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Factors influencing long-term street tree survival in Milwaukee, WI, USA

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ABSTRACT

Street trees are exposed to a variety of site conditions, environmental factors, and physical disturbances which influence their survival in urban areas. This study draws on 25 years of urban forest monitoring data from the city of Milwaukee, WI (United States) to model the impacts of these factors on tree survival for a single cohort of trees. Tree condition, tree size, tree species, and site attributes were measured initially in 1979. These factors were measured again in 1989 and 2005 and compared to construction data for the same area during the study period. Multivariate logistic regression was used to identify factors associated with tree survival. Cross-validation show the final model could successfully predict tree survival nearly 85% of the time. Results indicate that tree survival varied by species. Additionally, trees were more likely to die as trunk diameter increased, planting space width decreased in the tree lawn, and tree condition decreased. Finally, trees adjacent to construction were nearly twice as likely to die as those not exposed to development and redevelopment activities.

Introduction

The economic benefits generated by an urban forest are greatly influenced by urban tree longevity. Depending on the location and valuation method applied, it may take one or more decades before the benefits of a newly planted urban tree equals the costs associated with its installation and maintenance (Mcpherson et al., 1997). Unfortunately, construction activities near street trees can have significant impact on tree health and survival resulting in a loss in net urban forest value (Hauer et al., 1994). Understanding the many tree- and site-related factors that influence urban tree longevity in the presence and absence of construction activities is critically important for urban tree managers charged with maximizing net urban forest value.

While street trees can potentially benefit urban infrastructure by reducing the maintenance demand of asphalt roadways through shading (McPherson and Muchnick, 2005), it is more common to find accounts of urban gray and green infrastructure in conflict (Hauer et al., 1994; Francis et al., 1996; McPherson, 2000; Randrup et al., 2001; Grabosky and Gilman, 2004; Celestian and Martin, 2005; Day et al., 2010a,b). As tree roots grow outward and expand, pressure is exerted on adjacent soil and nearby infrastructure surfaces (Grabosky and Nenad, 2011). This root pressure can lead to, among other things, sidewalk lifting (Francis et al., 1996; Randrup et al., 2001; D'Amato et al., 2002a; Grabosky and Nenad, 2011) and the widening of cracks or seams in foundations or pipes (Day, 1991; Rolf and Stål, 1994; Östberg et al., 2012). If street trees are responsible of these infrastructure damages, then the repair reduces the net benefit of street trees.

Just as street trees can impact the functional lifespan of constructed materials, their health, size, and ultimate longevity are also impacted by close proximity to infrastructure and site conditions (Hauer et al., 1994; Grabosky and Gilman, 2004; Celestian and Martin, 2005). Compacted base soil layers and impervious surfaces can reduce soil water, aeration, and root growth (D'Amato et al., 2002b; Grabosky et al., 2002; Grabosky and Gilman, 2004; Smiley et al., 2006). In addition to limiting rooting space, the replacement of damaged or worn out hardscape elements can cause significant mechanical injury and loss of stability, especially in instances where existing structural roots are severed near the trunk for trenching, road expansion, or curb replacement (Hauer et al., 1994; Smiley, 2009).

Many factors beyond construction influence tree survival (Miller, 2007). A recent meta-analysis of urban tree longevity research found annual survival rates were approximately 94.9–96.5% (Roman and Scatena, 2011). Within this overall

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success rate, newly planted trees tend to die at a higher rate than established trees (Miller and Miller, 1991; Nowak and Crane, 2004). Young tree death may result from inadequate watering, vandalism, non-compatibility with environmental conditions at the planting site, improper planting practices, or a combination of factors during the establishment phase. Miller and Miller (1991) found that much of the mortality associated with newly planted, street trees (4–5 cm caliper) occurs one to 2 years after installation. Death linked to transplant failure typically tapers off after 5 years. Once established, mortality rates generally decrease until trees grow larger and overly mature (Nowak and Crane, 2004; Miller, 2007). Street trees in poorer condition also die at higher rates (Hauer et al., 1994; Nowak and Crane, 2004).

The long-term survival of street trees can be impacted by construction near trees (Hauer et al., 1994). In one study in Milwaukee, WI, United States, street trees directly adjacent to these development activities experienced 5% greater mortality than nearby control trees (Hauer et al., 1994). Similarly, the condition of surviving construction trees (as determined by a visual Council of Tree and Landscape Appraisers rating) declined by approximately 5% compared to trees not subjected to construction four to 8-years earlier (Hauer et al., 1994). An increase in the tree lawn width (distance between the curb and sidewalk) was also positively correlated with greater tree condition.

This study draws on a combined tree monitoring and construction project data set that spans a quarter-century. Beginning with a baseline tree inventory conducted in 1979 (before street construction activities), the study site was revisited in 1989 and 2005 to assess tree survival in the absence or presence of curb and sidewalk replacement activities. The duration of this study period goes well beyond the typical lifespan of most experiments, offering a unique assessment of long-term survival rates of urban street trees exposed to- and spared from-periodic construction disturbance events. This work offers a greater understanding of the factors associated with tree mortality and may offer important insights for public officials, urban planners, urban foresters, arborists, and other professionals managing urban development and street tree populations. It is intended to given decision makers additional evidence to support their efforts in increasing the functional lifespan and maximizing the environmental, social, and economic benefits of urban trees.

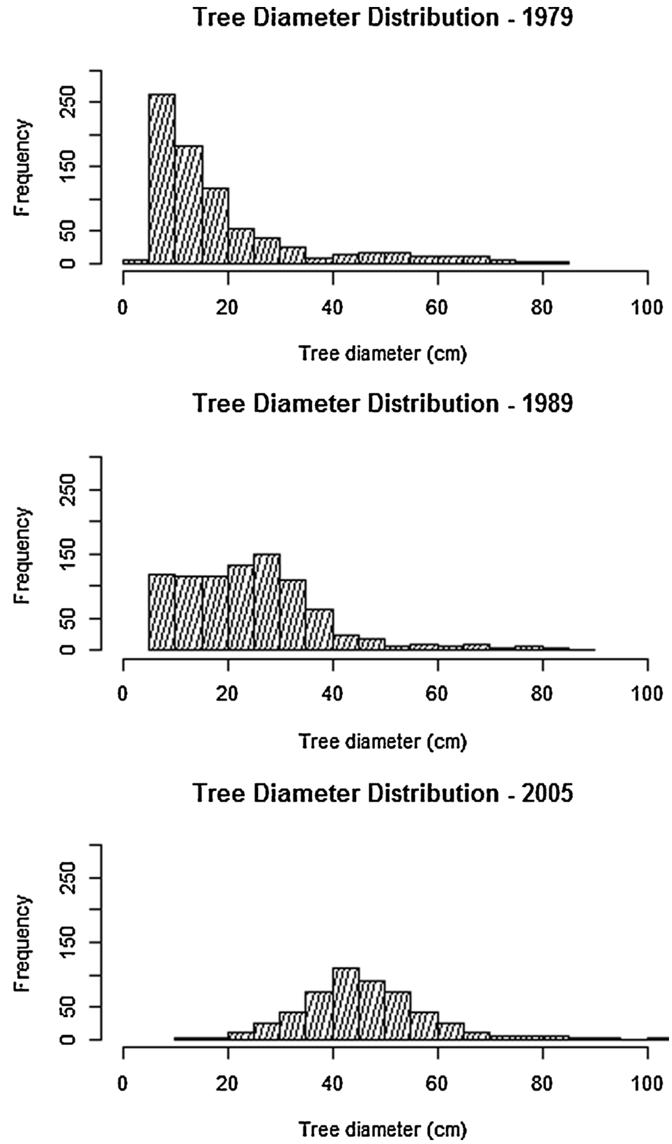

Fig. 1. Age/size class distributions of the street tree study cohort in 1979, 1989, and 2005. Cohort was from the urban forest of the city of Milwaukee, WI, United States (43.0389° N, 87.9064° W).

Methods

This study investigated factors associated with the survival of street trees in the city of Milwaukee, WI, United States (43.0389° N, 87.9064° W). Trees were either subjected to street and sidewalk construction or spared from such activities during two time periods. The first time period (Pre-1989) occurred prior to the enactment of a comprehensive municipal tree protection program in 1989. Key elements of this Milwaukee tree protection program initiated after the first study time period included the inclusion of forester inspectors to review public and private construction plans, use of alternative construction techniques, work site inspections, and cost recovery measures for damaged trees. The tree population (surviving trees and replacements) was again measured during a second time period (Post-1989) in 2005 – approximately 15 years following the full enactment of the tree protection program. Size class distributions for the three measurement years are provided in Fig. 1. Given the separation of the data (temporally and analytically), only general comparisons are made between the Pre- and Post-ordinance survival models. The primary focus of this paper is on site attributes and tree species that may relate to street tree survival.

The sampling methods for this project are an extension of past work by Hauer et al. (1994). Trees were sampled from city blocks that either had construction activities or nearby control blocks where construction did not occur. Of 100 construction projects (conducted at the block level), 25 of similar scope were randomly selected to serve as the study sample. These sites reflected typical construction work (e.g., street widening and combined curb and sidewalk replacement) and the diversity of species present in the city of Milwaukee. For both construction and control blocks the first 25 trees per block were included in the sample.

Baseline urban forest inventory data was collected by the City of Milwaukee Bureau of Forestry in 1979 prior to any construction, in 1989 for the Pre-program data set, and in 2005 for the post-program data set. The inventoried data included tree species, tree lawn width (distance between curb and sidewalk), diameter at 1.37 m above ground level (dbh), and percent condition rating based on the Council of Tree and Landscape Appraisers system (Neely, 1988). Tree condition was a function of the rating of foliage, twigs, scaffold branches, trunk, and roots in this system with equal weight given to each of the five categories. During each