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Tree Type and Urban Growing Conditions Associated with Street Tree Stress: Lessons from Two US Cities

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Abstract. Background: Trees provide crucial ecosystem services for urban areas, but the stress of the urban environment can influence tree health and ecosystem service provision. Street trees grow in particularly stressful conditions, but often receive care from some combination of municipal agencies, private businesses, nonprofits, and individuals. Methods: In this study, we quantified tree stress using 4 canopy-based metrics (leaf discoloration, leaf defoliation, dieback, and overall crown stress) to see how stress varies with growing conditions and tree characteristics in 2 US cities: Chicago, IL, and Durham, NC. Using separate Bayesian models for each city, we examined the relationship between tree stress and tree characteristics (e.g., species), site-condition variables (e.g., land use) and cues to care (e.g., mulch). Results: In both cities and for most tree stress metrics, the degree of tree stress was associated with species group and either site type and/or land use. Cues to care were not clearly associated with reduced stress in either city. Defoliation was better explained by the models than the other metrics of tree stress. Discoloration, defoliation, and dieback provided unique information on tree stress and therefore can be useful indices for tree health monitoring. Conclusions: Consistent with arborist practices, species selection plays a large role in informing the degree of tree stress. Because the benefits of tree care were unclear, future work focusing on the context dependence of tree care effectiveness could clarify the conditions under which tree care (especially mulch) is most effective.

Keywords. Arboriculture; Cues to Care; Land Use; Planting Space; Urban Forest.

INTRODUCTION

Urban trees support biodiversity and climate resilience by providing ecosystem goods and services (Czaja et al. 2020). However, urban tree canopy cover and growing conditions vary across cities (Czaja et al. 2020; Locke et al. 2021). While patterns in tree canopy are increasingly well-documented, patterns of tree stress are not. Here, we quantify how street tree stress varies within 2 USA cities. Using a dense urban and a semi-suburban city as examples, we examine whether street tree stress is associated with tree characteristics (species, tolerance to urban stress); site conditions (land use, planting site); and cues to care.

Urban growing conditions impact tree stress, especially for street trees that are exposed to pollution, compacted soils, conflicts with built infrastructure (e.g., utility lines), and limited space (Randrup et al. 2001; Czaja et al. 2020). Trees in small planting sites and in commercial and industrial zones are especially stressed (Czaja et al. 2020; Tan and Shibata 2022; Bigelow et al. 2024). Growing near impervious surfaces, like pavement, can reduce tree growth and leaf area compared to trees surrounded by pervious cover (Zhu et al. 2021; Tan and Shibata 2022). Cities do not provide homogeneously stressful conditions; the extent of impervious surfaces, conflicting infrastructure, and other stressors varies and differentially impacts trees.

Tree care practices can mitigate the stress of urban conditions and promote tree survival (Roman et al. 2015; Vogt et al. 2015; Breger et al. 2019), but the impacts of care on nonlethal tree stress are understudied (though see Esperon-Rodriguez et al. 2025). Tree care can be vital for tree growth and survival during stressful events, like droughts, and for recently planted trees (Roman et al. 2015; Breger et al. 2019). Because street trees are cared for by overlapping actors (municipal foresters, nonprofits, residents, etc.), it is often impossible to document all the care a tree may receive over time without interviews or extensive maintenance datasets. However, we can note cues to care, like mulching, pruning, or landscaping that are visible for months or years after initially implemented. Alongside the direct potential benefits that care like mulching can provide (Green and Watson 1989; Vogt et al. 2015), there is evidence that cues to care contribute to people's perceptions of place and can encourage broader pro-environmental behavior that could benefit trees (Li and Nassauer 2020).

Though nonlethal tree stress can be difficult to quantify, tree canopy characteristics can act as early signs of stress. Stress is visible in the tree canopy as leaf discoloration, leaf absence as dieback, or damage to leaves through leaf defoliation (Pontius and Hallett 2014). Leaf discoloration is driven by the presence and efficiency of photosynthetic pigments, which are in turn influenced by water levels, nutrient levels, and pathogens (Mu and Chen 2021; Talebzadeh and Valeo 2022). Leaf photosynthesis is also limited by root damage, dry and nutrient-poor soils (e.g., from drought or soil quality), pollutants, and salt stress (Czaja et al. 2020). Leaf defoliation is a sign of insect herbivory, which is common in hot urban landscapes (Dale and Frank 2014). Pathogens can also cause leaf defoliation along with discoloration (Prins and Verkaar 1992). Microbes and fungi, with enough time, access, and appropriate environmental conditions, can lead to trunk and branch decay and thus both discoloration and, eventually, dieback (Parfitt et al. 2010). For various stressors, if the degree of stress is high enough or sustained enough, they can prompt trees to shed leaves (i.e., dieback)(Escudero and del Arco 1987; Pontius and Hallett 2014). Managers often use a condition or overall crown stress rating to estimate tree health, ranging from dead to excellent (Schomaker et al. 2007; Dale and Frank 2014). These ratings rely on expert knowledge but incorporate elements of the crown structure like discoloration, defoliation, and dieback. Although these metrics all highlight mechanisms of tree stress, it is unclear to what degree they influence one another and how they relate to urban growing conditions.

This research quantifies tree stress within 2 contrasting cities in the USA to understand how tree stress varies with urban growing conditions and cues to care. The 2 cities included here, Chicago, IL, and Durham, NC, are examples of common USA city layouts. Chicago is a large, dense city where street trees represent a considerable proportion of the regional tree canopy cover (Whiteside et al. 2023). Durham is a midsized, semi-suburban city where street trees make up a minority of the canopy cover (SavATree Consulting Group 2017). Using these 2 cities as examples, we investigate whether and how street tree stress corresponds to tree characteristics, site conditions, and cues to care in diverging contexts. We hypothesize that tree stress (especially discoloration, dieback, and crown stress) are higher in smaller rooting spaces, nonresidential zones, and when lacking clear signs of tree care. That said, the vulnerability of young/newly planted trees and species-level differences in tolerance of urban growing conditions may play a role as well. Therefore we expect tree characteristics to play a large role, especially for defoliation and discoloration.

MATERIALS AND METHODS

Data were collected to assess the relationship between tree stress and growing conditions in a dense urban (Chicago) and a semi-suburban city (Durham). Within each city, data were collected during the growing seasons between 2021 and 2023 from all street trees on a stratified random selection of streets, described below. Tree stress responses were modeled separately in each city using Bayesian models, comparing a multivariate model with 3 response variables (leaf discoloration, leaf defoliation, and dieback) to a univariate model with only overall crown stress as a response variable.

Site Descriptions

Chicago, Illinois

Chicago is a large city in the Midwestern USA with a continental climate and a population of more than 2.7 million people as of 2022 (around 4,500 people per km^2)(US Census Bureau 2022)(Table 1). Chicago has warm summers and cold winters with an average annual precipitation of 962 mm (Table 1)(Ford 2024b). Chicago has an estimated 4 million trees, with an overall canopy cover of 16% to 20% (Whiteside et al. 2023). The Bureau of Forestry manages street trees and responds to resident calls for tree pruning.

However, developers and property owners are expected to support public way maintenance during the first 5 years after construction, including weeding, mowing, controlling pests, watering, and other care (Bureau of Forestry 2024a). A nonprofit runs a Tree-Keeper program that also does tree planting and pruning in the city (Openlands 2024). The city also has a tree planting guide that provides guidance on species selection (Bureau of Forestry 2024b).

Because Chicago is a large and heterogeneous city, here we focus on one region, the West Side (population of 355,000)(US Census Bureau 2022). The West Side, as defined by the Healthy Chicago Equity Zones (City of Chicago 2020), includes neighborhoods with a range of racial/ethnic compositions and socioeconomic characteristics. For a further discussion of the way structural inequality plays into the patterns of tree health observed here, see Poulton Kamakura et al. (2026).

Durham, North Carolina

Durham is a midsized city of 290,000 (around 1,000 people per km^2), with a warm, wet climate and high tree canopy cover (US Census Bureau 2022)(Table 1). The city averages 1,219 mm of rain annually (North Carolina State Climate Office 2021) with slightly warmer summers and much warmer winters than Chicago (Table 1)(NOAA 2021). Durham has 53% canopy cover as of 2017; the city boundaries include a large university forest and other heavily treed areas (SavATree Consulting Group 2017).

Durham has an urban forestry division that manages street trees and legislation that requires tree planting and care on public and private property. The urban forestry division manages trees on city property and rights-of-way, though residents can also request trees be planted (City of Durham 2023). The city works with nonprofits and the state cooperative extension to run a Tree Keepers program that trains volunteers to plant and prune young trees (Keep Durham Beautiful 2024). Trees near utility lines are heavily pruned by the regional energy company (City of Durham 2024), and universities help steward trees near their campuses. The city also produced a tree planting guide that describes which tree species can be planted (Durham City-County Planning Department 2005).

Choosing Sampling Locations

In both cities, we sampled trees within the public rights-of-way based on a stratified random sample of streets. Each city was split into a grid that matches sampling schemes devised for ongoing research in each city (1.5 km × 1.5 km in Chicago, 1 km × 1 km in Durham). Grid cells were selected based on stratification (performed separately for each city) using percent renter occupied housing, median home value, and percent tree canopy cover (USDA Forest Service 2021; US Census Bureau 2022). Tree canopy cover is known to influence and be influenced by other elements of urban conditions (e.g., temperature, inequities)(Locke et al. 2021; Wang et al. 2023), rentership rates can be related to patterns of tree survival (Vogt et al. 2015), and home values are influenced by various elements of the social and physical context, including tree canopy cover in some cases (e.g., Sachs et al. 2023). The values for each cell were the area-weighted mean of the census variables or the mean

Table 1. Selected attributes of study sites. Population estimates are from the US Census (US Census Bureau 2022), and tree canopy cover estimates are from separate LiDAR-based analyses in each city in 2017 (in Chicago: Chicago Region Trees Initiative 2022)(in Durham: SavATree Consulting Group and University of Vermont Spatial Analysis Lab 2017). LiDAR (Light Detection and Ranging); EPA (Environmental Protection Agency).

Attributes	Chicago, Illinois	Durham, North Carolina
Average precipitation	962 mm	1,219 mm
Average July temperature	24.1 °C	25.5 °C
Average January temperature	−3.8 °C	3.5 °C
Population (within city boundary) in 2021	2,600,000	290,000
Percent tree canopy cover in 2017	20%	53%
EPA Level III Ecoregion	Central Corn Belt Plains	Piedmont

for canopy cover. These values were then categorized based on their quartile compared to all grid cells within the city (Durham) or region (West Side of Chicago). Using a random number generator, grid cells were then chosen to include at least one grid cell from the upper and lower quartiles of each of the stratification variables and to ensure unique combinations of quartiles. In Durham, where a city tree inventory was available and street trees were less common, selected grids had to include at least 10 city-managed street trees. This selection criteria was to make sure that randomly drawn street segments had a chance to include at least one city-managed street tree that we had permission to sample. However, it means that the sample population is biased towards areas near the downtown (with low overall canopy cover), areas with historical city tree planting (generally wealthy, white), and current priority tree planting areas (City of Durham 2018).

A random 0.8-km street segment, representing a sample of the streets in the grid cell, was created for each cell based on a protocol developed by the US Forest Service (e.g., Bigelow et al. 2024). A fine-scale grid (100 m × 100 m) was overlaid on geographic information system (GIS) layers of public roads to create 100-m road segments. Highways, onramps, and alleys were excluded. One 100-m road segment was randomly selected from within each coarse grid cell (1.5 km^2 or 1 km^2) as a starting point. This 100-m road segment was extended to 0.8 km in Google MyMaps (Google, Mountain View, CA, USA), using a random number generator to decide which turns to make (right, left, or straight ahead). To obtain samples of more than 500 trees in more than 10 neighborhoods, we sampled 13 street segments in Chicago's West Side and 24 in Durham (Figure S1). For each 0.8-km street segment, we sampled all street trees within city inventories (Durham) or within 3 m of the street (the public right-of-way in Chicago).

Data Collection

Sampling occurred from 2021 to 2023 in Chicago and 2022 to 2023 in Durham between May and August. To account for interannual variation in stress, some trees were resampled in each city. The total number of trees and tree-year observations is: 998 unique trees with 1,424 observations in Chicago and 541 unique trees with 754 observations in Durham (see Table S1 for details on number of trees resampled each year). Trees were sampled by trained research staff, including several co-authors. Training was performed to ensure all members of the team consistently described tree characteristics, site conditions, cues to care, and tree stress and sampling. In line with Healthy Trees, Healthy Cities (HTHC) protocols, sampling was performed in teams of two to augment consistency and allow discussion of borderline conditions. Additionally, for each year and in both locations, 10% to 20% of the trees were resampled as part of quality control protocols to ensure tree stress values were consistent across teams and through time. Errors estimated from this resampling are available in Tables S2 and S3.

We collected site condition variables, cues to care, and tree characteristics for each tree to use as predictors for our models of tree stress (see below).

Site Condition Variables

Site condition variables describe the physical growing conditions and were collected in the field. Based on the Urban Tree Monitoring Field Guide (Roman et al. 2020), they included latitude/longitude location, site type, land use, the presence of powerlines, percent impervious surface in the root zone (approximately twice the canopy width), crown light exposure, and whether a tree was within 3 m of a street and/or sidewalk. Land use was determined by field teams based on the types of buildings/structures adjacent to the tree and, for residential areas, whether buildings were obviously subdivided into two or more units (single-family vs. multi-family). For parking lots, the land use was determined by what the parking lot was for (e.g., a grocery store). Powerlines were listed as present if they were aboveground and within 1 m of the top of the canopy of the sampled tree and listed as absent otherwise. Site type, also collected in the field, described a tree's immediate location (e.g., street median, planter box). Percent impervious surface in the root zone was an ordinal variable, measured as (1) trace; (2) 2% to 25%; (3) 26% to 50%; (4) 51% to 75%; or (5) 76% to 100%. We used approximately twice the canopy width as an imperfect estimate of the potential root zone for consistency and as a proxy for root restriction from barriers to root growth. Crown light exposure was measured based on HTHC protocols (Hallett et al. 2019) ranging from zero to five. Zero means the tree receives no light; one means the tree receives light on one side (at least a third of the side for the whole day or the whole side for at least a third of the day); two means the tree receives light on two sides; and so forth, up to five meaning the tree receives light on all sides (see Table S7 for sampling frequencies).

Tree Characteristics

Tree characteristics account for differences in tree biology (e.g., urban-tolerance, size) that could influence tree conflicts with infrastructure and stress levels. Data collection was based on protocols described by Roman et al. (2020). Variables collected in the field were diameter at breast height (DBH), species (or genus if unsure), and a photo of the tree. Additionally, whether a species was considered urban-tolerant or whether a tree "adapt[s] exceptionally well to a variety of environmental and/or urban stresses, such as heat, drought, and compacted, infertile soils" (a binary tolerant/not) was derived from Dirr (2016). Basal area was calculated based on DBH. Potential mature tree height was taken from Dirr (2016). See Table S5 (Chicago) and Table S6 (Durham) for genera and species sampled.

Cues to Care

Cues to care are identifiable examples of tree care. These included the presence of mulch, tree guards, staking, pruning, and landscaping intensity. For pruning and mulch, we noted if it was present and if it followed arborist best management practices (BMPs) (Lilly et al. 2019). Landscaping intensity is an ordinal variable with 4 classes: (1) minimal or no mowing or other evidence of tree care; (2) minor evidence of care/management of plantable area (e.g., mowing, weeding a planter box); (3) evidence of gardening/management focusing on the tree; and (4) extensive evidence of gardening/management of the tree and throughout the plantable area (see Table S7 for sampling frequencies).

Tree Stress Metrics

Tree stress is recorded using 4 overlapping metrics that capture aspects of tree stress responses. The metrics are from the HTHC protocol (Hallett et al. 2019): leaf discoloration, leaf defoliation, fine twig dieback, and overall crown stress. Leaf discoloration is defined as the percent leaf area discolored. Leaf defoliation is defined as the percent total leaf area missing without the entire leaf being gone. Fine twig dieback is defined as percent total leaf area missing due to lost leaves on the small, outer twigs of the canopy (Schomaker et al. 2007). Metrics were simplified before data analysis due to lack of sample variation: 3 levels for defoliation (trace, 2% to 25%, > 25%); 4 levels for discoloration (trace, 2% to 25%, 26% to 50%, > 50%); and 5 levels for dieback (trace, 2% to 5%, 6% to 10%, 11% to 25%, > 25%)(see Table S8). Overall crown stress is a summary metric that depends upon discoloration, defoliation, fine twig dieback, and large-branch dieback. It ranges from one (minimal stress) to five (dead)(Tables S6, S7). Class one includes trees with less than 10% cumulative fine defoliation, discoloration, and dieback with no major branch mortality. Class two includes trees with 10% to 25% cumulative defoliation, discoloration, and dieback and/or < 25% of the crown area missing due to large branch death. Class three includes trees with 25% to 50% cumulative defoliation, discoloration, and dieback and/or 50% or less of the crown area missing due to large branch death. Class four is greater than 50% cumulative defoliation, discoloration, and dieback and/or more than 50% of the crown area missing due to large dead branches, and class five is dead.

Data Cleaning and Model Preparation

To construct models of tree stress, predictor variables were selected from tree characteristics, site conditions, and cues to care. Potential predictors were: site condition (site type, land use, percent impervious surface, powerlines, sidewalks, crown light exposure); tree characteristics (species group, basal area, species urban tolerance); cues to care (mulch following BMPs, pruning following BMPs, landscaping); and baseline variables (street segment, tree ID, year)(Figure 1). Basal area values were log-transformed for analyses due to their otherwise skewed distribution. In addition, due to limited sample sizes, some categories were simplified. For land use, categories were grouped while ensuring that categories commonly used in land-use-based analyses (residential, commercial, and parks or natural areas) remained. For example, in Durham where multi- family residential was not common, multi-family and single-family residential was grouped together into "residential". This left 6 classes in Chicago and 5 classes in Durham. Site type was grouped by the extent of the rooting space, with sidewalk cutouts/other hardscape (the most restrictive), then sidewalk planting strips (the most common, moderately restrictive), then other categories that had more rooting space (see Table S4 for original and simplified categories). For species group, commonly sampled tree species (having at least 5% of the total observations,

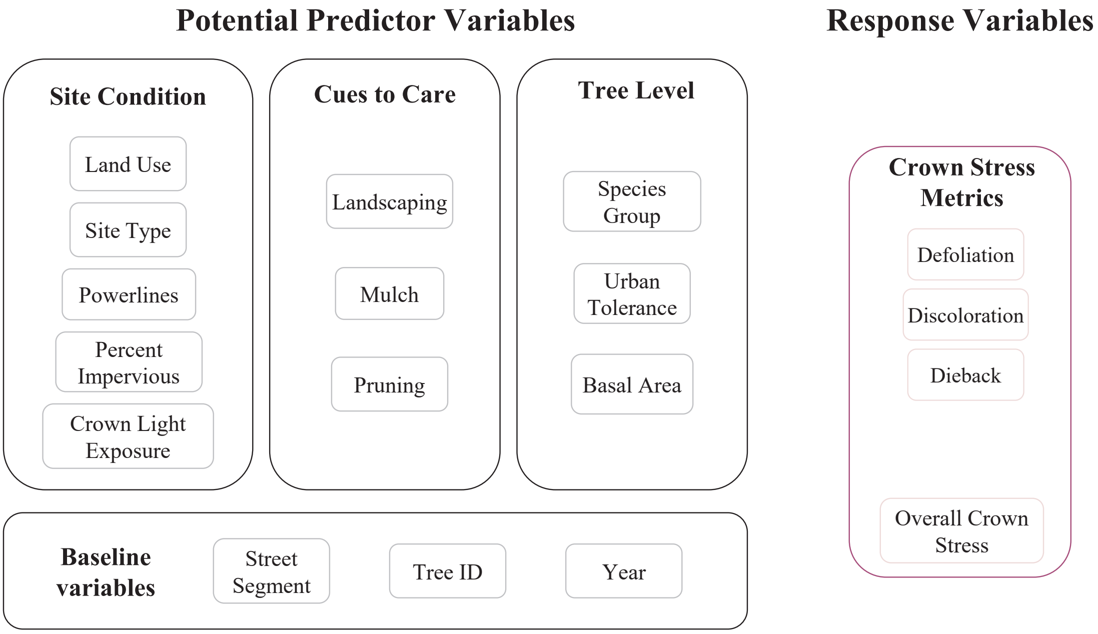

Figure 1. Predictors used to model tree stress in Chicago, IL, and Durham, NC. Site condition variables describe the underlying stressors present in a location, cues to care describe potential mediating variables that can reduce the impact of the stressors, and tree characteristics describe a trees' tolerance for the stressors present. The baseline variables are included to account for the sampling design. Defoliation, discoloration, and dieback were all modeled together in one multivariate model while overall crown stress was modeled separately.

71 observations in Chicago, 41 observations in Durham) were analyzed at the species level, and for the remaining individuals genera with at least 5% of the total observations were analyzed at the genus-level. All other individuals were grouped based on mature tree size (small ≤ 10.5 m, medium between 10.5 m and 15.25 m, and large > 15.25 m). A list of species and their grouping for analysis and genera is available in Table S5 (Chicago) and Table S6 (Durham).

To allow for cross comparisons between Chicago and Durham, we included only predictors that varied in both cities and were not highly correlated (full list of excluded variables in Table S9). For example, whether or not a tree was next to a sidewalk was not included as a predictor because more than 90% of trees in Chicago were next to a sidewalk, leaving too few not near sidewalks for parameter estimation. We set up the models to initially include variables that are known to have impacts on tree survival and stress susceptibility, namely tree size (basal area), tree type (species group), land use, and site type (as a proxy for rooting space)(Hilbert et al. 2019; Roman et al. 2020; Bigelow et al. 2024). We then added other measured variables, excluding those that were highly correlated (variable inflation factor > 5)(see Table S9)(Shrestha 2020). Year and segment were used to account for differences in sampling across years and potential spatial covariance. Because some trees were sampled multiple times and those samples were not independent, tree ID number was included as a random effect. Generalized joint attribute modeling (GJAM) handles random effects such that trees that are not resampled will be grouped into a "rare groups" category because otherwise the lack of multiple observations makes parameter estimation impossible. The sampling frequencies of included variables can be found in Table S7.

The models for tree stress included some interactions between predictor variables (tree level, site condition, and cues to care variables), with multiplicative parameterization. The first interaction (basal area and species group) accounts for species and genus-level differences in the relationship between tree basal area and senescence and likelihood of conflicting with built infrastructure (Randrup et al. 2001; Qiu et al. 2021). The second interaction (urban tolerance and site type) accounts for an individual species' ability to survive conditions (pollution, salt, drought, small space) that are most relevant for site types with limited rooting space (Dirr 2016; Bigelow et al. 2024).

Data Analysis and Modeling

Due to various inter-city differences, we modeled each city separately. Although the same variables were recorded in both cities, predictors do not have the same implications for trees in the two locations. For example, though both cities have commercial zones, Chicago has commercial areas embedded within residential areas, while in Durham they are primarily downtown or in strip malls. Because of these and other differences (climate, population density, species composition), we expected best-fitting models to differ between cities.

For each city there were two models: one with defoliation, discoloration, and dieback as joint response variables, and one with overall crown stress as a sole response variable. Defoliation, discoloration, and dieback were modeled using a multivariate ordinal model: a Generalized Joint Attribute Model (GJAM) (Clark et al. 2017). GJAM models response variables jointly, recognizing their nonindependence, but still provides an estimate of model fit and predictor parameter estimates for each individual response variable (Clark et al. 2017). The responses (defoliation, discoloration, and dieback) were modeled as integer values corresponding to the ordered categories described above (see Table S8). In this case, GJAM follows Lawrence et al. (2008): a multivariate probit model with the addition of parameter expansion to sample the posterior distribution and allow for a Bayesian approach. The second model has only overall crown stress as a response in a univariate ordinal model, also modeled off of Lawrence et al. (2008). This approach allows us to compare the variation explained for a combined metric (overall crown stress) to the 3 individual but overlapping ones (discoloration, defoliation, dieback). For all models, priors for predictor variables were set as gaussian centered around zero. To test model configurations, variables and/or interactions were iteratively removed based on sensitivity, though year, tree ID, and (log-transformed) basal area were always included in potential models due to their relevance for sampling design and basic tree biology (see above). The best model was then selected based on Deviance Information Criterion (DIC), commonly used for Bayesian model comparison (Spiegelhalter et al. 2002). For all evaluated models, trace plots were checked to ensure that models converged (e.g., Figures S2, S3). All data cleaning and modeling were performed using R (R Core Team 2023) with the dplyr (Wickham et al. 2026) and GJAM packages (Clark et al. 2017). Other functions were written in C++. A full list of evaluated models and their DIC values can be found in Tables S10 to S13, with the predictors tested summarized in Table S14.

RESULTS

Both the West Side of Chicago and Durham had a similar range of tree sizes and stress levels. However, Durham had the larger maximum DBH, and Chicago had the larger median DBH (Table 2). There were more than triple the average trees per street segment in Chicago compared to Durham (Table 2).

In line with differences in climate, size, density, and history between Chicago and Durham, different predictors were in the best models for tree stress in the two cities. Because this could be explained by a range of differences between the two cities (climate, population density, etc.), we focus here on similarities and major differences.

Parameter estimates for all predictor variables included in the best-fitting models (based on DIC values and model selection described above) can be found in Tables S15 to S18.

Discoloration, Defoliation, and Dieback

Site Condition Variables

Both site type and land use were in the best-fitting models for defoliation, discoloration, and dieback in both cities, but the effects diverge (Table 3, Figure 2). In Chicago, trees in sidewalk planting strips were associated with low dieback compared to trees in sidewalk cutouts. In Durham, planting strips were associated with high defoliation and dieback compared to trees in the most restrictive rooting spaces (sidewalk cutouts, other hardscape). For land use, commercial zones were associated with higher discoloration and dieback than single-family residential zones in Chicago, but that was not the case in Durham (Figure 2).

Tree Characteristics

The associations between tree characteristics and tree stress diverge between the two cities, but in both cases tree stress is associated with species group (Figure 3). Urban tolerance was also in the best models in both cities along with the interaction between urban

Table 2. Summary of information for street segments and sampled trees in Chicago and Durham. Mean values for basal area, discoloration, defoliation, dieback, and overall crown stress are calculated using the most recent observation for any given tree to avoid counting a tree more than once. More information on the number of trees with different attributes (e.g., land use, mulching) can be found in Table S7. DBH (diameter at breast height);

Variable	Chicago	Durham
Individual trees	998	541
Observations	1,424	754
Number of 0.8-km street segments	13	24*
Mean trees per segment (min to max)	76.8 (34 to 106)	22.5 (1* to 76)
Total number of species**	59	63
Median DBH (cm)(min to max)	31 (0.254 to 114.3)	11.7 (0.254 to 121.4)
Mean DBH (cm)	33	19.8
Mean defoliation (1–4) ± standard deviation	1.34 ± 0.5	1.35 ± 0.49
Mean discoloration (1–4) ± standard deviation	1.82 ± 0.9	2.19 ± 0.94
Mean dieback (1–5) ± standard deviation	2.50 ± 1.323	2.19 ± 1.39
Mean overall crown stress (1–5) ± standard deviation	2.13 ± 1.07	2.25 ± 1.18

*For analysis, segments with 10 or fewer trees were grouped as “Other”, leaving 15 levels for street segment (14 segments and 1 “Other”).

**Some individuals were only identified to genus, so this is a conservative estimate of the number of species sampled. For a full list of species, see Tables S5 and S6.

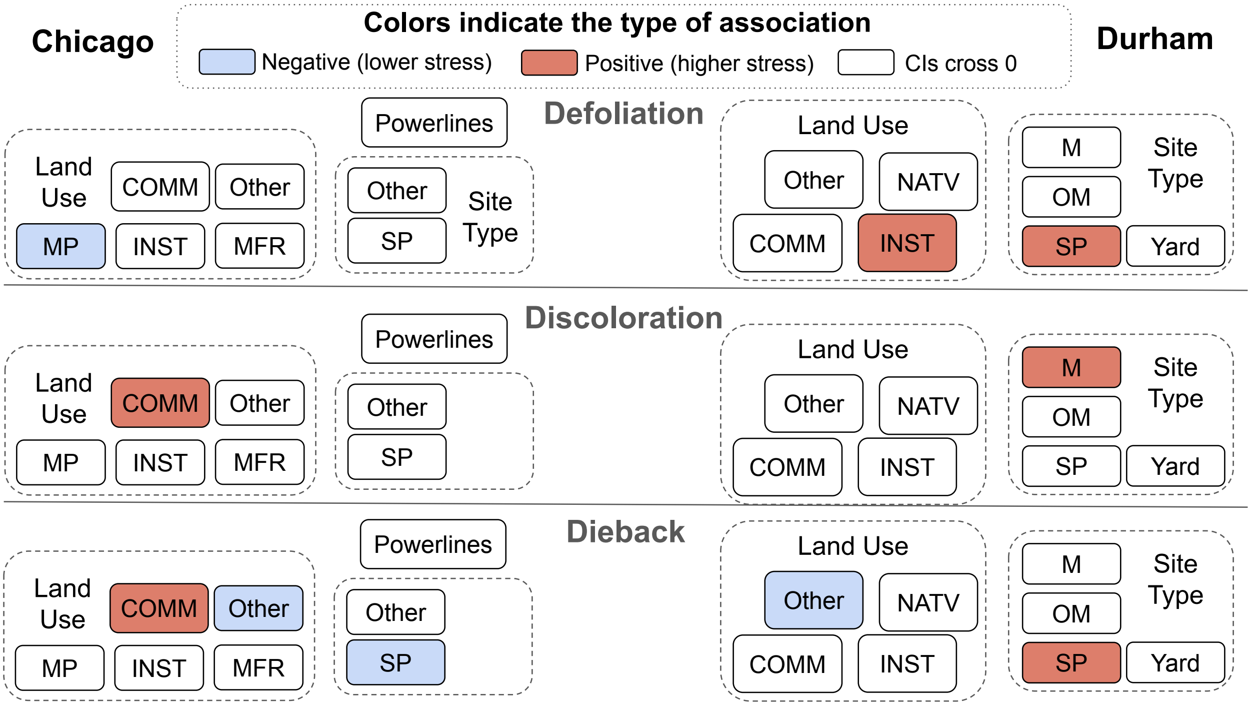

Figure 2. Relationships between site conditions (site type, powerlines, land use) and tree stress responses (defoliation, discoloration, and dieback) in the multivariate model for Chicago and Durham. Box colors signify the type of association: negative (light blue), positive (red), or with confidence intervals (CIs) that cross zero (white). The abbreviations for land use are: commercial and mixed-use (COMM), managed park (MP), institutional (INST), multi-family residential (MFR), and natural area/vacant lot (NATV). The abbreviations or site types are sidewalk planting strip (SP), median (M), and other maintained area (OM). The baseline category for site type is sidewalk cutout in Chicago and sidewalk cutout and other hardscape in Durham. The baseline category for land use is single-unit residential in Chicago and residential for Durham. Full parameter estimates with standard errors and CIs can be found in Tables S15 and S17.

tolerance and site type, though the confidence intervals for the interaction crossed zero for all three metrics in both cities (Figure 3). In Chicago, basal area was associated with lower discoloration and higher dieback, and in both cities the interaction between basal area and species group had different associations depending on the stress metric and species group of interest (Figure 3). In both cities, the baseline species group is the most commonly sampled species (*Gleditsia triacanthos* in Chicago and *Lagerstroemia* cultivars in Durham), both of which are urban tolerant species. Compared to this baseline species, in Chicago, *Fraxinus* spp. (struggling with emerald ash borer) were associated with high dieback, while in Durham, *Quercus phellos* was associated with high dieback, and in both cases the interaction with basal area indicates that the association with high stress increases as the trees get larger (Figure 3). However, many of the other species or genera included were not associated with higher discoloration or dieback compared to the baseline urban tolerant species (Figure 3).

Cues to Care

In both cities, cues to care did not appear to play a major role (Tables S15, S17). Landscaping intensity and mulch were both in the best models for defoliation, discoloration, and dieback in both cities (Table 3). The parameter estimates were generally negative, associated with lower stress, but the confidence intervals routinely crossed zero (Tables S15, S17).

Relationship Among Tree Stress Variables

Discoloration and dieback were correlated beyond what is explained by predictors in Chicago, but not in Durham (residual covariance = 0.1787 in Chicago). The same is true for discoloration and defoliation in Chicago (residual covariance = 0.2759), but not in Durham (Tables S19, S20). This residual covariance in Chicago indicates that discoloration tends to occur with dieback and with defoliation beyond what is expected from the predictors alone, though the same is not true for the co-occurance of defoliation and dieback.

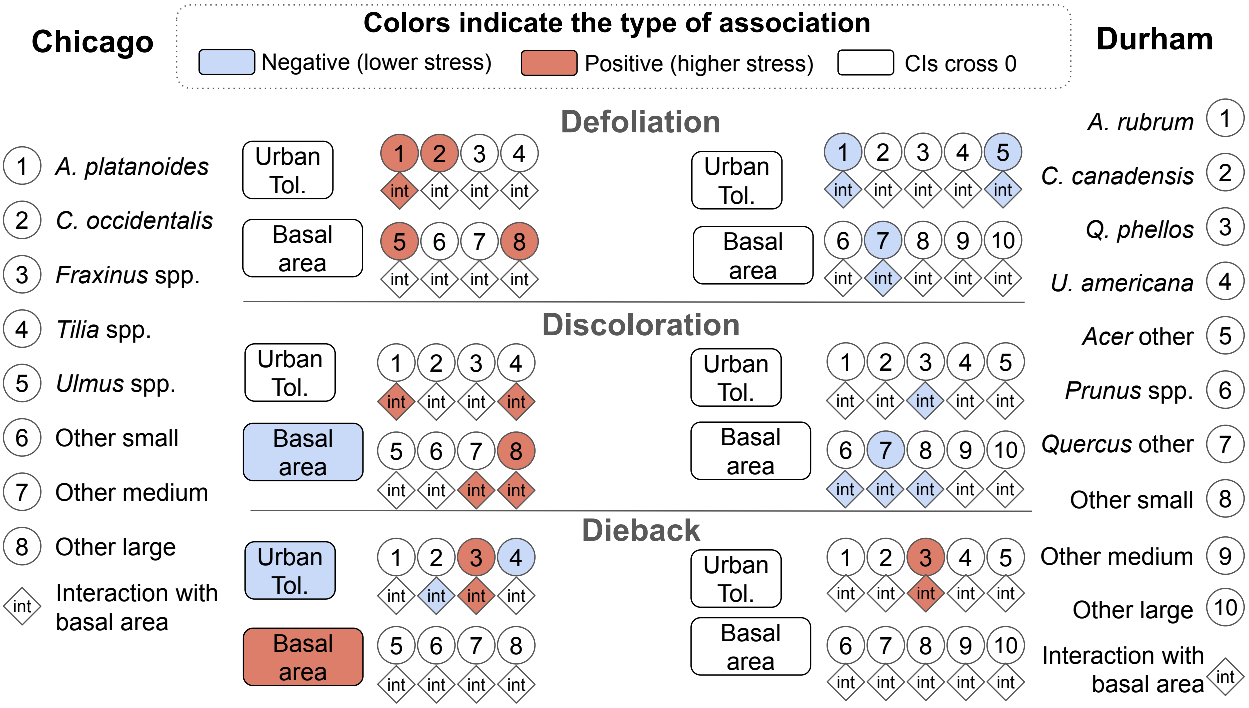

Figure 3. Relationships between tree characteristics and stress responses (defoliation, discoloration, and dieback) in the multivariate model for Chicago and Durham. Box colors signify the type of association: negative (light blue), positive (red), or with confidence intervals (CIs) that cross zero (white). Numbers correspond to species groups, labeled on the left (Chicago) and right (Durham) sides of the figure. The diamonds with the letters "int" in them represent the interaction between basal area and the species group above the diamond. The abbreviation "spp." stands for "species" and the abbreviation "tol." here stands for "tolerance". The baseline categories for species group are the most common, urban tolerant species in each city: G. *triacanthos* (honeylocust) in Chicago and *Lagerstroemia* spp. (crape myrtle) in Durham. The list of species in each species group with sample sizes are available in Tables S4 and S5. Full parameter estimates with standard errors and CIs can be found in Tables S15 and S17.

Table 3. Predictors and R^2 values models of tree stress. There are two submodels for each city: one multivariate model with defoliation, discoloration, and dieback as response variables; and a univariate model with overall crown stress as the response variable. For tables of DIC values for all tested models, see Tables S10–S13. For a table of all tested and included predictors in the final models, see Table S14. DIC (Deviance Information Criterion);

Location	Predictors	Tree stress metric	R^2 value
Chicago	Street Segment, Year, Basal Area × Species Group, Powerline, Landscaping Intensity, Urban Tolerant × Site Type, Land Use, Mulch, Pruning	Defoliation	0.655
		Discoloration	0.288
		Dieback	0.225
	Street Segment, Year, Basal Area × Species Group, Urban Tolerant × Site Type	Overall crown stress	0.198
Durham	Street Segment, Year, Basal Area × Species Group, Landscaping Intensity, Urban Tolerant × Site Type, Land Use, Mulch	Defoliation	0.567
		Discoloration	0.341
		Dieback	0.247
	Street Segment, Year, Basal Area + Species Group, Powerline, Landscaping Intensity, Urban Tolerant × Site Type, Land Use, Mulch, Pruning	Overall crown stress	0.327

Overall Crown Stress

Site Condition Variables

The associations between site condition variables and overall crown stress diverged in the two cities but were similar to the results for dieback. Site type was in the best-fitting models for both cities, and land use and powerlines were in the best-fitting model for Durham. For site type, in Chicago, sidewalk planting strips were associated with lower crown stress than sidewalk cutouts. In Durham, sidewalk planting strips were associated with higher stress compared to the most restrictive rooting spaces (Figure S4).

Tree Characteristics

Overall crown stress highlighted the importance of basal area and species group, especially in Durham. In both cities, higher basal area was associated with lower overall crown stress, and in Chicago urban tolerance was also associated with lower overall crown stress (Figure 4). In Durham, the parameter estimates for species group indicated that all groups had higher overall crown stress than the baseline urban tolerant group (*Lagerstroemia* spp.)(Table S16). The interaction between basal area and species group was not in the best-fitting model for Durham, but in Chicago, the interaction indicated that larger basal area may be associated with higher stress for medium and large stature trees, among others (Figure 4).

Cues to Care

No cues to care were in the best-fitting model for overall crown stress in Chicago, and in Durham the parameter estimates for mulch and landscaping were all negative (associated with lower stress than no mulch or landscaping), but all the confidence intervals crossed zero (Tables S16, S18).

DISCUSSION

Each of the canopy stress metrics here provide similar but not identical insight into the relationship between tree characteristics, site conditions, and stress. Using defoliation, discoloration, and dieback highlighted the influence of land use and site types (Figure 2). Overall crown stress, defined as the sum of the other stress metrics with the addition of large branch dieback, highlighted the role of basal area in reducing overall stress (Figure 4) and the relative urban tolerance of the baseline species group in Durham (*Lagerstroemia* spp.). However, overall crown stress, as a composite metric, is less capable of capturing mechanisms driving stress responses if they differ between the components (e.g., pollution stress from cars for discoloration vs. extensive herbivory facilitated by surrounding vegetation for defoliation). Because the HTHC methodology is designed to be accessible to nonexperts and training resources are freely available (Hallett et al. 2019), there is potential for volunteers, residents, and others to collect monitoring data that could complement the crown vigor assessments analogous to "overall crown stress" used here (discussed below). Though more complicated than just using one metric, discoloration, defoliation, and dieback provide distinct information that is not always clear from overall crown stress alone.

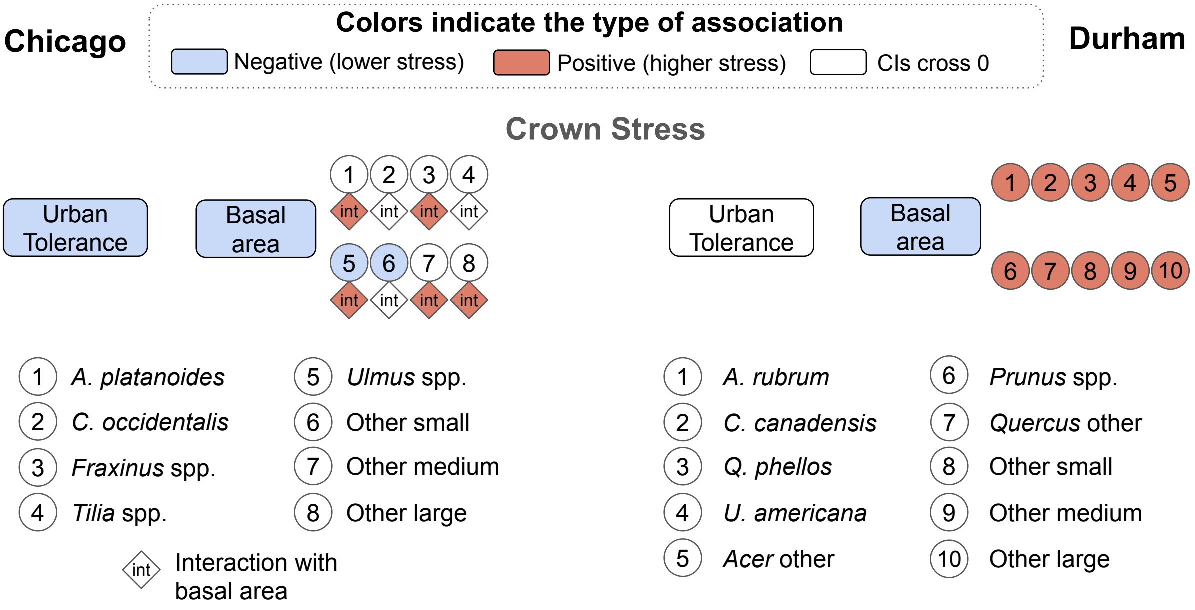

Figure 4. Relationships between tree characteristics (genus, basal area, and urban tolerant) and overall crown stress in the univariate model for Chicago and Durham. Box colors signify the direction of the relationship: negative (light blue), positive (red), or with confidence intervals (CIs) that cross zero (white). Numbers correspond to species groups, labeled on the left (Chicago) and right (Durham) sides of the figure. The diamonds with the letters "int" in them represent the interaction between basal area and the species group above the diamond. The abbreviation "spp." stands for species. The baseline categories for species group are the most common, urban tolerant species in each city: G. *triacanthos* (honeylocust) in Chicago and *Lagerstroemia* spp. (crape myrtle) in Durham. The list of species in each species group with sample sizes are available in Tables S5 and S6. Full parameter estimates with standard errors and CIs can be found in Tables S16 and S18.

Defoliation

Defoliation is primarily driven by herbivory or pathogens, and many pathogens and herbivores have restricted hosts and diet preferences (Prins and Verkaar 1992; Fraser 1997). Therefore, defoliation can reflect species or genus level differences in herbivory or pathogen vulnerability. Though we did not directly sample for herbivores or pathogens, in some cases their influence was evident. For example, in Chicago, *Celtis occidentalis* had high defoliation (Figure 3). This came almost exclusively from Psyllid galls, which were not found in the other species groups (Yang and Mitter 1994).

The relationship between site conditions and defoliation in Durham and Chicago don't point to clear overlaps and, if anything, highlight how different the conditions in the two cities are for defoliation (Figure 2), though direct sampling of herbivore or pest densities would help clarify how/if they vary across land use and site types in both cities.

Discoloration

The association between tree characteristics and discoloration, specifically species group and basal area, were consistent with planting stress and stress from restricted rooting spaces. Larger trees were associated with lower discoloration either directly (Chicago) or indirectly (Durham)(Figure 3), consistent with smaller trees being more recently planted and suffering from transplant shock (Watson 2005; Czaja et al. 2020) and/or having more limited root systems that may be less able to access deep water. In Durham, though basal area was not individually associated with lower discoloration, its interaction with species group indicated that it might be for some tree types with deep roots (e.g., *Q. phellos* and other oaks, *Prunus* spp.). That said, root depth is also heavily driven by soil conditions and not just tree species, and other species groups can also grow deep roots in urban settings (e.g., *U. americana*)(Day et al. 2010; Czaja et al. 2020). Also, the sampled *Prunus* trees were all relatively small (average DBH 4.6 cm compared to 29 cm for the baseline *Lagerstroemia* and 55 cm for *Q. phellos*), so the effect may be a sampling artifact. Although basal area itself was associated with lower discoloration in Chicago, the interaction between basal area and some species groups (e.g., *Tilia* spp., other large trees) indicates that in some cases high basal area may have less of a beneficial effect, especially for trees with large mature height (Figure 3). This moderated benefit in Chicago could be due to the restricted rooting spaces (all the trees were either in sidewalk cutouts or planting strips, compared to 53% in Durham) (Table S7) that provide less space for extensive root systems (Day et al. 2010; Czaja et al. 2020).

The relationship between discoloration and site type and land use diverged in Chicago and Durham, but heavy car traffic might have played a role in both. In Chicago, commercial areas had high discoloration compared to single-family residential areas (Figure 2). Commercial districts in Chicago tended to have sidewalk cutouts and heavily trafficked roads, which are more likely to have restricted rooting spaces and elevated levels of PM2.5 and other pollutants from cars that can influence discoloration (Dos Santos-Juusela et al. 2013; Mu and Chen 2021; Talebzadeh and Valeo 2022). Although commercial areas were not similarly associated with discoloration in Durham, trees in street medians had high discoloration (Figure 2), which is consistent with stress from being near heavy car traffic (Dos Santos-Juusela et al. 2013; Czaja et al. 2020).

Dieback

Dieback can be a sign of longer-term or intense tree stress (Camarero 2021). Small trees experiencing significant dieback are less likely to have sufficient leaf area to compensate for the loss and so may die, be replaced, and thus be removed from the sample (as seen for five trees with DBH < 6 cm on one segment in Chicago). These removals could explain the association with larger basal area and higher dieback in Chicago (Figure 3). Unsurprisingly, some species were also associated with high dieback relative to the most common, urban tolerant species in each city (Figure 3). The high dieback in *Fraxinus* trees in Chicago is likely related to emerald ash borer, though the city has provided some treatments (Bureau of Forestry 2014) with some sampled trees having no signs of treatment and others with tags indicating treatments as recent as 2020. For *Q. phellos* in Durham, despite some urban tolerance, they tend to have higher dieback in street tree conditions compared to lawn conditions (Salisbury and Grabosky 2020). However, the result could also be a sampling artifact. Of the 10 largest trees (all with DBH > 94 cm), 7 of them were *Q. phellos*. These large *Q. phellos* may have high dieback because they are starting to senesce or display retrenchment.

The two cities had diverging relationships between dieback and sidewalk planting strips. In Chicago, the low dieback for trees in sidewalk planting strips (Figure 2) is consistent with the planting strips having more rooting space than the small sidewalk cutouts (Bigelow et al. 2024). However, in Durham, the opposite is true, and sidewalk planting strips are associated with more dieback relative to sidewalk cutouts. Though sidewalk cutouts were in a variety of areas in Chicago, in Durham 82% of the trees in the most restrictive conditions (sidewalk cutouts and other hardscape) were in just 2 segments, both of which were in the downtown area. These areas have relatively high temperatures and high car traffic, which can be stressful for trees, but are also areas where nearby businesses may provide extra care for the trees that our sampling did not account for (like irrigation) that might offset these stresses. There may also be differences in tree pit design in Durham compared to Chicago that might make the sidewalk cutouts less stressful (e.g., use of pavement suspension systems, porous pavement). That said, dieback was relatively poorly explained by the models (pseudo-$R^2 = 0.225$ in Chicago, pseudo-$R^2 = 247$ in Durham), so other unexamined drivers are likely important (e.g., pruning history, soil conditions).

Relationship Among Defoliation, Discoloration, and Dieback

Residual association between dieback and discoloration in Chicago (Table S19) was consistent with dieback from prolonged water stress. Dieback could indicate the impacts of drought on top of chronic stress (Camarero 2021), and Chicago experienced dry spells in both 2021 and 2023 (Ford 2021, 2024a). The same was not true for Durham, which did not experience droughts in our sampling period (Davis and Dello 2023, 2024). The association between defoliation and discoloration in Chicago (Table S19) could be related to pathogens that cause both (e.g., psyllid galls) or could be because existing stress (like from drought in Chicago) can make trees more vulnerable to new stressors (e.g., drought stressed trees being more susceptible to herbivory)(Gely et al. 2020). Future research tracing tree defoliation, discoloration, and dieback over time and through droughts could clarify the relationship between these stress metrics, though they likely vary by species.

Overall Crown Stress

Overall crown stress, though poorly explained in Chicago (pseudo-$R^2 = 0.198$), did highlight the value of species selection. The association between urban tolerance and lower overall crown stress in Chicago (Figure 4) is consistent with long-standing arborist practices, choosing especially urban tolerant trees for the harshest conditions in cities (Minckler 1941). In Durham, though urban tolerance was not individually associated with low overall crown stress, all species groups were associated with high overall crown stress relative to the baseline urban tolerant species group (*Lagerstroemia* spp. or crape myrtle). *Lagerstroemia* have been and continue to be bred for tolerance to a variety of urban stressors and site types (Orlóci et al. 2025), thus it is not surprising that the *Lagerstroemia* had relatively low overall crown stress.

The site condition variables in the best-fitting models highlighted a key divergence between site types in the two cities that was also present with dieback. Again, sidewalk planting strips were associated with lower stress than the restrictive sidewalk cutouts in Chicago (consistent with the lower stress of more rooting space)(Bigelow et al. 2024), but the opposite was true in Durham (Table S18). The reason why sidewalk planting strips were relatively stressful in Durham is not immediately clear from the data collected here, and, as discussed above, could be related to tree care, tree pit design, or other unmeasured variables.

Cues to Care

Despite the positive impacts of tree care on tree survival and health (Roman et al. 2015; Esperon-Rodriguez et al. 2025), we did not see strong associations between cues to care and reduced tree stress (though most of the parameter estimates are negative, their confidence intervals cross zero)(Tables S15 to S18). The impacts of pruning are hard to detect over short timescales and pruning needs vary by species (Clark and Matheny 2010; Poulton Kamakura et al. 2025). The benefits of mulch can be context dependent (Esperon-Rodriguez et al. 2025; Poulton Kamakura et al. 2025), and without testing the composition of the mulches and the underlying soil conditions, we may not be able to detect when or if mulch has positive benefits for street trees. Urban soils are notoriously heterogeneous, and soil structure and nutrient loads can vary with current site types along with historical land uses and broader sociopolitical patterns not examined here (Pickett and Cadenasso 2009; Czaja et al. 2020). Additionally, the function of cues to care partly depends on how they relate to the cultural values and expectations of residents (Li and Nassauer 2020), and we did not interview residents to see how they viewed the cues to care we catalogued. There are also a variety of sociopolitical factors that can influence the effectiveness of stewardship practices, including whether there is a consistent group providing irrigation or a collective watering strategy (Breger et al. 2019) that cannot be assessed without robust surveys or interviews. Further work could investigate whether landscaping, mulch, or pruning impact how nearby residents, businesses, and others interact with trees as well as how tree care is provided.

Limitations

This study focused on a subset of potential variables influencing tree stress but was limited in the number of trees sampled, the areas covered, and the predictor variables characterized. Though a sample size of 998 individual trees for Chicago and 541 individual trees in Durham does allow us to understand some interactions between predictor variables, the sample sizes were too small to investigate other interactions (between, for example, forms of tree care). We also only had 3 years of sampling in Chicago and 2 years of sampling in Durham. On top of that, not all trees were resampled every year, which limited our ability to understand interannual variation. The spatial extent was also limited such that, in Durham, only areas that had some city managed street trees could be sampled, excluding some of the areas with high canopy cover not prioritized for street trees and some areas without sidewalks. In Chicago, we only focused on the West Side of the city, which includes neighborhoods that vary in sociodemographic characteristics but is not representative of the rest of the city and especially excludes the wealthiest parts of the city, the densest parts of the downtown, and some areas heavily impacted by industrial pollution. Thus, the results in Durham are more relevant to areas with city-managed street trees, and results in Chicago are more relevant to the West Side and might differ from those seen across the whole city.

There were other potentially influential predictor variables that we did not sample, including and especially soil conditions and microclimatic conditions.

As discussed in Poulton Kamakura et al. (2026), we did initially include soil electrical conductivity and soil compaction. However, pilot soil electrical conductivity measurements varied heavily with rain conditions, and sampling could not easily be adjusted to avoid rainy days (Figure S5). For soil compaction, values similarly depended on whether technicians moved mulch to sample and whether it was raining (Figure S6). However, soil conditions are known to have substantial impacts on tree stress, especially as it relates to available nutrients, soil moisture, and available soil volume (Day et al. 2010; Czaja et al. 2020). Microclimatic conditions can also influence tree stress, especially as it relates to water needs and physical stresses from wind (Czaja et al. 2020). We did sample crown light exposure as one form of microclimatic condition that is important for tree growth and health; however, other sampling of tree microclimates proved challenging because we only sampled most trees once a season, and microclimates vary with synoptic weather patterns as well as diurnally (Oke et al. 2017). To facilitate comparison across a given city, sampling temperature or wind, for example, would have had to occur at the same time of day and, ideally, under similar synoptic weather conditions. We did not have the personnel for that kind of sampling. Irrigation is also important for tree survival especially soon after planting (Breger et al. 2019). We at one point included irrigation infrastructure as part of the sampling scheme. However, pilot sampling in Chicago made clear that often residents watered the street trees with hoses brought out from their houses that would be difficult to detect unless we actively observed the watering, interviewed residents, or arrived soon after watering. Some of the included predictor variables (e.g., percent impervious surface in the root zone, site type, cues to care) can be proxies for some of the variables mentioned above (e.g., impervious surface is related to temperature, site type to rooting space), but more direct sampling would clarify the importance of soil conditions and microclimate.

CONCLUSIONS

Street tree stress was related to site conditions and tree characteristics in both cities. Urban tolerant species and larger trees were associated with lower stress in some cases, and areas with heavy car traffic were associated with high stress. Defoliation, discoloration, and dieback provide evidence of distinct forms of tree stress, though in Chicago dieback was associated with discoloration in a manner consistent with drought, and discoloration and dieback were associated in a manner consistent with either compound stressors or the presence of pathogens that cause both defoliation and discoloration. Overall crown stress highlighted the importance of species selection in both cities.

Understanding how tree care can reduce tree stress is vital for urban forest longevity. Unfortunately, this analysis did not detect consistent relationships between cues to care and discoloration, defoliation, dieback, or overall crown stress. Future work investigating how residents, nonprofits, and city employees care for and manage trees would help clarify the long-term benefits of tree care. Interviews and other qualitative analyses could also highlight any broader environmental and social benefits that could come from tree care. Tree care professionals also have a wealth of knowledge about the effectiveness of different tree care strategies, and their expertise is essential for understanding how, when, and if tree care can mitigate tree stress in urban growing conditions.

Data Availability

Data with processing and analysis code, along with supplemental materials, are available on GitHub: https://github.com/rpkamakura/StreetTreeStress_ChiDur. Tree stress data can also be accessed through the HTHC dashboard [https://hthc.itreetools.org/home].

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Appendix

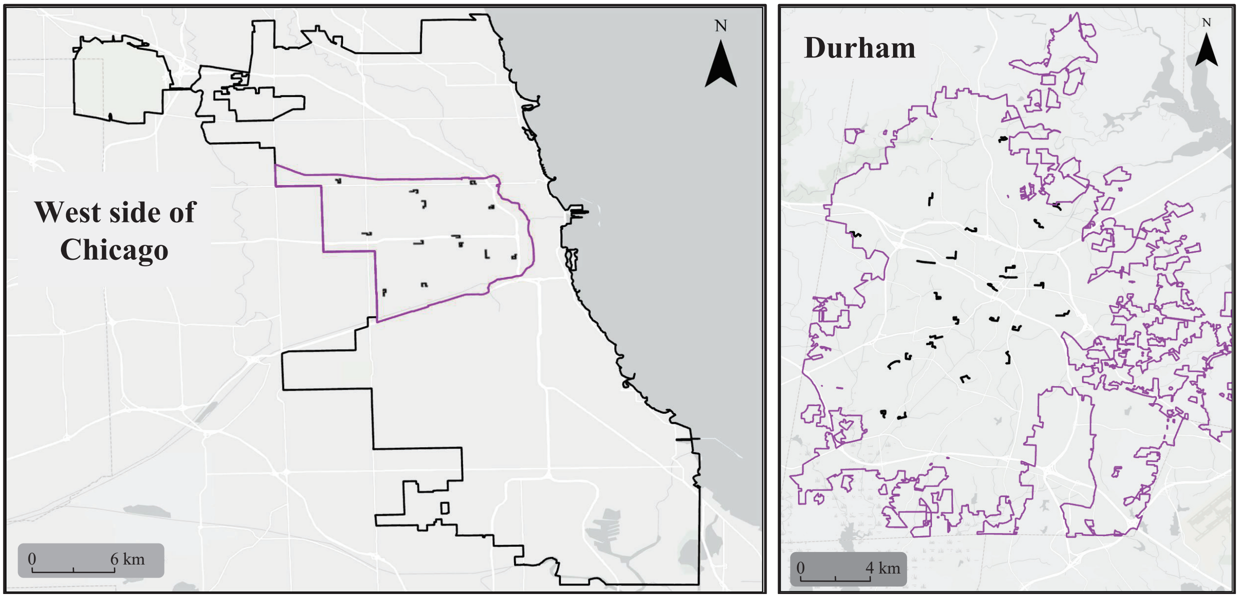

Figure S1. Sampling locations in Chicago, IL, and Durham, NC. The small black lines each represent a sampled street segment while the purple outline shows the outline of the West Side of Chicago (City of Chicago 2020) and the outline of the city (in Durham). The black outline in the Chicago map is the outline for the entire city of Chicago.

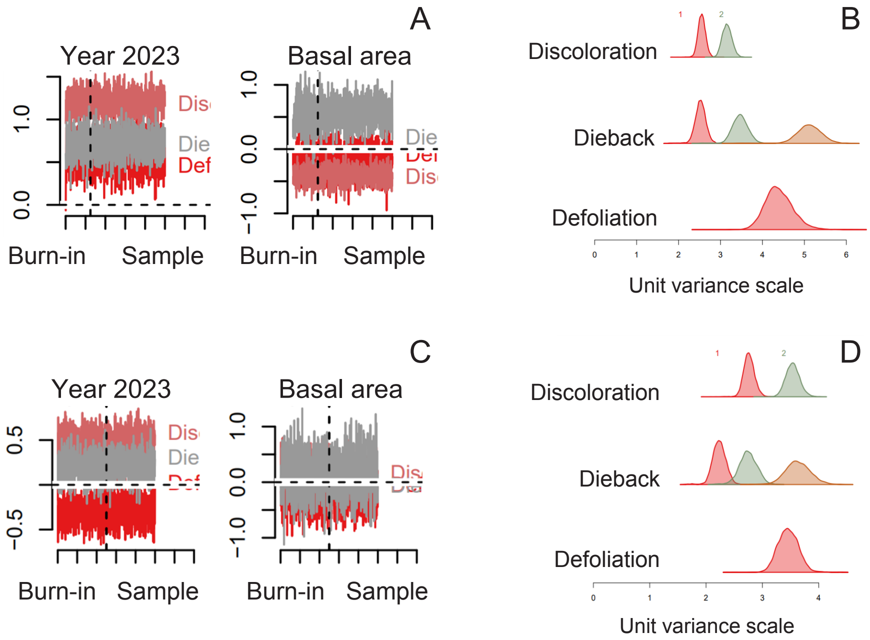

Figure S2. Model diagnostics for best-fitting multivariate models in Chicago (A, B) and Durham (C, D). The multivariate models have Discoloration, Defoliation, and Dieback as ordinal response variables. Panels A and C show example chains for 2023 (compared to 2021 in Chicago and 2022 in Durham) and for basal area parameter estimates. The vertical dashed line shows where the burn-in ends and the samples used to estimate the posterior begin. Panels B and D show the partition estimates for the 3 ordinal response variables, with Discoloration having 3 levels, Dieback having 4, and Defoliation having 2. For both cities, the burn-in was set to 5,000, and in Durham the model was run for 10,000 iterations, whereas for Chicago (with more trees and years) it was run for 20,000 iterations to ensure the posterior was well sampled.

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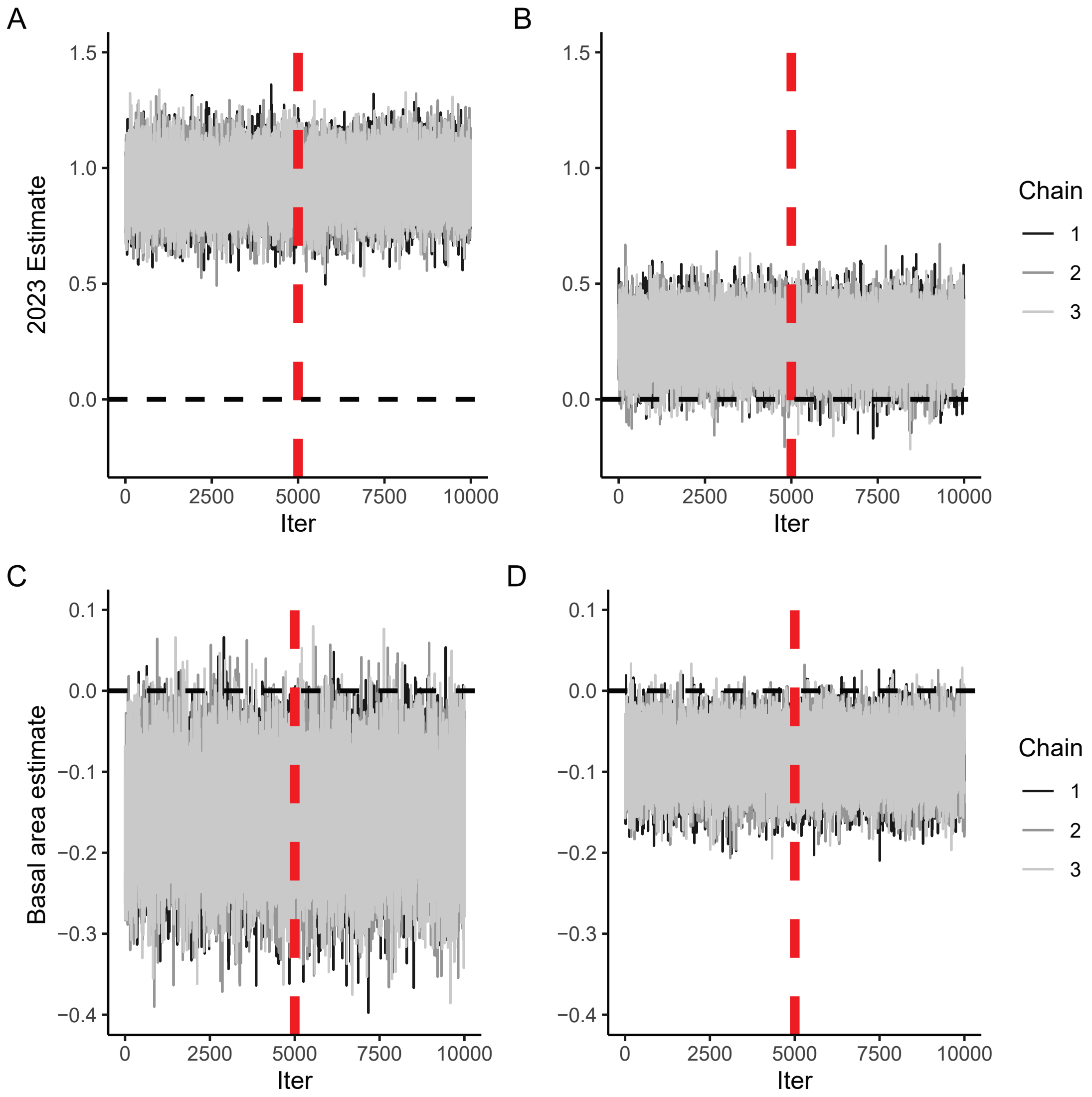

Figure S3. Chains for best-fitting univariate (crown stress) models in Chicago (A, C) and Durham (B, D). As examples of chain convergence, panels A and B show example chains for 2023 (compared to 2021 in Chicago and 2022 in Durham), and panels C and D show the chains for basal area. The vertical red dashed line shows where the burn-in ends and the samples used to estimate the posterior begin, while the horizontal black dashed line is at zero. For both cities, the burn-in was set to 5,000 (red dashed line), and the model was run for 10,000 iterations. The models were run with 3 chains, colored in greyscale.

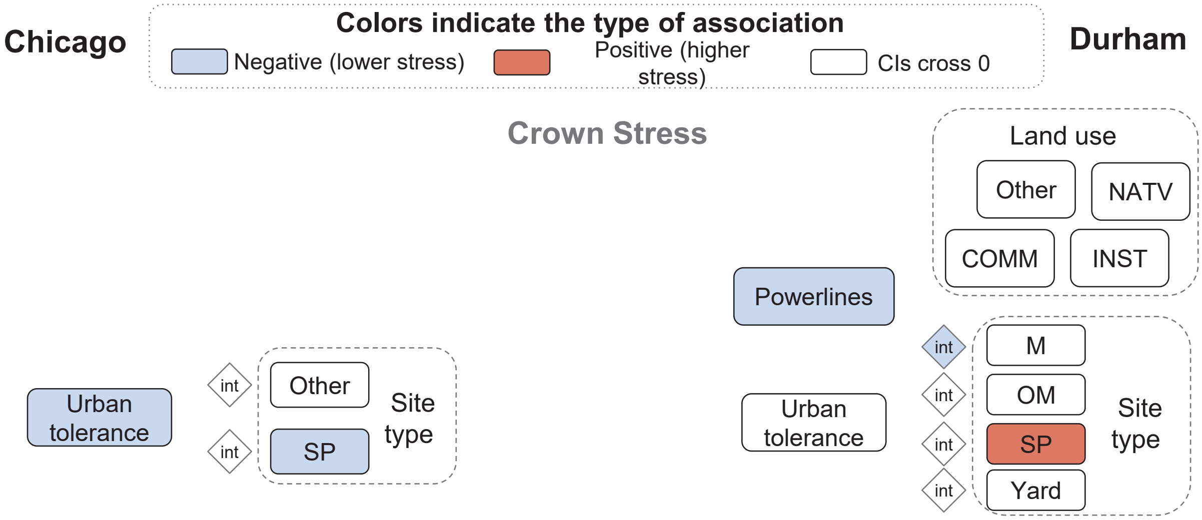

Figure S4. Relationships between site condition predictors variables and crown stress in Chicago and Durham. Box colors signify the type of association: negative (light blue), positive (red), or with confidence intervals (CIs) that cross zero (white). The abbreviations for land use are: commercial and mixed-use (COMM), managed park (MP), institutional (INST), multi-family residential (MFR), and natural area/vacant lot (NATV). The abbreviations or site types are sidewalk planting strip (SP), median (M), and other maintained area (OM). The abbreviation "int" stands for interaction. The baseline category for site type is sidewalk cutout for Chicago and sidewalk cutout and other hardscape for Durham. The baseline category for land use is residential for Durham. Full parameter estimates with standard errors and CIs can be found in Tables S15 and S17.

Figure S5. Pilot soil compaction data and presence of mulch for a subset of Chicago segments in 2022 (*n* = 367 trees). Each pair of boxplots (grey and black) refers to a different pilot street segment in Chicago. Soil compaction was measured with a pocket penetrometer at 6 points around the base of the trunk, within the canopy drip line. The presence or absence of mulch was noted as part of field data collection.

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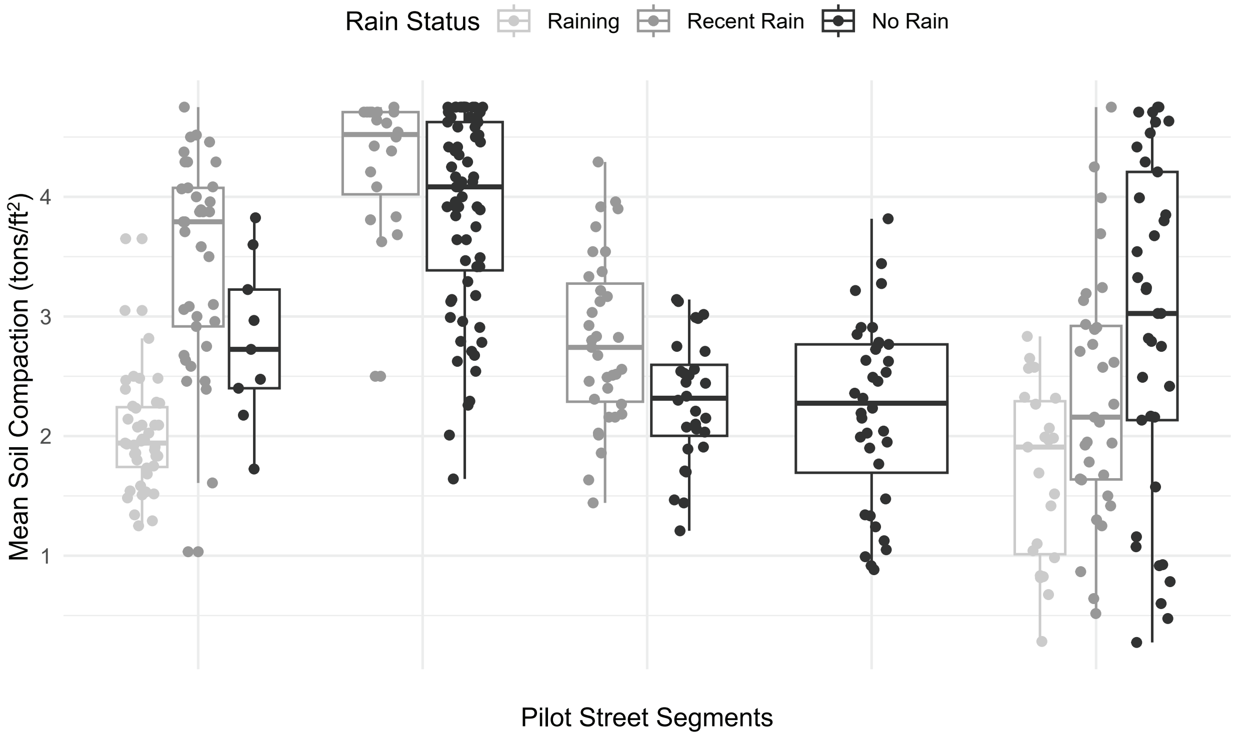

Figure S6. Pilot soil compaction data and whether fieldwork occurred in the rain for a subset of Chicago segments in 2022 (*n* = 367 trees). Each trio or duo of boxplots (light grey, grey, black) is from a different pilot street segment in Chicago. Soil compaction was measured with a pocket penetrometer at 6 points around the base of the trunk, within the canopy drip line. Days with recent rain were those where at least 2.5 cm of rain was recorded in the previous 24 hours.

Table S1. Trees sampled each year in Chicago, IL, and Durham, NC. In Chicago, trees resampled in 2023 were all previously sampled trees of 7 species that were common and represented both native and non-native species. These species were Elms (*Ulmus* spp., including hybrid cultivars identified by tree tags), Norway maple (*Acer platanoides*), Freeman's maple (*A. × freemanii*), Honeylocust (*Gleditsia triacanthos*), Kentucky coffeetree (*Gymnocladus dioicus*), Little-leaf linden (*Tilia cordata*), and Hackberry (*Celtis occidentalis*). In Durham, trees resampled in 2023 were all those accessible from 2022. Note that the column with "resampled from previous" indicates trees that were resampled from previous years, not those sampled as part of quality control.

Year	Chicago total trees sampled	Chicago resampled from previous	Durham total trees sampled	Durham resampled from previous
2021	376 (in 2021)	– (in 2021)	–	–
2022	389 (in 2022)	104 (in 2022)	273	–
2023	659 (in 2023)	322 (in 2023)	481	213

Table S2. Quality assessment results for street tree sampling in Durham and Chicago using categories in final analysis. A random sample of 10% to 25% of sampled trees were resampled within the same season to see if there is a difference between estimated tree health outcome variables and crown light between two repeat visits (measurement error). This table shows the results for categories that match those used in the analyses, which is a simplification of the raw categories. For example, the initial values for dieback ranged from 1 to 21, increasing in 5% intervals after the initial "trace" category. Since higher levels of dieback were rare, dieback was simplified in analyses down to only go from 1 to 6 instead of 1 to 21. Table S3 shows measurement error with the raw categories and Table S8 shows the change from the raw categories to the categories used for analysis.

Dataset	# of trees	Average discoloration difference	Average defoliation difference	Average dieback difference	Average crown stress difference	Average crown light exposure difference
Durham 2022	27	0.407	0.074	0.370	0.370	0.333
Durham 2023	56	0.446	0.161	0.466	0.534	0.259
All Durham	83	0.434	0.133	0.435	0.482	0.282
Chicago 2021	23	0.435	0.435	0.478	0.435	0.391
Chicago 2022	69	0.435	0.319	0.565	0.754	0.385
Chicago 2023	71	0.324	0.155	0.310	0.366	0.225
All Chicago	163	0.387	0.264	0.442	0.540	0.314
All	246	0.402	0.220	0.440	0.520	0.303

Table S3. Quality assessment results for street tree sampling in Durham and Chicago using original categories recorded in the field. Note that there are no columns for crown stress and crown light exposure because those categories were not modified for analysis. See Table S8 for the adjustments to the tree health variable categories done for analysis and the corresponding initial values collected in the field.

Dataset	# of trees	Average discoloration difference	Average defoliation difference	Average dieback difference
Durham 2022	27	0.407	0.074	0.593
Durham 2023	56	0.482	0.161	0.759
All Durham	83	0.458	0.133	0.706
Chicago 2021	23	0.435	0.435	1.000
Chicago 2022	69	0.449	0.319	0.855
Chicago 2023	71	0.324	0.155	0.465
All Chicago	163	0.393	0.264	0.706
All	246	0.415	0.220	0.706

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Table S4. Category simplifications for explanatory variables used in data analysis. The "original category" column indicates the values for a given variable that were recorded in the field. The "new category" column indicates the new groupings used in analysis for a given variable based on variation present in the data. See Table S7 for the number of individual trees within each category.

City	Variable	Original category	New category
Durham	Land use type	Single-family residential – Attached	Residential
		Single-family residential – Detached	
		Multi-family residential	
		Commercial	Commercial/mixed
		Mixed-use	
		Institutional	Institutional
		Vacant	Low intensity management
		Natural areas	
		Transportation	Other
		Agriculture	
	Site type	Sidewalk cutout	Restricted rooting space
		Planter box	
		Other maintained hardscape	
		Sidewalk planting strip	Sidewalk planting strip
		Median	Median
		Front yard	Yard
		Side yard	
		Other maintained area	Other maintained
		Natural area	Natural area
Chicago	Land use type	Single-family residential – Attached	Single-family residential
		Single-family residential – Detached	
		Multi-family residential	Multi-family residential
		Commercial	Commercial/mixed use
		Mixed-use	
		Institutional	Institutional
		Managed park	Park
		Agriculture	Other
		Vacant	
		Transportation	
		Industrial	
		Utility	
	Site type	Sidewalk cutout	Sidewalk cutout
		Sidewalk planting strip	Sidewalk planting strip
		Other maintained area	Other
		Maintained park	

Table S5. Species groups for trees in Chicago. Total number of observations is the total data points for a group while the number of trees is the number of unique trees in a group since some trees were resampled. Those in the "Other" categories include species with fewer than 71 observations (5% of the total). Genera that, in aggregate, met the 71-observation threshold were included as their own group (excluding any individual species that separately met the 71-observation threshold). The "Other" group was split based on mature tree height (from Dirr [2016]), with small as ≤ 10.5 m, medium between 10.5 m and 15.25 m, and large as > 15.25 m. The Base identifies the baseline category in the model.

Group in model	Number of observations | trees	Species included (observations | trees)
*Gleditsia triacanthos*Base	299 | 159	*G. triacanthos* (299 | 159)
Acer planatoides	156 | 84	*A. platanoides* (156 | 84)
Celtis occidentalis	72 | 40	*C. occidentalis* (72 | 40)
Ulmus spp.	186 | 111	*Ulmus* hybrid (136 | 87), *U. americana* (50 | 24)
Fraxinus spp.	159 | 148	*F. americana*, *F. pennsylvanica*, *F. nigra* (grouped due to uncertain IDs)
Acer other	142 | 133	*A. griseum* (1 | 1), *A. palmatum* (2 | 2), *A. rubrum* (36 | 33), *A. saccharinum* (45 | 45), *A. saccharum* (10 | 8), *A. × freemanii* (47 | 43), Unknown (1 | 1)
Tilia spp.	95 | 67	*T. americana* (48 | 40), *T. cordata* (46 | 26), *T. tomentosa* (1 | 1)
Other large	147 | 114	*Aesculus flava* (4 | 2), *A. hippocastanum* (1 | 1), *Betula nigra* (1 | 1), *B. papyrifera* (1 | 1), *Ginkgo biloba* (21 | 17), *G. dioicus* (63 | 37), *Liquidambar styraciflua* (3 | 3), *Metasequoia glyptostroboides* (1 | 1), *Picea* unknown (4 | 3), *Pinus* unknown (4 | 4), *Platanus hybrida* (8 | 7), *P. occidentalis* (3 | 3), *Populus deltoides* (2 | 2), *Quercus alba* (1 | 1), *Q. bicolor* (11 | 11), *Q. imbricaria* (9 | 9), *Q. macrocarpa* (4 | 4), *Q. rubra* (2 | 2), *Taxodium distichum* (4 | 4)
Other medium	107 | 94	*Aesculus* unknown (1 |1), *Ailanthus altissima* (19 | 18), *Alnus glutinosa* (2 | 1), *Catalpa speciosa* (19 | 16), *Diospyros virginiana* (1 | 1), *Juniperus virginiana* (1 | 1), *Morus alba* (10 | 8), *M. rubra* (2 | 1), *Nyssa silvatica* (3 | 3), *P. pungens* (2 | 2), *P. tremuloides* (4 | 4), *Pyrus calleryana* (14 | 11), *Q. muhlenbergii* (13 |13), *Robinia pseudoacacia* (9 | 9), *Taxus* unknown (1 | 1), *Thuja occidentalis* (6 | 4)
Other small	61 | 48	*A. glabra* (2 | 2), *Amelanchier × grandiflora* (1 | 1), *Cercis canadensis* (4 | 3), *Crataegus crus-galli* (3 | 3), *Magnolia liliiflora* (2 | 1), *Malus* unknown (9 | 7), *Prunus cerasifera* (15 | 9), *P. serrulata* (8 | 6), *Prunus* unknown (3 | 2), *Syringa reticulata* (3 | 3), *Thuja* unknown (11 | 11)

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Table S6. Species groups for trees in Durham. Total number of observations is the total data points available for a given genus (or species), while the number of trees describes the number of unique trees in a group since some trees were sampled more than once. Those in the "Other" categories include species with fewer than 41 observations (5% of the total). Genera that, in aggregate, met the 41-observation threshold were included as their own group (excluding any individual species that separately met the 41-observation threshold). The "Other" group was split based on mature tree size (from Dirr [2016]), with small as ≤ 10.5 m, medium between 10.5 m and 15.25 m, and large as > 15.25 m. The $^{\text{Base}}$ identifies the baseline category in the model.

Group in model	Number of observations | trees	Species included (observations | trees)
Acer rubrum	67 | 42	*A. rubrum* (67 | 42)
Cercis canadensis	58 | 35	*C. canadensis* (58 | 35)
Ulmus americana	48 | 32	*U. americana* (48 | 32)
Quercus phellos	43 | 36	*Q. phellos* (43 | 36)
Lagerstroemia spp.$^{\text{Base}}$	83 | 69	*L. indica* (13 | 13), Unknown (70 | 56)
Quercus other	50 | 39	*Q. bicolor* (10 | 10), *Q. coccinea* (6 | 3), *Q. lyrata* (7 | 6), *Q. macrocarpa* (6 | 5), *Q. rubra* (1 | 1), *Q. virginiana* (15 | 11), Unknown (5 | 3)
Prunus spp.	49 | 37	*P. persica* (4 | 4), *P. serotina* (3 | 3), *P. yedoensis* (16 | 13), Unknown (26 | 17)
Acer other	47 | 28	*A. buergerianum* (14 | 9), *A. campestre* (2 | 1), *A. palmatum* (3 | 3), *A. platanoides* (11 | 6), *A. platanoides × truncatum* (2 | 1), *A. saccharum* (8 | 5), *A. truncatum* (6 | 3), *A. × freemanii* (2 | 1), Unknown (1 | 1)
Other large	136 | 100	*B. nigra* (2 | 1), *Carya illinoinensis* (3 | 3), *G. biloba* (17 | 11), *G. dioicus* (26 | 13), *L. styraciflua* (27 | 27), *Liriodendron tulipifera* (2 | 2), *M. grandiflora* (2 | 2), *M. rubra* (1 | 1), *P. taeda* (5 | 5), *P. acerifolia* (1 | 1), *P. occidentalis* (1 | 1), *T. ascendens* (3 | 3), *T. distichum* (4 | 4), *T. cordata* (2 | 1), *U. alata* (11 | 6), *Zelkova serrata* (30 | 20)
Other medium	52 | 35	*Cladrastis kentukea* (1 | 1), *Ilex* unknown (1 | 1), *J. virginiana* (7 | 5), *N. sylvatica* (1 | 1), *P. calleryana* (2 | 2), *U. parvifolia* (10 | 5), *Ulmus* unknown (8 | 4)
Other small	121 | 88	*Albizia julibrissin* (1 | 1), *A. canadensis* (1 | 1), *Amelanchier* unknown (1 | 1), *A. × grandiflora* (2 | 1), *Asimina triloba* (5 | 3), *Carpinus caroliniana* (28 | 14), *Carpinus* unknown (1 | 1), *C. reniformis* (4 | 4), *Chionanthus retusus* (12 | 12), *Cornus florida* (6 | 3), *C. kousa* (3 | 2), *C. viridis* (8 | 4), *Ficus carica* (2 | 2), *I. cornuta* (1 | 1), *M. stellata* (9 | 9), *M. virginiana* (10 | 5), *Melia azedarach* (2 | 1), *Parrotia persica* (4 | 2), *Pistacia chinensis* (20 | 20), *P. communis* (1 | 1)

Table S7. Number of trees for each of the variables used in growing condition models. Dashes indicate that there were no sample trees in a given category. In Durham, there were no obviously multi-family residential units within the sample area (e.g., apartment buildings), though it is likely that several of the single-family homes were in fact split into multiple subunits. Since those residential types are difficult to distinguish from the field, here we just combine all the trees into a broader "residential" category. BMP (best management practices).

Variable	Type	Durham	Chicago
Number of trees	Total number of unique trees across all years	541	998
Land use	Single-family residential	322	515
	Multi-family residential		323
	Commercial or mixed	97	96
	Institutional	89	17
	Park	0	26
	Low-management (Natural area, vacant)	15	0
	Other	18	21
Percent impervious surface	1 (< 25%)	184	26
	2 (26% to 50%)	135	44
	3 (51% to 75%)	118	248
	4 (76% to 100%)	101	680
Power line	Present	96	244
	Absent	445	754
Mulched	According to BMP	167	299
	Not according to BMP	54	42
	Not mulched	320	657
Pruned	According to BMP	254	683
	Not according to BMP	112	246
	Not pruned	175	69
Landscaping intensity	1 (minimal or no landscaping)	119	152
	2 (evidence of mowing or minor landscaping)	314	627
	3 (landscaping with focus on the tree)	57	123
	4 (landscaping throughout plantable area)	51	96
Site type	Most restrictive (sidewalk cutout, planter box, other hardscape)	61	188
	Sidewalk planting strip	229	783
	Yard (front, side, or back)	140	-
	Median	58	-
	Other managed	53	-
	Other	0	27

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Table S8. Description of tree stress variables measured as part of the US Forest Service and The Nature Conservancy Healthy Trees, Healthy Cities protocols (Hallett et al. 2019). The last column describes how these categories were simplified for analysis based on the variability present within our sample (i.e., few trees had high dieback, so the higher categories were collapsed). Quality controls were done by replicating data collection for a subset of trees, within a given year; results available in Tables S2 and S3.

Tree stress variable	Description	Categories	Simplified categories
Leaf discoloration	Percent of total leaf area that is discolored from the normal range of color for the species/cultivar.	(1) trace (< 2%)	(1) trace (< 2%)
		(2) 2% to 25%	(2) 2% to 25%
		(3) 26% to 50%	(3) 26% to 50%
		(4) 51% to 75% (5) 76% to 100%	(4) 51% +
Leaf defoliation	Percent of total leaf area that is missing due to holes or missing sections in the leaves. Note: this requires that some part of the leaf remains.	(1) trace (< 2%)	(1) trace (< 2%)
		(2) 2% to 25%	(2) 2% to 25%
		(3) 26% to 50% (4) 51% to 75% (5) 76% to 100%	(3) 26% +
Fine twig dieback	Percent of total leaf area that is missing due to lost leaves. Only count leaves on small twigs on the outer edge of the tree canopy.	(1) trace (< 2%)	(1) trace (< 2%)
		(2) 2% to 5%	(2) 2% to 5%
		(3) 6% to 10%,	(3) 6% to 10%
		(4) 11% to 15% (5) 16% to 20% (6) 21% to 25%	(4) 11% to 25%
		(7) 26% to 30% (8) 31% to 35% (9) 36% to 40% (10) 41% to 45% (11) 46% to 50% (12) 51% to 55% (13) 56% to 60% (14) 61% to 65% (15) 66% to 70% (16) 71% to 75% (17) 76% to 80% (18) 81% to 85% (19) 86% to 90% (20) 91% to 95% (21) 96% to 100%	(5) 26% +
Crown stress	An overall measure of tree stress that incorporates the 3 measures above alongside large branch dieback.	1 (< 10% cumulative dieback, discoloration, and defoliation and no major branch mortality)	Same as original
		2 (10% to 25% cumulative dieback, discoloration, and defoliation and/or 25% or less crown area missing due to broken or dead large branches)	
		3 (26% to 50% cumulative dieback, discoloration, and defoliation and/or 50% or less crown area missing due to broken or dead large branches)	
		4 (more than 50% cumulative dieback, discoloration, and defoliation and/or more than 50% crown area missing due to broken or dead large branches)	
		5 (dead)	

Table S9. Predictors removed from models in Chicago and Durham. VIF came from running versions of the models with the predictors included. VIF (variable inflation factors).

City	Predictor	Reason
Both	Nearby street	Not enough variation in Chicago
Both	Nearby sidewalk	Not enough variation in Chicago
Both	Tree guards	Not enough trees with guards in Chicago
Both	Tree gator bags, staking	Rare in both cities
Both	Percent impervious surface	VIF > 5
Both	Crown light	VIF > 5

Table S10. DIC values for models tested for multivariate model in Chicago. Response variables are defoliation, discoloration, and dieback. The variables noted in Table S9 were already excluded due to lack of variation or high variable inflation factors. The bolded row is the model with the lowest DIC, used for interpretation in the main text. DIC (Deviance Information Criterion).

Model formula	DIC
(Base model) Response ~ segment + year + basal area × species group + powerline + mulch + landscaping intensity + pruning + urban tolerant × site type + land use	**42,118.89**
Base model without pruning	42,482.05
Base model without powerline	42,458.90
Base model without landscaping intensity	42,359.97
Base model without basal area × species group interaction (just additive)	42,362.25
Base model without urban tolerant × site type interaction (just additive)	42,374.87

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Table S11. DIC values for models tested for univariate model in Chicago. The response variable is crown stress. The variables noted in Table S9 were already excluded due to lack of variation or high variable inflation factors. The bolded row is the model with the lowest DIC, used for interpretation in the main text. DIC (Deviance Information Criterion).

Model formula	DIC
(Base model) Response ~ segment + year + basal area × species group + powerline + mulch + landscaping + pruning + urban tolerant × site type + land use	2,765.5
Base model without powerline	2,762.6
Base model without powerline or landscaping	2,756.3
Base model without powerline, landscaping, or land use	2,751.7
Base model without powerline, landscaping, or pruning	2,756.1
Base model without powerline, landscaping, pruning, or land use	2,753.0
Base model without powerline, landscaping, land use, or mulch	2,751.1
Base model without powerline, landscaping, land use, mulch, or pruning	**2,750.2**
Base model without powerline, landscaping, land use, mulch, pruning, or basal area × species group interaction (just additive)	2,763.5
Base model without powerline, landscaping, land use, mulch, pruning, or urban tolerant × site type interaction (just additive)	2,753.3

Table S12. DIC values for models tested for multivariate model in Durham. Response variables are defoliation, discoloration, and dieback. The variables noted in Table S9 were already excluded due to lack of variation or high variable inflation factors. The bolded row is the model with the lowest DIC, used for interpretation in the main text. DIC (Deviance Information Criterion).

Model Formula	DIC
(Base model) response ~ segment + year + basal area × spp. group + powerline + mulch + gardenscape + urban tolerance × site type + land use	23,923.38
Base model without powerline	**23,825.96**
Base model without powerline and mulch	23,887.71
Base model without powerline and urban tolerance	24,391.80

Table S13. DIC values for models tested for univariate model in Durham. The response variable is crown stress. The variables noted in Table S9 were already excluded due to lack of variation or high variable inflation factors. The bolded row is the model with the lowest DIC, used for interpretation in the main text. DIC (Deviance Information Criterion).

Model formula	**DIC**
(Base model) response ~ segment + year + basal area × spp. group + powerline + mulch + gardenscape + pruned correct + urban tolerance × site type + land use	1,850.8
Base model without basal area × species group (just additive)	1,839.6
Base model without pruning or basal area × species group (just additive)	**1,837.7**
Base model without pruning or either interaction (basal area × species group and urban tolerance × site type)	1,842.1
Base model without pruning, mulch, or basal area × species group (just additive)	1,837.8
Base model without pruning, mulch, urban tolerance, or basal area × species group (just additive)	1,855.3

Table S14. All predictors tested and those present in the best-fitting models in Chicago and Durham (assessed through DIC). Note that some predictors were not used at all due to high VIF values or limited variation (see Table S9). If a predictor is present in the best-fitting model, the corresponding box is marked with an ×. Each city has a multivariate ordinal model (with discoloration, defoliation, and dieback all as response variables) and a univariate model (with just crown stress as a response variable). DIC (Deviance Information Criterion); VIF (variable inflation factors).

Predictor	**Chicago**		**Durham**	
	Multivariate: discoloration, defoliation, dieback	Univariate: crown stress	Multivariate: discoloration, defoliation, dieback	Univariate: crown stress
Street segment	×	×	×	×
Year	×	×	×	×
Land use	×		×	×
Site type	×	×	×	×
Crown light	Excluded due to high VIF			
Power lines	×			×
Percent impervious surface	Excluded due to high VIF			
Landscaping	×		×	×
Mulch	×		×	×
Pruning	×			
Species group	×	×	×	×
Urban tolerance	×	×	×	×
Basal area	×	×	×	×
Basal area × species group	×	×	×	
Urban tolerant × site type	×	×	×	×

Appendix continued on next page

Table S15. All parameter estimates for multivariate (discoloration, defoliation, dieback) growing condition model in Chicago. The baseline for street segment is the wealthiest street segment (arbitrarily numbered 1), the baseline for year is 2021, the baseline for species group is the most abundant species (*Gleditsia triacanthos*), the baseline for landscaping intensity is no landscaping, the baseline for site type is the most restrictive rooting zone (sidewalk cutout), and the baseline for land use is single-family residential. CI_025 and CI_975 together describe the 95% confidence interval around the parameter estimate, and sig95 indicates whether or not the 95% confidence interval crosses zero. SE (standard error); CI (confidence interval); BMPs (best management practices).

Response	Predictor	Predictor level	Estimate	SE	CI_025	CI_975	sig95
Defoliation	Segment	2	0.06720	0.4820	–0.86300	1.01000	
		3	–0.37900	0.4240	–1.23000	0.43700	
		4	–0.49200	0.4150	–1.33000	0.29600	
		5	–0.66000	0.4490	–1.56000	0.20000	
		6	–0.01980	0.3750	–0.75400	0.72600	
		7	–1.45000	0.5240	–2.53000	–0.47900	*
		8	–0.72400	0.5370	–1.80000	0.29300	
		9	–0.24400	0.4210	–1.08000	0.56000	
		10	–0.23600	0.3590	–0.94600	0.47100	
		11	0.62300	0.3230	0.00213	1.27000	*
		12	–0.79800	0.4820	–1.75000	0.15300	
		13	–0.46200	0.4690	–1.40000	0.42700	
	Year	2022	0.72400	0.2040	0.32800	1.13000	*
		2023	0.58500	0.1890	0.22000	0.95900	*
	Basal area		–0.11400	0.1310	–0.37100	0.13900	
	Species group	*Acer platanoides*	2.12000	0.9220	0.38300	3.98000	*
		Celtis occidentalis	3.20000	0.8950	1.52000	4.99000	*
		Fraxinus spp.	–0.47600	0.8430	–2.12000	1.18000	
		Tilia spp.	0.57800	0.6820	–0.79600	1.91000	
		Ulmus spp.	4.77000	0.6930	3.50000	6.20000	*
		Other large	1.79000	0.7060	0.42500	3.20000	*
		Other medium	0.33000	0.6650	–0.99100	1.61000	
		Other small	0.12300	1.0600	–2.06000	2.17000	
	Powerline		0.00112	0.2030	–0.40800	0.38800	
	Mulch	Correct	0.08540	0.2120	–0.33500	0.49700	
		Volcano	–0.08930	0.3980	–0.90400	0.66000	
	Landscaping	Minor	0.02780	0.2200	–0.40100	0.46900	
		Moderate	–0.22800	0.3240	–0.88500	0.38400	
		Extensive	–0.26000	0.3510	–0.97200	0.41000	
	Pruned following BMPs		0.05850	0.1670	–0.26100	0.39500	
	Urban tolerant		0.03240	0.4580	–0.86200	0.92400	
	Site type	Other	0.01540	0.9790	–1.97000	1.89000	
		Sidewalk planting strip	0.09130	0.2770	–0.45200	0.63900	

Table S15. Continued.

Response	Predictor	Predictor level	Estimate	SE	CI_025	CI_975	sig95
Defoliation	Land use	Commercial and mixed	–0.08320	0.3430	–0.75000	0.58400	
		Institutional	–0.23400	0.6920	–1.60000	1.10000	
		Multi-family residential	0.12900	0.1820	–0.22900	0.48600	
		Managed park	–1.49000	0.6760	–2.84000	–0.18800	*
		Other	0.59100	0.4850	–0.38900	1.52000	
	Basal area × species group	*Acer platanoides*	0.62200	0.3230	0.03030	1.30000	*
		Celtis occidentalis	–0.02940	0.2330	–0.48700	0.42000	
		Fraxinus spp.	0.04860	0.3000	–0.52900	0.65000	
		Tilia spp.	–0.07870	0.2060	–0.49300	0.31500	
		Ulmus spp.	0.23300	0.1770	–0.11300	0.58000	
		Other large	0.25200	0.1710	–0.08270	0.59100	
		Other medium	–0.00470	0.1720	–0.34200	0.33700	
		Other small	–0.06260	0.2320	–0.53000	0.38000	
	Urban tolerance × site type	Other	1.47000	1.5600	–1.61000	4.49000	
		Sidewalk planting strip	–0.65500	0.4320	–1.53000	0.16000	
Discoloration	Segment	2	0.96700	0.3200	0.33500	1.59000	*
		3	0.64900	0.2570	0.14300	1.16000	*
		4	0.54800	0.2340	0.09380	1.01000	*
		5	0.37500	0.2470	–0.10300	0.86100	
		6	0.80600	0.2430	0.32800	1.28000	*
		7	0.20300	0.2470	–0.27900	0.68000	
		8	0.37800	0.2940	–0.19800	0.95800	
		9	0.01210	0.2630	–0.51200	0.51200	
		10	0.32000	0.2240	–0.12000	0.75500	
		11	0.61500	0.2090	0.20700	1.03000	*
		12	0.68900	0.2930	0.11600	1.27000	*
		13	–0.18600	0.2660	–0.70900	0.32900	
	Year	2022	0.48100	0.1360	0.21600	0.74600	*
		2023	1.20000	0.1280	0.95200	1.45000	*
	Basal area		–0.26000	0.0775	–0.41400	–0.10900	*
	Species group	*Acer platanoides*	0.69400	0.4560	–0.18200	1.59000	
		Celtis occidentalis	0.46000	0.5570	–0.64300	1.55000	
		Fraxinus spp.	–0.68900	0.3970	–1.46000	0.08100	
		Tilia spp.	0.42300	0.4300	–0.41000	1.26000	
		Ulmus spp.	–0.57800	0.3780	–1.32000	0.15000	
		Other large	1.06000	0.4140	0.24300	1.88000	*
		Other medium	–0.03820	0.3730	–0.77500	0.69600	
		Other small	–0.68600	0.6960	–2.07000	0.66400	

Table S15 continued on next page

Table S15. Continued.

Response	Predictor	Predictor level	Estimate	SE	CI_025	CI_975	sig95
Discoloration	Powerline		–0.09520	0.1200	–0.33600	0.13800	
	Mulch	Correct	0.13900	0.1230	–0.09820	0.37800	
		Volcano	–0.05860	0.2480	–0.54100	0.42800	
	Landscaping	Minor	0.17100	0.1310	–0.08330	0.43000	
		Moderate	–0.00628	0.1780	–0.36000	0.34000	
		Extensive	0.13100	0.1980	–0.26500	0.51700	
	Pruned following BMPs		–0.08060	0.0990	–0.27400	0.11300	
	Urban tolerant		–0.34800	0.2700	–0.87700	0.18000	
	Site type	Other	0.23800	0.5230	–0.78200	1.28000	
		Sidewalk planting strip	–0.19900	0.1660	–0.52100	0.12600	
	Land use	Commercial and mixed	0.47700	0.2030	0.07600	0.87900	*
		Institutional	0.19900	0.4080	–0.60500	0.98700	
		Multi-family residential	–0.08290	0.1070	–0.29300	0.12600	
		Managed park	0.08500	0.3210	–0.54200	0.71100	
		Other	0.15500	0.3020	–0.43600	0.74000	
	Basal area × species group	*Acer platanoides*	0.41700	0.1440	0.13900	0.70400	*
		Celtis occidentalis	0.26500	0.1550	–0.03950	0.57200	
		Fraxinus spp.	0.10700	0.1430	–0.17100	0.38800	
		Tilia spp.	0.49000	0.1420	0.21500	0.77200	*
		Ulmus spp.	0.20300	0.1190	–0.03070	0.43700	
		Other large	0.42400	0.1040	0.22100	0.63100	*
		Other medium	0.21300	0.1020	0.01310	0.41400	*
		Other small	0.09850	0.1540	–0.20200	0.40300	
	Urban tolerance × site type	Other	–1.29000	0.9040	–3.08000	0.44700	
		Sidewalk planting strip	0.16100	0.2540	–0.33100	0.66100	
Dieback	Segment	2	2.14000	0.6090	0.94200	3.35000	*
		3	0.11400	0.4420	–0.72800	1.00000	
		4	–0.11600	0.3980	–0.90700	0.67000	
		5	1.18000	0.4370	0.32400	2.05000	*
		6	–0.27900	0.4200	–1.09000	0.54100	
		7	–0.42700	0.4100	–1.24000	0.37100	
		8	1.17000	0.5390	0.09770	2.25000	*
		9	–0.18100	0.4350	–1.03000	0.67300	
		10	0.47400	0.3700	–0.24800	1.22000	
		11	–0.16700	0.3700	–0.89700	0.56500	
		12	–1.34000	0.5560	–2.45000	–0.27100	*
		13	0.52500	0.4430	–0.33600	1.41000	
	Year	2022	0.30000	0.1550	–0.00542	0.60400	
		2023	0.70300	0.1480	0.41400	0.99300	*

Table S15. Continued.

Response	Predictor	Predictor level	Estimate	SE	CI_025	CI_975	sig95
Dieback	Basal area		0.36400	0.1340	0.09920	0.62600	*
	Species group	*Acer platanoides*	1.28000	0.8630	–0.40000	3.00000	
		Celtis occidentalis	–0.86700	0.9910	–2.77000	1.10000	
		Fraxinus spp.	2.02000	0.6860	0.68600	3.38000	*
		Tilia spp.	–2.63000	0.7980	–4.21000	–1.0500	*
		Ulmus spp.	0.85700	0.6600	–0.42000	2.16000	
		Other large	0.08940	0.7140	–1.30000	1.47000	
		Other medium	0.69700	0.6090	–0.50700	1.89000	
		Other small	–0.84000	1.2700	–3.35000	1.65000	
	Powerline		–0.07140	0.2030	–0.47400	0.33400	
	Mulch	Correct	0.26400	0.2250	–0.17700	0.70400	
		Volcano	0.85600	0.4050	0.06260	1.65000	*
	Landscaping	Minor	–0.37000	0.2410	–0.83600	0.10400	
		Moderate	–0.22400	0.3140	–0.84000	0.39500	
		Extensive	–0.43100	0.3620	–1.15000	0.26400	
	Pruned following BMPs		0.01700	0.1810	–0.33900	0.37200	
	Urban tolerant		–1.68000	0.4830	–2.61000	–0.72300	*
	Site type	Other	0.35700	0.8950	–1.37000	2.12000	
		Sidewalk planting strip	–0.82800	0.3000	–1.42000	–0.24700	*
	Land use	Commercial and mixed	0.83800	0.3710	0.10800	1.57000	*
		Institutional	0.87900	0.7240	–0.52600	2.33000	
		Multi-family residential	0.05140	0.1650	–0.26800	0.37700	
		Managed park	–0.78500	0.5810	–1.94000	0.34700	
		Other	–1.32000	0.5190	–2.35000	–0.3100	*
	Basal area × species group	*Acer platanoides*	0.19500	0.2860	–0.37000	0.76300	
		Celtis occidentalis	–0.65100	0.2820	–1.21000	–0.10200	*
		Fraxinus spp.	0.61500	0.2670	0.09550	1.14000	*
		Tilia spp.	–0.50900	0.2600	–1.02000	0.00654	
		Ulmus spp.	0.32900	0.2160	–0.08650	0.76500	
		Other large	–0.17300	0.1820	–0.52900	0.18300	
		Other medium	–0.18600	0.1790	–0.53900	0.16600	
		Other small	–0.33900	0.2860	–0.90400	0.22200	
	Urban tolerance × site type	Other	0.54300	1.5400	–2.47000	3.58000	
		Sidewalk planting strip	0.81100	0.4610	–0.10300	1.70000	

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Table S16. All parameter estimates for univariate (crown stress) growing condition model in Chicago. The baseline for street segment is the wealthiest street segment (arbitrarily numbered 1), the baseline for year is 2021, the baseline for species group is the most abundant species (*Gleditsia triacanthos*), the baseline for landscaping intensity is no landscaping, the baseline for site type is the most restrictive rooting space (sidewalk cutout), and the baseline for land use is single-family residential. CI_025 and CI_975 together describe the 95% confidence interval around the parameter estimate and sig95 indicates whether or not the 95% confidence interval crosses zero. SE (standard error); CI (confidence interval).

Predictor	Predictor level	Estimate	SE	CI_025	CI_975	sig95
(Intercept)		–0.393800	0.27140	–0.92780	0.12610	
Segment	2	0.587000	0.22780	0.14020	1.03200	*
	3	0.494000	0.18780	0.12860	0.86570	*
	4	0.332800	0.18640	–0.03454	0.70170	
	5	0.750000	0.18310	0.39360	1.11100	*
	6	0.617800	0.18480	0.26050	0.98700	*
	7	0.158800	0.19100	–0.21960	0.52740	
	8	0.603900	0.21330	0.19400	1.02500	*
	9	0.051010	0.21490	–0.36710	0.47070	
	10	0.113400	0.18150	–0.24000	0.47050	
	11	0.527700	0.15390	0.22760	0.82960	*
	12	0.009728	0.22540	–0.42820	0.44970	
	13	0.206600	0.19200	–0.17290	0.58030	
Year	2022	0.518600	0.12180	0.27940	0.75870	*
	2023	0.934600	0.10800	0.72180	1.14600	*
Basal area		–0.154300	0.06061	–0.27380	–0.03468	*
Species group	*Acer platanoides*	0.539500	0.36900	–0.19060	1.26700	
	Celtis occidentalis	0.095680	0.43360	–0.74810	0.94080	
	Fraxinus spp.	0.368800	0.32200	–0.26760	1.00500	
	Tilia spp.	–0.295400	0.33760	–0.95310	0.36380	
	Ulmus spp.	0.676600	0.28630	0.11310	1.24500	*
	Other large	0.432700	0.33950	–0.23810	1.09200	
	Other medium	0.198900	0.29310	–0.37200	0.76960	
	Other small	–1.188000	0.56980	–2.30400	–0.07240	*
Urban tolerance		–0.455700	0.21860	–0.89430	–0.03202	*
Site type	Other	0.376800	0.41900	–0.44320	1.19500	
	Sidewalk planting strip	–0.309500	0.13100	–0.56510	–0.05066	*
Basal area × species group	*Acer platanoides*	0.330300	0.11510	0.10630	0.56110	*
	Celtis occidentalis	0.063250	0.12170	–0.17560	0.30010	
	Fraxinus spp.	0.340100	0.12110	0.10350	0.57810	*
	Tilia spp.	0.175500	0.10600	–0.02933	0.38440	
	Ulmus spp.	0.362800	0.09055	0.18570	0.53950	*
	Other large	0.224400	0.08389	0.05809	0.38580	*
	Other medium	0.161600	0.08167	0.00126	0.32160	*
	Other small	–0.100300	0.12580	–0.34600	0.14460	
Urban tolerance × site type	Other	–1.360000	0.70660	–2.76200	0.02730	
	Sidewalk planting strip	0.230900	0.20040	–0.16630	0.62770	

Table S17. All parameter estimates for multivariate (discoloration, defoliation, dieback) growing condition model in Durham. The baseline for street segment is the wealthiest street segment with at least 10 trees (arbitrarily numbered 1), the baseline for year is 2022, the baseline for species group is the most common group (*Lagerstroemia* spp.), the baseline for landscaping intensity is no landscaping, the baseline for site type is the most restrictive rooting spaces (sidewalk cutouts and other hardscape), and the baseline for land use is residential. CI_025 and CI_975 together describe the 95% confidence interval around the parameter estimate, and sig95 indicates whether or not the 95% confidence interval crosses zero. SE (standard error); CI (confidence interval).

Response	Predictor	Predictor level	Estimate	SE	CI_025	CI_975	sig95
Defoliation	Intercept		–1.53000	0.8430	–3.2100	0.1070	
	Segment	2	1.95000	0.7410	0.5870	3.4700	*
		3	1.60000	0.8420	0.0375	3.2500	*
		4	1.44000	0.8110	–0.1660	3.0600	
		5	0.23500	0.8800	–1.4900	1.9700	
		6	–0.75800	0.7580	–2.2700	0.7410	
		7	0.82300	0.7390	–0.6390	2.3100	
		Other	0.87500	0.7220	–0.5170	2.2700	
		8	0.21700	0.7580	–1.2800	1.7100	
		9	0.35900	0.8230	–1.2500	1.9800	
		10	1.06000	0.7490	–0.4270	2.5700	
		11	0.56400	0.8310	–1.1100	2.1900	
		12	1.07000	0.7370	–0.2770	2.5900	
		13	1.49000	0.7860	–0.0781	3.0200	
		14	1.01000	0.7440	–0.4400	2.4600	
	Year	2023	–0.29500	0.1440	–0.5770	–0.0128	*
	Basal area		–0.09640	0.0977	–0.2900	0.0929	
	Species group	*Acer rubrum*	–2.82000	0.8180	–4.4700	–1.1900	*
		Cercis canadensis	1.50000	1.2100	–0.8780	3.8800	
		Quercus phellos	–0.82900	0.7450	–2.3200	0.5810	
		Ulmus americana	1.28000	1.3000	–1.2100	3.8600	
		Acer other	–2.83000	1.1400	–5.1000	–0.6730	*
		Prunus spp.	1.42000	0.9880	–0.5110	3.3800	
		Quercus other	–2.13000	0.8670	–3.8600	–0.5170	*
		Other large	–0.48600	0.6120	–1.6700	0.7170	
		Other medium	–1.38000	0.8650	–3.0900	0.2440	
		Other small	–1.06000	0.7810	–2.6300	0.4800	
	Mulch	Correct	0.05390	0.1600	–0.2610	0.3710	
		Volcano	0.17900	0.3230	–0.4640	0.8000	
	Landscaping	Minimal	0.79800	0.2670	0.2730	1.3000	*
		Moderate	0.58800	0.3820	–0.1590	1.3000	
		Extensive	0.45100	0.3970	–0.3290	1.2100	

Table S17 continued on next page

Table S17. Continued.

Response	Predictor	Predictor level	Estimate	SE	CI_025	CI_975	sig95
	Urban tolerance		0.04310	0.4890	–0.9180	0.9880	
Defoliation	Site type	Median	0.24700	0.5440	–0.8140	1.3200	
		Other maintained	0.61900	0.4530	–0.2650	1.5300	
		Sidewalk planting strip	0.69100	0.3410	0.0439	1.3800	*
		Yard	0.31200	0.3680	–0.3840	1.0600	
	Land use	Commercial and mixed	0.00348	0.3620	–0.7080	0.7050	
		Institutional	0.69400	0.2800	0.1420	1.2400	*
		Natural area or vacant	0.09180	0.3350	–0.5710	0.7540	
		Other	0.04900	0.4860	–0.9270	0.9800	
	Basal area × species group	*Acer rubrum*	–0.41400	0.1500	–0.7170	–0.1190	*
		Cercis canadensis	0.08450	0.1780	–0.2630	0.4390	
		Quercus phellos	–0.13100	0.2250	–0.5800	0.3030	
		Ulmus americana	0.05900	0.2080	–0.3390	0.4720	
		Acer other	–0.44900	0.1800	–0.8080	–0.1010	*
		Prunus spp.	0.06720	0.1500	–0.2180	0.3620	
		Quercus other	–0.32500	0.1570	–0.6480	–0.0260	*
		Other large	0.00062	0.1140	–0.2200	0.2260	
		Other medium	–0.16300	0.1700	–0.4980	0.1690	
		Other small	–0.12300	0.1300	–0.3710	0.1340	
	Urban tolerance × site type	Median	1.63000	0.8430	–0.0400	3.2700	
		Other maintained	0.75900	0.8360	–0.8500	2.3500	
		Sidewalk planting strip	–0.45300	0.5490	–1.5400	0.6200	
		Yard	–0.28600	0.5700	–1.4500	0.7950	
Discoloration	Intercept		0.67400	0.5640	–0.4300	1.7700	
	Segment	2	0.48400	0.4980	–0.4770	1.4600	
		3	0.29700	0.5420	–0.7580	1.3900	
		4	0.48200	0.5620	–0.5940	1.6100	
		5	–0.33500	0.6600	–1.6100	0.9570	
		6	0.42100	0.5020	–0.5510	1.4300	
		7	0.35500	0.4960	–0.6140	1.3300	
		Other	–0.05470	0.4840	–0.9830	0.9030	
		8	0.75400	0.5320	–0.2900	1.8100	
		9	0.76800	0.5790	–0.3630	1.9400	
		10	0.18400	0.5130	–0.8060	1.1900	
		11	–0.30700	0.5770	–1.4300	0.8320	
		12	0.80900	0.4610	–0.0843	1.7200	
		13	1.00000	0.5800	–0.1030	2.1500	
		14	–0.11700	0.5010	–1.1100	0.8790	
	Year	2023	0.50800	0.1140	0.2820	0.7340	*

Table S17. Continued.

Response	Predictor	Predictor level	Estimate	SE	CI_025	CI_975	sig95
Discoloration	Basal area		0.07700	0.0816	–0.0854	0.2350	
	Species group	*Acer rubrum*	–0.11300	0.5600	–1.2100	0.9870	
		Cercis canadensis	0.78100	1.1100	–1.4300	2.8900	
		Quercus phellos	–0.26500	0.4990	–1.2600	0.6880	
		Ulmus americana	–0.27700	1.1200	–2.5500	1.8700	
		Acer other	0.03550	0.6750	–1.3000	1.3900	
		Prunus spp.	–1.34000	0.9150	–3.1500	0.4250	
		Quercus other	–1.32000	0.5530	–2.4200	–0.2330	*
		Other large	0.14000	0.4700	–0.7830	1.0600	
		Other medium	0.64600	0.5830	–0.4920	1.8000	
		Other small	–0.47400	0.5490	–1.5500	0.6120	
	Mulch	Correct	0.04070	0.1320	–0.2110	0.2990	
		Volcano	–0.07790	0.2590	–0.5940	0.4270	
	Landscaping	Minimal	–0.25400	0.2180	–0.6900	0.1700	
		Moderate	–0.45200	0.2970	–1.0400	0.1270	
		Extensive	–0.04870	0.3010	–0.6420	0.5300	
	Urban tolerance		0.07620	0.3160	–0.5460	0.6880	
	Site type	Median	0.81800	0.3770	0.0910	1.5600	*
		Other maintained	0.30700	0.2990	–0.2860	0.9010	
		Sidewalk planting strip	0.37300	0.2490	–0.1150	0.8520	
		Yard	0.28100	0.2820	–0.2780	0.8320	
	Land use	Commercial and mixed	–0.25100	0.2970	–0.8440	0.3340	
		Institutional	–0.25200	0.2430	–0.7250	0.2170	
		Natural area or vacant	–0.26900	0.3070	–0.8670	0.3370	
		Other	–0.23200	0.4350	–1.1100	0.6010	
	Basal area × species group	*Acer rubrum*	–0.19800	0.1230	–0.4350	0.0463	
		Cercis canadensis	–0.26500	0.1630	–0.5960	0.0466	
		Quercus phellos	–0.52400	0.1670	–0.8470	–0.1980	*
		Ulmus americana	–0.32800	0.1830	–0.6990	0.0149	
		Acer other	–0.07560	0.1190	–0.3090	0.1620	
		Prunus spp.	–0.31500	0.1370	–0.5860	–0.0429	*
		Quercus other	–0.39700	0.1170	–0.6370	–0.1680	*
		Other large	–0.16100	0.0954	–0.3460	0.0258	
		Other medium	–0.07150	0.1300	–0.3290	0.1800	
		Other small	–0.30700	0.1000	–0.5070	–0.1100	*
	Urban tolerance × site type	Median	–0.35600	0.5480	–1.4300	0.7410	
		Other maintained	–0.28900	0.5730	–1.4000	0.8170	
		Sidewalk planting strip	–0.28900	0.3650	–1.0300	0.4240	
		Yard	–0.40900	0.3920	–1.1700	0.3680	

Table S17 continued on next page

Table S17. Continued.

Response	Predictor	Predictor level	Estimate	SE	CI_025	CI_975	sig95
Dieback	Intercept		1.51000	0.9800	–0.3800	3.4400	
	Segment	2	–1.46000	0.8810	–3.2100	0.3160	
		3	–1.05000	0.9330	–2.8600	0.7360	
		4	–0.82000	1.0100	–2.8400	1.1300	
		5	–3.03000	1.2900	–5.6800	–0.6060	*
		6	–0.71800	0.9390	–2.6100	1.0500	
		7	–1.56000	0.9240	–3.4400	0.2230	
		Other	–0.89300	0.8700	–2.6300	0.7800	
		8	–0.16700	0.9860	–2.1200	1.7500	
		9	0.25700	1.0900	–1.9000	2.3700	
		10	–2.00000	0.9380	–3.8900	–0.1990	*
		11	–1.85000	1.0600	–3.9800	0.1910	
		12	–0.07660	0.8250	–1.7200	1.5900	
		13	0.51100	0.9780	–1.4100	2.3800	
		14	–1.38000	0.8770	–3.1800	0.2690	
	Year	2023	0.20400	0.1370	–0.0625	0.4700	
	Basal area		0.06070	0.1510	–0.2330	0.3570	
	Species group	*Acer rubrum*	1.29000	1.0100	–0.6310	3.3400	
		Cercis canadensis	1.94000	1.9500	–1.8500	5.7700	
		Quercus phellos	2.12000	0.8830	0.4620	3.9200	*
		Ulmus americana	–3.14000	1.9000	–6.7400	0.5700	
		Acer other	0.54500	1.2400	–1.8800	2.9800	
		Prunus spp.	2.73000	1.6300	–0.3630	6.0200	
		Quercus other	1.51000	0.8510	–0.1130	3.2600	
		Other large	1.07000	0.7890	–0.4800	2.6300	
		Other medium	0.10300	0.9980	–1.8500	2.0400	
		Other small	0.26100	0.9470	–1.5800	2.1100	
	Mulch	Correct	–0.12200	0.2020	–0.5060	0.2790	
		Volcano	0.62500	0.5060	–0.3320	1.6600	
	Landscaping	Minimal	–0.17200	0.3000	–0.7710	0.4230	
		Moderate	0.35400	0.5050	–0.6280	1.3500	
		Extensive	–0.81800	0.4900	–1.7800	0.1570	
	Urban tolerance		–0.07000	0.6150	–1.2600	1.1200	
	Site type	Median	–0.13000	0.6830	–1.4600	1.1900	
		Other maintained	–0.22000	0.6000	–1.3700	1.0000	
		Sidewalk planting strip	0.92500	0.4720	0.0116	1.8700	*
		Yard	0.61800	0.4990	–0.3710	1.5800	

Table S17. Continued.

Response	Predictor	Predictor level	Estimate	SE	CI_025	CI_975	sig95
Dieback	Land use	Commercial and mixed	–0.21900	0.5550	–1.2900	0.8700	
		Institutional	–0.25400	0.4590	–1.1500	0.6540	
		Natural area or vacant	–0.05270	0.6020	–1.2500	1.1200	
		Other	–1.98000	0.8080	–3.5700	–0.4350	*
	Basal area × species group	*Acer rubrum*	–0.03650	0.2210	–0.4790	0.4220	
		Cercis canadensis	0.05370	0.2860	–0.5020	0.6080	
		Quercus phellos	0.63800	0.3300	0.0161	1.3100	*
		Ulmus americana	–0.55400	0.3080	–1.1500	0.0492	
		Acer other	0.05320	0.2260	–0.4010	0.4910	
		Prunus spp.	0.43400	0.2510	–0.0627	0.9380	
		Quercus other	0.35300	0.2050	–0.0283	0.7850	
		Other large	0.04710	0.1690	–0.2850	0.3800	
		Other medium	–0.07490	0.2190	–0.4960	0.3450	
		Other small	–0.17000	0.1790	–0.5180	0.1720	
	Urban tolerance × site type	Median	–1.42000	1.0500	–3.5000	0.5770	
		Other maintained	0.14100	1.1800	–2.1400	2.4300	
		Sidewalk planting strip	–1.20000	0.7190	–2.5800	0.2280	
		Yard	–0.33400	0.7120	–1.7900	1.0200	

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Table S18. All parameter estimates for the univariate (crown stress) growing condition model in Durham. The baseline for street segment is the wealthiest street segment with at least 10 trees (arbitrarily numbered 1), the baseline for year is 2022, the baseline for species group is the most common group (*Lagerstroemia* spp.), the baseline for landscaping intensity is no landscaping, the baseline for site type is the most restrictive rooting spaces (sidewalk cutouts and other hardscape), and the baseline for land use is residential. CI_025 and CI_975 together describe the 95% confidence interval around the parameter estimate, and sig95 indicates whether or not the 95% confidence interval crosses zero. SE (standard error); CI (confidence interval).

Predictor	Predictor level	Estimate	SE	CI_025	CI_975	sig95
(Intercept)		0.004498	0.48570	–0.94070	0.960400	
Segment	2	–1.208000	0.46860	–2.12800	–0.290400	*
	3	–0.769200	0.47870	–1.71000	0.178800	
	4	–1.062000	0.50170	–2.04300	–0.075490	*
	5	–1.142000	0.58310	–2.29700	–0.004780	*
	6	–0.529100	0.47590	–1.47500	0.400800	
	7	–1.151000	0.45840	–2.05300	–0.247900	*
	Other	–0.972700	0.44250	–1.84900	–0.108400	*
	8	–0.428300	0.48040	–1.38200	0.512200	
	9	–0.222000	0.54690	–1.29700	0.840800	
	10	–1.167000	0.46110	–2.07500	–0.263600	*
	11	–1.447000	0.51030	–2.45200	–0.453800	*
	12	–0.955700	0.42360	–1.79200	–0.122600	*
	13	–0.082160	0.52220	–1.09900	0.943200	
	14	–1.833000	0.45960	–2.73500	–0.938300	*
Year	2023	0.243100	0.10620	0.03594	0.449800	*
Basal area		–0.084320	0.03216	–0.14670	–0.020560	*
Species group	*Acer rubrum*	1.297000	0.27960	0.75290	1.846000	*
	Cercis canadensis	2.111000	0.31630	1.50200	2.745000	*
	Quercus phellos	1.487000	0.31180	0.87880	2.098000	*
	Ulmus americana	1.408000	0.30250	0.81950	2.004000	*
	Acer other	0.717400	0.27840	0.16350	1.262000	*
	Prunus spp.	0.790400	0.27460	0.25270	1.327000	*
	Quercus other	0.941700	0.29460	0.37160	1.515000	*
	Other large	1.372000	0.25260	0.88190	1.866000	*
	Other medium	1.020000	0.26850	0.49480	1.550000	*
	Other small	1.466000	0.24350	0.99100	1.946000	*
Powerline		–0.361700	0.13900	–0.63540	–0.088370	*
Mulch	Correctly	–0.220800	0.11940	–0.45310	0.013630	
	Volcano	–0.346900	0.23580	–0.80840	0.121700	
Landscaping	Minimal	–0.378000	0.19260	–0.75120	0.003994	
	Moderate	–0.419900	0.27120	–0.95140	0.107700	
	Extensive	–0.356600	0.27130	–0.88280	0.177200	

Table S18. Continued.

Predictor	Predictor level	Estimate	SE	CI_025	CI_975	sig95
Urban tolerant		–0.304000	0.29320	–0.88140	0.276300	
Site type	Median	0.678500	0.35160	–0.01713	1.361000	
	Other maintained	0.350200	0.27120	–0.18310	0.880600	
	Sidewalk planting strip	0.502400	0.22690	0.05451	0.946300	*
	Yard	0.299000	0.25050	–0.18740	0.789500	
Land use	Commercial or mixed	–0.319900	0.25530	–0.82350	0.176900	
	Institutional	–0.310600	0.21510	–0.73040	0.109100	
	Natural area or vacant	–0.092000	0.25710	–0.59800	0.407600	
	Other	–0.487000	0.37410	–1.21200	0.248000	
Urban tolerance × site type	Median	–1.405000	0.50990	–2.41700	–0.418000	*
	Other maintained	0.161200	0.49020	–0.80170	1.133000	
	Sidewalk planting strip	–0.476800	0.32770	–1.11900	0.154700	
	Yard	0.033430	0.34000	–0.64380	0.693700	

Table S19. Residual covariance between tree stress variables in Chicago. (±) values are the standard errors. Since the tree stress variables (defoliation, discoloration, dieback) were modeled together in GJAM, the output includes a residual covariance matrix that describes the correlation between tree stress variables after the predictors have been accounted for. The matrix is symmetrical so only one set of pairwise comparisons are shown. GJAM (generalized joint attribute modeling).

Tree stress metric	Defoliation	Discoloration	Dieback
Defoliation	1	0.2759 ± 0.0987	–0.0708 ± 0.1320
Discoloration		1	0.1787 ± 0.0809
Dieback			1

Table S20. Residual covariance between tree stress variables in Durham. (±) values are the standard errors. Since the tree stress variables (defoliation, discoloration, dieback) were modeled together in GJAM, the output includes a residual covariance matrix that describes the correlation between tree stress variables after the predictors have been accounted for. The matrix is symmetrical so only one set of pairwise comparisons are shown. GJAM (generalized joint attribute modeling).

Tree stress metric	Defoliation	Discoloration	Dieback
Defoliation	1	0.0471 ± 0.0772	0.0956 ± 0.1135
Discoloration		1	–0.0165 ± 0.1020
Dieback			1