Urban Forestry & Urban Greening 17 (2016) 104–115

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

# Structure, function and value of street trees in California, USA

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ARTICLE INFO

*Article history:*
Received 9 December 2015
Received in revised form 22 March 2016
Accepted 30 March 2016
Available online 16 April 2016

*Keywords:*
Community forest
Municipal forest
Tree benefits
Urban ecosystem services

ABSTRACT

This study compiled recent inventory data from 929,823 street trees in 50 cities to determine trends in tree number and density, identify priority investments and create baseline data against which the efficacy of future practices can be evaluated. The number of street trees increased from 5.9 million in 1988 to 9.1 million in 2014, about one for every four residents. Street tree density declined from 65.6 to 46.6 trees per km, nearly a 30% drop. City streets are at 36.3% of full stocking. State-wide, only London planetree (*Platanus × hispanica*) comprises over 10% of the total, suggesting good state-wide species diversity. However, at the city scale, 39 communities were overly reliant on a single species. The state's street trees remove 567,748 t $CO_2$ (92,253 t se) annually, equivalent to taking 120,000 cars off the road. Their asset value is $2.49 billion ($75.1 million se). The annual value (USD) of all ecosystem services is $1.0 billion ($58.3 million se), or $110.63 per tree ($29.17 per capita). Given an average annual per tree management cost of $19.00, $5.82 in benefit is returned for every $1 spent. Management implications could include establishing an aggressive program to plant the 16 million vacant sites and replace removed trees, while restricting planting of overabundant species. Given the tree population's youth there is likely need to invest in pruning young trees for structure and form, which can reduce subsequent costs for treating defects in mature trees.



## 1. Introduction

Street trees, defined as trees growing along public street right-of-way and managed by the city, account for a relatively small fraction of the entire urban forest, but are prominent because of their visual and physical impacts on the quality of urban life. For example, although street trees in the City of Chicago accounted for only 10% of the city's tree population, they comprised 24% of total leaf surface area (McPherson et al., 1997). This study examines the structure, function and value of California's current street tree population. Several studies indicate that street tree density in California is declining. One goal of this study is to determine if this remains cause for concern. A second goal is to prioritize management challenges at the state and regional levels. For the first time, this study quantifies the value of ecosystem services produced by California's street tree population. This assessment provides a baseline for California and it is among the first to present a comprehensive view of a state's street tree resource.

Municipal forests consist of street and park trees managed for the public good. Street tree populations have their own unique structure, tending to be less diverse, containing more large-stature species and exhibiting higher levels of spatial continuity than other components of the urban forest (Jim and Liu, 2001).

The following review begins with a description of street tree assessments conducted at large scale, for the entire United States and for several states within the U.S. It then narrows its focus to studies concerned with municipal forests in the state of California.

### 1.1. United States and state-wide assessments

In 1989, an assessment of street trees in 320 U.S. cities was conducted (Kielbaso and Cotrone, 1990). There were identified approximately 61.6 million street trees averaging 63.4 trees per street km (102/mile) and 0.4 per person. Assuming trees were planted 15.2 m (50 ft) apart, there was room for planting another 66 million street trees. The ratio of trees planted to removed each year was 0.99, a decrease from 1.2 found several years earlier. The authors reported that this ratio dropped in larger cities, as did the condition rating of trees. The asset value of the nation's street trees was an estimated $30 billion, assuming $500 per tree.

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http://dx.doi.org/10.1016/j.ufug.2016.03.013
1618-8667/Published by Elsevier GmbH.

A more recent U.S. survey focused on public tree management (Tschantz and Sacamano, 1994). In 1994, the average number of publically-owned street and park trees was 0.63 per capita. The average municipal tree management budget was $2.49 per capita, down from $4.14 in 1986.

State-wide assessments in the U.S. have varied in their methods and scope. A 1994 survey of public trees in 20 Michigan communities estimated 1.67 million street trees state-wide with 49% full stocking (Wildenthal and Keilbaso, 1994). Between 2001 and 2003 the US Forest Service Forest Health Monitoring (FHM) team partnered with Urban & Community Forestry staff in Wisconsin (Cumming et al., 2008), Maryland and Massachusetts (Cumming et al., 2006) to survey street trees state-wide. The most serious management issue noted was lack of species diversity. The top five species accounted for 45% to 60% of the total street tree populations, indicating overreliance on a small number of species. The susceptibility of black walnut (*Juglans nigra*) street trees to Thousands Cankers Disease (resulting from the fungus *Geosmithia morbida*) in Kansas (Treiman et al., 2010) and ash trees to emerald ash borer (*Agrilus planipennis*) in South Dakota (Ball et al., 2007) were the subjects of state-wide analyses of tree inventories. A region-wide-assessment used street tree inventory data to examine threats posed by exotic borers in eastern North America (Raupp et al., 2006).

A 2008 study of street trees in 23 Indiana communities applied i-Tree Streets (formerly STRATUM) software to calculate the economic value of ecosystem services produced annually by the state's 1.42 million street trees (Davey Resource Group, 2010a,b). Annual services were valued at $78.7 million or $55.51 per tree.

In 2010 street trees on 284 plots in 44 Missouri communities were resurveyed after previous inventories in 1989 and 1999 (Treiman et al., 2011a,b). This 20-year longitudinal assessment is unique. Street tree density increased from 28.7 trees per km (46.2/mile) in 1989 to 40 (64.3/mi) in 2010. During the same period the percentage of total street tree sites filled with trees, or percentage of full stocking, increased from 33% to 56%. State-wide, 33.9% of all trees were juvenile (<15 cm dbh), 22.5% were maturing (15–30 cm dbh), 30.6% were semi-mature (30–61 cm dbh) and 13.0% were mature (>61 cm dbh). The most frequent condition class was Fair (62.1%), followed by Good (19.2%), Poor (16.2%) and Dead/Dying (2.5%). Sidewalk conflicts occurred with 30.2% of the trees. Annual ecosystem benefits totaled $147.9 million ($90.55 per tree).

A state-wide assessment for New York used 142 inventory datasets (Cowett and Bassuk, 2014). Total street trees were estimated by weighting the sample using the relative percentages of summed street length for each climate zone. Statistical analyses found that average minimum winter temperature was the best predictor of species composition. Therefore, data were presented for each USDA Hardiness Zone, as well as for the entire state. There were an estimated 4.2 million street trees and the weighted mean street tree density was 50 trees per km (80.5/mile). Trees in the genus *Acer* (maple) accounted for 44.1% of the total, a cause for concern because of their vulnerability to Asian longhorned borer (*Anoplophora glabripennis*).

### *1.2. California's municipal forests*

Several studies have assessed the structure and function of municipal forests in California. Computerized street and park tree inventories from 29California communities were analyzed to score their relative stability (McPherson and Kotow, 2013). Grades were assigned to four aspects of a stable and resilient municipal forest: species dominance (based on numbers and size), age structure (based on dbh distribution), pest threat (based on pest count and severity) and potential asset loss (based on percentage of total asset value at high and very high risk of loss from pests). Thirteen inventories received their lowest grade for age structure, largely because juvenile trees were underrepresented. Data were not compiled to estimate tree numbers state-wide.

Muller and Bornstein (2010) reviewed trends in species diversity using policies and planting lists from 49California communities and inventories from 18 cities. They reported that species richness was high (mean of 185 taxa per community) but recent plantings lacked diversity. This trend towards planting of a few preferred species was previously noted by Lesser (1996) as well.

Comprehensive questionnaires were administered to municipal forest managers in California communities in 1988, 1992, 1998 and 2003 to identify trends (Bernhardt and Swiecki, 1989, 1993; Thompson, 2006; Thompson and Ahern, 2000). Over the 15-year period the state's street tree population and street trees per capita were estimated to have increased from 5.9 to 7.2 million and 0.24–0.29, respectively. However, the California surveys identified several troubling trends:

- increased planting of small, short-lived species due to lack of space for street trees
- declining species diversity
- average city tree budget has declined in real dollars from about $3 per capita in 1988 to $2 in 2003
- higher percentages of programs report removing more trees than they plant (18% in 1988–22% in 2003)
- reduction in the average number of trees per km street length, from 65.6 in 1988 to 64.3 in 1993 (105.5–103.5/mile).

If street tree stocking levels are decreasing so might the ecosystem services they provide, such as energy savings, carbon storage, air pollutant uptake and rainfall interception. One goal of this study is to determine if trends in street tree stocking levels are increasing or decreasing. Although previous studies have calculated tree numbers, density and stocking levels, their estimates were derived from questionnaires, not tree inventories. Estimates were not well substantiated, lacking standard errors or other measures of variance. This study improves the quality of the assessment of the state's municipal forest structure by using tree inventories, allowing measures of variance to be presented. A second goal of this study is to identify planning and management priorities based on the assessment of structure, function and value. The third goal is to generate new information on street tree function and value scaled to the state-wide level. Hence, this assessment serves as a comprehensive baseline against which the efficacy of future planning and management practices can be evaluated.

## 2. Methods

### *2.1. Climate zones*

For purposes of i-Tree modeling (McPherson, 2010) California was subdivided into six climate zones based largely on aggregation of Sunset National Garden Book's 45 climate zones (Brenzel, 1997) and ecoregion boundaries delineated by Bailey (2002) and Breckle (1999) (Fig. 1). Extensive tree size measurements were made in a reference city in each climate zone, with growth equations used for benefit modeling in the i-Tree Streets application (McPherson and Peper, 2012; Peper et al., 2001).

### *2.2. Street tree inventories*

Fifty-six tree inventories were obtained from CAL FIRE, who has funded inventories and management plans in many California communities. To be included in this study the inventory had to: