AN ABSTRACT OF THE THESIS OF

Joshua S. Petter for the degree of Master of Science in Forest Ecosystems and Society presented on May 25, 2018.

Title: Tree Species Selection Across Municipalities in the Pacific Northwest

Abstract approved:

Paul D. Ries

There are many benefits provided by trees in urban areas. While there are many recommendations on maximizing the returns from urban trees, there has been little research examining how these managers are prioritizing their tree species selection. A survey instrument was constructed to survey Tree City USA designated cities across the Pacific Northwest. Two components of this survey instrument were analyzed in greater detail and are presented in manuscript format. The first manuscript focuses on how International Society of Arboriculture certification and municipality size influence tree species selection criteria. These were analyzed using Mann-Whitney U tests. The second manuscript focused on which tree species that the managers are planting and how current research is being operationalized across these municipalities. It was determined that both ISA Certified Arborists® and large municipalities are more likely to consider existing tree species diversity to be important. ISA Certified Arborists® are also less likely to plant native tree species than those that are not certified. However, ten municipalities reported planting ash among their top five most commonly planted tree species in 2016. Other municipalities are also planting tree species that are a cause for concern. There is ample room for increasing educational opportunities and regional cooperation.

Tree Species Selection Across Municipalities in the Pacific Northwest

by
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A THESIS

Submitted to

Oregon State University

In partial fulfillment of
the requirements for the
degree of

Master of Science

Presented May 25, 2018
Commencement June 2018

Master of Science thesis of Joshua S. Petter presented on May 25, 2018.

APPROVED:

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Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Joshua S. Petter, Author

ACKNOWLEDGEMENTS

The Author expresses sincere appreciation for help in the development of this thesis and academic success to Paul Ries, committee, family, and friends.

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Chapter 1: Introduction:

Trees in urban areas provide a wide array of benefits to people; these trees help make cities more beautiful and sustainable (Nowak, Crane & Dwyer, 2002). They provide an array of social, ecological, and economic benefits for the residents of cities and those benefits are increased when appropriate tree species are selected (McPherson & Simpson, 1999). There are many reasons to select a tree, but too often the incorrect tree species is planted. Trees that outgrow their location become hazardous and do not provide the desired benefits (Escobedo, Kroeger, & Wagner, 2011). Selecting the right tree for the right location can help maximize the social, ecological, and economic benefits provided by trees. While there are several other sectors that also influence the composition of the urban forest (e.g. nonprofits, nurseries, and private residents) this study is limited to the scope of the public sector. The trees planted in the public sector can play an important role in providing benefits for those who cannot afford them, as well serve as an educational tool to influence private tree selection.

1.1 Importance of trees

As the global population continues to increase and approaches 9 billion people in 2050, there will be a drastic increase in the number of urban residents (Roberts, 2011). It is expected that urban area will nearly double from 2000 to 2050, which will put additional pressure on existing forests to provide vital ecosystem services (Nowak & Walton, 2005). Urban trees can play a role in the reduction of air pollution (Escobedo & Nowak, 2009), carbon sequestration (Nowak, Stevens, Sisinni & Luley, 2002), and health of residents (Matsuoka & Kaplan, 2007). Studies in the Pacific Northwest (PNW) indicate that reducing impervious surfaces and increasing tree cover can mitigate stormwater issues and help improve salmon habitat (Booth, Hartley & Jackson, 2002; Hottenroth, Harper & Turner, 2002). The types of tree species, the form, and general structure of the urban forest all seem to play into the overall benefits found in the urban forest (Roy & Pickering, 2012). Selecting the right tree for the right place can lead to longer lived trees (McPherson & Simpson, 1999), increased energy savings (Sawka, Millward, Mckay & Sarkovich, 2013), and a reduction in maintenance costs (Escobedo, Kroeger & Wagner, 2011). The built infrastructure, such as buildings and roadways, play a key role in influencing urban climates. Often the constructed components lead to a hotter climate, referred to as the urban heat island effect. Trees can play a key role in reducing the urban heat island effect, particularly if they are selected to maximize coverage of reflective surfaces (Sieghardt et al., 2005). In addition to the ecological benefits provided by trees there are a number of social benefits including: reduced crime, increased social interactions, and greater use of communal space (Kuo, 2003).

Various pathogens and pests can cause substantial damage to urban forests, which result in municipalities assuming high removal costs in a relatively short period of time. (Raupp, Cumming & Raupp, 2006). The emerald ash borer (EAB) is one of the most concerning pests threatening the urban forest. The large-scale decline of ash trees, and the rapid expansion of this pest are resulting in the removal of ash and a reduction in planting of ash across many municipalities (Polland & McCullough, 2006). Even in the absence of introduced pests urban trees are subjected to greater stress due to things such as limited soil volume, pollutants, and infrastructure conflicts (Nowak, Kuroda & Crane, 2004). Diversification of the urban forest is thought to help mitigate the issues associated with pests, particularly those that are unanticipated (Santamour, 1990). However, there are some that argue urban trees should be selected primarily based on proven ability to survive in the harsh urban environment (Richards, 1983).

As more data is acquired regarding urban trees there has been an increase in the use of modeling to minimize conflicts and maximize benefits provided by the urban forest. Laćan & McBride (2008) developed a model to explore the potential risks of introduced pests and develop strategies to mitigate those risks. Models can also be used to assess the vulnerability of urban areas to the broad-scale loss of ecosystem services; constructing clear indicators and monitoring them can help inform management decisions (Steenberg, Millward, Nowak & Robinson, 2016). Urban forests may or may not be able to retain their form amid changing social and environmental factors. Humans play a large role in influencing how these forests change and should be proportionately taken into account when modeling the changes of urban ecosystems (Alberti & Marzluff, 2004). The scale of management in urban areas is important when considering how to increase biodiversity. There are a diverse group of stakeholders and different managing bodies. While it is necessary to look at the entire picture to increase biodiversity on a broad scale, the individual property owners also have an impact on vegetation structure and species composition (Savard, Clergeau & Mennechez, 2000). While this paper focuses on tree species on public land, private citizens have a stake in how that land is managed.

1.2 History of urban forest management and arboriculture

There has been active management of urban trees in the U.S. since the late 1700s and early 1800s (Gerhold, 2007). Tree wardens were some of the first managers of public trees, and were first appointed in Massachusetts. These professionals are still responsible for managing public trees across much of New England, and acquire information in a variety of ways. They are highly engaged in interactive learning, conferences, and communication with other professionals (Ricard & Bloniarz, 2006). Research and education in the field of urban forestry have helped shape the field. The older techniques, such as painting tree wounds, have fallen out of favor and are being replaced by scientifically sound practices (Gerhold, 2007).

Humans are an inherent part of urban ecosystems and are a major factor in how that ecosystem operates. Accounting for the entire life-cycle of each component of the urban environment, coupled with an increase in multi-disciplinary planning can lead to more sustainable municipalities (Pincetl, 2012). Unfortunately, one of the major challenges municipalities face is lack of funding; this may be partly explained by authorities not being fully aware of the various benefits provided by trees (Kronenberg ,2015). Furthermore, this is somewhat complicated by residents' perceptions of good management. Many people desire highly managed forests, and dislike dead wood, which may conflict with some ecological management goals (Tyrväinen, Silvennoinen, Kolehmainen, 2003). Aesthetics are a major factor in private tree species selection, however, there is a variety of preferred aesthetics. There is also generally a lack of understanding regarding tree biology which contributes to a discrepancy between citizen preference and public management (Conway, 2016). More recently many of the concepts of urban forestry have been situated into the broader framework of green infrastructure. This is essentially an effort to increase the connectivity of green spaces in order to provide a healthier and more habitable living environment. It strives to incorporate interdisciplinary research and adaptable goals in order to further sustainable municipalities (Tzoulas et al., 2007).

Urban foresters are required to manage both trees and people. Managers must be able to balance both social and ecological criteria in order to successfully manage an environment as dynamic as an urban forest. While there tends to be a focus on things such as pruning and species identification, education and outreach are often overlooked (Elmendorf, Watson & Lily, 2005). Management and funding of urban forestry programs (e.g. tree planting and pruning) can vary considerably based on municipality size (Kenney & Idziak, 2000). Los Angeles and New York City have adopted aggressive tree planting policies to increase ecosystem services and improve quality of life. However, there are many other factors to consider (e.g. planting space, environmental justice, maintenance costs) in order to maximize the benefits of trees (Pincetl, Gillespie, Pataki, Saatchi & Saphores, 2013). Often these tree planting programs are more successful if they involve citizen participation (Summit & Sommer, 1998). There are a variety of professional organizations related to urban forestry; the Society for Municipal Arborists (SMA) was founded to address issues related to urban forestry. Members of this organization think that ecosystem services are important management objectives in their municipalities, and will become increasingly important (Young, 2010). Some studies use empirical evidence to highlight the benefits of certification through the International Society of Arboriculture (ISA) (Carlson, 1995; Green, 2002). Few, if any studies have explicitly examined how ISA certification influences urban forest management. However, many job descriptions require it as a prerequisite.

1.3 Equitable planting of trees

Many municipalities utilize canopy cover as an indicator of their urban forest health, but this should not be the only thing they monitor (Kenney et al., 2011). In addition to canopy cover, many other urban forest management plans focus on tree diversity and maintenance activities such as pruning. While many plans incorporate additional goals, they can be ambiguous with poorly defined measurement criteria. A reoccurring problem is the absence of a parameter for equitable distribution of canopy cover. Often canopy cover goals state percentages or number of trees needed to be planted, but do not outline a plan for increasing canopy cover in areas with few trees. This results in high concentrations of trees in affluent areas (Ordóñez & Duinker, 2013). As noted by Pincetl et al. (2013) planting more trees does not always indicate good management. Donovan & Mills (2014) examined the potential for inequitable participation in tree planting programs in Portland OR, which can further the unequitable distribution of trees based on socio-economic status. They found that more affluent people, who already had trees, were more likely to participate in tree plantings. Moreover, many cities have a lot of trees on private property, which can further exacerbate the discrepancy in benefits provided by trees in the urban forest. This indicates that city governments should have a larger role in maintaining equitable tree distribution

(Heynen, Perkins & Roy, 2006). Donovan et al., (2013) found that the largescale loss of ash trees (*Fraxinus* spp.) is correlated with an increase in death due to cardiovascular and respiratory illness. It is possible that this could be seen in other largescale losses of trees. If other tree species have a similar impact on human health than urban reforestation, or replacement of trees, is critical to maintaining public well-being. In Milwaukee, WI, reforestation efforts are partially based on providing residents with publicly funded trees. While this can help increase canopy cover, there are issues with the equitable distribution of benefits provided by these trees. Homeowners are more likely to be involved in these programs than renters, leading to a greater concentration of trees in wealthy neighborhoods (Perkins et al., 2004). Equitable and accessible options should be considered when reforesting after large-scale deforestation of urban trees caused by a pathogen or pest. While green spaces are important for all city residents, the addition of these spaces can lead to an increase in housing prices. One potential solution is to strategically place these new green spaces as to not raise housing prices, but provide equitable access to all residents (Wolch, Byrne & Newell, 2014).

1.4 Regional Context

The unique climate and culture in the PNW heavily impacts the region's flora; seasonal water availability influences what species thrive in urban areas. Furthermore, there is increasing competition between urban areas and agriculture for access to water resources due to seasonal water fluctuations and a changing climate (Mote et al., 2014). Infrastructure conflicts are common in municipalities across Western Washington and Oregon, and are leading to the removal of many trees. Smaller trees and smaller budgets are leading to shrinking urban forests. The annual benefits vary based on tree size and species; in Western Washington and Oregon, on average, a small tree produces $11.73 in annual benefits, medium $29.16, and large $51.46. Many of these municipalities are recycling their tree waste in some capacity, but their main costs are transport of the waste (McPherson et al., 2002). Donovan & Butry (2010) conducted a study of how trees influence house pricing in Portland Oregon; the number of trees and crown size explained most of the price increase related to trees. However, when homeowners are responsible for the tree maintenance outside their house the benefits are substantially less for the homeowner, but those trees still benefit surrounding properties without incurring maintenance costs. If tree planting and maintenance costs are assumed by the municipality or state it is more likely that there will be a greater investment in those resources (Donovan & Butry, 2010).

1.5 Purpose of Research

The first objective was to quantify which criteria are important to managers in tree species selection. While no tree can solve all of the problems or provide all of the benefits, knowing which selection criteria are most important can shed light on how people are prioritizing various criteria in tree species selection. Furthermore, it is important to know how managers are ranking various criteria. This can help inform educational campaigns, or direct further research. This is explored in both of the manuscripts.

The second objective was to explore how ISA certification influences how managers prioritize different criteria in tree species selection. The hypothesis was that those not certified would prioritize different criteria in tree species selection. This was aimed at exploring how these factors influence tree species selection, and sought to explore potential gaps in experience. Only prioritizing a limited number of criteria for tree species selection could increase the vulnerability of the urban area. This objective was designed to explore how ISA certification influences one specific population, but may be justification for additional research. This is explored in the first manuscript.

The third objective was to determine if there is any difference in tree species selection based on the size of the municipality. With more resources, it would seem logical that larger municipalities are likely to be selecting more diverse trees for their municipality. Additionally, this study explored what impact municipality size has on tree inventory, which in turn has an impact on broader management decisions across the municipality. The hypothesis was that larger municipalities were more likely to have a completed and regularly updated tree inventory. This is explored in the first manuscript.

The fourth objective was to explore what the most common tree species are being planted across Tree City USA designated cities in the PNW. There are many problematic species (e.g. invasive, and prone to disease) that should not be planted. In addition to seeing which tree species are most commonly selected, open-ended responses were used to help clarify why these were selected. Overall, the objective was to broaden theory on why and how tree species selection is operationalized. This is explored in the second manuscript.

The survey instrument in this study was designed to quantify the criteria used in tree species selection in municipalities across the Pacific Northwest. This study assumed that the decisions made by urban foresters have a significant impact on the social, economic, and ecological functions of the urban forest. More specifically, it assumed that the tree species that urban foresters select make an important difference in maximizing the benefits from trees in urban areas. This study helps illuminate potential vulnerability issues and provides insight on how to create a more resilient urban forest in the Pacific Northwest. Results could help inform a regional planting plan that emphasizes connectivity, informs municipalities how they compare to others, and reveal potential partnerships. Overall this information can increase the discourse related to urban planning and tree species selection in the Pacific Northwest. This project utilized similar methodology to a study in Toronto (Conway & Vecht, 2015), and contributes to the broader research in the growing field of urban forestry. While there is a lot of information regarding species densities and planting plans, little literature has explored what criteria are most important in tree species selection or how these differ across managers.

The results of this study cannot be inferred to a broader geographic population, but could help to broaden research on tree species selection, urban forest management, and further statistical analysis in social science of urban forestry. Specifically, this research is aimed at aiding managers, and ideally provides them with tangible results that they can use to inform their management decisions. This study attempted to create a usable document for managers in the Pacific Northwest and to increase discourse related to the subject of tree health and urban forest management.

In urban forestry, there is generally more of a focus on ecological and economic quantitative data collection. There is less of a focus on survey-based research, and even less using qualitative research (Roy & Pickering, 2012). This survey was designed to collect information on how managers are making tree species selection across municipalities in the PNW. This survey contained a mixture of multiple choice, rank-order, and short-answer questions. The research team — which includes an expert in urban forestry and one in woody ornamentals — reviewed this survey to ensure that it was easy to follow, and the terminology was appropriate for professionals in this field. The first survey instrument was sent to Tree City USA designated cities (must have a tree committee, tree ordinance, celebrate Arbor Day, and spend $2 per capita on urban forestry)(Arbor Day Foundation, n.d.) in Idaho to further test the validity and reliability of it (Vaske, 2008). Then the survey was sent to Tree City USA designated cities in Oregon and Washington.

A partial replication of methods found in Conway & Vecht (2015) was used to build upon tree species selection theory. Instead of focusing on various stakeholders in one geographic location, the use of a broader geographic area allowed this study to test how tree species selection varies across an assortment of urban forest managers that contribute to decisions impacting the regional diversity of flora. While a single survey instrument was utilized for data collection, the analysis was focused on two distinctive parts. The first manuscript focuses on how ISA certification and municipality size influences tree species selection. Using quantitative statistical analysis, this study explores how professionals in the PNW are prioritizing tree species selection in their municipalities based on those two variables. This analysis was designed to explicitly explore the relationship between ISA certification and elicit information on how this certification impacts urban forest managers. Kenny & Idziak (2000) explored how municipality size influenced urban forestry programs, but this study looks more specifically at how urban forest managers prioritize various tree species selection criteria across PNW municipalities. In the second component of analysis a mixed-methods approach was employed to elucidate how managers in the PNW are making tree species selections (Creswell, 2013). Using responses from open-ended questions this study explores what tree species are currently being selected and how various factors may be impacting those selections. Essentially, this study is exploring how tree species selection is operationalized in those municipalities. These two components combined to further expand on tree species selection theory, and provide information to improve education of those studying urban forestry and arboriculture.

CHAPTER 2

Manuscript 1: How Professional Certification and Municipality Size Influence Tree Species Selection Across Pacific Northwest Municipalities

Keywords: ISA Certified Arborists®, Municipality Size, Tree Species Selection, Pacific Northwest, Tree City USA

Abstract:

Trees provide an array of social, economic, and ecological benefits; furthermore, those that are on public land are critical for providing those benefits to people who cannot afford to buy or maintain their own trees. Different tree species perform well under different conditions, it is important to know how managers — those responsible for tree species selection — make tradeoffs and prioritize different criteria in order to target educational campaigns at the state or regional level. Primary contacts for Tree City USA designated cities were surveyed across the Pacific Northwest. Of these municipalities 79 out of 151 responded (52.3% response rate), with 6 municipalities providing responses from different departments for a total of 85 responses. Results were statistically analyzed with a Mann-Whitney U test comparing International Society of Arboriculture (ISA) Certified Arborists® to those that are not certified across various tree species selection criteria. Another Mann-Whitney U test was used to compare small (≤50,000) and large (>50,000) municipalities across the same criteria. ISA Certified Arborists® showed statistically significant differences from those that are not certified in a number of tree species selection criteria. They also differed in how they approached urban forest management on a city-wide scale, particularly in favoring greater tree species diversity. Smaller municipalities also showed statistically significant difference from larger municipalities across some of these criteria. Currently, there are primarily descriptive statistics in relation to tree species selection. This study provides a framework for future statistical analysis and greater exploration of how municipalities and managers are selecting tree species. The differences in urban forest management between ISA Certified Arborists® and non-certified — and between municipality size — can help to influence future educational campaigns.

Introduction

Urban land is expected to more than double in the United States from 2000 to 2050, drastically reducing natural areas and native forests. As a result of shifting land use there may be increasing conflicts with fire, recreation, wildlife, and agriculture. An increase in impervious surfaces will lead to a decline in forest commodities and ecosystem services. As this trend continues urban forests are more important for providing critical services to their residents (Nowak & Walton, 2005). Municipalities plant trees to benefit their city in a wide variety of ways; equally as diverse are the reasons why they select particular species. Selecting a tree suitable for the planting site increases the survival rate, which in turn increases the social, economic, and ecological value of the tree (Roy & Pickering, 2012). With proper management, urban forests can provide a wide variety of benefits including, reducing air pollution, reducing healthcare costs, and improving recreation (Dwyer, McPherson, Schroeder & Rowntree, 1992). Urban forests provide a range of social benefits that contribute to the health of residents (Matsuoka & Kaplan, 2007). Additionally, retrofitting urban areas to include more green space and trees creates a more livable city (Hagerman, 2007). Selecting the right tree for the right site will help to increase these benefits and reduce conflicts.

The unique climates of urban areas are shaped by the buildings and green spaces within. Green spaces, including trees, play a critical role in moderating urban climates. Hotter temperatures caused by the urban heat island effect create a more stressful environment for both people and trees. With strategic planning and planting, green spaces can be used to mitigate the negative effects of urban heat and pollution (Sieghardt et al., 2005). Trees that are selected for the right site will grow quicker, live longer, and in turn sequester more CO_2 (McPherson & Simpson, 1999). Through good management, urban forests can help to increase CO_2 sequestration and moderate energy uses in buildings. Planting trees, particularly on the western side of a building, can provide substantial energy savings. These savings typically start small and can nearly double after ten years. Species selection, planting location, and orientation are all important factors in how much energy savings can be accrued over the years (Sawka, Millward, Mckay & Sarkovich, 2013).

The cost of maintaining trees in urban areas can be reduced by selecting an appropriate tree species for the planting location. If the tree is too large for the site it may limit the mature size, increase maintenance costs, and minimize the ecosystem services provided by the tree. Often trees planted in the public sector outgrow their initial space, and conflict with utilities, sidewalks or other types of built infrastructure. Additionally, the perceptions of citizens can play an important role in the success of an urban forestry program. Trees with a large amount of leaf litter or allergens are often considered undesirable. Careful planning and the regular maintenance of the urban forest can alleviate many of these conflicts (Escobedo, Kroeger & Wagner, 2011).

There is a long history of planting trees in urban areas and with an increase in urbanization and a greater understanding of tree biology there has been a growing need for tree management. Arboriculture, the study of trees, is a major component of urban forestry, but is often unregulated. There are several institutions and organizations that are attempting to standardize urban forestry and arboriculture, but standards vary across municipalities. The International Society of Arboriculture (ISA) is one of the more prominent organizations and helps to set industry standards; these standards are optional and are driven by participation from consumers and arborists. Having a professional certification from the ISA helps to differentiate arborists that are engaging in continuing education. The Arbor Day Foundation is another organization that helps set guidelines for urban forestry and is responsible for the Tree City USA designation; these cities are required to spend $2 per capita on urban forestry, celebrate Arbor Day, maintain a tree board, and have a tree ordinance (Arbor Day Foundation, n.d.). There has generally been an increase in research and knowledge regarding urban forestry and arboriculture; tree care has progressed from pouring cement in cavities to a more scientific endeavor. More universities are offering courses or majors in arboriculture and urban forestry, in turn leading to more research being conducted (Gerhold, 2007). Elmendorf, Watson & Lily (2005) showed that among the arboriculture community there was strong support for ISA Certification, and that it overall raised industry standards. Additionally, tree selection was ranked highly among education topics for arboriculture programs (Elmendorf et al., 2005).

Statement of the Problem

There is an array of benefits to carefully weighing different criteria for tree species selection. Many of these are obvious, such as longevity and increased biodiversity, however, some managers may be basing their selections on outdated criteria or lack the information to make the best selection. There are new tools (e.g., electronic inventories) that can help provide managers with more information. When selecting trees, managers should consider how residents perceive trees because it could increase public support for tree planting initiatives. Careful consideration of management activities and ecological diversity could become increasingly important as a greater percentage of the landscape becomes urbanized (Vogt et al., 2017). Both the benefits and threats to urban forests have been well documented; however, it is important to determine how the public funds are being used for tree species selection and in turn how urban forest management is being conducted.

It is necessary to define the terms **urban trees** and **urban forests** as they can be confusing and ambiguous terms. As suggested by Roy & Pickering (2012), this study defines an **urban tree** as a woody perennial with lateral branches that originate some distance from the ground; a mature height of twelve feet is required to be considered a tree. Additionally, both single and multi-stemmed trees are included. Only trees that originate within the boundaries of a municipality and are planted on public land are included — growing both in clusters and singularly. Furthermore, seedlings are excluded and only trees that are a height of four feet upon planting will be counted — this *includes bare root, container, and balled and burlap trees.* The broad definition, and inclusion of multi-stem trees, is designed to assess the full potential for diversity of the urban forest. **Urban forest** is used to describe all the plants and green spaces within the boundaries of the municipality. Urban trees are a highly visible component of the urban forest and they contribute to the broader ecological health.

There is a growing body of literature that is exploring the potential of modeling urban forest vulnerability; and there is an increasing focus on how to make urban forests more resilient to threats (Adger, 2006; Burton, Huq, Lim, Pilifosova & Schipper, 2002; Ordóñez & Duinker, 2014; Steenberg, Millward, Nowak & Robinson, 2016). Urban forest vulnerability is a measurement of how likely a municipality is to see a decline in their ecosystem services. Vulnerability can be further broken up into exposure, sensitivity, and adaptive capacity. Urban forests are exposed to a wide variety of pests and are inherently more sensitive to changes than many other ecosystems (e.g. stormwater mitigation, urban cooling, and air purification). Through modeling and the use of indicators it is possible to make more informed decisions on urban forest management. Indicators should be selected to maximize representativeness, but should not be relied on exclusively; often indicators can be misleading. Indicators such as site size, street width, and pollution can vary considerably from one municipality to another. (Steenberg et al., 2016). These models are underused, but have great potential to assess the vulnerability of the urban forest to climate change scenarios. While this study is not building upon vulnerability modeling, it will incorporate some of the concepts to help explore management decisions regarding the urban forest resource. There is information on how to model vulnerability of urban forests, but there is a lack of information regarding how people weight some of the indicators in tree species selection.

Survey Context

Exploring how managers make decisions on tree species selection could improve education and potentially lead to an increase of benefits provided by those trees. Poor tree species selection manifests itself in a variety of ways, including: infrastructure damage, shortened life span, increased hazards, pest and disease susceptibility, large removal costs, and reduced genetic diversity. Professional organizations such as the ISA could help to bridge this gap and increase awareness of tree species selection issues. Different tree species perform well under different conditions, it is important to know how managers—those responsible for tree species selection—make tradeoffs and prioritize different criteria in order to target educational campaigns at the state or regional level.

There has been a limited body of research examining how professional certification influences urban forest management. There have been a number of studies that have used empirical evidence to justify ISA certification (Carlson, 1995; Green, 2002). It is clear that ISA is providing continuing education (Carlson, 1995). Elmendorf et al., (2005) showed that there was good internal support for ISA Certification, however there has been little that investigates how this training is operationalized in actual arboriculture practices. There have also been studies examining how other professional organizations play a role in the urban forest, such as the Society of Municipal Arborists (e.g. Young, 2010). Ries (2017) found that participation in the Municipal Forestry Institute (MFI) leadership training increased the likelihood of various levels of leadership outcomes. While there are an increasing number of certifications and training programs there has not been any explicit exploration of how ISA Certified Arborists® differ from those that are not.

Conway & Vecht (2015) conducted a study in Toronto, Canada exploring the criteria used for tree species selection. Through surveys and interviews they collected data on four groups: garden centers, Toronto Urban Forestry Department, non-profit organizations, and nurseries. They found that there were some differences in selection criteria between organizations, but there was also a lot of overlap in terms of species planted. The Toronto urban forestry department had a general policy to diversify their canopy, plant native species, and increase canopy cover. A partial replication of the methods in Conway & Vecht (2015) over a broader geographical scale serves to explore how municipalities may differ in tree species selection, rather than how stakeholders differ within a municipality. Furthermore, this study incorporates similar criteria from Conway & Vecht (2015) and builds on the broader theory surrounding tree species selection and will seek to quantify the criteria for tree species selection in Pacific Northwest municipalities. This study differs from Conway & Vecht (2015) due to the exclusive use of an online questionnaire and restricting the survey to public managers responsible for tree selection across the selected municipalities. This study incorporates additional statistical analysis beyond the descriptive statistics used in Conway & Vecht (2015).

Methods

Study Area

The population is Tree City USA designated cities across Oregon and Washington.There are 61 Tree Cities in Oregon, roughly half the population of the state resides within a tree city. The largest tree city in the state is Portland with a population around 609,456 and the smallest is Rivergrove with a population around 485 (Arbor Day Foundation, 2016 a). There are 90 Tree Cities in Washington, with about 47 percent of the population living in a tree city. The largest tree city is Seattle with a population around 653,000 and the smallest is Farmington with a population around 148 (Arbor Day Foundation, 2016 b). Targeting Tree Cities helped to eliminate those cities that are not actively managing their urban forests.

Regional Context

Our research is focused within the PNW, in Washington and Oregon. The climate of the PNW is influenced by the Pacific Ocean, the Cascades, and Olympic Mountains. These mountain ranges cast a rain shadow over the eastern high desert portions of Washington and Oregon. The substantial decline in precipitation is a dominant factor in influencing the composition of flora in the eastern part of this region. As climate change alters precipitation and temperature there will inevitably be shifts in tree species across various regions of the Pacific Northwest. It is likely that Douglas-fir (*Pseudotsuga menziesii*) in eastern Washington and Oregon will suffer from a decrease in moisture. Subalpine fir (*Abies lasiocarpa*) and mountain hemlock (*Tsuga mertensiana*) are likely to replace Douglas-fir (*P. menziesii)* in some of these areas (Albright & Peterson, 2013). Western Washington and Oregon are characterized by wetter winters and dry summers. The more moderate climate allows for a greater diversity of tree species than the eastern portions of the states (McPherson et al., 2002). The unique climate and culture in the Pacific Northwest heavily impacts the region's flora; seasonal water availability influences what species thrive in urban areas. (Mote et al., 2014). Selecting species in urban areas that are well-suited to the existing conditions on the site will help mitigate loss of tree species to a changing climate. Forest ecosystems that are more diverse and are sustainably managed are going to be more resilient to climate change. Adjusting what species are planted and educating the public on how tree species may shift with environmental changes are key components to climate resiliency (Spittlehouse & Stewart, 2004).

Study design

The sample frame was developed in conjunction with the Oregon Department of Forestry, and the Washington State Urban and Community Forestry program. Primary contacts for each tree city were provided, which consisted of urban foresters, park staff, and others (they will be collectively referred to as urban forest managers). The initial 22-question survey instrument was developed using Qualtrics (Qualtrics, 2017) and was approved by a University Institutional Review Board. Primarily close-ended quantitative questions were used to examine tree species selection criteria. The survey was targeted towards those who plant primarily on public lands and was designed to explore the motivations behind tree species selection as well as how managers are using existing research. This survey was designed to explore how social, ecological, and economic factors manifest into tree species selection across municipalities in the Pacific Northwest.

An initial pilot survey was sent to Tree Cities in Idaho. The pilot survey included an extra question to test for clarity and ease. No adjustments had to be made to increases the effectiveness and validity of the survey (Vaske, 2008). Responses from Idaho deemed the survey comprehensive and no further iterations were needed; therefore, the same survey instrument was sent to the primary contact for Tree Cities in the Pacific Northwest. 79 municipalities out of 151 responded (52.3% response rate), with 6 municipalities providing responses from different departments for a total of 85 responses. Sample size varied between questions, ranging from 60 to 85. Participants were asked to base their responses on tree species choices on public land and not on private property. Using methods outlined by (Millar &

Dillman, 2011) an attempt was made to increase response rate. An initial contact was made via email, requesting participation in this survey. The relevant risks were explained, and the link to the Qualtrics survey was sent out. A reminder email with the link to the survey was sent out two weeks later. A third email with the link to the survey was sent out a week after the second reminder. While sending out a hardcopy of the survey after the electronic copy has shown to increase response rate (Millar & Dillman, 2011), funding eliminated this as a possibility.

Tree species selection has been examined through a variety of lens: climate adaptability (Roloff, Korn & Cillner, 2009); residential attitudes (Kirkpatrick, Davison & Daniels, 2012); and those who plant on public land (Conway & Vecht, 2015). This study primarily builds on a study conducted in Toronto, Canada by Conway & Vecht (2015) exploring the criteria used for tree species selection on public land. They found the factors most influential in tree species selection for urban foresters primarily focused on increasing canopy cover, native species, and increasing local and overall tree species diversity (Conway & Vecht, 2015). This study utilizes similar criteria, but additional statistical analysis to increase knowledge surrounding tree species selection. Two matrices were the primary focus of analysis. The first was constructed to measure tree species selection on a site by site basis. Respondents were asked to rank 16 tree species selection criteria: 'aesthetics', 'mature height and width', 'existing tree diversity in your city', 'tree planting budget', 'availability', 'genetic diversity', 'maintenance costs', 'citizen preference', 'resistance to pests and disease', 'native species', 'soil type', 'root space', 'tree hardiness', 'water requirements', 'hours of sun', and 'proximity to buildings, utilities, sidewalks and other infrastructure'. There were 81 responses recorded, and each criterion was ranked on a 5-point scale of 1 'not at all important' to 5 'very important'. The second matrix was designed to measure tree species selection on a city scale; 78 responses were recorded. The following statements were used: 'I strive to plant no more than 10% of a species, 20% of a genus, or 30% of a family', 'increasing canopy cover in the city I live in is important', 'my city's street tree list strongly influences what I plant', 'my city generally plants the same 3-5 tree species year to year', 'the tree species my city plants have changed a lot over the course of my career', 'community engagement is a critical component of my department's success', 'I use the tree inventory to influence the trees I select'. A 7-point scale from 1 'strongly disagree' to 7 'strongly agree'— with the inclusion of an 8th option 'no opinion'— was used to determine managers opinions on broader species selection. The category 'no opinion' was coded as missing data.

Analysis

Other natural resource fields have used statistical analysis to analyze management decisions, it is time for urban forestry to do the same. All results were analyzed using IBM's Statistical Package for the Social Science (SPSS) (IBM corp., 2016). Significance levels of $\propto = .05$ were used for all statistical analysis. Due to small sample sizes and a lack of normality, primarily nonparametric statistics were used. This helps to eliminate outliers, but potentially reduces the power of the statistics, and leads to a greater likelihood of type two error. However, there were still statistically significant differences, providing a conservative approach to data analysis (Field, 2013). Butler & Koontz (2005) used similar statistical analysis for a United States Department of Agriculture Forest Service survey. A non-response bias check was conducted comparing respondents from the three different waves (Armstong & Overton, 1977; Atif & Bilgin, 2012). There was only statistically significant difference (Kruskal-Wallis-H = -18.86, $p < .01$) between the first and last wave based on planting budget. Third wave respondents were more likely to rate planting budget as important (median = 5 'very important') than first wave respondents (median = 4 'important'). This is not surprising considering there was a greater number of small municipalities responding later in the survey. No non-response bias was conducted on non-respondents due to a lack of phone contacts.

It is important to explore how this certification is operationalized in a municipal setting. This study examines how tree species selection criteria (Table 2.1) and selection criteria on a city scale (Table 2.2) differ across ISA Certified Arborists® and non-ISA Certified Arborists® using the Mann-Whitney U test. This analysis meets all the assumptions for the Mann-Whitney U test. The dependent variables of tree species selection criteria are on a continuous scale, while the independent variable of ISA certification is measured in two mutually exclusive groups. Both of these groups have a similar, but skewed shape (Field, 2013).

Municipalities with larger populations typically have better developed and funded urban forestry programs. Larger municipalities, greater than 50,000, were more likely to have a tree inventory than those under 50,000 (Kenney & Idziak, 2000). Based on the results in Kenney & Idziak (2000). Population size of the municipalities was split into two categories, those above 50,000 and those below 50,000. There were 67 municipalities with populations of 50,000 and under (small), and 14 over 50,001 (large). A

X^2 analysis was conducted to test the association between municipality size and the status of tree inventory. Additionally, a Mann-Whitney U test was conducted to test how municipality size impacted tree species selection criteria, and another conducted to test municipality size vs. selection on a city scale.

Results

Respondents were overall well-educated, 39.7% (n = 29) had a Bachelor's degree and 32.9% (n = 24) had a Master's degree or above. Males accounted for 58.9% (n = 43) of the responses and females accounted for 39.7% of responses (n = 29). This is generally consistent with research conducted by Kuhns, Bragg & Blahna (2002), which found that the majority of professionals in urban forestry are male. There were a variety of professions that responded: urban forester, arborist, landscape architect, urban planner, park manager, public works specialist, and other.

Respondents were asked to rank tree species selection criteria from 1 'not at all important' to 5 'very important'. These were grouped by ISA Certified Arborists® and those that are not certified. These two groups had statistically significant differences on three criteria: mature size, existing diversity, and native species. ISA Certified Arborists® were more likely to consider mature size an important criteria (median = 5 'very important'; mean = 4.8) than those that are not certified (median = 5 'very important'; mean = 4.4). These two groups showed statistically significant differences ($U = 433$, $Z = -2.54$, $p = 0.01$) when considering the mature size of tree species (Table 2.1). Effect size ($r = -0.3$) was medium (Cohen, 1988; Rosenthal, 1991).

ISA Certified Arborists® were more likely to consider existing diversity an important criterion (median = 4 'important'; mean = 4.2) than those that are not certified (median = 4 'important'; mean = 3.5). These two groups showed statistically significant differences ($U = 400$, $Z = -2.70$, $p < 0.01$) when considering the existing diversity of tree species (Table 2.1). Effect size ($r = 0.31$) was between medium and large (Cohen, 1988; Rosenthal, 1991).

ISA Certified Arborists® were less likely (median = 3, 'neither important nor unimportant') to plant native species than those who are not certified (median = 4, 'important'). These two groups showed statistically significantly difference ($U = 837$, $Z = 2.49$, $p = 0.01$), meaning those that are certified are less likely to consider this an important criterion in tree species selection (Table 1). Effect size (*r* = 0.29) was between small and medium (Cohen, 1988; Rosenthal, 1991).

Table 2.1: Tree species selection criteria by ISA Arborist

	ISA Arborist[1,2]					
	No	Yes	*U*	*Z*	*r*	*p*
Aesthetics	4	3	686	0.74	0.09	0.46
Mature size	5	5	433	-2.54	-0.30	0.01
Existing diversity	4	4	400	-2.70	0.31	<0.01
Planting budget	4	4	763	1.65	0.19	0.10
Availability	4	4	586	-0.45	0.05	0.65
Genetic diversity	3	3	529	-1.11	-0.13	0.27
Maintenance costs	4	4	764	1.71	0.20	0.09
Citizen preference	3	3	571	-0.62	-0.07	0.53
Resistance to pest and disease	4	4	642	0.23	0.03	0.82
Native species	4	3	837	2.49	0.29	0.01
Soil type	4	4	675	0.61	0.07	0.54
Root space	4.5	4	645	0.26	0.03	0.80
Tree hardiness	4	5	473	-1.90	-0.22	0.06
Water requirements	4	4	556	0.81	-0.09	0.42
Hours of sun	4	3.5	630	0.10	0.01	0.94
Proximity to infrastructure	5	5	692	0.93	0.11	0.35

1. Cell entries are medians of tree selection criteria, 1 “not at all important” to 5 “very important”
2. (N = 74; no = 48; yes = 26)

Respondents were asked various statements pertaining to tree species selection across the entire municipality. These were grouped by those who are ISA Certified Arborists® and those that are not. Respondents were asked to respond to each statement on a scale of 1 ‘strongly disagree’ to 7 ‘strongly agree’. ISA Certified Arborists® were generally more likely to agree with all the statements except, ‘my city generally plants the same 3-5 tree species year to year’.

ISA Certified Arborists® were more likely to agree (median = 6, ‘agree’) with the statement ‘I strive to plant no more than 10% of a species, 20% of a genus, or 30% of a family’ than non-certified arborists (median = 4, ‘neither disagree or agree’). These differ significantly (*U* = 197, *Z* = -4.03, *p* <0.01), meaning that ISA Certified Arborists® are more likely to follow this rule of thumb to increase diversity (Table 2). Effect size (*r* = -0.51) was large (Cohen, 1988; Rosenthal, 1991)

ISA Certified Arborists® were more likely to disagree (median=2, 'disagree') that their city plants the same 3-5 tree species every year than those without the certification (median=4, 'Neither disagree or agree'). This difference (U = 781, Z = 2.58, p = 0.01) indicates that ISA Certified Arborists® are more likely to change the tree species they plant from year to year (Table 2.2). Effect size (r = 0.31) was between medium and large (Cohen, 1988; Rosenthal, 1991)

Table 2.2: Tree species selection on a city scale grouped by ISA Arborist

	ISA Arborist[1]					
	No	Yes	*U*	*Z*	*r*	*p*
Ten twenty thirty[2]	4	6	197	-4.03	-0.51	<0.01
Canopy cover[3]	6	6	426	-1.88	-0.22	0.06
Tree list[4]	6	6	518	-0.43	-0.05	0.67
Plant same[5]	4	2	781	2.58	0.31	0.01
Species change[6]	4	5	384	1.77	-0.22	0.08
Com engage[7]	6	6	544	-0.38	-0.05	0.70
Tree inventory[8]	4	5	430	-0.97	-0.12	0.33

1. Cell entries are medians from 1 "strongly disagree" to 7 "strongly agree" (8 'no opinion' coded as missing)
2. *'I strive to plant no more than 10% of a species, 20% of a genus, or 30% of a family'* (n = 62, no =38, yes = 24)
3. *'increasing canopy cover in the city I live in is important'* (n =71, no = 46, yes = 25)
4. *'my city's street tree list strongly influences what I plant'* (n = 70, no = 46, yes = 24)
5. *'my city generally plants the same 3-5 tree species year to year'* (n =70, no = 44, yes = 26)
6. *'the tree species my city plants have changed a lot over the course of my career'* (n = 67, no = 43, yes = 24)
7. *'community engagement is a critical component of my department's success'* (n = 71, no = 46, yes = 25)
8. *'I use the tree inventory to influence the trees I select'* (n = 65, no = 40, yes = 25)

Respondents were asked to categorize the status of their tree inventory. They were provided with four options: 'no inventory', 'in progress', 'have an inventory, but it is not updated regularly', and 'have an inventory, and is updated regularly'. Large and small municipalities showed statistically significant differences in the status of their inventories, X^2 (df = 3, N = 74) = 13.65, p < 0.01. Of the small municipalities 32 percent do not have a tree inventory, while all large municipalities have some level of inventory. Fifty percent of large municipalities have an inventory and update it regularly, whereas only 24 percent of small municipalities do this (Table 2.3). Effect size is 0.385, which was between medium (0.3) to large (0.5) (Cohen, 1988). This analysis was conducted using Crammers v, using likelihood ratio which is appropriate for comparing a dichotomous and categorical variable (Vaske, 2008). Differences in status of tree inventories based on municipality size are consistent with past research (Kenney & Idziak, 2000).

Table 2.3: Relationship of city size to status of tree inventory

	Municipality size[1,2]					
	Small (≤50,000)	Large (>50,000)	Total	X^2 value	p-value	Cramer's V effect size
No	32	0	27	13.65	<0.01	0.385
In Progress	16	42	20			
Yes, not regularly	27	8	24			
Yes, Regularly	24	50	28			

1. Cell entries are percentages (%) of small or large municipalities that reported their inventory status
2. (N = 74; small = 62; large = 12)

Managers from large municipalities were more likely (U = 574, Z = 2,74, $p < 0.01$) to consider existing diversity important (median = 5, 'very important') than small municipalities (median = 4, 'important'). Effect size (r = 0.31) was between medium and large (Cohen, 1988; Rosenthal, 1991). Managers from large municipalities were more likely to (U = 570, Z = 2.67, $p < 0.01$) to consider availability of plant material important (median = 5, 'very important') compared to small municipalities (median = 4, 'Important') (Table 1. 4). Effect size (r = 0.30) was medium (Cohen, 1988; Rosenthal, 1991). There were no other differences across other variables.

Table 2.4: Tree species selection criteria by municipality size

	Municipality Size[1,2]					
	Small (≤50,000)	Large (50,000)	U	Z	r	p
Aesthetics	4	3.5	380	-0.16	-0.02	0.88
Mature size	5	5	420	0.49	0.06	0.62
Existing diversity	4	5	574	2.74	0.31	<0.01
Planting budget	4	4	358	-0.47	-0.05	0.64
Availability	4	5	570	2.67	0.30	<0.01
Genetic diversity	3	3.5	457	0.97	0.11	0.33
Maintenance costs	4	4	415	0.38	0.04	0.70
Citizen preference	3	3	385	0.07	-0.01	0.94
Resistance to pest and disease	4	4.5	423	0.52	0.06	0.61
Native species	4	2.5	260	-1.90	-0.22	0.06
Soil type	4	4	369	0.31	-0.04	0.76
Root space	5	4	370	-0.31	-0.03	0.76
Tree hardiness	4	5	449	0.92	0.11	0.36

Water requirements	4	5	471	1.22	0.14	0.22
Hours of sun	4	4	500	1.63	0.19	0.10
Proximity to infrastructure	5	4.5	336	-0.91	-0.10	0.36

1. Cell entries are medians of tree selection criteria, 1 “not at all important” to 5 “very important”
2. (N=77; small = 65; large = 12)

Large municipalities were generally more likely to agree with all of these statements except for ‘my city plants the same 3-5 tree species year to year’. This is generally consistent with previous research (Kenney & Idziak, 2000) and common recommendations in the field (Santamour, 1990; Clark, Matheney, Cross & Wake, 1997; Kenney, Van Wassenaer & Satel, 2011). Statistically significant differences occurred between small and large municipalities for four statements (Table 2.5). Respondents from large municipalities were more likely to agree (median = 6 ‘agree’) with the 10-20-30 rule than small municipalities (median = 4 ‘neither disagree or agree’); this was statistically significant ($U = 469$, $Z = 4.09$, $p < 0.01$). Effect size ($r = 0.53$) was large (Cohen, 1988; Rosenthal, 1991).

Larger municipalities were more likely to agree (median = 7, ‘strongly agree’) that increasing canopy cover was important than smaller municipalities (median = 6, ‘agree’); this was statistically significant ($U = 478$, $Z = 2.44$, $p = 0.02$). Effect size ($r = 0.29$) was between small and medium (Cohen, 1988; Rosenthal, 1991).

Respondents from large municipalities are more likely to agree ($U = 494$, Z = 2.92, $p < 0.01$) that tree species have changed over the course of their career (median = 6, ‘agree’) than small municipalities (median = 4.5, ‘somewhat agree’). Effect size (r = 0.35) was between medium and large (Cohen, 1988; Rosenthal, 1991).

Respondents from large municipalities are more likely to agree that tree inventories influenced their tree species selection (median = 6, ‘agree’) than small municipalities (median = 4.5, ‘somewhat agree’); this was statistically significant ($U = 421$, Z = 2.20, $p = 0.03$). Effect size (r = 0.27) was between small and medium (Cohen, 1988; Rosenthal, 1991).

Table 2.5: Tree species selection on a city scale grouped by municipality size

	Municipality Size[1]					
	Small	Large	*U*	*Z*	*r*	*p*
Ten twenty thirty[2]	4	6	469	4.09	0.53	<0.01
Canopy cover[3]	6	7	478	2.44	0.29	0.02
Tree list[4]	6	6	346	0.35	0.04	0.73
Plant same[5]	3	2	242	-1.43	-0.17	0.15
Species change[6]	4.5	6	494	2.92	0.35	<0.01
Com engage[7]	6	6	395	1.06	0.13	0.29
Tree inventory[8]	4.5	6	421	2.20	0.27	0.03

1. Cell entries are medians from 1 "strongly disagree" to 7 "strongly agree" (8 'no opinion' coded as missing)
2. *'I strive to plant no more than 10% of a species, 20% of a genus, or 30% of a family'* (n = 60, small = 49, large = 11)
3. *'increasing canopy cover in the city I live in is important'* (n = 71, small = 60, large = 11)
4. *'my city's street tree list strongly influences what I plant'* (n = 70, small = 59, large = 11)
5. *'my city generally plants the same 3-5 tree species year to year'* (n = 71, small = 60, large = 11)
6. *'the tree species my city plants have changed a lot over the course of my career'* (n = 69, small = 58, large = 11)
7. *'community engagement is a critical component of my department's success'* (n = 71, small = 60, large = 11)
8. *'I use the tree inventory to influence the trees I select'* (n = 65, small = 54, large = 11)

Discussion

Overall this study found that municipalities of different sizes and ISA certification ® are influencing how managers are making tree species selection decisions. These variables are critical in terms of how these managers are prioritizing various criteria, particularly with regards to increasing tree species diversity. Exploring the differences in tree species selection and tree inventory based on municipality size can help tailor state funding and assistance to municipalities of different sizes (Kenney & Idziak, 2000). There has been an increase in the use of tree inventories across municipalities. Tree inventories can help managers make decisions based on existing tree species diversity, prioritize maintenance, calculate ecosystem services, and are largely considered important components of successful urban forestry programs (Clark et al., 1997; Kenney et al., 2011). Unfortunately, tree inventories can be expensive and labor intensive. This study can help demonstrate how municipalities of different sizes use tree inventories, and how that influences tree species selection.

ISA Certified Arborists ®

There are some studies exploring professional development in arboriculture (Carlson, 1995; Green, 2002; Ries, 2017; Young, 2010) but there is a lack of research exploring how ISA Certified Arborists® differ from those who are not certified. ISA Certified Arborists® are prioritizing different criteria when selecting tree species than those managers that are not certified. They are more likely to consider 'mature size of the tree' and 'existing tree species diversity' important criteria. The mature size of the tree accounts for a variety of benefits and costs. Larger trees typically provide more benefits overall, but they also incur more costs in infrastructure damage if poorly sited. It is important to carefully consider the limitations of the site and select an appropriately sized tree (Mullaney, Lucke & Trueman, 2015). Increasing existing diversity can help to reduce potential pest outbreaks and promote overall urban forest health (Santamour, 1990). However, ISA Certified Arborists® are less likely to consider 'native species' as an important criterion. As more land is converted into urban use, planting native species are thought to help preserve biodiversity (McKinney, 2002). While there are advantages of native tree species in many contexts (e.g. well-suited for the climate) there is also research to suggest that native species are not always the best choice in urban areas. Native species may sometimes increase insect diversity and are certainly appropriate in environmental restoration projects, but the unique challenges posed by urban areas preclude these as options in all situations. Generally, the literature suggests that noninvasive nonnative species are good additions to the urban forest. Managers should focus on function and diversity as opposed to exclusively native species (Chalker-Scott, 2015). ISA Certified Arborists® are presumably making an educated decision by weighing native species less heavily than those that are not certified.

In addition to ranking existing diversity as more important, ISA Certified Arborists® are more likely to consider the 10-20-30 rule-of-thumb (Santamour, 1990) more important than those who are not certified. Over the course of their careers ISA Certified Arborists® are also more likely to have changed the tree species they plant. This fits with a general trend towards increasing tree species diversity and it could be a result of continuing education. There has been a trend in literature to increase diversity in urban forests to minimize loss from pests (Alvey, 2006; Chalker-Scott, 2015; Santamour, 1990). Certification seems to be increasing awareness of the importance of increasing tree species diversity, which could lead to increase in policies to promote biodiversity. A major limitation in this study is that there was no exploration of how managers may be considering diversity on a neighborhood scale. Increasing tree species diversity on a municipality scale or landscape scale is good, however, it is also important to consider diversity on a more localized scale. Urban forests are not distributed equitably in terms of socioeconomic criteria (Heynen, Perkins & Roy, 2006). After dieback or removal of trees, neighborhoods with renters are less likely to be reforested, further contributing to the inequitable distribution of benefits provided by the urban forest (Perkins, Heynen & Wilson, 2004).

Surprisingly certification did not have a statistically significant impact on the prioritization of genetic diversity. This could have been caused by lack of understanding of the question, or perhaps the question did not fully measure how managers view intraspecific diversity. Regardless, there likely needs to be an increase in focusing on diversity within species and a shift away from exclusive reliance on single cultivars. It is advantageous to plant cultivars when one needs a specific form and function, but in other situations preference should be given to increasing intraspecific genetic diversity (Santamour, 2004). It appears that ISA Certified Arborists® are more likely to follow emergent trends in urban forestry literature and education. This could provide some justification to hiring a certified arborist in management positions. In addition, these results may suggest that this is a successful means of conveying new knowledge; however, it is critical to ensure that those who are providing education are providing the correct information.

Municipality Size

Municipality size influences the status of tree inventory, tree species selection criteria, and urban forest management. All the large municipalities have a tree inventory in some level of completeness. This could be because it is difficult to manage an urban forest in a larger municipality without an inventory. In order to increase tree species diversity, it is necessary to know what tree species exist in the municipality. Furthermore, status of inventory is used as an important monitoring criteria in urban forestry (Clark et al., 1997; Kenney et al., 2011). This is important when looking at how tree inventory impacts tree species selection; larger municipalities are statistically significantly more likely to use a tree inventory to influence tree species selection. This difference could occur based on differences in funding or perhaps these smaller municipalities do not require a tree inventory. Smaller municipalities may need assistance in developing other components of their urban forest programs such as tree species selection, funding, or tree species diversification. It is also possible that smaller municipalities could benefit from tree inventories in another way, such as, increasing public awareness. There could be further research conducted to see how tree inventories are being used and how this is operationalized in urban forest management, particularly when considering municipality size.

Larger municipalities are more likely to consider ‘existing diversity’ and ‘availability’ important criteria in tree species selection. If large municipalities look to increase tree species diversity, tree availability may become an issue. It can be difficult for nurseries to anticipate the needs of urban foresters, which may be perpetuated by a reduction in communication between stakeholders (Sydnor, Subburayalu & Bumgardner, 2010). There are additional differences when comparing municipality size to tree selection on a city scale. Larger municipalities are more likely to utilize the 10-20-30 rule-of-thumb (Santamour, 1990), prioritize increasing canopy cover, change the tree species they are planting, and utilize the tree inventory to make tree species selection. This is consistent with prior research that larger cities have more active management (Kenny & Idziak, 2000). While it would be good to increase some of these management objectives in smaller municipalities, it could potentially indicate that education and resources should be allocated differently in smaller vs. larger municipalities. It would be good for these municipalities to maximize benefits provided by the trees they are planting and minimize those species that are susceptible to pests. Smaller municipalities should consider increasing diversity even if they are only planting a small number of trees each year. Larger municipalities likely have a greater need for active management due to the amount of land that is being converted into urban use. It is possible that this is a product of resources, or that city size dictates management objectives. Further statistical analysis should be conducted to explore how municipalities of different sizes prioritize tree species selection and urban forest management.

Tree planting campaigns have been popular in many municipalities; however, urban forests are complicated and require a unique combination of social and ecological management. Thoughtlessly increasing canopy cover can lead to a lower return on ecosystem services and an inequitable distribution of those services. In addition to considering ecological criteria such as water use, it is important to consider how the general public is being involved, and how these decisions are influencing them (Princetl, Gillespie, Pataki, Saatchi & Saphores, 2013). Understanding how managers are making these decisions and the factors that influence them are important in furthering the effective management of the urban forest. There have been a number of documents providing recommendations regarding: maximizing ecosystem services (Escobedo et al., 2011), community tree planting guidelines (McPherson et al., 2002), site limitations (Sieghardt et al., 2005), and inequitable distribution of the urban forest (Heynen et al., 2006). This study explored how those are operationalized in the PNW and differ based on municipality size and certification. As new literature emerges in relation to how tree species perform in urban areas there should be corresponding research to explore how this is operationalized.

Limitations

This study was limited by the small sample size and limited geographic area. Nonparametric statistics were used in an effort to account for this and provide conservative results. Future studies should aim for a larger sample size and an expanded geographic area. It would be interesting to see if these trends hold true across the entire United States. There are a lot of common principles in urban forestry that are applied across a broad range of geographic, social, ecological, and economic areas without sufficient research to determine if these hold true across such broad factors. It would likely be beneficial to incorporate interviews or a qualitative component to add additional context to this issue. Specifically, it would be helpful to know how managers view the impact of ISA Certification ® and municipal resources in how they select tree species.

Conclusion

Despite these limitations this study provides a framework for future statistical analysis and greater exploration of how municipalities and managers are selecting tree species. ISA certification and municipality size impact individual tree species selection and influences levels of urban forest management. Currently, there are primarily descriptive statistics in relation to tree species selection (e.g. Conway & Vecht, 2015). Exploring how urban forest management is operationalized by ISA Certified Arborists® vs. non-certified — and different municipality sizes — can help to focus state or regional assistance to different professionals and municipalities.

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CHAPTER 3

Manuscript 2: Are the Right Trees Being Selected for the Right Places in the Pacific Northwest?

Keywords: Urban Forest Managers, Tree Species Selection, Tree Species Diversity, Emerald Ash Borer

Abstract: As urban areas increase there are a greater number of urban trees; however, there are lower concentrations of trees overall. A reduction in overall trees results in a reduction of ecosystem services. Additionally, these urban trees are under greater stress and must be more actively managed to maintain those services. Selecting tree species for the right site initially can lead to greater benefits and longer-lived trees. Increasing diversity of urban trees can help to mitigate some of the threats facing urban forests such as, invasive pests, and climate change. While there are studies and recommendations regarding how to select tree species there is little information on how managers are operationalizing this information. We surveyed Tree City USA designated cities across the Pacific Northwest region of the US regarding how they are selecting tree species for their municipality. Responses were recorded for 79 out of 151 municipalities for a 52.3% response rate. Both open-ended questions and descriptive statistics were used to triangulate how managers are selecting tree species in municipalities across the PNW. There is evidence to suggest that these municipalities are actively diversifying the urban forest; however, there are still 10 municipalities that reported Ash (*Fraxinus* spp.) in their top five most frequently planted species in 2016. Many municipalities are still planting large quantities of maple (*Acer* spp.). Overplanting certain genera and species can lead to an increase in pest susceptibility. There seems to be room for an additional increase in diversification of tree species in urban areas. Emergent themes in open-ended responses indicate a variety of justifications for tree species selection and the challenges of balancing those criteria.

Introduction

Urban Trees

The global population could reach nine billion by the year 2050, and the fastest growth rates will be occurring in urban areas (Roberts, 2011). Tree planting is becoming an increasingly popular solution to environmental problems and climate change in urban areas; Los Angeles and New York have both proposed plans to plant one million trees, which demonstrates their commitment to tree planting (Pincetl, Gillespie, Pataki, Saatchi & Saphores, 2013). In California there has been an increase in the number of overall street trees, but the street trees are more spread out, and there are still a large numbers of vacant planting sites. Cumulatively, these street trees are estimated to have an approximately 1-billion-dollar impact (McPherson, van Doorn & de Goede, 2016). Different tree species and site locations can have different impacts on the social, ecological, and economic benefits; each tree should be appropriately sited to maximize benefits (McPherson et al. 1997). Trees, particularly evergreens, can help to remove air pollutants (Escobedo & Nowak, 2009). Urban trees can help to sequester carbon, but the rate of carbon sequestration largely depends on the tree species. Additionally, the management practices (e.g. tree disposal) should be considered in terms of net environmental benefits provided by the tree (Nowak, Stevens, Sisinni & Sulley, 2002). Trees can play a role in stormwater mitigation through the role of improved drainage in compacted soils; as with other benefits this varies based on tree species (Bartens, Day, Harris, Dove & Winn, 2008). Furthermore, urban residents have highly rated the benefits of cooling and stress relief provided by trees (Lohr, Pearson-Mims, Tarnai & Dillman, 2004). While there are a lot of benefits to tree planting, an arbitrary number may not produce the desired impact. It is important to consider maintenance, water use, existing climate, funding, community support, and an array of other factors. The benefits provided by trees can be increased with good science and sound management, but may be hindered by poor management (Pincetl et al., 2013). There have been a number of studies that have examined, and in some cases demonstrated, the potential downsides of trees, including: hazards, pollen, maintenance costs, and infrastructure damage (Roy and Pickering, 2012).

Pests and Pathogens

Urban forests are subjected to harsh growing conditions and face a wide variety of pests. Historically, pests such as chestnut blight (C*ryphonectria parasitica*) and Dutch elm disease (O*phiostoma ulmi*) have caused large scale decline in North American urban forests. More recent invasions of pests such as the Asian longhorn beetle (*Anoplophora glabripennis*) and hemlock wooly adelgid (A*delges tsugae*) are raising similar concerns. These pests burden cities with enormous tree removal costs, often in a relatively short time period (Raupp, Cumming & Raupp, 2006). One of the pests that is decimating the urban forests in the Midwest is the emerald ash borer (EAB) (*Agrilus planipennis*). Since its discovery in 2002, this insect has caused substantial destruction of the ash genus (*Fraxinus* spp.), in urban areas. Cities are often more susceptible to pests due to planting practices and the large influx of goods; an increase in pests complicates tree species selection (Polland & McCullough, 2006). Asian longhorn beetle (*A. glabripennis*) could have an economic impact of $669 billion across U.S. cities. This number was developed with 1997 data and is an estimate of compensatory value, which would likely be much higher today (Nowak, Pasek, Sequeira, Crane & Mastro, 2001). Even without pest infestations urban trees often have short lifespans and high mortality rates. Factors such as tree species, size, health, and land use are all significant factors in determining survival and growth rate (Nowak, Kuroda & Crane, 2004). Selecting the right tree for the right place can help to increase the survival rate and minimize other conflicts. Essentially, one should examine the planting site and then determine an appropriate species that is well suited for the growing conditions and limitations.

Urban Forest Diversification

In order to avoid large scale loss of the urban forest resource, Santamour (1990) suggests that no more than 10% of a tree species, 20% of a genus, or 30% of a family should be planted in the confines of a municipality. This rule was based on empirical evidence and professional advice to foster diversity, not as a result of scientific research. As new research progresses, it is clear that the 10-20-30 rule is not the only rule to consider when selecting tree species. Raupp et al., (2006) points out that this formula does not take into account susceptibility of multiple species to a singular pest. Another example they used is that if two species of ash were planted, and each ash species represented 10% of the urban forest, then 20% of the urban forest could be wiped out by EAB (*A. planipennis*). When attempting to create a more diverse forest, species should be selected that minimize risk of overlapping pest problems; this could manifest itself as further consideration of tree diversity at familial and ordinal levels (Raupp et al., 2006). Conversely, past research has argued for the perpetuation of the tree species that are the oldest in the urban forest. These species are thought to be well-suited to the harsh conditions of the urban forest and provide ideal form (Richards, 1983). While there is good reason to plant species tolerant of the tough urban environment it does notadequately account for the introduction of new foreign pests.

Tree species diversity can help reduce fungal parasites in forest ecosystems through the greater potential of finding resistant genes. This is slightly less true when the pathogen is spread via insect vectors mostly due to the rate of spread. Conversely, forest ecosystems can have greater levels of diversity in the presence of pathogens (Pautasso, Holdenrieder & Stenlid, 2005). In urban forests there is less need for the selection pressure produced by pathogens. However, there is a large dominance of cultivars which results in a reduction of intraspecific genetic diversity. It is advantageous to plant cultivars when one needs a specific form and function, but in other situations preference should be given to increasing intraspecific genetic diversity (Santamour, 2004). While increasing the number of tree species in an urban area can lead to a reduction in removal costs, there should be consideration given to increasing intraspecific diversity as well.

Increasing tree species diversity should be an intentional and directed management objective. Most municipalities have the potential to increase tree species diversity as well as the potential to create more diverse habitat types. Parks have a particularly useful function and can be used to increase connectivity and serve as biodiverse hotspots in cities. Unsurprisingly, larger parks tend to have higher levels of tree diversity (Cornelis & Hermy, 2004). A survey of Washington wholesale nurseries suggested that support of tree species diversity is high, but knowledge of what diversity means is varied; less than half of the respondents thought planting more than 10% of the same species increased susceptibility to pests (Polakowski, Lohr & Cerny-Koenig, 2011). This may indicate that other professionals in horticulture, arboriculture, and urban forestry do not adhere to a constant definition of the term ‘diversity’. While the 10-20-30 rule can be viewed as a minimum standard for tree species diversity, empirical evidence should be used to increase diversity and minimize susceptibility to pests. Furthermore, tree species diversity should be increased on a neighborhood scale to maximize benefits provided by those trees. While increasing diversity within an area is achievable, regional or national diversity should be considered as well. Many urban areas are increasing their tree species diversity locally, but the same species are being planted across broad regions. Importing exotic species can potentially lead to the spread of invasive species and a decline in diversity. With deliberate selection and management, local tree species diversity can contribute to broader regional diversity. While many urban habitats are unsuitable for native trees, there is still ample opportunity to increase tree species diversity across municipalities (Alvey, 2006).

Past Research and Study Justification

There has been a large increase in the number of papers written about urban forestry since the year 2000; but as of 2011 only a small subset of those papers on urban trees have used survey-based social science methods (Roy & Pickering, 2012). There has been a general lack of qualitative research in urban forestry (McClean, Jensen & Hurd, 2007). The use of a qualitative framework can be used to capture the context of social components, such as what residents prioritize in urban forest management, whereas quantitative data are better suited for assessing the abiotic and biotic factors that influence urban forest management (Ordóñez & Duinker, 2014). There is a growing body of literature to guide people in tree species selection (Alvey, 2006; Conway & Vecht, 2015); however, there is sometimes a disconnect between science and management. Historically, many municipalities have overused tree species—such as Callery pear—which can become invasive (Culley & Hardiman, 2007). The trees these managers plant are in part a result of what is grown in nurseries and a result of communication between those groups (D'Amato et al. 2002). It is important to know how support of diversity or pest resistance is operationalized in these municipalities because it will directly impact forest resiliency and ultimately removal costs. While there appears to be support for a wide variety of criteria (e.g. resistance to pests) there seems to be additional opportunity for diversification of the urban forest.

This study explores the top five most commonly planted tree species by each manager (i.e. those responsible for tree species selection within their municipality), and use qualitative data to explore emergent themes of tree species selection. Common tree species selection criteria — and the resulting tree species — will be situated in current research and through the use of quantitative and qualitative analysis potential areas of improvement will be identified. Among the challenges of increasing diversity are lack of awareness of new cultivars or species, as well as availability at nurseries (D'Amato, Sydnor & Struve, 2002). Tree planting goals should be tailored to the city's climate and ability to plant trees, not based on initiatives in other cities. Many municipalities use canopy cover (i.e. the percentage of land covered by the trees' canopy) as a quick way to provide a broad assessment of their urban forest. Exclusively using canopy cover as a measurement for the success of the urban forestry program can lead to an unsustainable system (Kenney et al., 2011). Tree species selection on public land can be critical in providing benefits, but it is a complex process that involves both social, ecological, and economic criteria. As more municipalities establish urban forest programs, survey research has explored how these programs operate (e.g. Kenney & Idziak, 2000). Beatty & Heckman (1981) conducted one of the first major surveys of urban forest programs in the United States, which helped to illuminate some of the constraints faced by urban forest managers. Others have used data to provide advice on what tree species to plant (McPherson et al. 2002), but few studies have used a mixed methods approach to see how managers are operationalizing these variables or practices.

Methods

Study Area

We conducted research in the Pacific Northwest states of the US, which includes Oregon and Washington. By only surveying Tree City USA designated cities (which means they invest $2 per capita in urban forestry, have an Arbor Day celebration, have an established tree board, and a tree ordinance), we further restricted the number of municipalities to ensure that there was active management (Arbor Day Foundation, n.d.). There were 61 Tree Cities in the state of Oregon and 90 in the state of Washington in 2016. In the PNW in 2016 approximately half the population resided in Tree Cities (Arbor Day Foundation, 2016 a; Arbor Day Foundation, 2016 b). Oregon in particular has a large nursery industry, so urban forest managers have access to a wide selection of tree species.

Study design

A mixed-methods study was designed to better understand tree species selection in urban areas. The study combines descriptive statistics with open-ended questions to explore tree species selection on public land across municipalities in the Pacific Northwest (PNW). We analyzed an open-ended question in Nvivo to add additional context to tree species selection. While the quantitative results were given a greater focus, we included the qualitative component in an effort to further triangulate (Creswell, 2013) tree species selection. There have been studies (Conway & Vecht, 2015; Petter, Chapter 2) that examined quantitative components of tree species selection in urban areas, but it is necessary to construct a greater understanding of tree species selection. These qualitative and quantitative components were then used to see how tree species selection is operationalized in urban areas. Together the quantitative and qualitative components help explore tree species selection by managers at a greater depth.

Data collection was similar to Petter (Chapter 2), however the focus was on different components in the survey instrument. Contacts for Tree Cities across the PNW were collected with assistance from state agencies. A survey was designed in Qualtrics and was then presented to a University Institutional Review Board for approval. Two open-ended questions were used to assess the most commonly planted species in each municipality in 2016, as well as the species planted before 2016. Two open-ended qualitative questions were used to examine motivations behind those selections. Additional quantitative questions assisted in further analysis of the concepts laid out in the open-ended questions. The survey was targeted towards those who plant primarily on public lands and was designed to explore the motivations behind tree species selection, as well as how managers are using existing research (e.g. Santamour

1990). Furthermore, this research aims to contribute to a broader framework for urban tree species selection—specifically, how do common trends such as 'right tree, right place' and the 10-20-30 rule manifest themselves in actual decisions. Prior to administration, the survey was reviewed and revised by a team of researchers. Contacts from Tree Cities in Idaho were used to test the survey for internal and external validity (Vaske, 2008). There was a 52.3% response rate, with 79 municipalities represented out of the potential 151 Tree Cities. Six municipalities provided multiple responses from different departments, which resulted in 85 total responses. There was an effort to increase response rate by contacting respondents multiple times (Millar & Dillman, 2011).

Analysis

Two open-ended questions were used to compare existing diversity to species selection in 2016. The following two questions were used: 'Please list the 5 most common tree species PLANTED in 2016 in your municipality'—'Please list the 5 most common tree species that are GROWING in your municipality'. Respondents were asked to use scientific names for both of these questions if possible. These responses were then complied into a table (Table 3.4) to compare existing diversity with more recent tree species. If a respondent only specified genus (e.g. *Acer*), it was placed into *Acer* spp., however where possible cultivar and species names were retained to assess diversity on the broadest spectrum. Common names were converted to scientific names. For each species listed we provided a genus and family to calculate the most common genera and families in those municipalities (Table 3.4). This provided insight into the five most commonly selected tree species, genera, and families across the sample population.

Two open-ended questions were analyzed in NVivo. The first question was, 'In your own words please describe the most important criteria to you personally for tree species selection?'. The second question was, 'Does being a Tree City USA city influence tree species selection, if so how?' We used summative content analysis, which involved creating a count of common nodes, to explore and further develop theory (Hsieh & Shannon, 2005) surrounding tree species selection. The criteria that were used in Petter (Unpublished) were used as nodes in the summative content analysis. Other common themes of urban forestry such as 'right tree, right place' were also used as nodes. Furthermore, this provided an opportunity to explore additional criteria that had not been listed in Petter (Unpublished). While many of these nodes are discussed in urban forestry, this provides a more scientific approach to how managers are using these criteria. Triangulation of quantitative and qualitative data were used to further explore tree species selection and how that is operationalized in the tree species managers are selecting. Peer debriefing (i.e. a second researcher reviewed the coding) was used to check coding and ensure validity of the qualitative research (Creswell & Miller, 2000).

Respondents were asked to rank tree species selection criteria on a scale of 1 'not at all important' to 5 'important' (Petter, 2018). They were also asked to select their top three most important criteria out of the same list, and rank them in order of importance. A Borda count was then used to calculate which criteria were ranked the highest. This involved providing three points for a ranking of one, two for a ranking of two, and one for a ranking of three (i.e. 1=3, 2=2, 3=1), to provide a hierarchy of their overall rankings (Van Erp & Schomaker, 2000). These were compared to each other, as well as open-ended responses to illicit greater detail regarding how managers prioritize tree species selection.

Results

Respondents were asked to answer a variety of questions based on their tree species selection and the components that influence it, such as: budget, and the number of nurseries they source material from. Respondents had a mean experience level of 15.5 years. This is a generally experienced group, however, there is a wide range of experience from one to 53 years. The first quartile occurred at six years, the second at 13.5 years, and the third at 22.5 years. Overall there were generally small numbers of trees planted by municipalities. The mean number of trees planted by municipalities occurred between 41-60 trees per year, while the median range was 11-20 trees per year. The first quartile occurred at 0-10 trees, the second at 11-20 trees, and the third at 51-60 trees. Interestingly enough five respondents reported planting 500 or more trees. More experience was correlated with planting more trees (Spearman's $rho=.308$, $p=.013$).

Twenty respondents (29%) reported having a tree planting budget of $1000 or less (Table 3.1). Only five municipalities reported having a tree planting budget over $50,000. Of those municipalities reporting budgets over $50,000 one reported having a budget between $70,001-$80,000. The other four reported having a budget in excess of $90,000.

Table 3.1: Tree planting budgets of municipalities

Budget in $	Frequency	Percent
0-1000	20	29.0
1001-2000	8	11.6
2001-3000	7	10.1
3001-4000	2	2.9
4001-5000	9	13.0
5001-6000	3	4.3
6001-7000	2	2.9
7001-8000	1	1.4
8001-9000	1	1.4
9001-10,000	1	1.4
10,001-20,000	6	8.7
20,001-30,000	2	2.9
30,001-40,000	1	1.4
40,001-50,000	1	1.4
50,001-60,000	0	0.0
60,001-70,000	0	0.0
70,001-80,000	1	1.4
80,001-90,000	0	0.0
90,000 or more	4	5.8

Of all the respondents 54.4% reported that a particular tree species is unavailable at a nursery 5% of the time or less. This means that a little under 50% of managers responded that they cannot source a tree species more than 6% of the time (Table 3.2).

Table 3.2: How often a tree species is unavailable at a nursery

Percent of times a species is unavailable at a nursery	Frequency	Percent
5% or less	37	54.4
6-20%	9	13.2
21-30%	14	20.6
31-40%	3	4.4
41-50%	1	1.5
51-60%	3	4.4
More than 61%	1	1.5

Generally, most respondents reported using under five nurseries to source their tree species. Over 50% of respondents source their trees from 1-3 nurseries. One respondent indicated that they source trees from 12 different nurseries (Table 3.3). More experience was positively correlated with sourcing trees from a greater number of nurseries (Spearman's rho=.408, p=.001).

Table 3.3: Number of tree nurseries used to source trees

Number of nurseries	Frequency	Percent
1	8	11.8
2	16	23.5
3	16	23.5
4	8	11.8
5	15	22.1
6	2	2.9
7	1	1.5
10	1	1.5
12	1	1.5

In 2016, managers across the PNW reported 236 different species (or cultivars), 49 genera, and 23 families among their top five most commonly planted tree species. This is a drastic increase to the top five most common species currently in municipalities, which was represented by 77 species, 33 genera, and 15 families. There is a marked increase in the number of different tree species managers selected in 2016 compared to those growing across the region. When looking at managers across the entire PNW it is clear that there is a trend towards more diverse species selection, however, there are still many similarities in tree species selection across many municipalities. One interesting finding is that 10 managers listed ash (*Fraxinus* spp.) in their top five most commonly planted genera (Table 3.4). There is also a tendency to plant large quantities of *Acer* spp., which is already abundant in many PNW municipalities. There are 4 families appearing in both 2016 and those before 2016, indicating a large number of municipalities are planting species from these families. In response to the question 'Does being a Tree City USA City influence tree species selection, if so how?', 42 respondents said 'no' and 11 said 'yes'.

Table 3.4: Breakdown of most commonly planted species in municipalities

	2016	Number of municipalities who reported it in top 5	Planted before 2016	Number of municipalities who reported it in top 5
5 most common species[1]				
	Acer rubrum	15	*Pseudostuga menzeisii*	24
	Acer spp.	7	*Acer rubrum*	16
	Pseudostsuga menzeisii	7	*Acer platanoides*	15
	Quercus garryana	7	*Acer macrophyllum*	13
	Thuja plicata	7	*Acer spp.*	12
	Zelkova serrata	6	*Pinus ponderosa*	10
5 most common genera[1]				
	Acer	48	*Acer*	67
	Quercus	25	*Pseudostuga*	24
	Prunus	11	*Fraxinus*	21
	Pyrus	10	*Prunus*	18
	Fraxinus	10	*Quercus*	16
	Cornus	10		
5 most common families[1]				
	Sapindaceae	49	*Sapindaceae*	68
	Rosaceae	39	*Pinaceae*	49
	Fagaceae	27	*Rosaceae*	36
	Pinaceae	17	*Oleaceae*	21
	Cornaceae	15	*Cupressaceae*	16
			Fagaceae	16

1. Categories with six (species, genera, or families) either have a tie, or in the case of species the genus *Acer* is included because managers reported maples.

Aesthetics, mature size, and planting budget were most frequently ranked as the most important tree species selection criteria. Genetic diversity, citizen preference, and hours of sun were not ranked as the most important criteria by any manager (Table 3.5). Using a Borda Count ranking system (Van Erp & Schomaker, 2000) the most frequent responses were ranked in order of importance. Mature size was listed as the most important overall, followed by aesthetics, and proximity of infrastructure. Genetic diversity, citizen preference, and hours of sun found themselves at the bottom of the ranking system.

Table 3.5: Top three tree species criteria ranked

Trait	1st [1]	2nd [1]	3rd [1]	Borda count[2]
Mature size	25	11	8	105
Aesthetics	11	6	8	53
Proximity of infrastructure	7	9	9	48
Resistance to pests and disease	4	8	11	39
Tree hardiness	4	7	9	35
Maintenance costs	4	7	7	33
Planting budget	7	2	4	29
Root space	2	10	3	29
Existing diversity	3	5	9	28
Water requirements	3	6	2	23
Native species	5	1	1	18
Availability	1	4	2	13
Soil type	2	0	1	7
Genetic diversity	0	1	2	4
Citizen preference	0	1	2	4
Hours of sun	0	0	0	0

1. Cell entries are the frequency of ranking the specific trait
2. Borda Count assigns weights in reverse order 1 = 3, 2 = 2, 3 = 1

Mature height is the second highest percentage in this table (Table 3.6), which is consistent with it being the highest ranked. Of respondents, 67.9% said proximity to infrastructure was very important, but only nine ranked it as the most important. 49.4% of respondents ranked root space as very important, yet only 2.6% ranked it as their most important criterion.

Table 3.6: Most important criteria vs. percent reporting very important

Trait	Very important[1]	1st [2]
Proximity of infrastructure	67.9	9.0
Mature size	63.0	32.1
Soil type	49.4	2.6
Root space	49.4	2.6
Citizen preference	46.9	0.0
Tree hardiness	39.5	5.1
Genetic diversity	35.8	0.0
Existing diversity	34.6	3.8
Planting budget	27.2	9.0
Water requirements	27.2	3.8
Native species	25.9	6.4
Aesthetics	22.2	14.1
Hours of sun	19.8	0.0
Resistance to pests and disease	14.8	5.1
Maintenance costs	12.3	5.1
Availability	12.3	1.3

1. Percentage of respondents listing trait as 'Very important'
2. Percentage of respondents ranking that criterion as the most important

This table shows the frequencies of responses to what people consider the most important factor in tree species selection. This incorporates many of the initial criteria that are listed in the above tables, and also encompasses other themes that emerged while coding. Aesthetics appeared most frequently in this open-ended question, which is consistent with respondents ranking it as the second most important criterion overall in tree species selection. Diversity and 'right tree, right place' were also frequent nodes in the qualitative analysis.

Table 3.7: Open-ended responses to most important criteria in tree species selection

Node	Example	Number of times coded
Aesthetics	aesthetically pleasing features, either seasonally or year-round	20
Diversity	"Diversity to protect from disease and to show the public what varieties look like. "	15
Right Tree, Right Place	"Understanding the growth requirements of the tree and tailoring the specific species to successfully fit the site conditions without the need for future maintenance or removal."	15
Maintenance	"have the ability to endure poor maintenance"	14
Hardiness	"Trees I plant must be hardy, tough"	11
Mature size	"Height and width for each individual site."	11
Form and habit	"Habit and form"	9
Water requirements	"Drought tolerant"	7
Infrastructure conflict	"Making sure we avoid Utility conflicts, Right-of-Way obstructions, and building conflicts."	6
Soil Type	"First the tree must be one that will grow in our alkaline soil."	6
Ecosystem services	"Capable of providing numerous ecological services"	5
Function	"Function based on location (park, street) and purpose."	5
Longevity	"I plant trees for my grandkids. I am looking for long lived trees."	5
Root Space (Soil Volume)	"The trees are usually planted in a tree pit in the sidewalk, and have limited soil volume available."	5
Education	"I want a diverse selection of trees, so that the community can see there is more than Tree of Heaven, Silver Maples, and Siberian Elms."	4
Native	"Native, we would like to stick with native drought tolerant trees."	4
Utilities	"Utility conflicts"	3
Budget	"budget sources"	2
Maximizing size	"Largest tree that can fit within the site constraints."	2
Personnel change	"So many times there is personnel turnover and often trees are planted without a thought to what they will be like at maturity."	2
Pest and disease resistance	"Disease and insect resilient"	2
Wildlife habitat	"Habitat for wildlife"	2
Adaptable to climate change	"adaptable to climate change"	1
Citizen preference	"desires of the applicant (whether it's a public or private proposal)"	1
Hours of sun	"Light"	1
Quality of nursery stock	"When I select a tree from a nursery the first thing I check is how the tree resembles the characteristics for the species I am selecting."	1

Discussion

The greater exploration of tree species selection criteria can be used to further additional research and provide researchers with a greater detail of what criteria managers may be using in selecting tree species. Additionally, it is important to see how these criteria have been operationalized in terms of the tree species that are being planted in these areas. This can help to direct assistance to updating acceptable street tree lists that can minimize the impact of invasive pests and other conflicts. The quality of research and advice being produced is irrelevant if it is not being effectively disseminated and put into practice.

It is not surprising that experience is correlated with planting more trees and using more nurseries to source plant material from. This could be a result of accumulating more contacts, or the more experienced professionals may be working in larger municipalities with a greater number of resources. The availability of nursery stock can be a limiting factor in the species managers plant in urban areas. Some respondents indicated that availability of nursery stock was potentially an issue, but this could be because most municipalities are only sourcing from a few different nurseries. This is consistent with previous studies that have identified potential gaps in availability at nurseries (D'Amato et al. 2002). Conway & Vecht (2015) found that availability played a greater role in tree species selection for landscape architects than urban foresters, primarily from issues related to quality or size. Some of the differences in species selection could come from the scope of management. Landscape architects are not often required to manage for diversity on a city scale, whereas urban foresters are. (Conway & Vecht, 2015). The majority of respondents in our study indicated that they could not find a species less than 5% of a time (Table 3.2). This could be due to the large amount of nursery product in Oregon and Washington (USDA, 2007), or perhaps they are selecting species based on what is available at nurseries. While there are respondents reporting difficulties sourcing trees, it seems like the greater issue lies in the extremely limited tree planting budgets. It is concerning that 29% of municipalities reported annual tree planting budgets of $0-$1000 (Table 3.1), while this does not encompass the entire budget, it is consistent with many other municipalities not spending much on their tree resources, including Canada (Kenny & Idziak, 2000). Future research could examine how public managers are influencing the species chosen by private residents, which in turn could further influence what tree species are planted by urban foresters.

The fact that 10 municipalities reported *Fraxinus* spp. among their top five most commonly planted species (Table 3.4) should be a cause for concern. This is an issue due to the pending threat posed by EAB, an incredibly destructive beetle that kills all ash native to the U.S. Other states are spending enormous quantities of money treating, removing, and replanting ash. There is also substantial investment in preventing the spread of EAB (Kovacs et al., 2010). Most of the management efforts are devoted to slowing the spread of EAB, and it naturally only spreads around 20km. Unfortunately, people often play a vital role in the spread of this insect. There were no preventative measures taken to prevent the introduction of EAB since it was not thought to be a pest in its native habitat (Herms & McCullough, 2014). While it is less concerning that there is a large number of ash currently planted, the continued investment in a species that could very well be wiped out is counter to prevailing sustainability practices. It is possible that these municipalities have not received adequate information on EAB or they do not believe it to be a threat to the west coast. A proactive and low-cost solution to reducing the impact of EAB is to stop planting ash.

In 2016 *Acer rubrum* L. was the most commonly selected species, *Acer* the most common genus, and *Sapindaceae* as the most common family. It is clear that this is inhibiting the movement towards greater diversification of tree species in urban areas. Unfortunately, this is a common trend across many municipalities in the United States. Raupp et al. (2006), found that *Acer* represented a large percentage of street trees in 12 eastern cities, up to 57% in Toledo, OH. If *Acer* is continually selected by managers, it is logical to expect the street tree population to continue to be dominated by this genus. Some municipalities in the PNW are restricting the planting of some maples (*Acer* spp.) — although often excluding natives *Acer macrophyllum* and *Acer circanatum* (City of Eugene, 2015). Maples with included bark or codominant stems are more likely to exhibit branch failure than those with good branch bark ridges and single leaders (Eisner, Gilman, Grabosky & Beeson, 2002). Other maples (e.g. *Acer saccharum*) are not well adapted to the climate found in the PNW, and require supplemental irrigation (McKenney, Pedlar, Lawrence, Campbell & Hutchinson, 2007). In addition to a large number of maples still being planted across the PNW, this survey revealed that there are some municipalities planting other problematic species. In 2016 five municipalities reported Callery pear (*Pyrus calleryana*) in their top five species planted within their municipality. Certain cultivars of this tree are known to have serious structural defects and there is also potential for this species to be highly invasive in some areas across the United States (Culley & Hardiman, 2007).

The overuse of particular plants, and inconsistent operationalization of diversity guidelines found in this study is consistent with previous research (Polakowski et al., 2011). While diversity was mentioned 15 times in the open-ended response (Table 3.7), it was not ranked highly in the Borda count or highly prioritized (Table 3.5 & 3.6). There is an increase in the number of tree species respondents selected in 2016 compared to the existing tree species planted in municipalities. While this doesn't necessarily indicate an overall increase in species diversity within a municipality, it may indicate that managers are considering diversity when selecting trees for public areas. One respondent emphasized this in their open-ended response, "I want a diverse selection of trees, so that the community can see there is more than Tree of Heaven, Silver Maples, and Siberian Elms". Tree species diversity can help to minimize vulnerability to certain pest species, and can be used as a potential indicator when modeling urban forest resiliency (Raupp et al., 2006; Santamour, 1990; Steenberg et al., 2016). Blindly increasing tree species diversity is not necessarily desirable due to the potential for invasive tree species, or at the very least poor-performing species. A deliberate and well-researched approach is best when increasing tree species diversity, and can help maximize the benefits (McPherson et al., 1997). Conferring with neighboring municipalities can shed light on which species have performed well in similar environments. With proper planning it is possible to maximize certain benefits provided by trees on a neighborhood scale (Escobedo & Nowak, 2009). While some information can be garnered through increased regional communication, managers should also try new species whenever possible to increase diversity and education (Santamour, 2004). Future research could expand on perceptions of 10-20-30 rule, as this is predominantly based on empirical evidence.

It is expected that floras across urban areas will continue to become more homogenous. While complete global homogenization in urban floras have been avoided thus far, smaller spatial scales are more likely to exhibit homogenization (Yang et al., 2015). Just as it is necessary to look at neighborhood diversity within a municipality, we should also look at biotic homogenization on a regional scale. Raupp et al. (2006), suggests an increase in use of species that are underutilized, and maybe a broader consideration of diversity on an ordinal scale. If there is a shift to manage tree species diversity on an ordinal level there would likely need to be additional education on this topic provided within the field of arboriculture. While this data indicates a greater consideration for diversity than is currently planted in the municipalities, the results — particularly the selection of *Acer rubrum, Pyrus calleryana, and Fraxinus* spp.— also indicate that there is a need for additional consideration of diversity. Future research could explore perceptions of biotic homogenization, as well as the perceptions of intraspecific tree species diversity.

It is clear that there is a wide variety of criteria that must be considered when selecting tree species for an environment as dynamic as an urban ecosystem. With the inclusion of social, and additional economic considerations, traditional silviculture cannot fully account for the complex combination of variables. Interestingly, no manager had reported 'hours of sun' in their top three most important criteria. Perhaps the hours of sun received is less important in urban areas where tree species are less limited by the amount of sunlight than in more natural areas. While 46.9% of respondents ranked 'citizen preference' as 'very important', none of them ranked it as the most important (Table 3.6). Using the Borda count rating system (Van Erp & Schomaker, 2000) citizen preference actually ends up being the second to last criterion (Table 3.5). It is possible that managers are saying that this is an important thing, but are not actually taking it into account. Generally, people with higher incomes, more education, and greater knowledge about the program are more likely to support urban forestry. However, it seems like not all groups are being effectively engaged which may result in less overall support (Zhang, Hussain, Deng, & Letson, 2007). Soil type is rated in a similar manner, with 49.4% of respondents ranking it as 'very important', but only 2.6% ranking it as the most important criterion (Table 3.6). Some argue that there is not enough consideration of the below-ground component, particularly the fungal ecosystem (Green, 2002). This seems to be reflected in the results.

Open-ended themes resulted in a small, but important number of people reflecting on longevity of the tree resource, one respondent said, "I'm planting trees for my grandkids. I am looking for long lived trees." Tree City USA designation may help to provide a broader framework for communities to manage their tree resource on a longer time scale (Carlson, 1995). However, there is room for improvement in terms of their ability to address issues surrounding tree species selection. Our results show that 42 respondents said that the designation did not really influence their tree species selection and 11 said that it did. Perhaps there is room for additional educational opportunities. It certainly seems like there could be a reduction in planting ash, and maple. Furthermore, Arbor Day foundation (those responsible for Tree City USA designation) could play an increasing role of providing an explicit framework for improving tree species selection in terms of longevity. Alternatively, there may be other organizations that can provide additional technical assistance on tree species selection such as, the Society of Municipal Arborists.

Notably form and habit were not considered in the initial survey instrument, and could actually represent an important addition. While mature size might capture some components, form and habit seem to be unique and nine respondents indicated this was important for them. Another interesting thing that was missing from the survey are the issues of personnel change and tree longevity. These two seemed to encompass something that was missing on the initial list of criteria. Longevity of the resource is an important consideration, but it can be difficult to preserve tree resources with changing social and political pressure over multiple generations. Additional research should utilize the criteria found in open-ended responses (Table 3.7) specifically with the additions of: 'wildlife habitat', 'habitat and form', 'longevity', 'maximizing size', and 'education'. While the criteria laid out in our study essentially attempt to quantify what 'right tree, right place' means to managers, it would be interesting to conduct research where these criteria are divided by social, ecological, and economic groupings.

Limitations and Future Research

We were limited primarily by our small sample size and budget. If there were additional resources it would have been possible to survey a greater percentage of municipalities in the PNW, or other states. Additionally, more resources could have been directed at further exploring how backgrounds influence tree species selection. Our qualitative responses were limited to a single box, and more context and depth could have been obtained through semi-structured interviews. Finally, this study was limited by just surveying Tree City USA designated cities. While this ensures that there is some active management, it is very likely not representative of all municipalities across the PNW.

Future research could further explore how this designation impacts tree species selection and urban forest management. It would be interesting to conduct a survey on manager knowledge of the below-ground components of trees, particularly the fungal components of urban ecosystems. Using exploratory or confirmatory factor analysis could help explore the relationships between tree species selection criteria and how managers are prioritizing one over the other. Other qualitative research could be conducted to further explore what 'right tree, right place' means to managers; it is quite possible that there is a wide variety of interpretations of this concept. Finally, while exploring public tree species is important, private selection is increasingly important due to the sizable percentage of trees on private land (Clark, Matheny, Cross & Wake, 1997). Additional research should be conducted to determine how to incorporate best management practices and quality tree species selection in private areas with the goal of increasing equitable canopy cover, forest resiliency, and the benefits provided by the urban forest.

Conclusion

Despite these limitations this study helps to elucidate how current research is operationalized into tree species selection. It also exposes areas, such as lack of tree species diversity, that can be targeted with additional educational campaigns. There is room for improving sustainability, and tree species diversity without the investment of additional funding. Furthermore, this study contributes to a broader collection of research on tree species selection.

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Chapter 4: Discussion and Conclusion

4.1 Discussion

This study was designed to explore tree species selection across Tree City USA designated cities in the PNW. In the first manuscript this study looked at two factors that influence tree species selection (municipality size, and ISA certification) and the second manuscript explored the species of trees planted, and reasons for prioritizing various criteria. While each manuscript looks at a narrow component of urban forest management, they are inherently intertwined. Selection of tree species is one of the foundations and a key starting point in urban forest management.

ISA certification can be expensive, but is often required in job descriptions. Like many things the justification is largely based on empirical evidence. This study seems to suggest that there are some tangible differences in how ISA certified managers make decisions compared to those that are not certified. This could be an important consideration as we hire managers who can maximize benefits, minimize conflicts, and incorporate relevant research into tree species selection. This study bolsters the arguments made for continuing education in the field of arboriculture (Carlson, 1995; Green, 2002; Ries, 2017; Young, 2010). For example, the fact that ISA Certified Arborists® were less likely to prioritize native species and more likely to consider existing diversity is consistent with current research (Chalker-Scott, 2015). Furthermore, ISA Certified Arborists® are less likely to plant the same 3-5 species from year to year and more likely to prioritize the 10-20-30 rule. All these factors indicate a greater support of diversifying the urban forest.

Density of the city has an impact on how ecosystem services operate in urban areas (Tratalos, Fuller, Warren, Davies & Gaston, 2007), there is also reason to believe that population size impacts urban forest management (Kenny and Idziak, 2000). This study explored how municipality size impacts tree species selection criteria, and showed that there are differences in how these municipalities are prioritizing tree species selection. Generally, larger municipalities were more likely to prioritize tree species diversity on a larger scale. This may be attributed to having a larger budget and more resources. Combined density and population size probably have a large impact on things like available planting space, budget, and what managers are prioritizing in terms of management objectives. Smaller municipalities in this study were less likely to have a tree inventory, but perhaps they do not require one to effectively manage their urban forest. That being said, smaller municipalities should still practice 'right tree, right place' and make sure to maximize their resources.

This study indicates that there is room for improvement in terms of the tree species that municipalities select, and there could be more attention paid to achieving the 10-20-30 rule (Santamour, 1990). There are still many municipalities in the PNW planting a large amount of maples (*Acer* spp.), which is generally consistent with municipalities across the country (Raupp et al., 2006). Our reliance on a small number of species, genera, and families seems short-cited and in direct contradiction to establishing a resilient urban forest (Raupp et al., 2006; Steenberg et al., 2016). Urban trees contribute to a unique sense of place and hep increase feelings of belonging (Dwyer, Schroeder, & Gobster, 1991). Perhaps Washington being the 'Evergreen State' and Oregon having a Douglas-fir (*Pseudotsuga menziesii*) on its license plate indicate that there should be special consideration for the tree species planted. This may operationalize through managers in the PNW planting more than 10% of Douglas-fir (*Pseudotsuga menziesii*), and maybe planting less red maple (*Acer rubrum*). It is important to consider what type of overall aesthetic the municipality wants. Should every town center in the United States sport the same box stores with the same box-shaped trees? This is certainly a subjective qualification; however, there are good reasons to plant native tree species. Conversely, Chalker-Scott (2015) correctly points out that there are good reasons to plant non-native, non-invasive tree species in urban areas.

As leaders in the field, urban forest managers need to engage all stakeholders, including other members of the green industry. Our study found that these municipalities are generally only sourcing from a few nurseries and sometimes are unable to find the tree species they want. Obviously, nurseries play a large role in what is available for urban foresters, as well as the private sector. There has been research suggesting that there is a discrepancy between what urban foresters want and what is available (D'Amato et al., 2002; Sydnor et al., 2010). Sydnor et al. (2010), notes that nurseries are struggling from the introduction of EAB, which is good justification for them to have a diverse selection of tree species. Urban foresters should be leading the way in the fight against EAB by not planting ash trees. They can further help by diversifying their tree species selection thus providing a market for nurseries that grow a diverse selection of trees. Regulating invasive species is important, but also effective communication throughout the supply chain is key to creating a more sustainable forest. Forging partnerships can help to make sure that nurseries remain profitable and become more sustainable.

Managers across the survey ranked a wide range of criteria as most important in tree species selection; overall 13 different criteria received at least one vote as the most important criterion in tree species selection. Mature size was overall ranked the highest, followed by aesthetics. Citizen preference was ranked second to last, only barely above 'hours of sun'. Ultimately, the tree species that managers plant are a small subset of the total urban forest. These managers can serve in a leadership capacity, but if there isn't greater citizen participation then it will be difficult or impossible to achieve a sustainable urban forestry initiative. While almost half of urban forest managers ranked citizen preference as very important, none ranked it as the most important criterion. Perhaps it is not the most important criterion, but citizen involvement and engagement are critical to the success of urban forestry. Funding comes from the public, and the continued success of these programs lies firmly in the power of the people. This should continue to be a grassroots bipartisan movement. Furthermore, there needs to be better methods developed in order to effectively communicate with citizens. Effective communication and education can help to increase stakeholder involvement (Moskell, Broussard & Ferenz, 2010).

4.2 Future Research

Further research should be conducted to explore how various stakeholders interact and influence tree species selection. Specifically, the relationships between those groups: citizens, urban foresters, landscape architects, nurseries, and landscapers. There should be ample opportunity for cooperation and working together can further everyone's mission, however there is reason to believe this is not the case. While this study demonstrates that there are differences between ISA Certified Arborists® and those who are not certified, additional research should be conducted on this certification. Currently, this is restricted to municipal arborists and does not explore how this certification might be operationalized in the private sector. Furthermore, additional research could focus on citizen knowledge and perception of this professional certification. Can this certification be effectively monetized, and is it improving private practice?

It would be beneficial to be more consistent with social science research methodology in urban forestry and more explicit in how those methods are conducted. Further replications of these studies are important for better developed theory, particularly in the realm of social science. Conversely, there are many broad recommendations (e.g. 10-20-30, or increase canopy cover) that may not hold true across the U.S. or globe. Planting one million trees in LA may not necessarily yield the same results as it would in another region (Pincetl et al., 2013). There is a complex array of social, economic, and ecological factors that dictate how municipal forests should be managed. While establishing a broad framework for the management is good, it is important to conduct local research to better inform management decisions.

Research on quantifying the benefits of the urban forest, and how to improve those benefits is critical to the success of urban forestry as a whole. At the same time, it is important to research how these findings are being operationalized in the field of urban forestry. Are there unforeseen obstacles or barriers to implementing these findings? How can communication be improved, and funding obstacles overcome? The answers to these questions could be very different across municipalities, and it is important to continue to explore the connections between the social and ecological components of urban forests.

4.3 Limitations:

This study was limited by a number of factors. There was a time restriction for data collection, processing, and analysis. No external funding was acquired so the study was limited to an online questionnaire. While the response rate was relatively high compared to many other studies using similar methods, the survey was very limited in the number of respondents. By restricting this survey to Tree City USA Designated cities in the PNW the sample size became too small for parametric statistics. This necessitated the use of non-parametric statistics, and in turn less powerful results. In future studies a minimum sample of 200 should be the goal, if not far more. By including other states, municipalities, or stakeholders it would have been easy to increase sample size without increasing the cost of the study. Furthermore, this would not have drastically increased the amount of time to administer the survey instrument or analyze the data. Due to the small sample size it was difficult to break data up and explore differences based on background. Initially one of the goals was to see if urban foresters with different backgrounds exhibited differences in tree species selection criteria. This could have elucidated information on what role prior education plays in urban forest management. Funding prevented the use of mail surveys, which typically have a higher response rate than online surveys (Millar & Dillman, 2011). Finally, a lack of phone contacts for the state of Washington prevented an effective non-response bias check from being conducted.

4.4 Management implications:

It is important to know how municipal urban foresters are making tree species selection decisions, and exploring what may be potentially limiting them. As expected, low budgets are probably the largest issue. But, there is room for improvement even if the budgets are not adjusted. There should not be additional ash trees planted. Managers in small municipalities should plant species that are not problematic (e.g. invasive, weak branch attachments, and aggressive roots), and could rely on larger municipalities to figure out what those species are. Small municipalities may not have the financial means to test new cultivars. By rotating the tree species they plant from year to year managers can still deliberately increase diversity, and might be able to partner with other municipalities to get reduced prices on trees.

Perhaps there is additional room for state, regional, or national levels of assistance. There needs to be additional funding mechanisms and continued level of support for such a vital resource. Currently, communities and citizens are not adequately accounting for the benefits provided by these resources. Together it is possible to build a more sustainable network of green infrastructure. Using such a framework can help to ensure the longevity of this resource and ease the burdens of interdisciplinary planning.

4.5 Conclusion

This study provides evidence that some municipalities across the PNW are not adhering to diversity specifications discussed in this thesis. While larger municipalities and ISA Certified Arborists® are more likely to adhere to these standards, it is concerning that there are municipalities that are not following some of these specifications. It is important to note that the study population was only Tree City USA designated cities across the PNW, which was meant to ensure active management. It is quite possible that the urban forest management in other municipalities are in much worse shape. While there has been an increase in urban forest research (Roy & Pickering, 2012), funding of these programs is largely inadequate (Hauer & Johnson, 2008). In order to establish effective management of the urban forest resource there needs to be adequate funding, community support, and continuing education. Many of the issues and challenges in urban forestry (e.g. EAB) are regional, therefore planning must be done both locally and regionally.

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