removed (including stumps) counted towards mortality.

One student interpreter carried out initial virtual data collection, with all records then double-checked by a second student interpreter. When a tree could not be confidently located, or when there was disagreement across the interpreters, the tree was flagged, and quality assurance activities were conducted as follows. Review sessions with the project research lead were conducted on a regular basis, at least once per week. If a tree could not be located accurately and coded clearly in this initial review, the tree was flagged again and documented for further review with PHS staff. Two of these second-round reviews were conducted. In these reviews, planting records and past email correspondences with Tree Tenders group leaders were referenced so that PHS staff and interpreters reached consensus. Trees that were still unable to have their locations confidently confirmed were excluded from further analysis (11 trees). Yard trees were also excluded from analysis (457 trees), as such trees are not reliably easy to discern from Google SV. Instances of clearly duplicate data rows were excluded (18 trees). Trees that lacked survival observations in any year (from SV imagery or volunteers, see below) were excluded (18 trees). The total sample of street trees with known mortality/survival status in at least one year was 2,884, with varying subsets used for the analyses to follow, depending on data availability at different time steps since planting.

Civic Science Field Data

Tree Checkers, started in 2011, is an offshoot of Tree Tenders that encourages volunteers to participate in civic science field monitoring in the first summer after planting (Roman et al. 2018b). Volunteers attend a 2-hr training about data collection and the PHS Urban Forest Cloud. Tree Checkers is required of all Tree Tenders groups, but not all choose or are able to participate (Riedman et al. 2024). Of the 2,884 trees in our study, 80.7% had Tree Checkers mortality status for the first summer after planting. When SV imagery was not available for the first summer after planting, and Tree Checkers data was available, we used the latter to complement the virtual data collection.

Analysis

Survival Rates

To address our first research question, we combined all planting years/seasons together and summarized survival (% alive) and mortality (% dead/removed) rates in 7 ways: (1) planting to first summer; (2) planting to second summer; (3) planting to third summer; (4) planting to fourth summer; (5) first to second summer; (6) second to third summer; and (7) third to fourth summer. Notably, the percent survival and mortality exclude missing observations, with the number of missing observations varying at each time step. Note that the monitoring period from planting to first summer was less than a full year, and monitoring for subsequent years was approximately one full year (one summer to the next summer) depending on Google SV imagery dates. Therefore survival and mortality between one summer and the next represent annual survival and annual mortality, respectively (Roman et al. 2016).

To summarize performance at the species level, we calculated survival rates for the 7 taxa with over 100 individuals planted, which account for 59% of all 2,884 trees. Due to the wide array of cultivars and hybrids for *Prunus* and *Malus*, these taxa were analyzed at the genus level. To provide these taxa-level findings in a manner more useful to managers, survival rates were separated by planting season.

Site, Neighborhood, and Species Characteristics Related to Mortality

We used logistic regression modeling to understand how site, neighborhood, and species characteristics relate to tree survival outcomes. We followed an iterative model building approach from Hosmer et al. (2013). Briefly, this approach begins by constructing individual models for each candidate independent variable and the dependent survival outcome (1 = survival, 0 = mortality). Candidate variables with P-values < 0.25 in their individual models were then combined into a multiple logistic regression model. Variables with $P > 0.05$ were removed from the multiple logistic regression model, and then excluded variables were entered into the model one-by-one to be sure that their explanatory power did not increase substantially in the presence of other independent variables in the model. Next, we checked for interactions among independent variables using both statistical evidence and potential real-world relevance (for example, it is plausible that species drought tolerance could interact with the amount of impervious surfaces surrounding the planting site). Once a final model was developed, we assessed its performance using the area under the ROC curve (AUC) following Hosmer et al. (2013). AUC values range from 0 to 1, where values above 0.5 and approaching 1 indicate increasingly better model performance. We constructed 6 logistic regression models to describe survival outcomes over different time horizons. Four models analyzed survival outcomes from planting to the first through fourth summers, respectively. Two additional models were constructed to explain survival from summer one to summer two, and from summer two to summer three. We did not create a model for survival from summer three to summer four due to low sample size.

Various species, neighborhood, and planting site characteristics were included in the model building process as candidate independent variables (Table 2). Native status, mature size, and drought tolerance were species traits that could plausibly influence tree performance. These species traits were derived primarily from the University of Florida's tree fact sheets (University of Florida 2013) and complemented by the Missouri Botanical Garden Plant Finder (Missouri Botanical Garden 2018) and nursery listings for cultivars.

Planting season has been related to mortality in several studies (Hilbert et al. 2019). Tree Tenders group activity captured neighborhood stewardship within the PHS planting program, where high-activity groups were those that planted more than the median number of trees ($n = 48$), participated in planting for at least the median number of seasons ($n = 6$), and served on the citywide Tree Tenders committee. Low-activity groups planted less than 48 trees, participated fewer than 6 seasons, and/or did not serve on the committee. The remaining 8 Tree Tenders groups fell between high and low and were categorized as medium activity. We expected that high-activity groups may also provide greater maintenance and thereby improve survival.

Impervious surfaces may impact tree vigor and survival by limiting soil volumes, increasing heat stress, and altering hydrology (Sanders and Grabosky 2014; Just et al. 2018). We calculated the percentage of impervious surfaces within 15 m of each tree, based on 2015 high-resolution impervious surface data from Pennsylvania Spatial Data Access (PASDA 2025). Construction or demolition activities could impact tree survival by disrupting the tree above or belowground, or by directly resulting in tree removal (Morgenroth et al. 2017; Roman et al. 2022). We used building and zoning permit data from OpenDataPhilly (OpenDataPhilly 2010) to determine whether construction and/or demolition took place within 15 m of the tree during the time frame when a given tree existed at a site (e.g., a demolition event taking place in the year prior to a tree being planted, or in the year after a tree was removed, would not be considered). For both impervious surfaces and construction, a distance of 15 m was chosen to reflect the expectation that these effects would be localized in close proximity to the tree and for consistency with another street tree study in Philadelphia (Bigelow et al. 2024). Finally, we included a measure of social vulnerability because tree mortality has commonly been related to socioeconomic characteristics (Hilbert et al. 2019). We used the Social Vulnerability Index (SVI)(ATSDR 2024),

Table 2. Variables considered in regression models for tree survival. CDC/ATSDR (Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry).

Variable	Values	Description	Values observed (*n* = 2,884)
Native status	Yes, no	Is the species native to Pennsylvania?	45.3% yes, 54.6% no
Mature size	Small, medium, large	Mature tree size category	33.3% small, 50.0% medium, 16.6% large
Drought tolerance	Low-medium, high	Species drought tolerance category. Low and medium categories were combined due to small sample sizes for low tolerance.	63.6% low-medium, 36.4% high
Planting season	Fall, spring	Fall plantings occurred in November, and spring occurred in April	54.4% fall, 45.6% spring
Tree Tenders group activity	Low, medium, high	Neighborhood tree steward groups were categorized based on total trees planted, seasons involved in planting, and participation on the Tree Tenders committee.	12.4% low, 20.0% medium, 67.6% high
Impervious surfaces	Continuous	Percent impervious cover within 15 m of the tree	Range = 16.9% – 100%; 25th percentile = 81.9%; 50th percentile = 95.9%; 75th percentile = 99.6%
Construction	Yes, no	Was there an active construction and/or demolition permit issued within 15 m of the planting site?	34.1% yes, 65.9% no
Social vulnerability	Continuous	CDC/ATSDR Social Vulnerability Index, ranging from 0 (low vulnerability) to 1 (high vulnerability)	Range = 0.042 – 0.994; 25th percentile = 0.426; 50th percentile = 0.665; 75th percentile = 0.849

an index that is comprised of 16 USA Census variables capturing socioeconomic status, household characteristics, racial and ethnic minority status, and housing type and transportation. We used the composite SVI index, and values for each tree planting site were derived using inverse distance weighting to interpolate SVI values from census tract polygons to tree point locations.

Geospatial data processing was conducted using ArcGIS Pro (ESRI, Redlands, CA, USA). Statistical analyses were conducted in R (R Foundation, Vienna, Austria) with packages aod (Lesnoff and Lancelot 2023), lmtest (Zeileis and Hothorn 2002), and ROCR (Sing et al. 2005).

RESULTS

Survival Rates

The overall survival decreased from 92.5% alive in the first summer after planting to 77.1% alive by the fourth summer after planting (Table 3). Mortality rates decreased over time, with 7.5% dead/removed by the first summer, 5.6% dead/removed between the first and second summers, and 3.5% between the third and fourth summers.

For the 7 most common taxa, survival rates varied according to taxa and planting season (Table 4). For example, *Prunus* spp. tended to have higher survival for fall plantings while *Gleditsia triacanthos* had higher survival for spring plantings. However, other taxa were not consistent with respect to survival trends according to planting season.

Site, Neighborhood, and Species Characteristics Related to Survival

Logistic regression models showed that several factors were associated with tree survival (Tables 5 and 6). Across 4 of the 6 models, higher impervious surface levels were significantly associated with lower survival, and it was the only factor included in the model for survival from planting to first summer. For every increase of one percentage point in impervious cover, a tree was 0.987 times less likely to survive from planting to first summer (i.e., the odds ratio estimate); stated another way, for every one percentage point decrease in impervious cover, a tree was 1.01 times more likely to survive from planting to first summer. In other models, the effect size of this relationship slightly intensified. Impervious surfaces were

Table 3. Percent of trees observed to be alive and dead/removed at various time horizons (excluding missing observations). Rows reporting data from one summer to the next only include trees that were observed to be alive in the earlier summer.

Time period	Alive		Dead/removed		Missing observations
	Count	Percent	Count	Percent	
Planting to 1st summer	2,637	92.5	213	7.5	34
Planting to 2nd summer	1,618	87.2	238	12.8	143
Planting to 3rd summer	1,044	80.9	246	19.1	76
Planting to 4th summer	523	77.1	155	22.9	45
Summer 1 to summer 2	1,618	94.4	96	5.6	101
Summer 2 to summer 3	1,044	96.3	40	3.7	34
Summer 3 to summer 4	523	96.5	19	3.5	28

Table 4. Percent of trees in the most common taxa observed to be alive. Observations are summarized by planting season and time period. Numbers represent the percent of trees alive at the beginning of the period that were also alive at the end of the period.

Species	Count	Planting to first summer		Summer 1 to summer 2		Summer 2 to summer 3		Summer 3 to summer 4	
		Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Prunus spp.	581	94.8	91.6	95.9	93.7	98.4	96.1	98.4	95.3
Syringa reticulata	308	93.5	96.2	93.5	91.3	100.0	96.3	90.9	89.7
Malus spp.	224	92.3	96.2	94.8	98.5	91.2	86.8	100.0	100.0
Cladrastis kentukea	203	92.7	89.1	96.0	94.7	88.9	96.8	100.0	95.2
Amelanchier laevis	135	91.8	93.0	100.0	96.2	93.8	90.3	n/a	92.3
Amelanchier × *grandiflora*	124	90.1	93.1	100.0	100.0	93.9	94.7	100.0	n/a
Gleditsia triacanthos var. *inermis*	123	98.7	100.0	100.0	100.0	97.4	100.0	100.0	100.0

included in the model for survival from first to second summer, but their impact was not significant.

Higher social vulnerability was significantly associated with lower survival in all models except planting to first summer. For every unit increase in the index, a tree was 0.371 times less likely to survive from planting to second summer; stated another way, for every unit decrease in the vulnerability index, a tree was 2.70 times more likely to survive from planting to second summer.

Planting season was significantly associated with survival in 4 of the 6 models, and spring planting had poorer survival outcomes than fall planting. Trees planted in the spring were 0.667 times less likely to survive from planting to second summer; in other words, trees planted in the fall were 1.50 times more likely to survive from planting to second summer.

Trees classified as low-medium drought tolerance were significantly associated with higher survival (as compared to high drought tolerance) in 3 models. The model for survival from planting to fourth summer was the only model to show lower survival for medium Tree Tenders group activity (compared to high activity). Mature tree size was also included in the model from planting to fourth summer, but it was not significant.

DISCUSSION

The mortality and survival rates for recently planted street trees found in this study align with typical establishment mortality from the Hilbert et al. (2019) literature review. In that review, across 16 studies reporting annual mortality rates in the first 5 years after planting, the 25th, 50th, and 75th percentiles were

2.81% to 3.76%, 4.40% to 6.48%, and 7.09% to 9.33%, respectively. Our mortality rates for planted street trees in Philadelphia were at the high end of this range for planting to first summer (7.5%). Notably, planting to first summer was less than a full year of time, as trees were planted in November and April, and SV imagery was observed May through October. This finding suggests that mortality rates may be markedly higher in the first few months after planting, compared to later in establishment. The annual mortality rates in our study dropped considerably as time progressed, lowering after the first-to-second summer (5.6%) to the second-to-third (3.7%) and third-to-fourth (3.5%) summer intervals. Indeed, these mortality rates several years after planting are similar to annual mortality observed across all ages and size classes of street trees in Philadelphia (3.7%)(Bigelow et al. 2024) and Cambridge, Massachusetts, USA (3.6%)(Boukili et al. 2017). Therefore, heightened mortality may be most pronounced in the first two years after planting. Accordingly, managers might consider interventions to boost street tree survival during the first two years, when trees are most vulnerable.

In our study, the variables that predicted survival in most models were: (1) level of impervious surface; (2) social vulnerability; and (3) planting season. The level of impervious surface was the only significant predictor of survival for the model concerning planting to first summer, and this variable was included in most other models. Previous research has similarly found that trees surrounded by higher levels of impervious surface were more likely to experience mortality, as well as slower growth, lower health, and heightened heat stress (Sanders and Grabosky 2014; Scharenbroch et al. 2017; Bigelow et al. 2024). Street tree stress in highly paved sites also relates to limited water availability (Schütt et al. 2022). Given the generally high levels of impervious surfaces surrounding the trees in our study (median 95.9%)(Table 2), strategic site alterations could be implemented to promote tree survival. Arborists and landscape designers have developed various strategies to enhance biophysical growing conditions, including structural soils, biochar or compost amendments, and permeable pavers (Morgenroth et al. 2013; Mullaney et al. 2015; Somerville et al. 2020; Scharenbroch et al. 2022). These strategies were not used for the street trees in our study due to lack of funds. Budgets for planting initiatives in the USA are used mostly for purchasing trees, and the number of trees planted is often touted as a goal (Eisenman et al. 2022; Eisenman et al. 2025). In the USA, spending scarce resources on expensive site alterations is a pervasive challenge in urban forest management. Future research that examines the return-on-investment of soil and site alterations, in terms of tree health, growth, survival, and ecosystem services outcomes, can inform decision making about such investments.

Social vulnerability appeared significant in most models (except planting to first summer). There has been extensive recent scholarship on distributional inequities in urban tree canopy cover, showing general trends for more canopy where there are more white and wealthy residents (Gerrish and Watkins 2018; Watkins and Gerrish 2018), albeit with substantial variation in relationships across local socioecological contexts and temporal dynamics (Riley and Gardiner 2020; Locke et al. 2023). Research about canopy cover inequities has contributed to practitioner discourse in urban forest management around environmental justice, such as the American Forests Tree Equity score (Leahy and Serkez 2021). A study from Portland, Oregon, USA, showed distributional inequities in planting patterns (Donovan and Mills 2014) which can reinforce canopy inequities. Our analysis in Philadelphia contributes to this growing body of literature on urban forest equity by showing the connection between social vulnerability and establishment mortality (even after controlling for levels of impervious surface), indicating inequitable early tree performance. Such differences may be related to perspectives and behaviors of residents, maintenance practices, vandalism, and injuries from vehicles (Richardson and Shackleton 2014; Geron et al. 2023). Future research should investigate the potential tree performance benefits (e.g., survival, growth, health) of paid and unpaid tree maintenance programs (particularly in low-income and under-resourced neighborhoods) and systematic evaluation of tree injuries from vandalism and vehicles.

Prior research has demonstrated that programmatic support for tree care, such as maintenance carried out by organized volunteers or paid seasonal staff, produces high establishment survival (Koeser et al. 2014; Mincey and Vogt 2014; Roman et al. 2015; Vogt et al. 2015b). For example, relatively low establishment annual mortality—0.6% annual mortality in the first 6 years after planting—was observed for street trees in East Palo Alto, California, USA, due in part to investments in maintenance through a paid youth internship program alongside arboricultural expertise in species selection and installation (Roman et al. 2015). In another example, young street trees in Holyoke, Massachusetts, USA, had higher survival in comparison to yard trees, largely due to seasonal local staff and foresters carrying out irrigation for the street trees (Breger et al. 2019). However, the role of maintenance was not well explored in the present study. We used available information about Tree Tenders groups to generate a variable for group activity level, and higher activity was only significantly related to survival for one model (planting to fourth summer)(Table 5). We conclude that Tree Tenders group activity level is not likely representing maintenance and may be a proxy for other unmeasured neighborhood effects. As with research on soil and site

Table 5. Logistic regression results for tree survival from planting to summers 1 through 4. Separate models were constructed for survival from 1 to 4 summers postplanting, respectively. Sample size for each model reflects the number of observations available for that time period (Table 3). Area under curve measures model performance. AUC (area under curve); Std (standard); CI (confidence interval).

Variables	Estimate	Std Error	*Z*-value	*P*	Odds ratio estimate (95% CI)
Survival from planting to 1st summer (*n* = 2,850; AUC = 0.56)					
Intercept	3.661	0.455	8.051	< 0.0001	38.903 (15.956 to 94.856)
Impervious surfaces	–0.013	0.005	–2.586	0.0097	0.987 (0.978 to 0.997)
Survival from planting to 2nd summer (*n* = 1,856; AUC = 0.61)					
Intercept	3.564	0.492	7.248	< 0.0001	35.318 (13.472 to 92.590)
Spring planting	–0.404	0.141	–2.861	0.0042	0.667 (0.506 to 0.880)
Low-medium drought tolerance	0.304	0.143	2.130	0.0332	1.355 (1.025 to 1.792)
Impervious surfaces	–0.011	0.005	–2.182	0.0291	0.989 (0.979 to 0.999)
Social vulnerability	–0.991	0.289	–3.423	0.0006	0.371 (0.211 to 0.655)
Survival from planting to 3rd summer (*n* = 1,290; AUC = 0.66)					
Intercept	4.383	0.543	8.074	< 0.0001	80.094 (27.64 to 232.12)
Spring planting	–0.648	0.147	–4.409	< 0.0001	0.523 (0.392 to 0.698)
Impervious surfaces	–0.017	0.006	–3.046	0.0023	0.983 (0.973 to 0.994)
Social vulnerability	–1.635	0.299	–5.472	< 0.0001	0.195 (0.109 to 0.350)
Survival from planting to 4th summer (*n* = 678; AUC = 0.65)					
Intercept	2.531	0.336	7.535	< 0.0001	12.566 (6.506 to 24.272)
Spring planting	–0.434	0.192	–2.262	0.0237	0.648 (0.445 to 0.944)
Low-medium drought tolerance	0.474	0.209	2.270	0.0232	1.607 (1.067 to 2.420)
Low Tree Tender group activity	–0.203	0.294	–0.690	0.4905	0.817 (0.459 to 1.452)
Medium Tree Tender group activity	–0.702	0.239	–2.940	0.0033	0.496 (0.310 to 0.791)
Social vulnerability	–1.413	0.393	–3.592	0.0003	0.243 (0.113 to 0.526)
Medium mature size	–0.503	0.265	–1.897	0.0579	0.605 (0.360 to 1.017)
Small mature size	–0.079	0.321	–0.246	0.8055	0.924 (0.493 to 1.734)

alterations, there is a need for return-on-investment studies of establishment maintenance, including quantifying the intensity, frequency, duration, and extent of maintenance (Vogt et al. 2015a). Recent urban forest plans and a literature review have stressed that maintenance is deeply tied to equity and community perceptions (Myers et al. 2023; PPR 2023; City of Oakland 2024), yet postplanting tree care is not generally well-funded in the USA (Eisenman et al. 2022), making it imperative to evaluate the direct impacts of maintenance on trees and residents to inform policy and management. Such evaluations would require field observations, resident surveys, and/or administrative records that were outside the scope of our virtual monitoring methods, demonstrating one limitation of virtual data collection.

We found that trees planted in the Fall were more likely to survive compared to trees planted in the Spring. Past research has also found a relationship between planting season and establishment survival, but results have not been consistent (Hilbert et al. 2019), which may relate to regional climate differences, variation in the exact timing of planting within a given season, or potentially species-specific and stock-specific tolerances for planting timing. For the bare root tree stock planted through the PHS Tree Tenders program in Philadelphia, it seems that the timing of Spring plantings is not ideal. Spring plantings in this program have historically occurred the weekend after Arbor Day, which is the last Friday in April. Urban forestry advisors from Pennsylvania State University and Cornell University assert that Spring bare root plantings should occur early in the spring before buds burst (Buckstrup and Bassuk 2003; Jackson 2023). Although the April timing may be acceptable for areas of New England in the USA with long, cold winters, local leading arborists in Philadelphia consider early March to be more suitable timing for bare root plantings in this area (J. Lubar, personal communication, 2025 January 15). However, such timing may be logistically impractical for PHS staff due to their organization running the Philadelphia Flower Show in early March, a major event which is “the nation’s largest and oldest indoor flower show” (Crimmins 2024). In light of these logistical challenges, spring planting could prioritize taxa like *Amelanchier* spp. and *Gleditsia* spp. that perform relatively well when planted in spring (Table 4). Notably, PHS plantings in Spring 2025 occurred in early April, and it remains to be seen if this timing change impacts tree survival. The timing of optimal planting may continue to shift due to climate change, making it

Table 6. Logistic regression results for tree survival from one summer to the next. Separate models were constructed for survival from year 1 to year 2 and from year 2 to year 3, respectively. Sample size for each model reflects the number of observations available for that time period (Table 3). Area under curve measures model performance. AUC (area under curve); Std (standard); CI (confidence interval).

Variables	Estimate	Std Error	*Z*-value	*P*	Odds ratio estimate (95% CI)
Survival from 1st summer to 2nd summer (*n* = 1,714; AUC = 0.67)					
Intercept	5.197	0.826	6.292	< 0.0001	180.659 (35.796 to 911.774)
Spring planting	–0.516	0.216	–2.392	0.0168	0.597 (0.391 to 0.911)
Low-medium drought tolerance	0.564	0.213	2.649	0.0081	1.758 (1.158 to 2.670)
Impervious surfaces	–0.016	0.008	–1.861	0.0627	0.984 (0.968 to 1.001)
Social vulnerability	–1.528	0.457	–3.343	0.0008	0.217 (0.089 to 0.532)
Survival from 2nd summer to 3rd summer (*n* = 1,084; AUC = 0.68)					
Intercept	7.714	1.542	5.002	< 0.0001	2,239.35 (108.99 to 46,009.80)
Impervious surfaces	–0.003	0.016	–2.138	0.0325	0.967 (0.938 to 0.997)
Social vulnerability	–2.088	0.715	–2.918	0.0035	0.124 (0.031 to 0.504)

imperative to consider local climate patterns as well as stock dormancy signs in deciding when to plant.

When drought tolerance was significant (in 3 models), it was opposite of our expected direction; trees with low to medium drought tolerance were more likely to survive. We are uncertain how to explain this finding, which contradicts other street tree research in the same city (Bigelow et al. 2024), and with broader understandings of street tree planting sites as being water limited (Vico et al. 2014), thus making drought tolerant taxa more amenable to street tree settings. It is possible that the particular species in the drought tolerance categories had other traits that were related to survival, or that the drought tolerance categories we used were too coarse. Other measures, such as leaf turgor loss (Sjöman et al. 2018), would enable more direct evaluation of tree physiology and drought tolerance. Additionally, while our analysis was focused on mortality status and derived from virtual monitoring of SV imagery, field data on shoot extension, crown vigor, and soil conditions would enable more fine-grain assessment of tree health and growth during establishment (Levinsson et al. 2017; Scharenbroch et al. 2017; Breger et al. 2019).

CONCLUSION

Tree survival and mortality data is critical to evaluate planting programs and accurately estimate benefits based on empirical data (Ko et al. 2015). Our study demonstrates the value of SV image interpretations to provide mortality data on street trees planted through a local program over multiple years. Having (nearly) all trees from each planting year being tracked makes this study unique compared to other studies that tracked samples of planted trees. Consistent with past research, we found that tree survival was related to level of impervious surface, socioeconomic characteristics, and planting season. These findings have management ramifications pertaining to planting site modifications, equity in planted tree performance, and the timing of planting events. There is potential for scaling up our approach using machine learning approaches to track street tree survival across multiple cities and to determine whether the patterns we observed hold in other biophysical, socioeconomic, and institutional contexts.

LITERATURE CITED

Agency for Toxic Substances and Disease Registry (ATSDR). 2024. Social Vulnerability Index (SVI). Atlanta (GA, USA): US Department of Health and Human Services (HHS). https://www.atsdr.cdc.gov/place-health/php/svi/index.html

Armitage D, Berkes F, Dale A, Kocho-Schellenberg E, Patton E. 2011. Co-management and the co-production of knowledge: Learning to adapt in Canada's Arctic. *Global Environmental Change*. 21(3):995-1004. https://doi.org/10.1016/j.gloenvcha.2011.04.006

Bancks N, North EA, Johnson GR. 2018. An analysis of agreement between volunteer- and researcher-collected urban tree inventory data. *Arboriculture & Urban Forestry*. 44(2):73-86. https://doi.org/10.48044/jauf.2018.007

Beery S, Wu G, Edwards T, Pavetic F, Majewski B, Mukherjee S, Chan S, Morgan J, Rathod V, Huang J. 2022. The Auto Arborist dataset: A large-scale benchmark for multiview urban forest monitoring under domain shift. In: *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*. 2022 June 18–24; New Orleans, LA, USA. New Orleans (LA, USA): IEEE. p. 21262-21275. https://doi.org/10.1109/CVPR52688.2022.02061

Berland A, Lange DA. 2017. Google Street View shows promise for virtual street tree surveys. *Urban Forestry & Urban Greening*. 21:11-15. https://doi.org/10.1016/j.ufug.2016.11.006

Berland A, Roman LA. 2020. New possibilities for virtual street tree inventories. *Arborist News*. 30(1):22-26. https://www.fs.usda.gov/nrs/pubs/jrnl/2020/nrs_2020_berland_001.pdf

Berland A, Roman LA, Vogt J. 2019. Can field crews telecommute? Varied data quality from citizen science tree inventories conducted using street-level imagery. *Forests*. 10(4):349. https://doi.org/10.3390/f10040349

Berland A, Shiflett SA, Shuster WD, Garmestani AS, Goddard HC, Herrmann DL, Hopton ME. 2017. The role of trees in urban stormwater management. *Landscape & Urban Planning*. 162:167-177. https://doi.org/10.1016/j.landurbplan.2017.02.017

Bigelow LM Jr, Fahey RT, Grabosky J, Hallett RA, Henning JG, Johnson ML, Roman LA. 2024. Predictors of street tree survival in Philadelphia: Tree traits, biophysical environment, and socioeconomic context. *Urban Forestry & Urban Greening*. 94:128284. https://doi.org/10.1016/j.ufug.2024.128284

Boukili VKS, Bebber DP, Mortimer T, Venicx G, Lefcourt D, Chandler M, Eisenberg C. 2017. Assessing the performance of urban forest carbon sequestration models using direct measurements of tree growth. *Urban Forestry & Urban Greening*. 24:212-221. https://doi.org/10.1016/j.ufug.2017.03.015

Branson S, Wegner JD, Hall D, Lang N, Schindler K, Perona P. 2018. From Google Maps to a fine-grained catalog of street trees. *ISPRS Journal of Photogrammetry and Remote Sensing*. 135:13-30. https://doi.org/10.1016/j.isprsjprs.2017.11.008

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

Buckstrup M, Bassuk NL. 2003. Creating the urban forest: The bare root method. Ithaca (NY, USA): Urban Horticulture Institute, Department of Horticulture, Cornell University. https://urbanforestrysouth.org/resources/library/ttresources/creating-the-urban-forest-the-bare-root-method

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

Choi K, Lim W, Chang B, Jeong J, Kim I, Park CR, Ko DW. 2022. An automatic approach for tree species detection and profile estimation of urban street trees using deep learning and Google street view images. *ISPRS Journal of Photogrammetry and Remote Sensing*. 190:165-180. https://doi.org/10.1016/j.isprsjprs.2022.06.004

City of Oakland. 2024. Oakland urban forest plan. Oakland (CA, USA): Oakland City Hall. [Started 2019 January 7; Completed 2024 December 16]. https://www.oaklandca.gov/Community/Community-Development/Sustainability-Environment/Sustainability-Plans/Oakland-Urban-Forest-Plan

City of Philadelphia. 2009. Greenworks program. Philadelphia (PA, USA): Mayor's Office of Sustainability. https://www.phila.gov/documents/greenworks-program-archives

Coleman AF, Harper RW, Eisenman TS, Warner SH, Wilkinson MA. 2022. Street tree structure, function, and value: A review of scholarly literature (1997–2020). *Forests*. 13(11):1779. https://doi.org/10.3390/f13111779

Cregg B, Ellison D. 2018. Growth and establishment of container-grown London planetrees in response to mulch, root-ball treatment and fertilization. *Urban Forestry & Urban Greening*. 35:139-147. https://doi.org/10.1016/j.ufug.2018.08.014

Crimmins P. 2024. Come together: 'United by flowers' at the Philly Flower Show. Philadelphia (PA, USA): WHYY. [Accessed 2025 January 1]. https://whyy.org/articles/philadelphia-flower-show-united-community

Crown CA, Greer BZ, Gift DM, Watt FS. 2018. Every tree counts: Reflections on NYC's third volunteer street tree inventory. *Arboriculture & Urban Forestry*. 44(2):49-58. https://doi.org/10.48044/jauf.2018.005

Donovan GH, Mills J. 2014. Environmental justice and factors that influence participation in tree planting programs in Portland, Oregon, U.S. *Arboriculture & Urban Forestry*. 40(2):70-77. https://doi.org/10.48044/jauf.2014.008

Eaton K. 2019 January 22. Atlas—Opening the door to the City's data. Philadelphia (PA, USA): City of Philadelphia. https://www.phila.gov/2019-01-22-atlas-opening-the-door-to-the-citys-data

Eisenman TS, Chang SE, Laurian L. 2022. Stewarding street trees for a global urban future. In: Brears RC, editor. *The Palgrave encyclopedia of urban and regional futures*. Cham (Switzerland): Palgrave Macmillan. p. 1656-1673. https://doi.org/10.1007/978-3-030-87745-3_226

Eisenman TS, Roman LA, Östberg J, Campbell LK, Svendsen E. 2025. Beyond the g*olden shovel*: Recommendations for a successful urban tree planting initiative. *Journal of the American Planning Association*. 91(1):133-143. https://doi.org/10.1080/01944363.2024.2330943

Elmes A, Rogan J, Roman LA, Williams CA, Ratick SJ, Nowak DJ, Martin DG. 2018. Predictors of mortality for juvenile trees in a residential urban-to-rural cohort in Worcester, MA. *Urban Forestry & Urban Greening*. 30:138-151. https://doi.org/10.1016/j.ufug.2018.01.024

Elton AJ, Harper RW, Bullard LF, Griffith EE, Weil BS. 2023. Volunteer engagement in urban forestry in the United States: Reviewing the literature. *Arboricultural Journal*. 45(2):96-117. https://doi.org/10.1080/03071375.2022.2030620

Ettinger AK, Bratman GN, Carey M, Hebert R, Hill O, Kett H, Levin P, Murphy-Williams M, Wyse L. 2024. Street trees provide an opportunity to mitigate urban heat and reduce risk of high heat exposure. *Scientific Reports*. 14:3266. https://doi.org/10.1038/s41598-024-51921-y

Geron NA, Martin DG, Rogan J, Healy M. 2023. Residents' roles as environmental policy actors urban an urban governance framework: A case study of a tree planting program. *Cities*. 135:104201. https://doi.org/10.1016/j.cities.2023.104201

Gerrish E, Watkins SL. 2018. The relationship between urban forests and income: A meta-analysis. *Landscape and Urban Planning*. 170:293-308. https://doi.org/10.1016/j.landurbplan.2017.09.005

Grant A, Edge S, Millward AA, Roman LA, Teelucksingh C. 2024. Centering community perspectives to advance recognitional justice for sustainable cities: Lessons from urban forest practice. *Sustainability*. 16(12):4915. https://doi.org/10.3390/su16124915

Hall JM, Handley JF, Ennos AR. 2012. The potential of tree planting to climate-proof high density residential areas in Manchester, UK. *Landscape and Urban Planning*. 104(3-4):410-417. https://doi.org/10.1016/j.landurbplan.2011.11.015

Hauer RJ, Peterson WD. 2016. *Municipal tree care and management in the United States: A 2014 urban & community forestry census of tree activities*. Stevens Point (WI, USA): College of Natural Resources, University of Wisconsin. Special Publication 16-1. 71 p. https://caufc.org/wp-content/uploads/2025/03/Hauer-Peterson-2014-urban-forest-program-census.pdf

Hauer RJ, Timilsina N, Vogt J, Fischer BC, Wirtz Z, Peterson W. 2018. A volunteer and partnership baseline for municipal forestry activity in the United States. *Arboriculture & Urban Forestry*. 44(2):87-100. https://doi.org/10.48044/jauf.2018.008

Hilbert DR, Roman LA, Koeser AK, Vogt J, van Doorn NS. 2019. Urban tree mortality: A literature review. *Arboriculture & Urban Forestry*. 45(5):167-200. https://doi.org/10.48044/jauf.2019.015

Hosmer DW Jr, Lemeshow S, Sturdivant RX. 2013. *Applied logistic regression*. 3rd Ed. Hoboken (NJ, USA): Wiley. 510 p. https://doi.org/10.1002/9781118548387

Jack-Scott EJ. 2011. Survival and growth factors affecting community-planted urban street trees. *Cities and the Environment*. 4(1):10. https://digitalcommons.lmu.edu/cate/vol4/iss1/10

Jackson DR. 2023. Planting bare-root tree seedlings in the spring. University Park (PA, USA): Penn State Extension. [Updated 2023 November 13]. https://extension.psu.edu/planting-bare-root-tree-seedlings-in-spring

Jaramillo C. 2020. Racism left Hunting Park overheated. Neighbors are making a cooler future. Philadelphia (PA, USA): WHYY. https://whyy.org/articles/racism-left-hunting-park-overheated-neighbors-are-making-a-cooler-future

Jayasingh S, Jayasooriya V, Dassanayake SM, Muthukumaran S. 2024. Effects of street tree configuration and placement on roadside thermal environment within a tropical urban canyon. *International Journal of Biometeorology*. 68:1133-1142. https://doi.org/10.1007/s00484-024-02653-1

Johnson ML, Campbell LK, Svendsen ES, Silva P. 2018. Why count trees? Volunteer motivations and experiences with tree monitoring in New York City. *Arboriculture & Urban Forestry*. 44(2):59-72. https://doi.org/10.48044/jauf.2018.006

Just MG, Frank SD, Dale AG. 2018. Impervious surface thresholds for urban tree site selection. *Urban Forestry & Urban Greening*. 34:141-146. https://doi.org/10.1016/j.ufug.2018.06.008

Ko Y, Lee JH, McPherson EG, Roman LA. 2015. Long-term monitoring of Sacramento shade program trees: Tree survival, growth and energy-saving performance. *Landscape and Urban Planning*. 143:183-191. https://doi.org/10.1016/j.landurbplan.2015.07.017

Koeser AK, Gilman EF, Paz M, Harchick C. 2014. Factors influencing urban tree planting program growth and survival in Florida, United States. *Urban Forestry & Urban Greening*. 13(4):655-661. https://doi.org/10.1016/j.ufug.2014.06.005

Laumer D, Lang N, van Doorn N, Mac Aodha O, Perona P, Wegner JD. 2020. Geocoding of trees from street address to street-level images. *ISPRS Journal of Photogrammetry and Remote Sensing*. 162:125-136. https://doi.org/10.1016/j.isprsjprs.2020.02.001

Leahy I, Serkez Y. 2021 June 30. Since when have trees existed only for rich Americans? *New York Times*. https://www.nytimes.com/interactive/2021/06/30/opinion/environmental-inequity-trees-critical-infrastructure.html

Leatherbarrow EE. 2019. Tools for growth: A case study processing UC Green's planting records using remote software tools [masters thesis]. Philadelphia (PA, USA): University of Pennsylvania. 43 p. https://repository.upenn.edu/handle/20.500.14332/40588

Lesnoff M, Lancelot R. 2023. aod: Analysis of overdispersed data. R package version 1.3.3. https://doi.org/10.32614/CRAN.package.aod

Levinsson A, Fransson AM, Emilsson T. 2017. Investigating the relationship between various measuring methods for determination of establishment success of urban trees. *Urban Forestry & Urban Greening*. 28:21-27. https://doi.org/10.1016/j.ufug.2017.09.014

Li X, Zhang C, Li W, Ricard R, Meng Q, Zhang W. 2015. Assessing street-level urban greenery using Google Street View and a modified green view index. *Urban Forestry & Urban Greening*. 14(3):675-685. https://doi.org/10.1016/j.ufug.2015.06.006

Locke DH, Roman LA, Henning JG, Healy M. 2023. Four decades of urban land cover change in Philadelphia. *Landscape and Urban Planning*. 236:104764. https://doi.org/10.1016/j.landurbplan.2023.104764

Maslin M. 2005. *The tree tenders handbook*. Philadelphia (PA, USA): Pennsylvania Horticultural Society. 77 p. https://phs.kohacatalog.com/cgi-bin/koha/opac-detail.pl?biblionumber=10472

Meunpong P, Bauthong S, Kaewgrajang T. 2019. Google Street View virtual survey and in-person field surveys: An exploratory comparison of urban tree risk assessment. *Arboricultural Journal*. 41(4):226-236. https://doi.org/10.1080/03071375.2019.1643187

Miklas L. 2023. Is fall for planting? Philadelphia (PA, USA): Penn State Extension. [Updated 2023 July 5]. https://extension.psu.edu/is-fall-for-planting

Mincey SK, Vogt JM. 2014. Watering strategy, collective action, and neighborhood-planted trees: A case study of Indianapolis, Indiana, U.S. *Arboriculture & Urban Forestry*. 40(2):84-95. https://doi.org/10.48044/jauf.2014.010

Missouri Botanical Garden. 2018. Plant finder. St. Louis (MO, USA): Missouri Botanical Garden. https://www.missouribotanicalgarden.org/plantfinder/plantfindersearch.aspx

Moore GM. 2022. Lifetime cost models for large, long-lived, street trees in Australia. *Arboricultural Journal*. 44(1):21-41. https://doi.org/10.1080/03071375.2021.2014689.

Morgenroth J, Buchan G, Scharenbroch BC. 2013. Belowground effects of porous pavements—Soil moisture and chemical properties. *Environmental Engineering*. 51:221-228. https://doi.org/10.1016/j.ecoleng.2012.12.041

Morgenroth J, O'Neil-Dunne J, Apiolaza LA. 2017. Redevelopment and the urban forest: A study of tree removal and retention during demolition activities. *Applied Geography*. 82:1-10. https://doi.org/10.1016/j.apgeog.2017.02.011

Mullaney J, Lucke T, Trueman SJ. 2015. The effect of permeable pavements with an underlying base layer on the growth and nutrient status of urban trees. *Urban Forestry & Urban Greening*. 14(1):19-29. https://doi.org/10.1016/j.ufug.2014.11.007

Myers G, Mullenbach LE, Jolley JA, Cutts BB, Larson LR. 2023. Advancing social equity in urban tree planting: Lessons learned from an integrative review of the literature. *Urban Forestry & Urban Greening*. 89:128116. https://doi.org/10.1016/j.ufug.2023.128116

National Oceanic and Atmospheric Administration (NOAA). 2021. U.S. climate normals quick access. Monthly: 1991-2020. Asheville (NC, USA): National Centers for Environmental Information. Version 1.0.1. https://www.ncei.noaa.gov/access/us-climate-normals

O'Neil-Dunne J. 2019. Tree canopy assessment: Philadelphia, PA. Burlington (VT, USA): University of Vermont, Spatial Analysis Laboratory. 16 p. http://treephilly.org/wp-content/uploads/2019/12/Tree-Canopy-Assessment-Report-Philadelphia-2018.pdf

OpenDataPhilly. 2010. OpenDataPhilly. https://opendataphilly.org

Pennsylvania Spatial Data Access (PASDA). 2025. Open GIS data access for the Commonwealth of Pennsylvania. University Park (PA, USA): The Pennsylvania State University. https://www.pasda.psu.edu

Philadelphia Parks and Recreation (PPR). 2023. Philly tree plan: Creating a ten-year plan for the growth and care of Philadelphia's urban forest. Philadelphia (PA, USA): City of Philadelphia. [Accessed 2024 May 28]. https://www.phila.gov/programs/philly-tree-plan

Philadelphia Water Department (PWD). 2011. Amended: Green city, clean waters: The City of Philadelphia's program for combined sewer overflow control program summary. [Amended 2011 June 1; Accessed 2024 May 28]. 48 p. https://water.phila

.gov/wp-content/uploads/files/GCCW_AmendedJune2011_LOWRES-web.pdf

Richardson E, Shackleton CM. 2014. The extent and perceptions of vandalism as a cause of street tree damage in small towns in the Eastern Cape, South Africa. *Urban Forestry & Urban Greening*. 13(3):425-432. https://doi.org/10.1016/j.ufug.2014.04.003

Riedman E, Pearsall H, Roman LA, Ifill T, Maslin M, Dentice D, Samaha J, Davis AL. 2024. Uncovering the role and labor of volunteer leaders within a community-led urban tree planting initiative. *Society & Natural Resources*. 37(9):1294-1312. https://doi.org/10.1080/08941920.2024.2349874

Riedman E, Roman LA, Pearsall H, Maslin M, Ifill T, Dentice D. 2022. Why don't people plant trees? Uncovering barriers to participation in urban tree planting. *Urban Forestry & Urban Greening*. 73:127597. https://doi.org/10.1016/j.ufug.2022.127597

Riley CB, Gardiner MM. 2020. Examining the distributional equity of urban tree canopy cover and ecosystem services across United States cities. *PLoS ONE*. 15(3):e0228499. https://doi.org/10.1371/journal.pone.0228499

Roman LA, Battles JJ, McBride JR. 2014. Determinants of establishment survival for residential trees in Sacramento County, CA. *Landscape and Urban Planning*. 129:22-31. https://doi.org/10.1016/j.landurbplan.2014.05.004

Roman LA, Battles JJ, McBride JR. 2016. Urban tree mortality: A primer on demographic approaches. Newtown Square (PA, USA): USDA Forest Service, Northern Research Station. General Technical Report NRS-158. 28 p. https://www.fs.usda.gov/nrs/pubs/gtr/gtr_nrs158.pdf

Roman LA, Campbell LK, Jordan RC. 2018a. Civic science in urban forestry: An introduction. *Arboriculture & Urban Forestry*. 44(2):41-48. https://doi.org/10.48044/jauf.2018.004

Roman LA, Catton IJ, Greenfield EJ, Pearsall H, Eisenman TS, Henning JG. 2021. Linking urban tree cover change and local history in a post-industrial city. *Land*. 10(4):403. https://doi.org/10.3390/land10040403

Roman LA, Fristensky JP, Lundgren RE, Cerwinka CE, Lubar JE. 2022. Construction and proactive management led to tree removals on an urban college campus. *Forests*. 13(6):871. https://doi.org/10.3390/f13060871

Roman LA, Scharenbroch BC, Östberg JPA, Mueller LS, Henning JG, Koeser AK, Sanders JR, Betz DR, Jordan RC. 2017. Data quality in citizen science urban tree inventories. *Urban Forestry & Urban Greening*. 22:124-135. https://doi.org/10.1016/j.ufug.2017.02.001

Roman LA, Smith BC, Dentice D, Maslin M, Abrams G. 2018b. Monitoring young tree performance 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, 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): USDA Forest Service, Northern Research Station. General Technical Report NRS-194. 48 p. https://www.fs.usda.gov/nrs/pubs/gtr/gtr_nrs194.pdf

Roman LA, Walker LA, Martineau CM, Muffly DJ, MacQueen SA, Harris W. 2015. Stewardship matters: Case studies in establishment success of urban trees. *Urban Forestry & Urban Greening*. 14(4):1174-1182. https://.doi.org/10.1016/j.ufug.2015.11.001

Roy S. 2017. Anomalies in Australian municipal tree managers' street-tree planting and species selection principles. *Urban Forestry & Urban Greening*. 24:125-133. https://doi.org/10.1016/j.ufug.2017.03.008

Salisbury AB, Miesbauer JW, Koeser AK. 2022. Long-term tree survival and diversity of highway tree planting projects. *Urban Forestry & Urban Greening*. 73:127574. https://doi.org/10.1016/j.ufug.2022.127574

Sanders JR, Grabosky JC. 2014. 20 years later: Does reduced soil area change overall tree growth? *Urban Forestry & Urban Greening*. 13(2):295-303. https://doi.org/10.1016/j.ufug.2013.12.006

Scharenbroch BC, Carter D, Bialecki M, Fahey R, Scheberl L, Catania M, Roman LA, Bassuk N, Harper RW, Werner L, Siewert A, Miller S, Hutyra L, Raciti S. 2017. A rapid urban site index for assessing the quality of street tree planting sites. *Urban Forestry & Urban Greening*. 27:279-286. https://doi.org/10.1016/j.ufug.2017.08.017

Scharenbroch BC, Fite K, Catania M. 2022. An arboriculture treatment of biochar, fertilization, and tillage improves soil organic matter and tree growth in suburban street tree landscape in Bolingbrook, Illinois, USA. *Arboriculture & Urban Forestry*. 48(3):203-214. https://doi.org/10.48044/jauf.2022.015

Schütt A, Becker JN, Gröngröft A, Schaaf-Titel S, Eschenbach A. 2022. Soil water stress at young urban street-tree sites in response to meteorology and site parameters. *Urban Forestry & Urban Greening*. 75:127692. https://doi.org/10.1016/j.ufug.2022.127692

Seiferling I, Naik N, Ratti C, Proulx R. 2017. Green streets—Quantifying and mapping urban trees with street-level imagery and computer vision. *Landscape and Urban Planning*. 165:93-101. https://doi.org/10.1016/j.landurbplan.2017.05.010

Silvera Seamens G. 2013. Mainstreaming the environmental benefits of street trees. *Urban Forestry & Urban Greening*. 12(1):2-11. https://doi.org/10.1016/j.ufug.2012.08.004

Sing T, Sander O, Beerenwinkel N, Lengauer T. 2005. ROCR: Visualizing classifier performance in R. *Bioinformatics*. 21(2):3940-3941. http://rocr.bioinf.mpi-sb.mpg.de

Sjöman H, Hirons AD, Bassuk NL. 2018. Improving confidence in tree species selection for challenging urban sites: A role for leaf turgor loss. *Urban Ecosystems*. 21:1171-1188. https://doi.org/10.1007/s11252-018-0791-5

Somerville PD, Farrell C, May PB, Livesley SL. 2020. Biochar and compost equally improve urban soil physical and biological properties and tree growth, with no added benefit in combination. *Science of the Total Environment*. 706:125736. https://doi.org/10.1016/j.scitotenv.2019.135736

The Pew Charitable Trusts. 2021. Philadelphia 2021: State of the city. [Accessed 2024 May 28]. https://www.pewtrusts.org/en/research-and-analysis/reports/ 2021/04/philadelphia-2021-state-of-the-city

The Pew Charitable Trusts. 2022. Philadelphia 2022: State of the city. [Accessed 2024 May 28]. https://www.pewtrusts.org/

en/research-and-analysis/reports/ 2022/04/philadelphia-2022-state-of-the-city

United Nations Economic Commission for Europe (UNECE). 2024. Trees in cities challenge. Ittigen (Switzerland): Federal Office for the Environment (FOEN). https://treesincities.unece.org/tree-o-meter#sthash.o3InJdw2.IwBnpGfZ.dpbs

University of Florida. 2013. Environmental horticulture: 680 tree fact sheets. Gainesville (FL, USA): University of Florida. [Updated 2021 October 28]. https://hort.ifas.ufl.edu/database/trees/trees_scientific.shtml

Vico G, Revelli R, Porporato A. 2014. Ecohydrology of street trees: Design and irrigation requirements for sustainable water use. *Ecohydrology*. 7(2):508-523. https://doi.org/10.1002/eco.1369.

Vogt J, Abood M. 2020. A transdisciplinary, mixed methods research agenda for evaluating the collective impact approach for tree planting: The CommuniTree initiative in northwest Indiana, U.S. *Urban Forestry & Urban Greening*. 53:126735. https://doi.org/10.1016/j.ufug.2020.126735

Vogt J, Hauer RJ, Fischer BC. 2015a. The costs of maintaining and not maintaining the urban forest: A review of the urban forestry and arboriculture literature. *Arboriculture & Urban Forestry*. 41(6):293-323. https://doi.org/10.48044/jauf.2015.027

Vogt JM, Watkins SL, Mincey SK, Patterson MS, Fischer BC. 2015b. Explaining planted-tree survival and growth in urban neighborhoods: A social-ecological approach to studying recently-planted trees in Indianapolis. *Landscape and Urban Planning*. 136:130-143. https://doi.org/10.1016/j.landurbplan.2014.11.021

Watkins SL, Gerrish E. 2018. The relationship between urban forests and race: A meta-analysis. *Journal of Environmental Management*. 209:152-168. https://doi.org/10.1016/j.jenvman.2017.12.021.

Wattenhofer DJ, Johnson GR. 2021. Understanding why young urban trees die can improve future success. *Urban Forestry & Urban Greening*. 64:127247. https://doi.org/10.1016/j.ufug.2021.127247

Widney S, Fischer BC, Vogt J. 2016. Tree mortality undercuts ability of tree-planting programs to provide benefits: Results of a three-city study. *Forests*. 7(3):65. https://doi.org/10.3390/f7030065

Yang J, McBride J. 2003. A unique technique for street tree planting in Beijing. *Arboricultural Journal*. 27(1):1-10. https://doi.org/10.1080/03071375.2003.9747358

Zeileis A, Hothorn T. 2002. Diagnostic checking in regression relationships. *R News*. 2(3):7-10. https://cran.r-project.org/doc/Rnews/Rnews_2002-3.pdf

ACKNOWLEDGEMENTS

This research was supported by a Research Joint Venture Agreement between the USDA Forest Service Northern Research Station and the Pennsylvania Horticultural Society (PHS). We thank the dedicated Tree Tenders of Philadelphia for their labor and advocacy towards growing the city's canopy and serving their communities. We appreciate current and former PHS staff who contributed to early planning for this study or provided feedback on results, including T. Ifill, M. Maslin, M. Fox, A. Davis, and A. Mitchell. We are grateful to S. Czerki for data collection. The planting data used for this study were analyzed under permission from the PHS and are not publicly available. Data are available from the corresponding author upon reasonable request and with permission from PHS. The opinions and findings expressed in this paper are those of the authors and should not be construed to represent any official USDA or US Government determination or policy.

Lara A. Roman (corresponding author)
United States Department of Agriculture, Forest Service
Pacific Southwest Research Station
San Diego, CA, USA
lara.roman@usda.gov

Adam Berland
Ball State University
School of Earth, Atmosphere, and Sustainability
Muncie, IN, USA
amberland@bsu.edu

Sabine Nix
University of Pennsylvania
Department of Earth & Environmental Science
Philadelphia, PA, USA
nixs@sas.upenn.edu

Dana Dentice
Pennsylvania Horticultural Society
Philadelphia, PA, USA
ddentice@pennhort.org

Conflicts of Interest: The authors reported no conflicts of interest.

Résumé. Contexte: La plantation d'arbres d'alignement est courante dans les programmes de verdissement urbain et ces arbres fournissent des services écosystémiques importants qui s'accroissent à mesure que les arbres atteignent leur maturité. Le suivi de terrain visant à connaître les taux et les causes de mortalité est précieux pour la gestion des forêts urbaines, mais il nécessite beaucoup de temps. Méthodes: Nous avons utilisé des vues réalisées au niveau de la rue pour surveiller virtuellement la survie de 2 884 arbres de rue pendant plusieurs années suivant leur plantation à Philadelphie, Pennsylvanie, aux États-Unis. Résultats: Nous avons constaté des taux de mortalité similaires à ceux d'autres études, avec 7,5% des arbres morts ou enlevés au cours du premier été suivant la plantation, puis un taux de mortalité diminuant à 3,5% entre le troisième et le quatrième été suivant la plantation. Des modèles de régression logistique ont été élaborés selon différents horizons temporels afin de comprendre quelles caractéristiques du site, du quartier et de l'espèce étaient liées aux résultats en matière de survie. Ces modèles ont montré qu'une survie plus élevée des arbres était associée à une surface imperméable moins étendue autour de l'arbre, à une vulnérabilité sociale moindre dans le quartier et à une plantation automnale d'arbres plutôt qu'au printemps. Conclusions: Nos résultats identifient des mesures de gestion susceptibles d'améliorer les taux de survie, telles que l'amélioration des sites de plantation et l'entretien des jeunes arbres, ainsi que l'utilisation des données de suivi afin de guider les choix concernant la saison de plantation. Cette recherche démontre l'intérêt pour l'interprétation de vues effectuées au niveau de la rue afin de fournir des données sur la mortalité d'un grand nombre d'arbres d'alignement plantés au long de plusieurs années.

Zusammenfassung. Hintergrund: Die Anpflanzung von Straßenbäumen ist in städtischen Begrünungsprogrammen weit verbreitet, und diese Bäume leisten wichtige Ökosystemdienstleistungen, die mit zunehmendem Alter der Bäume noch an Bedeutung gewinnen. Feldbasierte Überwachungen zur Ermittlung der Sterblichkeitsraten und -ursachen sind für die städtische Waldbewirtschaftung sehr wertvoll, aber auch sehr zeitaufwendig. Methoden: Wir haben Straßenbilder verwendet, um das Überleben von 2.884 Straßenbäumen über mehrere Jahre nach der Pflanzung in Philadelphia, Pennsylvania, USA, virtuell zu überwachen. Ergebnisse: Wir beobachteten ähnliche Sterblichkeitsraten wie in anderen Studien: 7,5% der Bäume waren im ersten Sommer nach der Pflanzung abgestorben oder wurden entfernt, und die Sterblichkeitsrate sank zwischen dem dritten und vierten Sommer nach der Pflanzung auf 3,5%. Es wurden logistische Regressionsmodelle über verschiedene Zeithorizonte erstellt, um zu verstehen, welche Standort-, Nachbarschafts- und Artenmerkmale mit den Überlebensraten zusammenhängen. Diese Modelle zeigten, dass eine höhere Überlebensrate der Bäume mit weniger undurchlässigen Oberflächen in der Umgebung der Bäume, einer geringeren sozialen Vulnerabilität in der Nachbarschaft und einer Baumpflanzung im Herbst im Gegensatz zum Frühjahr verbunden war. Schlussfolgerungen: Unsere Ergebnisse weisen auf Managementmaßnahmen hin, die die Überlebensrate verbessern könnten, wie z. B. die Verbesserung der Pflanzorte und die Pflege der Anpflanzungen sowie die Verwendung von Überwachungsdaten als Grundlage für Entscheidungen bezüglich der Pflanzsaison. Diese Studie zeigt den Wert der Auswertung von Straßenbildern für die Bereitstellung von Mortalitätsdaten zu einer großen Anzahl von Straßenbäumen, die über mehrere Jahre hinweg gepflanzt wurden.

Resumen. Antecedentes: La plantación de árboles en las calles es común en los programas de forestación urbana, y estos árboles proporcionan importantes servicios ecosistémicos que aumentan a medida que alcanzan la madurez. El monitoreo de campo para comprender las tasas de mortalidad y sus causas es valioso para la gestión forestal urbana, pero requiere mucho tiempo. Métodos: Utilizamos imágenes a nivel de calle para monitorear virtualmente la supervivencia de 2884 árboles en las calles durante varios años después de su plantación en Filadelfia, Pensilvania, Estados Unidos. Resultados: Observamos tasas de mortalidad similares a las de otros estudios: el 7.5 % de los árboles murieron o fueron retirados durante el primer verano tras la plantación, y la tasa de mortalidad descendió al 3.5 % entre el tercer y el cuarto verano tras la plantación. Se construyeron modelos de regresión logística en varios horizontes temporales para comprender qué características del sitio, el vecindario y las especies se relacionaban con los resultados de supervivencia. Estos modelos mostraron que una mayor supervivencia de los árboles se asoció con una superficie menos impermeable alrededor del árbol, una menor vulnerabilidad social en el vecindario y la plantación de árboles en otoño en lugar de primavera. Conclusiones: Nuestros resultados apuntan a actividades de manejo que podrían mejorar los resultados de supervivencia, como la mejora de los sitios de plantación y el mantenimiento del establecimiento, y el uso de datos de monitoreo para tomar decisiones sobre la temporada de plantación. Este estudio demuestra el valor de las interpretaciones de imágenes a nivel de calle para proporcionar datos de mortalidad sobre una gran cantidad de árboles urbanos plantados durante varios años.

Arboriculture & Urban Forestry CEU Quizzes

Arboriculture & Urban Forestry quizzes are available free online to members for one year after the date of publication; a maximum of six quizzes are available at any time. CEU quizzes for older articles may be purchased by both members and non-members.

A passing score for this quiz requires sixteen correct answers. Quiz results will display immediately upon quiz completion. CEU(s) are processed immediately. You may take the quiz as often as is necessary to pass.