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A Tree Selection Survey of Tree City USA Designated Cities in the Pacific Northwest

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Abstract. As urban areas expand, there are a greater number of urban trees; however, development often leads to a reduction in urban trees in many areas. A reduction in the canopy volume of trees results in a reduction in the number of benefits. Additionally, urban trees can have additional stressors and must be more actively managed to maintain those services. Selecting tree species for the right site 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. We surveyed Tree City USA designated cities across Oregon and Washington to explore how they are selecting tree species for their municipalities. 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. Emergent themes in open-ended responses indicate a variety of justifications for tree species selection and the challenges of balancing those criteria. 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 5 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 susceptibility to pests and pathogens. We recommend an increase in consideration for the diversification of tree species in urban areas.

Keywords. Emerald Ash Borer; Tree Species Diversity; Tree Species Selection; Urban Forest Managers.

INTRODUCTION

The global population could reach 9 billion by the year 2050, and the fastest growth rates will be occurring in urban areas (Roberts 2011). Tree planting is an increasingly popular solution to address environmental problems such as climate change in urban areas; the city governments of Los Angeles and New York have both proposed plans to plant 1 million trees, demonstrating their commitment to tree planting (Pincetl et al. 2013). In California, the total number of street trees has increased; however, the trees are more spread out, and there are many vacant planting sites (McPherson et al. 2016). Cumulatively, California's street trees are estimated to have an approximately $1 billion impact from energy savings, carbon dioxide sequestration, improved air quality, stormwater mitigation, and increased property value (McPherson et al. 2016).

Urban Trees

Different tree species and site locations can have different impacts on social, ecological, and economic benefits; each tree should be appropriately sited to maximize benefits (e.g., cooling, stormwater mitigation, wildlife habitat, and aesthetics)(McPherson et al. 1997). Trees, particularly evergreens, can help to remove air pollutants (Escobedo and Nowak 2009). Urban trees can help to sequester carbon, but the rate of carbon sequestration largely depends on the tree species (Nowak et al. 2002). Additionally, management practices (e.g., wood salvage vs. wood chipping) should be considered in terms of net environmental benefits provided by the tree (Nowak et al. 2002). Furthermore, urban residents have highly rated the benefits of cooling and stress relief provided by trees (Lohr et al. 2004). An arbitrary number of trees planted may not necessarily yield the desired impact. The benefits provided by trees can be increased by utilizing current science and sound tree management, but may be hindered by neglect or lack of 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 et al. 2012). So, while large municipalities' pledges to plant a million trees seem noble, they must choose the proper trees to realize the full potential from planting and not exacerbate issues through poor tree selection. This could lead to an even age distribution, which could lead to large removal costs when the forest matures. Additionally, this would result in a large loss of benefits and canopy cover all at the same time. It is important to have both tree species diversity and age diversity.

Pests and Pathogens

Urban forests are subjected to harsh growing conditions and face a wide variety of pests and pathogens. Historically, pathogens such as chestnut blight (*Cryphonectria parasitica*) and Dutch elm disease (*Ophiostoma ulmi*) have caused large scale decline in North American urban forests. Pests and pathogens burden cities with enormous tree removal costs and loss of benefits, often in a relatively short time period (Raupp et al. 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 (e.g., inadequate soil volume) and the large influx of goods (e.g., wood products). An increase in pests complicates tree species selection (Poland and McCullough 2006). Within a 15-year period in the USA, insects that are commonly associated with wood were found during routine inspections of goods originating from over 100 different countries; insect species that were found more frequently were more likely to be established in the USA (Haack 2006). Even without pest infestations, urban trees often have shorter life spans and higher mortality rates. Factors such as tree species, size, health, maintenance, and land use are all significant factors in determining survival and growth rate (Nowak et al. 2004). Selecting the right tree for the right place can help to increase the survival rate and minimize conflicts.

Urban Forest Diversification

In order to avoid large scale loss of the urban forest resource, Santamour (1990) suggested 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 controlled scientific research. As research progresses, it is clear that the 10-20-30 rule is not the only rule to consider when selecting tree species. A survey of the Nursery and Landscape Association showed that there is a heavy reliance on cultivars, which are genetically identical to each other. For many tree species there are only a small number of cultivars that comprise the majority of the plantings (Iles and Vold 2003). Reliance on a few cultivars results in less diversity within a species. Raupp et al. (2006) point out that this formula does not take into account susceptibility of multiple species to a singular pest. Another example is that if 2 species of ash were planted, and each ash species represented 10% of the urban forest, then 20% could be wiped out by EAB. 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 within families and orders (Raupp et al. 2006). Conversely, past research has argued for the perpetuation of the oldest tree species in the urban forest. These species are thought to be well-suited to the harsh urban conditions and provide ideal form (Richards 1983). While there is good reason to plant species tolerant of the tough urban environment, it does not adequately account for the introduction of foreign pests, changing climates, and other unanticipated changes.

Most municipalities have the potential to increase tree species diversity as well as the potential to create more diverse habitat types to preserve biodiversity and create more resilient urban forests. For example, many parks provide valuable tree habitat and can be used to increase connectivity and serve as biodiverse hot spots in cities. Unsurprisingly, larger parks tend to have higher levels of tree diversity (Cornelis and Hermy 2004). A survey of personnel responsible for tree inventories at their nurseries in Washington State suggested that support for 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 et al. 2011). It is unclear how other professionals in horticulture, arboriculture, and urban forestry utilize the term "diversity." The 10-20-30 rule can be viewed as a minimum standard for tree species diversity, but this rule could be further defined to increase diversity and minimize susceptibility to pests. Additionally, increased tree species diversity on a neighborhood scale may help to maximize benefits provided by those trees. Furthermore, managers should consider regional or national diversity as well. Many urban areas are increasing their tree species diversity locally, but the same tree species are being planted in many urban areas. With deliberate selection of tree species that are uncommon in the area and continued management, local tree species diversity can contribute to broader regional diversity (Alvey 2006).

Historically, many municipalities have planted large numbers of certain tree species—such as Callery pear (*Pyrus calleryana*)—which can become invasive (Culley and Hardiman 2007) and have poor branch structure. Among the challenges of increasing diversity are lack of awareness of new cultivars or species, as well as availability at nurseries (D'Amato et al. 2002). Tree selection is often influenced by what is grown in nurseries, which in turn is influenced by communication between managers and nurseries (D'Amato et al. 2002). Tree planting goals should be tailored to the city's climate, ability to plant trees, planting site characteristics, desired function from the trees, and ability to maintain those trees, not based on initiatives in other cities. Additionally, the city should create realistic tree planting goals that take into account the need for maintenance (e.g., structural pruning and tree removal) throughout the trees' life spans. 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). If managers solely rely on canopy cover to assess the urban forest, they may miss crucial details, such as tree age distribution, forest health, or tree species diversity (Kenney et al. 2011). As more municipalities establish urban forest programs, survey research has explored how these programs operate (e.g., Kenney and Idziak 2000).

Study Context

The number of papers published about urban forestry has increased since 2000; but as of 2011, only a small subset of those papers on urban trees have used survey-based social science methods (Roy et al. 2012). Also lacking is qualitative research in urban forestry (McLean et al. 2007). The use of a qualitative framework can 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 and Duinker 2014). Beatty and 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 combined qualitative and quantitative data in a mixed-methods approach to see how managers are operationalizing these variables or practices.

METHODS

Study Area and Design

We conducted research in the Pacific Northwest (PNW) states of Oregon and Washington. By only surveying Tree City USA designated cities (which invest $2 per capita in urban forestry, have an Arbor Day celebration, have an established tree board, and have a tree ordinance)(Arbor Day Foundation 2020), we targeted municipalities that we thought had active urban tree management. There were 61 Tree Cities in the state of Oregon and 90 in the state of Washington in 2016; approximately half of the PNW population resided in Tree Cities (Arbor Day Foundation 2016a, 2016b). Our survey targeted those who plant primarily on public lands.

Contacts for Tree Cities across the PNW were collected with assistance from the Oregon Department of Forestry and the Washington Department of Natural Resources. A survey was designed in Qualtrics and was approved by the University Institutional Review Board. Prior to administration, the survey was reviewed and revised by the authors. 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 eighty-five total responses. There was an effort to increase response rate by contacting respondents multiple times (Millar and Dillman 2011).

We defined the urban forest as all trees growing within the boundaries of the municipality. Our goal was to assess tree species selection specifically on public lands that utilize public funds. These trees are highly visible and collectively owned. Our research aims to contribute to a broader framework for urban tree species selection—specifically, how common trends such as "right tree, right place" and the 10-20-30 rule manifest themselves in actual decisions. We explored why managers are selecting species of concern that do not adhere to best management practices. Finally, we wanted to compare the quantitative and qualitative responses to see how selection criteria are being utilized.

Analysis

The survey included closed-ended descriptive questions about respondents' experience in the field, municipal budgets, and how many trees they plant per year. Data collection was similar to Petter et al. (2020), however, the study combined descriptive statistics from closed-ended questions with responses to open-ended questions to explore tree species selection on public land across municipalities in the PNW. While the quantitative results were the main focus, we included a qualitative component in an effort to further triangulate (Creswell 2013) tree species selection. There have been studies (Conway and Vander Vecht 2015; Petter et al. 2020) that examined quantitative components of tree species selection in urban areas, but the qualitative component is necessary to construct a greater understanding of tree species selection as well as to investigate emergent themes 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.

This study explored the top 5 most commonly planted tree species as expressed by managers (i.e., those responsible for tree species selection within their municipality). 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: "Please list the 5 most common tree species PLANTED in 2016 in your municipality," and "Please list the 5 most common tree species that are GROWING in your municipality." Respondents were asked to use scientific names for these questions if possible. Responses were then compiled to compare existing diversity with those tree species planted in 2016. 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 within and among taxonomic ranks. 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. This provided insight into the 5 most commonly selected tree species, genera, and families across the sample population.

Two open-ended qualitative questions were used to examine motivations behind those selections. We analyzed two open-ended questions using the Nvivo qualitative analysis software to add additional context to tree species selection. The first question coded in Nvivo was, "In your own words please describe the most important criteria to you personally for tree species selection." The second question coded in Nvivo 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 and Shannon 2005) surrounding tree species selection. Each response was placed into a broader category or node (e.g., aesthetics, diversity, and function) and tallied; some responses were broken into multiple nodes. The criteria that were used in Petter et al. (2020) 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 et al. (2020). 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 was 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 and Miller 2000).

Respondents were asked to rank tree species selection criteria on a scale of 1 "Not at all important" to 5 "Very important" (Petter et al. 2020). They were also asked to select their top 3 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 (Van Erp and Schomaker 2000). Three points were assigned 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 and 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 had a mean experience level of 15.5 years. The group was generally experienced, however, there was a wide range of experience, from 1 to 53 years. The first quartile occurred at 6 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 was between 41 to 60 trees per year, while the median range was 11 to 20 trees per year. The first quartile occurred at 0 to 10 trees, the second at 11 to 20 trees, and the third at 51 to 60 trees. Five respondents reported planting five hundred or more trees.

Twenty respondents (29%) reported having a tree planting budget of $1000 or less (Table 1). Only 5 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 and $80,000. The other 4 reported having a budget greater than $90,000.

Of the respondents, 54.4% reported that a particular tree species was unavailable at a nursery 5% of the time or less. Our results showed that 11.8% of respondents indicated that a tree species is unavailable at a nursery 31% of the time or greater (Figure 1). Most respondents reported using under 5 nurseries to source their tree species. Over 50% of respondents sourced their trees from 1 to 3 nurseries. One respondent indicated that they source trees from twelve different nurseries (Table 2).

In 2016, managers across the PNW reported 236 different species (or cultivars), 49 genera, and 23 families among their top 5 most commonly planted tree species. This was a drastic increase to the top 5

Table 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

Table 2. 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

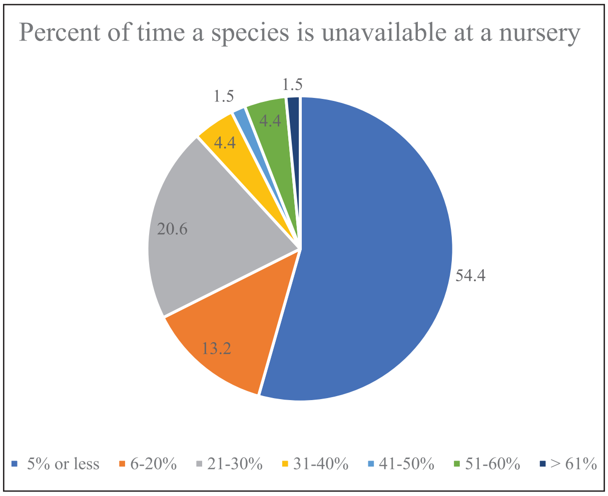

Figure 1. Respondents were asked to report the percent of times they were unable to locate a desired tree species at a nursery.

Table 3. Breakdown of most commonly planted species in municipalities.

Planted in 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.

most common species currently in municipalities, which was represented by 77 species, 33 genera, and 15 families. Managers across the PNW were trending towards more diverse species selection; however, there were still many similarities in tree species selection across municipalities. One interesting finding was that ten managers listed ash (*Fraxinus* spp.) in their top five most commonly planted genera (Table 3). Our results showed there was a tendency to plant large quantities of *Acer* spp., which is already abundant in many PNW municipalities. Four families appeared in both 2016 and those planted before 2016, indicating a large number of municipalities were 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."

Using a Borda count ranking system (Van Erp and Schomaker 2000), we ranked the most frequently selected tree species selection criteria 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 were at the bottom of the ranking system (Figure 2). Mature height was ranked as very important by 63% of respondents (Table 4), which is consistent with it being the highest ranked in the Borda count. Of respondents, 67.9% said proximity to infrastructure was very important, but only 9% ranked it as the most important. Root space was ranked as very important by 49.4% of respondents, yet only 2.6% ranked it as their most important criterion.

The frequency of open-ended responses to what managers consider the most important factor in tree species selection were tallied in Table 5. 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, "right tree, right place," maintenance, and hardiness were also frequent nodes in the qualitative analysis.

DISCUSSION

The availability of nursery stock can be a limiting factor in the species managers plant in urban areas.

Table 4. Respondents were asked to rank the criteria on a scale of 1 "Not at all important" to 5 "Very important." The second column shows the percentage of respondents ranking the criterion as very important. The third column shows the percentage of respondents listing the criterion as their number one criterion.

Trait	Very important	1st
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

Some respondents indicated that availability of nursery stock was a limitation, which could be explained by proximity to nurseries or the number of nurseries municipalities are sourcing trees from. This is consistent with previous studies that have identified potential discrepancies in tree species desired by managers and availability at nurseries (D'Amato et al. 2002). Conway and Vander 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. The majority of respondents in our study indicated the inability to find a species occurred less than 5% of the time (Figure 1). 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 to $1000 (Table 1); while this does not encompass the entire budget, it is consistent with many other municipalities facing funding issues, including municipalities in Canada (Kenny and Idziak 2000).

Species of Concern

The fact that 10 municipalities reported *Fraxinus* among their top 5 most commonly planted genera in 2016 (Table 3) 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 USA. Other states are spending enormous quantities of money treating and removing ash (Kovacs et al. 2010). Most of the management efforts are devoted to slowing the spread of EAB, as it naturally only spreads around 20 km annually. Unfortunately, people often play a role in the spread of this insect through transporting wood. 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 and McCullough 2014). While it is less concerning that there is a large number of ash trees currently planted, the continued investment in a species that could be wiped out is counter to prevailing sustainability practices. It is possible that these PNW municipalities have not received adequate information on EAB or they do not believe it to be a threat to the west coast. We recommend a departure from planting ash trees as a proactive and low-cost solution to reducing the impact of EAB.

In 2016, *Acer rubrum* was the most commonly selected species, *Acer* the most common genus, and *Sapindaceae* the most common family. In our opinion, 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). Some maples (e.g., *Acer saccharum*) are not well adapted to the climate found in the PNW and require supplemental irrigation (McKenney et al. 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, 5 municipalities reported Callery pear (*Pyrus calleryana*) in their top 5 species planted. Certain cultivars of this tree are known to

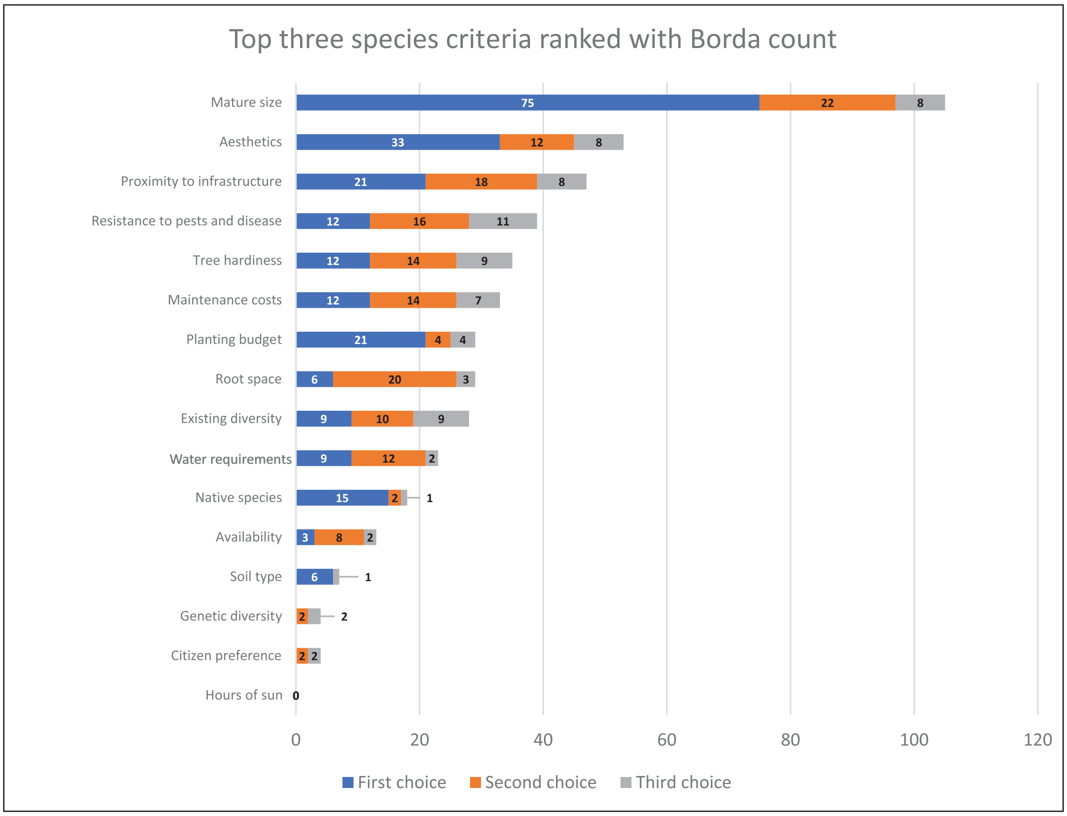

Figure 2. Respondents were asked to rank their top 3 tree species criteria. Using a Borda count, weights were assigned in reverse order. Respondents' first choice was provided a weight of 3, second choice a weight of 2, and third choice a weight of 1 (i.e., 1 = 3, 2 = 2, 3 = 1).

have serious structural defects, and there is also potential for this species to be highly invasive in some areas across the United States (Culley and Hardiman 2007).

We recommend the Arbor Day Foundation (those responsible for Tree City USA designation) further consider issues surrounding tree species selection. Our results show that 42 respondents said that the Tree City USA designation did not influence their tree species selection, and 11 said that it did. There is need for additional educational opportunities specifically addressing species of concern. We recommend reducing the number of ash and maple trees in municipalities. Alternatively, there may be other organizations that can provide additional technical assistance on tree species selection, such as the Society of Municipal Arborists.

Tree Species Diversity

The overuse of particular species and inconsistent operationalization of diversity guidelines found in this study was consistent with previous research (Polakowski et al. 2011). While diversity was mentioned 15 times in the open-ended responses (Table 5), it was not ranked highly in the Borda count or highly prioritized (Figure 2, Table 4). There was an increase in the number of tree species respondents selected in 2016 compared to the existing tree species planted in municipalities. While this does not 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 pests and diseases and can be used as a potential indicator when modeling urban forest resiliency (Santamour 1990; Raupp et al. 2006; 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 in order to maximize the benefits and minimize conflicts (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 and 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). We recommend managers consider the importance of intraspecific diversity, as the 10% of the rule is crucial. While it is unlikely that we will eliminate our reliance on cultivars, we need improved communication across the green industry to reduce reliance on a small number of cultivars (Iles and Vold 2003).

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, there is a greater likelihood of homogenization on a landscape-scale due to the smaller scale and similarities found within a landscape (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) suggested an increase in use of species that are underutilized and a broader consideration of diversity utilizing orders in addition to family, genus, and species. If there is a shift to manage

Table 5. 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

tree species diversity within orders, there would likely need to be additional education on this topic provided within the field of arboriculture. In turn, municipal policy and tree planting policies would have to be revised to reflect a greater consideration for tree species diversity. Our results, particularly the selection of *Acer rubrum*, *Pyrus calleryana*, and *Fraxinus* spp., indicate that there is a need for additional consideration for increasing tree species diversity.

Selection Criteria

Exploration of tree species selection criteria can provide researchers with greater detail on how managers are utilizing those criteria. Additionally, it is important to see how various selection criteria impact the tree species that are being planted in these areas. This can help 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.

We recommend managers consider a wide variety of criteria 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 3 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 4). Using the Borda count rating system (Van Erp and Schomaker 2000), citizen preference actually ends up being the second to last criterion (Figure 2). It is possible that managers are saying it is important but are actually prioritizing other criteria. 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 4). Some argue that there is not enough consideration of the belowground component, particularly the fungal ecosystem (Green 2002).

Open-ended themes resulted in a small but important number of people reflecting on longevity or life span 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). Personnel change and tree life span were two themes that were missing on the initial list of survey criteria but were captured when creating nodes. Longevity or life span 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. The Arbor Day Foundation could play an increasing role of providing an explicit framework for improving tree species selection in terms of maximizing tree benefits over a longer time period. This should encompass tree species diversity, long-term management, tree age diversity, and equitable tree distribution.

Limitations and Future Research

We were limited primarily by our small sample size due to available resources. Additionally, 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 only 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 belowground components of trees in urban ecosystems; this survey could include pH, microbes, fungal ecology, root growth, and pollutants to help elucidate knowledge gaps. Other qualitative research could be conducted to further explore what “right tree, right place” and the 10-20-30 rule mean to managers; it is quite possible that there are a wide variety of interpretations of these concepts. Of particular interest would be to further investigate how various stakeholders differently define diversity in terms of the urban forest ecosystem. While exploring public tree species is important, private selection is increasingly important due to the sizable percentage of trees on private land (Clark et al. 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.

We recommend additional research utilize the criteria found in open-ended responses (Table 5), specifically with the additions of: "wildlife habitat," "habitat and form," "longevity or life span," "maximizing size," and "education." While the criteria laid out in our study essentially attempt to clarify 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. 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.

CONCLUSION

Despite limitations, this study helps to elucidate how urban forest managers are selecting tree species. As expected, low budgets are probably the largest issue in urban forestry. Adequate funding for tree planting is necessary for well-informed urban tree species selection, site preparation, and maintenance. Proper planting and maintenance are a key component to maximizing the success of the selected tree species. Based on our results it is clear that not all communities are adequately funding tree planting. There is room for improvement in tree species selection even if the budgets are not substantially adjusted. We recommend not planting additional ash trees or trees that can become invasive, such as Callery pear. Managers in small municipalities should plant species that are not problematic (e.g., invasive, weak branch attachments, and aggressive roots) and could garner information on those species from larger municipalities. By rotating the tree species year to year, managers can deliberately increase diversity without spending more on trees.

Many of the similarities found in tree species selection in the year 2016 and prior to that are likely driven by tree species availability at nurseries, as well as familiarity with those species. Everyone has implicit biases that influence which trees they select. We recommend focusing more continuing education on the types of tree species available and what function or role they could play in an urban forest. It is impossible to select a tree that you are not aware of. We recommend bringing together managers, landscape architects, nursery workers, and other stakeholders for these educational events to encourage cross-disciplinary training and improve communication. Each of these groups has valuable knowledge that can contribute to the health and resiliency of the urban forest. Organizations such as the Arbor Day Foundation or International Society of Arboriculture can help engage more stakeholders to facilitate interdisciplinary cooperation. Additional engagement may help address the issues associated with planning for the longevity of the urban forest by establishing a stronger network of support. 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 et al. 2007). With engagement from more communities, it is possible to build a more sustainable network of green infrastructure both in cities and between cities.

The City of Portland, OR, discusses the 5-10-20 guideline—do not plant more than 5% of a species, 10% of a genus, and 20% of a family—and notes that it does not meet this specification (City of Portland 2017). This updated specification can be found in some urban forestry management plans and attempts to improve upon the 10-20-30 rule. This will likely further the resiliency of urban forestry programs that have the resources to implement it. Perhaps a 5-10-20-30 rule could be implemented, restricting orders to 30% within a municipality. Initially considering diversity at orders could facilitate diversity, and the results would propagate all the way to species. For example, our study found Sapindales and Pinales were two of the most common orders, and the diversity issues are perpetuated all the way to species.

We recommend that larger municipalities strive to achieve diversity on a neighborhood scale, perhaps 10-20-30, and work towards equitable distribution of canopy cover. Neighborhoods would have to vary their 10-20-30 distributions in order to reach a 5-10-20-30 distribution across the entire city. Managers should select the right tree for the right place; however, they should also strive to maximize the size of the tree and in turn the potential benefits of that planting space. This will vary across neighborhoods based on available planting spaces and other factors. When diversifying the tree species, it is important to consider maintaining a stratified age distribution to avoid all of the trees maturing at the same time.

In our opinion, regional diversity could be accomplished in a few ways. First, continuing to plant native species helps to set a particular region or area apart from others and provides a unique sense of place. Second, we recommend partnering with local nurseries to grow a greater variety of tree species. If there is a market, tree nurseries are more willing to grow that species. Third, where feasible, more trees should be planted that were grown from seed, both for native and nonnative tree species. This will increase the intraspecific tree diversity, help to produce trees that are better suited for the local climate, and reduce reliance on cultivars.

Management Implications

1. Select the tree based on site characteristics.
2. Avoid tree species that have known problems (e.g., weak branch attachment) or are potentially invasive.
3. Engage more stakeholders and improve interdisciplinary cooperation.
4. Increase diversity: strive for 5-10-20-30; 10-20-30 on a neighborhood scale.
5. Consider regional diversity, both in terms of increasing the number of species and increasing diversity within species that are specifically adapted to your region.

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Résumé. Avec l'expansion des zones urbaines, il y a un plus grand nombre d'arbres urbains, cependant le développement entraîne souvent une diminution des arbres dans de nombreux secteurs. Une réduction du volume de la canopée arborescente entraîne une réduction conséquente des bénéfices. De plus, les arbres urbains peuvent subir des stress additionnels et doivent être gérés activement afin de maintenir le niveau des services générés. La sélection de l'espèce appropriée en fonction du site peut conduire à de plus grands bénéfices et à une plus longue espérance de vie pour les arbres. Accroître la diversité des arbres urbains peut aider à atténuer certaines des menaces auxquelles sont confrontées les forêts urbaines, dont les ravageurs et les changements climatiques. Nous avons mené une enquête auprès de villes reconnues par le programme Tree City USA à travers les états d'Orégon et de Washington afin d'analyser la manière dont le choix des espèces est effectuée dans ces villes. Des réponses furent recueillies auprès de 79 des 151 communautés pour un taux de réponse de 52.3%. Des questions ouvertes et des statistiques descriptives ont été utilisées pour trianguler la manière dont les gestionnaires sélectionnent les espèces d'arbres. Les thèmes émergents dans les réponses ouvertes indiquent une variété de justifications pour la sélection des espèces d'arbres et les défis de composer avec ces critères. Des éléments montrent que ces municipalités diversifient activement leur forêt urbaine cependant, il y a toujours 10 villes qui signalent que les frênes (*Fraxinus* spp.) sont encore parmi les cinq espèces le plus fréquemment plantées en 2016. Plusieurs municipalités continuent encore à planter de larges quantités d'érables (*Acer* spp.). La plantation excessive de certains genres et espèces peut entraîner une augmentation de la susceptibilité aux parasites et aux agents pathogènes. Nous recommandons de prendre davantage en considération la diversification des espèces d'arbres dans les zones urbaines.

Zusammenfassung. Mit der Ausdehnung städtischer Gebiete steigt die Zahl der Stadtbäume; die Entwicklung führt jedoch in vielen Gebieten häufig zu einem Rückgang der Stadtbäume. Eine Verringerung des Volumens der Baumkronen führt zu einer Verringerung der Anzahl der Vorteile. Darüber hinaus können Stadtbäume zusätzliche Streßfaktoren haben und müssen aktiver gepflegt werden, um diese Funktionen zu erhalten. Die Auswahl von richtigen Baumarten für den richtigen Standort kann zu größerem Nutzen und langlebigeren Bäumen führen. Eine zunehmende Vielfalt an Stadtbäumen kann dazu beitragen, einige der Bedrohungen zu mildern, denen Stadtwälder ausgesetzt sind, wie z.B. invasive Schädlinge und Klimawandel. Wir haben die von Tree City USA benannten Städte in Oregon und Washington befragt, um herauszufinden, wie sie Baumarten für ihre Gemeinden auswählen. Die Antworten wurden für 79 von 151 Gemeinden mit einer Rate von 52.3% erfasst. Sowohl offene Fragen als auch deskriptive Statistiken wurden verwendet, um zu ermitteln, wie die Verantwortlichen die Baumarten auswählen. Aufkommende Themen in den offenen Antworten weisen auf eine Vielzahl von Begründungen für die Baumartenauswahl und die Herausforderungen bei der Abwägung dieser Kriterien hin. Es gibt Anhaltspunkte dafür, dass diese Kommunen den Stadtwald aktiv diversifizieren; es gibt jedoch immer noch 10 Kommunen, die im Jahr 2016 die Esche (*Fraxinus* spp.) unter ihren fünf an den häufigsten gepflanzten Baumarten aufgeführt haben. Viele Gemeinden pflanzen immer noch große Mengen von Ahorn (*Acer* spp.). Die Überpflanzung bestimmter Gattungen und Arten kann zu einer Zunahme der Anfälligkeit für Schädlinge und Krankheitserreger führen. Wir empfehlen eine verstärkte Rücksichtnahme auf die Diversifizierung der Baumarten in städtischen Gebieten.

Resumen. A medida que las áreas urbanas se expanden, hay un mayor número de árboles urbanos; sin embargo, el desarrollo a menudo conduce a una reducción de los árboles urbanos en muchas áreas. Una reducción en el volumen del dosel de los árboles resulta en una reducción del número de beneficios. Además, los árboles urbanos pueden tener factores de estrés adicionales y deben administrarse más activamente para mantener esos servicios. La selección de especies de árboles para el sitio adecuado puede conducir a mayores beneficios y árboles de vida más larga. El aumento de la diversidad de árboles urbanos puede ayudar a mitigar algunas de las amenazas que enfrentan los bosques urbanos, como las plagas invasoras y el cambio climático. Hemos encuestado las ciudades designadas por Tree City USA en Oregón y Washington para explorar cómo están seleccionando especies de árboles para sus municipios. Se registraron respuestas para 79 de los 151 municipios, con una tasa de respuesta del 52.3%. Tanto las preguntas abiertas como las estadísticas descriptivas se utilizaron para triangular la forma como los gerentes están seleccionando especies de árboles. Los temas emergentes en las respuestas abiertas indican una variedad de justificaciones para la selección de especies arbóreas y los desafíos de equilibrar esos criterios. Hay evidencia que sugiere que estos municipios están diversificando activamente el bosque urbano; sin embargo, todavía hay 10 municipios que reportaron el fresno (*Fraxinus* spp.) en sus cinco especies más frecuentemente plantadas en 2016. Muchos municipios todavía están plantando grandes cantidades de arce (*Acer* spp.). La sobreplantación de ciertos géneros y especies puede conducir a un aumento de la susceptibilidad a plagas y patógenos. Recomendamos un aumento en la consideración para la diversificación de especies arbóreas en las zonas urbanas.