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Street Tree Diversification and Location Considerations

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Table of Contents

Glossary of Terms and Acronyms

Carbon Footprint	The amount of greenhouse gases emitted into the atmosphere
Chlorosis	Tree disease associated with lack of iron or other nutrient (typically results in bleached or pale leaves)
Chlorotic	Condition of tree that is suffering from chlorosis (see chlorosis)
DBH	Diameter at Breast Height
Externality	Side effect of something, either positive or negative, that is usually not reflected in cost
Family	Taxonomic unit of an individual, above genera and below class (example: bur oak is part of the beech family of trees – Fagaceae family)
Genera	Plural of genus in taxonomy of an individual (see genus)
Genus	Taxonomic unit of an individual, above species and below family (example using Latin name: bur oak – *Quercus macrocarpa*, *Quercus* is the genus)
GIS	Geographic Information System
GPS	Global Positioning System
Ordinance	Legislation enacted by a municipality
Park strip	Piece of ground between a roadway and a sidewalk
pH	Acidity or alkalinity of a particular soil (low pH is acidic, high pH is alkaline)

Species	Lowest taxonomic unit of an individual, below genus. (example using Latin name: bur oak – *Quercus macrocarpa*, *macrocarpa* is the species)
Street trees	Trees planted along roads, parking lots, and highways in urban areas.
Vector	Organism that transmits insects or disease from one individual to another

List of Figures

List of Maps

List of Tables

List of Appendices

Abstract. Although essential in an urban forest, street trees create numerous challenges for municipalities as well as private owners. Lack of species diversity is usually pronounced. In addition, inappropriate species are commonly planted along streets. Selection of street trees should follow established percentage guidelines for tree species, genera, and family in order to maintain diversity when planting in a municipality. Numerous variables such as proximity to buildings or vehicular traffic, soil area, exposure, and road salt usage should also be considered when planting any tree. Planting a diverse urban forest with the right tree in the right place can enhance a city streetscape and reduce the long-term cost of tree replacement and maintenance.
Key Words. Street trees, species diversity, location considerations

Introduction

While street trees present a challenge for city foresters, their value to urban areas is significant. City foresters and urban residents consider street trees to be a significant asset because they help reduce the carbon footprint of a city, buffer sound, soften hardscape areas, reduce storm water runoff, and offer a refuge from extreme temperatures (Donovan and Butry 2012, Gorman 2004). Urban trees can be as important to city residents as trees in native forested areas are to the species that live there (Getz, et al. 1982).

Because city streets provide an especially challenging environment for trees, street trees can be one of the major impediments for successful urban forestry programs. City streets are commonly lined with trees of various sizes, amidst gaps where trees have succumbed to stress or vehicle collision. Some of the tree trunks are void of bark on entire sections or have large wounds that may never heal. Some of these trees are topped or pruned in "V" shapes to allow for power lines (See Appendix D). These factors contribute to decay which may cause the tree to fail, damaging property or injuring people. Trees in poor condition are a liability for a municipality. The sidewalks around street trees may be heaving, as roots escape the bounds of the park strip. The cost of replacing these trees, and repairing the structural damage caused by them, is significant. However, these problems can often be avoided if the right tree is planted in the right place.

Unfortunately, most municipalities have a monoculture of trees growing in their streetscapes. Park strips tend to foster a low variety of species in comparison to the large volume of trees lining them. Some city park strips may embody the same species for miles. This is particularly hazardous when a certain species of tree becomes subject to an outbreak of disease or damaging insects (Bassuk 1990). Hundreds of trees can perish in a short period of time, leaving a formerly tree lined street barren. Unfortunately, this problem occurred with the American elm (*Ulmus americana*), which once graced many of America's streets, but was decimated by Dutch elm disease beginning in 1950, and today only about 8,000 elms still remain on city streets. (Bassuk 1990, US Forest Service 2011). Ash trees, planted to replace the American elms lost from Dutch elm disease, are facing their own threat of mass die-off through the introduction in the U.S. of the emerald ash borer in 2002. This exotic beetle has killed millions of ash trees throughout the

east coast and mid-west, costing municipalities millions of dollars (Michigan State University 2013).

To address the problem of a mass die-off of urban trees due to an introduction of a disease or exotic insect, city foresters should be looking at diversifying their urban forests. With an increasing number of species being tested and introduced for use in urban settings, there should be greater opportunities to acquire unique and diverse species. However, current species diversity appears to be lower now than it was several decades ago. Usually older parks have larger trees and greater species diversity than newer parks (Nagendra and Gopal 2010). Many landscapers and installers appear to choose common favorites, instead of expanding their palette of tree species.

However, the destruction of the American elm trees, have shown us mass planting of a single species can pose serious problems for municipalities. Although it is tempting to find a single new species of tree with desirable characteristics to fill the niche of the American elm; as city managers across the U.S, found with ash trees, this is not a wise solution (Santamour 1990).

Planting a variety of species can reduce the effects of a devastating insect or disease epidemic. Several studies have focused on the benefits of street tree diversity. Some of these studies have provided percentage recommendations for the amount that each tree species, genus, and family should be used. One of the earliest contributers to this idea was Phillip A. Barker, who advised that a certain tree species should not exceed 5 percent of the total street tree population (Barker 1975). Other researchers proposed that in addition to the 5 percent rule for species, a certain genus should not make up more than 10-15 percent of the total tree population of the entire city (Raupp, et al. 2006; Maco and McPherson 2003). Frank Santamour advised using no more than 10 percent of any species, 20 percent of any genus, or 30 percent of any family (Santamour Jr 1990).

A diverse population of street trees can vastly enhance the overall urban forest, which in some cases can host a greater biodiversity than the surrounding native forests (Alvey 2006, Zipperer, et al. 1997). Diseases have a greater chance of being introduced in urban areas, with nursery trees coming from various locations across states. An increase in diversity can help reduce the number of trees lost when infestations of insects or disease affecting a single species occurs.

Another advantage of increased street tree diversity is the opportunity to reduce the cost of maintaining an urban forest. In a monoculture, even if trees are not wiped out in a single destructive event, the fatalities over a long period of time can cost municipalities a significant amount of money for replacement. Ironically, trees are usually replaced with the same species that just died. Breaking up the monotony of a monoculture would allow for cheaper replacement, if a single species is declining. While it may be expensive to replace an entire block of trees due to decline, it is still less expensive than replacing several miles of the same species of tree. If, however, a large number of trees need to be replaced, or cause damage to surrounding structures, valuable street trees may become a liability for the municipality.

In addition to augmenting tree diversity, choosing tree species that can tolerate the stresses of an urban setting is vital. Trees growing in park strips are exposed to a barrage of hazards, including:

- road salt
- heat radiation from surrounding surfaces
- trunk damage from mowing equipment and automobiles
- vandalism
- heavy pruning for traffic and power lines
- limited crown and root area

Additionally, many park strips have less than ideal irrigation, due to the size of the area and competition with other utilities. Perhaps the greatest challenge for trees in a park strip is the lack of ample soil in the root zone (Lindsey and Bassuk 1992). Although most of the obstacles that plague street trees are caused by the site itself, proper species selection can assuage some of these hurdles and increase the potential for survival (McPherson and Peper 1995). Examination of some sites may reveal no trees should be planted at those particular locations (Davis and Johnson 2007).

To ensure the long-term survival of trees it is essential the right trees are planted in the right place. A good example of this is when trees are planted under power lines. Many species remain small enough at maturity to work well under power lines. However, care must be taken not to solely plant small trees in every park strip throughout a city. In the long run, this could greatly reduce the overall biomass of trees throughout the city, reducing the amount of carbon dioxide, pollution, and solar radiation absorbed by trees (Jim and Liu 1999).

Many cities have tree ordinances that address issues such as pruning height for vehicular and pedestrian clearance. They may also specify the numbers of trees required in a particular location. However, few city tree ordinances specify which tree species are appropriate to plant in parkstrips. It is even less likely they will specify which species would be most successful in relation to parkstrip width, overhead powerlines, etc. If city foresters specified in their tree ordinances which species should be planted in specific locations it would eleviate many of the problems street trees currently experience, and provide a clearer understanding of expectations between developers and private landscapers and, city planners, elected officials, and urban foresters.

Goals / Objectives

Although street trees are an important asset to a municipality, they also can generate myriads of problems for a municipality. In my capstone project I have attempted to determine ways municipalities can identify and plant street trees that cause less damage to their surroundings, and will be less problematic for municipalities to maintain.

- The first objective of my project was to conduct an inventory of the street trees maintained by South Jordan City using a variety of geographical information system equipment. This allowed me to count each species and map their locations. As I conducted an inventory of the street trees in the city, I identified which tree species were or were not thriving in the city. The information I collected in my tree inventory included: species, DBH (diameter at breast height), date, location, and overall condition of the tree. I took note of items such as power lines, park strip width, and other characteristics that may limit which tree species can grow in each location. I plotted the points I collected and added it to the city's existing geographical information system data.

- With the street tree inventory completed I used the information to identify which species currently are working well as street trees. I used Arc Reader and Microsoft Excel to interpret these data. I also conducted research on other tree species, not currently found in the city, which could work well under the conditions of the inventory area.

- With this information, I created a tree diversity guide for South Jordan City maintained park strips, with a variety of species options for the replacement of declining trees. In this guide, I suggest a variety of tree species from numerous genera and families as replacement trees when current trees die-off, with consideration of percentages for each category. Ultimately, use of this guide by South Jordan City foresters will facilitate a more diverse planting scheme for the city, and introduce new species to areas currently populated with only one or two species of trees. In addition, this information could be incorporated into South Jordan City's urban forestry ordinance, making it more specific and useful to developers and private landscapers in meeting the city's need for diversity in street tree species, and identifying species that can tolerate living in park strips.

- My final objective was the publication of a more general guidebook that included recommended street tree species for northern Utah, along with different street conditions that street trees may or may not be able to tolerate. For this publication, I referred to scholarly publications and reference books to supplement my own experience and findings on each tree species.

My ultimate goal is that municipalities and residents of northern Utah will be able to use this reference for choosing street trees. My intention is that this guidebook will be used to increase the diversity of tree species planted, particularly along streets and in parking lots. Hopefully the

guidebook will increase awareness of the need to plant the appropriate tree for the location, and reduce future costs and damage experienced by municipalities and homeowners. This diversification should also enhance the quality of the urban forest, increasing the forest's vitality and appeal to local residents.

Methods of Analysis and Description of Study Site

The study site was an area that covered all of the city-owned street trees throughout South Jordan City (See Appendix A). These trees were evaluated and put into a tree inventory.

This data was gathered with a Trimble Juno 3B portable GPS unit. Before conducting the tree inventory I set up the various fields that would be used to input data on each tree:

1. Field 1 included a list of scientific names for all tree species I would be likely to encounter in the city. These names were stored in a drop down window that could be selected for each tree.
2. Field 2 was used for entering the size of the tree, or DBH (diameter at breast height). I measured each tree using a diameter tape.
3. Field 3 included information about the condition of the tree, such as damage by equipment, disease, or insects.
4. Field 4 allowed for recommendations of further action to be performed, such as pruning, staking, or removal.
5. Field 5 was reserved for additional information about the tree, such as the date it was planted or if it is a cultivar.
6. Each tree was given a unique number, used mainly for counting purposes.
7. Each tree was given an easting and westing coordinate.

The bulk of this GPS data was gathered from 2011 to 2013. The inventory mainly took place in the winter months when leaves were not on the trees. This allowed for a clearer signal from satellites and provided more accurate location coordinates for each tree.

After collecting information from every city owned street tree, the data was uploaded into Arc Maps. I extracted a Microsoft Excel spreadsheet to run statistics on the species data. I came up with percentages of each tree species planted along the streets in South Jordan City. I used this information to create pie charts (see Figures 1, 2, and 3 below), which visually illustrate which trees are over-used and under-used throughout the city.

Findings of Analysis

The results of my street tree inventory provided useful information in regards to the current number of street trees, and their species. Overall, 3,455 street trees are maintained by South Jordan City. Of these trees, Norway maple (*Acer platanoides*) is the most abundant, at 530 individuals. Flowering pear (*Pyrus calleryana*) is a close second, with 529 individuals.

What I found from the tree inventory data was that 50 percent of the street tree population of South Jordan City is represented by only four species: the two mentioned previously, as well as littleleaf linden (*Tilia cordata*), and honey locust (*Gleditsia triacanthos*). The other 50 percent is represented by a well-rounded 25 additional species, making 29 species in all.

The top ten street tree species represented in the inventory include the four previously mentioned species, as well as apple serviceberry (*Amelanchier x grandiflora*), crabapple (*Malus* spp.), London planetree (*Platanus x acerifolia*), bur oak (*Quercus macrocarpa*), Japanese zelkova (*Zelkova serrata*), and hedge maple (*Acer campestre*). Figure 1 below and Table 1 in Appendix A are a list of all street tree species found in South Jordan City, with their count and overall representation.

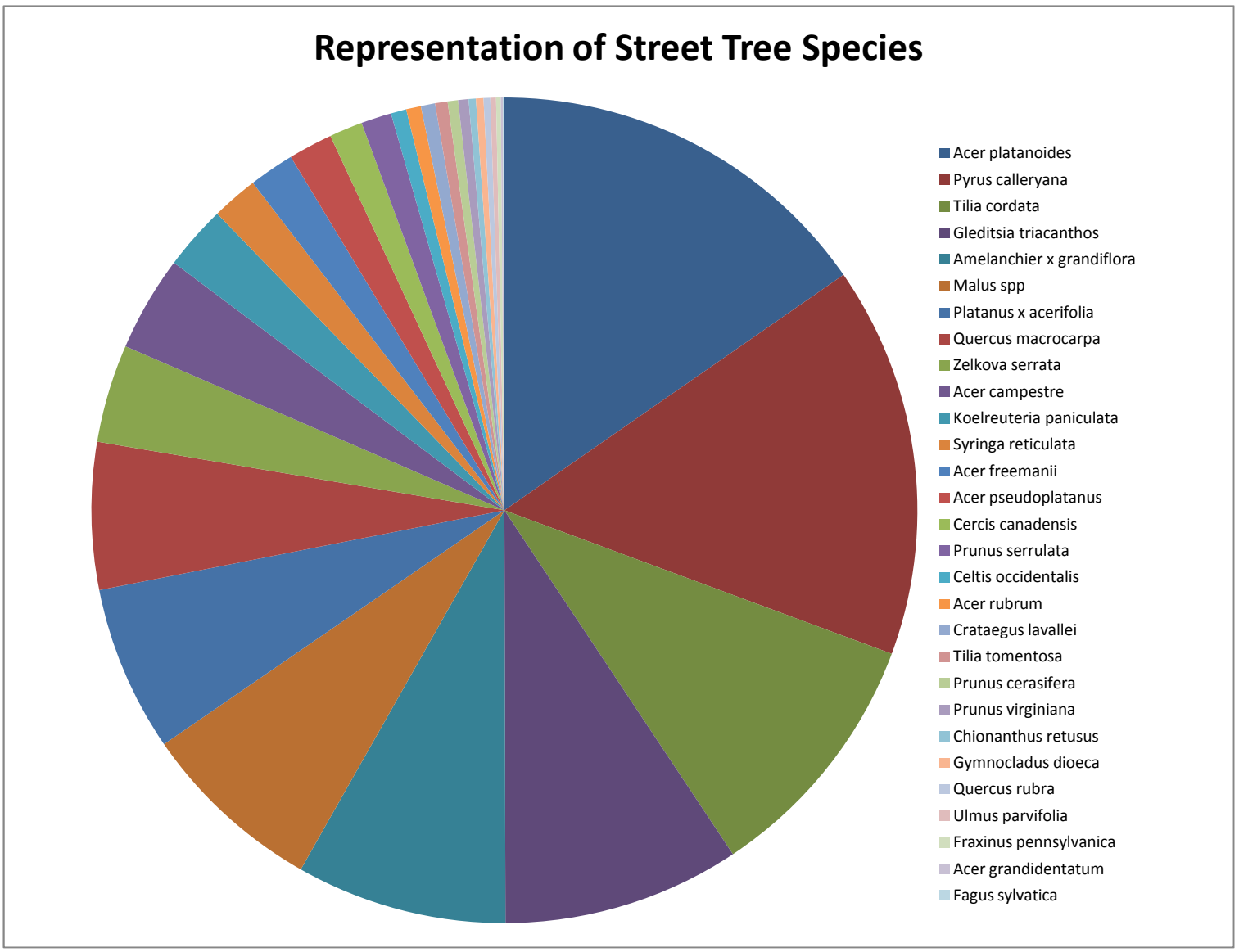

Figure 1: This chart illustrates the percentage of each species of city-owned street tree. Notice that half of all the trees are comprised of just four species.

After the species identification, I categorized all the street trees by genus. Eighteen genera are represented among the city's street trees. Of those, 50 percent of the total population is represented by only 3 genera: *Acer, Pyrus, and Tilia*. Furthermore, 75 percent of the total population is represented by only 6 of the 18 genera: *Acer, Pyrus, Tilia, Gleditsia, Amelanchier*, and *Malus*. The remaining 12 genera only represent 25 percent of the population. Figure 2 below and Table 2 in Appendix A are a list of all street tree species found in South Jordan City, with their count and overall representation.

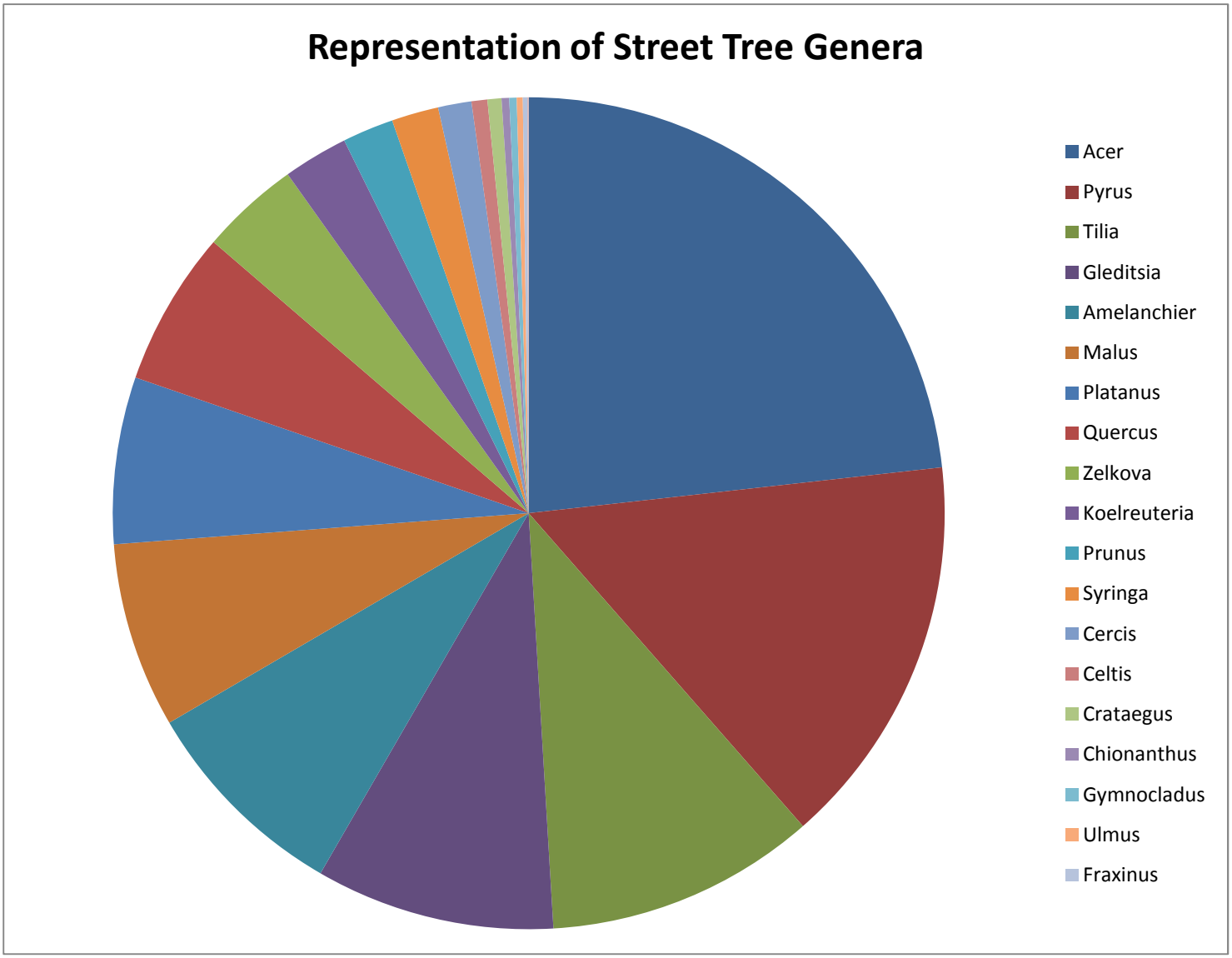

Figure 2: This chart illustrates the percentage of each genera of city-owned street tree.

Finally, I evaluated the corresponding tree families. Overall, there are nine tree families represented along South Jordan City's streets. The most abundant are Rosaceae at 33 percent and Sapindaceae at 26 percent. Next are Fabaceae and Malvaceae, both at 11 percent. The remaining 19 percent is made up of Platanaceae, Fagaceae, Oleaceae, Ulmaceae, and Cannabaceae. Figure 3 below and Table 3 in Appendix A are a list of all street tree species found in South Jordan City, with their count and overall representation.

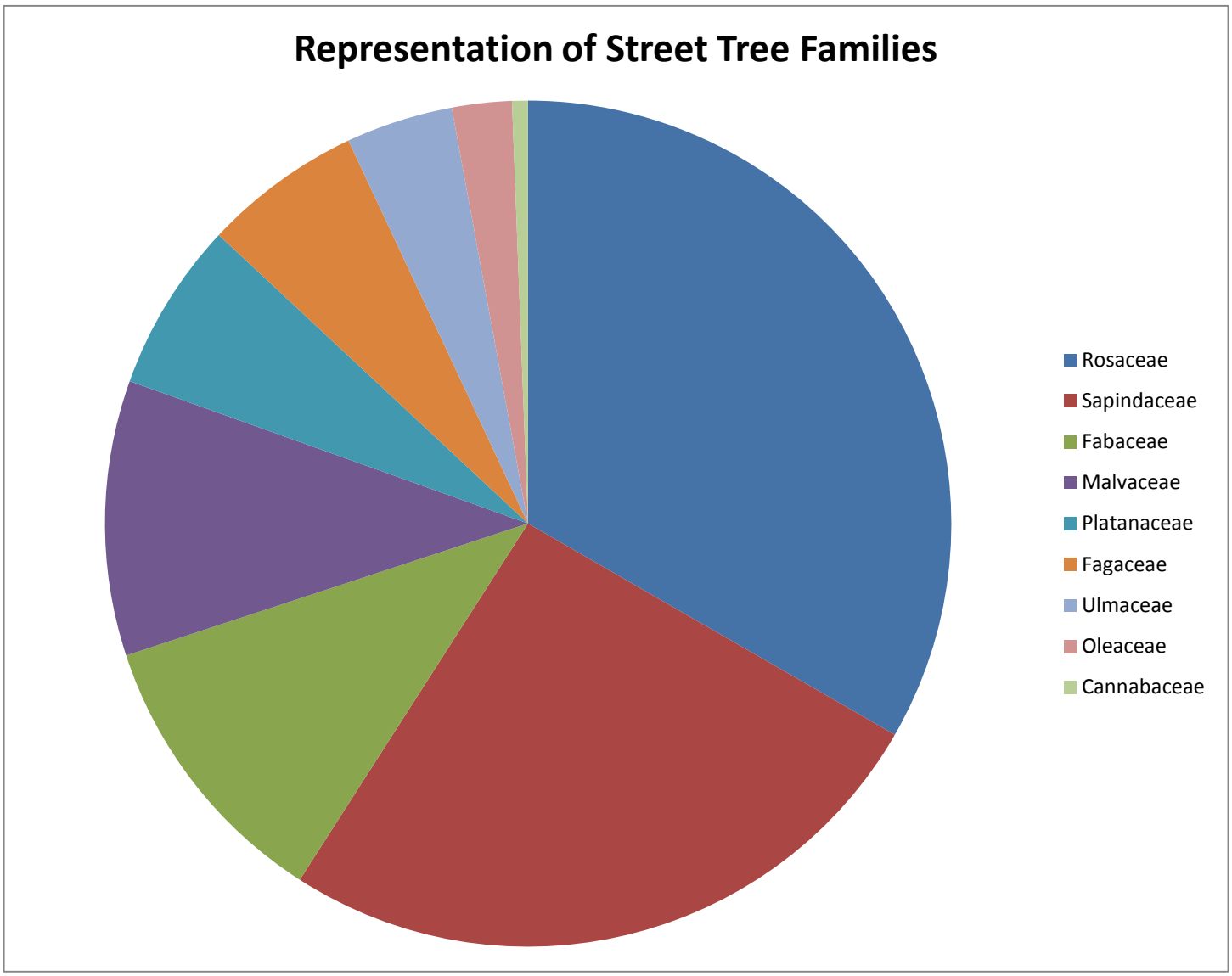

Figure 3: This chart illustrates the percentage of each family of city-owned street tree.

The tree inventory revealed the following list of tree genera and families suitable for street tree plantings, which are currently underutilized in South Jordan City:

Family	Genus
Magnoliaceae	*Liriodendron*
Hamamelidaceae	*Parrotia*
Moraceae	*Morus*
Betulaceae	*Corylus*
Ginkgoaceae	*Ginkgo*
Fabaceae*	*Cladrastis, Sophora*
Sapindaceae*	*Aesculus*

*Other genera in these families are frequently used.

In addition to the counts I extracted of tree species, genera, and families, this tree inventory project provided other valuable information. For example, the information from this inventory will allow the city to track the cost of installation, maintenance, and removal of trees in the future. It also will help determine the cost of various species in the urban landscape, which may be compared to the benefits the trees provide.

While planting a single species as the primary street tree in a municipality is not a good idea, city foresters should also be aware of other problems associated with certain species commonly used as street trees. Below is an evaluation of some of the other potential problems South Jordan City may encounter with their 10 most common street trees:

1. Norway maple (*Acer platanoides*) – This is a sturdy tree that holds up well in urban areas, however, it is considered invasive in the eastern United States. This isn't really an issue in Utah, but the seeds do germinate in adjacent flower beds. This tree is often infested with aphids which exude honeydew, leaving sticky spots on vehicles and sidewalks. Sidewalks eventually turn black due to fungi that feed on the honeydew.
2. Flowering pear (*Pyrus calleryana*) – This tree has a weak branch structure, making it susceptible to extreme damage from storms or strong winds. It is vulnerable to fire blight attacks, which can be fatal to the tree.
3. Littleleaf linden (*Tilia cordata*) – The sweet blossoms on this tree have a tendency to attract bees. This can be a problem in high pedestrian traffic areas. Branching structure can also be a problem on some trees. Many of the branches form "V" shaped crotches which lead to branches splitting from the trunk. This tree is also susceptible to aphids, leading to sticky honeydew on anything sitting underneath the tree.
4. Honeylocust (*Gleditsia triacanthos*) – This is a fast growing tree with a tendency to heave sidewalks and curbs when planted in a small park strip. Some varieties produce many seed pods which can create a litter problem. Honeylocust has a poor vertical form unless structural pruning is done often when young. The trunk is usually covered with dozens of small water sprouts which must be removed annually.
5. Serviceberry (*Amelanchier x grandiflora*) – Serviceberry does not have many problems. It is an excellent small tree for use in park strips. However, because it stays so small this tree cannot be limbed up high enough for pedestrian or vehicular traffic to pass underneath. Thus, it should be planted in park strips that are large enough to contain the spread of the tree. Also, it does have some issues with leaf rust, which creates unsightly spots on the leaves and can cause early defoliation.
6. Crabapple *(Malus* spp.) – Crabapples are extremely hardy trees, however, some varieties produce massive amounts of fruit, which can create a significant mess in high traffic areas. Crabbapples are also susceptible to a variety of rusts, as well as fire blight.
7. London planetree (*Platanus x acerifolia*) – This tree is quite susceptible to anthracnose, a disease that can defoliate entire branches. If this happens several years in a row, the tree can be permanently damaged. Usually, leaves remain on the tree into early winter, which can contribute to branch breakage from early snowfall. Additionally, seedlings have a high mortality rate through the first few winters.
8. Bur oak (*Quercus macrocarpa*) – Because this is slow-growing and eventually gets massive, it is unsuitable for small parkstrips. In addition newly transplanted trees have the tendency to bend unnaturally, requiring stakes to support them.
9. Japanese zelkova (*Zelkova serrata*) – The main problem with this tree is the sharp angle of its branches making them more likely to split down the trunk.

10. Hedge maple (*Acer campestre*) – This is an excellent urban tree, however, the seeds will germinate easily in nearby flowerbeds. It also has a dense branch structure which needs regular pruning.

Human Dimensions

The Site: South Jordan City is situated in the south end of the Salt Lake Valley. It was once a rural farming town, but is now a booming city of over 58,000 residents. It is part of the conglomerate of other municipalities comprising the Salt Lake metropolitan area. Like most areas along the Wasatch Front, the climate is moderate in comparison to the surrounding mountains and valleys. Temperatures usually do not drop below zero degrees Fahrenheit in the winter and typically do not exceed 100 degrees in the summer. While a large number of trees can survive in these temperatures, low precipitation rates and alkaline soils with high pH levels limit the number of tree species that can actually thrive in this climate.

Many of the streets have two to four lanes, which could facilitate a nice forest of street trees. Unfortunately, most of the park strips are five feet or less in width, which reduces the chance for long-term survival of many larger street tree species. Most of the roads throughout the city experience mainly local traffic. However, there are several state highways and an interstate that run through the city. The main attractions to the city are commercial retail stores and restaurants, with some large scale industry on the outskirts of town. The residential areas are mainly comprised of single family residences, with many new town homes, condos, and upper scale apartment buildings currently under construction.

When the town was settled in 1859, the land was mostly devoid of trees, except for along the banks of the Jordan River. South Jordan City's population growth is a relatively recent event (within the past twenty years), so nearly all of the street trees in the city are still young.

Many partnerships in the city exist with regards to street trees, including partnerships between residents, businesses, the Church of Jesus Christ of Latter-day Saints, Salt Lake County, and the Utah Department of Transportation. My inventory only included trees owned and maintained by the city, but street trees planted by others benefit the city as well. The non-city-owned trees tend to follow the same trends as city trees in the species planted and the ratio of these species.

The city-owned street trees I evaluated are socially beneficial, according to a social welfare study conducted by Sherman & Dixon in 1991 in that it benefits the public as a whole and not just a private party. Some of these benefits include: providing shade, beautifying the area, reducing pollution and urban noise, and reducing the amount of water runoff from rain, which could lead to flooding or erosion. The funding for installation and maintenance of these trees is provided by the city, but the benefits are enjoyed by residents and visitors alike.

Street trees provide many benefits for the city's residents and businesses. These benefits include economic, psychological, social, and political (Scheyvens 1999). For example:

- Economic: There are many street trees that dot the commercial plaza around South Jordan City Hall. These trees help create an atmosphere that attracts consumers to the

various local businesses. By planting trees around their store, it gives the impression that a company cares about the environment (Lohr, et al. 2004).

- Psychological: Studies have shown that people like having urban trees for the calming effect and the natural sounds their leaves make (Lohr, et al. 2004). The city is a designated Tree City USA, a national program that recognizes cities meeting cost, management, planting, and public involvement requirements. South Jordan also uses a tree for the city logo.

- Social: South Jordan is one of the fastest growing communities in the State of Utah. An attractive urban forest may contribute to this growth. City growth provides opportunity for more street trees to be planted throughout the city. Trees provide city residents with a stronger sense of community and pride and tree planting projects can enhance a community's sense of unity (Dwyer, et al. 1992). South Jordan City has an annual Arbor Day tree planting and other forestry events that attract residents and allow them to participate in service for the city.

- Political: City government plays an active role in ensuring ample vegetation exists in city streetscapes. City ordinances are in place that require planting a certain number of trees in parkstrips, regardless of whether the trees will be maintained by the city, or a local business or resident.

Overall, street trees help contribute to an attractive atmosphere and enhance other amenities the city has to offer. Urban trees create an atmosphere that allows people to slow down and relax (Dwyer, et all. 1990). Studies have shown areas that provide shade contribute to activities such as sleeping, reading, conversing, eating, and playing (Smardon 1988). Streets lined with trees help slow traffic, create a buffer from vehicle noise, and soften the straight lines of buildings and structures (Dwyer, et al. 1992). Trees can make an area more recognizable and give a municipality a unique sense of place (Smardon 1988). The street trees in South Jordan City contribute to the overall feel of the city. However, residents may have negative feelings about city street trees if they block signs or are not maintained properly (Lohr, et al. 2004).

Ecology

Trees in an urban setting are easy to inventory. The difficulty comes in determining the effects of a population of street trees on its environment.

Street trees have a positive effect on the surrounding environment. Trees reduce pollutants contained in the soil from getting into our waterways, as well as the effects of carbon emission, by "catching" airborne pollutants such as ozone, nitrogen oxides, sulfur dioxides, carbon monoxide, carbon dioxide, and small particulates less than 10 microns in size (Keep Indianapolis Beautiful Inc. 2014). Trees remove pollutants that are emitted into the atmosphere by automobiles and factories. Their foliage helps in absorbing sunlight, which lessens the heat radiated by concrete and asphalt. Trees that shade buildings also reduce the use of air conditioners. A reduction in power usage further benefits the environment as the demand on power plants is reduced (Brack 2002). Trees also catch rainfall and reduce the amount of runoff that may pollute lakes and streams (Brack 2002) .

Elected officials may be more willing to fund tree plantings if they can see actual numbers associated with benefits to a municipality. With the development of computer programs such as i-Tree, which calculates values according to data input from a tree inventory, quantifying the benefits of municipal trees is becoming easier (i-Tree, 2013).

Another important assessment is how a particular population of street trees affects surrounding street tree populations. This information is especially useful when it comes to disease and insect control. Trees infected with certain diseases or insects may serve as a bridge to allow insects and pathogens to spread to adjacent populations (Raupp, et al. 2006). Studying the relationship between different tree populations can help municipal foresters make educated decisions with regard to pest outbreaks. It may be more beneficial to remove infected trees rather than trying to save them and risk infecting nearby populations.

The relationship between street tree populations and wildlife is another important area of study. Certain tree species attract wildlife that is in decline due to urban sprawl (Nowak and Dwyer 2007). Some tree species may help to link green pockets, providing animals with corridors to travel between areas of suitable habitat.

Another relationship to consider is how a population of trees affects the individual members of a particular street tree population. Trees naturally grow together and should be planted in groupings rather than individual specimens (Morris 2013). With this in mind, street trees might be healthier and more likely to survive if planted in groups of three or five, with appropriate spacing between them. This will help diminish the monotony caused by rows of identical trees (Morris 2013).

Economics

Street trees in South Jordan City are a major asset for those living in the city, and a positive externality for those visiting it. Benefits from trees can be considered environmental externalities because the trees provide things such as shade, which cools a building, but the tree is not paid for this service (McPherson 1992). Trees increase property values and make the city more attractive in welcoming visitors. One study by Kathleen Wolf claims that people are willing to pay 10 percent more for items in a commercial area with trees than without (Wolf 2004). It is difficult to determine the actual monetary value of the benefits a tree provides. However, research has determined the value of urban trees in the city of Modesto, California is nearly $5 million, or $27 per resident (McPherson, et al. 1999).

The benefits trees provide, however, come with a cost to municipalities. The cost of buying a new tree ranges between $50 and $300 for most trees planted in the city. Additional costs include planting, irrigation systems, water and fertilizers, pruning, and eventually removal. Urban trees tend to have significantly shorter lives than their wild counterparts (Center for Watershed Protection and US Forest Service Northeastern Area State and Private Forestry 2008).

The estimated cost of a tree during its lifetime varies upon species and location. When a tree is destroyed by an automobile, for example, an appraisal of its value can be determined. A formula

called the *Trunk Formula Method* is commonly used, but can be biased, depending on the person evaluating the tree. Information such as the trunk diameter at breast height, tree condition, contribution of the tree to the site, and the species all factor into the formula, which ultimately calculates a total value of the tree (Council of Tree and Landscape Appraisers 2000). While the tree condition and contribution to site can be subjective, the species ratings are determined by each local chapter of the International Society of Arboriculture. Each species has a range of percentages that can be added to the calculation, based on the condition of the particular tree (Kuhns 2012).

A tree is a significant investment; yet, little consideration usually goes into deciding which species to plant and where to plant it. Many times the species is either chosen by a landscape architect, or by simply planting the same species that exists on nearby streets.

In South Jordan City's, boundaries, a number of streets go on for several miles and are lined with the same species of tree the entire length. As previously mentioned, planting a single species can cause mass die-offs if a disease or insect infestation occurs, causing financial and social problems for the city and its residents. Additionally, cities often choose species not suitable for the location, which can result in high maintenance costs. For example, London planetrees (*Platanus x acerifolia*) are often planted under power lines, which require the trees to be chopped into "V" shapes (See Appendix D). When flowering cherries (*Prunus serrulata*) are planted in a 2.5 foot wide park strip with pavement on either side, the stress can make the trees more susceptible to diseases or insect infestations. In South Jordan City, one park strip is planted with red maples (*Acer rubrum*). Several of these trees succumb to the stresses of iron chlorosis and die each year. For years, these dead trees have been replaced with more red maples. The park strip is now a medley of different sized red maples, all with dead branches and yellow, chlorotic leaves. When the wrong species of tree is planted in a certain streetscape, it can become a liability for the city, instead of an asset.

It is bad enough to install the wrong tree in the first place, but to continue replacing it with the same species over and over again is a foolish waste of funds and resources. The street tree diversity guide for South Jordan City will help to diminish this problem (see Appendix B). It will facilitate the replacement of problematic street trees with more suitable alternatives. The street tree reference book will help in determining a superior species for a particular type of street tree planting. For example, if the site is underneath power lines and next to a busy collector street with excessive amounts of road salt in the winter; a tree can be chosen that will not exceed 25 feet at maturity and tolerates high amounts of salt.

It is anticipated the street tree reference book will help municipalities throughout Utah reduce spending on street tree replacements. This money can be used to better maintain existing trees and provide for additional tree planting projects.

Policy

A street tree master plan listing tree species approved for planting in the city's park strips is a great first step to establishing a more efficient urban forestry program. South Jordan City

currently has an ordinance requiring street trees be chosen from an approved list of trees. I have made several revisions to the list as I have discovered new species that are suitable, and realized other tree species do not work well in South Jordan park strips. I have recently revised this street tree list to reflect the findings of this research project (See Appendix C). This street tree list is available for contractors, residents, and anyone else in the city required to comply with the ordinance and use this species list when planting a park strip tree in the city.

In addition to having the street tree list as part of the city ordinance, the street tree master plan should be included in the ordinance. This ensures diversification of tree species continues, regardless of who is managing the program or the city. When these documents are adopted as part of the city ordinance, they become enforceable. South Jordan City has code enforcement officers that inspect violations, and institute the appropriate measures for non-compliance, such as a written warning or a fine.

Administration

The urban forester has the ultimate responsibility to manage a community forest appropriately. The first step this person should take is to complete an inventory. This inventory will identify the tree species that are most commonly found in the municipality and their compatibility with the areas where they are planted. With this information, decisions can be made as to what direction the city wants to go with its forestry program. Goals can be set and areas of focus determined. It is essential the urban forester discusses these goals with city managers and elected officials. It is also critical that the forester is involved in public outreach programs, such as volunteer projects and Arbor Day activities. The forester needs to take these opportunities to present information to the public on the need for tree species diversity and proper tree placement.

It can be difficult for cities and individuals to find many of the under-utilized tree species at local nurseries. Urban foresters can assist in changing this by working with local nurseries and requesting that a wider variety of species be provided. Nurseries usually will not order new species unless they are confident they can sell them. Urban foresters should promote the planting of a diversity of species to local residents and help them understand the benefits of planting less-common species that have a better chance of long-term survival in Utah. This action may encourage nursery owners to order a wider variety of tree species.

Solutions

Using my own experience of what grows well in the area along the Wasatch Front, I have created a list of 42 species that are suitable as street trees in this area. I carefully considered each of these species and supplemented my experience of growing and observing these species with research on each one. As I evaluated which species to include, I considered the following criteria:

- Is the species relatively available or can it be ordered through local nurseries?
- Is the tree hardy enough to tolerate urban conditions?

- Are there examples of this species actually existing on a street tree along the Wasatch Front?
- Is the species reasonably clean (no frequent branch shedding or large, messy fruit)?
- Does the species tolerate pruning to provide proper clearance?
- Does the species tolerate soil with high pH levels?
- Does the species tolerate road salt?
- Is the species susceptible to pests or disease?
- Is the species considered invasive in the U.S.?

Using these criteria, I eliminated many species that grow well along the Wasatch Front but are not suitable for use as a street tree. I immediately eliminated all conifers from the list, since they do not meet most of the criteria. I removed all cottonwoods (*Populus*) and willows (*Salix*), since they are prone to limb breakage. Also, black walnut (*Juglans nigra*) and other trees that produce messy or damaging fruit were eliminated from the list. I eliminated magnolias (*Magnolia*), flowering cherry (*Prunus serrulata*), and other sensitive trees that cannot tolerate the stresses of being a street tree. Trees such as bald cypress and red maple that struggle with alkaline soil, as well as trees prone to excessive disease and insect damage, such as green ash (*Fraxinus pennsylvanica*) were also eliminated from consideration. Finally, I removed invasive tree species, such as Siberian elm (*Ulmus pumila*) and tree of heaven (*Ailanthus altissima*).

Some of the 42 species included on the list may have a slight problem with one or more of the criteria. For example, red oak (*Quercus rubra*) is known to struggle in some areas with alkaline soil. In spite of this it is found to thrive along many streets in the Wasatch Front, so I decided to keep it on the list. Other species clearly over-used as street trees, such as Norway maple (*Acer platanoides*), flowering pear (*Pyrus calleryana*), honey locust (*Gleditsia triacanthos*), and little leaf linden (*Tilia cordata*) were included on the list because they make wonderful street trees, and there is still a place for them provided they are not planted excessively.

The 42 species selected comprise 26 genera and 14 families. For this study, I have only considered actual tree species and not cultivars or varieties. Using this list I created a guide for tree diversity in South Jordan City (See Appendix B). The purpose of this plan is to diversify the species of street trees planted throughout the city. After analyzing the various recommendations for species, genera, and family diversity, I decided to use the limits suggested by Frank Santamour, which are no more than 10 percent per species, 20 percent per genus, and 30 percent per family (Santamour Jr 1990). The 5 percent suggestion seems like a good goal, but for a city with an established street tree population, this would be difficult to reach.

Using the 10-20-30 plan with the current street trees in South Jordan City would mean that out of the 3,455 street trees, only 345 could be a certain species, 691 could be from a certain genus, and 1,036 could be from a certain family. Two species, *Acer platanoides* and *Pyrus calleryana* far exceed this limit. *Acer* is the only genus that exceeds the 20 percent rule for any given genus. Rosacea is the only family that exceeds the 30 percent rule for any given family.

Achieving the recommended diversity levels could be relatively simple to create on paper, but more challenging to actually implement. However, when any of the current street trees die and need to be replaced, I have come up with an alternative species to replace them.

To make the process of increasing tree diversity easier I created a chart in Excel (see Appendix B) as a guide to tree diversity for the city. This chart has separate columns for family, genus, and species of the 42 tree species I am recommending for use as street trees. I have color coded each family, genus, or species according to the percentages currently in use along the streets in South Jordan. Trees with red cells are above the recommended percentage and are currently overused. Trees with yellow cells are not overused yet, but could be if many more are planted. Green cells represent those that are underused and need to be planted more in the city. By looking across the three cells of each tree species genus and family, it is easy to determine if the tree in question is a good choice to be planted. Trees that have one or more red or yellow cells should be reconsidered for use in future plantings.

By following this chart, I can easily come up with alternative replacements for street tree species. I can also use this chart when planning for new street plantings. However, when large numbers of trees are installed, I must continue to update my ratios and this chart to reflect the new percentages of each family, genus, and species. Otherwise, trees that are now under-used, could one day become over-used.

Conclusion

Street trees can have beneficial and adverse effects on a municipality. This could include aesthetic effects, which may draw more visitors or permanent residents into the city because of the attractive street plantings, or it could include financial effects, which result in a burden on the city. Usually the effects are beneficial, such as increased revenue for businesses and municipalities. Diversification and properly placed trees can also reduce replacement and maintenance costs. Additionally, street trees can have a positive effect on the overall health of a municipality and its residents. For example, street trees aid in removing pollutants and lowering summer temperatures by providing shade and reducing reflective heat. Street trees can also reduce stress in residents by providing natural sights and sounds such as rustling leaves (Smardon 1988). Finally, street trees can create a sense of place for a municipality, by contributing to the overall identity of a community.

Because of the important role street trees play in enhancing the aesthetics of municipalities and improving the quality of life for urban residents, more thought and planning needs to go into determining what species should be planted and where they should be planted. Planners, engineers, and urban foresters need to focus on diversifying the tree species planted in streetscapes. This increased focus on diversity will ultimately aid in making less-common trees more available in local nurseries. Planners, engineers, and urban foresters also need to consider all of the surrounding elements and make sure the trees they are planting will thrive in their locations. In order to assist with these goals, municipalities need to incorporate the ideas presented in this report into their ordinances and provide means to enforce them.

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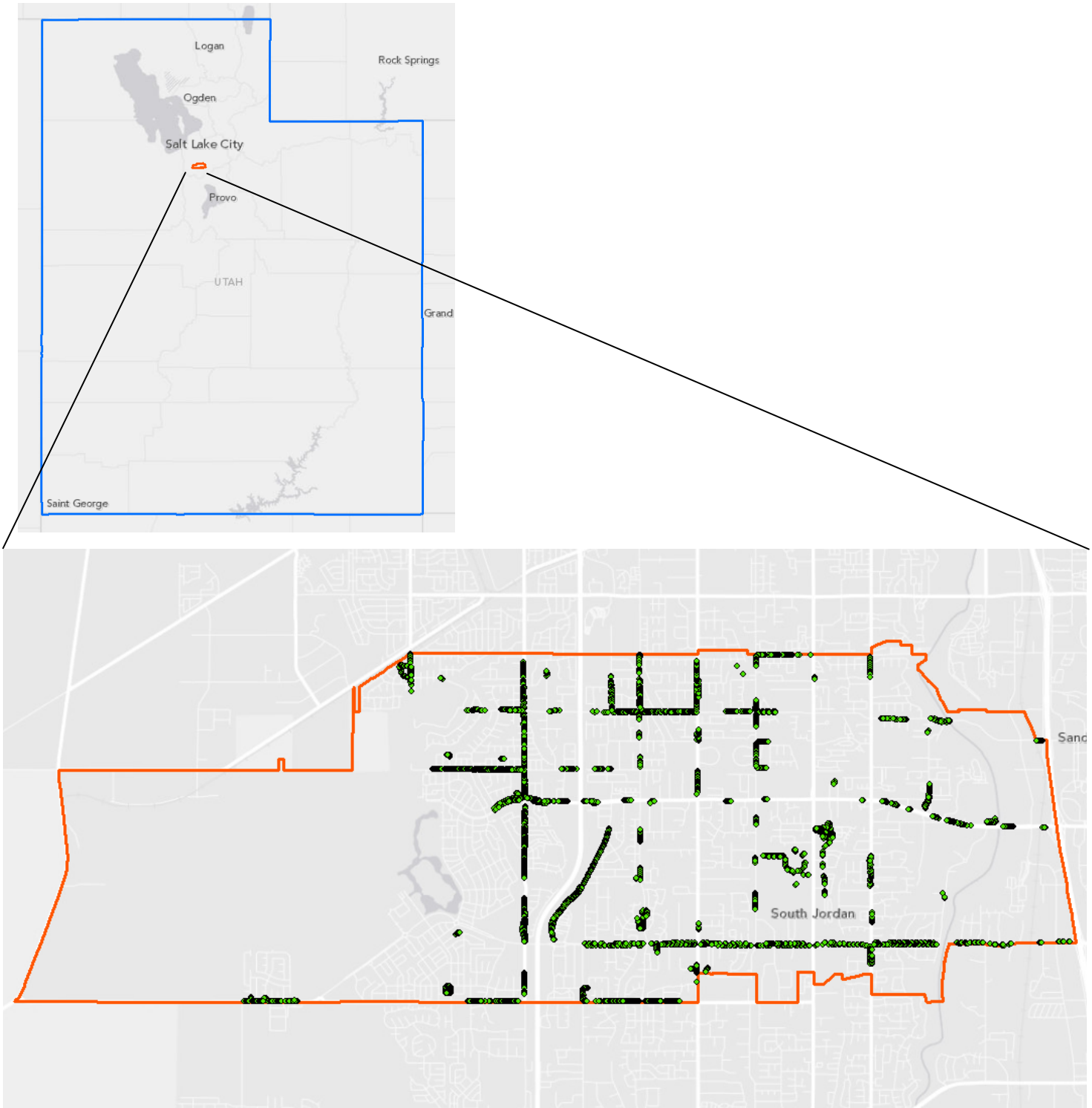
Appendix A



Map 1: This map shows the position of South Jordan City within the state of Utah. State boundaries are blue, city boundaries are orange. City owned street trees are represented by green dots. Geographic Coordinate System: GCS North American 1983. Data courtesy of South Jordan City, DeLorme, www.esri.com.

Map 2: This map shows a close up of some city-owned street trees in South Jordan City. This map extends from 3600 W to 2700 W and from 9400 S to 9800 S. Each green dot represents a street tree that was plotted by GPS. Geographic Coordinate System: GCS North American 1983. Data courtesy of South Jordan City and www.esri.com.

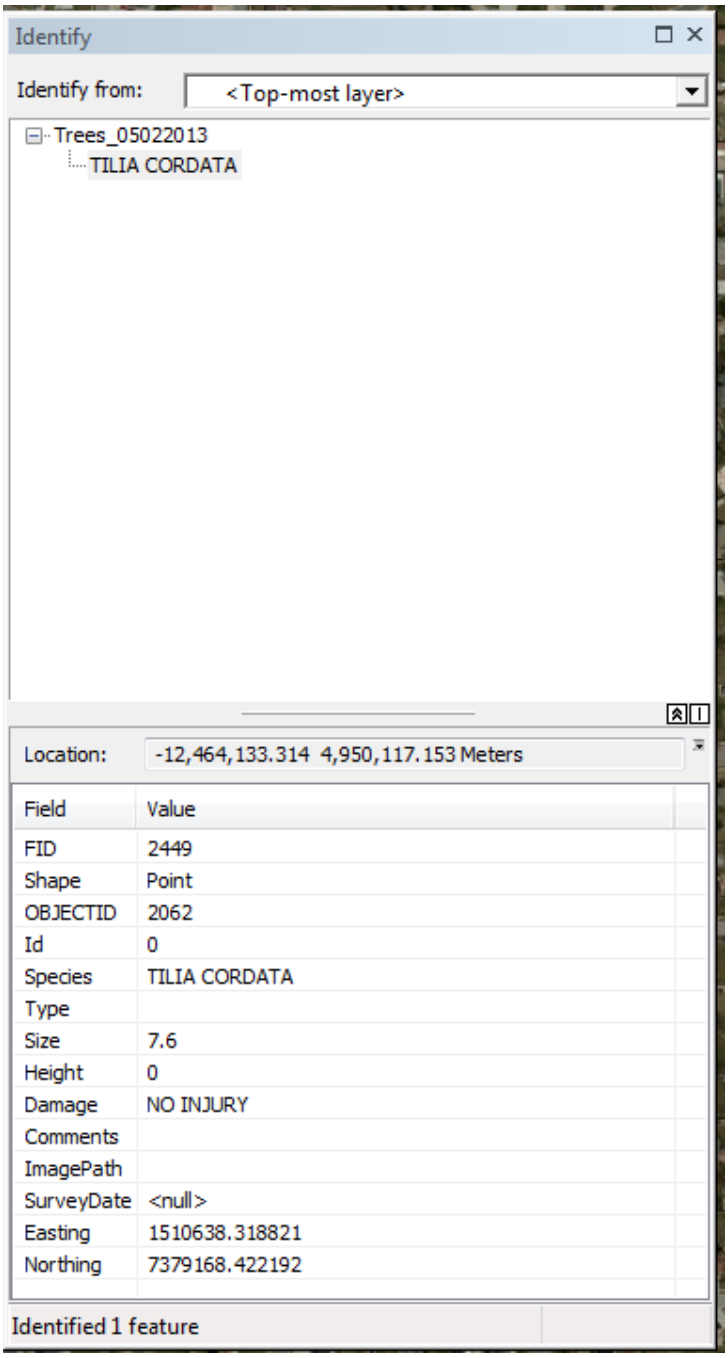


Figure 4: This image shows an example of some of the information for a specific city-owned street tree that was collected by GPS. This information was accessed using ArcMap 10.1. Data courtesy of South Jordan City.

Table 1: Tree Species

	Count	(%)
Acer platanoides	530	15.34%
Pyrus calleryana	529	15.31%
Tilia cordata	346	10.01%
Gleditsia triacanthos	321	9.29%
Amelanchier x grandiflora	285	8.25%
Malus spp	249	7.21%
Platanus x acerifolia	224	6.48%
Quercus macrocarpa	199	5.76%
Zelkova serrata	133	3.85%
Acer campestre	129	3.73%
Koelreuteria paniculata	87	2.52%
Syringa reticulata	63	1.82%
Acer freemanii	61	1.77%
Acer pseudoplatanus	60	1.74%
Cercis canadensis	45	1.30%
Prunus serrulata	41	1.19%
Celtis occidentalis	21	0.61%
Acer rubrum	20	0.58%
Crataegus x lavallei	19	0.55%
Tilia tomentosa	17	0.49%
Prunus cerasifera	14	0.41%
Prunus virginiana	14	0.41%
Chionanthus retusus	10	0.29%
Gymnocladus dioicus	10	0.29%
Quercus rubra	9	0.26%
Ulmus parvifolia	8	0.23%
Fraxinus pennsylvanica	6	0.17%
Acer grandidentatum	3	0.09%
Fagus sylvatica	2	0.06%
Total	3,455	100.00%

Table 2: Tree Genera

	Count	(%)
Acer	803	23.24%
Pyrus	529	15.31%
Tilia	363	10.51%
Gleditsia	321	9.29%
Amelanchier	285	8.25%
Malus	249	7.21%
Platanus	224	6.48%
Quercus	208	6.02%
Zelkova	133	3.85%
Koelreuteria	87	2.52%
Prunus	69	2.00%
Syringa	63	1.82%
Cercis	45	1.30%
Celtis	21	0.61%
Crataegus	19	0.55%
Chionanthus	10	0.29%
Gymnocladus	10	0.29%
Ulmus	8	0.23%
Fraxinus	6	0.17%
Fagus	2	0.06%
Total	3,455	100.00%

Table 3: Tree Families

	Count	(%)
Rosaceae	1,151	33.31%
Sapindaceae	890	25.76%
Fabaceae	376	10.88%
Malvaceae	363	10.51%
Platanaceae	224	6.48%
Fagaceae	210	6.08%
Ulmaceae	141	4.08%
Oleaceae	79	2.29%
Cannabaceae	21	0.61%
Total	3,455	100.00%

Appendix B

Table 4: Guide for Tree Diversity

This spreadsheet illustrates the guide for tree diversity I created for South Jordan City. It utilizes the percentages of family, genus, and species that should be planted to maintain species diversity in the city. The smaller spreadsheet defines the percentages for family, genus, and species. The main spreadsheet includes the acceptable trees that can be used as street trees in South Jordan City. Green cells represent trees that are underutilized and should be planted more. Yellow cells represent trees that are close to being over-planted and should be used with caution. Red cells represent trees currently over-used and which should not be considered at this time. For example, a tulip tree (*Liriodendron tulipifera*) would be an acceptable tree, since family, genus, and species are all underutilized. Silver linden (*Tilia tomentosa*) is acceptable, but should not be planted in excess, since the genus *Tilia* and the family Malvaceae are close to being over-used. However, littleleaf linden (*Tilia cordata*) should probably not be used since its species is currently over-used. The Rosaceae family is considered over-used, because of the massive amounts of flowering pear (*Pyrus calleryan)* in the city. However, species in the *Crataegus and Prunus* genera are still under-used.

Family	Genus	Species
>30%	>20%	>10%
10% - 20%	20% - 7%	10% - 5%
<10%	<7%	<3%

Family	Genus	Species
Magnoliaceae	Liriodendron	tulipifera
Hamamelidaceae	Parrotia	persica
Moraceae	Morus	alba
Betulaceae	Corylus	colurna
Ginkgoaceae	Ginkgo	biloba
Cannabaceae	Celtis	occidentalis
Oleaceae	Chionanthus	retussus
		virginicus
	Syringa	reticulata
Ulmaceae	Ulmus	parvifolia
	Zelkova	serrata
Fagaceae	Quercus	bicolor
		rubra
		macrocarpa
Platanaceae	Platanus	x acerifolia
Malvaceae	Tilia	americana
		tomentosa
		cordata
Fabaceae	Gymnocladus	dioicus
	Cladrastis	kentuckea
	Sophora	japonica
	Cercis	canadensis
	Gleditsia	triacanthos
Sapindaceae	Aesculus	hippocastanum
		x carnea
	Koelreuteria	paniculata
	Acer	grandidentatum
		griseum
		tataricum
		truncatum
		pseudoplatanus
		campestre
		platanoides
Rosaceae	Crataegus	crusgallii
		phaenopyrum
		x lavallei
	Prunus	maackii
		padus
		virginiana
	Amelanchier	x grandiflora
	Malus	spp
	Pyrus	calleryana

Appendix C

Approved Street Tree List - South Jordan City

This approved list of street trees for South Jordan City has been compiled from research conducted by the urban forester. They are trees that can tolerate urban conditions and the stresses that accompany street locations. They are divided into three size categories: small, medium, and large.

Small (under 30 feet)
Trees in the small category are the only ones that may be planted under power lines. Most of these trees are too short to be pruned to an appropriate height for vehicular traffic to pass under. Thus, they should be planted in larger park strips.

Common Name	Botanical name	Salt Tolerance
Paperbark maple	*Acer griseum*	medium
Tatarian maple	*Acer tataricum*	medium
Purpleblow maple	*Acer truncatum*	medium
Apple serviceberry	*Amelanchier x grandiflora*	medium
Eastern redbud	*Cercis canadensis*	none
Chinese fringetree	*Chionanthus retusus*	none
Fringetree	*Chionanthus virginicus*	none
Cockspur hawthorn	*Crataegus crusgallii*	medium
Washington hawthorn	*Crataegus phaenopyrum*	low
Lavelle's hawthorn	*Crataegus x lavallei*	low
Crabapple	*Malus spp.*	medium
Persian ironwood	*Parrotia persica*	low
Amur chokecherry	*Prunus maackii*	medium
European bird cherry	*Prunus padus*	medium
Chokecherry	*Prunus virginiana*	medium
Pecking lilac	*Syringa peckingensis*	medium
Japanese tree lilac	*Syringa reticulata*	medium

Medium (30-50 feet)
Trees in the medium category can be pruned to facilitate vehicular traffic. These trees can handle smaller park strips than the other two categories.

Common Name	Botanical name	Salt Tolerance
Hedge maple	*Acer campestre*	medium
Freeman maple	*Acer x freemanii*	medium
Bigtooth maple	*Acer grandidentatum*	low
Norway maple	*Acer platanoides*	medium
Red horsechestnut	*Aesculus x carnea*	medium

Yellowwood	*Cladrastis kentuckea*	low
Turkish filbert	*Corylus colurna*	low
Golden raintree	*Koelreuteria paniculata*	medium
White mulberry	*Morus alba*	high
Flowering pear	*Pyrus calleryana*	medium
Lacebark elm	*Ulmus parvifolia*	medium

Large (50 + feet)
Trees in the large category can form canopies over most streets. They should be planted in large park strips to accommodate their large trunks and root systems.

Common Name	Botanical name	Salt Tolerance
Sycamore maple	*Acer pseudoplatanus*	high
Horsechestnut	*Aesculus hippocastanum*	medium
Hackberry	*Celtis occidentalis*	medium
Ginkgo	*Ginkgo biloba*	medium
Honeylocust	*Gleditsia triacanthos*	high
Kentucky coffeetree	*Gymnocladus dioicus*	medium
Tulip tree	*Liriodendron tulipifera*	none
London planetree	*Platanus x acerifolia*	medium
Swamp white oak	*Quercus bicolor*	medium
Bur oak	*Quercus macrocarpa*	high
Red oak	*Quercus rubra*	high
Japanese pagoda tree	*Sophora japonica*	medium
American linden	*Tilia americana*	low
Littleleaf linden	*Tilia cordata*	low
Silver linden	*Tilia tomentosa*	medium
Japanese zelkova	*Zelkova serrata*	medium

Unacceptable Street Trees
Certain tree species should not be planted in park strips for various reasons, such as limb dropping, invasive qualities, or intolerance to street tree conditions. While this is not an exhaustive list, it provides a guideline for trees to avoid in park strips.

Common Name	Botanical name	Reason
Eastern cottonwood	*Populus deltoides*	limb shedding
Willow	*Salix* spp.	limb shedding
Russian olive	*Eleagnus angustifolia*	invasive
Tamarisk	*Tamarix ramosisima*	invasive
Tree of Heaven	*Ailanthus altissima*	invasive
Siberian elm	*Ulmus pumila*	invasive
European white birch	*Betula pendula*	intolerant of conditions
Quaking aspen	*Populus tremuloides*	intolerant of conditions

Fruit and nut trees that create excessive mess or damage vehicles
Conifers (pine, spruce, fir)

Appendix D

Figure 5: London planetrees (*Platanus x acerifolia*) cut into "V" shaped formations to facilitate overhead powerlines. Photo by Jeran Farley 2014.

Figure 6: Extreme example of Siberian elm (*Ulmus pumila*) cut into "V" shaped formation to facilitate overhead powerlines. Photo by Jeran Farley 2014.