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Biological, Social, and Urban Design Factors Affecting Young Street Tree Mortality in New York City

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Abstract

In dense metropolitan areas, there are many factors including traffic congestion, building development and social organizations that may impact the health of street trees. The focus of this study is to better understand how social, biological and urban design factors affect the mortality rates of newly planted street trees. Prior analyses of street trees planted by the New York City Department of Parks & Recreation between 1999 and 2003 (n=45,094) found 91.3% of those trees were alive after two years and 8.7% were either standing dead or missing completely. Using a site assessment tool, a randomly selected sample of 13,405 of these trees was surveyed throughout the City of New York during the summers of 2006 and 2007. Overall, 74.3% of the sample trees were alive when surveyed and the remainder were either standing dead or missing. Results of our initial analyses reveal that highest mortality rates occur within the first few years after planting, and that land use has a significant effect on street tree mortality. Trees planted in one- and two-family residential areas had the highest survival rates (82.7%), while young street trees planted in industrial areas, open space and vacant land had the lowest rates of street tree survival (60.3% -62.9%). Also significant in predicting street tree success and failure are species type, tree pit enhancements, direct tree care/stewardship, and local traffic conditions. These results are intended to inform urban forest managers in making decisions about the best conditions for planting new street trees.

Keywords

Urban forestry; street trees; mortality; stewardship; urban design; planting

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INTRODUCTION

It is understood that the establishment period following planting of an urban street tree is crucial to its survival (Richards 1979; Gilbertson and Bradshaw 1990), yet little is known about the factors or relationships that ultimately contribute to tree mortality or survival. Improving the survival of young street trees can do more to reduce replacement needs than will investments to maintain older trees (Richards 1979). This study of young street trees planted throughout neighborhoods in New York City provides a context in which to understand how biological, social, and urban design factors impact the establishment of new street trees through a multi-disciplinary site assessment framework that examines the conditions of the urban street. In this study, we present our rationale, methods, and descriptive statistics on the subject in an effort to contribute to the literature on street tree health and as a means to inform similar practitioner-based efforts in other urban areas.

One of the fundamental challenges to city managers and civic groups is ensuring the survival of newly-planted street trees in places as dynamic, heterogeneous, and diverse as cities. Population growth, vehicular traffic, poor air quality, and building and sidewalk designs all present challenges to urban street trees, yet trees must reach maturity in order to maximize proven biophysical and social benefits (Dwyer et al. 1992). While there is much research on soil regimes, nursery stock, and species selection, survival rates still vary widely—from 34.7% to 99.7% according to a recent review of the literature (Roman 2006). As cities around the United States increase their investment in tree planting via programs such as MillionTreesNYC, Million Trees Los Angeles, and Keep Indianapolis Beautiful, urban forest managers must be able to ensure young trees' best chance of survival.

Other published work on tree mortality provides insight into factors impacting the life of an urban street tree. One early study analyzes street trees in three Boston neighborhoods that differ both socioeconomically and demographically and reports a 26% mortality rate of 136 trees planted two to four years prior on one commercial street (Foster and Blaine 1978). The authors also observed low rates of vandalism, high rates of automobile damage, and the potential for tree stakes to damage newly-planted trees. Localized effects could also be at play in the findings of an Oakland study that assesses street tree growth and mortality of 480 volunteer-planted trees along a 5.4-mile stretch of one boulevard; after two years, 34% of the trees were dead or removed (Nowak et al. 1990). Although the authors find differences in mortality related to adjacent land uses, it is uncertain if the mortality here is high overall due to conditions local to the boulevard; if the trees were planted incorrectly by the volunteers; or if the trees were too small to withstand minor stresses that may not affect trees of a larger caliper; or some other factor. Another study with a local focus reports on environmental factors influencing 1,000 urban street trees in New York City (Berrang et al. 1985). Because all of the trees in this study are sited directly around electrical power facilities, it is difficult to determine if their observations are a result of this adjacent land use or if they can be applied across the urban landscape. Observational studies such as these give insight into potential factors influencing the survival of newly-planted trees, but have yet to be tested on a city-wide scale. This study examines similarities and differences among a wide range of site conditions and neighborhoods.

The published study with the largest sample size reports on observations of 10,000 newly-planted trees in northern England and finds 9.7% mortality after one year (Gilbertson and Bradshaw 1985). The researchers draw attention to the many factors potentially affecting mortality levels such as stock quality, planting technique, and maintenance regime, but do not attempt to directly link any of these phenomena to tree mortality rates. A similar study tracks four groups of newly-planted trees during their first year in urban Brussels (Impens and Delcarte 1979). The average mortality rate after one year is 11.3%, but detailed information that describes the size, species, or specific location of the trees is not addressed by the study.

A second study about the survival of newly-planted urban trees in Northern England reports on constant, in-situ monitoring of the study trees, which has the potential to provide more detailed information about precisely when and how the tree died (Gilbertson and Bradshaw 1990). The authors found 22.7% mortality after three growing seasons in the inner-city compared with 17% in greater Liverpool. Although the difference is assumed to be linked to the inhospitable environment of the study cohort, vandalism is not a primary cause of tree death in inner city Liverpool. Instead, biological factors such as species tolerance, transplant stress, water stress, and weed competition are deemed most crucial for urban tree establishment (Gilbertson and Bradshaw 1990).

The methods used in urban tree mortality research are broad and varied, making it difficult to compare rates of survival, but several key observations can be gleaned from these prior studies that likely have implications on mortality rates. Vandalism, as measured by the observation of broken branches in the canopy or a broken main stem, is an important factor in the mortality of urban trees (Gilbertson and Bradshaw 1985; Nowak et al. 1990; Pauleit et al. 2002; Roman 2006); adjacent land use can negatively affect street tree populations (Nowak et al. 2004; Roman 2006); and some species of trees fare much better than others as street trees (Gilbertson and Bradshaw 1990; Miller and Miller 1991; Sydnor et al. 1999; Pauleit et al. 2002). Few studies have analyzed the role of physical urban design factors such as traffic volume or the tree's location within the streetscape on mortality rates. Previous studies have not fully investigated the contribution of social or stewardship factors including sociability of the area proximate to the tree (e.g. seating, gardens, front yards) or signs of direct tree care and stewardship (e.g. weeding, mulching, gardening in tree bed), to young street tree success. The goal of this study is twofold, to develop an assessment tool that includes biological, social, and urban design factors and apply it across a wide range of land uses and neighborhood settings to gain insight into the multiple pathways and processes impacting the health of young street trees.

METHODOLOGY

Sampling Plan

The 13,405 trees analyzed in this study were pulled from a larger sample of 45,094 trees using a partial inventory technique based on stratified random sampling (Sun and Bassuk 1991; Jaenson et al. 1992). The sample was stratified by time in-ground and land use in order to get a random and comprehensive sample of trees in each of these groups. At the time of field survey, all trees had been in the ground between 3 and 9 years. For the stratified random sample, the trees planted from spring 1999 to fall 2003 were grouped into three planting periods. The sample was also stratified using aggregated land use classes from the New York City Primary Land Use Tax Lot Output (PLUTO) data set (NYC Department of City Planning 2005); the original land use types were grouped into One & Two Family Residential, Multi-family Residential; Mixed, Commercial and Public Institutions; Industrial, Utility & Parking; and Open Space & Vacant Land. During field surveys we found that the land use information in PLUTO was not up-to-date or accurate. Forty eight percent of the tree planting locations visited had actual land uses that differed from the PLUTO data. Because of issues encountered with the accuracy of the PLUTO database, we present our results using the land use types observed for the tree in the field. We also readjusted our stratified sample to account for the distribution of field-verified land use.

Field Methods

In order to efficiently visit and record data on 13,405 trees across all five boroughs of New York City, a grid map series at roughly 1:10,000 was produced using ArcGIS. A custom data collection form designed in Pendragon Forms allowed survey questions to be loaded on a Palm Pilot for mobile data collection. These field data were directly synchronized into Microsoft Excel. In this study, the data were collected at multiple scales - the tree level, then the building level, and at the block level. In order to

facilitate easy repetition of data collection, all variables were optimized for simple field observation and require no laboratory analysis or precise measurements. The data are organized into the three groups of relevant information: biological factors that may affect young street trees, urban design factors, and sociability/stewardship factors. Some of the variables we collected can apply to more than one tier – for example, presence or absence of a tree guard can be both a physical design and a stewardship factor, depending on whether they are routinely installed as part of municipal tree planting.

These methods were based upon social site assessment models used for natural resource management (Freudenburg 1986) with city foresters taking an active role in training and supervising researchers in the field. All fieldwork was conducted by 20 interns hired and trained by the New York City Department of Parks & Recreation (NYC Parks) and the USDA Forest Service Northern Research Station (NRS). Data collection took place over the summers of 2006 and 2007 in hundreds of New York City neighborhoods. Recording the presence or absence of observable phenomena, the team used a combined study approach and developed a data collection framework that resulted in the collection of over forty items of data at the location of each tree. Street tree locations varied widely, from high-rise areas, to low-rise brownstone neighborhoods, to single family structures in suburban settings. For the purposes of this analysis, missing trees were counted as dead, following the precedent of previous studies (Gilbertson and Bradshaw 1990; Miller and Miller 1991; Pauleit et al. 2002).

Biological Factors

Table 1 lists the biological factors that may have an effect on the success and failure of young street trees. If the tree cannot obtain its minimum biological requirements, it will not thrive, regardless of the urban context in which it was planted. This first layer of data collection provides important clues to the overall health of the tree. The data items listed below may indicate tree health, growth rates, damage and decay, or soil health or identify biological stressors affecting establishment. They are most useful in determining the overall health of a living street tree; if a tree is dead or missing from where it was planted, it is not possible to collect many of these data items. In light of the developing awareness in an objective methodology in appraising tree health (Bond 2010) and linking urban tree evaluations into the forest inventory analysis (FIA) through the ongoing International Union of Forest Research Organizations (IUFRO) Urban Forestry Data Standards effort, our approach is certainly subject to change as methods become standardized. Soil compaction was measured by applying pressure to the soil with a screwdriver tip; if the screwdriver easily entered the soil, the soil was said to be uncompacted.

Data Item	Response type
water pooling in tree pit	presence/absence
soil compaction	presence/absence
animal waste	presence/absence
sucker growth	presence/absence
evidence of leaf chlorosis	presence/absence
evidence of insect damage	presence/absence
evidence of dieback	presence/absence
guiding wires girdling tree	presence/absence
guard/grate girdling tree	presence/absence
broken branches	presence/absence
unnatural lean	presence/absence
trunk wound	presence/absence
pit soil level	categorical
planting depth	categorical
species	categorical
diameter at breast height	categorical

Table 1. Biological factors potentially affecting young street trees in NYC.

Sociability/stewardship Factors

The social factors which potentially influence young street tree mortality are listed in Table 2. Our data collection methodology includes recording direct signs of tree stewardship at the level of each tree (i.e. planting in tree pits, adding mulch), which are indicators that individuals or groups are caring for a tree. At the building and neighborhood level, we observed off-tree signs of stewardship such as the presence of home decorations, front yard gardens, and murals. These factors are considered "cues to care" that provide evidence that individual and/or community-level stewardship is taking place (Nassauer 1995). A well-cared for urban street tree and pit area is considered to be a sign of active local stewardship. We also collected data on practices that could have conflicting effects on a tree's health; for example, tree lights could retard tree growth by strangling the tree, but also could draw attention to the presence of a tree thereby triggering stewardship.

Table 2. Sociability/stewardship factors potentially affecting street trees in NYC

	Data Item	Response type
Tree/tree pit level	pit off curb (at least 12" away)	presence/absence
	curb intact	presence/absence
	tree grate	presence/absence
	block paving in tree pit	presence/absence
	tree guard*	presence/absence
	tree pit type	categorical
	presence/condition of block pavers	presence/absence; categorical
	tree pit size (square feet)	number
Building level	ground floor door	presence/absence
	awning on adjacent building	presence/absence
	scaffolding on adjacent building	presence/absence
	number of building stories	number
	land use classification	categorical
Streetscape level	median strip on street	presence/absence
	on-street parking	presence/absence
	bus stop nearby (< 5')	presence/absence
	driveway nearby (< 5')	presence/absence
	bike rack nearby	presence/absence
	sidewalk condition	categorical
	traffic volume	categorical
	tree placement in slope	categorical
	sidewalk width	number
	number of traffic lanes	number
	% pavement within drip line	number

* the variable presence of a tree guard can also apply to the sociability / stewardship category

Data were collected about neighborhood sociability to ascertain whether the tree is incorporated into active street life. For example, benches are built into tree pits, seating is arranged under trees' canopies, or play equipment is often proximate to the tree. At the neighborhood level, signs of sociability indicate more "eyes upon the street" (Jacobs 1961) or the orientation of urban space to enhance community awareness and engagement. This sociability can influence tree survival via multiple pathways, such as through prevention of tree vandalism. Moreover, these signs of sociability can be considered indicators of community street life and may relate to stewardship over time. Given a study that collects observational data at one moment in time, it is important to use these proximate measures of social life as indicators that stewardship may have occurred historically. Areas of community street activity include facilities such as places of worship and schools, which are known to sponsor local stewardship activities. Drawing upon the work of Wilson and Kelling (1982), negative indicators were also observed, such as the presence of broken windows, vacant lots and buildings, and (non-mural) graffiti. Known as the "broken-window theory," the presence of vacant buildings and lots strewn with garbage tend to attract more visible disorder on and around neighborhood streets. Researchers documented the presence and absence of disorder around each street tree.

One difference in this section of data is that it is possible for some items to have two response types. For example, if a front yard is present (presence/absence), it may be valuable to note what type of yard (categorical; i.e. paved, grass). The same can be said for gardens, building security, murals, and public facilities. Collecting this second tier of data gives researchers the ability to strengthen an analysis of the dynamic social factors affecting street tree mortality.

Urban Design Factors

This study suggests that physical urban design factors influence the success of young street trees; this category includes information at three different levels: tree/tree pit, building, and streetscape (listed in Table 3). The factors measured at the level of the tree and tree pit itself are more directly connected with the tree success or failure, while others, such as the presence of a bike rack nearby and the width of the sidewalk, are more exploratory in nature and may only provide insights into potential influences. All factors comprise the physical urban context into which the tree has been planted. They are the result of urban design, zoning practices, or unplanned piecemeal development and they affect the flow of pedestrians, bicycles, and motor vehicles through the environment surrounding the tree. At the same time, these factors also affect airflow, sunlight, and wind speed that can impact the growing conditions of trees (McGrath et al. 2007).

Most of these data are collected in the presence/absence format, but some other responses are categorical in nature. For example, pit type could be characterized as a sidewalk cutout or tree lawn; block paving status can range from good to raised or altogether missing; traffic volume could be low, medium, or high; and sidewalk condition could be good, cracked, poor condition, etc.

Table 3. Urban design factors potentially affecting street trees in NYC.

	Data Item	Response type
Tree/tree pit level	tree care-related signage	presence/absence
	stakes present, but no wires	presence/absence
	walled tree well	presence/absence
	tree pit plantings	presence/absence
	tree guard*	presence/absence
	tree pit paved to tree trunk	presence/absence
	mulch in tree pit	presence/absence
	gravel in tree pit	presence/absence
	bench near/around pit	presence/absence
	bird feeder in tree or tree pit	presence/absence
	irrigation bag	presence/absence
	evidence of weeding of tree pit	presence/absence
	litter in tree pit	presence/absence
	evidence of pruning	presence/absence
	debris in canopy of tree	presence/absence
	electrical outlet in tree pit	presence/absence
	lights in or around tree	presence/absence
Building level	seating area associated with building	presence/absence
	play equipment in yard of building	presence/absence
	flag on building	presence/absence
	decorations on door of building	presence/absence
	flower planters	presence/absence
	building has front yard (type)	presence/absence; categorical
	building has garden (type)	presence/absence; categorical
	building security (type)	presence/absence; categorical
Streetscape	graffiti on adjacent buildings	presence/absence
	broken/missing windows	presence/absence
	mural on adjacent building (type)	presence/absence; categorical
	public facilities on block (type)	presence/absence; categorical
	block-level vacancies	categorical

* the variable presence of a tree guard can also apply to the urban design category

FINDINGS FROM DESCRIPTIVE STATISTICS

The following descriptive statistical analyses examine the effects of time since planting, land use, and selected biological, social, and urban design factors on urban young street tree mortality. Contingency tables and chi-square analyses were used to assess the effect of each variable, with the simplifying assumption that variables are independent and do not interact with each other. Although in reality our dataset contains many nested, correlated and confounding variables, as practitioners we are interested in evaluating the contributions of each variable from a management perspective and for refining planting policies and site selection procedures. Formal analysis incorporating combinations of and interactions between these factors is ongoing and will be treated in future manuscripts.

Time Since Planting

As previously mentioned, it is widely assumed in the literature that there is some time after planting in which the mortality rates of street tree populations stabilize. In order to determine if and possibly when this is occurring in New York City, we performed a preliminary analysis to determine if time since planting is related to street tree mortality. Our data do in fact suggest this type of trend, as the rate of tree loss for trees inspected 6-8 and 8-9 years after planting are nearly identical. Contingency table analysis found years since planting to have a significant influence on tree survival (Pearson's X^2=24.65, df=2, p<0.001). The decrease in survival rate between the first two time periods is the most marked, which reflects the immediate difficulty that young street trees face after being transplanted into the urban landscape. The two-year survival rate for these young street trees was calculated using operational contract data.

Table 4. Young street tree survival by years since planting.

Years since planting	Alive		Not Alive		Total sample size
	No. of trees	%	No. of trees	%	
*2 years after planting**	*41,169*	*91.3%*	*3,925*	*8.7%*	*45,094*
3-6 years after planting	1,891	78.2%	526	21.8%	2,417
6-8 years after planting	3,690	73.0%	1,363	27.0%	5,053
8-9 years after planting	4,381	73.8%	1,554	26.2%	5,935
Total	9,962	74.3%	3,443	25.7%	13,405

* 2 year survival rate is based on contractual guarantee inspection data and is only provided for reference.

Land Use

Because previous research highlighted the importance of adjacent land use in young street tree mortality, we performed an additional analysis examining this phenomenon in New York City. For this analysis, observed land uses were grouped into five categories: one/two family residential; multi-family residential; mixed, commercial, and public institutions; industrial, utility, and parking; and open space/vacant land.

In New York City, young street trees in one and two family residential areas have the highest survival rate (Table 5), while industrial areas and open space/vacant land had the lowest rates of street tree survival (ranging from 60.3% to 62.9%). Pearson's chi-square test found land use group to have a significant influence on tree survival (X^2=455.432, df=4,p<0.001). This data suggests that neighboring human activities do have an effect on young street tree survival and our results are similar to those found in other studies (e.g. Nowak et al. 1990; Nowak et al. 2004).

Table 5. Young street tree survival by land use group

Land Use Group	Alive		Not Alive		Total sample size
	No. of trees	%	No. of trees	%	
One/Two Family Residential	4,821	82.7%	1,009	17.3%	5,830
Multi-Family Residential	2,232	72.3%	856	27.7%	3,088
Mixed, Commercial and Public Institutions	388	62.9%	229	37.1%	617
Industrial, Utility and Parking	1,903	66.2%	972	33.8%	2,875
Open Space and Vacant Land	545	60.3%	359	39.7%	904
Total	9,889	74.3%	3,425	25.7%	13,314

Biological, Sociability/Stewardship, And Urban Design Factors

As mentioned previously, we looked at how individual or groups of variables affected survival rates through a series of two-way contingency tables. The results presented here begin to lay out the type of processes at work in the urban forest. Our initial results are summarized in Tables 6 through 8.

Biological Factors

Previous research has shown that species does matter with respect to the mortality of urban street trees, and this study reinforces that idea that there are significant differences in survival rates between species (Table 6). Of the trees planted that comprise greater than one percent of the total, callery pear (*Pyrus calleryana*) is the most successful. Although the entire suite of species that NYC Parks plants are known to be tolerant of urban conditions, some have higher tolerances than others. Anecdotally, one of the most common stressors that an urban street tree faces believed to face is deposition of animal waste in the tree pit, yet in our results the presence of scat was unexpectedly associated with higher survival, underscoring how these simplistic analyses based on one-time observations should be interpreted with caution.

Table 6. Young street tree survival and select contributing biological factors

Independent Variable	Alive	Not Alive	% Survival	X^2 value	*df*	*p*-value
Tree species (>1% of all planted trees)						
Pyrus calleryana	1,863	381	83.0%			
Gleditsia triacanthos	1,274	332	79.3%			
Tilia cordata	617	168	78.6%			
Quercus palustris	639	177	78.3%			
Zelkova serrata	537	149	78.3%			
Tilia tomentosa	143	41	77.7%			
Quercus rubra	145	42	77.5%			
Fraxinus pennsylvanica	268	85	75.9%	178.611	18	<0.001
Prunus cerasifera (Purpleleaf plum)	113	37	75.3%			
Acer rubrum	245	81	75.2%			
Prunus serotina (Kwanzan cherry)	266	88	75.1%			
Japanese pagoda tree	310	109	74.0%			
Prunus virginiana (Shubert cherry)	452	184	71.1%			
Tilia tomentosa	477	204	70.0%			
Acer campestre	170	73	70.0%			
Liquidambar styraciflua	171	77	69.0%			
Prunus spp.	210	107	66.2%			
Gingko biloba	370	189	66.2%			
Plantanus acerifolia	112	68	62.2%			
Presence of animal scat in tree pit or near tree						
Present	627	139	81.9%	24.19	1	<0.001
Not present	9,335	3,301	73.9%			

Sociability/ Stewardship Factors

These variables can help to elucidate the level of engagement that an individual or local community group has with trees in the urban landscape. In terms of sociability, trees with adjacent seating or an adjacent front yard were all more likely to survive in the urban environment (Table 7). Our data also show that a tree is more likely to survive if the building in front of which it is planted has a garden or planters/window boxes. If a garden is present, though, the type or visible level of garden care does not have any bearing on young street tree survival. Our interpretation of these results is that either (1) the mere presence of adjacent stewardship of other natural amenities (lawns, gardens) is adequate to engage

local residents in the care of maintenance of their street trees; or (2) presence of signs of off-tree stewardship may be an indicator of on-tree stewardship that has occurred historically.

A stewardship index was constructed from factors that directly affect the area in and around the tree pit, including: presence of signage, plantings in pits, mulch, and evidence of weeding. This stewardship index is significantly correlated with tree survival. Planting in the tree pit was the most often observed stewardship behavior (1,039 trees), followed by mulch (962 trees), weeding (317 trees), and signage (232 trees). Evidence of active, direct tree stewardship is a positive indicator or predictor of street tree survival.

Table 7. Young street tree survival and select sociability/stewardship factors

Independent Variable	Alive	Not Alive	% Survival	X^2 value	*df*	*p*-value
Presence of seating near tree						
With seating	694	135	83.7%	28.44	1	<0.001
No seating	8,719	2,824	75.5%			
Presence of front yard near tree						
Yard present	5,246	1,170	81.8%	236.40	1	<0.001
No yard	4,167	1,789	70.0%			
Presence of a garden near tree						
Garden present	3,266	607	84.3%	210.59	1	<0.001
No garden	6,147	2,352	72.3%			
Garden type (if present)						
Natural	3,345	623	84.3%	1.04	1	0.308
Plastic	12	4	75.0%			
Garden care (if present)						
Good	3,201	580	84.7%	4.40	1	0.036
Poor	155	41	79.1%			
Presence of planters or window boxes						
Present	1,623	244	86.9%	142.19	1	<0.001
Not present	7,790	2,715	74.2%			
Presence of stewardship signs*						
4 signs	20	0	100.0%			
3 signs	112	3	97.4%			
2 signs	328	11	96.8%	412.36	4	<0.001
1 sign	1,325	122	91.6%			
None	8,177	3,307	71.2%			

* signs of stewardship include presence of signage on or near the tree; plantings in street tree pits; mulch placed in pit; and evidence of weeding

Urban Design Factors

Our research indicates that the urban context into which street trees are planted is an important factor in their success and failure (Table 8). Street trees have a greater chance at survival when planted in lawn strips rather than sidewalk cutouts. In our data the size of sidewalk cut out pits does not have a significant influence on the survival of young street trees. Given that larger tree pits yield greater volumes of uncompacted soil for the roots to grow and greater surface area for water to enter the tree pit, one would expect that street trees would fare much better in large tree pits. One possible interpretation of this result is that tree pit size is not as important in the early life of a young street tree, but will become a limiting factor as the tree begins to grow out of its spot in the sidewalk.

Installing a perimeter tree pit guard prevents vandalism and vehicular damage, prevents animal waste deposition, and is visually representative of a tree that is being cared for by someone. It is likely because of a combination these factors that trees in pits with perimeter guards have a greater chance at success than trees in unprotected pits. The presence/absence of tree guards can also be considered as a sociability/stewardship factor, not just a physical design variable. This is because while the mechanism for reduced mortality for street trees with tree guards are physical (by preventing soil compaction or

inadvertent contact to the tree by cars), tree guards are typically installed privately and not by NYC Parks, and therefore also represents an act of stewardship. This may vary in other urban areas.

Table 8. Young street tree survival and select urban design factors

Independent Variable	Alive	Not Alive	% Survival	X^2 value	*df*	*p*-value
Pit type						
Lawn	3,548	992	78.1%			
Sidewalk	5,917	2,196	72.9%	58.43	2	<0.001
Continuous	397	193	67.3%			
Presence of perimeter tree guard						
With guard	1,121	83	93.1%	116.42	1	<0.001
No guard	8,841	2,150	80.4%			
Tree Pit Size (sidewalk trees only)						
55+ sq. ft	42	7	85.7%			
45 to <55 sq. ft	160	29	84.7%			
15 to <25 sq. ft	3,066	570	84.3%			
05 to <15 sq. ft	336	70	82.8%	7.48	5	0.188
35 to <45 sq. ft	266	58	82.1%			
25 to <35 sq. ft	2,007	446	81.8%			
Tree location						
Located on curb	9,413	2,959	76.1%	262.78	1	<0.001
Located on median	549	484	53.1%			
Observed traffic volume						
Light	6,785	1,842	78.6%			
Moderate	2,224	1,026	68.4%	280.49	2	<0.001
Heavy	806	530	60.3%			

The physical location of the tree within the urban streetscape is also significant. Trees planted in street medians have a poor chance at survival when compared to trees planted at the curbside. Traffic volume also has an effect on young street tree mortality, with trees in low traffic areas faring better than those planted in moderate or high traffic thoroughfares.

Another finding not explored here but worthy of discussion is that of missing trees. Of the over 13,000 trees visited in this study, nearly twenty percent of them were not present from their planted location while only six percent were standing dead. Although these two groups were collapsed for the purpose of discussing overall mortality, their large number warranted further analysis. We looked at whether or not the populations of standing and dead trees were significantly different with respect to some of our variables and found the following: trash in the tree pit is more common with dead trees than missing; missing trees are more likely when a sidewalk is less than five feet wide; trees are more likely to be missing than standing dead in a lawn strip than any other pit type. Missing trees are not statistically linked to the following: street slope, presence of street parking, sidewalk condition, or traffic volume. Urban forest managers in New York City agree that there are several possibilities of the fate of those missing trees: vandalism, vehicular collision, or tree removal without subsequent replacement but, regardless of the pathway, these missing trees are dead.

DISCUSSION

The highly local and specific nature of other published street tree mortality studies inspired this study to examine which factors may affect mortality in New York City. New York City's street tree planting mortality rates are lower than those published for other cities (see Figure 1). Some possible reasons for this distinction are: trees planted in New York City are planted by experienced contractors working under the supervision of trained foresters, while other tree planting programs frequently use volunteers with little or no planting experience (e.g. Nowak et al. 1990) or aren't working with strict contract specifications; and larger caliper trees (2.5-3") are planted in New York City, while smaller stock was planted in other locations (Nowak et al. 1990; Gilbertson and Bradshaw 1990).

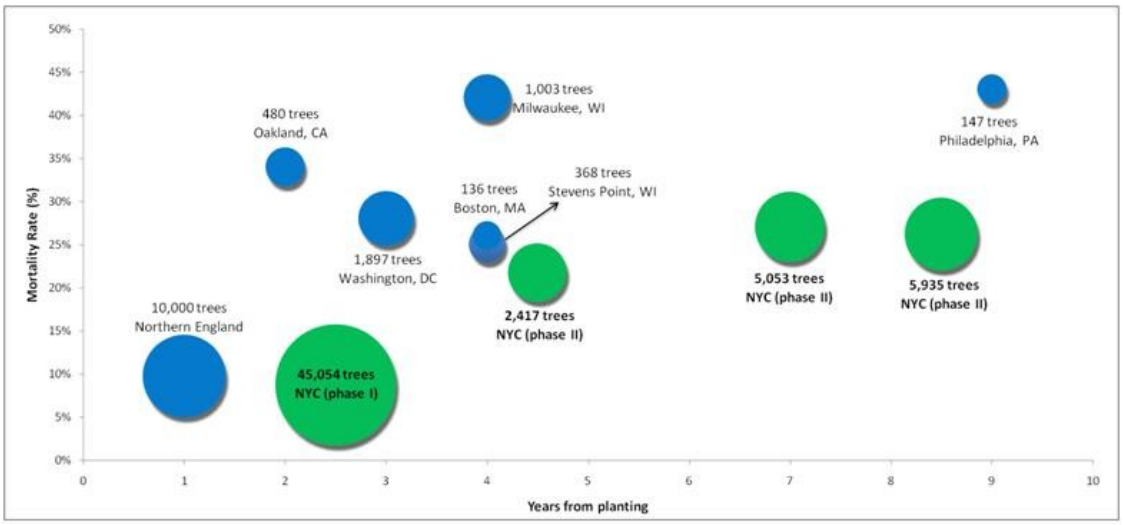

Figure 1. Other newly-planted street tree mortality studies (Aggregated from Roman, 2006), including the results from New York City.

In this manuscript we present a socio-ecological-design framework for future young street tree mortality research, with the intention of facilitating the replication of this type of study in other urban areas. Based on this work we have developed a Site Assessment Tools Description (available at http://www.nyc.gov/parks/ystm), a step-by-step guide for city managers and researchers on how to assess early street tree survival and mortality. Our hope is that other cities will replicate at least part of this study and over time build up data sets which will allow for cross-city comparisons.

These preliminary results provide an initial understanding of some of the factors that are important in the success and failure of young street trees planted in New York City, and provides direct feedback that managers can use to refine NYC Parks' planting practices and policies. Variation in planting survival rates by species has important implications for the long-term dynamics of New York City's street tree population. In terms of a tree's urban design and neighborhood context, this study confirms the observations of many urban foresters that curbside trees planted in lawn strips and in low-vehicular traffic areas are more likely to survive. This study also quantifies the disproportionately high mortality rates of trees that are planted in street medians compared to trees located on the curb. Based on this result, NYC Parks has already changed their planting policies for median trees, and is planting trees in only the widest street medians, where adverse factors like collisions, salt exposure, and minimal soil volume are less likely. Similarly, our observation of the effectiveness of tree guards in protecting young street trees is corroborated by the experiences of NYC's practicing urban foresters. Such demonstrated effectiveness may justify the expense of securing street tree guards at the time of planting.

Our results suggest that civic stewardship and neighborhood sociability is a critical complement to municipal management and investment in new street tree plantings. However, we have only started to explore how the data we collected could be used to develop more comprehensive indices representing stewardship or neighborhood sociability. The mechanisms that relate the signs of neighborhood sociability – or even of other non-tree signs of stewardship – to improved tree survival cannot be revealed through this study. While we hypothesize that active presence of residents on the street can serve to help ensure that vandalism of trees does not occur, other qualitative methods such as interviews and repeated social observational studies would be required to evaluate this hypothesis. Moreover, this study cannot determine directionality of observed relationships. For example, the presence of stewardship activities in

nearby lawns and gardens may either inspire the care of street trees, or the presence of the new tree itself may encourage other acts of local stewardship along the street.

The initial results presented here offer an important basis for urban planning programs as well as for researchers interested in further exploring factors affecting tree canopy restoration efforts in the urban environment. This is just the beginning of what we will be able to learn from the data we collected using this integrated socio-ecological framework. The current MillionTreesNYC campaign aims to plant street trees in every available and feasible sidewalk location across a wide range of site types in New York City, but at other times and in other places, difficult choices must be made in terms of street tree planting locations. Taken together, these biological, social, and urban design factors can be weighed by urban foresters when designing and selecting the locations for street tree plantings and developing community stewardship programs. Further analysis of our data set will assess the relative importance of these and the remaining data variables that were collected during the field survey of these trees. As cities such as New York continue to develop and implement comprehensive tree planting campaigns, these findings provide insight in the field of natural resource management on the relationship between locations and vulnerability; stewardship and sustainability.

ACKNOWLEDGEMENTS

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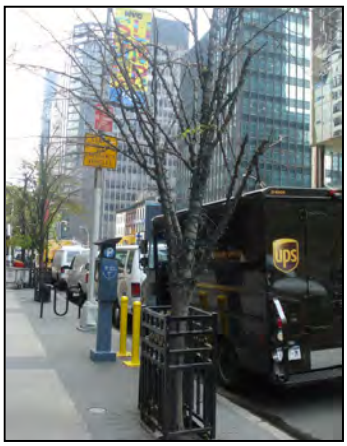
New York City's
Young Street Tree Mortality Study

Site Assessment Tools Description



New York City's Urban Street Tree Mortality Study
Site Assessment Tools Description

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New York City's Urban Street Tree Mortality Study
Site Assessment Tools Description

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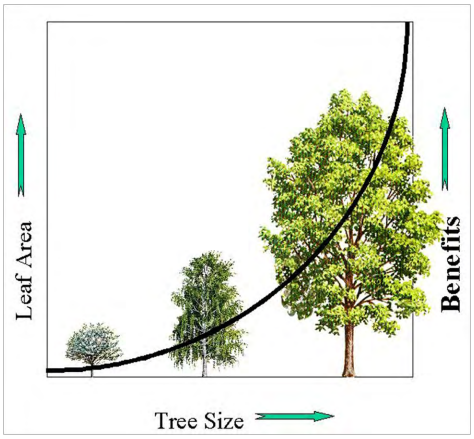
October 2010

INTRODUCTION

Background

It is assumed that the early years, from 5 to 10 years after planting, are critical to the establishment of a healthy urban street tree. Yet little is known about the factors or significant relationships that ultimately contribute to tree mortality or survival. This project provides a context in which to understand how social, biophysical and neighborhood design factors impact the establishment of street trees. The project brought together a multi-disciplinary set of researchers and practitioners to study the conditions of the urban street tree in an unprecedented study of unique spatial design, scale and intensity.



One of the fundamental challenges to city managers and civic groups is to ensure the survival of newly planted street trees in places as dynamic and diverse as cities. Because residents and managers value the health and benefits of an older tree canopy, we need ensure that what we plant today will live as long as this older stock. Population growth, vehicular traffic, poor air quality and building and sidewalk designs all present challenges to the contemporary urban street trees. Yet in order to maximize proven urban forestry benefits (both biophysical and social), trees must reach maturity. While there is much research on soil regimes, nursery stock, and species selection, survival rates still vary widely—from 34.7% to 99.7% according to a recent review of the literature (Roman, 2006). As cities around the United States increase their investment in tree planting, we must be able to ensure the trees' best chance of survival.

The Purpose of This Report

This report is intended to provide a step by step guide for city managers and researchers on how to assess early street tree survival and mortality. While it is based on the 2006/2007 study completed in New York City, it does not report its results. Rather it provides a detailed look at what data we collected and why in order to serve as a stand-alone guidance document. Our hope is that other cities will replicate at least part of this study in order to add to the profession's body of knowledge about early tree planting success in ways that allows us to compare our successes and learn from one another.

About the Study

Funded by the National Urban and Community Forestry Advisory Council and the Tree Fund, the New York City Department of Parks & Recreation (Parks) assembled a multi-disciplinary team of researchers to develop preliminary hypotheses and data collection tools. The data set consisted of 45,000 street trees planted by Parks between 1999 and 2003. Street tree locations varied widely, from concrete downtown to grassy outer borough. The team used a combined study approach that examined social (presence of garbage, stewardship, graffiti, etc), biological (soil compaction, tree condition, etc.) and physical (street width, building height, street slope,

etc.) factors with the potential to impact trees in the first decade of street tree establishment. The study investigated factors on two scales. First, we looked at the entire tree population using existing data sets. Second we sampled 14,000 street trees from the larger group of trees , visited them, and collected over 40 additional pieces of related data.

All field work was conducted by interns hired and trained by Parks. Data collection took two summers (2006 and 2007). Interns used a survey tool on palm pilots to record data in the field.

SITE TYPES

New York City, with a population of eight million people and five different boroughs, is a heterogeneous urban landscape with a wide variety of sit types. Each site type provides a different growing environment and different challenges for street trees. The most common site types are:

1. Skyscraper dominated business districts

These streets resemble canyons of concrete, steel, and glass. There is high pedestrian and car traffic, reduced sunlight and likely increased water pollution.

2. Residential neighborhoods with high-rise apartment buildings

These residential areas have very tall buildings with thousands of tenants, but they have little if any street level commerce.

3. Densely populated residential neighborhoods with 1, 2, or 3 family homes

These residential neighborhoods are filled with smaller buildings with no more than three units each. Although these blocks are densely populated, but less dense than #2 above, there is little if any commerce.

4. Suburban-like neighborhoods with lawns in front of single family homes

These neighborhoods have low buildings on relatively large properties and residents often own rather than rent their homes.

5. Industrial districts

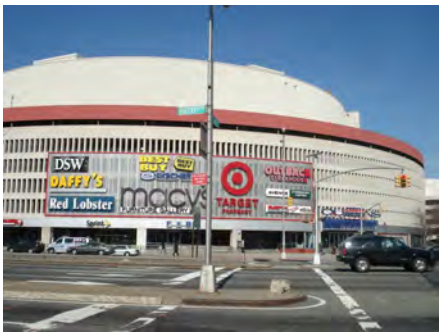
Industrial districts' activities are typically limited to the early part of the day when streets are filled with trucks loading and unloading merchandise. At all other times these neighborhoods are relatively devoid of street life.

6. Neighborhood commercial centers

Pedestrians, outdoor vendors, and delivery trucks all compete for limited sidewalk space in these areas, which serve as commercial centers for local residents. These blocks may or may not include residences above the shops, but the street level is dominated by commerce.

7. Big box shopping districts

Vehicle traffic, pollution, limited soil volume, and extreme heat from an abundance of reflective surfaces characterize these shopping districts.



8. Neighborhoods in transition from industrial to residential.

In the past decade, many city neighborhoods have seen a conversion of industrial zones to residential neighborhoods. These areas have industrial conditions side by side with large-scale construction of new high-rise residential buildings. Street tree plantings typically accompany the construction of new residences.

9. Low-density residential neighborhoods in transition from high vacancy rates to new homes

In these neighborhoods old and/or vacant houses are torn down and are replaced by new low-density residential buildings. Often the new buildings are larger with the new footprints occupying more space than the previous building.

10. Waterfront neighborhoods

These communities may have any number of residential or commercial development but share harsh environmental conditions with salt spray and wind.

Field Data Indicators

The data collected comprised of 42 criteria grouped with three broad areas: biological, sociability and stewardship, and physical. Below is a list of the data categories including the rationale behind each one. Please note that several indicators are cross-listed due to their applicability to more than one category.

Biological Factors

Data collected	May indicate
Sucker growth, leaf chlorosis, insect/ disease damage, twig dieback, whole branch dieback, broken branches, unnatural lean, or trunk wound.	Overall tree health
Diameter at breast height, time in ground, species	Growth rates
Planting too high, soil erosion	Tree root damage, storm water damage
Planting too low, added soil level	Trunk decay
Compacted soil	Soil moisture and oxygen levels
Pooling water	Compacted soil
Tree pit opening	Soil moisture
Animal scat	Soil chemistry, animal urine
Strong wind	Growth rate

Sociability and Stewardship Factors

Data collected	May Indicate
Type of front yard and barrier, visibility into front yard, presence of play equipment, presence and condition of garden, ground floor door in vicinity of tree, seating area, porch, stoop, ramp, balcony, type of building security, door decorations, flower planters, or flag.	Building sociability
Chalk or art on the sidewalk, murals, and public facilities.	Neighborhood sociability
Amount of loose trash, canopy debris, graffiti, broken windows, vacancies.	Neighborhood decay
Citizen encounters	Public perception of urban street trees
Evidence of pruning, bench, bird feeder, or sign-age in tree pit; evidence of weeding; tree gator bag	Tree stewardship
Presence and condition of a walled tree well, pe-rimeter pit guard, or tall, narrow pit guard	Protection of the tree
Block paving, gravel, mulch, or plantings in the pit	Protection from soil compaction and tree root damage.
Choking guards, grates, or wires; electrical outlet in the pit; bicycle locked to tree; tree lights	Negative attitudes or lack of understanding about street tree care

Physical Neighborhood Factors

Data collected	May Indicate
Median strip, number of traffic lanes, and traffic volume	Traffic patterns, air pollution levels and potential for mechanical damage from vehicles
Parallel or perpendicular street parking and pit location (on or off curb)	Tree's proximity to vehicular traffic
Sidewalk width	Increased pedestrian impacts in tree pit
Pit type and cutout size	Amount of available soil, soil moisture, and rooting space
Slope	Drainage and potential for soil erosion.
Proximity to driveway or bus stop	Potential for mechanical damage from vehicles
Presence and condition of a walled tree well, perimeter pit guard, or tall, narrow pit guard indicates	Protection of the tree
Block paving, gravel, mulch, or plantings in the pit	Protection from soil compaction and tree root damage.
Choking guards, grates, or wires	Negative impact on tree health
Electrical outlet in the pit	Tree lights are used.
Bike locked to tree	Source of trunk damage
Telephone wires, awnings, and scaffolding	Limited above growing space
Building height	Available light

Methods

Sampling Plan

Trees were selected for inclusion in the study using a partial inventory technique based on stratified random sampling (Sun and Bassuk, 1991 and Jaenson et al., 1992). A 14,000 tree sample was pulled from a 45,000 tree data set. The sample was stratified by time in-ground and land use. A sampling plan was developed to determine the required sample size for each planting period and land use grouping.

A random number was assigned to each of the 45,000 records using a script in the GIS. The records were exported in groups based on their land use and planting period. In Excel, the records for each exported group were sorted by the random number. The highest random number to be included in the sample (based on required sample size per planting period/land use) was noted. The records with a sample number within the required range were given an attribute in the GIS field, "InSamp." The final sample contained 14,090 trees.

The data was stratified by time in ground and land use. To confirm a large enough sample size, some land use categories were combined.

Field Data Collection

We pulled information from the existing data set to help confirm the exact trees included in the study. In addition, a grid map series at roughly 1:10,000 was produced using ArcGIS.

Tree Sample Number	Address	Loc	No.	Tree Species	DBH	Year Planted	Comm. Board	Land Use	Tree Not Found
1	1710. WEBSTER AV	S	4	GIBI	3	2001	0	05	
2	498. CLAREMONT PKWY	S	0	TITO	3	1999	103	01	
3	1573. WASHINGTON AV	S	0	TITO	3	1999	103	06	
4	1573. WASHINGTON AV	S	0	TITO	3	1999	103	06	
5	1824. WASHINGTON AV	S	3.0A	ZESE	3	2001	106	02	
6	499. E 175 ST	S	2.0X	GLTR	3	2001	106	08	
7	410. E 173 ST	S	1	PYCA	3	2003	103	08	
8	4006. 3 AV	S	1	TICO	3	2001	103	06	
9	1745. BATHGATE AV	S	0	GLTR	3	2002	103	11	
10	1745. BATHGATE AV	S	0	GLTR	3	2002	103	11	
11	3805. 3 AV	S	1	GLTR	3	19992000	103	02	
12	3823. 3 AV	S	1	GLTR	3	19992000	103	02	

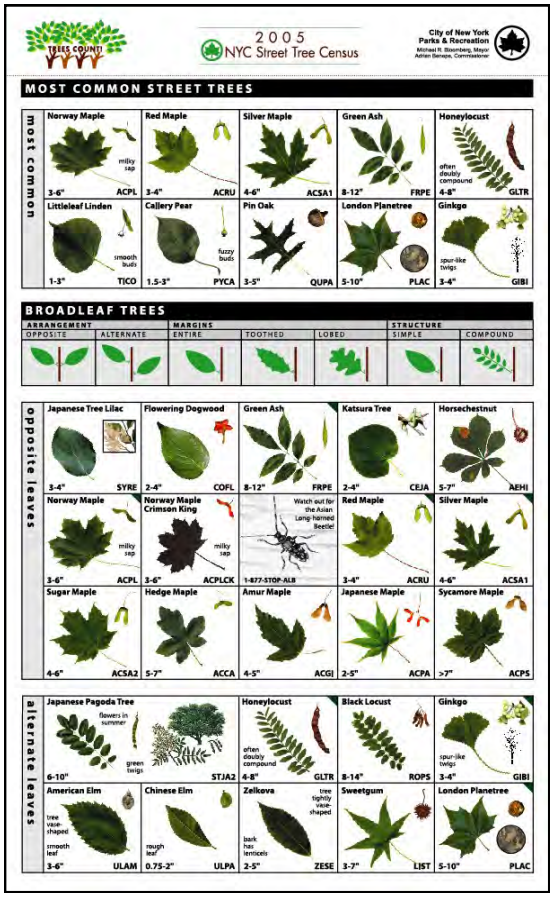
Researchers prepared the data collection fields based on the key factors under study. Then, they collaborated to develop a field observation assessment tool. Standards were determined for each data field to ensure consistency and so that the study could be replicated in the future. See Appendix I: Field Observation Guide for complete survey questions and descriptions.

In order to record data in the field, a custom data collection form was designed in Pendragon Forms, an application designed for Palm handhelds. This program allowed survey questions to be loaded on a Palm Pilot for mobile data collection. The field data was then directly synchronized into Microsoft Excel.

For two summers, 18 interns collected data in all five boroughs. Two interns from the first field season returned to coordinate the second season's data collection. This helped provide consistency from one year to the next.

The interns worked in pairs and traveled either on foot or by car. Manhattan and the more urban parts of the Bronx, Queens and Brooklyn were surveyed on foot while Staten Island and the less urban parts of the Bronx, Queens and Brooklyn were surveyed by car.

In the field, the interns carried:



- Road maps
- Detailed GIS generated field maps showing the location of the trees to be surveyed
- A list of all trees with information obtained from the original data set:
  - a unique sample number
  - address
  - additional location information (such as across from, adjacent to, or at rear of address)
  - the tree number at that address (1st tree, 4th tree, etc.)
  - species
  - DBH at time of planting
  - the season and year of planting.
- Census tree ID guide (see image at right)
- Husky #2 Phillips screwdriver (product number 537-340 U HD) to measure soil compaction.
- Caliper to measure DBH
- Palm Zire21 handheld device
- Tree species identification guide
- Data collection instructions

All data was entered in the Palm Pilot. It took 4,320 person hours to survey 14,667 trees over the two survey seasons. Additional time was spent cleaning up the data after it was uploaded from the Palms.

Recommendations

In preparing for this study and in the course of two summers of data collection clean up, we have collected a vast amount of wisdom and some recommendations on the best ways to conduct such a study. What follows are some of the key suggestions useful for similar efforts.

- Verify Tree Locations
  Finding and confirming the study tree was the single most time consuming part of the study. It is important to keep excellent records on planting location from the initial time of planting using whatever method is preferred, such as GPS, geocoding, or address association.

- Confirm the Quality of Data Sets
  If possible, it is important to field verify remotely gathered data. For example, we found the city generated land use designation for the parcel associated with the study tree did not always match field conditions. In fact they only matched 52% of the time.

- Avoid Extraneous Variables
  Some data proved may be less useful than we had hoped. For example: pooling water and measured compaction is highly impacted by recent rainfall. Other data was difficult to detect: e.g. weeded pits and strong winds.

- Consider Importance of Rarely Occurring Variables
  Some data, such as electrical outlets or tall tree guards were found so rarely, that it is difficult to make any conclusions about the impact of their presence; however, if combined with data from other cities, we may be able to gain useful insight.

- Streamline Data Collection Fields
  It is important to test the data collection tool before the collection instrument is finalized. We found that by carefully organizing the order in which the fields were listed, the choices within each field, and the default responses, we could streamline data collection significantly. For example, we placed the tree condition choice "good" first on the check off list since that one was most often noted. In addition, we kept all of the items that required examining a specific location together; area around the base of the tree, tree canopy, street area, and adjacent building required different places to look and these observations were grouped. In addition we ordered fields so that later ones built on information collected in earlier fields. For example, we placed overall tree condition in the list after the more specific health assessments (such as tree damage).

- Standardize Data Collection with Visuals
  Data collection standards must be clearly defined with detailed descriptions and photos.

Appendix I
Field Observation Guide

Data for over 14,000 randomly selected street trees planted between 1999 and 2003 and stratified by land use and planting period, was collected using palm pilots loaded with Pendragon Forms. The following list details what data was collected and how it was collected and entered into the Palm. **Bold** face type indicates the exact wording as it appeared in the palm pilot.

I. Preliminary

The following four entries need to be completed in order for the data to be saved

Tree Inventory #

This number is automatically generated by the palm pilot. Each palm is set so that its unique number will not overlap with another palm.

Tree Sample #

This unique number is entered manually and corresponds to the sample number on the list of trees.

Date & Time

These two entries record the date and time the survey was performed. The palm pilot is programmed with the current date and time so that the two entries need only to be confirmed in order for both to be recorded.

Team & Team 2

These two entries include the initials or code numbers of the team members that filled out the survey for that individual tree sample.

II. Tree Level

This portion of the survey refers to the tree itself and the building the tree is located in front of.

1. **Median Strip: Yes / No**
   Note whether there is a median present. Check even if the tree is located in the median. If tree is located in median strip, then the following questions should not be answered: pit off curb (5), ground floor door (24), building type (25), front yard (26), Sociability (27) , Building/façade (28), Building Security (29), Building Stewardship (30), Building Stories (31). The following should only be answered if the tree is planted in a sidewalk cutout in the median: sidewalk width (4) and sidewalk condition (9).

Median

2. **# Traffic Lanes**: limited list of 1-10
   Count the number of traffic lanes, including parking lanes.

3. **On Street Parking Yes / No**
   Parallel o
   Perpendicular o

Parallel parking

Perpendicular

Select yes if there is parking directly in front of specified tree. If there is parking, check only one box to indicate if the parking is parallel to the curb or perpendicular to the curb.

4. **Sidewalk Width: select one**
   <5, 5-10, 10-15, >15
   Estimate the sidewalk width (in feet) from the tree pit edge to the point where the sidewalk meets a limited object, e.g. porch, lawn, fence, stoop, building. This was not measured with a measuring tape.

Sidewalk < 5 feet

Sidewalk 5-10 feet

Sidewalk 10-15 feet

Sidewalk > 15 feet

5. **Pit Off Curb: Yes / No**
   Note whether the tree pit is located along the curb (select No) or at least five feet off the curb (Yes).

Pit off curb

Pit on curb

6. **Pit Type**
   Select one of the three choices:
   - ❑ **Sidewalk**-a pit cut out of the paved sidewalk surface.
   - ❑ **Continuous**- pit with two or more trees planted in a shared sidewalk cut out or growing space with block paving in between trees.
   - ❑ **Lawn**- trees planted in a curb strip dominated by grass or soil.

Sidewalk pit

Continuous pit

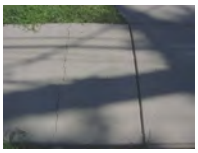
Lawn pit

7. **Cutout Size**
   For sidewalk pits: use a measuring tape to measure the length (side parallel to the curb) and the width (side perpendicular to the curb).
   For lawn or continuous pits, use a measuring tape to measure only the width. Count the number of trees in the stretch of lawn pit (or number that could fit) and put that number in continuous pit length. If there is a double/parallel row of trees, only count the number which would indicate the length of the pit.

8. **Is there a Slope Yes / No**
   Use your eye/judgement to determine if a slope is present. A slope indicates the whole street, not just within the pit. Select the placement of the tree in relationship to the slope.

Degree of Slope: select one
Low, Med, High Slope
Placement: select one
Bottom, Middle, Top

9. **Sidewalk Condition: select as many as necessary**
   - ❑ **Chalk/play drawings-** temporary chalk that will most likely wash away after precipitation
   - ❑ **Good**- no cracks and is not raised
   - ❑ **Cracked**- cracks in flags adjacent to tree pit
   - ❑ **Raised**- pavement that is pushed up by at least an inch in flags adjacent to the tree pit
   - ❑ **Art-** permanent drawings on pavement


Cracked sidewalk

Chalk drawings

Raised sidewalk

Curb not intact

10. **Curb intact? Yes / No**
    An "intact" curb is one that still functions as a curb--holding soil back from the street, and keeping street and storm runoff from entering the tree pit. Select "no" if the curb is broken to the extent that soil can wash away. Cracks and small missing chunks alone <u>do not</u> indicate that a curb's function is undermined.

Tree near bus stop

11. **Tree Pit:** **Within 5'of Driveway** **o**
    Within 5'of Bus **o**
    Check the appropriate box. "Bus" actually means the entire bus stop and includes school buses; bus should be checked off if it appears that any part of the bus stops within 5 feet of the tree pit on a regular basis.

Signage present on tree guard

Signage present on tree

12. **Signage Present Yes / No**
    Record only signs in these three specific locations. You do not need to record signs that are posted directly in the sidewalk or on nearby buildings. Note: Tree Pit-Pole means that there is a sign post inside the tree pit.
    On Tree **o**
    On Tree Pit-Pole **o**
    On Tree Guard **o**

    Signage Type
    Record the type of sign that you noted above.
    - ❑ **Other**
    - ❑ **Parking**: may be temporary paper sign or permanent sign.
    - ❑ **Trash**: e.g. "No Littering"
    - ❑ **Advertising**
    - ❑ **Tree Care- General**: may include instructions on how to take care of the tree
    - ❑ **Tree Care- Animals**: e.g. Curb Your Dog signs

Signage present on tree guard

Signage present on tree pit pole

- ❑ **Tree Care- Stewardship**: indicates who takes care of the tree. This could be a block group, business improvement zone, or an individual.
- ❑ **Commemorative**: Indicates the tree was planted to memorialize a person or event, or in honor of someone.

Planted too high

Planted too low

13. Site Conditions: Check as many as apply

- ❑ **Planted too High**: top of root ball visible, surface woody roots do not count.
- ❑ **Planted too Low**: cannot see the flared base of the tree trunk.
- ❑ **Choking Wires:** wires that restrict growth of tree.
- ❑ **Water Pooling**: water pooled in tree pit at time of inspection.

Choking wires

Soil compaction

14. Soil Compaction

Use a Husky #2 Phillips head screwdriver to determine the level of difficulty to penetrate the soil. Measure the soil one foot from the trunk of the tree. If you can feel a rock or other solid impediment, try shifting the screwdriver slightly.

- ❑ **Difficult/Impossible to Penetrate**- this means that a great amount of force is required to push screwdriver into soil or the soil is impossible to penetrate.
- ❑ **Easy to Penetrate**- little to moderate amount of force is required to penetrate soil.

Erosion

Added soil

15. Pit Soil Level

- ❑ **Erosion**- soil appears to have washed away over time with roots exposed
- ❑ **Added Soil**- soil is piled in a mound around the tree trunk or added to fill a pit with a walled tree wall
- ❑ **None:** the soil level has not been altered.

16. Pit Observation

Check all that apply.

- ❑ **Pruned**- you can see one or more clean pruning cuts
- ❑ **Stakes, no wires**
- ❑ **Gator Bag**- an irrigation bag that wraps around the tree trunk
- ❑ **Bench**- bench may be part of walled tree guard or may be in pit
- ❑ **Bird Feeder**- stuck in ground or attached to tree
- ❑ **Bike Rack**- This includes a bike rack in a tree pit as well as a bike resting or locked to a tree.
- ❑ **Walled Tree Wall**- (typo: should be "Walled Tree Well") solid wall around the perimeter of tree pit; could be brick railroad ties or other solid material.
- ❑ **Tree Grate**- flat metal grate lying at sidewalk grade directly covering the tree pit.
- ❑ **Plantings**- intentionally planted in tree pit
- ❑ **Mulched**- wood chips intentionally placed in tree pit; not natural debris.

Pruned

Stakes, no wires

Gator bag

Bird feeder

Bike rack

Bench

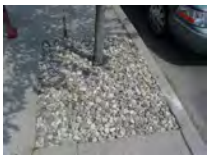
Mulched

Plantings

Walled tree well

Tree grate

Walled tree well


Gravel

Weeded

Animal scat

Suckers

- ❑ **Weeded**- note when there is evidence that someone has recently weeded the tree pit, this should <u>not</u> be checked if there is merely an absence of weeds.
- ❑ **Gravel**- intentionally added, not just natural debris
- ❑ **Animal Scat**- animal feces in or within 5 feet of tree pit
- ❑ **Suckers**- shoots coming from base of tree trunk
- ❑ **Block Paving? *Yes/No***
  This could be cement or stone blocks in tree pit; may or may not have mortar in between blocks. Most of the time these are the blocks that Parks installs after planting. They also may include non-standard materials such as bricks.

  Granite o
  Concrete o
  Other o

Granite block

Concrete block

If block paving is checked, then look for the following conditions and check all that apply.

Block Paving Status

- o **Unaligned:** blocks are not sitting in straight lines.
- o **Gaps:** there are gaps larger than 1" between blocks, or the gaps are inconsistently sized, indicating a deterioration of the installation over time.
- o **Missing:** one or more blocks are missing from the established installation pattern.
- o **Raised:** one or more blocks are sitting 1" or higher above the established grade of the block pavers.
- o **Sunken :** one or more blocks are sitting 1" or lower than the established grade of the block pavers.

Gaps/unaligned

Missing block pav-

Raised block pav-

Sunken block

Damaged guard

- **Perimeter Tree Pit Guard? *Yes / No***
  This means an open structure usually fabricated from steel but could be a picket fence. It would be constructed around the edge of the tree pit. Do not check this for a walled tree well.
  - ❑ **Guard Damaged**?- broken, deformed, or piece missing from guard, do not note if guard is intentionally three sided.
  - ❑ **Guard Choking?-** note if guard is causing damage to the tree or impeding growth

- **Tall, Narrow Tree Guard? *Yes / No***

Tall, narrow

Tall, narrow

These are usually made from steel or some other metal and are constructed close to the tree trunk within the tree pit.

- ❑ **Guard Damaged?** - broken, deformed, or piece missing from guard
- ❑ **Guard Choking?** - causing damage to tree; impeding growth

Light man-made

Heavy man-made

17. Loose Trash? *Yes / No*

Look for trash in and around the tree.

In Tree Pit o
On Sidewalk o
Against Building o

Man-made o
Natural Debris o

Include grass clippings; wood chips; fallen, or collected tree branches

Trash Amount

- ❑ **Light**
- ❑ **Heavy**

Light man-made

Heavy man-made

Natural debris

Leaf Chlorosis

Insect/Disease

18. Tree Damage *Yes / No*

- ❑ **Leaf Chlorosis**- yellowing of leaves throughout the tree
- ❑ **Insect Disease/Damage**- could be any number of signs including small holes around the trunk; spots on leaves, holes in leaves, insect skeletons.
- ❑ **Twig Dieback**- dead twigs at the tips of branches throughout tree
- ❑ **Whole Branch Dieback**- dead branch or branches; does not include broken branches

Twig dieback

Broken branch

Whole branch dieback

Unnatural lean

Trunk wound

- ❑ **Broken Branch**- broken part of branch may or may not be there
- ❑ **Unnaturally Lean**- (typo: should be "Unnatural Lean") entire tree leaning in one direction
- ❑ **Trunk Wound-** at least one unhealed or healed wound; deeper than bark

19. Infrastructure Conflicts? *Yes / No*

- ❑ **Canopy Debris**- large or significant amount of trash stuck either in canopy or intersection of branch and trunk, this could include plastic bags (not just one bag), shoes, etc.
- ❑ **Paved to Trunk**- pavement extends to the base of trunk; could be solid concrete or paving blocks/bricks
- ❑ **Choked by Guard/Grate**- causing damage to tree; impeding growth
- ❑ **Tree Lights**- lights wrapped around trunk and/or branches
- ❑ **Electrical Outlet**- in tree pit
- ❑ **Bagged Trash in Pit**
- ❑ **Other-** examples include wires (marked "tw")

Canopy debris

Choked by tree guard

Paved to trunk

Choked by grate

Bagged trash in

Electrical outlet in tree

Telephone wires

20. Pavement in Canopy Zone

Estimate how much of the tree's canopy covers paved surfaces.

- ❑ 0 – 24%
- ❑ 25 – 49%
- ❑ 50 – 74%
- ❑ 75 – 100%

0-24%

25-49%

50-74%

75-100%

21. Overall Tree Condition (*Choose one*)

The tree condition should take into account canopy health, trunk wounds, decay, and evidence of insect and disease. Follow these guidelines for canopy damage or dieback. For example, if a tree just has 20-40% canopy damage then it is rated good, but if it has 20-40% damage as well as a large trunk cavity it would be rated poor.

- ❑ **Good**- damage on 20-40% of tree
- ❑ **Excellent**- damage on 0-20% of tree as recommended by Jason Grobasky (in reality more like 0-5% damage)
- ❑ **Fair**- damage on 40-60% of tree
- ❑ **Poor**- damage on 60-80% of tree
- ❑ **Dead**
- ❑ **Stump**
- ❑ **Absent**- tree not on site, regardless of presence of pit. Also check if tree has been replaced.

Excellent

Good

Fair

Poor

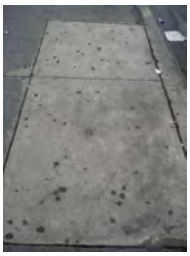
Dead

Dead

Stump

If tree is absent what remains? (*Choose one)*

- ❑ **Empty Pit**: choose this for any one of the following situations…
  - pit remains with no tree
  - pit obviously belonging to study tree has been replaced with a new tree after the guarantee period. Evidence includes a planting tag with a recent year.
  - Lawn area with a newly planted tree in location study tree would have been in
- ❑ **Filled In** - a sidewalk pit filled in with relatively new asphalt or concrete surface; not a new sidewalk; can distinguish from surrounding pavement; filled in area should approximate the



Filled in

Empty pit

size of an average tree pit; obvious that tree pit once existed there

- ❑ **New Sidewalk** - unclear whether or not tree pit once existed

26. DBH

Using a caliper measure, measure the DBH (diameter at breast height), making sure that the measurement is taken 4 ½ feet from the base of the tree. If trunk is clearly uneven measure around trunk 2-3 times and record the average diameter. If trunk splits below 4 ½ feet measure the trunk at the highest point before the swell. Round to the nearest half -inch and select from the drop down list.

27. Species Correct? *Yes / No*

Confirm that the tree found in the field matches the species code on the tree sample listing.

Correct Species (Lookup table)

If the tree listing is incorrect use the lookup table to record the code for the actual species found. If it is not found on the lookup table, use the free text field under **Other Species** to record the encountered species.

28. Ground Floor Door *Yes / No*

Indicate if there is an entrance/exit in front of the tree location or within your field of vision when standing at the tree.

29. Building Type *(choose one)*

- ❑ **Retail/Comm**: any retail or commercial business on ground floor of building directly in front of tree. Do not use this if the business is within the same building but down the block from the tree.
- ❑ **Industrial**: select this for light or heavy manufacturing, not a patron based operation.
- ❑ **Public Instit**: select this for schools (including private), churches, hospitals, recreation center, senior center—as long as it on the ground floor in front of tree.
- ❑ **Private Res**- apartment buildings, houses, (includes public housing) etc.
- **X** **Mixed Use**- was on the original version but should not have been used. If it was checked then it should be changed to Retail/Commercial. We are only interested in the ground floor activity, not the zoning.

Select the appropriate response for each of the following items encountered directly in front of the tree—not down the block.

- **Seating Area *Yes / No***
  - benches, area where people are likely to bring folding chairs
- **Porch/Stoop *Yes / No***

Seating area

Porch/stoop

Ramp

- **Ramp** ***Yes / No***
- **Balcony** ***Yes / No***
  - within the height of the tree

30. Front Yard

- **Yard Present?** ***Yes / No***
  - Yard should be large enough and capable of being used in some way, e.g. sitting, throwing a ball.

- **Yard Paving**
  Paved o
  Unpaved o

- **Barriers Present?** ***Yes / No***
  Check all that apply.
  - ❑ **High Fence**- greater than five feet
  - ❑ **Low Fence**- less than five feet
  - ❑ **Chain Link Fence**
  - ❑ **Ornamental Fence**

- **Shrubs** ***Yes / No***

- **Visibility (Select one)**
  - ❑ **Good**
  - ❑ **Poor**

Paved yard

Unpaved yard

High fence; good visibility

High fence; poor visibility

Ornamental fence

Low fence

31. Sociability

- **Play Equipment** ***Yes / No***
  This could include small private jungle gym type equipment or extensive playgrounds

- **Garden Present** ***Yes / No***
  Select Yes if there is any type of ornamentation beyond a grass lawn including flowering or ornamental plantings purposely installed.

Garden Type (select one)

- ❑ **Plastic**- only plastic decorations
- ❑ **Natural**- may include plastic decorations, but majority of garden must have organic, live plantings

Play equipment

Play equipment

Good natural garden

Good natural

Poor natural garden

If natural garden, care status

- ❑ **Good**- properly maintained, cared for on a regular basis
- ❑ **Poor**- dead plants, no recent sign of any maintenance

32. Building/Facade

- ❑ **Graffiti**- not considered art; tagging
- ❑ **Mural-** solid painting that takes up most or entire side of wall
- ❑ **Advertising**- large sign or mural advertising for business not at present location (not checking advertising if sign is for on-site business)
- ❑ **Broken Windows**- one or more windows
- ❑ **No Windows-** facing the tree
- ❑ **Awning**- within or near tree canopy or trunk
- ❑ **Scaffolding-** temporary structure within or near tree canopy or trunk

Graffiti

Mural

Advertising

Awning

Scaffolding

33. Building Security *Yes / No*

- ❑ **Home Alarm**- signage is present
- ❑ **Surveillance Camera**- signage that indicates presence of camera and/or camera itself
- ❑ **Doorman**
- ❑ **No Trespassing Sign**
- ❑ **No Parking Sign:** not official city DOT sign**.**
- ❑ **Window Bars**- do not include child safety bars

Home alarm

Surveillance

No trespassing

No trespassing;

34. Building/Stewardship

- ❑ **Door Decorations**
- ❑ **Flower Planters**- in yard, on porch/stoop or in window boxes
- ❑ **Flag**- visible from street
- ❑

Doorman

Window bars

35. Building Stories (Select one)

Visually inspect building and estimate the number of stories and select the correct range from the drop down list.

- ❑ **< 5**
- ❑ **5 – 10**

Door decorations

Flower planters; flag

- ❑ **10 – 20**
- ❑ **> 20**

36. Correct Land Use? ***Yes / No***

Confirm that the land use listed on the tree sample listing matches the building in front of the tree. If the tree is on the median, select the more dominating land use or has a greater potential impact. For example, if there is a single family home on one side and a large apartment building on the other, select "Multi-family elevator". If the land use on the listing is not correct, then select correct land use. Note that the code listed below is not on the palm but is on the listing.

- ❑ **01: 1 or 2 Family**
- ❑ **02: Multi-Fam walk-up**
- ❑ **03: Multi Fam Elevator- assume that any building which exceeds 6 stories has an elevator.**
- ❑ **04: Residential/Commercial mix**
- ❑ **05: Commercial/Office**
- ❑ **06: Industrial**
- ❑ **07: Transportation / utility**
- ❑ **08: Parking**
- ❑ **09: Public Institution- schools (including private), churches, hospitals, recreation centers**

1-2 family

1-2 family

Multi-family

Multi-family walk-up

Multi-family elevator

Commercial/ office

Residential/ commercial mix

Industrial

Commercial/office

Vacant land

Transportation/

Transportation/ utility

Parking

Open space

- ❑ **10: Open Space- Parks (city, state, private), community garden**
- ❑ **11: Vacant Land- no sign that land is being used**

III. Block Level

This portion of the survey refers to the entire block on which the tree is planted. These observations should reflect a visual check of the entire block.

1. Traffic Volume *(Select one)*

- ❑ **Light**
- ❑ **Moderate**
- ❑ **Heavy**

2. Murals *Yes / No*

These represent purposeful efforts of art and not graffiti.

- ❑ **Nature**- environmental, animals, plants, planets, etc.
- ❑ **Memorial/RIP**
- ❑ **Advertisement/Retail-** can be for present business or other businesses
- ❑ **Hate/Profanity**- derogatory or hateful message
- ❑ **Public Health**- promotes awareness of health issues
- ❑ **Art**- murals that cannot be categorized or do not pertain to any specific topic
- ❑ **Nationality**- flags or other symbols of U.S. or other countries
- ❑ **Community**- depiction of people/surroundings/ name of community
- ❑ **Religion-** religious symbols or words

3. Vacancy *(Choose one)*

This refers to vacant lots, undeveloped lots in less urban contexts, abandoned buildings, or high vacancy rates of existing residential or commercial buildings.

- ❑ **Few**- less than half of the block
- ❑ **Many**- more than half of block
- ❑ **None**

4. Public Facilities

- ❑ School (not nursery)
- ❑ Hospital
- ❑ Fire Station
- ❑ Police Station
- ❑ Senior Center

School

Hospital

Fire station

Police station

Senior center

Recreation center

Place of worship

Other

- ❑ Recreation Center
- ❑ Place of Worship
- ❑ Other

5. **Strong Wind?** ***Yes / No***
   Select if you feel a constant strong wind

6. **Citizen Encounter?** ***Yes / No***
   Note if surveyor met anyone while surveying the tree,.
   - **Citizen Age (select one)**
     - ❑ **Senior**- about 65 or over
     - ❑ **Adult**- age 18-65
     - ❑ **Child**- less than 18 years of age

   - **Citizen Sex**
     - ❑ **Male**
     - ❑ **Female**
     - ❑ **M/F Couple**
     - ❑ **F/F Couple**
     - ❑ **M/M Couple**

   - **Citizen Attitude**
     - ❑ **Positive**- appreciates tree, curious about tree condition or survey
     - ❑ **Negative**- suspicious, not appreciative of tree or parks department
     - ❑ **Neutral**- no positive or negative comments or actions regarding tree or survey

7. **Location Comments**
   Please use this space to provide any clarifications or corrections to the location provided in the listing.

8. **Misc.**
   Please include any other notes that may be needed, including picture taken and if so the picture #; also if and when tree was replaced. Also include information given by neighbors that may provide useful in study.

9. **Is all the information finalized and complete for this tree? Yes/No**

Appendix II: Literature Review

Survey techniques

Goodwin, D.W. 1996. A street tree inventory for Massachusetts using a geographic information system. J. Arboriculture. 22(1): 19-28. Explores various techniques for mapping tree locations and creates a spatial database of tree locations and fourteen tree attributes.

Smiley, E.T. and F.A. Baker. 1988. Options in street tree inventories. J. Arboriculture 14(2): 36-42. Outlines and discusses how to set up and carry out street tree inventories. Includes what data should be collected, how it should be collected, budgeting.

i-Tree Sample Plot Generator for UFORE. Typically, 200 one-tenth acre plots for a large city and 30 plots for a small town.

Johannsen, H.J. 1975. Municipal tree survey and urban tree inventory. J. Arboriculture April 1975: 71-74. Describes system for identifying street trees.

Cumming, A.B., M.F. Galvin, R.J. Rabaglia, J.R. Cumming, and D.B. Twardus. 2001. Forest health monitoring protocol applied to roadside trees in Maryland. J. of Arbor. 27(3):126-138. Methodology for assessing the condition of roadside trees.

Jaenson, R., N. Bassuk, S. Schwager, and D. Headley. 1992. A statistical method for the accurate and rapid sampling of urban street tree populations. J. Arboriculture. 18(4): 171-183. Develops statistical sampling method, based on stratified random sampling, that can be used to estimate the species composition of an urban street tree population. Results presented for four New York cities.

Sun, W.-Q. and N.L. Bassuk. 1991. Landscape Urban Plann. 20: 277-283. Recommends sampling size for street tree surveys. Computer simulation concludes that sample quality improves little after a certain sampling size, but quality declines significantly at a smaller size.

Tree health studies

Berrang, P., K.F. Karnosky, and B.J. Stanton. 1985. Environmental factors affecting tree health in New York City. J. Arboriculture. 11(6): 185-189. Presents the results of data collection on over 80 variables for 375 trees planted near Consolidated Edison Company facilities in New York City. The study finds excessive soil moisture, mounding of soil on roots, soil salts, and root system size to be the most important factors affecting tree health.

Chacalo, A., A. Aldama, and J. Grabinsky. 1994. Street tree inventory in Mexico City. J. Arboriculture. 20(4): 222-226. Surveyed 1261 street trees in Mexico City, collecting data for seven variables. Problems with tree health are attributed to planting in inappropriate locations, species choice, and lack of adequate maintenance and planning.

Gartner, J.T., T. Treiman, and T. Frevert. 2002. Missouri urban forest—a ten-year comparison. J. Arboriculture. 28 (2): 76-83. Surveyed sample plots in 44 urban communities throughout Missouri as a follow-up to a 1989 survey of tree size, condition, and history, conducted by the American Forestry Association and the USDA Forest Service. The study finds that communities need to devote more of their resources and time to tree maintenance, as opposed to new plantings.

Skiera, Bob and Gary Moll. 1992. The sad state of city trees. American Forests. Summary of the American Forestry Association's survey of 20 U.S. cities. Finds that average life of a downtown street tree is 13 years.

Hauer, R.J., R.W. Miller, and D.M. Ouimet. 1994. Street tree decline and construction damage. J. of Arboriculture. 20(2): 94-97. Hauer et al. (1994) followed a cohort 10 years after planting, examining 845 trees. Construction damage from street widening and curb and sidewalk replacement were found to negatively affect both tree sur-

vival and condition. Trees in narrow tree lawns suffered the greatest reduction in condition from construction damage. Construction damage was found to have a high economic impact on street tree value.

Nowak, D.J., M. Kuroda, and D.E. Crane. 2004. Tree mortality rates and tree population projections in Baltimore, Maryland, USA. Urban For. and Urban Green. 2: 139-147. Research by scientists in the LTER Baltimore Ecosystem Study. Nowak et al (2004) found that smaller diameter trees have significantly higher mortality than larger trees, but this study did not focus on causality.

Thompson, J.R. , D.J. Nowak, D.E. Crane, and J.A. Hunkins. 2004. Iowa, U.S., communities benefit from a tree-planting program: characteristics of recently planted trees. J of Arbor. 30(1): 1-9. Species diversity, survival, size, growth, carbon uptake, carbon storage, and pollution removal of 932 trees planted in 21 communities in different parts of Iowa were assessed by repeated measurements over a 4-year period.

Management

Tate, R.L. 1985. Uses of street tree inventory data. J. Arboric. 11(7): 210-213. How to create, increase, improve or save an urban tree management program.

Meza, H.M. 1992. Current situation of the urban forest in Mexico City. J. Arboriculture. 18(1): 33-36. Discusses history of arboriculture in Mexico City, current problems with management of urban trees and programs in place to improve the situation.

Tree benefits

Nowak, D.J. and D.E. Crane. 2002. Carbon storage and sequestration by urban trees in the USA. Environmental Pollution 116: 381-389. Carbon storage and sequestration by urban trees based on field data from 10 cities in the USA and national urban tree cover data. Regional variation dicussed. Urban trees currently store 700 million tons of carbon, with an annual sequestration rate of 22.8 million tons (equal to USA population emissions over 5 days).

Urban ecology theory

Zipperer, W.C., S.M. Sisinni, and R.V. Pouyat. 1997. Urban tree cover: an ecological perspective. Urban Ecosystems 1: 229-246. Evaluation of urban tree cover based on patch dynamics. Treed patches are classified by their origin, structure, and management intensity. Using the patch approach, Zipperer et al. evaluate ecological patterns and processes for remnant, emergent and planted patches, which differ according to origin. A patch is a fundamental unit of measurement for landscape analysis and management. Patches imply a relatively discrete spatial pattern and a relationship of interactions and exchanges between patches. Ecological patterns and processes discussed include morphology, canopy cover, forest development, species richness, biomass, succession and nutrient and carbon cycling.

Social science

Hope, D., C. Gries, W.Zhu, W.F. Fagan, C.L. Redman, N.B. Grimm, A.L. Nelson, C. Martin, and A. Kinzig. 2003. Socioeconomics drive urban plant diversity. PNAS 100(15): 8788-8792. Spatial variation in plant diversity was found to be driven by a combination of land use, elevation, median family income, and whether the site has ever been farmed. This study finds a relationship between wealth and plant diversity that has been observed in other cities as well.

Gorman, James. 2004. Residents' opinions on the value of street trees depending on tree location. J. Arboric. 30 (1): 36-44. Residents' opinions on the value (or negative aspects) of street trees were impacted by the presence or absence of a tree directly in front of their residence. Statistical significance found for 5 positive factors: give shade; flowers on tree; neighborhood is more liveble; increased property values. And 3 negative factors: branches break power lines in storms; sidewalk damage; and trees block visibility.

Grove, J. Morgan; Cadenasso, Mary L.; Burch, William R., Jr.; Pickett, Steward T.; Schwarz, Kirsten; O'Neil-Dunne, Jarlath; Wilson, Matthew; Troy, Austin; Boone, Christopher 2006. Data and methods comparing social structure and vegetation structure of urban neighborhoods in Baltimore, Maryland Society and Natural Resources 19:117-136. Looks at diversity as it relates to population, lifestyle behavior and social stratification.