Landscape and Urban Planning 136 (2015) 130–143

Contents lists available at ScienceDirect

Landscape and Urban Planning

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

Research Paper

Explaining planted-tree survival and growth in urban neighborhoods: A social–ecological approach to studying recently-planted trees in Indianapolis

Jessica M. Vogt[a,b,f,*], Shannon Lea Watkins[b,c], Sarah K. Mincey[c,d,e,f], Matthew S. Patterson[g], Burnell C. Fischer[c,f,b]

[a] Furman University, Department of Earth and Environmental Sciences, 3300 Poinsett Highway, Greenville, SC 29613, United States
[b] Indiana University Bloomington, Center for the Study of Institutions, Population, and Environmental Change, 408 N. Indiana Ave., Bloomington, IN 48407, United States
[c] Indiana University Bloomington, School of Public and Environmental Affairs 1315 E. 10th St., Bloomington, IN 47405, United States
[d] Indiana University Bloomington, Integrated Program in the Environment, 702 N. Walnut Grove Ave, Bloomington, IN 47405, United States
[e] IU Research and Teaching Preserve, 702 N. Walnut Grove Ave, Bloomington, IN 47405, United States
[f] The Vincent and Elinor Ostrom Workshop in Political Theory and Policy Analysis, 513 N. Park Ave., Bloomington, IN 57508, United States
[g] University of Washington, Urban Ecology Research Laboratory, 432 Gould Hall, 3949 15th Ave. NE, Seattle, WA, United States

HIGHLIGHTS

- We examined the relationship between social–ecological system (SES) factors & street tree success.
- Variables from all SES factors influence recently-planted tree survival & growth.
- The impact of neighborhood watering strategy on tree success depends on planting season.
- Future research should consider social–ecological context of planted urban trees.

ARTICLE INFO

Article history:
Received 28 February 2014
Received in revised form
24 November 2014
Accepted 27 November 2014
Available online 30 December 2014

Keywords:
Tree growth
Tree survival
Street trees
Social–ecological systems
Community characteristics
Institutions

ABSTRACT

This research seeks to answer the question, what factors of the urban social–ecological system predict survival and growth of trees in nonprofit and neighborhood tree-planting projects? The Ostrom social–ecological system framework and Clark and colleagues' model of urban forest sustainability inform our selection of variables in four categories in the social–ecological system; these categories are the trees, the biophysical environment, the community, and management institutions. We use tree inventory methods to collect data on the survival, growth, and the social–ecological growing environment of recently-planted street trees in Indianapolis, IN to answer our research question. We use a probit model to predict tree survival, and a linear regression model to predict tree growth rate. The following variables are positively related to tree success (survival and/or growth): ball-and-burlap or container packaging, a visible root flare, good overall condition rating, the size of the tree-planting project, planting area width, median household income, percent of renter occupied homes, resident tenure, prior tree planting experience, correct mulching, and a collective watering strategy. The following variables are negatively related to tree success: caliper at planting, crown dieback, and lower trunk damage. Additional variables measured have less clear connections to tree success and should be examined further. Given that models including variables from all four categories of the social–ecological system generally outperform models that exclude some components, we recommend that future research on urban tree survival and growth should consider the holistic social–ecological systems context of the urban ecosystem.

* Corresponding author. Tel.: +001 920 850 2016.
E-mail addresses: jessica.m.vogt@gmail.com, jessica.vogt@furman.edu (J.M. Vogt), shawatki@indiana.edu (S.L. Watkins), skmincey@indiana.edu (S.K. Mincey), tertiarymatt@gmail.com (M.S. Patterson), bufische@indiana.edu (B.C. Fischer).

http://dx.doi.org/10.1016/j.landurbplan.2014.11.021

1. Introduction

In the last two decades, many cities in the United States have increased tree planting activities and set tree planting or canopy cover goals (McPherson & Young, 2010). However, relatively little is known about the factors that influence the success of these young urban trees. Trees in urban environments face challenges to their survival and growth that are different from those faced by trees in forests or nurseries (Whitlow & Bassuk, 1987). Trees in urban settings are affected not only by environmental conditions, but by the people who plant, own, maintain, pass by, and benefit from these trees. However, much research on tree outcomes has taken place as experiments in greenhouses or nurseries, which cannot simulate the actual growing conditions of urban trees that grow in such close proximity to people. This paper studies the survival and growth of young trees planted along city streets. It uses a holistic framework to explain recently planted urban tree success that accounts for characteristics of the trees, the biophysical environment, the surrounding community, and maintenance institutions. We build upon previous research in urban forestry and on social–ecological systems by conducting *in situ* research on urban tree survival and growth and by explicitly considering that planted trees are part of a larger urban social–ecological system.

1.1. Studying urban tree survival and growth in situ

Our review of the literature finds that the majority of research about urban tree success comes from experiments conducted in relatively controlled nursery settings rather than in the urban environment where street trees grow. Few studies attempt to control for the additional stresses that come from the urban environment. Few comprehensively measure the combined effects of biophysical conditions and management factors on tree success, much less combine social or community influence with these biophysical factors. One exception is the recent study by Lu et al. (2011), which examined the influence of local biophysical factors (urban design, biological condition, etc.) and social factors (e.g., a weeded tree plot as evidence of tree stewardship) on the mortality rates of young street trees in New York City. Jack-Scott, Piana, Troxel, Murphy-Dunning, and Ashton (2013) also make use of information about tree surroundings to inform their study of tree success.

1.2. Urban forests as social–ecological systems

The urban forest can be understood as a social–ecological system of linked human and natural components (Mincey, 2012; Mincey et al., 2013; Vogt & Fischer 2014). This perspective (see Table 1) builds on two theories of sustainable resource management: the model of urban forest sustainability (Clark, Matheny, Cross, & Wake, 1997) and the social–ecological system framework (Ostrom, 2009) and highlights potential factors that might influence tree survival and growth. The model of urban forest sustainability was developed in the field of urban forest management in the mid-1990s. The model identities three elements that are necessary for an urban forest to be sustainable (i.e., able to continue producing benefits at the same level over time): (1) a healthy vegetative resource (the trees and their growing environment), (2) a supportive community, and (3) an adequate management regime (Clark et al., 1997). The social–ecological system (SES) framework suggests similar categories of factors that appear most relevant to social and ecological outcomes in rural natural resource systems. The late Nobel Laureate Elinor Ostrom and colleagues developed the SES framework through decades of case study research on common pool resource management in rural forests, fisheries, and irrigation systems (Ostrom, 2009). The SES framework uses four core sets of variables to categorize influences on outcomes of linked human and natural systems: (1) the resource units (e.g., fish, trees), (2) the attributes of the biophysical resource system (e.g., size of a lake or forest), (3) the characteristics of the community of actors, or resource users (e.g., number of users), and (4) the institutional factors of the governance system (e.g., rules for fishing or timber harvesting; Ostrom, 2009). Specific variables in these four categories interact with one another and with the larger ecological and socio-political context to produce social and ecological outcomes (Ostrom, 2009; Epstein, Vogt, Mincey, Cox, & Fischer, 2013, Vogt, 2014). As coupled human-natural systems (Liu et al., 2007) of trees and people, urban forests are social–ecological systems, and the SES framework can help explain observed outcomes. However, the original SES framework was developed largely using research conducted in extractive resource systems in rural settings; thus, we adapt this framework for our application to urban forests that provide non-extractive benefits.

Our urban forests as social–ecological systems perspective (Table 1) contains four broad categories of variables that might influence the success of the urban forest: (1) the trees, (2) their biophysical environment, (3) the surrounding community, and (4) the maintenance institutions that affect the tree. We use this theoretical framework to model tree success. In the rest of this section, we describe what previous research tells us about how each of these categories might influence tree success in the urban forest.

1.2.1. Trees

The survival and growth of planted trees is influenced by the characteristics of those trees. Previous horticultural and arboricultural research provides some insight here. For instance, the size of the tree when it is planted (Neal & Whitlow, 1997; Struve, Burchfield, & Maupin, 2000; Watson, 2005; Lambert, Harper, & Robinson, 2010), the type of plant packaging (Gilman & Beeson, 1996; Lambert et al., 2010), and the tree species (e.g. Iakovoglou, Thompson, Burras, & Kipper, 2001; Grabosky & Gilman, 2004) may influence its survival and growth. Planting depth can impact tree survival: trees that are planted too deeply, with too much soil covering the rootball, are at greater risk of mortality (Gilman & Grabosky, 2004). Additionally, tree health and condition reflect overall tree vigor and should also be related to the survival (e.g. Roman, 2013) and growth (Berrang, Karnosky, & Stanton, 1985; Achinelli, Marquina, & Marlats, 1997) of the tree.

1.2.2. Biophysical environment

The biophysical environment also influences tree success. Evidence suggests that tree survival is influenced by surrounding land use type (Miller and Miller, 1991; Rhoades & Stipes, 1999; Lu et al., 2011), as well as available growing space (Lu et al., 2011) and rooting volume, which constrains root growth and therefore also aboveground growth (Krizek & Dubik, 1987; Grabosky & Gilman, 2004; Day, Wiseman, Dickinson, & Harris, 2010). Tree growth is also impacted by water stress (Kramer, 1987; Krizek & Dubik, 1987; Graves, Joly, & Dana, 1991), poor soil conditions (Smith, May, & Moore, 2001; Scharenbroch, Lloyd, & Johnson-Maynard, 2005; Scharenbroch, 2009) and competition for space with other urban infrastructure both above and below ground (Green & Watson, 1989; Gilman, 1990a; Kjelgren & Clark, 1992; Grabosky & Gilman, 2004). Competition with other trees for rooting space, nutrients and water belowground and for space and light aboveground influences growth rates (Nowak, McBride, & Beatty, 1990; Rhoades & Stipes, 1999; Iakovoglou et al., 2001), as can the season in which a tree is planted (Solfjeld & Hansen, 2004).

1.2.3. Community

We define community to be the people within and surrounding a resource system who provide, use, and benefit from that resource (whether they know it or not). The community has potential to