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Urban tree survival and stewardship in a state-managed planting initiative: A case study in Holyoke, Massachusetts

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ABSTRACT

Stewardship is essential for the survival of trees planted in challenging urban conditions and for reaching canopy cover goals and anticipated benefits. The governance structure of the stewardship network can dictate stewardship efficacy and ultimately, tree survival. While many planting initiatives are managed locally, the stewardship network and survival rates of a state-managed initiative are not commonly addressed in scholarly literature. The Greening the Gateway Cities Program (GGCP) in Massachusetts is planting thousands of trees in post-industrial cities around the state. We carried out a mixed-methods case study of 2014 to 2016 tree planting in Holyoke, a GGCP pilot city, to assess the factors that influence survival. Specifically, we interviewed program stakeholders and coupled that data with field monitoring of trees planted along streets and on commercial and institutional landscapes. A logistic regression model shows that trees stewarded by state foresters were approximately 5.18 times more likely to survive, and trees which were not impacted by a summer 2016 drought were approximately 2.80 times more likely to survive. However, the drought impact was muted for trees stewarded by the state, and species characteristics were not significantly related to survival. Importantly, stewardship and planting site type strongly overlapped, providing insight into links between tree survival and stewardship network. At program launch, local recipients and partners agreed to water newly planted trees. But interviews revealed that tree recipients had neither the time nor staffing to adequately care for their trees. The GGCP intended for the local municipal public works department to assume stewardship responsibility, but the latter was unable and/or unwilling to do so due to a lack of funding and misalignment of goals, leaving stewardship as the state's responsibility. Dedicated funding and staffing for maintenance is essential for strengthening stewardship networks and improving survival of large-scale urban tree plantings. Additionally, urban tree survival can be more strongly mediated by stewardship actors than some biophysical factors.

1. Introduction

Municipalities worldwide are showing substantial interest in urban greening, defined as organized or semi-organized efforts to introduce, conserve, or maintain outdoor vegetation in urban areas (Eisenman, 2016; Feng and Tan, 2017; Kuchelmeister, 1998). Urban greening includes a range of policies, incentives, and initiatives aiming to vegetate the urban landscape (Beatley, 2017; Tan and Jim, 2017). This often involves substantial tree planting. Across the United States, cities have established ambitious canopy cover goals (Locke, 2017) and major tree planting programs, including initiatives to plant a million trees (Young, 2011).

Achieving desired increases in urban tree canopy cover and anticipated benefits requires young trees to survive through establishment and reach maturity (Roman, 2014; Widney et al., 2016). Conditions in urban environments, however, present challenges to survival and growth, including but not limited to compacted soils and limited soil volume (Craul and Lienhart, 1999), impervious surfaces (Chen et al., 2017; Quigley, 2004), and lack of water (Sjöman et al., 2018). These biophysical stressors are to be expected given that cities are highly engineered environments built by and for humans (Groffman et al., 2014) – not necessarily trees. For this reason, maintenance by people is essential for planted trees to survive, yet stewardship plans and practice may be inconsistent in urban tree planting initiatives (Young, 2011).

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Recent studies have recognized stewardship indicators as predictors of young tree establishment in planting programs, including maintenance activities such as watering, mulching, staking, pruning, and weed removal (Boyce, 2011; Koeser et al., 2014; Roman et al., 2015, 2014b; Vogt et al., 2015a). Scholars have described urban environmental stewardship broadly as “conserving, managing, monitoring, advocating for, and educating” people on matters pertaining to local natural resources (Fisher et al., 2012). Tree stewardship has also been defined more narrowly as “the post-planting maintenance of trees” (Moskell and Allred, 2013). Among urban tree professionals, environmental stewardship likewise has varied meanings, ranging from environmental improvement through organizational goals to individual values and actions (Romolini et al., 2012). Drawing upon Roman et al. (2015), we use stewardship to refer to community tree care practices and associated program operations.

The structure of the stewardship network and the responsibilities vested in various actors can impact stewardship effectiveness, and ultimately, tree survival (Jack-Scott et al., 2013). Roman et al. (2014b) found that homeowner stability (i.e., homes without renter occupancy, foreclosure, and/or new owners) strongly predicted yard tree survival and was linked with appropriate tree maintenance. In Roman et al. (2015), high tree survival was found for street tree programs that had maintenance carried out by paid youth interns at local non-governmental organizations (NGOs), and drought-tolerant species selection was also important. Finally, Vogt et al. (2015) examined survival of street trees planted by an NGO and found a positive association between survival and collective watering strategies.

As tree stewardship requires the coordination of people, equipment, and funding, clear governance approaches – efforts to coordinate human actions towards goals (Konijnendijk van den Bosch, 2014) – are necessary to facilitate the flow of resources and clarify the interaction of various actors. Institutional capacity and stakeholder knowledge and attitudes are important dimensions of governance (Park and Youn, 2013). Contemporary tree planting and urban forestry is, in turn, characterized by a governance network that includes public, private, and civic society actors (Campbell, 2014; Konijnendijk van den Bosch, 2014). Since maintenance is an essential component of urban tree survival, and governance structure can influence stewardship efficacy, the very makeup of the network becomes another predictor of urban tree survival. However, governance is a relatively new line of research in urban forestry literature. A 2010 assessment of contributions to *Urban Forestry & Urban Greening* found that governance accounted for less than 10 percent of published articles; and specifically, the governance of urban tree maintenance activities had not been investigated systematically (Bentsen et al., 2010).

Governance-themed scholarship published since that assessment has largely focused on analysis of tree planting activities and networks among stewardship organizations (Connolly et al., 2014; Fisher et al., 2015). Governance literature focused on community engagement in tree planting programs primarily emphasizes impacts on environmental awareness and advocacy (Hunter, 2011; Krasny and Delia, 2014), social cohesion (Sommer et al., 1994; Westphal, 2003), and democratic participation (Fisher et al., 2015; Moskell et al., 2016; Moskell and Allred, 2013). In other words, research on urban tree governance has not focused on maintenance per se, nor connections to the survival of planted trees.

The Massachusetts Greening the Gateway Cities Program (GGCP) presents an opportunity to study the governance structure of a state-managed urban planting initiative and look closely at the relative importance of the stewardship network and other biophysical factors for young tree survival. In 2014, the state of Massachusetts initiated an urban tree planting program which focuses on 26 municipalities identified as “Gateway Cities,” a term that describes struggling post-industrial cities that serve as a gateway to the regional economy. Gateway Cities are designated as having a population between 35,000 and 250,000, with an average household income and a bachelor’s degree attainment rate both below the state’s average (Commonwealth of Massachusetts, 2016). In 2014, the GGCP was created by the Massachusetts Executive Office of Energy and Environmental Affairs (EEA). It is managed by the Department of Conservation and Recreation (DCR), with funding provided from the Department of Energy Resources (DOER) and in partnership with the Department of Housing and Community Development (DHCD). Though managed by the Massachusetts DCR, the program is implemented with the cooperation of four local program partners: three municipal agencies (conservation agency, planning and development, public works), and a local NGO that works on issues related to food, agriculture, and the environment. DCR foresters and the local program partners worked together to recruit local program tree recipients. This program frames trees as green infrastructure (DCR, 2017) and has a goal of increasing canopy cover by 5%–10% in select neighborhoods to reduce heating and cooling costs for residents (Commonwealth of Massachusetts, 2017).

To the best of our knowledge, GGCP is an unusual planting program in the United States in that it is both *funded* and *managed* by state-level staff who conduct tree acquisition, siting, planting, and maintenance at the municipal level. While many municipal tree planting programs receive state funds (Hauer and Petersen, 2016), the degree of state involvement in Massachusetts is atypical. Research on state actors is a new area of scholarship in the urban forestry literature. As one of the first cities that the program engaged in 2014, Holyoke provides an opportunity to understand how interactions between state and local organizations impact tree survival. Tree planting in Holyoke also reflects the contemporary urban greening movement in under-resourced post-industrial cities (McKendry, 2018). Meanwhile, urban forestry practitioners are increasingly monitoring planting initiatives to evaluate survival as an indicator of program performance, with some funders requiring monitoring reports (Roman et al., 2013). Our study is thus relevant to burgeoning scholarship about urban forest governance as well as the practical needs of managers.

The goals of this mixed-methods study were to: 1) quantify the survival of trees planted from May 2014 to November 2016 in Holyoke through the GGCP; 2) analyze the factors that influence the survival of these trees; and 3) assess the stewardship network for said trees in the context of a state-led planting initiative. We then discuss potential ways to improve stewardship and governance.

2. Methods

2.1. Study site

Holyoke is located in western Massachusetts, at the transition of New England’s coastal and highland ecosystems (City of Holyoke, 2013). There are approximately 7,163 acres of forested land in Holyoke, or 49% of the overall area of the municipality, with most of this located along a mountain range to the east (City of Holyoke 2013). Situated in USDA Plant Hardiness Zone 6A (2018), the city has an average temperature in January of $-5.0\,^{\circ}C$ and $21.6\,^{\circ}C$ in July and receives 122.8 cm of precipitation steadily throughout the year (NOAA, 2018). In the summer of 2016, 90% of Hampden County (where Holyoke is situated) had a severe drought after months of reduced rainfall and excessive heat (U.S. Drought Monitor, 2017). Typically, between May-October, Holyoke receives 66.8 cm of precipitation, but in that same period in 2016 the city received only 42.4 cm (NOAA, 2018), generating concerns about urban tree survival in the area (Harper, 2016).

Holyoke was developed in the mid-19th century as a water-powered industrial hub and the biggest papermaking city in the world. The population peaked at 65,000 in the early 1920s, after which capital and jobs began to flee, and the city’s population steadily declined to roughly 40,000 today (Lotspeich, 2009). Holyoke is now one of the state’s poorest cities with a poverty rate of 28.6%, while the statewide rate is 10.4% (U.S. Census Bureau, 2018). Originally drawn to factory jobs and nearby tobacco farms in the 1960s-70 s, the city has a sizable Hispanic community, most of whom are of Puerto Rican heritage (Kummer, 2008). The Hispanic population now represents a plurality of the overall population (City of Holyoke, 2013).

GGCP tree planting in Holyoke targets environmental justice communities, defined by the Commonwealth of Massachusetts (2018) as census block groups whose annual median household income are equal to or less than 65% of the statewide median ($62,072 in 2010); or 25% or more of the residents identify as a race other than white; or 25% or more of households have no English-speaking adults. These areas now include much of the urban core and surrounding residential neighborhoods. Holyoke's environmental justice communities had 26.5% tree canopy cover in 2012 (Davey Tree Expert Company, 2014).

Planting was carried out by DCR in the spring and fall, with each city at the directive of a DCR forester and a crew of laborers and forestry assistants hired from the local community. Trees planted in Holyoke were all sourced from a local nursery and range from 2.5 to 5 cm caliper, with stock either balled and burlapped or in Rootmaker® grow bags.

2.2. Study design

In developing this case study (Yin, 2009), we relied on multiple sources of evidence to investigate urban tree survival in a real-life context. Our research design followed a concurrent embedded mixed-methods approach (Creswell, 2009). Qualitative data in the form of stakeholder interviews elucidated the stewardship network which we drew upon to explain the results from quantitative tree monitoring. All interviews were conducted in confidentiality, and the names of interviewees are withheld by mutual agreement.

2.3. Tree survey

Students and faculty from Clark University and University of Massachusetts, Amherst surveyed trees planted between 2014–2016 through the GGCP from May 30, 2017 to June 27, 2017. The 749 trees monitored included trees planted along streets and in public parks (n = 477), as well as those planted on commercial and institutional landscapes, (n = 272) such as schools, public housing facilities, businesses, a museum, and a data technology center. These two groups of trees differed not only in site type but also in steward type, as street trees were generally stewarded by the state DCR, while local program recipients were charged with maintenance of trees planted on their properties. The study excluded trees planted on private residential property as access to these landscapes is limited. The DCR provided GIS maps including location and species for each tree.

Based upon protocols described by Roman et al. (2017) and Pontius and Hallett (2014), trees were surveyed for survival, vigor, and planting site type (Figs. 1 and 2). Survival categories included alive, standing dead, and removed. We considered mortality to be a combination of standing dead and removed trees (Roman et al., 2014a).

2.4. Stakeholder interviews

Stakeholders involved in the Holyoke GGCP planting initiative were identified and interviewed through snowball sampling (Goodman, 1961), with the objective of depicting the stewardship network of trees planted between 2014–2016 and assessing links between this network and tree survival. Stakeholders were grouped into three categories based on their roles in the program: state program sponsor, local program partners, and local program recipients. The state program sponsor is DCR and an interview was conducted with the two DCR foresters who oversaw the GGCP in Holyoke. Interviews were also conducted with four individuals spanning the four local program partners (conservation agency, planning and development, public works, and a local NGO). While Holyoke's Department of Public Works (DPW) has a municipal forester (or "tree warden") as mandated by the state of Massachusetts (Ricard, 2005), this person did not agree to be interviewed. Of the 14 organizations identified as local program recipients, representatives of 10 agreed to be interviewed. These organizations were four private businesses, a public school, an NGO, a museum, a property management agency, the public library, and the public housing authority.

Interviews were semi-structured, using both closed-ended and open-ended prompts (Galletta and Cross, 2013). This variety allows researchers to explore specific dimensions of research questions, while leaving flexibility for participants to offer new meaning to inform the data (Patton, 2002). Semi-structured interviews are particularly important in mixed methods research, allowing for focused, two-way communication that adds depth, nuance, and meaning to otherwise abstract quantitative data (Galletta and Cross, 2013; Hyman, 1955). We prompted each local program recipient to talk about what led them to participate in the tree planting, and their experiences and feedback related to the program.

3. Data analysis

3.1. Logistic regression model

We used logistic regression to analyze the association between potential risk factors and tree survival, our outcome of interest. These risk factors and outcomes are outlined in Table 1. The variable drought impact reflects the potential impact of a major drought in summer 2016 (Harper, 2016; NOAA, 2018), which could have affected trees from the fall 2015 to the fall 2016 planting seasons. The variable steward type categorizes the actors responsible for tree maintenance, based on interviews with key stakeholders, with the variable differentiating

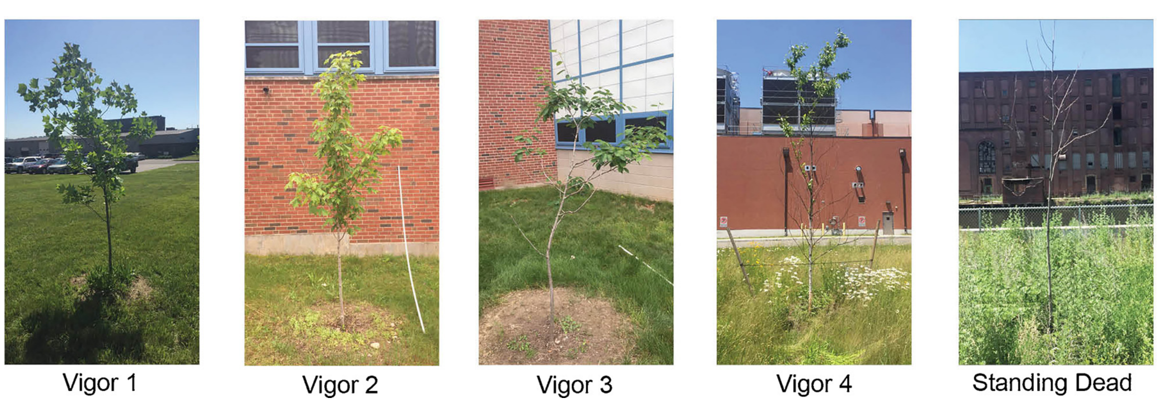

Fig. 1. Photographs of GGCP trees planted in Holyoke, Massachusetts representing vigor classes from left to right, starting with class 1 (healthy) to class 4 (extreme twig dieback and discolored leaves) and a typical standing dead tree.

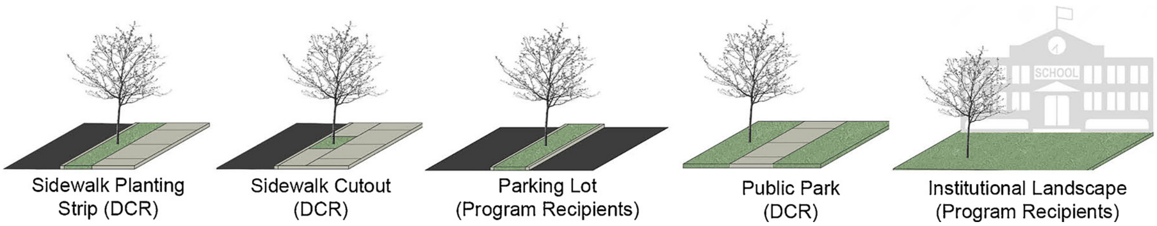

Fig. 2. Typical tree planting site types and steward for that site type. In general, trees along streets and in parks were maintained by state foresters, while other site types were maintained by local program recipients.

between trees maintained by DCR versus those maintained by local program recipients themselves. Steward type and site type aligned very closely (Fig. 2), thus our analysis included only one of these variables, namely, steward type. Species tolerances, native tree status, and expected mature size class are based on regional urban forestry resources (Bassuk et al., 2009; Vermont Urban and Community Forestry, 2012). These species classifications were used to indicate possible survival patterns among functional and tolerance groupings that are meaningful for managers' species selection choices.

We built logistic regression models using the 'logit' function in Stata 11 (StataCorp, 2009). The general form of a logistic regression model is:

$$\log(\frac{p_{x,y}}{1-p_{x,y}}) = a + bx + cy$$

(after Jewell (2003), eqn. 14.2)

where x and y represent independent risk factors, and $p_{x,y}$ is the probability of survival given the risk factors taking on particular values. With risk factors that are ordinal variables (e.g., months since planting), the coefficient b can be interpreted as the odds ratio (OR) – a measure of effect size – of a unit increase in, holding c fixed. Higher ORs mean higher probability of surviving.

We used an iterative model building process to compare nested models with likelihood ratio tests (Hosmer and Lemeshow, 2000; Jewell, 2003). The final model was evaluated with the receiving operator characteristic (ROC) curve. The area under the ROC curve assesses model discrimination, where > 0.9 indicates outstanding discrimination, 0.8–0.9 excellent discrimination, 0.7–0.8 acceptable discrimination, and 0.5 no discrimination (Hosmer and Lemeshow, 2000).

Because 14 trees had unknown species from the DCR planting records, we repeated the entire model building process twice for survival outcomes: first, with all trees (n = 749), but skipping the species-related variables, and second, with a reduced data set consisting of trees with known species (n = 735), and including the species-related variables.

Because drought impact and steward type were included in our final model, and because we suspected potential interactive effects of those variables – trees watered during drought would presumably fare better – we also did a stratified χ^2 test using the 'cc' command in STATA. Specifically, we stratified drought impact by steward type and evaluated for homogeneity across strata using the Mantel-Haenzel test (Jewell, 2003).

3.2. Qualitative analysis

All key stakeholder interviews were recorded, transcribed, and coded using NVivo qualitative analysis software to identify themes (QSR International Pty Ltd, 2016). We coded interview results using the four dimensions of the Policy Arrangement Approach (PAA) to understand the dynamics of changes in policies: actors, resources and power, discourses, and "rules of the game," which include formal and informal procedures and routines in decision-making and implementation (Arts and Tatenhove, 2004; Park and Youn, 2013).

We then divided coded results into strengths, weaknesses, opportunities, and threats (SWOT) related to tree survival. SWOT analysis is commonly used in strategic planning and allows researchers to understand both internalities (strengths and weaknesses) and externalities (opportunities and threats) in order to determine actionable steps towards an organization or program's goals, such as maximum tree survival (Gürel and Tat, 2017).

Once categorized using both SWOT and PAA, nodes were arranged into cognitive maps for the two interview groups to explore emergent themes in PAA dimensions. Cognitive mapping has been employed by urban and rural forestry researchers to illustrate knowledge structures, composed of people's assumptions and beliefs, that influence their interpretation of and response to new information and experiences (Kearney, 2006; Romolini et al., 2012; Tikkanen et al., 2006). By graphically displaying stakeholders' conceptions of PAA dimensions, their valuation of these dimensions, and the interconnections of themes, these cognitive maps, paired with our logistic regression models, generated socio-ecological insight into tree survival outcomes. Understanding that individual responses constitute a limited perspective, we gave greater weight to recurring themes (i.e., those mentioned by three or more key stakeholders and/or four or more local program recipients).

4. Results

The survey of 749 trees found an overall survival rate of 77.8%. Of the surviving trees (n = 583), most (87.1%) were in good health (vigor

Table 1
Variables used in logistic regression model building.

Variable	Description
mortality	mortality status of the tree, used as the model outcome (0 = standing dead and removed trees, 1 = surviving trees)
months since planting	number of months between planting and field monitoring
season planted	fall or spring planting season (0 = fall)
drought impact	planting impacted by summer 2016 drought (0 = yes)
steward type	whether the tree was stewarded by DCR or tree recipient (0 = other entities)
recommended urban species	whether the tree is recommended for urban use (0 = yes)
native status	where the species originates (northeastern US, elsewhere in US, outside of US)
drought tolerance	whether the tree is considered drought tolerant (0 = intolerant and moderately tolerant)
salt tolerance	whether the tree is considered tolerant of road salt (0 = intolerant)
mature size class	size class of species at maturity (0 = medium and large)

Table 2
Final model for survival outcome, considering all trees (n = 749). A higher odds ratio (OR) indicates a higher probability of surviving. Additional months since planting decreased the chances of surviving; not experiencing the summer 2016 drought and being stewarded by DCR, increased the chances of surviving.

Variable	OR	95% confidence interval	p-value
months since planting	0.95	0.90, 0.99	0.025
drought impact	2.80	1.54, 5.07	0.001
steward type	5.18	3.52, 7.64	< 0.001

classes 1 and 2). Of the 166 tree mortality instances, 55.4% were standing dead trees and 45.6% were removed. Trees stewarded by DCR (n = 477) survived at a rate of 88.5% while those stewarded by local program recipients (n = 272) survived at a rate of 59.2%.

4.1. Survival modeling

For survival outcomes, considering all trees (but omitting species-related variables), the final logistic regression model included months since planting, drought impact, and steward type (Table 2). In terms of time since planting, for every additional month, trees were 0.95 times less likely to survive. Trees that were not impacted by the 2016 drought were 2.80 times more likely to survive, compared to trees which were impacted by the drought. Trees stewarded by DCR were 5.18 times more likely to survive, compared to trees maintained by tree recipients. The area under the ROC was 0.73, indicating fair discrimination.

When we conducted model building using species-related variables, considering only trees with known species, none of the species-related variables were significant in the final model (results not shown). Rather, the variables for drought impact and steward type were again significant, with similar effect sizes to the model built using the full data set (although months since planting was not significant in the model built using the reduced data set).

4.2. Stewardship network

Stakeholder interviews elucidated the network of major stewarding actors for GGCP trees planted in Holyoke between 2014–2016 (Fig. 3). We found that at the outset of the initiative, stakeholders had agreed upon a division of responsibilities where the state, municipality, local NGOs, tree recipients, and residents played important and complementary roles in implementing the tree planting and maintaining trees' health. However, stakeholders' roles shifted as challenges arose and the capacities and commitments of different stakeholders became apparent.

Prior to launching the GGCP in Holyoke, it was agreed that DCR would plant trees with community outreach support from the municipal conservation agency and a local NGO partner. Subsequently, DCR would transfer responsibility for watering and long-term tree care to the Holyoke DPW for street trees and to tree recipients for those planted on their property. At the outset, Holyoke's DPW accepted this responsibility for all publicly planted street trees, while local program recipients signed a written agreement that they would water trees on their property for two years. Where public street trees were planted near program recipient properties, landowners were informed of the tree planting and given the option of rejecting these street trees (i.e., "opt-out"). For trees planted on program recipient properties, all eligible landowners in the selected planting zone were informed of the free trees and asked to "opt-in" by accepting free trees on their private land. This system was intended to allow DCR to minimize investment in trees that might be unwanted and not cared for, yet ultimately, stewardship by tree recipients was insufficent, as will be discussed.

After three years of GGCP planting, our interviews revealed a network of tree stewardship that was largely reliant upon DCR. Fig. 3 illustrates this network, including breakdowns in the stewardship network relative to the original agreement. It became clear in the first year that Holyoke's DPW could not, or would not, consistently commit to watering, despite the initial agreement. As a result, DCR foresters, not wanting to see newly planted trees die, assumed responsibility for watering all public trees in sidewalk planting strips and sidewalk cutouts adjacent to roads. The DPW also withdrew from plans, which they had drafted in coordination with DCR, to increase plantings in public spaces by improving or adding planting strips and sidewalk cutouts, citing inadequate equipment and labor as the reason for this withdrawal. The lack of municipal engagement in stewardship caused some stakeholders to express concern for the long-term maintenance of trees once DCR completes its work in Holyoke. Indeed, local program sponsors were not aware of any formal management plan going forward. Staff at the municipal conservation agency said, "I need to figure out what to do about the watering," while a DPW representative said, "I don't know, and I haven't really thought about it."

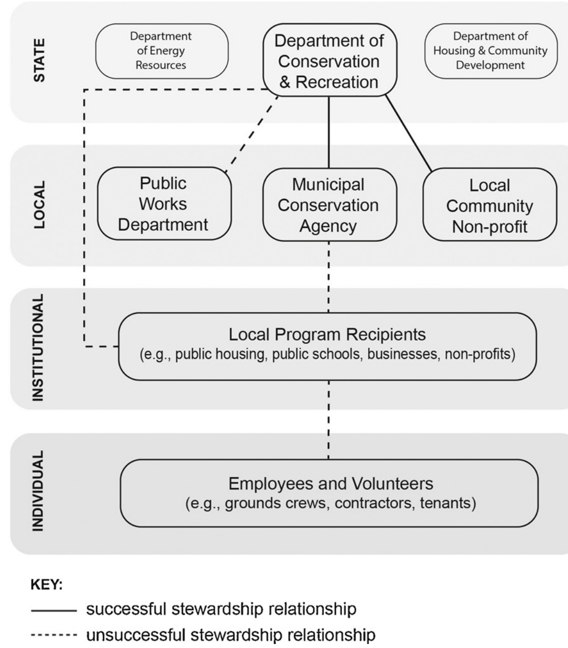

Fig. 3. Stewardship network for street trees and local program recipient trees planted in Holyoke, Massachusetts through the GGCP for which stewardship could be determined and evaluated. In this figure, instances of "successful stewardship relationship" are those leading to high tree survival.

The role of the municipal conservation agency evolved as the planting program advanced. In the beginning, a conservation staff person served informally as a forester and led outreach to local stakeholders. This role then phased out as the program became well-established and DCR hired a second forester. In addition, conservation staff used the momentum and local knowledge created by GGCP to launch a municipal nursery, with the help of a $100,000 Massachusetts Gateway City grant (Plaisance, 2015). The nursery aimed to provide the city and residents with free trees once DCR completed planting. The municipal conservation agency remained committed to supporting the work of the GGCP, however, that agency is understaffed, holds many responsibilities above and beyond the GGCP, and was unable to influence funding and resource allocation by the DPW.

EEA was able to obtain US Forest Service funding to enable a local NGO to provide outreach and door-to-door canvassing efforts to help spread the word about the program. Besides this main grant objective, DCR's local NGO partner helped to bridge local and state interests by running two programs in the first year of the GGCP initiative: "adopt-a-tree" and the "bike brigade." Volunteers canvassed the community within the targeted planting zone, asking residents and businesses to "adopt-a-tree" by receiving free trees on their properties or caring for a publicly planted tree. Meanwhile, the "bike brigade" recruited local youth in a summer program, guided by DCR, that equipped them with bikes and hoses to water newly-planted trees around the city. The NGO staff said they saw their mission as aligned with that of GGCP. While the NGO primarily promotes agriculture and community development throughout the city, many initiatives have tapped the group as a partner because it is seen as capable of community outreach and is especially well-connected to the large Hispanic population of the city.

Lastly, the level of stewardship conducted by local program recipients on their own properties greatly impacted overall tree survival outcomes. Our inventory found a significantly higher rate of tree mortality and trees left standing dead on program recipient properties (businesses, schools, public housing), than the street trees stewarded by the DCR. Interviews suggested potential causes of this disparity. First, while decisions about tree species, location, and number planted were usually made by the tree recipient director or manager, the trees were often cared for by landscape contractors or maintenance crews who were not directly involved in decision-making and did not receive instruction from DCR on tree care. Second, although tree recipients agreed to water trees for two years, interviewees indicated that the removal of dead trees had not been discussed or planned for prior to planting. One tree recipient, frustrated by the number of dead GGCP trees they had seen, argued that there should be more accountability for tree survival both because the trees gifted by the state were a substantial investment and because dead trees reflected poorly on the city.

4.3. Links between drought, stewardship, and survival

Based upon findings from our tree survey and stakeholder interviews, and the straightforward intuition that irrigation helps trees to survive drought conditions, we analyzed links between steward type and drought impact. Considering trees stewarded by DCR, those impacted by drought had 90.5% survival while those not impacted by the drought had 87.5% survival. Considering trees that were stewarded by local program recipients, those impacted by the drought had 47.1% survival, while those not impacted by the drought had 72.0% survival. For the mortality cases of trees stewarded by tree recipients that were drought-impacted, a substantial proportion were standing dead (Fig. 4).

Based on the stratified χ^2 test, the Mantel-Haenszel test of homogeneity was significant ($p = 0.0078$), indicating that the association between drought-impacted plantings and survival differed by steward type (Table 3). For trees that were maintained by tree recipients, the drought effect was pronounced; such trees that were not drought-impacted were approximately 2.88 times more likely to survive. For trees stewarded by DCR, the drought effect was not substantial, as the 95% confidence interval crossed one, i.e., there is no difference in risk.

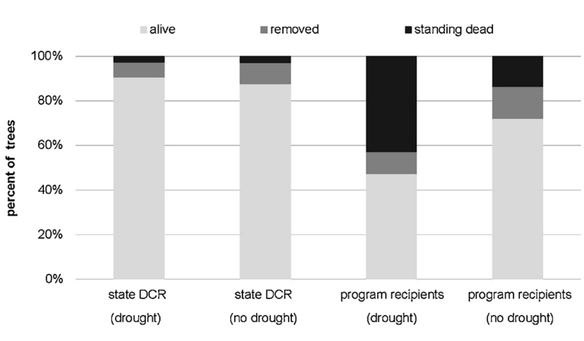

Fig. 4. Tree survival and mortality (trees removed and standing dead) by stewardship actor and drought impact.

Table 3
Stratified χ^2 test for steward type strata within drought impact. A higher odds ratio (OR) indicates a higher probability of surviving. The crude OR represents drought impact effect without considering steward type (note that this is a different OR from the regression model due to the regression model holding both steward type and months since planting constant).

Steward Type	OR	95% Confidence Interval
other parties	2.88	1.69, 4.93
DCR	0.73	0.36, 1.43
crude	2.16	1.50, 3.11

5. Discussion

Our results support a small but growing body of evidence that stewardship of young urban trees is an essential predictor of survival (Boyce, 2011; Elmes et al., 2018; Koeser et al., 2014; Roman et al., 2015, 2014b; Vogt et al., 2015b). Tree survival, in turn, is critical to achieving the environmental and social outcomes envisioned in urban tree planting programs. This highlights the importance of stewardship when planning and implementing planting initiatives, especially when programs are predicated on long-term goals and aspirations that frame urban trees as green infrastructure (Campbell, 2017; Young, 2011). However, the distribution of urban trees across a range of spatial configurations, land uses, land owners, and land cover types presents challenges to successful stewardship. By extension, urban tree planting initiatives may require new forms of governance that foster greater institutional capacity and account for a range of stakeholder attitudes that are not the norm in municipal management of landscapes and traditional grey infrastructure (e.g., Nguyen et al., 2017; Pincetl, 2010). The relationship between these important factors is depicted in Fig. 5. We use this diagram to facilitate the ensuing discussion of lessons learned from our case study.

5.1. Tree survival

Our tree survey corroborates prior literature concerning the important link between survival and stewardship and adds nuance regarding the impacts of severe drought. Despite being planted primarily in hardscaped sites – generally considered harsh growing environments (Moll, 1989; Skiera and Moll, 1992) – street trees that received adequate stewardship with routine watering by the state DCR survived at a much higher rate (88.5%) than trees that were under-stewarded by local program recipients (59.2%). This confirms that in some cases, stressors and challenges to urban tree survival are more strongly mediated by how and whom a tree is cared for, than biophysical factors such as site type (see Fig. 4). Indeed, lawn trees in Sacramento, California had 10 times higher annual young tree mortality (6.6%) than street trees in East Palo Alto, California (0.6%), with maintenance (or lack thereof) related to both outcomes (Roman et al., 2015, 2014b).

The planting period in Holyoke also coincided with a severe drought, and our results confirm that the drought further exacerbated the survival differential between stewards (Fig. 4). The drought impact was significant and pronounced for trees stewarded by tree recipients but muted for trees stewarded by DCR (Table 3), suggesting that DCR's watering efforts effectively overcame the vulnerability brought on by drought. Importantly, species factors, including drought tolerance itself, did not impact tree survival. This could be due to many GGCP trees being selected for urban conditions, although it is possible that in the future, the various species in Holyoke will show differential long-term growth and health responses to climate stressors (Sjöman et al., 2018). In light of the increasing frequency and severity of drought conditions due to climate change (Easterling et al., 2000), which exacerbates tree stress in urban environments (Gillner et al., 2014), post-planting maintenance is of increasing urgency as cities and states implement large-scale tree planting initiatives. Our findings indicate that

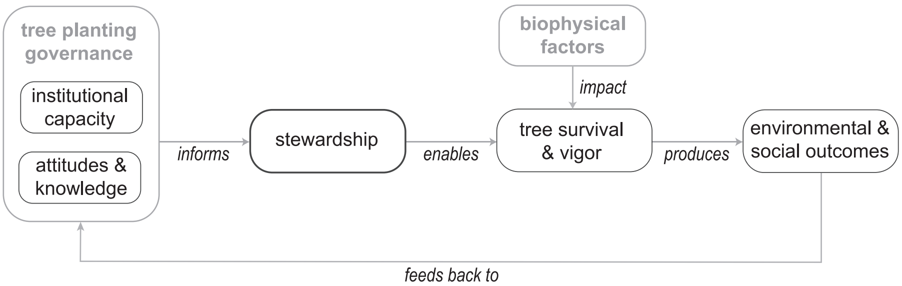

Fig. 5. Conceptual framework showing how governance of urban tree planting initiatives can produce environmental and social outcomes. Stewardship is an essential mediating link that enables tree survival and vigor, which is also impacted by biophysical factors. This process can recursively feedback to inform future governance that is shaped by institutional capacity and stakeholder attitudes and knowledge.

successful stewardship can negate the impacts of both severe drought and challenging site conditions, highlighting the important role of stewardship planning and execution in urban greening campaigns.

5.2. Stewardship

Our findings agree with Young (2011) regarding the importance of developing a stewardship plan – before tree planting begins – that outlines responsibilities as well as the flow of communication and resources amongst actors. For example, Mincey and Vogt (2014) and Young (2011) cite the use of stewardship contracts and watering agreements with NGOs or landscape contractors. These agreements typically stipulate that stewards are responsible for replacing dead trees. This creates an intrinsic financial incentive for tree survival, as tree planting in the United States typically costs $175-423 per tree (Hauer and Peterson, 2016). For trees that fail to survive, those planting expenditures represent sunk costs (Mincey and Vogt, 2014; Nguyen et al., 2017). Yet, a stewardship contract alone does not guarantee maintenance actions will occur. The previously mentioned yard tree program in Sacramento with relatively high young tree mortality involved both signed residential stewardship agreements and a brief consultation with program staff, yet less than one-quarter of those trees met maintenance guidelines (Roman et al., 2014b). In Holyoke, local program recipients did agree to water trees planted on their property for two years, however, DCR did not provide funding to support this stewardship (discussed further below).

In addition, our interviews revealed that communication between DCR and local program recipients was often hindered as DCR was in direct contact with the property owner, not the landscape staff charged with actual tree maintenance, which impacted stewardship capacity (see Fig. 3). This became problematic in two ways. First, local grounds crews did not always know the location of new trees or understand that they were planted through the GGCP, and in one case 10 trees were removed due to frustration with having to mow around them. Second, as trees began to die quickly during the drought, a rapid response was lacking. These findings highlight the importance of engaging directly with the employees who are charged with tree maintenance, making them aware of tree planting, providing training on tree care, and being available for return visits and answering questions.

In Holyoke, state DCR foresters provided local program recipients with verbal explanations of tree stewardship needs, in addition to leaving an informational brochure on tree watering and offering their contact information for ongoing support. However, DCR relied on local program recipients to purchase slow-release watering bags or buckets and to seek help if trees under their local stewardship did not fare well. By contrast, most DCR-stewarded trees benefitted from pre-purchased watering bags, drastically reducing the time needed for watering. These distinctions are important, as tree stewardship by large public and private property holders – such as the local program recipients in our study (e.g., schools, public housing, commercial complexes) – has not been well-studied but is an important factor for the success of municipal tree planting campaigns, as these properties occupy a significant percentage of land in cities (Nguyen et al., 2017).

5.3. Tree planting governance

As noted by others (Foo, 2018; Pincetl, 2013; Young, 2011), governance structures and the financial and staffing capacities they beget, directly inform tree stewardship. Multi-stakeholder governance is an emerging norm in urban forestry practice, reflecting a shift from "governance by government" to "governance with/without government" (Konijnendijk van den Bosch, 2014). In our case study, this multi-stakeholder governance structure generally applies. But unlike urban tree planting campaigns led by municipalities, the Holyoke initiative was led by a state entity. This created distinct benefits and challenges.

5.4. Institutional capacity

State and municipal actors lauded the GGCP, believing that Holyoke could not have planted so many trees without state support. But interviewees also expressed concern that few additional resources were allocated to local actors to support municipal maintenance of new trees. However, DCR did set aside funding for a landscape contractor in 2015 to water GGCP street trees, but the agency realized it could do this cheaper in-house and took over watering responsibility (e-mail correspondence with DCR official, December 10, 2018).

Importantly, interviewees described Holyoke's DPW as spread thin. For example, in 2002 the DPW, forestry, and parks departments merged as one administrative unit (Reid, 2002). But the parks labor force has since been reduced from 50 full-time employees to only eight (e-mail correspondence with municipal DPW employee, June 7, 2018). This 84% reduction suggests that the city is already under-resourced to manage its existing green spaces, and such austerity raises critical questions about local capacity to manage additional green infrastructure in the form of new trees. For example, Roman et al. (2015) have shown that newly planted trees can require 30 to 60 minutes of stewardship per tree per year to achieve relatively high establishment survival. If we translate this to the GGCP case in Holyoke, the 477 trees planted along streets and in public parks that were meant to be stewarded by the municipal DPW, amounts to 238 to 477 hours of labor per year to maintain new trees. This would have been a difficult undertaking given DPW's drastic reduction in staff and lack of funding and helps explain why DCR assumed stewardship responsibility for these trees. Notably, even the municipal tree warden, whose position within the DPW is most directly related to the work of the state GGCP, was not involved in the GGCP tree planting initiative, according to DCR foresters and other municipal representatives. As noted earlier, the municipal tree warden did not respond to requests for an interview, so we cannot speculate about their motivations for not engaging in the program.

Additionally, DCR's local NGO partner withdrew from engagement in the GGCP due to lack of funding after the initial one-year grant expired. This development echoes a cautionary note offered by Young (2011): NGOs and volunteers can provide tree-planting and long-term stewardship capacity, but without financial support they likely cannot match sustained engagement by the public sector – an observation echoed by the Holyoke Conservation Agency (e-mail correspondence, December 3, 2018). Likewise, when relying on volunteer stewards, urban tree planting sponsors may want to consider diverse attitudes and levels of knowledge (Kirkpatrick et al., 2013; Carmichael and McDonough, 2019), and provide post-planting support. These concerns are especially timely for the GGCP, which envisions long-term stewardship of thousands of trees currently being planted in under-resourced cities across the state, to be the responsibility of local NGOs (Cahill, 2018).

Given Massachusetts' dedication of $12 million over the course of three years to plant trees through the GGCP (Gronendyke, 2017), some of these resources might be specifically dedicated to fund local salaries, seasonal interns, and/or equipment in participating Gateway Cities during the post-planting period. More broadly, it behooves urban greening practitioners to explore new governance structures and learn from best practices in other places to develop an effective strategy for stewardship and survival of urban trees (Foo, 2018; Pincetl, 2013). New York City, for example, moved stewardship and tree procurement funds into the capital budget to be less vulnerable to budget cuts (Young, 2011). Community Development Block Grants (CDBG) have also been used for tree planting and maintenance (City of Pittsfield, Massachusetts, 2010; The Delaware Center for Horticulture, 2017). For two programs with unusually high young tree survival in Philadelphia, Pennsylvania and East Palo Alto, California, paid youth interns from underserved neighborhoods were crucial to young tree maintenance, and those interns were supported through private foundations rather than public funds (Roman et al., 2015). Further research is warranted to delineate the various funding mechanisms and governance structures that can support institutional capacity for post-planting stewardship.

5.5. Stakeholder attitudes

Municipal street tree management and associated funding and staffing is rooted primarily in risk management for large, mature trees that may injure people and damage property and built infrastructure, sometimes resulting in liability (Mortimer and Kane, 2004; Hauer and Petersen, 2016; Roman et al., 2013). Indeed, our interviews found that the Holyoke DPW viewed trees as a threat to the utilities and sidewalks that it maintains. This reasonable concern can lead municipal arborists to focus on pruning and removing mature trees rather than planting the next generation of young trees.

Municipal landscape managers can face substantial practical challenges when incorporating large numbers of new trees, given that their focus is primarily mature tree management. In the Holyoke case, consolidation of parks and forestry under one department could, in theory, facilitate a holistic approach that embraces both stewardship of new trees and maintenance of mature trees. But that did not seem to be the case. Future research could examine ways to foster sustained engagement among various agencies and community partners that endures beyond initial agreements into short- and long-term post-planting stewardship.

6. Conclusion

Stewardship is essential for ensuring urban tree survival, achieving environmental and social benefits associated with canopy cover goals, and gaining public acceptance for future planting projects. In the GGCP pilot in Holyoke, trees that were stewarded by local program recipients died at a higher rate than trees stewarded by the state DCR. Trees maintained by local recipients during drought faired particularly poorly. This survival and stewardship differential may be explained by a lack of institutional capacity and misalignment of tree management goals among key actors. Urban tree planting programs may see higher survival if they plan for and fund maintenance of newly-planted trees in coordination with municipal government, NGOs, and other local actors. This could include financing and implementation of short-term staffing plans to ensure maintenance during the initial establishment phase. Future studies could look at ways to improve the institutional capacity, financing, and governance structure of urban tree planting initiatives. This is especially important in under-resourced communities and post-industrial cities that are often targeted for greening. Finally, mixed-methods analyses that address social factors as well as biophysical attributes are essential to understanding tree survival in complex socio-ecological systems.

Contributing roles

Breger co-conceptualized this study, acquired financial support to implement tree vigor inventory, led inventory of tree vigor and associated data curation, co-led development of tree vigor methodology, supported tree vigor analysis, co-led project administration, led data visualization, and co-led writing and revisions.

Eisenman co-conceptualized this study, supported acquisition of financial support to implement tree vigor inventory and stakeholder interviews, supported development of tree vigor methodology and co-led stakeholder interview methodology, co-led project administration, and co-led writing and revisions.

Kremer co-conceptualized this study, acquired financial support to implement stakeholder interviews, co-led development of stakeholder interview methodology, led stakeholder interviews and associated data curation, assisted in tree vigor inventory, co-led governance discussion, and contributed writing and revisions.

Roman led training of tree vigor inventory, led development of tree vigor methodology, led statistical analysis, and contributed to writing and revisions.

Martin and Rogan contributed data for tree vigor inventory, supported development of stakeholder interview methodology, managed student research assistants in support of tree inventory, co-led tree vigor inventory, and contributed revisions to first full draft of manuscript and ensuing revisions.

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References

Arts, Bas, Van Tatenhove, Jan, 2004. Policy and power: a conceptual framework between the 'Old' and 'New' policy idioms. Policy Sci. 37 (3–4), 339–356.
Beatley, Timothy, 2017. Handbook of Biophilic City Planning & Design. Island Press, Washington, D.C.
Bentsen, Peter, Christian Lindholst, A., Konijnendijk, Cecil C., 2010. Reviewing eight years of Urban Forestry & Urban Greening: taking stock, looking ahead. Urban For. Urban Green. 9 (4), 273–280.
Boyce, Steven, 2011. It takes a stewardship village: is community-based urban tree stewardship effective? Cities Environ. (CATE) 3 (1).
Cahill, Mathew, 2018. Greening the Gateway Cities. Massachusetts Urban & Community Forestry Program, The Citizen Forester. September 2018.
Campbell, Lindsay K., 2014. Constructing New York City's urban forest: the politics and governance of the MillionTreesNYC campaign. In: Sandberg, Anders L., Bardekjian, Adrina, Butt, Sadia (Eds.), Urban Forests, Trees, and Greenspace: A Political Ecology Perspective. Routledge, Florence, KY, pp. 242–260.

Campbell, Lindsay K., 2017. City of Forests, City of Farms: Sustainability Planning for New York City's Nature. Cornell University Press.
Carmichael, C.E., McDonough, M.H., 2019. Community stories: explaining resistance to street tree-planting programs in Detroit, Michigan, USA. Soc. Nat. Resour. 32 (5), 588–605.
Chen, Yuanyuan, Wang, Xiaoke, Jiang, Bo, Wen, Zhi, Yang, Ning, Li, Li, 2017. Tree survival and growth are impacted by increased surface temperature on paved land. Landsc. Urban Plan. 162 (Supplement C), 68–79.
City of Holyoke, 2013. City of Holyoke Open Space and Recreation Plan 2013-2018: A Five-Year Action Plan for Parks and Natural Resources. Holyoke, MA. https://www.holyoke.org/wp-content/uploads/2012/10/reducedfinal2.pdf.
City of Pittsfield, Massachusetts, 2010. Pittsfield CDBG Fact Sheet." Department of Community Development. http://www.cityofpittsfield.org/city_hall/community_development/community_development_and_housing/docs/Pittsfield_CDBG_FACT_Sheet_new.pdf.
Commonwealth of Massachusetts, 2016. General Laws, Part 1, Title II, Chapter 23A, Section 3A. The 190th General Court of the Commonwealth of Massachusetts. 2016. https://malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter23A/Section3A.
Commonwealth of Massachusetts, 2017. Greening the Gateway City Tree Planting Program. 2017. Mass.Gov.. https://www.mass.gov/service-details/greening-the-gateway-city-tree-planting-program.
Commonwealth of Massachusetts, 2018. Environmental Justice Communities in Massachusetts. 2018. Mass.Gov.. https://www.mass.gov/info-details/environmental-justice-communities-in-massachusetts.
Connolly, James J.T., Svendsen, Erika S., Fisher, Dana R., Campbell, Lindsay K., 2014. Networked governance and the management of ecosystem services: the case of urban environmental stewardship in New York city. Ecosyst. Serv. 10, 187–194.
Bassuk, N., Curtis, D.F., Neal, B., 2009. p. Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance. Urban Horticulture Institute, pp. 122. Retrieved from: http://www.hort.cornell.edu/uhi/outreach/recurbtree/pdfs/~recurbtrees.pdf.
Craul, Phillip J., Lienhart, James R., 1999. Urban Soils: Applications and Practices. Wiley, New York.
Creswell, J.W., 2009. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (Third). Sage Publications, Inc, Thousand Oaks, CA.
Davey Tree Expert Company, 2014. Holyoke, Massachusetts – Urban Tree Canopy Assessment. Retrieved from: https://holyokeredevelopment.com/wp-content/uploads/Holyoke-Urban-Tree-Factsheet.pdf.
DCR, (Department of Conservation and Recreation), 2017. Tree Planting and Retention for Demand-Side Energy Use Reduction. Massachusetts Department of Conservation and Recreation, Boston, MA. https://www.mass.gov/files/documents/2017/12/06/stewardship-council-presentation-2017-september-greening.pdf.
Easterling, D.R., Meehl, G.A., Parmesan, C., Changnon, S.A., Karl, T.R., Mearns, L.O., 2000. Climate extremes: observations, modeling, and impacts. Science 289 (5487), 2068–2074.
Eisenman, Theodore S., 2016. Greening cities in an urbanizing age: the human health bases in the nineteenth and early twenti-first centuries. Change Over Time 6 (2), 216–246.
Elmes, Arthur, Rogan, John, Roman, Lara A., Williams, Christopher A., Ratick, Samuel J., Nowak, David J., Martin, Deborah G., 2018. Predictors of mortality for juvenile trees in a residential urban-to-rural cohort in Worcester, MA. Urban For. Urban Green. 30, 138–151.
Feng, Y., Tan, P.Y., 2017. Imperatives for greening cities: a historical perspective. In: Tan, P.Y., Jim, C.Y. (Eds.), Greening Cities: Forms & Functions. Springer, Singapore, pp. 41–70.
Fisher, Dana R., Campbell, Lindsay, Svendsen, Erika S., 2012. The organisational structure of urban environmental stewardship. Env. Polit. 21 (1), 26–48.
Fisher, Dana, Svendsen, Erika S., Connolly, James J.T., 2015. Urban Environmental Stewardship and Civic Engagement: How Planting Trees Strengthens the Roots of Democracy. Routledge Explorations in Environmental Studies. Routledge, Abingdon, UK.
Foo, Katherine, 2018. Examining the role of NGOs in urban environmental governance. Cities 77, 67–72.
Galletta, Anne, Cross, William E., 2013. Mastering the Semi-Structured Interview and Beyond: From Research Design to Analysis and Publication. NYU Press, New York.
Gillner, Sten, Bräuning, Achim, Roloff, Andreas, 2014. Dendrochronological analysis of urban trees: climatic response and impact of drought on frequently used tree species. Trees 28 (4), 1079–1093.
Goodman, Leo A., 1961. Snowball sampling. Ann. Math. Stat. 32 (1), 148–170.
Groffman, Peter M., Cavender-Bares, Jeannine, Bettez, Neil D., Morgan Grove, J., Hall, Sharon J., Heffernan, James B., Hobbie, Sarah E., et al., 2014. Ecological homogenization of Urban USA. Front. Ecol. Environ. 12 (1), 74–81.
Gronendyke, Katie, 2017. Baker-Polito Administration Celebrates Planting of 10,000th Greening the Gateway Cities Tree. November 13, 2017. Mass.Gov.. https://www.mass.gov/news/baker-polito-administration-celebrates-planting-of-10000th-greening-the-gateway-cities-tree.
Gürel, Emet, Merba, Tat, 2017. SWOT analysis: a theoretical review. J. Int. Soc. Res. 10 (51), 994–1006.
Harper, Rick, 2016. Perpetual Drought: The 'New Normal' for Urban Trees? September 6, 2016. UMass Center for Agriculture, Food and the Environment. https://ag.umass.edu/landscape/fact-sheets/perpetual-drought-new-normal-for-urban-trees.
Hauer, Richard, Petersen, Ward, 2016. Municipal Tree Care and Management in the United States: A 2014 Urban & Community Forestry Census of Tree Activities. Special Publication 16-1. University of Wisconsin – Stevens Point. https://www.uwsp.edu/cnr/Pages/Forestry—MTCUS.aspx.
Hosmer, David W., Lemeshow, Stanley, 2000. Applied Logistic Regression, 2nd edition. Wiley-Interscience Publication, New York.
Hunter, Mary Carol R., 2011. Impact of ecological disturbance on awareness of urban nature and sense of environmental stewardship in residential neighborhoods. Landsc. Urban Plan. 101 (2), 131–138.
Hyman, Herbert Hiram, 1955. Survey Design and Analysis: Principles, Cases, and Procedures. Free Press, Glencoe, Illinois.
Jack-Scott, E., Piana, M., Troxel, B., Murphy-Dunning, C., Ashton, M.S., 2013. Stewardship success: how community group dynamics affect urban street tree survival and growth. Arboric. Urban For. 39 (4), 189–196.
Jewell, Nicholas P., 2003. Statistics for Epidemiology. Chapman and Hall/CRC, Boca Raton.
Kearney, Anne R., 2006. Residential development patterns and neighborhood satisfaction impacts of density and nearby nature. Environ. Behav. 38 (1), 112–139.
Kirkpatrick, J.B., Davison, A., Daniels, G.D., 2013. Sinners, scapegoats or fashion victims? Understanding the deaths of trees in the green city. Geoforum 48, 165–176. https://doi.org/10.1016/j.geoforum.2013.04.018.
Koeser, Andrew K., Gilman, Edward F., Paz, Maria, Harchick, Chris, 2014. Factors influencing urban tree planting program growth and survival in Florida, United States. Urban For. Urban Green. 13, 655–661.
Konijnendijk van den, Bosch, Cecil, C., 2014. From government to governance: contribution to the political ecology of urban forestry. In: Sandberg, Anders L., Bardekjian, Adrina, Butt, Sadia (Eds.), Urban Forests, Trees, and Greenspace: A Political Ecology Perspective. Routledge, Florence, KY, pp. 35–47.
Krasny, Mariane E., Delia, Jesse, 2014. Natural area stewardship as part of campus sustainability. J. Clean. Prod. 106 (May), 87–96.
Kuchelmeister, Guido, 1998. Urban forestry in the Asia-Pacific region: status and prospects. Working Paper Series APFSOS/WP/44. Asia-Pacific Forestry Sector Outlook Study, Working Paper Series. Forestry Policy and Planning Division, Rome/Regional Office for Asia and the Pacific. FAO Forestry Policy and Planning Division, Bangkok.
Kummer, Corby, 2008. A Papaya grows in Holyoke. The Atlantic. 2008. https://www.theatlantic.com/magazine/archive/2008/04/a-papaya-grows-in-holyoke/306702/.
Locke, Dexter H., 2017. Tree canopy change in Coastal Los Angeles, 2009–2014. Cities Environ. (CATE) 10 (2). https://digitalcommons.lmu.edu/cate/vol10/iss2/3/.
Lotspeich, Charlie, 2009. Water power to the people of Holyoke. Valley Advocate (blog). 2009. http://valleyadvocate.com/2009/06/04/water-power-to-the-people-of-holyoke/.
McKendry, Corina, 2018. Greening Post-industrial cities: growth, equity, and environmental governance. Cities and Global Governance. Routledge, New York, NY.
Mincey, S.K., Vogt, J.M., 2014. Watering strategy, collective action, and neighborhood-planted trees: a case study of Indianapolis, Indiana, U.S. Arboric. Urban For. 40 (2), 84–95.
Moll, Gary, 1989. The state of our urban forest. American Forests.
Mortimer, M.J., Kane, B., 2004. Hazard tree liability in the United States: uncertain risks for owners and professionals. Urban For. Urban Green. 2 (3), 159–165.
Moskell, C., Bassuk, N., Allred, S., MacRae, P., 2016. Engaging residents in street tree stewardship: results of a tree watering outreach intervention. Arboric. Urban For. 42 (5), 301–317.
Moskell, Christine, Allred, ShornaBroussard, 2013. Residents beliefs about responsibility for the stewardship of park trees and street trees in New York city. Landsc. Urban Plan. 120 (4), 85–95.
Nguyen, Vi D., Roman, Lara A., Locke, Dexter H., Mincey, Sarah K., Sanders, Jessica R., Fichman, Erica Smith, Duran-Mitchell, Mike, Tobing, Sarah Lumban, 2017. Branching out to residential lands: missions and strategies of five tree distribution programs in the U.S. Urban For. Urban Green. 22, 24–35.
NOAA, (National Oceanic and Atmospheric Administration), 2018. Climate Data Online. 2018. National Climatic Data Center (NCDC). https://www.ncdc.noaa.gov/cdo-web/search.
Park, Mi Sun, Youn, Yeo-Chang, 2013. Development of urban forest policy-making toward governance in the Republic of Korea. Urban For. Urban Green. 12 (3), 273–281.
Patton, Michael Quinn, Patton, Michael Quinn, 2002. Qualitative Research & Evaluation Methods, Third Edition. Sage Publications, Thousand Oaks, California.
Pincetl, Stephanie, 2010. From the sanitary city to the sustainable city: challenges to institutionalising biogenic (Nature's Services) infrastructure. Local Environ.: Int. J. Justice Sustain. 15 (1), 43–58.
Pincetl, Stephanie, 2013. Urban ecology and nature's services infrastructure: policy implications of the million trees initiative of the city of Los angeles. Urbanization and Sustainability: Linking Urban Ecology, Environmental Justice and Global Environmental Change 3. Springer, Dordrecht, pp. 67 Human-Environment Interactions.
Plaisance, Mike, 2015. Holyoke Gets Municipal Tree Nursery With $100,000 Grant. Masslive.Com. https://www.masslive.com/news/index.ssf/2015/05/holyoke_getting_municipal_tree.html.
Pontius, Jennifer, Hallett, Richard, 2014. Comprehensive methods for earlier detection and monitoring of forest decline. For. Sci. 60 (6), 1156–1163.
QSR International Pty Ltd, 2016. NVivo Qualitative Data Analysis Software (version 11). Mac.
Quigley, Martin F., 2004. Street trees and rural conspecifics: will long-lived trees reach full size in urban conditions? Urban Ecosyst. 7 (1), 29–39.
Reid, David, 2002. Park guild objects to planned merger. The Republican, September 29, 2002. sec. News.
Ricard, Robert M., 2005. Shade trees and tree wardens: revising the history of urban forestry. J. For. 103 (5), 230–233.
Roman, Lara A., 2014. How many trees are enough? Tree death and the urban canopy. Scenario Journal (online publication). April 3, 2014. https://scenariojournal.com/article/how-many-trees-are-enough/.
Roman, Lara A., Battles, John J., McBride, Joe R., 2014a. The balance of planting and

mortality in a street tree population. Urban Ecosyst. 17 (2), 387–404.
Roman, Lara A., Battles, John J., McBride, Joe R., 2014b. Determinants of establishment survival for residential trees in Sacramento County, CA. Landsc. Urban Plan. 129, 22–31.
Roman, Lara A., Gregory McPherson, E., Scharenbroch, Bryant C., Bartens, Julia, 2013. Identifying Common Practices and Challenges for Local Urban Tree Monitoring Programs across the United States. https://www.nrs.fs.fed.us/pubs/45392.
Roman, Lara A., Scharenbroch, Bryant C., Ostberg, Johan P.A., Mueller, Lee S., Henning, Jason G., Koeser, Andrew K., Sanders, Jessica R., Betz, Daniel R., Jordan, Rebecca C., 2017. Data quality in citizen science urban tree inventories. Urban For. Urban Green. 22 (March), 124–135.
Roman, Lara A., Walker, Lindsey A., Martineau, Catherine M., Muffly, David J., MacQueen, Susan A., Harris, Winnie, 2015. Stewardship matters: case studies in establishment success of urban trees. Urban For. Urban Green. 14 (4), 1174–1182.
Romolini, M., Brinkley, W., Wolf, K.L., 2012. What Is Urban Environmental Stewardship? Constructing a Practitioner-Derived Framework. Res. Note PNW-RN-566. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 41 P 566, Portland, OR. https://doi.org/10.2737/PNW-RN-566.
Sjöman, H., Hirons, A.D., Bassuk, N.L., 2018. Improving confidence in tree species selection for challenging urban sites: a role for leaf turgor loss. Urban Ecosyst. 21, 1171–1188.
Skiera, B., Moll, G., 1992. The sad state of city trees. 1992. Am. For.
Sommer, R., Learey, F., Summit, J., Tirrell, M., 1994. Social benefits of resident involvement in tree planting: comparison with developer-planted trees. J. Arboric. 20 (6), 323.
StataCorp, 2009. Stata Statistical Software: Release 11. StataCorp LP, College Station, TX.
Tan, PuayYok, Jim, Chi Yung (Eds.), 2017. Greening Cities: Forms and Functions. Advances in 21st Century Human Settlements. Springer, Singapore.
The Delaware Center for Horticulture, 2017. 2017 CDBG Tree List. The DCH. 2017. https://www.thedch.org/content/2017-cdbg-tree-list.
Tikkanen, Jukka, Isokääntä, Tarja, Pykäläinen, Jouni, Leskinen, Pekka, 2006. Applying cognitive mapping approach to explore the objective–structure of forest owners in a northern finnish case area. For. Policy Econ. 9 (2), 139–152.
U.S. Census Bureau, 2018. QuickFacts: Holyoke City, Massachusetts. 2018. https://www.census.gov/quickfacts/fact/table/holyokecitymassachusetts/PST045216.
U.S. Drought Monitor, 2017. Time Series: Hampden County. 2017. http://droughtmonitor.unl.edu/Data/Timeseries.aspx.
USDA, (U.S. Department of Agriculture, Forest Service), 2018. Plant Hardiness Zone Map. 2018. http://planthardiness.ars.usda.gov/PHZMWeb/.
Vermont Urban and Community Forestry, 2012. Vermont Tree Selection Guide. https://vtcommunityforestry.org/resources/vermont-tree-selection-guide.
Vogt, Jess, Hauer, Richard J., Fischer Burnell, C., 2015a. The costs of maintaining and not maintaining the urban forest: a review of the urban forestry and arboriculture literature. Arboric. Urban For. 41 (6), 293–323.
Vogt, Jessica M., Watkins, Shannon Lea, Mincey, Sarah K., Patterson, Matthew S., Fischer, Burnell C., 2015b. Research paper: explaining planted-tree survival and growth in urban neighborhoods: a social–ecological approach to studying recently-planted trees in Indianapolis. Landsc. Urban Plan. 136, 130–143.
Westphal, Lynne M., 2003. Urban greening and social benefits: a study of empowerment outcomes. J. Arboric. 29 (3), 137–147.
Widney, Sarah, Fischer, Burnell C., Vogt, Jess, 2016. Tree mortality undercuts ability of tree-planting programs to provide benefits: results of a three-city study. Forests 7 (3), 65.
Yin, Robert, 2009. Case Study Research: Design and Methods Vol. 5 SAGE Publications, Inc, London Fourth.
Young, Robert F., 2011. Planting the living city: best practices in planning green infrastructure - results from major U.S. cities. J. Am. Plan. Assoc. 77, 368–381.