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The Impact of Tree Planting Program Governance Structure on Tree Survivorship and Vigor: A Case Study using the Massachusetts Greening the Gateway Cities program.

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Abstract

Trees in urban neighborhoods benefit residents by reducing building energy costs, providing cleaner air, decreasing surface runoff, and improving quality of life. However, tree canopy cover is not evenly distributed across neighborhoods in many mid-sized American cities which leads to higher air and surface temperatures, and increased energy bills for residents who are the most economically vulnerable. The state of Massachusetts (USA) created the Greening the Gateway Cities (GGC) program to increase tree canopy cover by 10% in post-industrial, midsized cities with lower educational attainment and lower income than state averages. The study posed two questions: what is the governance structure of the GGC program? How successful is the program using annual survivorship and vigor of the trees? This research examines the GGC program as a case study for a governance structure that fosters connections between the city, community and residents can create the social and environmental infrastructure to support increased tree canopy in urban neighborhoods. Data was collected in four gateway cities in Massachusetts: Chicopee, Fall River, Holyoke and Chelsea. 49 residents who received trees as part of the program were interviewed as well as two DCR foresters, three city planners, one head of the city's community maintenance (Department of Public Works), and two paid staff and three volunteers of community partners. These interviews informed the creation of a governance framework for the GGC program. Tree survivorship, annual mortality and vigor of 3459 trees were used to measure the initial success of the planting program and to forecast potential benefits to residents. Results show how the GGC planting program can produce increased sense of ownership between cities, communities and individuals in the planting zones. The governance model, with an emphasis on stewardship, showed high rates of annual survivorship (~96.5%), low annual mortality rates (~3.5%) and average vigor rating of 1.5 (1 being healthy, 5 being dead).

Introduction

Urban forests provide crucial environmental services to urban populations globally. In Massachusetts, impervious surfaces in urban areas increased between 2009 and 2014 while tree canopy cover decreased (Nowak and Greenfield 2018). The increase in impervious surface is concerning because urban trees along streets, in parks, and on residential and commercial private property provide energy benefits, stormwater runoff reduction, aesthetic benefits, carbon storage, reduce the urban heat island effect, clean the air, increase home values and build a sense of community in the neighborhood (McPherson and Rowntree, 1993; Nowak and Dwyer, 2007). These ecosystem services will become more valuable as urban populations continue to grow but tree survival is consistently threatened by nonnative species, development and poor management (Steenburg et al 2016, 2018).

Ecosystem services procured by trees are fully realized when juvenile trees become established (i.e., after 5-10 years). Models of future ecosystem services often assume 100% survivorship when this is rarely the case. A meta-analysis by Roman et al. (2011) shows a median annual survivorship of 95% which predicts

the population half-life would be between 13-20 years. Evaluation of tree planting programs needs to include annual survivorship in order to more accurately capture the potential future ecosystem benefits (Roman et al. 2016). As tree planting is not free, many programs need to demonstrate a return on investment to secure future funding (Pincetl et al. 2013). The success of programs is therefore inextricably tied to the annual survivorship rate which determines if trees will grow to be large enough to provide ecosystem services. However, the factors that influence survivorship range from the biophysical (climate, soil type) to the human (stewardship, land use) (Elmes et al. 2018, Steenberg 2018, Roman et al. 2018). In urban forestry, the governance structure of a tree planting program can mitigate negative factors influencing survivorship.

The study analyzed the governance model of the planting program with a focus on stewardship to gain an understanding of how a tree planting program can spur future sustainable urban forestry. It is necessary to define the key phrases as terminology such as sustainability, governance, and stewardship and as they apply to urban forestry (Clark et al., 1997). Clark et al. (1997) define sustainability as the maintenance of tree benefits in the present and for the future. Sustainable urban forestry is achieved through proper governance as defined by Tacconi (2011, p. 240) as:

> *"The formal and informal institutions, rules, mechanisms and processes of collective decision-making that enable stakeholders to influence and coordinate their interdependent needs and interests and their interactions with the environment at the relevant scales."*

In this paper, governance was framed by the stakeholder's roles in the tree planting program that influence the collective and individual decision making. This definition of governance incorporates differences of scale, power, and knowledge between stakeholders (Lawrence et al., 2013). This paper uses annual survivorship of different tree cohorts to judge the outcomes of the GGC program's governance model. Annual survivorship is associated with stewardship practices (Roman et al. 2015). Stewardship, according to Roman et al. (2015, p. 1176), is "community tree care practices and associated program operations." In this case, special focus will be paid to stakeholder's feelings of responsibility for stewardship and ownership of the trees. A governance model with an emphasis on stewardship will foster sustainable urban forestry management. It was necessary to include a definition of sustainability that is directly applicable to urban forestry as urban tree planting programs goals have more in common with natural resource management than conservation. The hypothesis is that the Greening the Gateway City's emphasis on tree stewardship will not only increase survivorship rates but also foster stakeholder's commitment to sustainable urban forestry.

Literature Review

This study uses the Greening the Gateway Cities program (GGC) in Massachusetts (USA) as a case study to research a tree planting program's governance and tree survivorship. Tree planting programs such as the Greening the Gateway Cities program (GGC) provide an opportunity to build the necessary networks in communities where planting is taking place to support stewardship of planted trees (Summit and Sommer 1998). Tree planting requires coordination between city government, nurseries, foresters, and residents (McCarmichael and McDonough 2018, Nesbitt et al. 2018). Therefore, tree planting programs have the potential to increase the density of trees and create lasting relationships within the community. These two goals are not mutually exclusive, the trees need a clear governance model to survive in urban environments, especially in the first five years of establishment. Resident attitudes and participation play

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a huge role as most of the potential planting area in cities is in front or backyards (O'Neil-Dunne 2012). If residents view the trees as a burden or a threat, they are less likely to participate in a neighborhood planting program (Conway and Yip 2016, McCarmichael and McDonough 2018).

The networks between different stakeholders involved in urban forestry reflect existing power structures (Fors et al 2015). For this reason, urban forestry reveals relationships and common interests that might be otherwise go unnoticed (Nesbitt et al. 2018). Urban forestry is complex because tree canopy cover is a result of decisions at very different organizational scales such as federal, state, municipal or individual (Sheppard et al. 2017). A stakeholder such as the city will have goals which can be at odds with residents' goals because each group approaches urban forestry with different motivations and perspectives. Residents are often unaware of planting programs or the benefits of trees (Conway 2016). NGOs and city planning departments are often fixed on the energy benefits while neglecting to factor in residents' interest in aesthetics or concern for tree debris. The ability of a tree planting program to generate appeal to a variety of stakeholders will influence the success of the planting initiative.

Nevertheless, urban trees are not universally embraced by residents in city neighborhoods (Carmichael and McDonough 2018). Trees can provide a variety of disservices, especially when the wrong tree is planted in the wrong place. Trees can damage buildings, grey infrastructure, create debris, and cause physical harm during storms (Conway and Yip 2016). Residents are aware of the disservices and costs related to trees in the city (Conway and Yip 2016,). Many of the disservices can be avoided by following right tree, right place guidelines, consistent transparent communication and regular maintenance (Carmichael and McDonough 2018). When residents have stable homeownership, there is also a correlated increase in tree survivorship (Roman et al. 2014). If residents and companies take on ownership over their trees, there is a potential for a sustainable urban forest (Sommer et al. 1994).

An urban tree planting program's success has been measured traditionally by the number of trees planted like in Million Trees NYC or Million Trees LA (Roman 2014). However, Roman et al. (2015) suggests that tree planting programs should be measured by their annual survivorship rates which determine the potential future benefits and ecosystem services for residents. Annual survivorship rates are inextricably linked by tree stewardship. Therefore, large tree planting programs need to ask themselves how their governance models can foster stewardship by participants. Residents' cultural preferences for trees and socioeconomic status can limit planting options and stewardship (Avolio et al. 2015). However, Nguyen et al. (2017) argues that studies must study the governance of the planting programs that contribute to maintenance post planting. The problem with current evaluation of tree planting programs success is a lack of research on the governance structure after planting has finished. A sustainable tree planting program would provide adaptive management for continued long term community involvement with the trees that were planted (Clark et al. 1997).

Objectives

This study aimed to answer two questions, what is the governance structure of the Greening the Gateway Cities (GGC) program in Chelsea, Chicopee, Fall River and Holyoke, what were the conditions of the trees and what biophysical or human factors might provide context to the condition of the trees. The first research objectives were to interview all stakeholders involved in the GGC and outline their roles in the program. The second research objective was to conduct a tree survey of all the trees planted to assess survivorship and tree health as outcome measures of evaluation of good governance (Lawrence et al., 2013).

Methods

Study Area

The Massachusetts Greening the Gateway Cities (GGC) program offered the opportunity to study how the creation of a network can influence the survivorship and vigor of juvenile trees. Data for this study was collected in 4 mid-sized post-industrial cities in Massachusetts that were participating in the GGC program: Chelsea, Holyoke, Chicopee and Fall River (Figure 1). Run by the Massachusetts Department of Conservation and Recreation (DCR), the GGC is planting trees in select neighborhoods in midsized post-industrial cities to increase tree canopy by 10%. These 'gateway cities' have populations between 30 and 250 thousand, lower levels of educational attainment and household income than state averages.

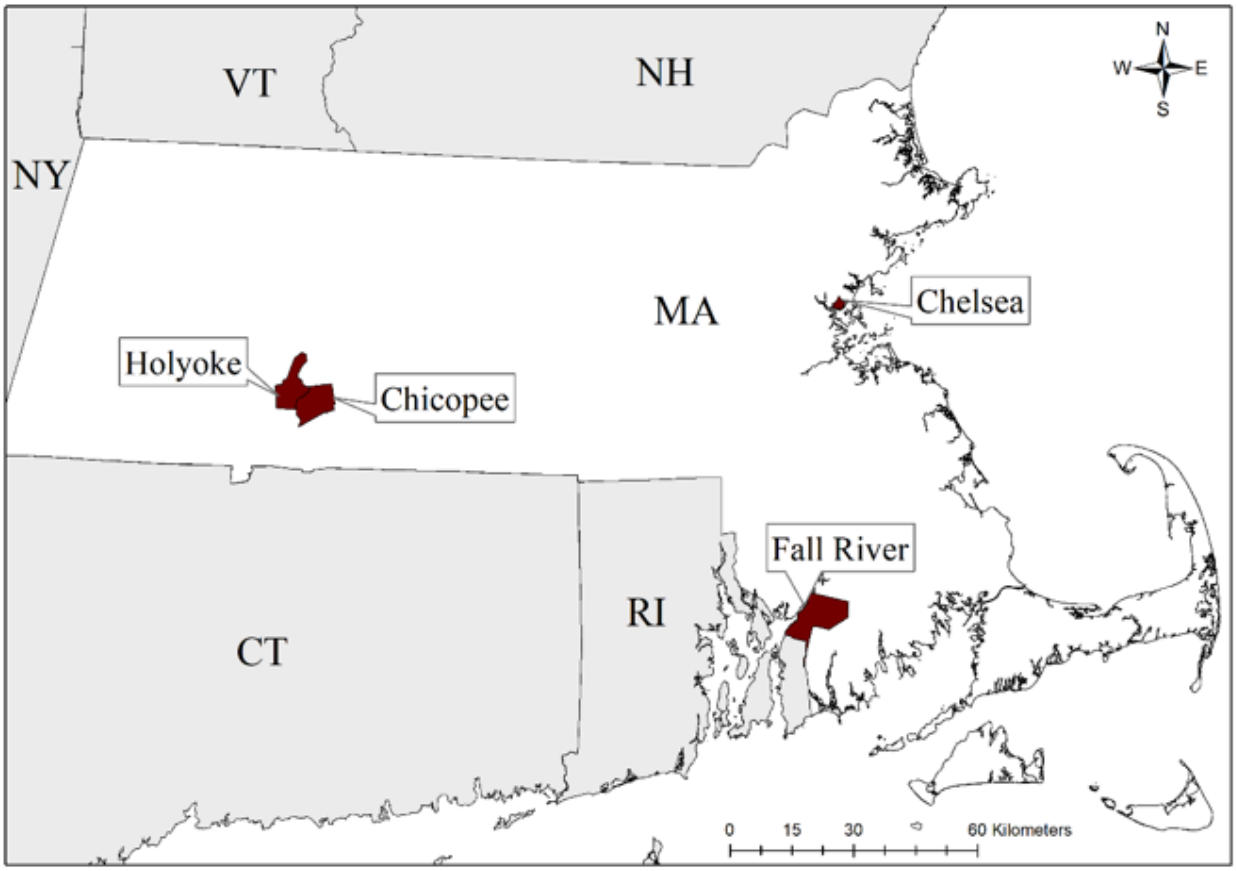

Figure 1: The spatial location of the four different gateway cities that are were studied in Massachusetts.

Planting zones were selected by current total canopy cover, renter population, wind speed, and age of building stock (Figure 2). The DCR used census data and existing tree canopy cover maps to create their planting zones. Finally, planting zones were modified to fit existing political neighborhood boundaries to facilitate communication between residents around who would be eligible for a free tree and who wouldn't be. The GGC program runs in each gateway city for three years. The first year involves promoting the benefits of tree planting and building community support. The second year focuses on tree planting. The third year continues tree planting but transitions to coordinating with the community to support tree maintenance. All the trees that are planted are chosen as a result of conversations between DCR foresters

and residents. The trees are planted by DCR employees at an approximate caliper of 1.5 inches for private trees and 2-3 inches for public trees. The program aims to plant 80% of their trees on residential property where there is the most planting area available and the trees will be hypothetically more protected. The DCR hires planters local to the city they are working in and hopes to leverage those connections to reach additional residents.

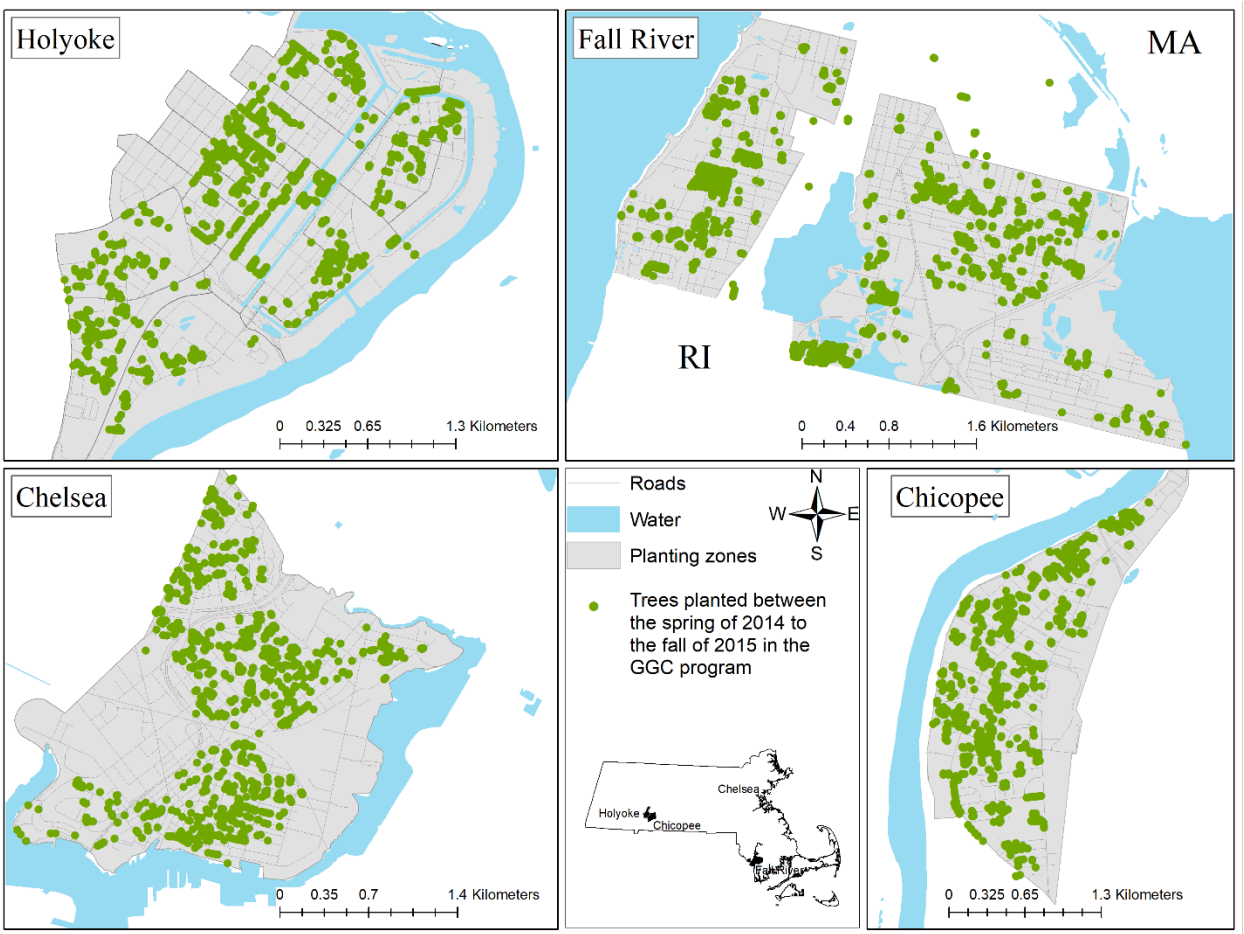

Figure 2: The planting zones in each city along with trees planted. The planting zone in Chelsea encompassed the entire city as it is much smaller than Chicopee, Holyoke, and Fall River.

Unit of Analysis

The unit for analysis in this study is trees planted. The study aimed to measure close to a census of all trees planted in the four cities in the study area. In addition to the tree survey, relevant stakeholders in the GGC were interviewed in order to map the network that the program creates. Interviews were categorized as residents, community organizations, city officials, and DCR foresters. Certain individuals filled multiple roles such as resident and community organization but were interviewed twice for their respective positions in the network.

Sampling Design

The tree survey data was collected in the GGC planting zones in Holyoke, Chelsea, Fall River and Chicopee. All publicly available trees were surveyed. Residents were called beforehand for permission to measure trees on their property. Residents who were unreachable by phone were visited in person to

ask if their trees could be measured. An effort was made to measure all the trees in each planting zone but not all trees were accessible, and permission was not always given. Field work was conducted in May and June of 2017 and 2018. Trees were recorded according to their vigor which combined leaf and wood condition into one metric (Berrang et al 1985). Notes were taken of any basal sprouting or other potential signs of stress or pests. Land use, site type, Diameter at Breast Height (DBH) and canopy width were also measured. It was noted if a tree was removed, missing, standing dead, or a stump. From the species, the native status of the tree and the type of the tree (shade, ornamental, fruit, evergreen) was determined.

Staff of the DCR, city officials and community organizations involved with the GGC were identified using snowball sampling. The roles of the DCR were consistent in each of the cities as well as the city officials. The staff of community organizations varied as the GGC partnered with a variety of community organizations from tree specific volunteer-based groups to community service organizations that provide housing, adult education and food assistance among other community programs. The roles of the interviewees varied; two DCR foresters, three city planners, one head of the city's community maintenance (Department of Public Works), and two paid staff and three volunteers of community partners.

Residents who took more than five trees were solicited by phone for interviews in all five cities. As trees were surveyed, residents who were home were also solicited for interviews. This method resulted in a bias of residents who were home during the day. Residents interviewed were generally older, homeowners, educated, female, spoke English at home and identified as white. 43 residents were interviewed in total with at least one resident interview in four of the cities.

Audio-recorded interviews with the DCR, city officials, community organizations and residents occurred in the summer of 2017 and the summer of 2018 in May, June and July. Tree survey data was collected during the same time period. The DCR, city officials and community organizations were solicited at several events such as the 1000th tree planted event in Chicopee or the Fall River Annual Event (Arbor day). Data collected from stakeholders included: (1) their personal goals in relation to the GGC (2) challenges for their organization in relation to GGC and (3) impact of the GGC on their organizations network. Residents were solicited as part of the tree survey whenever possible. Data was collected on: (1) stewardship of their trees (2) their communication with the GGC, DCR, city, and community organizations and (3) impact of the planted trees on their community (benefits, network, disservices).

Analysis

Tree survey data was analyzed using the same equations for annual mortality (m_{annual}), survivorship (l_{annual}) as Roman (2011) which are based off of demography and population ecology. The equation for annual mortality is $m_{annual} = 1 - (N_t/N_0)^{1/t}$ (Roman et al. 2011). For the purpose of this analysis, "N_0 is the number of trees planted at year and season of planting (tp) and N_t is the number of trees alive at the end of time interval (t)" (Roman et al. 2011 pp 270). Additional variables measured to explain survivorship are tree vigor (V) as well as biophysical (regional temperature and precipitation trends) and institutional (stakeholder interviews) factors.

Interview data was transcribed and coded in Nvivo, a data analysis software for qualitative data, along with field notes when appropriate. Codes were created based on interviewers' perceptions of major themes and then tested by two different researcher assistants on an example test interview. Codes were refined iteratively over multiple interviews until no new themes emerged. Sub-codes were added to differentiate

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specific themes to DCR, city and community organizations. The first author and a research assistant each coded multiple portions of the same interviews to ensure reliability.

Results

Greening the Gateway City Survivorship by City

The survivorship analysis is broken into three different sections by city, by season and then by city and season. The GGC program started in Holyoke, Fall River and Chelsea before expanding to Chicopee. As such many of the trees planted in 2014 and 2015 are in Chelsea and Holyoke while Fall River and Chicopee trees were planted in 2016 and 2017. A higher number of trees were measured in Fall River and Chicopee, with each city having the highest survivorship at 91 percent with an annual survivorship of 96 percent. Chelsea's overall survivorship is lower (86%) but as the trees are generally older, the annual survivorship rate is approximately the same as Fall River and Chicopee (Figure 3). Holyoke had a much lower annual survivorship of 92 percent, double the amount of annual mortality than other cities (Figure 3). This is accompanied with a worse average vigor (*V*). The lower survivorship in Holyoke could be an indication of a difference in stewardship.

City	# Trees (N_0)	# Trees Alive in 2017-2018	Survivorship % (l_t)	Annual Survivorship % (l_{annual})	Annual Mortality % (m_{annual})	Average Vigor (*V*)
Chelsea	417	360	86.33	95.22	4.78	1.99
Chicopee	922	846	91.76	95.79	4.21	1.45
Fall River	1336	1227	91.84	95.83	4.17	1.51
Holyoke	779	609	78.18	92.12	7.88	2.35

Figure 3: Survivorship, annual survivorship, annual mortality and average vigor for the 4 cities. Time since planting (t) was averaged to 3 years for Chelsea and Holyoke and 2 years for Fall River and Chicopee as this was the average age of the trees in those cities.

Interviews of Greening the Gateway Cities Stakeholders

The results from interviews with DCR officials (N = 2), city departments (4), community partners (5) and residents (43) reveal how the DCR is the focal point in planning, planting, communication and stewardship. One example is a city official in Chicopee described the city's interaction with the DCR as "[The DCR] have been doing a very good balance of planting on private property with the [GGC] program which is really what they are tasked to do and finding places where they can work with the city and do street trees as well". The DCR relationship with residents is well summarized by this Chelsea resident, "[The DCR] told me how to take care of them, give them so much water a week and stuff like that" and "The DCR gave me information. I call the DCR whenever I have questions, and they come by to help out and share information". Finally, the DCR worked with community partners to market the program as a Chicopee resident attested to "Through our neighborhood association, we found out about the free trees being given away, so that's how we got involved". In Fall River these connections were built on previous work by specific individuals "Jenn Smith actually worked quite hard to get [the Fall River Street Tree Planting Program (FRSTPP)] established" and "Jenn Smith came to our neighborhood meeting. We have a neighbor meeting once a month she explained to everyone about the free trees you can get." In the GGC,

the DCR stewards the city trees and residents steward private trees, "I water in the morning, and water when the sun comes down. Two times a day. I give them probably about three to five gallons each" (Chicopee resident). In Figure 4, each stakeholder in the program is listed with a list of their responsibilities. Solid arrows represent the primary relationships built by the program to residents, businesses, community partners and city government. These are supported by secondary relationships, represented by dotted lines, which as a result of the program bring together otherwise isolated groups. It is important to note that the DCR is the only group planting trees in the program while other stakeholders assist in planning, communication and stewardship.

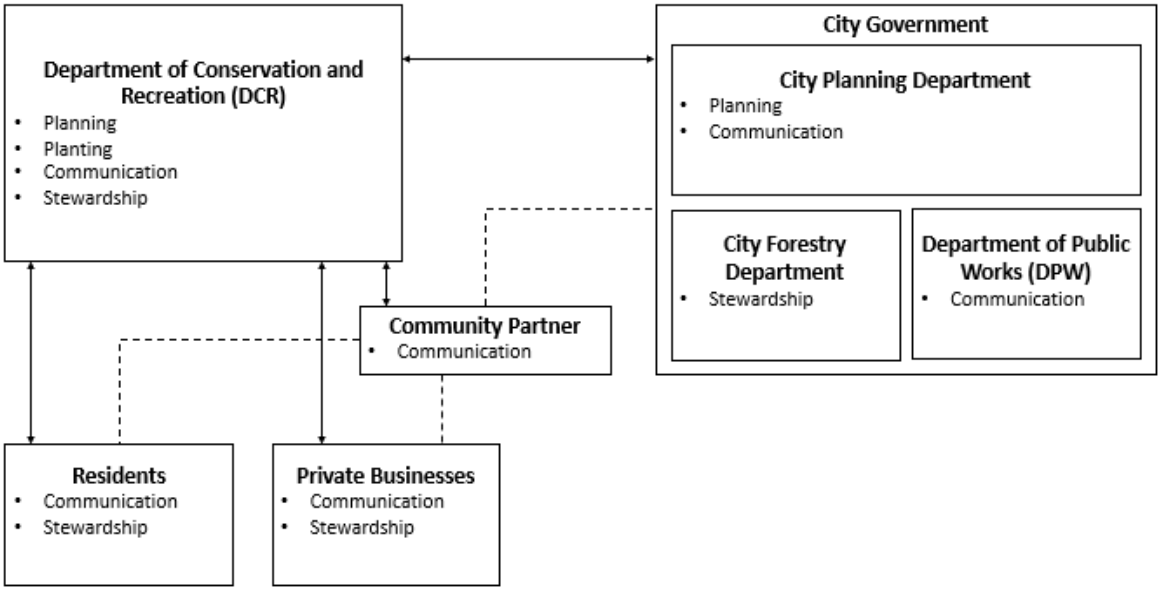

Figure 4: The stakeholders are outlined in Figure 4 along with their respective roles in the tree planting program. Bold arrows are the primary interactions established by the GGC program. Secondary interactions which either preexisted the program or were created as a result of the program are dotted lines.

Discussion and Conclusion

The first aim of this paper was to visualize the governance network connecting different stakeholders Greening the Gateway Cities program and outline their respective roles. The network in Figure 4 displays an aggregation of the program in each city however each city is not the same. The DCR made decisions reflexively when cultivating relationships between the city, residents, businesses and community partners. "[Community partner] did not have anything to do with tree planting or natural resources but it did coincide with their efforts in that they do a fuel assistance program. So, having trees planted on your property would help save you money on heat… So [the community partners] are realizing a lot of their programs are coinciding with our programs." In this quote, the DCR is educating the community partner in order to empower them in the future, aligning their interests at relevant scales. The DCR performed similar outreach to individuals and businesses. In each case, the DCR would use their influence and power to coordinate the GGC with resident, business and city at the appropriate scales (individual backyard, city street, neighborhood energy benefits). In return, the DCR would receive two-year commitments by

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stakeholders of stewardship, especially by residents and private businesses. This give and take is represented by the double arrows in Figures 4 and 5.

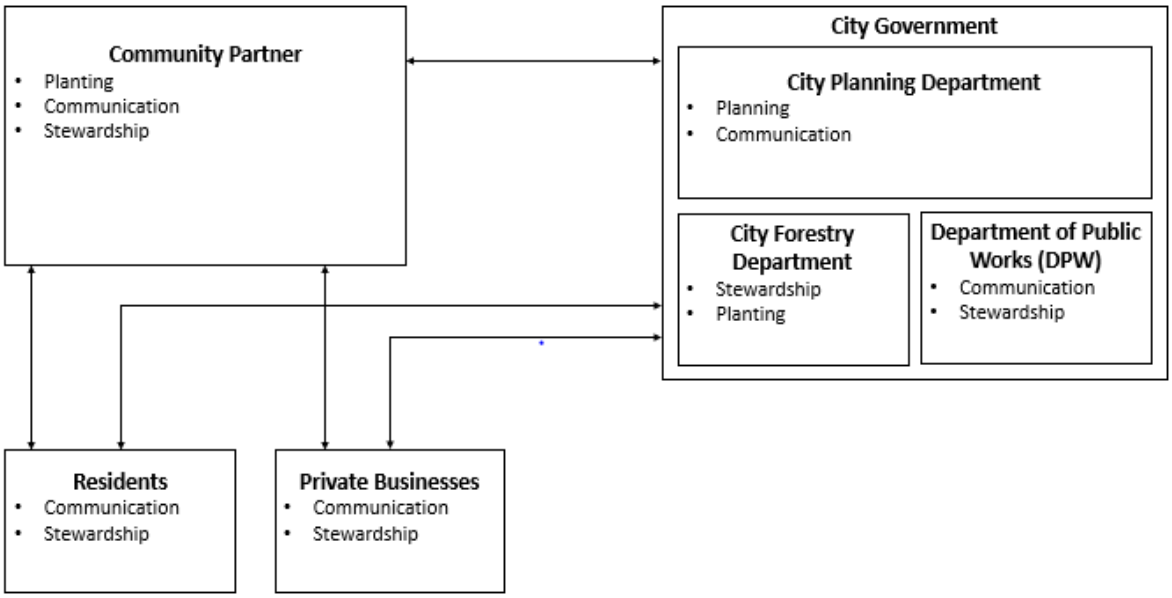

Figure 5: This figure depicts a future scenario after the DCR is no longer a stakeholder in the urban forestry in the cities. This scenario is currently true for areas outside of the DCR planting zone. In this scenario, community partners, city government, private businesses and residents all take an active role in communicating with each other and stewardship of the urban forest. City government and the community partner assume the DCR's role of planning and planting.

The secondary connections make the GGC governance model unique and provide potential for a local sustainable tree planting program after the DCR moves to other cities. The sustainability in each city depends on the secondary connections in Figure 4. In order to have a long-lasting effect in the neighborhoods and gateway cities the DCR is working in, the community partners and city's need to assume more roles, "[The GGC] program helped inspire [the city forester] to start his nursery and a planting program for residents in Holyoke not in our zone" (Figure 5). For example, either the community partners or the city forestry department will need to begin planting and stewardship (or both). The city planning department will need to work with community partners and residents to plan future plantings. Finally, all stakeholders will need to coordinate stewardship of trees. The secondary connections established by the GGCP between residents, community partners and city government will need to be established as explicit longstanding relationships, with an emphasis on stewardship, by the end of the GGC.

This study's second aim was to evaluate the success of the GGC's governance model program using tree survivorship, especially of the oldest cohort which are nearly 5 years old. The GGC is very successful judging by tree survivorship in the three of the four cities. In a meta-analysis of tree planting programs, Roman (2011) finds a median annual survivorship rate of 95%, with 75% of studies above 91% and 25% of studies with an annual survivorship higher than 97%. Of the 4 cities that were studied, the average annual survivorship rate was slightly above 95%. Fall River had the highest annual survivorship rates of 95.83%. Holyoke's lower survivorship reflects a potential breakdown in the interactions between stakeholders which would result in lower stewardship. The decrease in stewardship is visible in the worse

vigor scores of Holyoke compared to the other cities. The average vigor of 2.35 is almost 1 point higher than neighboring Chicopee of 1.45 (1 being healthy, 5 being dead). Prior research has shown stewardship to have a significant, positive impact tree vigor (Vogt et al. 2015). The low tree vigor in Holyoke is an indication for the breakdown in stewardship. More research is needed to determine whether the breakdown in the GGC governance model occurred between the DCR and businesses, residents, the community partner or the city government. However, the emphasis on stewardship in Chicopee, Fall River and Chelsea as well as the consistency in the planting process are two of the biggest reasons for the high annual survivorship rates the GGC.

In conclusion, the GGC program's governance structure of managing the planting and supporting the stewardship, planning, and communication is successful at creating long term sustainable tree planting in the gateway cities by establishing secondary connections focused on city greening between city government, community partners and residents. Other tree planting programs in the USA and internationally need to use their knowledge and power to educate other stakeholders in order to align their mutual interests in exchange for commitments to stewardship. The success of the GGC's governance is seen in the high annual survivorship rates of trees planted, especially the oldest cohort of trees in 2014. High annual survivorship rates bode well for the trees potential to reach maturity and provide the energy and social benefits the DCR is aiming to achieve.

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