Edugreen: A tree planting initiative and planting plans for elementary school sites in Manhattan, KS

by

Jia Cheng

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Approved by:

Major Professor
Jessica Canfield

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Abstract

Trees within a schoolyard landscape can directly benefit students—improving their physical, social, mental, and emotional health. Trees also provide significant environmental and economic benefits. When planted near playgrounds and activity areas, the shade cast from trees can help lower surface temperatures and provide enjoyable places to rest. An analysis of existing trees at eight elementary schools in Manhattan, KS, revealed a noticeable absence of trees within the schoolyard landscapes and a significant lack of shade for playground and activity areas. The USD 383 Manhattan-Ogden District provides landscape maintenance of the schoolyards. However, their resources for tree planting and care are limited. Yet, the need for more trees within these schoolyards is critical. Thus, this project explores how a district-wide tree planting initiative can be created to guide and increase tree planting at individual elementary school sites. A detailed tree inventory and site analysis was used to fully understand the existing conditions and to explore future opportunities for new trees at all eight sites. To learn what notable organizations and districts across the country are doing to increase trees at schools, a precedent study of school-based tree planting initiatives was done to reveal best practices for program administration and implementation. Additionally, a survey was sent to the principals of the eight schools to capture their perceptions and awareness about trees at their schoolyards. Findings from these methods helped to inform and structure the proposed Edugreen Tree Planting Initiative. The 5-year initiative illustrates the necessary steps needed to increase tree plantings at each school. A total of 137 trees are proposed. A species list and tree planting plan with annual goals and planting priorities is included for each school. Ultimately, for this district-wide tree planting initiative to succeed, the support of many dedicated individuals is needed. These individuals must champion and oversee tree implementation and ongoing maintenance at each

school. The benefits of implementing the initiative will include increased shade, environmental education, and reduced maintenance efforts from the district maintenance department.

EDUGREEN

A Tree Planting Initiative and Planting Plans for Elementary School Sites in Manhattan, KS

Jia Cheng | 2022

Major Professor | Jessica Canfield
Committee Member | Dr Amber Vennum
Committee Member | Leslie Wren

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Trees within a schoolyard landscape can directly benefit students—improving their physical, social, mental, and emotional health. Trees also provide significant environmental and economic benefits. When planted near playgrounds and activity areas, the shade cast from trees can help lower surface temperatures and provide enjoyable places to rest. An analysis of existing trees at eight elementary schools in Manhattan, KS, revealed a noticeable absence of trees within the schoolyard landscapes and a significant lack of shade for playground and activity areas. The USD 383 Manhattan-Ogden District provides landscape maintenance of the schoolyards. However, their resources for tree planting and care are limited. Yet, the need for more trees within these schoolyards is critical. Thus, this project explores how a district-wide tree planting initiative can be created to guide and increase tree planting at individual elementary school sites. A detailed tree inventory and site analysis was used to fully understand the existing conditions and to explore future opportunities for new trees at all eight sites. To learn what notable organizations and districts across the country are doing to increase trees at schools, a precedent study of school-based tree planting initiatives was done to reveal best practices for program administration and implementation. Additionally, a survey was sent to the principals of the eight schools to capture their perceptions and awareness about trees in their schoolyards. Findings from these methods helped to inform and structure the proposed Edugreen Tree Planting Initiative. The 5-year initiative illustrates the necessary steps needed to increase tree planting at each school. A total of 137 trees are proposed. A species list and tree planting plan with annual goals and planting priorities is included for each school. Ultimately, for this district-wide tree planting initiative to succeed, the support of many dedicated individuals is needed. These individuals must champion and oversee tree implementation and ongoing maintenance at each school. The benefits of implementing the initiative will include increased shade, environmental education, and reduced maintenance efforts from the district maintenance department.

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Preface

In the fall 2021 semester, my master's project studio focused on the urban forest in Manhattan, KS. As a studio, each student chose a direction to conduct a particular study on urban trees in the city of Manhattan. Our collective efforts resulted in a comprehensive presentation on Manhattan's urban forest to the public. I focused my project on trees at elementary schools, especially seeing if the trees provided usable shade for students.

This project is a continuation of my initial study, which included a complete tree inventory of the elementary schools. I found that all elementary schools lacked sufficient trees to provide students with beneficial shade. Depending on the species and context, it can take decades for a tree to grow and provide the ideal shade. However, benefits like reducing the surrounding temperature, absorbing carbon dioxide, and reducing stormwater runoff can take effect immediately after planting a tree. In addition, tree planting has immediate educational value. By participating in tree planting activities, teachers, students, and staff can gain an appreciation for trees and their community value.

It is not enough to just point out where trees can be planted. An initiative to plant trees in schools can only be made feasible if the various required resources are addressed from planning to planting and to subsequent maintenance.

The tree-planting initiative of this project was inspired by various types of tree planting plans in schools, especially the "Cool School Project" led by the Texas Tree Foundation. While tree planting initiatives require the participation of people from multiple parties, landscape architects play an important role in constructing the project framework and filling in the relevant details. This project showcases the design and planning that can be provided by a landscape architect in a school tree planting initiative.

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Chapter 01

Introduction

Introduction

1.1 Importance

Over the past decade, green schoolyard design has become a widespread practice due to a desire to improve the physical, mental, academic, social, and emotional health of students (Keena 2011). Green schoolyard design seeks to transform areas of concrete and lawn into a vibrant environment for student learning and play. Studies have shown the benefits of green schoolyards include improving academic outcomes, providing mental health benefits, increasing physical activities, and encouraging beneficial play (Berezowitz et al. 2015; Chawla et al. 2014; Dyment et al. 2009; Luchs and Fikus 2013). Because of these positive benefits, green schoolyard design has become a popular movement throughout the United States (Keena 2011).

Trees are considered a critical element in green schoolyard design as they are a long-lasting, low-maintenance plant material – making them ideal for schools seeking to improve their landscapes. In addition, the health benefits of trees, such as reduced UV exposure and lower microclimate temperatures, are higher than other forms of landscape material. For example, research shows that during hot sunny days, most children tend to use the shade under a tree more than they use gardens or nature trails (Lanza et al. 2021). The tree is the preferred landscape material for interaction by children (Lanza et al. 2021).

One of the most significant limitations for green schoolyard design is funding, as school districts often have minimal financial and physical resources dedicated to landscapes. Considering the limited resources that schools may have for maintaining landscapes, there is an opportunity for communities and organizations to be involved in and assist with the planting and maintenance of trees at schools.

Figure 1.11 Playground at Lee Elementary School
Swings in the schoolyard under direct sunlight at Lee Elementary School in Manhattan, KS.

Outside support can lead to landscape improvements without straining a school's budget. When communities and organizations take care of trees, this can increase engagement and participation between the public and schools.

1.2 Statement of the Problem

A lack of trees within schoolyards

A lack of beneficial shade for playground / activity areas

Limited landscape funding and maintenance capacity

In Manhattan, KS, the public school district is one of the largest public landowners in the city. There are just under 300 acres of grounds in USD 383 Manhattan-Ogden Public School District's 21 locations. This study examines eight elementary schools within the district, which equates to 62.4 acres or 0.49% of the total acreage within the city of Manhattan (Davis n.d.).

A preliminary analysis of existing trees at the eight elementary schools in Manhattan, KS revealed an overall lack of trees within schoolyards. There is a lack of trees where shade would be beneficial, such as shade at the playgrounds and other outdoor activity areas. In comparison, the city of Manhattan has 28% tree canopy cover, while the eight elementary schools only have 8% average coverage. There is even less tree canopy coverage above the playground, with some schools entirely lacking shade over the playground. Based on on-site observations, large mature trees on the periphery of a school's property appear to receive significantly less maintenance than the

trees located closer to the school buildings and activity areas.

USD 383 has limited dedicated resources to maintain the schoolyard landscape and existing trees (Davis n.d.). Thus, the schoolyard landscapes are basic and utilitarian, consisting mostly of lawn with some shrubs around building foundations. This simple landscape palette allows for efficient and minimal maintenance. According to the Manhattan-Ogden USD 383 Maintenance and Facilities Procedures document, the maintenance team consists of two turf maintenance technicians. The document states that due to the small maintenance force, the department pursues low or no maintenance landscape materials to reduce the amount of time required to maintain the grounds and facilities. The department also requires prior approval for any proposed additions or modifications

Figure 1.21 Trees at Lee Elementary School

Newly planted trees show signs of stress due to lack of maintenance at Lee Elementary School.

Figure 1.22 Trees at Marlatt Elementary School

The large mature trees (left photo) on periphery of the of the school's property line appear to receive significantly less maintenance than trees located closer to the school buildings (right photo) at Marlatt Elementary School in Manhattan KS.

to buildings or grounds to ensure improvements do not pose maintenance or safety issues (Davis n.d.). Such modifications to schoolyards may include the addition of gardens, flowerbeds, trees, shrubs, greenhouses, playgrounds, trails, etc.—all of which require approval by the District Facilities and Growth Committee. This committee requires specification as to who will do the maintenance and upkeep of a proposed modification as increasing the responsibilities for custodial or maintenance staff is not desirable (Davis n.d.).

Accordingly, this project prioritizes the establishment and management of trees in schoolyards and details the process to implement a district level tree planting initiative for elementary schools.

1.3 Research Question and Goals

How can a district-wide tree planting initiative be created to guide and increase tree planting at individual elementary school sites?

This project aims to develop a district-wide 5-year tree planting initiative which includes phased goals and a tree planting plan for eight elementary schools in Manhattan, KS.

Develop a tree planting initiative and timeline to guide the implementation and care for new trees and:

- clarify the responsibilities of project team at the district level and at the school level.
- explain the process from establishing the project team to conducting tree planting activities to subsequent maintenance.

Create a tree planting plan for each site that aims to:

- target shade for student activity areas that will provide comfortable outdoor spaces.
- select the species which are safe for students and tolerant of student activities.
- increase the number of trees to add more tree infrastructure at schools and help grow the city's tree canopy.
- recommend species to ensure tree species diversity and large shade, thus helping to create a healthier ecosystem.
- place trees to align with schools' current regulations and future development plans.

Expand student interaction with trees to increase awareness and education by:

- highlighting the beneficial purposes of trees during tree planting and relevant activities.
- providing suggestions for educational activities related to trees to increase awareness about the benefits of trees.
- increasing interest in stewardship.

Chapter 02

Background

Background

This chapter is to provide background information regarding the topic and problem explored through this project. First, the importance of trees is discussed, with an emphasis on the positive effects that trees have on children's physical and mental health. This is followed by a discussion on the ways in which green schoolyards can increase students contact with nature. Next, the definition of a tree planting initiative is listed along with its benefits. Since implementing tree planting initiatives in public schools faces many challenges, the ways that reduce the overall investment are also included, such as using stewardship to reduce school landscape maintenance efforts, choosing appropriate species, and implementing correct tree maintenance methods. Lastly, the scope of the project and the reasons for doing it are explained.

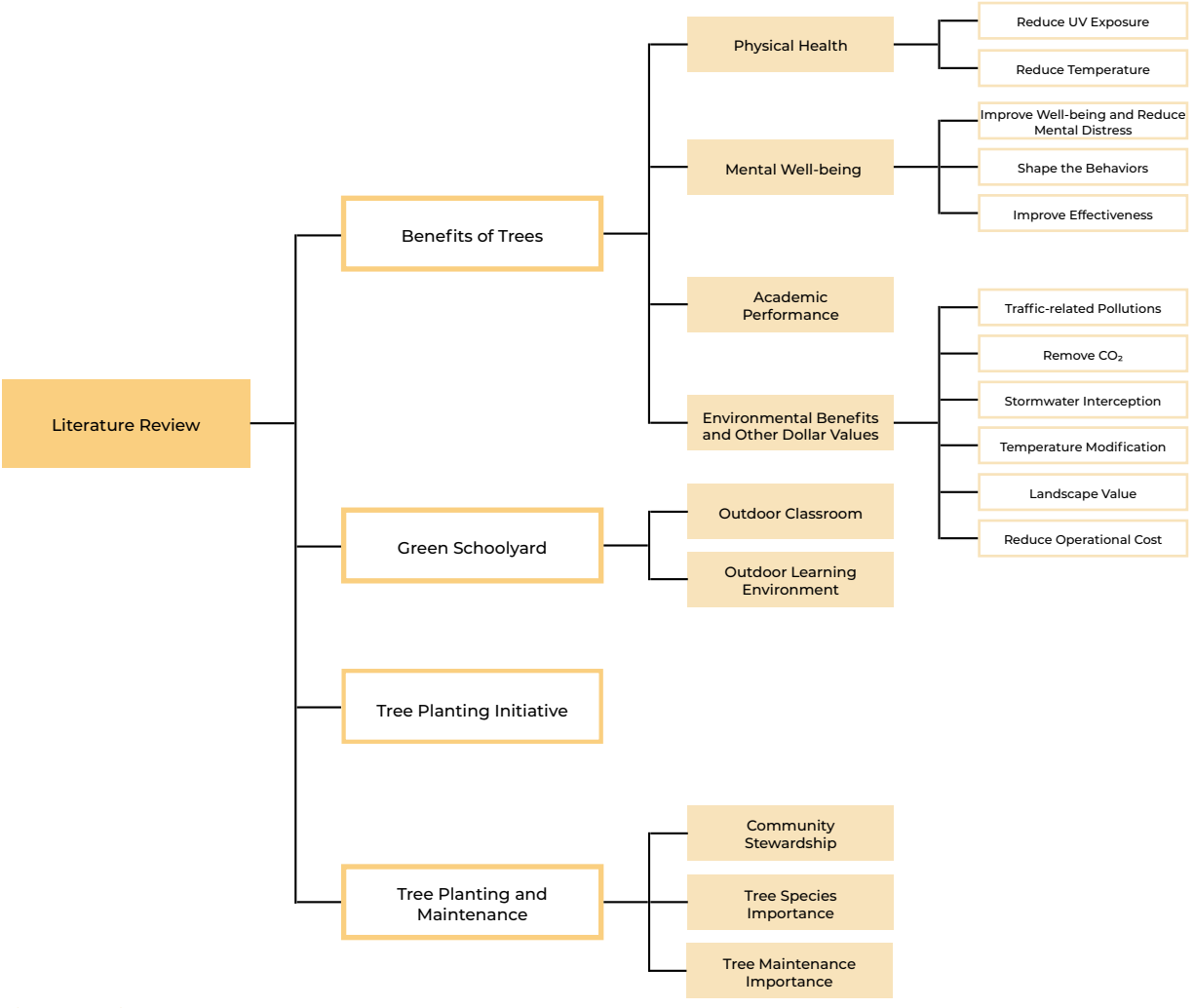


Figure 2.1 Literature map

2.1 Benefits of Trees

Trees provide environmental, social, and economic benefits. While trees provide measurable ecological and economic benefits once planted, they also provide shade that increases public health (Wolf et al. 2020), water quality (Center for Watershed Protection 2017), air quality (Nowak et al. 2014), public safety (Jansson et al. 2013), and equity (Landry and Chakraborty 2009). Shade from trees can be especially important to children, who are most susceptible to the effects of ultraviolet (UV) radiation and heat exposure. Shade can reduce sun exposure and heat-related illness for children (Holman et al. 2018; Vanos et al. 2016). The shade from trees also helps to create a comfortable outdoor environment for students, which can support outdoor learning and activity opportunities. This can lead to enhanced positive and decreased negative emotions of students, such as enhancing energy and hedonic tone as well as reducing stress and anger (Roe and Aspinall 2011). Natural settings also help students focus attention and regulate behavior, thereby improving their academic performance (Margherita 2015). Adding trees to schoolyards can, therefore, directly benefit students physically, emotionally, and academically.

2.11 Shade Matters to Children's Physical Health

The shade provided by the trees can be protective for students who are outdoors. The shade from trees reduces direct sunlight exposure, reduces the surface temperature of play equipment, and helps create a cooler microclimate for rest.

When students do outdoor activities in the schoolyard, reducing exposure from UV exposure is important. The Centers for Disease Control and Prevention (CDC) indicate that a personal history of one or more sunburns (an indicator of intense UV exposure) in childhood or adolescence has been found to increase the risk of developing basal cell carcinoma and melanoma as an adult (Adams-Taylor et al., n.d.). While more than half of a person's lifetime UV exposure typically occurs during childhood and adolescence, effective sun protection is practiced by less than one-third of youth in the United States (Adams-Taylor et al., n.d.). Thus, the CDC calls for promoting sun safety in schools, specifically that schools need to be sun-safe places to reduce children's exposure to UV radiation (Adams-Taylor et al., n.d.). Tree shade is a natural intervention that can provide protection from damaging UV exposure but still allow for the necessary UV-induced vitamin D production in the skin (Holman et al. 2018, 1608). Compared to expose in full sun conditions, providing tree shade can reduce total UV radiation exposure by 37% to 58% but still provide enough exposure to produce vitamin D. (Turnbull and Parisi 2009).

Tree shade over playgrounds and activity areas can help cool the microclimate temperature of these outdoor activity areas. Shade is especially important for reducing the surface temperature of playground equipment, thus making it safer for children to touch (Balbus and Malina 2009). On clear warm days with direct sunlight, the surface

temperature of playground equipment can easily approach or exceed values that cause children to burn (Vanos et al. 2016). Materials commonly found within playgrounds, such as metal, coated metal, stone, plastic, or wood, can absorb heat and become hot enough to burn the skin within a one-minute contact time if surface temperatures reach 140 ˚F (Vanos et al. 2016, 31). In measuring playground surface temperatures on September 15, 2014 in Arizona, the average daily temperature of 92.5 ˚F (from a range of 79.5-106.9˚F) correlated with more than half of the surface temperatures exceeding the burn thresholds within one minute. With the same materials under tree shade, no surface temperature exceeded 113˚F (Vanos et al. 2016, 35). By providing shade to playgrounds and outdoor activity areas, tree canopies can help reduce the surface temperature of playground areas and associated equipment (Vanos et al. 2016, 35).

Since research shows children position themselves under trees during periods of high heat indexes and extreme heat conditions (Lanza et al. 2021), adding trees to the students' high frequency activity areas will reduce the potential for heat-related illnesses, increase outdoor space usability, and mitigate urban heating.

2.12 Trees Promote Mental Well-being

Students receive various mental benefits from trees in the schoolyard. Trees help create a sense of place and make the schoolyard more like a natural environment. When people are physically active at least once a week in a natural environment, they reduce their risk of poor mental health by nearly half compared to physical activity performed in other environments (Mitchell 2013). Indeed, nature connectedness can positively affect a person's well-being and reduce mental distress (Barton and Rogerson 2017; White et al. 2021). Researchers from Denmark's University of Aarhus have found that childhood exposure to green space reduces the risk for developing an array of psychiatric disorders during adolescence and adulthood (Engemann et al. 2019).

Tree-filled schoolyards can also enhance student mental health though outdoor learning and activities. Compared to a conventional indoor school setting, spending time in a forest school, which has an outdoor education setting, can increase students' positive emotions and decrease their negative emotions (Roe and Aspinall 2011). These outdoor settings could also help reduce aggression and discipline problems of students (Bell and Dyment 2008; Nedovic and Morrissey 2013). In a study conducted by Rachel Kaplan, views of trees from windows were found to help rest an individual's directed attention (Kaplan 1993). For students, this can restore directed attention totheir schoolwork, which improves their effectiveness in completing academic tasks (Kaplan 1993).

2.13 Trees Increase Student Academic Performance

It is possible for urban school districts to improve children's academic performance by increasing tree-covered areas (Sivarajah et al. 2018). A study from the University of Toronto

compiled standardized performance scores in Grades 3 and 6 for the collective student body in 387 schools across the Toronto District School Board (TDSB) to analyze the relationship between tree cover and students' academic performance. The results demonstrate that students in the schools with higher tree canopy coverage had better academic performance (Sivarajah et al. 2018).

2.14 Trees Have Quantified Environmental Benefits and Other Dollar Values

In addition to health benefits, trees provide direct environmental and economic benefits once planted and established. Regardless of the location within a schoolyard, trees can reduce traffic-related pollutions (Dadvand et al. 2015), remove atmospheric carbon dioxide, intercept urban storm water runoff, and modify the ambient emperature (Isaifan and Baldauf 2020). Because of these benefits, increasing tree canopy coverage would provide a significant local environmental contribution to the global efforts to combat climate change. In addition, trees can also reduce electricity costs by enhanced cooling if they are planted next to the building (Pandit and Laband 2010). The shade cast by trees lowers air-conditioning demands, which results in lower operational costs for the school.

2.2 Green Schoolyards Increase Students' Access to Nature

Research suggests that spending time in nature benefits children's health development (Moore 1997). Given the amount of time children spend in school during childhood and adolescence, there is an opportunity for schools to provide access to nature to further student development The school has the opportunity to provide access to nature (Moore and Marcus 2008). A wide range of research shows that school greening promotes students' academic outcomes, mental health, physical activity, and beneficial play (Bikomeye et al. 2021; Rios and Brewer 2014; Raith 2017; Zarghami and Fatourechi 2015). In green schoolyards, students experience and interact with nature through play and learning and thus receive more benefits from green schoolyards than in the traditionally designed asphalt-covered ground. When developing green schoolyards, it is vital to consider the structures that students interact with so that the green features accommodate students' activities.

2.21 Outdoor Classroom

Schools have chance to set up outdoor classrooms to increase student contact with nature. This project proposes tree planting and tree maintenance activities can become a part of formal learning in schools. Some schools have already included student-involved tree planting activities as part of its landscaping project. Related precedent studies detailing these existing activities are discussed in detail in Chapter 4 of this report. Beyond courses directly related to

trees, green schoolyards could facilitate a formal learning experience (Dyment 2005). School ground could be designed to accommodate most curriculum areas (Rickinson et al. 2004). Outdoor learning in the green schoolyards helps students raise enthusiasm, increases vitality and motivation for learning, and helps to inspire students who do not learn well in the classroom (Dyment 2005; Rickinson et al. 2004). After the proposed planted trees have established a comfortable natural environment in the schoolyard, schools can consider the possibility of setting up formal classrooms outdoors, thereby increasing the opportunities for students to get in touch with and benefit from nature.

2.22 The Green Schoolyard as an Outdoor Learning Environment

Students can also get a non-formal learning experience through handling, touching, smelling, exploring, and modifying natural features in the green schoolyard. Informal, child-initiated, embodied learning experiences can make essential contributions to children's emotional, cognitive, social, and physical development (Dijk-Wesselius et al. 2020). Recent research has explored the relationship between seasonal changes in tree leaves and seasonal planting design strategies upon perceived attention restoration in elementary school students. The findings indicate that the seasonal changes in foliage color improve the restorative quality from seasonal mood disorders, such as difficulties concentrating, irritability, fatigue, decreased activity, social withdrawal, and school problems (Paddle and Gilliland 2016).

Therefore, in order for students to get more abundant experience from trees, attention should be paid to the diversity and seasonality of the tree species. The recommendation of tree species included in this project also pays attention to its diversity and attractive characters.

2.3 Tree Planting Initiative and how to Make it Successful

Tree planting initiatives in the United States are a discrete type of urban forestry (Eisenman et al. 2021). The range of tree planting initiatives can range from planting a few trees in school backyards to a trillion trees worldwide (Brancalion and Holl 2020). Regardless of scale, tree planting initiatives mobilize resources for urban greening and increase tree planting (Eisenman et al. 2021).

Planting a tree is often seen as a simple act of digging a hole, planting a sapling, and then filling the hole with soil. While this simplistic view fails to consider maintenance, the perceived simplicity of planting a tree has led to substantial funding for tree-planting efforts. However, most of these efforts have almost completely failed." (Brancalion and Holl 2020). Tree-planting initiatives should not simply pursue the number of trees planted. Rather, tree planting should be viewed as a means to achieve specified goals and should be part of a multidisciplinary decision-making process that comprehensively assesses trade-offs and uncertainties (Brancalion and Holl 2020).

Tree planting initiatives require long-term planning. However, funding and long-term management concerns make the benefits of tree planting initiatives uncertain (Young 2011). While there have been some successful, underfunded initiatives that focused on community-level engagement, institutionalized, diverse funding structures and strong institutional levels are most effective in maintaining and expanding urban forests (Young 2011). In comparing 41 urban tree-planting initiatives at the city-scale, recent research found that tree planting initiatives still need institutionalized, traditional financing infrastructure to maintain long-term viability (Eisenman et al. 2021). Furthermore, the researchers found that underinvestment in stewardship activities, such as watering and long-term maintenance, requires more financial investment in other fields that support green infrastructure (Eisenman et al. 2021).

2.4 Challenges and Opportunities for Tree Planting and Maintenance

An important consideration of traditional schoolyards designed with only asphalt and lawn is keeping the maintenance as simple as possible. Paved asphalt ground requires very little maintenance without vehicle traffic. Even though lawns need to be watered, trimmed, and fertilized regularly, maintenance can be done inexpensively with grounds-keeping staff with minimal training (Danks, 2010). Since public schools have limited resources to maintain the landscape, planting new trees with regulated maintenance is a challenge for implementing a tree planting initiative and a management plan. In a survey about the maintenance of school gardens, researchers developed an online survey and collected ninety-nine eligible school gardeners from 15 states about the barriers school gardeners face in developing, maintaining, and using school gardens. The identified barriers include time, staff, funding, curriculum, and space (Burt et al. 2018). These difficulties have also been carefully considered in this project.

2.41 Community Stewardship as the Primary Maintenance Model

The same survey revealed not only the challenges of maintaining green schoolyard designs but also summarized the characteristics of successful school gardens. One of the important aspects of a successful school garden is creating a sense of community (Burt et al. 2018). By involving a wider group of people from the community into the care of the green schoolyard, some time- and staff-related issues could be solved. Therefore, one solution to solve the maintenance challenges facing green schoolyards is distributing the responsibility to the community. This potential for influencing the success of a tree planting initiative has been demonstrated in studies that confirm stewardship has been instrumental in the success in establishing public trees (Boyce 2010).

This project utilizes the stewardship maintenance model in schoolyard management. By making community members aware that they, and children, will benefit from trees, their participation in tree planting and maintenance activities will reduce the pressure on the school to maintain trees. Stewardship is particularly essential in young tree establishment planting programs, which often includes maintenance activities such as watering, mulching, staking, pruning, and weed removal (Roman et al. 2015). This project proposes a tree planting initiative to empower school communities, and outside volunteers to take the responsibility of maintenance on newly planted trees.

2.42 Proper Tree Species Selection Reduces the Following Maintenance

The correct choice of tree species can help ensure desired function as well as reduce maintenance investment. In their book on tree species selection, Michael Dirr and Keith Warren (2019) suggest “trees are long-lived, potentially huge, and a valuable part of landscape breeding and

selection should strongly emphasize the functional and aspects of performanc e. Pest resistance, environmental tolerance, longevity, strength, and urban compatible form should be utmost importance" (Dirr and Warren 2019, 17). When receiving the same amount of maintenance effort as other species, a correctly chosen tree with genetic adaptations to heat, drought, flooding, soil compaction, high pH, and low humidity may have the key to long life (Dirr and Warren 2019, 17).

2.43 Proper Tree Maintenance Activities Reduce the Subsequent Maintenance

While maintaining trees costs money, this does not mean that removing maintenance tasks saves money. Tree maintenance costs are often very clear and related to specific activities, such as planting, mulching, watering, pruning, removal, pest and disease management, etc. These actions can lead to healthier trees and longer lifespans (Vogt et al. 2015). Maintenance activity in the early stages of a tree's development can reduce the cost of subsequent growing stages. Ryder and Moore (2013) compared the total costs of pruning and not pruning in the early stage of life and found that a tree not pruned during early stages of growth will cost $30 – $64 more than a similar tree pruned during this time frame (Ryder and Moore 2013). Similarly, Gilman (2001) examined the impacts of watering newly planted trees for five weeks versus for first six months following planting . Gilman found that trees with only five weeks of irrigation led to a greater cost due to the need to replace dead trees. This leads to a higher cost per-live tree for five-week irrigated trees compared to six-month irrigation. Additionally, watered trees, regardless of irrigation treatment, grew better than trees without water from irrigation (Gilman 2001).

Most of the watering, pruning, and general training on tree care can be done by nonprofessionals once they understand the principles of maintenance (van der Hoeven 1977). This project provides resource to guide schools and related community groups on how to maintain trees in the early stages following planting to reduce the long-term maintenance pressure on school districts and to reduce the future costs of caring for trees.

2.5 Project Scope and Site Description

The Manhattan-Ogden Unified School District (USD 383) is a public school district with about 300 acres of ground and 1.3 million square feet of building space. There are twenty-one schools within USD 383, including two high schools, two middle schools, ten elementary schools, two early learning buildings, six district support staff locations, and three vacant properties (Davis n.d.). This project focuses on eight of the ten elementary schools in the district. The eight schools identified for this project Amanda Arnold Elementary School, Bluemont Elementary School, Frank V. Bergman Elementary School, Lee Elementary School, Marlatt Elementary School, Northview Elementary School, Theodore Roosevelt Elementary School, and Woodrow Wilson Elementary School. The other two elementary schools were not included in the focus of this study due to limitations from geography (one is located outside of city limits) and newness (the other opened fall 2021).

This project focuses on elementary schools rather than middle or high schools as elementary school children can benefit the most from schoolyards trees. Since elementary school students spend more time outdoors each day, this increases their opportunities to benefit from schoolyard trees. According to the Manhattan-Ogden USD 383 Wellness Plan, the district suggests children and adolescents participate in at least 60 minutes of physical activity every day (Manhattan-Ogden USD 383 2021). All elementary students in grades K-5 receive physical education for at least 60-89 minutes per week throughout the school year. In addition, all elementary schools are asked to offer at least 20 minutes of recess on all days during the school year. When weather is amenable to outdoor play, students will have outdoor recess in the schoolyard (Manhattan-Ogden USD 383 2021).

Compared with adults, children are also more susceptible and vulnerable to the hot surrounding environment (Balbus and Malina 2009). Due to the scheduling complexities of physical education classes, sporting events, and other outdoor activities, elementary school students are more likely to be affected by environmental conditions and have a lower sense of self-prevention under extreme weather, such as sun and heat exposure(Adams-Taylor et al., n.d.). Therefore, elementary schoolyards should have increased provisions for students. Such provisions include creating sun-safe environments, supporting sun-safety policies, and providing skin cancer prevention education. Ensuring that school grounds have adequate shade is one of the critical ways in which a school can support sun-safe environments.

Figure 2.2 The locations of eight elementary schools at Manhattan, KS

Chapter 03

Methodology

Methodology

This chapter introduces the methodology designed for this project. To address the research question, five primary methods were used:

A site analysis of the eight elementary schools that includes
- a complete tree inventory for each school,
- analysis of existing tree benefits using iTree Ecosystem,
- site amenities and circulation inventory,
- slope study,
- utilities, and
- shade study.

A precedent study of existing successful tree planting initiatives for schools or for other organizations or municipalities that could be applicable to schools.

A survey of the principals of the eight elementary schools.

An interview with the maintenance crew of the USD 383 district.

Document review of available information from the USD 383 district website, City of Manhattan website, and Kansas Forest Service website.

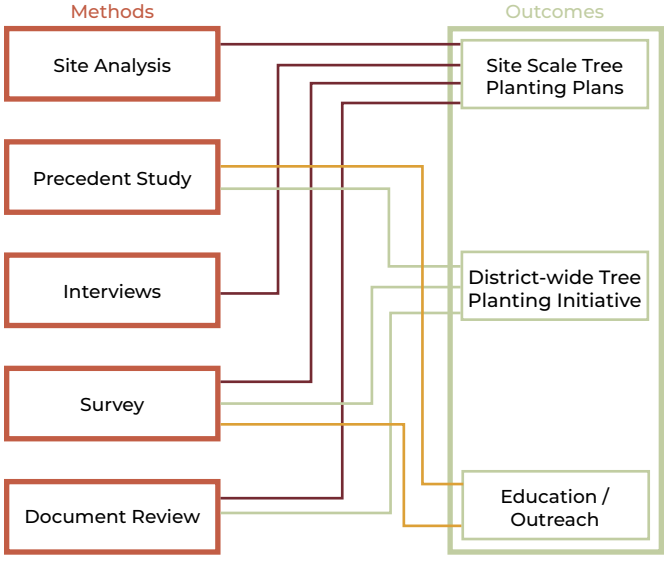


Figure. 3.1 Project outcomes

3.1 Site analysis

A site analysis is a program-driven assessment of a site's physical, biological, and cultural attributes (LaGro 2001, 117). The site analysis identifies the opportunities and constrains for a specific land use program (LaGro 2001, 117), which in this project is increased trees. A series of descriptive diagrams will be used to show existing conditions and future potentials.

3.11 Tree inventory

A tree inventory is a record of species, location, characteristics, and assessment of current condition of individual trees on a site (Bond and Buchanan 2006). For this project, a complete tree inventory, meaning an inventory of all trees, of the eight elementary school sites was conducted in fall 2021 prior to leaf drop. Since i-Tree Eco was the software used to analyze the value of the trees, the tree data collection was mainly based on the data required for the operation of i-Tree Eco. The data required by i-Tree Eco to run a complete tree analysis is tree species and diameter at breast height (DBH). Other data also included to generate a more accurate result was tree height, crown width, condition and percentage dieback, and crown light exposure. These variables were analyzed to determine the overall condition of the trees and to quantify the dollar value and environmental benefits of each tree. In addition, tree location and proximity to site amenities were also recorded and analyzed in order to reveal the opportunities for new trees at each site and inform the proposed initiative.

i-Tree Eco: Environmental Benefits and Dollar Value Assessment of Existing Trees

Knowing quantified benefits and values of individual trees could aid in tree management and advocacy. The International Society of Arboriculture, which is a non-profit research and education organization, identifies four factors to consider in evaluating the economic value of trees (Perry 1999):

- Tree size
- Tree species (hardy, well-adapted species are worth most)
- Tree condition or health
- Tree location (functional and aesthetic value)

In this project, the benefits and value of trees were calculated using i-Tree Eco. i-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and rural forestry analysis and benefits assessment tools (iTree 2021). i-Tree Eco is one of the software applications from the i-Tree software suite. To quantify forest structure, environmental effects, and value to communities, the software uses field data from complete inventories along with local hourly air pollution and meteorological data in a given study area (i-Tree Eco 2021).

The benefits and value estimated in i-Tree Design are an estimation for:

- **Pollution Removal,**
- **Carbon Storage,**
- **Carbon Sequestration,**
- **Oxygen Production,**
- **Avoided Runoff, and**
- **Replacement values.**

i-Tree Eco also provides information to show which species contributes the most benefits among each category. This is a great reference for the follow-up tree species recommendations for the planting plan.

Data collection: Diameter at Breast Height (DBH)

For each tree, its diameter was measured at breast height, which is defined as 4½ feet (137 cm) above average ground level using a 100 feet fiberglass measuring tape (Powell and Avenue, n.d.). For multi-stemmed trees, which are trees that fork between 12 and 4½ inches (30 and 137 cm) of height, a single diameter measurement was taken at the smallest trunk diameter below the fork (Magarik et al. 2020).

Data collection: Total Tree Height

Tree height was measured according to the "stick measured" recommendations by the Measuring Guidelines Handbook published by American Forests (American Forests 2016). First, standing at the base of the tree, a surveyor holds a stick (ruler) vertically at arm's length and then moves away from the tree until the part of the stick from the top of the

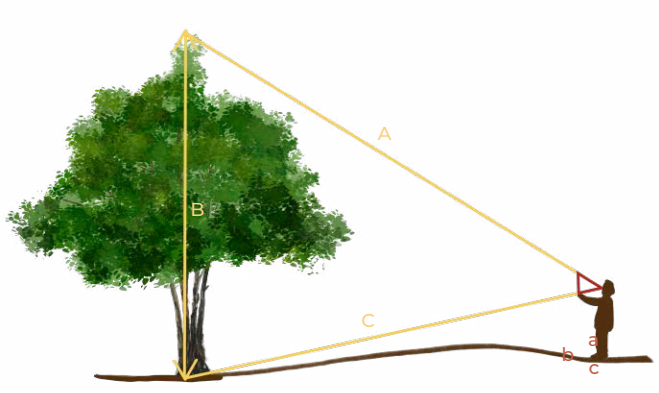


Figure 3.2 Measure the total tree height

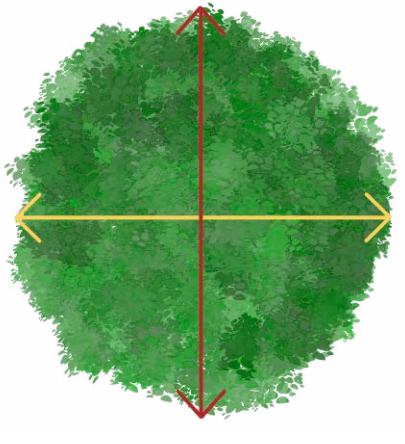


Figure 3.3 Measure the crown width

hand to the top of the ruler just covers the tree. Then, the ruler's length (b) above the hand is read. and the distance from the eye to the top of the hand (a) is measured. Next, the distance from the tree (A) is measured from the eye past the top of the hand and onto the tree's base Finally, the tree height is calculated by using:

(length of stick, b x distance to the tree, A) / (distance to eye, a) = tree height, B

Data collection: Crown Width

Based on the Complete Inventory Project - Tree Data Collection Sheet (2021) provided by i-Tree Eco, the tree crown width was collected by using tape to measure two distances: the distance between the north to south edges of the crown and the distance between the east to west edges of the crown. The crown size used for drawing inventory map was calculated by adding the north-south width and east-west width together and then dividing the sum by 2.

Data collection: Crown Health

The overall health and condition of existing trees was assessed in order to develop an effective management plan for their ongoing care and maintenance. Tree condition was determined by the percentage dieback and missing crown of each tree. The data imported into i-Tree Eco was the total percentage of dieback and missing crown . In addition, the tree conditions were assigned as excellent, good, fair, poor, dying based on the Tree Condition Guide provided by Project Learning Tree (2021) for better understanding the overall health of the school forest.

EXCELLENT: Full canopy, no damage to the trunk, no dieback of branches in the upper crown, no suckering (upright shoots growing from the roots or branches that appear out of place)

GOOD: Mostly full canopy, little damage to the trunk, no dieback of branches over 2" in diameter in the upper crown, little to no suckering (upright shoots growing from the roots or branches that appear out of place)

FAIR: Thinning canopy (tree may look different from similar trees around it), significant damage to trunk caused by insects or disease, premature fall coloring on foliage (leaves change color too early in the year)

POOR: Visible dead branches over 2" in diameter in the canopy, significant dieback of living branches, with no leaves on tips, severe damage to the trunk, including decay, bark may be peeling in dead or dying areas

DEAD/DYING: The tree is dead or significant portions of the tree are dead

(Project Learning Tree 2021)

Data collection: Crown light exposure

Crown light exposure was based on the i-Tree Eco Field Guide, and it is described as the number of sides that a tree's crown is receiving light from above or the side. The maximum number of the sides is five: one side from the top of the tree and four vertical sides. The four vertical sides are determined by dividing the crown vertically into four

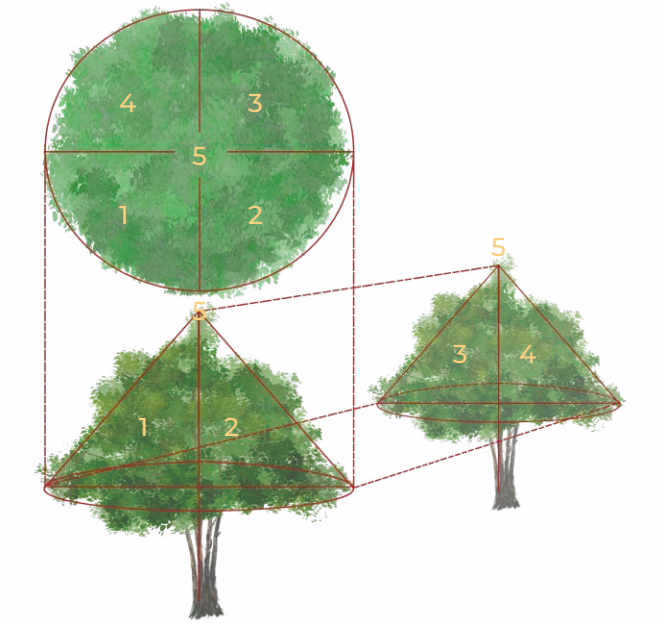


Figure 3.4 Record the crown light exposure

quadrants around the stem. The on-site inventory counted the number of sides that could receive light for each tree. For each of the five sides, a side of the tree is not counted as receiving direct light if any part of an adjacent tree crown or building is:

a) overtopping any part of the measured tree's crown side, or

b) within one average crown width away from the measured tree's stem and the object is at least as tall as the measured tree.

Amenities, Circulation, and Buildings

The site amenities inventoried included playgrounds and associated equipment. The location of all hardscape and sidewalk areas were also inventoried and mapped. The information of buildings was referenced from the Manhattan-Ogden USD 383 Master Plan 2037 (BG consultants 2018).

Tree Locations, Canopy Coverage, and Shade Study

Maps of the eight elementary schools were created to show the current tree location, condition, and the canopy covered areas.

- The tree location and the crown spread were marked on the map in AutoCAD to calculate the percentage of tree canopy coverage of each school and the overall canopy average rate of the eight schools.
- The tree canopy above the playground and associated equipment were marked in AutoCAD to calculate the percentage of critical shade of each school and the overall critical shade coverage rate of eight schools.
- The shade study involved building models for each school by using SketchUp to show the area and duration of shade of existing trees and buildings.

Distribution of Species

The species distribution of trees indicates the percentage of each species in relation to the total trees in the

schoolyard. Analyzing the species distribution growing in the schoolyards involved using the information obtained in the tree inventory to develop planting strategies that are appropriate for growing healthy tree populations (USDA Forest Service Northeastern Area n.d.).

The result of the species distribution was used to generate diagrams that illustrate the species composition of each school. This data enabled the development of a planting and management plan, which aims to provide a balanced range of tree in each schoolyard. The proposed planting plan and schedule addresses the need to provide a balanced distribution of trees based on species and age class for the future (USDA Forest Service Northeastern Area n.d.). By choosing the right tree species and distributing the trees planted within a schoolyard, the possibility of serious insect or disease outbreaks can be reduced. This allows for tree maintenance to be more evenly distributed over time (USDA Forest Service Northeastern Area n.d.).

Slope study

Knowing the slope of each schoolyard can help inform the proper place for tree planting. Based on site grading recommendations from the U.S. General Service Admission, the slopes of planted areas should permit easy maintenance. Areas with slopes steeper than 3:1 (33%) must be planted with ground cover or constructed with materials specifically designed to control erosion. Slopes steeper than 2:1 (50%) are not acceptable (GSA 2021). For the accessibility of maintenance equipment, the slope study was necessary in order to find suitable locations for new trees.

The slope information for each site was found from the Terrain: Slope Map provided by Environmental Systems Research Institute through ArcGIS Earth. The Terrain: Slope Map provides a colorized representation of the slope, enhancing contextual understanding of the schoolyard condition.

3.2 Precedent Study

A precedent study is a representation of knowledge about a past design or program in a form that makes it applicable or "reusable" in new sites with similar problems (Aygen and Flemming 1998). A precedent study was used to learn about existing tree planting programs, projects, or initiatives utilized by schools or other organizations or municipalities that could be applicable for schools. The following information was collected and tabulated for each precedent:

- **Title**
- **Background**
- **Location**
- **Scale / scope**
- **Year established**
- **Goals and Objectives**
- **Administrative structure and Partnership**
- **Funding and Budget**
- **Care and Maintenance**
- **Education and Outreach**

By comparing the commonalities between the precedents, the parts with high commonality were considered in this project's design. In addition, precedents with a similar situation to this project had additional focus.

The findings from the precedent study were summarized and used as a reference to guide the tree planting initiative and educational outreach.

3.3 Survey

The survey was used to learn about various issues and opportunities related to schoolyard design for USD 383 elementary schools. Survey questions were sent via email to the principals of eight elementary schools in the USD 383 Manhattan-Ogden Public Schools District. Questions included a mix of open response and multiple-choice types.

The objective of the survey was to better understand opportunities and constraints related to the schoolyard landscape and the design decision-making process for the placement of vegetation and trees at the elementary schools. (See Appendix 2)

3.4 Interview

The interview was utilized to learn about existing landscape maintenance practices for the USD 383 elementary schools. Interview questions were sent via email to the maintenance staff from USD 383 Manhattan-Ogden Public Schools District. They were asked to reply to the email and provide typed answers.

The objective of the interview was to better understand opportunities and constraints related to the maintenance practices and decision-making about the landscape, trees, and outdoor activity areas at the elementary schools.

Both the survey and interview are considered research involving human subjects. Before implementation, the detailed procedures were submitted to the Institutional Review Board (IRB) separately and approved by the Committee for Research Involving Human Subjects (IRB). (See Appendix 1)

3.5 Document Review

In addition to taking information from the site inventory, survey, and interview, documents provided by the school district, Manhattan Parks and Rec, and Kansas Forest Service were used for supplementing the design guidelines and tree planting initiative.

3.51 USD 383 district website

USD 383 Facilities Manual:

This document provides an overview of the USD 383 District Maintenance Department and guides current and future building administration to answer questions about proper procedures for maintenance-related items.

Manhattan- Ogden USD 383 Master Plan 2017:

This document presents a strategic plan to accommodate student enrollment growth over the next 20 years. The Master Plan assesses the student enrollment capacity of existing schools, evaluates concurrent maintenance needs, and projected sustainment needs to maintain the usability of schools and support buildings into the future.

The USD 383 school district is working on the bond construction by following the master plan. Land construction and modification on the district sites were started in 2018 and are estimated to finish in 2024. This document provides project sites' newest or planned building and hardscape information. Referring to this

document ensures the tree placements fit with each school's current situation and are not in conflict with future planning.

3.52 City pf Manhattan Parks and Rec

According to the site inventory, some public trees play an important role in providing schoolyard shade, especially at small-scale schools. It is possible to work with the City of Manhattan to plant trees on the right-of-way of streets around the school.

City of Manhattan Spring Street Tree Planting Program:

The City of Manhattan has a public tree program in which anyone can request a tree be planted on the city street right-of-way. Approximately 200 trees each year are available. People only need to fill out a simple application; then the city will review and plant trees for them.

3.53 Chapter 26 – MANHATTAN DEVELOPMENT CODE (MDC)

This Chapter combines the zoning regulations of the City of Manhattan and the subdivision regulations of the Manhattan Urban Area.

3.54 Kansas Forest Service

Growing trees successfully depends on selecting the right trees and planting them in the proper place. It is important to match the growing conditions and space available on the site with the cultural requirements and projected size of each tree to be planted. The Kansas Forest Service is one of the most trusted tree specialist organizations in Kansas, and it provides a series of plant lists that help people select trees suitable for the environment and soil conditions in different regions of Kansas.

Chapter 04

Findings

Findings

4.1 Site Analysis

A site analysis was conducted for each of the eight school sites, including general school information, existing trees' location, species, and value, site slope, utilities, and shade of current condition. This information helps to understand the current school site conditions.

4.11 Amanda Arnold Site Analysis

Site Location

1435 Hudson Avenue,

Manhattan, KS 66503

Statistics

Grade Served: PK-5

Enrollment student: Approx. 500 in 2020-21 per CCD

Year Built: 1985

Modernizations/Additions: 2010

Site Area: **9.6 acres**

i-Tree Ecosystem Analysis Findings

- Canopy coverage within the property line: **20.9%**
- Number of tree inventoried: **70**
- Tree cover of the 70 trees: **8.0 %**
- Percentage of trees less than 6” (15.2 cm) diameter: **5.7%**
- Pollution Removal: **48.8 pounds/year ($137/year)**
- Carbon Storage: **44.29 tons ($7.55 thousand)**
- Carbon Sequestration: **1511 pounds ($129/year)**
- Oxygen Production: **2.015 tons/year**
- Avoided Runoff: **1.871 thousand cubic feet/year ($125/year)**
- Replacement values: **$164 thousand**

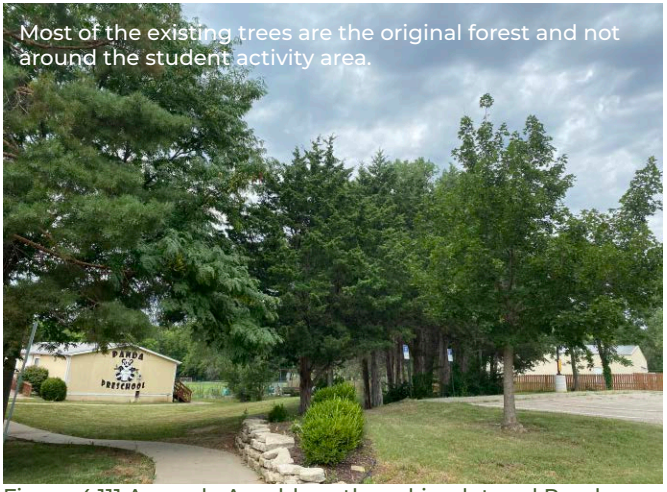


Figure 4.111 Amanda Arnold south parking lot and Panda preschool

Figure 4.112 Amanda Arnold northwest playground

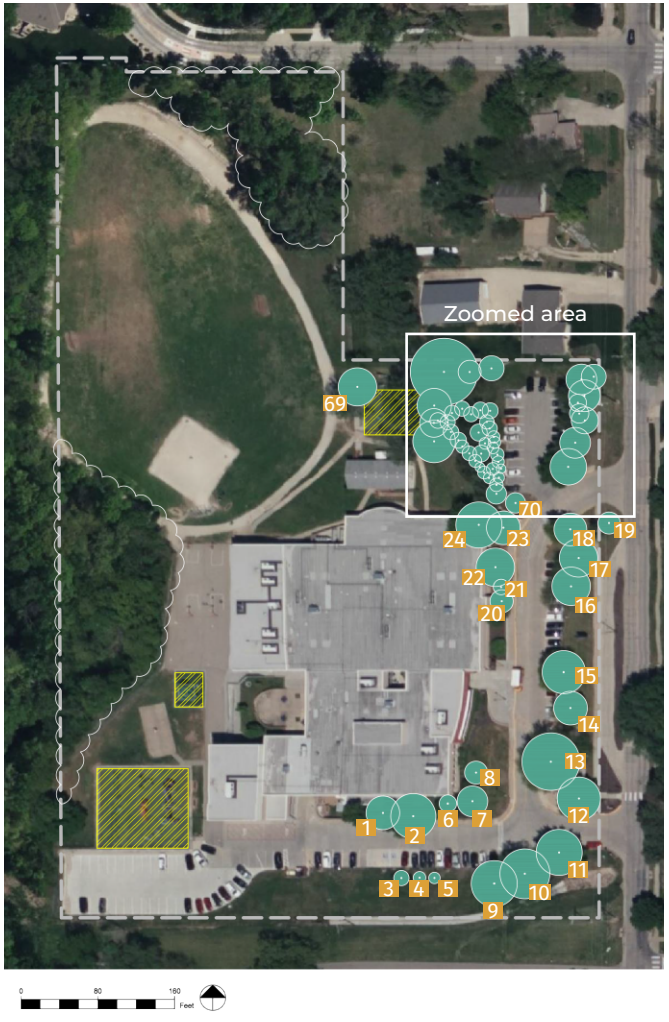
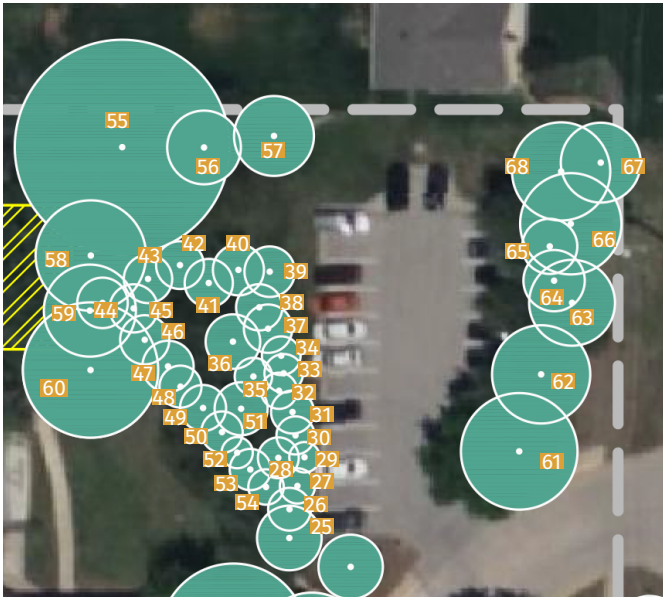


Figure 4.113 Amanda Arnold tree location



Zoomed area

Schoolyard trees inventoried

Playground equipment areas

Species List

Tree ID	Tree Species	DBH (inches)	Condition
1	Callery pear	20.25	Fair
2	Callery pear	22.17	Fair
3	eastern redbud	5.54	Fair
4	elm	4.59	Poor
5	elm	4.39	Poor
6	eastern redbud	7.64	Fair
7	eastern redbud	24.48	Fair
8	eastern redbud	7.64	Fair
9	elm	23.31	Fair
10	elm	33.25	Fair
11	oak	20.25	Fair
12	oak	20.64	Good
13	honeylocust	53.50	Fair
14	oak	16.82	Fair
15	honeylocust	19.49	Fair
16	honeylocust	18.34	Fair
17	honeylocust	16.05	Poor
18	oak	14.52	Good
19	Callery pear	16.43	Good
20	crabapple	14.14	Poor
21	crabapple	4.20	Poor
22	pine	8.03	Fair
23	pine	19.49	Good
24	honeylocust	19.11	Good
25	eastern redcedar	16.05	Fair

Tree ID	Tree Species	DBH	Condition
26	eastern redcedar	11.85	Fair
27	eastern redcedar	7.64	Fair
28	eastern redcedar	11.46	Fair
29	eastern redcedar	6.05	Fair
30	eastern redcedar	8.03	Fair
31	eastern redcedar	7.26	Fair
32	eastern redcedar	9.94	Fair
33	eastern redcedar	8.03	Fair
34	eastern redcedar	7.26	Fair
35	eastern redcedar	8.03	Fair
36	eastern redcedar	7.26	Fair
37	eastern redcedar	6.88	Fair
38	eastern redcedar	10.32	Fair
39	eastern redcedar	8.41	Fair
40	eastern redcedar	11.46	Fair
41	eastern redcedar	6.50	Fair
42	eastern redcedar	10.70	Fair
43	eastern redcedar	9.17	Fair
44	eastern redcedar	6.88	Fair
45	eastern redcedar	7.64	Fair
46	eastern redcedar	8.03	Fair
47	eastern redcedar	11.46	Fair
48	eastern redcedar	11.46	Fair
49	eastern redcedar	10.70	Fair
50	eastern redcedar	9.94	Fair

Tree ID	Tree Species	DBH	Condition
51	eastern redcedar	10.70	Fair
52	eastern redcedar	11.46	Fair
53	eastern redcedar	12.99	Fair
54	eastern redcedar	12.99	Fair
55	cottonwood	54.27	Fair
56	Kenturkey coffee tree	12.99	Fair
57	eastern redcedar	14.52	Fair
58	elm	13.38	Fair
59	elm	12.61	Fair
60	elm	22.93	Good
61	oak	19.11	Fair
62	eastern redcedar	15.67	Fair
63	eastern redcedar	12.99	Fair
64	eastern redcedar	14.90	Fair
65	eastern redcedar	16.82	Fair
66	eastern redcedar	22.93	Fair
67	eastern redcedar	14.90	Fair
68	eastern redcedar	16.82	Fair
69	elm	22.93	Fair
70	maple	7.26	Good

Table 4.11 Amanda Arnold tree species list

Species Composition

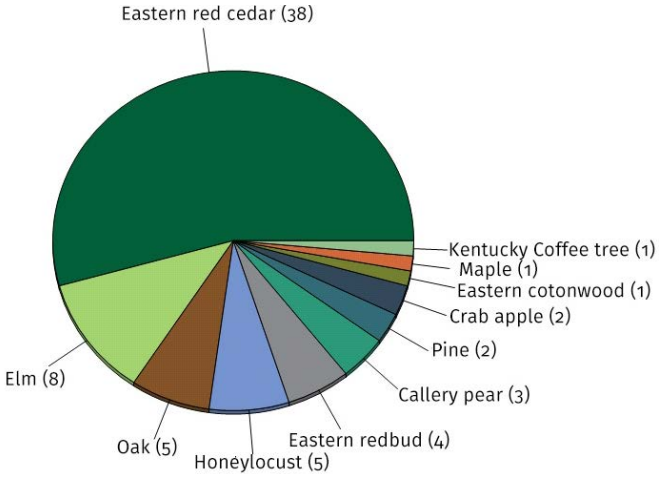
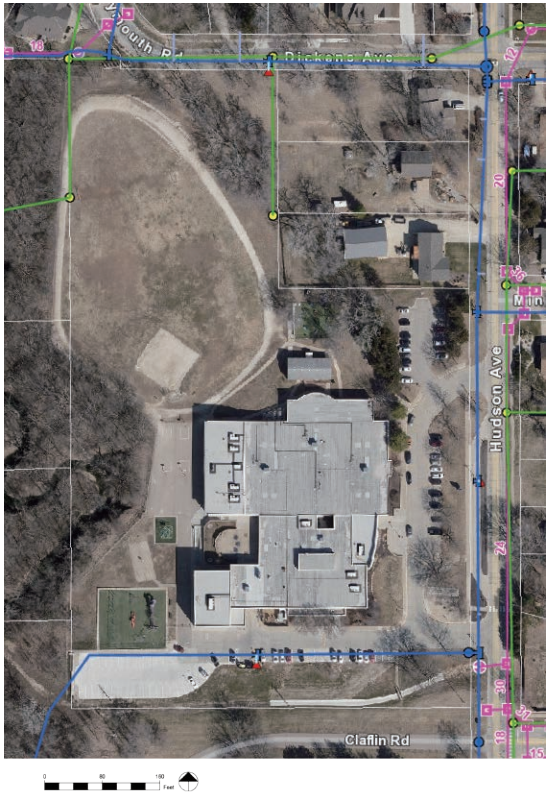


Figure 4.114 Amanda Arnold tree species distribution

- A total of **70** trees were inventoried at the Amanda Arnold site. The total tree canopy coverage is **8.0%** of the 9.6 acre site. The three most common species are **eastern red cedar (38)**, **elm (8)**, and **oak (5)**.
- Please refer to the full Amanda Arnold i-Tree Ecosystem Analysis Report (Appendix 3) for more information.

Utilities



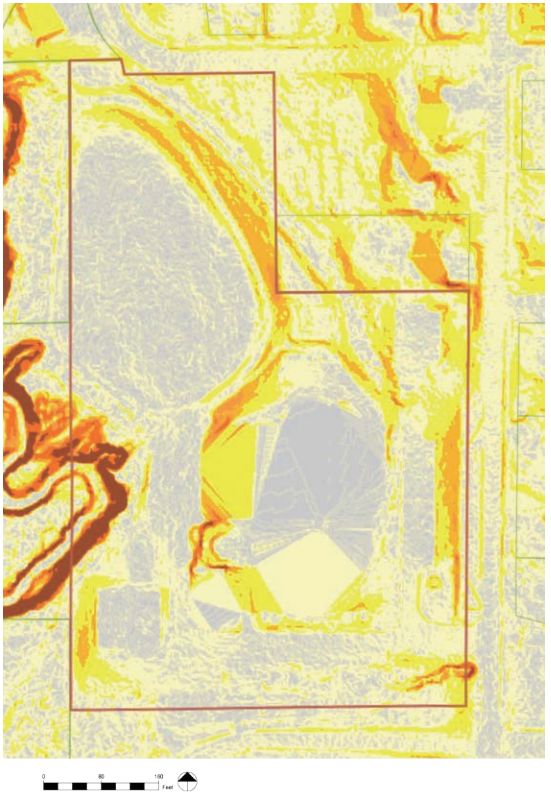
Stormwater
Sanitary Sewer
Water

Figure 4.115 Amanda Arnold utilities

Data from Riley County Community GIS Viewer

- The utility lines follow the perimeter of the site property line and will not affect the planting of trees.

Slope Study



0 5 10 15 21 31 →up to 90

Figure 4.116 Amanda Arnold site slope

Data from ArcGIS Terrain: Slope Map

- The steepest slope of the site is **below 15%**, so there is no need to consider the subsequent maintenance difficulties caused by the slope.

Shade Study

Shade pattern from 9 am to 3 pm on Mar. 21

Shade pattern from 9 am to 3 pm on Jun. 21

Shade pattern from 9 am to 3 pm on Sept. 21

Shade pattern from 9 am to 3 pm on Dec. 21

Playground equipment areas

- Existing trees on site cannot provide sufficient shade for student activity areas.

Figure 4.117 Amanda Arnold shade study

Figure 4.118 Potential tree placement locations at Amanda Arnold

Issues

- Most of the existing trees are not around the student activity area and do not provide useful shade for students.
- There are no trees close to the playground and student activity area.
- Most of the existing schoolyard trees are mature eastern redcedar. The species diversity is low.
- Elm and ash trees on site are susceptible to known pests and will likely die. Please refer to the Amanda Arnold i-Tree Ecosystem Analysis Report (Appendix 3) for more information.

Opportunities for new Trees

- Students would be benefit from adding shade around the playground.
- More trees can be added near the southern parking lot providing shade for vehicles.
- There is a potential to continue planting around the northern baseball field.

Schoolyard trees inventoried

First priority tree planting location

Second priority tree planting location

Location for future tree planting consideration

*Tree planting priorities will be explained later in Chapter 5.

4.12 Bluemont Site Analysis

Site Location

714 Bluemont Avenue,

Manhattan, Kansas 66502

Statistics

Grade Served: PK-5

Enrollment student: Approx. 235 in 2020-21 per CCD

Year Built: 1912

Modernizations/Additions: 1929, 1950/51, 1970, 1983, 2012

Site Area: **2.85 acres**

i-Tree Ecosystem Analysis Findings

- Canopy coverage within the property line: **11.4%**
- Number of tree inventoried: **16**
- Tree cover of the 16 schoolyard trees: **7.5 %**
- Percentage of trees less than 6" (15.2 cm) diameter: **25.0%**
- Pollution Removal: **16.45 pounds/year ($51.8/year)**
- Carbon Storage: **11.38 tons ($1.94 thousand)**
- Carbon Sequestration: **530 pounds ($45.2/year)**
- Oxygen Production: **1413 pounds/year**
- Avoided Runoff: **664 cubic feet/year ($44.4/year)**
- Replacement values: **$60.6 thousand**

Figure 4.121 Eastern redbud trees in Bluemont schoolyard

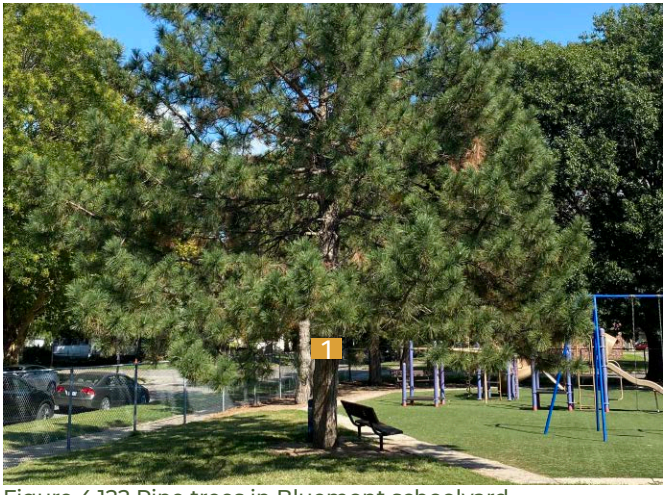


Figure 4.122 Pine trees in Bluemont schoolyard

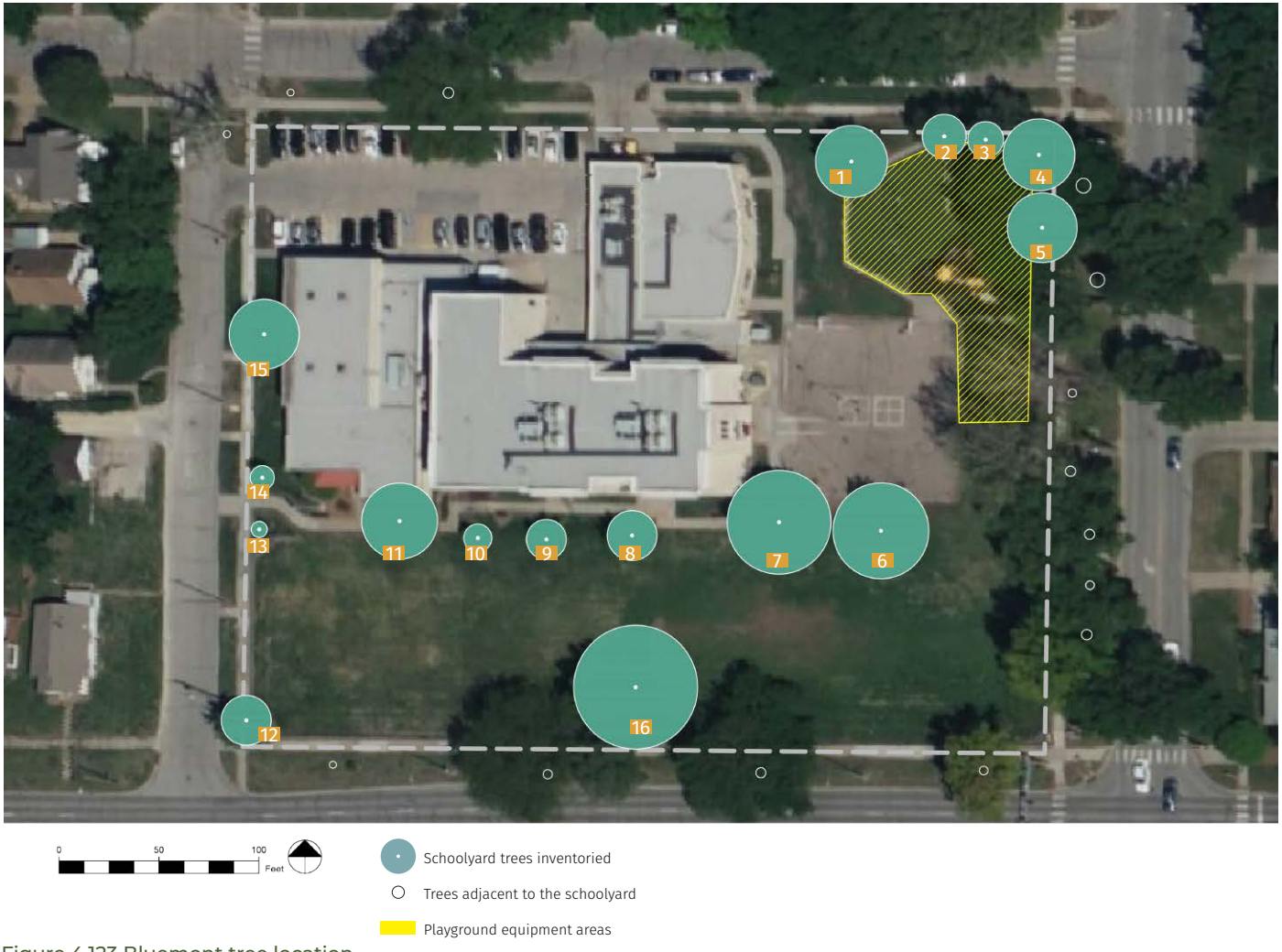


Figure 4.123 Bluemont tree location

Species List

Tree ID	Tree Species	DBH (inches)	Condition
1	pine	19.49	Good
2	pine	18.34	Fair
3	pine	17.20	Fair
4	eastern redcedar	23.69	Fair
5	eastern redcedar	19.11	Fair
6	ash	20.64	Good
7	ash	25.99	Good
8	maple	11.46	Good
9	oak	5.54	Fair
10	maple	3.82	Good
11	eastern redbud	20.64	Poor
12	eastern redcedar	17.96	Fair
13	eastern redbud	2.87	Poor
14	maple	3.82	Good
15	eastern redbud	15.29	Good
16	oak	25.22	Good

Table 4.12 Bluemont tree species list

Species Composition

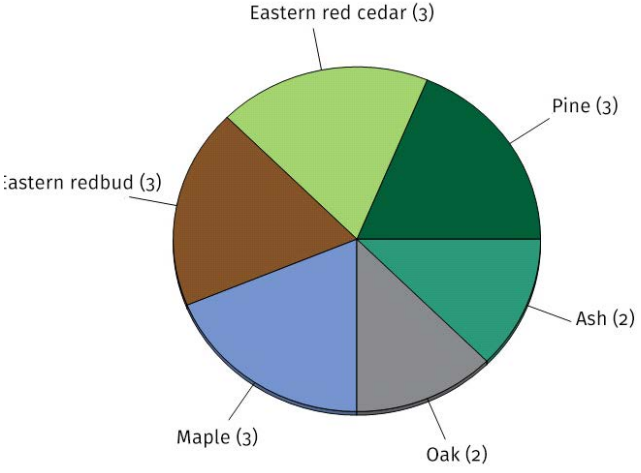


Figure 4.124 Bluemont tree species distribution

- A total of **16** trees were inventoried at the Bluemont site. The total tree canopy coverage is **7.5%** of the 2.85 acre site. The three most common species are **eastern redcedar (3)**, **eastern redbud (3)**, and **pine (3)**.
- Please refer to the full Bluemont i-Tree Ecosystem Analysis Report (Appendix 4) for more information.

Utilities

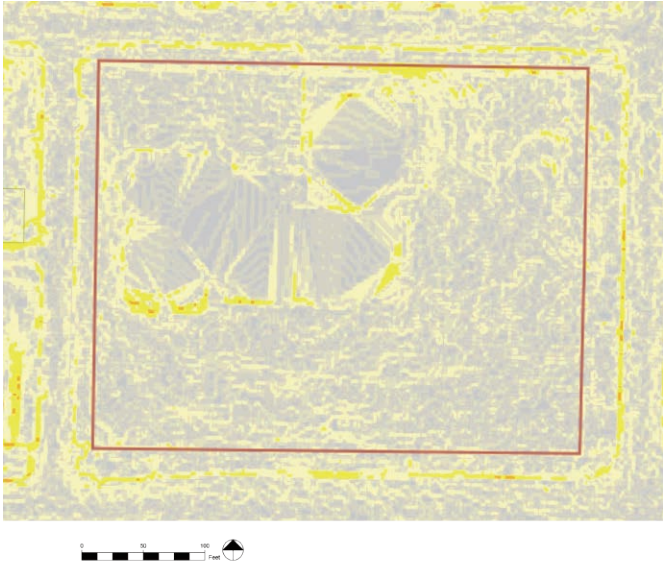
Stormwater
Sanitary Sewer
Water

Figure 4.125 Bluemont utilities

Data from Riley County Community GIS Viewer

- Most of the utility lines follow the perimeter of the site property line and will not affect the planting of trees.
- Attention should be paid to the sanitary sewer across the site.

Slope Study



0 5 10 15 21 31 →up to 90

Figure 4.126 Bluemont site slope

Data from ArcGIS Terrain: Slope Map

- The steepest slope of the site is **below 10%**, so there is no need to consider the subsequent maintenance difficulties caused by the slope.

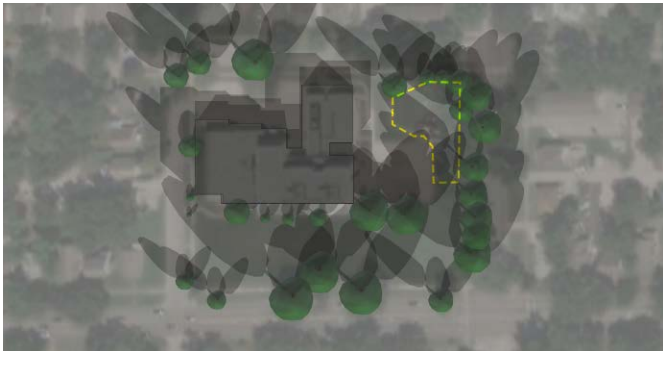
Shade Study

Shade pattern from 9 am to 3 pm on Mar. 21

Shade pattern from 9 am to 3 pm on Jun. 21

Shade pattern from 9 am to 3 pm on Sept. 21

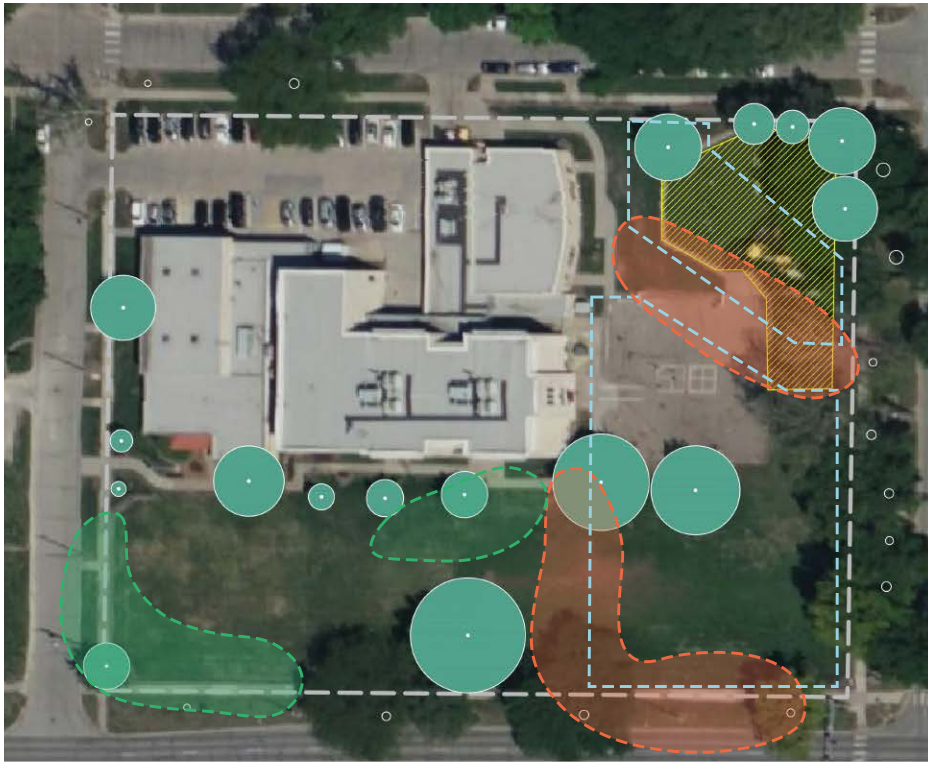
Shade pattern from 9 am to 3 pm on Dec. 21



Playground equipment areas

- Existing trees on site and surrounding street trees can provide shade for student activity areas. However, due to the future modification of the school ground, some existing trees will be removed.

Figure 4.127 Bluemont shade study



*Tree planting priorities will be explained later in Chapter 5.

Figure 4.128 Potential tree placement locations at Bluemont

Issues

- Existing trees on site and the surrounding street trees can provide shade for the student activity areas. However, due to the future modification of the school ground, some existing trees will be removed.
- Ash trees on site are susceptible to known pests and will likely die. Please refer to the Bluemont i-Tree Ecosystem Analysis Report (Appendix 4) for more information.

Opportunities for new Trees

- Students would be benefit from adding shade around the playground.
- Since a new hardscape play area will be added and adjacent to the street, trees could be planted on the street to provide shade for the schoolyard.
- The open space in the south of the school can be used to build an outdoor classroom and trees can also be planted around it.
- A parking lot will be added in the northwest of site. Adding trees around the parking lot can provide shade for vehicles.
- Adding trees around the schoolyards can increase the space enclosure.

4.13 Frank V. Bergman Site Analysis

Site Location

3430 Lombard,

Manhattan, Kansas 66503

Statistics

Grade Served: PK-5

Enrollment student: Approx. 410 in 2020-21 per CCD

Year Built: 1995

Modernizations/Additions: 2021

Site Area: **8.4 acres**

i-Tree Ecosystem Analysis Findings

- Canopy coverage within the property line: **1.4%**
- Number of tree inventoried: **13**
- Tree cover of the 13 schoolyard trees: **1.4 %**
- Percentage of trees less than 6” (15.2 cm) diameter: **0%**
- Pollution Removal: **8.355 pounds/year ($25.6/year)**
- Carbon Storage: **5.049 tons ($861)**
- Carbon Sequestration: **464 pounds ($39.6/year)**
- Oxygen Production: **1237 pounds/year**
- Avoided Runoff: **332.4 cubic feet/year ($22.2/year)**
- Replacement values: **$32.8 thousand**

Figure 4.131 Frank V. Bergman northern playground

Figure 4.132 Frank V. Bergman baseball field

Figure 4.133 Frank V. Bergman tree location

Species List

Tree ID	Tree Species	DBH (inches)	Condition
1	pine	13.38	Good
2	river birch	12.61	Fair
3	pine	12.61	Good
4	pine	14.14	Fair
5	pine	14.90	Fair
6	Callery pear	13.38	Good
7	Callery pear	15.29	Good
8	Callery pear	6.88	Poor
9	Callery pear	11.46	Good
10	oak	7.64	Good
11	pine	12.23	Fair
12	pine	15.29	Fair
13	pine	11.46	Poor

Table 4.13 Frank V. Bergman tree species list

Species Composition

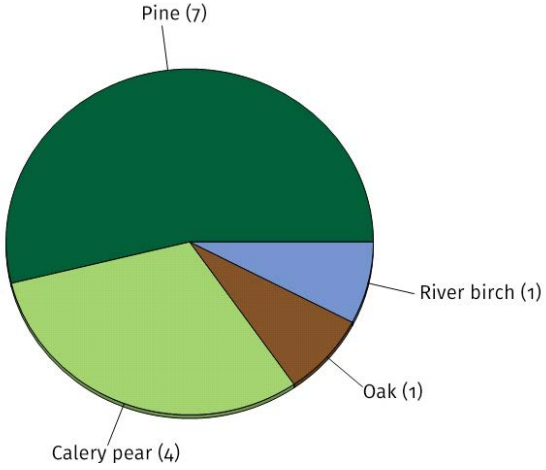


Figure 4.134 Frank V. Bergman tree species distribution

- A total of **13** trees were inventoried at the Frank V. Bergman site. The total tree canopy coverage is **1.4%** of the 8.6 acre site. The two most common species are **pine (7)** and **callery pear (4)**.
- Please refer to the full Frank V. Bergman i-Tree Ecosystem Analysis Report (Appendix 5) for more information.

Utilities

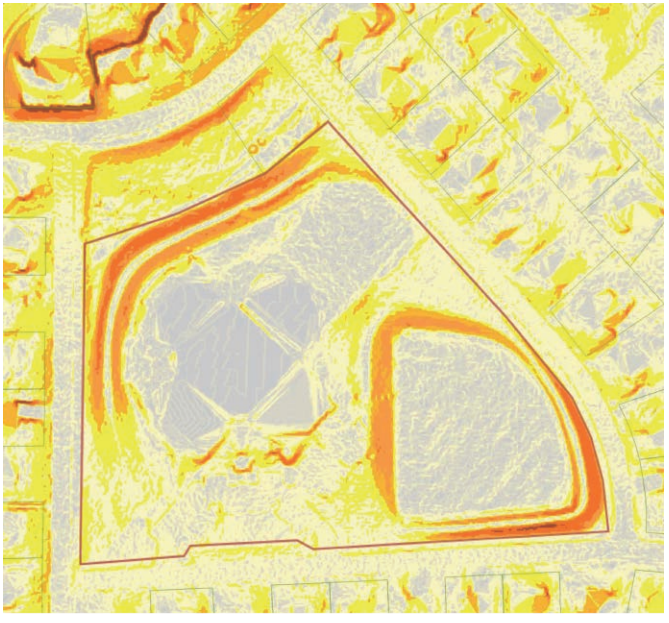
Stormwater
Sanitary Sewer
Water

Figure 4.135 Frank V. Bergman utilities

Data from Riley County Community GIS Viewer

- The utility lines follow the perimeter of the site property line and will not affect the planting of trees.

Slope Study



0 5 10 15 21 31 →up to 90

Figure 4.136 Frank V. Bergman site slope

Data from ArcGIS Terrain: Slope Map

- The north and northwest edges of the schoolyard and the edge of the baseball court in the southeast part of the site have steeper slopes. Considering the student activity area and the subsequent landscape maintenance may be affected by the slope, the tree planting areas will avoid these two steep slopes.

Shade Study

Shade pattern from 9 am to 3 pm on Mar. 21

Shade pattern from 9 am to 3 pm on Jun. 21

Shade pattern from 9 am to 3 pm on Sept. 21

Shade pattern from 9 am to 3 pm on Dec. 21

Playground equipment areas

- Existing trees on site cannot provide sufficient shade for student activity areas.

Figure 4.137 Frank V. Bergman shade study

*Tree planting priorities will be explained later in Chapter 5.

Figure 4.138 Potential tree placement locations at Frank V. Bergman

Issues

- Existing trees on site cannot provide sufficient shade for student activity areas.
- The existing pine and Callery pear will not develop into large shade trees.

Opportunities for new Trees

- Adding trees around the playground should be the priority for planting trees.
- Shade trees can be planted around the eastern baseball field to provide shaded resting areas.
- Almost all of the existing trees were removed during the parking lot reconstruction, so new trees should be added to the planting beds after the new parking lot is built.
- Additional planting could be at the northern open space.

4.14 Lee Site Analysis

Site Location

701 Lee Street,

Manhattan, KS 66502

Statistics

Grade Served: PK-5

Enrollment student: Approx. 400 in 2020-21 per CCD

Year Built: 1951

Modernizations/Additions: 1958, 2012, 2015

Site Area: **5.5 acres**

i-Tree Ecosystem Analysis Findings

- Canopy coverage within the property line: **2.2%**
- Number of tree inventoried: **24**
- Tree cover of the 24 schoolyard trees: **2.2 %**
- Percentage of trees less than 6” (15.2 cm) diameter: **66.7%**
- Pollution Removal: 6.662 pounds/year ($18.4/year)
- Carbon Storage: **3.788 tons ($646)**
- Carbon Sequestration: **388.3 pounds ($33.1/year)**
- Oxygen Production: **1035 pounds/year**
- Avoided Runoff: **292.5 cubic feet/year ($19.6/year)**
- Replacement values: **$19.9 thousand**

Figure 4.141 Lee southern playground

Figure 4.142 Dead maple tree in Lee

Figure 4.143 Lee tree location

Species List

Tree ID	Tree Species	DBH (inches)	Condition
1	ash	16.24	Good
2	maple	9.55	Good
3	ash	14.90	Good
4	elm	7.64	Good
5	maple	11.53	Poor
6	meple	3.06	Good
7	maple	1.53	Dead/Dying
8	maple	2.48	Fair
9	maple	2.87	Fair
10	shaggy bark hickory	7.64	Dead/Dying
11	maple	1.91	Good
12	maple	2.48	Good
13	maple	2.48	Good
14	sycamore	9.94	Fair
15	tree lilac	3.06	Fair
16	tree lilac	2.29	Fair
17	elm	2.68	Good
18	elm	3.44	Good
19	purple leaved plum	3.06	Poor
20	purple leaved plum	3.06	Poor
21	maple	14.14	Good
22	oak	19.87	Good
23	elm	3.06	Fair
24	elm	2.68	Fair

Table 4.14 Lee tree species list

Species Composition

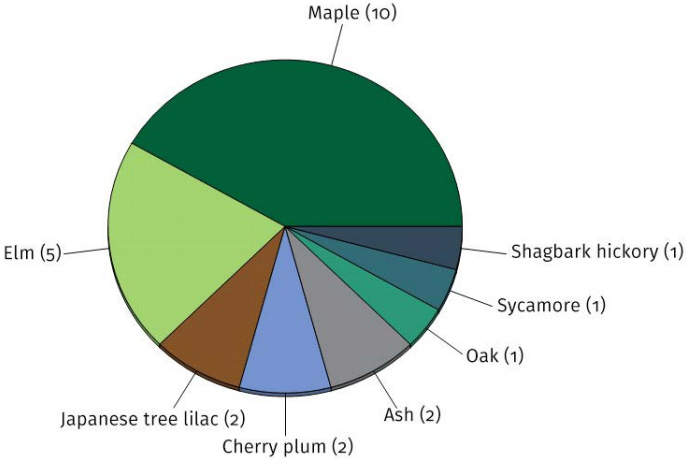


Figure 4.144 Lee tree species distribution

- A total of **24** trees were inventoried at the Lee elementary school site. The total tree canopy coverage is 2.2% of the 5.5 acre site. The two most common species are **maple (10)** and **elm (5)**.
- Please refer to the full Lee i-Tree Ecosystem Analysis Report (Appendix 6) for more information.

Utilities

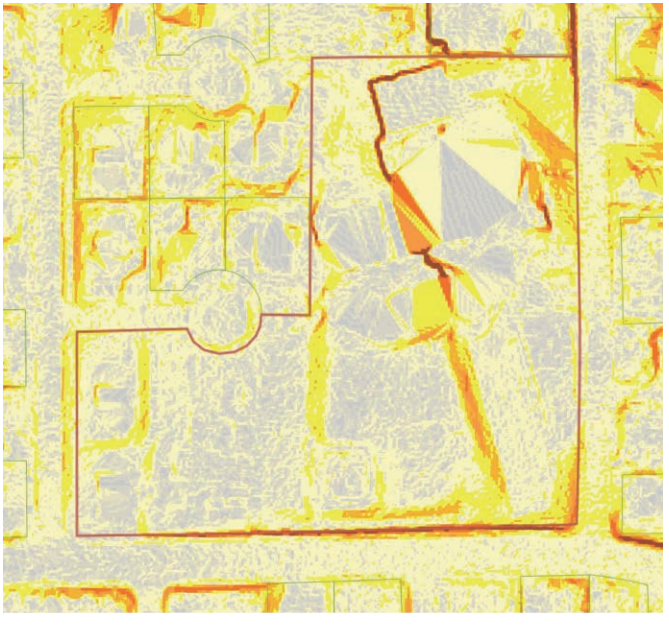
Stormwater
Sanitary Sewer
Water

Figure 4.145 Lee utilities

Data from Riley County Community GIS Viewer

- The utility lines follow the perimeter of the site property line and will not affect the planting of trees.

Slope Study



0 5 10 15 21 31 →up to 90

Figure 4.146 Lee site slope

Data from ArcGIS Terrain: Slope Map

- The steeply slope is the retaining wall in the north of the site.
- The slope of the student activity areas and the surrounding open areas is **below 20%**, so there is no need to consider the subsequent maintenance difficulties caused by the slope.

Shade Study

Shade pattern from 9 am to 3 pm on Mar. 21

Shade pattern from 9 am to 3 pm on Jun. 21

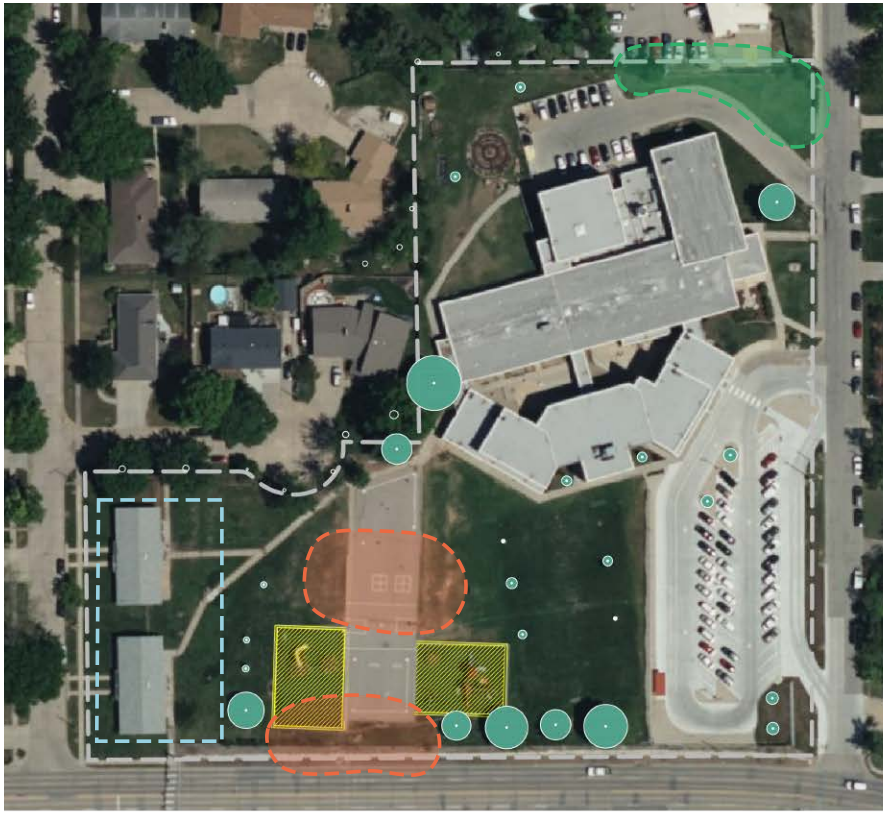
Shade pattern from 9 am to 3 pm on Sept. 21

Shade pattern from 9 am to 3 pm on Dec. 21

Playground equipment areas

- Existing trees on site cannot provide sufficient shade for student activity areas.

Figure 4.147 Lee site shade study



*Tree planting priorities will be explained later in Chapter 5.

Figure 4.148 Potential tree placement locations at Lee

Issues

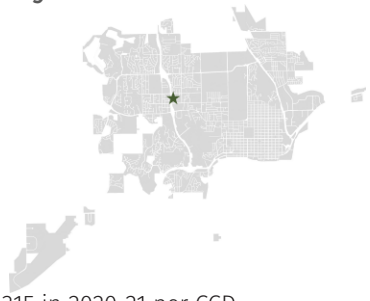
- Most existing trees are located in the playground's southern part and can provide shade. However, the existing trees still cannot provide enough shade for the student activity areas.
- The newly planted trees on the playground lack of maintenance.
- The small trees on the southern lawn are all maple. The species diversity is low.
- Elm and ash trees on site are susceptible to known pests and will likely die. Please refer to the Lee i-Tree Ecosystem Analysis Report (Appendix 6) for more information.

Opportunities for new Trees

- Students would be benefit from adding more shade around the playground.
- Trees can also be planted at planting beds interspersed between concrete paving.
- Trees do not shade the outdoor learning area located in the northern part of the site, but there is a garden close to the learning area. The garden may need more direct sunlight, so it is more recommended to use a built structure for the outdoor learning area shade.

4.15 Marlatt Site Analysis

Site Location



2715 Hobbs Drive,

Manhattan, Kansas 66502

Statistics

Grade Served: PK-5

Enrollment student: Approx. 315 in 2020-21 per CCD

Year Built: 1960

Modernizations/Additions: 2011

Site Area: **8.8 acres**

i-Tree Ecosystem Analysis Findings

- Canopy coverage within the property line: **9.3%**
- Number of tree inventoried: **73**
- Tree cover of the 73 schoolyard trees: **9.3 %**
- Percentage of trees less than 6" (15.2 cm) diameter: **32.9%**
- Pollution Removal: **47.47 pounds/year ($128/year)**
- Carbon Storage: **36.48 tons ($6.22 thousand)**
- Carbon Sequestration: **1759 pounds ($150/year)**
- Oxygen Production: **2.346 tons/year**
- Avoided Runoff: **1.886 thousand cubic feet/year ($126/year)**
- Replacement values: **$161 thousand**

Figure 4.151 Marlatt northern playground

Figure 4.152 English oak trees in Marlatt

Figure 4.153 Marlatt tree location

Species List

Tree ID	Tree Species	DBH (inches)	Condition
1	linden tree	9.94	Good
2	tulip tree	2.68	Fair
3	Callery pear	23.69	Good
4	Callery pear	17.96	Good
5	honeylocust	19.11	Good
6	Callery pear	13.76	Good
7	Callery pear	14.14	Good
8	Callery pear	26.37	Good
9	eastern redcedar	3.44	Fair
10	eastern redbud	11.08	Good
11	eastern redbud	9.94	Good
12	blue spruce	4.20	Fair
13	crabapple	1.91	Fair
14	crabapple	7.26	Fair
15	eastern redcedar	4.59	Fair
16	black walnut	27.13	Fair
17	black walnut	22.93	Fair
18	black walnut	15.67	Fair
19	black walnut	15.29	Fair
20	black walnut	22.93	Fair
21	hackberry	16.05	Fair
22	hackberry	24.46	Fair
23	hackberry	13.76	Fair
24	Nothern catalpa	29.43	Fair
25	black walnut	23.31	Fair

Tree ID	Tree Species	DBH (inches)	Condition
26	pecan	24.08	Fair
27	hackberry	21.78	Poor
28	hackberry	10.70	Poor
29	hackberry	15.67	Poor
30	hackberry	11.46	Poor
31	elm	32.10	Poor
32	elm	34.39	Poor
33	oak	28.66	Good
34	maple	1.53	Good
35	maple	2.29	Good
36	maple	2.29	Good
37	maple	1.53	Good
38	Callery pear	6.11	Good
39	Callery pear	6.50	Good
40	Callery pear	7.64	Good
41	Callery pear	7.64	Good
42	Callery pear	6.88	Fair
43	pine	19.49	Fair
44	pine	18.73	Fair
45	pine	23.69	Fair
46	pine	12.61	Fair
47	pine	20.64	Fair
48	pine	22.93	Fair
49	pine	13.38	Fair
50	pine	19.11	Fair

Tree ID	Tree Species	DBH (inches)	Condition
51	pine	21.78	Fair
52	Kenturkey coffee tree	1.91	Fair
53	maple	12.99	Good
54	maple	12.61	Good
55	oak	8.41	Good
56	oak	7.64	Good
57	oak	7.26	Good
58	oak	6.88	Good
59	oak	9.55	Good
60	maple	2.29	Good
61	maple	2.29	Good
62	maple	5.73	Good
63	crabapple	3.06	Good
64	crabapple	2.68	Good
65	crabapple	3.82	Good
66	eastern redbud	3.44	Good
67	eastern redbud	3.44	Good
68	eastern redbud	3.82	Good
69	eastern redbud	5.73	Fair
70	maple	1.91	Dead/Dying
71	Kenturkey coffee tree	2.29	Poor
72	mulberry	1.91	Poor
73	Kenturkey coffee tree	1.91	Poor

Table4.15 Marlatt tree species list

Species Composition

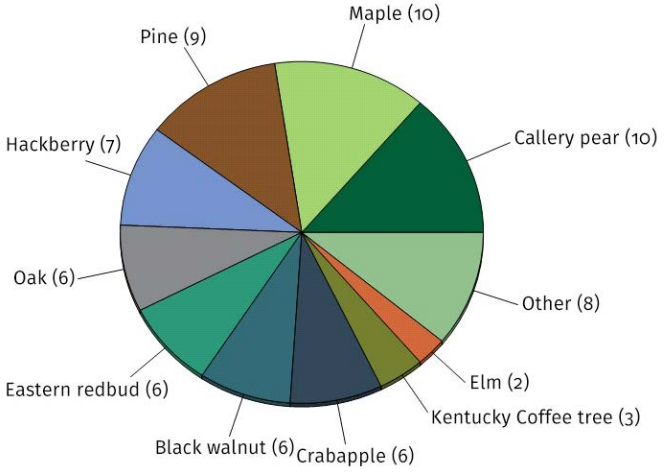


Figure 4.154 Marlatt tree species distribution

- A total of **73** trees were inventoried at the Marlatt site. The total tree canopy coverage is 7.5% of the 8.8 acre site. The three most common species are **Callery pear (10)**, **maple (10)**, and **pine (9)**.
- Please refer to the full Marlatt i-Tree Ecosystem Analysis Report (Appendix 7) for more information.

Utilities

Stormwater
Sanitary Sewer
Water

Figure 4.155 Marlatt utilities

Data from Riley County Community GIS Viewer

- The utility lines follow the perimeter of the site property line and will not affect the planting of trees.

Slope Study

0 5 10 15 21 31 →up to 90

Figure 4.156 Marlatt site slope

Data from ArcGIS Terrain: Slope Map

- The steeply sloped of the site is the retaining wall in the east of the site.
- The slope of the student activity areas and the surrounding open areas is **below 15%**, so there is no need to consider the subsequent maintenance difficulties caused by the slope.

Shade Study

Shade pattern from 9 am to 3 pm on Mar. 21

Shade pattern from 9 am to 3 pm on Jun. 21

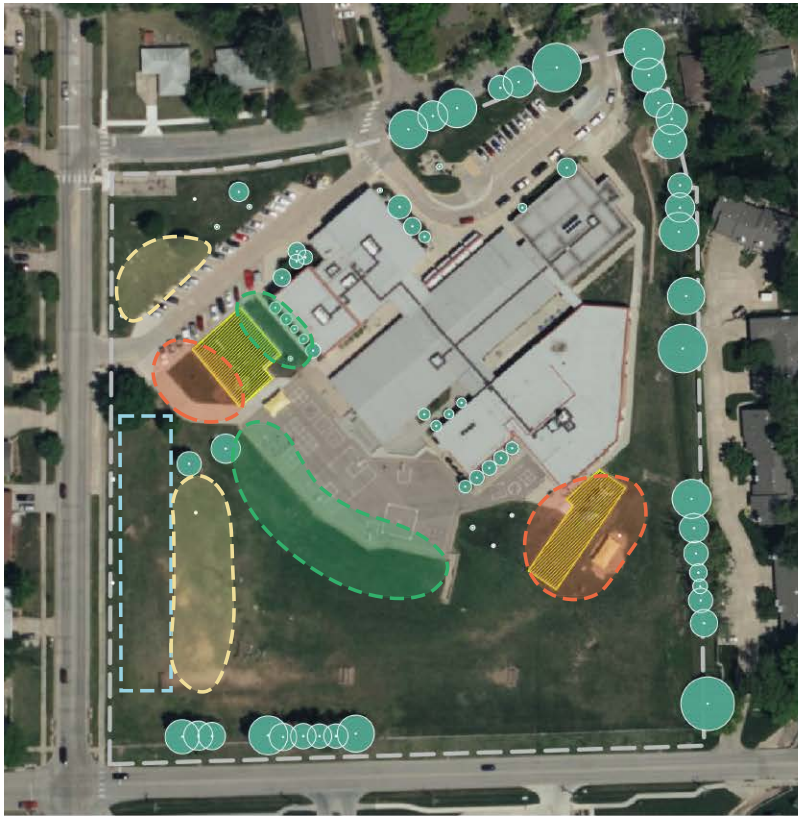
Shade pattern from 9 am to 3 pm on Sept. 21

Shade pattern from 9 am to 3 pm on Dec. 21

Playground equipment areas

- Existing trees on site cannot provide shade for student activity areas.

Figure 4.157 Marlatt site shade study



*Tree planting priorities will be explained later in Chapter 5.

Figure 4.158 Potential tree placement locations at Marlatt

Issues

- Most trees on site are located near the building. They are primarily small ornamental trees that do not provide beneficial shade.
- There are no trees close to the playground and activity areas.
- Most mature trees are located on the edge of the site and receive less maintenance than the landscape trees around the building.
- Elm trees on site are susceptible to known pests and will likely die. Please refer to the Marlatt i-Tree Ecosystem Analysis Report (Appendix 7) for more information.

Opportunities for new Trees

- The site area is large and new trees should be located around the playground.
- Large deciduous trees should be planted near the hardscape play area to increase shade and reduce surface temperature.
- The school is planning to add an outdoor classroom area, so large deciduous trees should be planted near this area to provide enclosure and shade.
- Trees can be planted near the parking lot to provide shade for vehicles.

4.16 Northview Site Analysis

Site Location

300 Griffith Drive,

Manhattan, Kansas 66502

Statistics

Grade Served: PK-5

Enrollment student: Approx. 435 in 2020-21 per CCD

Year Built: 1957

Modernizations/Additions: 1959, 1962, 1983, 2010

Site Area: **14 acres**

i-Tree Ecosystem Analysis Findings

- Canopy coverage within the property line: **1.7%**
- Number of tree inventoried: **26**
- Tree cover of the 26 schoolyard trees: **1.7%**
- Percentage of trees less than 6" (15.2 cm) diameter: **19.2%**
- Pollution Removal: **12.89 pounds/year ($34.8/year**)
- Carbon Storage: 10.16 tons **($1.73 thousand)**
- Carbon Sequestration: **717.6 pounds ($61.2/year)**
- Oxygen Production: **1914 pounds/year**
- Avoided Runoff: **555.4 cubic feet/year ($37.1/year)**
- Replacement values: **$58.4 thousand**

Figure 4.161 Northview southern playground

Figure 4.162 Northview northern playground

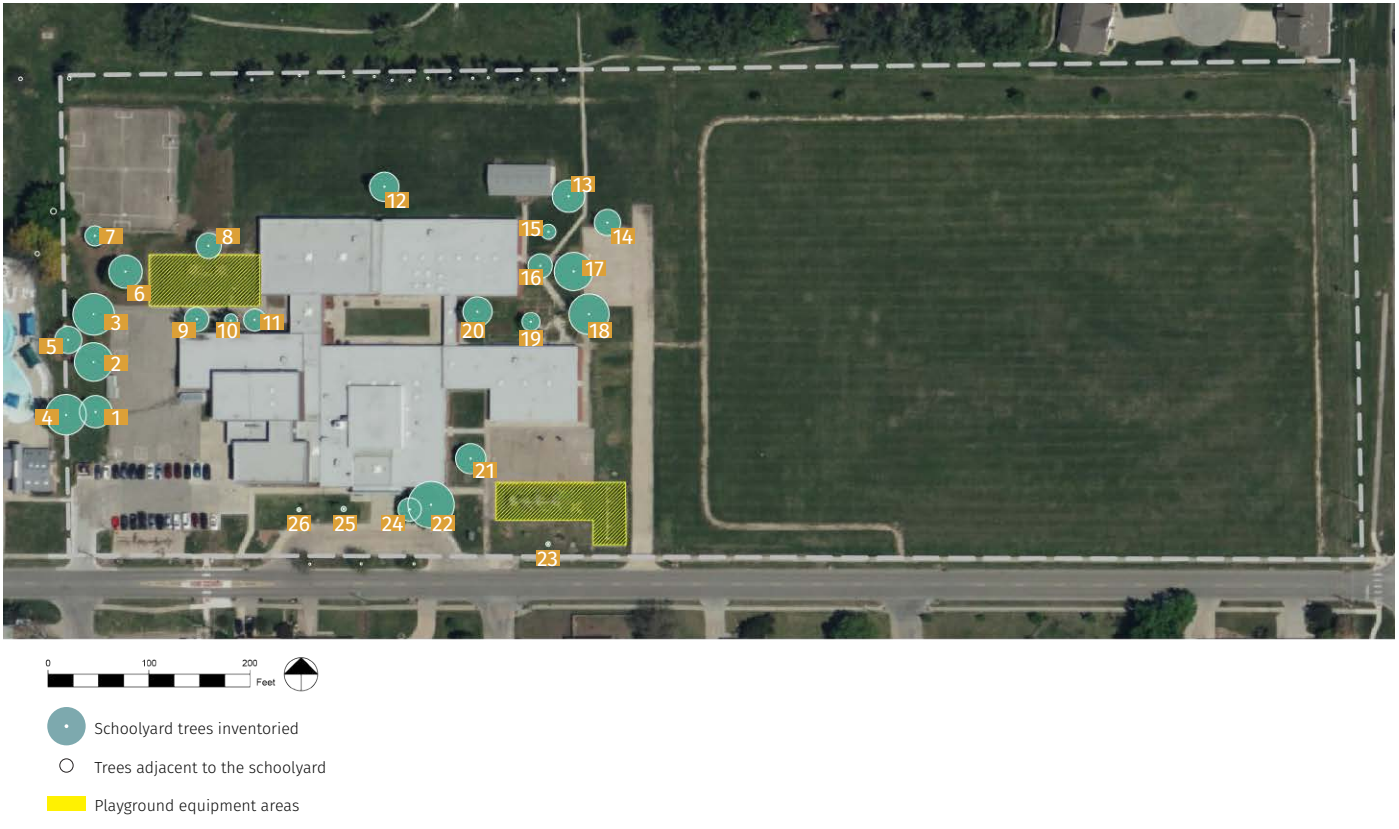


Figure 4.163 Northview tree location

Species List

Tree ID	Tree Species	DBH (inches)	Condition
1	baldcypress	17.96	Good
2	baldcypress	17.20	Good
3	baldcypress	18.15	Good
4	baldcypress	24.84	Fair
5	eastern redcedar	21.02	Poor
6	ash	22.17	Good
7	crabapple	9.55	Good
8	honeylocust	19.49	Dead/Dying
9	river birch	11.46	Poor
10	river birch	4.59	Poor
11	callery pear	16.43	Fair
12	oak	13.38	Poor
13	honeylocust	10.32	Fair
14	honeylocust	10.32	Fair
15	blue spruce	5.73	Good
16	crabapple	6.87	Poor
17	honeylocust	15.29	Fair
18	honeylocust	14.52	Fair
19	maple	13.75	Good
20	maple	9.36	Good
21	oak	14.52	Good
22	Callery pear	24.08	Fair
23	oak	2.29	Good
24	maple	7.26	Fair
25	maple	4.20	Good
26	maple	2.29	Good

Table4.16 Northview tree species list

Species Composition

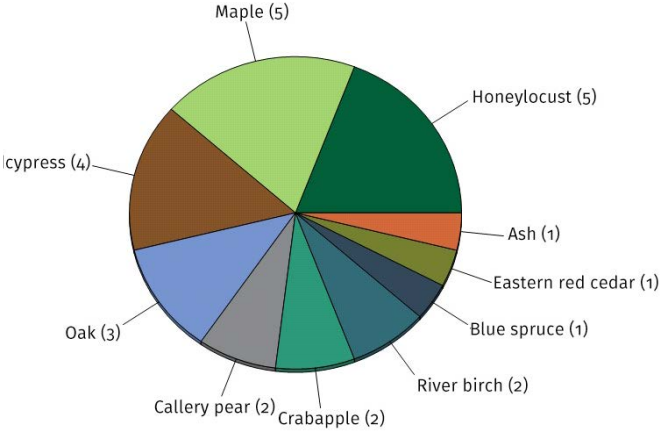


Figure 4.164 Northview tree species distribution

- A total of **26** trees were inventoried at the Northview site. The total tree canopy coverage is 1.7% of the 9.6 acre site. The three most common species are **honeylocust (5)**, **maple (5)**, and **baldcypress (4)**.
- Please refer to the full Northview i-Tree Ecosystem Analysis Report (Appendix 8) for more information.

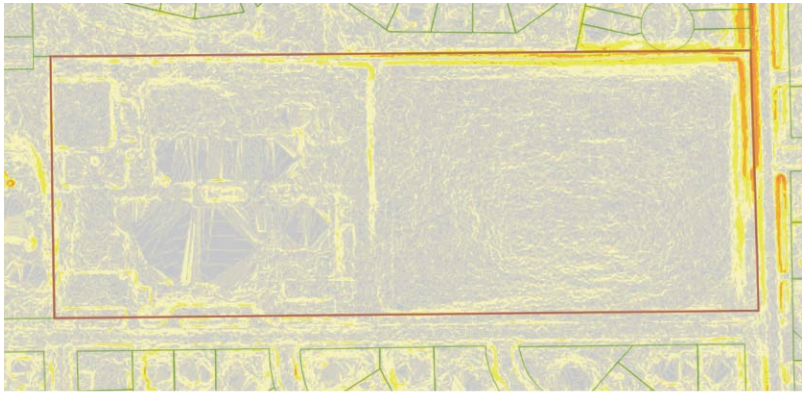
Utilities

Stormwater
Sanitary Sewer
Water

- The utility lines follow the perimeter of the site property line and will not affect the planting of trees.

Figure 4.165 Northview utilities
Data from Riley County Community GIS Viewer

Slope Study



0 5 10 15 21 31 →up to 90

- The steepest slope of the site is **below 10%**, so there is no need to consider the subsequent maintenance difficulties caused by the slope.

Figure 4.166 Northview site slope
Data from ArcGIS Terrain: Slope Map

Shade Study

Shade pattern from 9 am to 3 pm on Mar. 21

Shade pattern from 9 am to 3 pm on Jun. 21

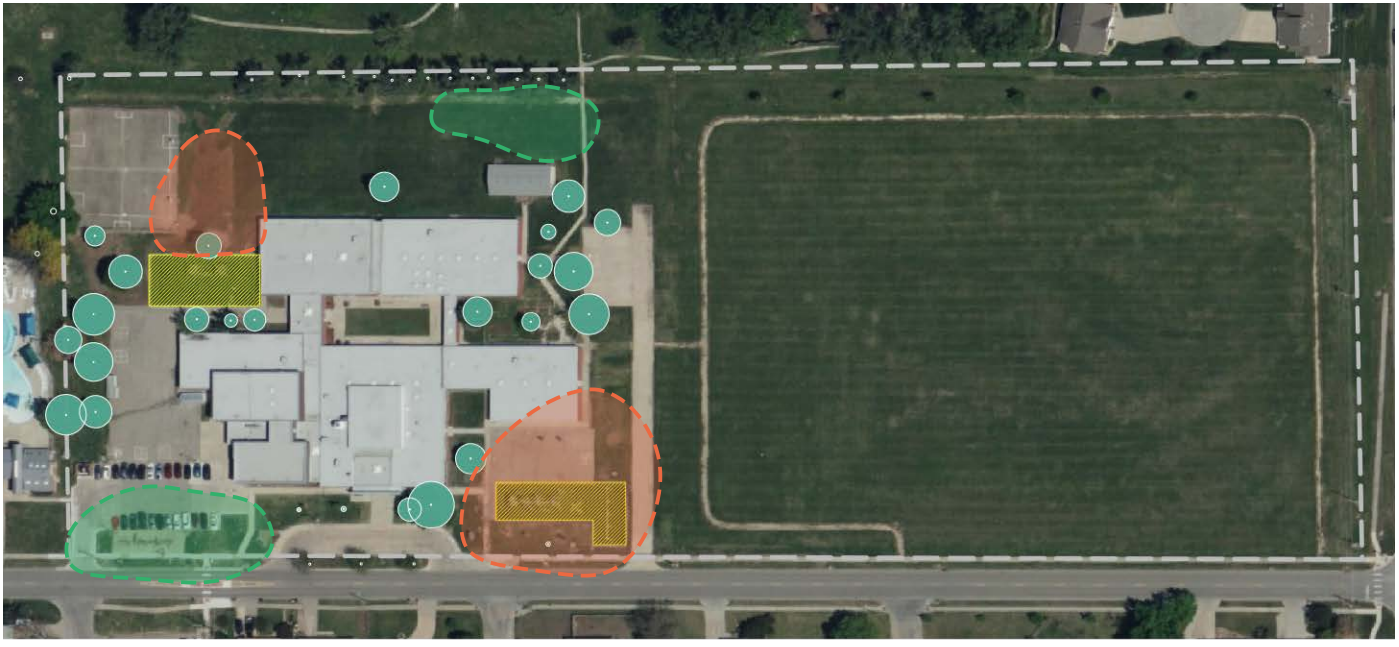
Shade pattern from 9 am to 3 pm on Sept. 21

Shade pattern from 9 am to 3 pm on Dec. 21

Playground equipment areas

- Existing trees on site cannot provide sufficient shade for student activity areas.

Figure 4.167 Northview site shade study



*Tree planting priorities will be explained later in Chapter 5.

Figure 4.168 Potential tree placement locations at Northview

Issues

- The majority of trees on site are located near the property line and far from the playground.
- Most of playground areas have no shade coverage.
- Ash trees on site are susceptible to known pests and will likely die. Please refer to the Northview i-Tree Ecosystem Analysis Report (Appendix 8) for more information.

Opportunities for new Trees

- New trees planted around the playground and hardscape areas will add beneficial shade and help lower surface temperatures.
- Trees can be planted near the parking lot to provide shade for vehicles.

4.17 Theodore Roosevelt Site Analysis

Site Location

1401 Houston Street,

Manhattan, Kansas 66502

Statistics

Grade Served: PK-5

Enrollment student: Approx. 350 in 2020-21 per CCD

Year Built: 1922

Modernizations/Additions: 1951, 1983, 1998, 2012

Site Area: **2.9 acres**

i-Tree Ecosystem Analysis Findings

- Canopy coverage within the property line: **12%**
- Number of tree inventoried: **14**
- Tree cover of the 14 schoolyard trees: **8.3%**
- Percentage of trees less than 6” (15.2 cm) diameter: **21.4%**
- Pollution Removal: **12.26 pounds/year ($32.2/year)**
- Carbon Storage: **12.68 tons ($2.16 thousand)**
- Carbon Sequestration: **458.6 pounds ($39.1/year)**
- Oxygen Production: **1223 pounds/year**
- Avoided Runoff: **492.3 cubic feet/year ($32.9/year)**
- Replacement values: **$54.7 thousand**

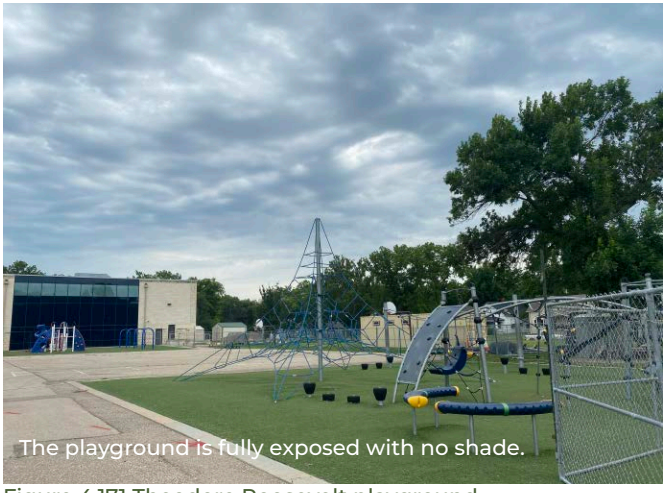


Figure 4.171 Theodore Roosevelt playground

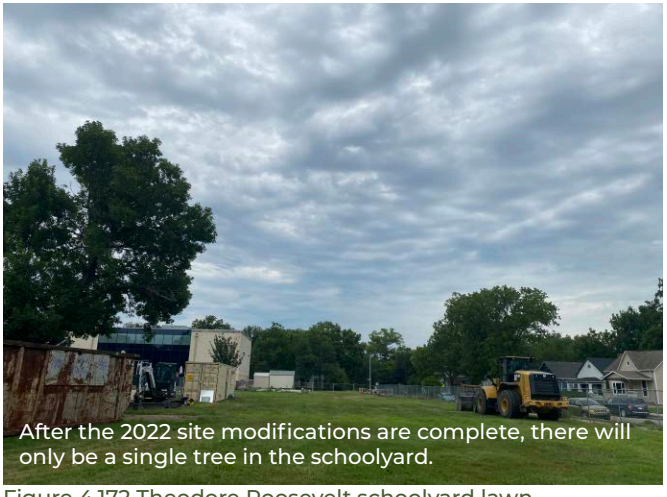


Figure 4.172 Theodore Roosevelt schoolyard lawn

PRODUCED BY AN AUTODESK STUDENT VERSION

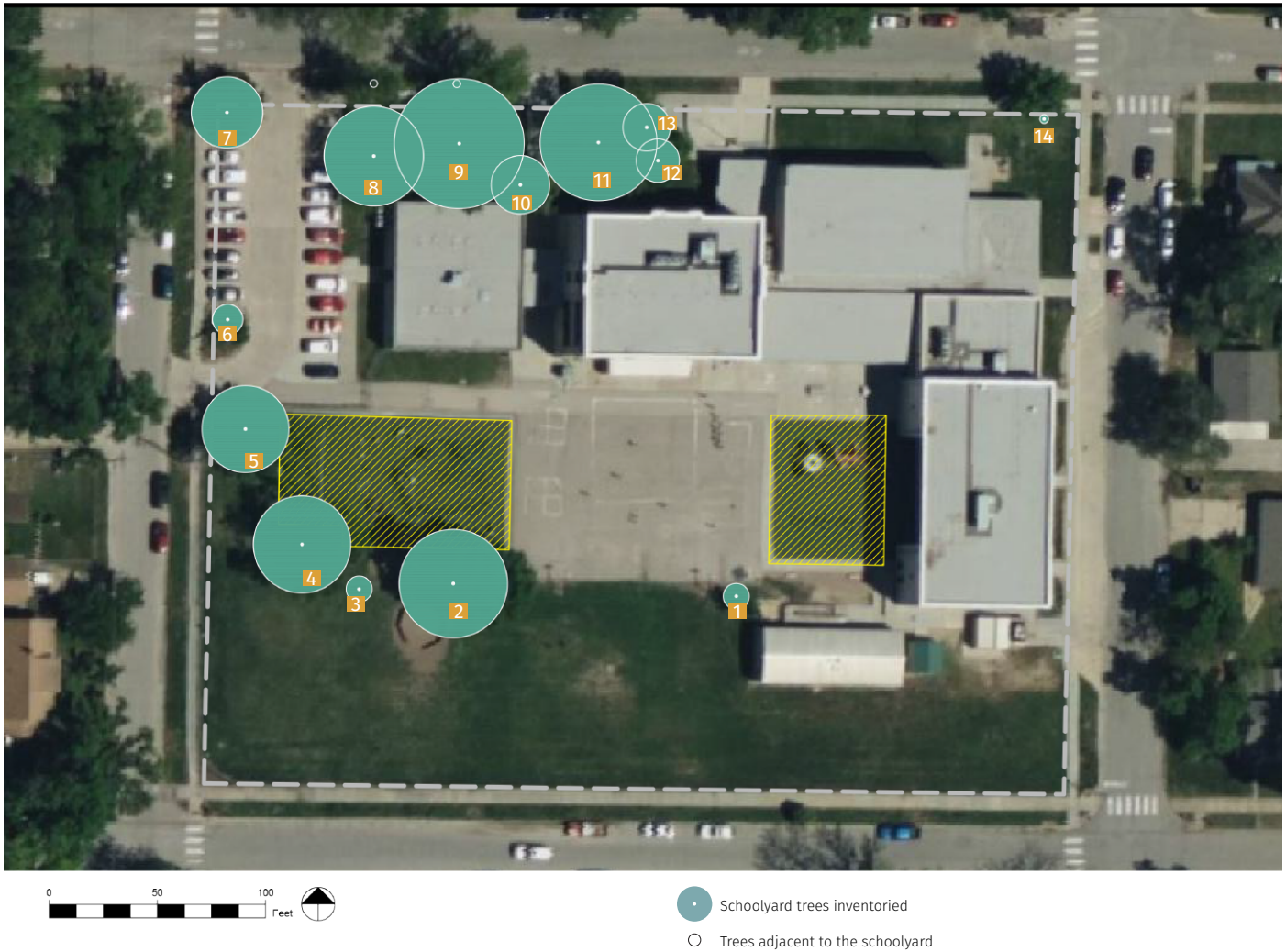


Figure 4.173 Theodore Roosevelt tree distribution

Species List

Tree ID	Tree Species	DBH (inches)	Condition
1	elm	6.50	Good
2	ash	31.91	Good
3	tree lilac	5.92	Fair
4	ash	24.08	Fair
5	ash	22.17	Fair
6	maple	4.59	Good
7	eastern redcedar	19.11	Poor
8	Callery pear	29.04	Good
9	white mulberry	25.22	Good
10	Nothern catalpa	14.52	Good
11	honeylocust	22.17	Good
12	eastern redbud	6.50	Good
13	oak	10.32	Good
14	ginkgo	1.91	Fair

Table4.17 Theodore Roosevelt tree species list

Species Composition

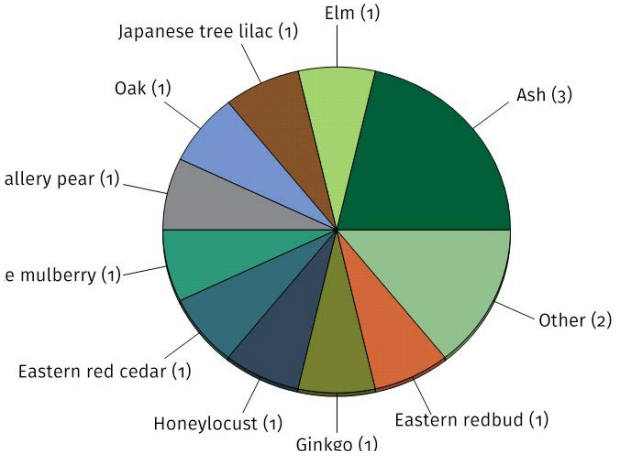


Figure 4.174 Theodore Roosevelt tree species distribution

- A total of **14** trees were inventoried at Theodore Roosevelt elementary site. The total tree canopy coverage is 8.3% of the 2.9 acres. The most common species is **ash (3)**.
- Please refer to the full Theodore Roosevelt i-Tree Ecosystem Analysis Report (Appendix 9) for more information.

Utilities

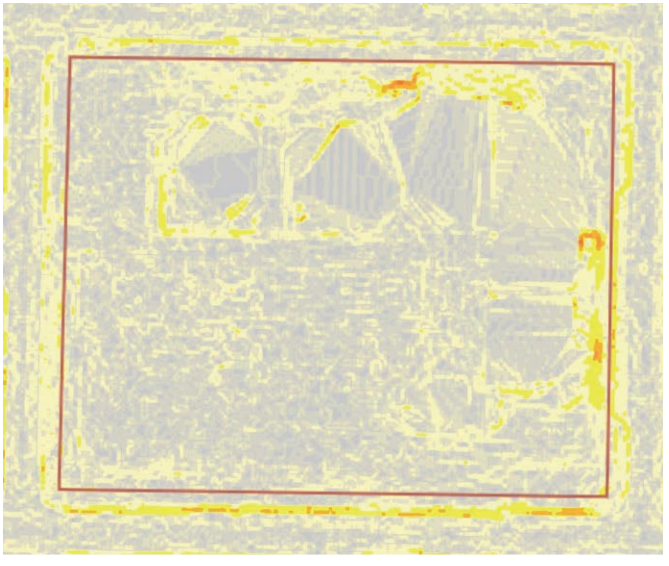
Stormwater
Sanitary Sewer
Water

Figure 4.175 Theodore Roosevelt utilities

Data from Riley County Community GIS Viewer

- The utility lines follow the perimeter of the site property line and will not affect the planting of trees.

Slope Study



0 5 10 15 21 31 →up to 90

Figure 4.176 Theodore Roosevelt site slope

Data from ArcGIS Terrain: Slope Map

- The steepest slope of the site is **below 15%**, so there is no need to consider the subsequent maintenance difficulties caused by the slope.

Shade Study

Shade pattern from 9 am to 3 pm on Mar. 21

Shade pattern from 9 am to 3 pm on Jun. 21

Shade pattern from 9 am to 3 pm on Sept. 21

Shade pattern from 9 am to 3 pm on Dec. 21

Playground equipment areas

- Existing trees on site can provide shade for student activity areas.
- Due to the future modification of the school ground, some existing trees will be removed and cannot provide sufficient shade for the modified playground.

Figure 4.177 Theodore Roosevelt site shade study

*Tree planting priorities will be explained later in Chapter 5.

Figure 4.178 Potential tree placement locations at Theodore Roosevelt

Issues

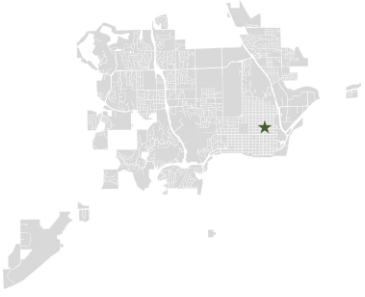
- After the 2022 site modifications are complete, there will only be one tree remaining on the school yard.
- The playground and activity areas are not shaded.
- Elm and ash trees on site are susceptible to known pests and will likely die. Please refer to the Theodore Roosevelt i-Tree Ecosystem Analysis Report (Appendix 9) for more information.

Opportunities for new Trees

- Students would be benefit from adding shade around the playground.
- Since the new playground is adjacent to the street, trees could also be planted on the street to provide shade for the activity areas.
- The open space in the south of the school can be used to build an outdoor classroom, and trees can be planted around it.
- Trees can be added along the property boundary to create a buffer and additional shade for the schoolyard.

4.18 Woodrow Wilson Site Analysis

Site Location



312 N. Juliette Avenue,

Manhattan, Kansas 66502

Statistics

Grade Served: PK-5

Enrollment student: Approx. 300 in 2020-21 per CCD

Year Built: 1923

Modernizations/Additions: 1951, 1983, 1996, 2012

Site Area: **2.86 acres**

i-Tree Ecosystem Analysis Findings

- Canopy coverage within the property line: **10.6%**
- Number of tree inventoried: **14**
- Tree cover of the 14 schoolyard trees: **6.8%**
- Percentage of trees less than 6" (15.2 cm) diameter: **21.4%**
- Pollution Removal: **11.19 pounds/year ($30.7/year)**
- Carbon Storage: **9.681 tons ($1.65 thousand)**
- Carbon Sequestration: **590.4 pounds ($50.3/year)**
- Oxygen Production: **1574 pounds/year**
- Avoided Runoff: **470.8 cubic feet/year ($31.5/year)**
- Replacement values: **$42.5 thousand**

Figure 4.181 Woodrow Wilson playground

Figure 4.182 Woodrow Wilson schoolyard lawn

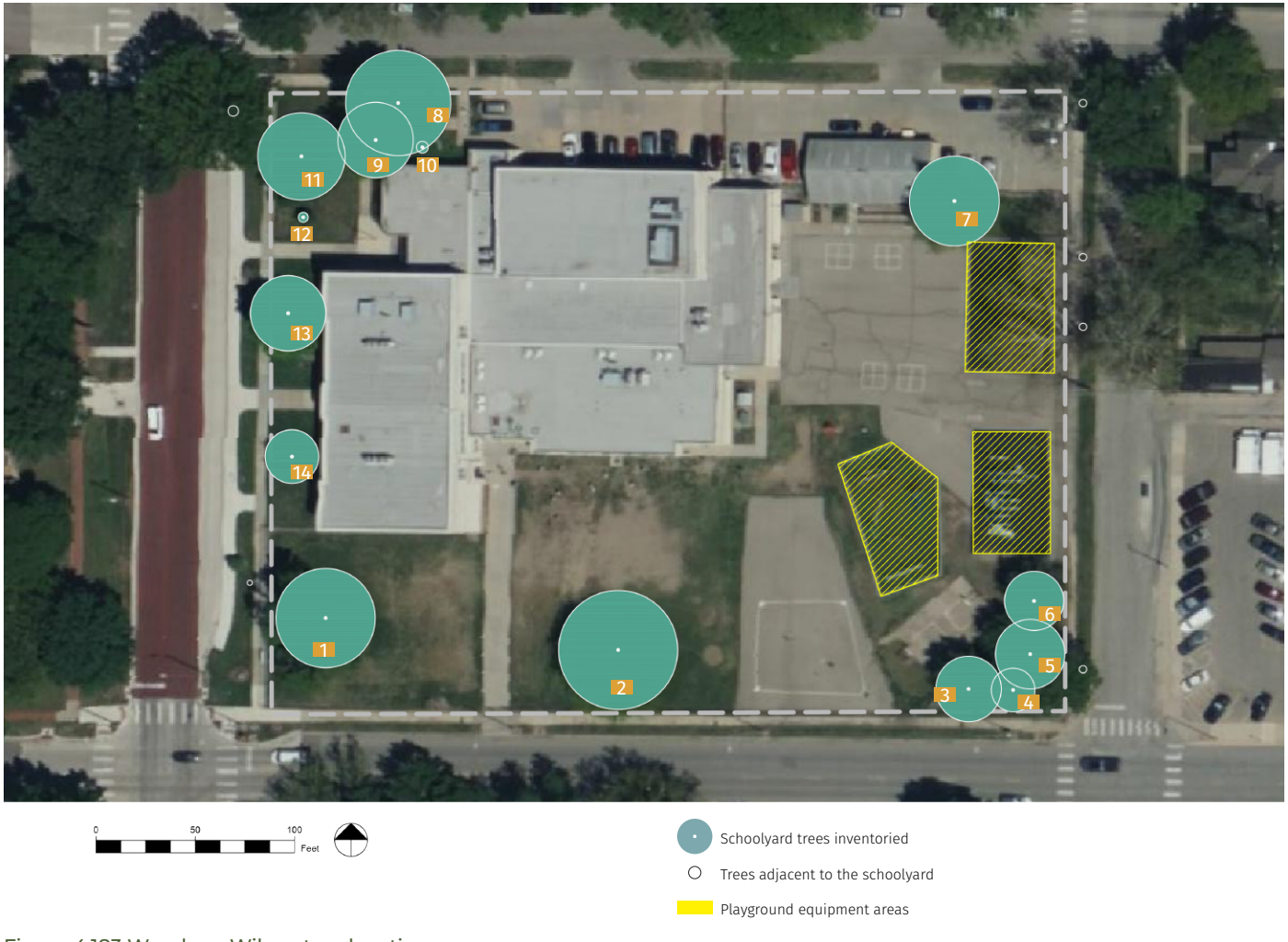


Figure 4.183 Woodrow Wilson tree location

Species List

Tree ID	Tree Species	DBH (inches)	Condition
1	ash	22.93	Poor
2	honeylocust	24.84	Fair
3	elm	14.14	Fair
4	crabapple	4.59	Fair
5	elm	12.23	Fair
6	pine	23.69	Fair
7	maple	17.58	Poor
8	oak	25.22	Good
9	Callery pear	18.73	Good
10	tree lilac	2.10	Good
11	Callery pear	18.73	Good
12	tree lilac	4.20	Fair
13	maple	15.67	Good
14	crabapple	7.64	Good

Table4.18 Woodrow Wilson tree species list

Species Composition

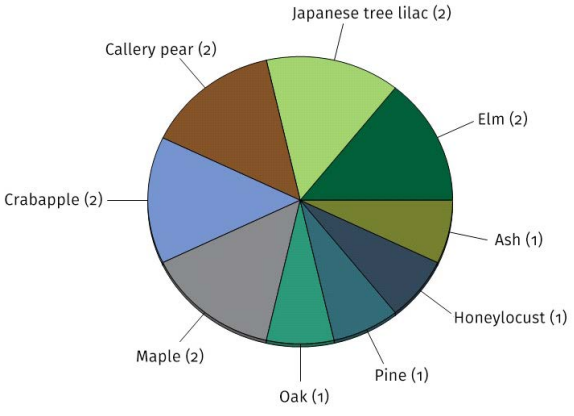


Figure 4.184 Woodrow Wilson tree species distribution

- A total of **14** trees were inventoried at Woodrow Wilson site. The total tree canopy coverage is 10.6% of the 2.86 acres.
- Please refer to the full Woodrow Wilson i-Tree Ecosystem Analysis Report (Appendix 10) for more information.

Utilities

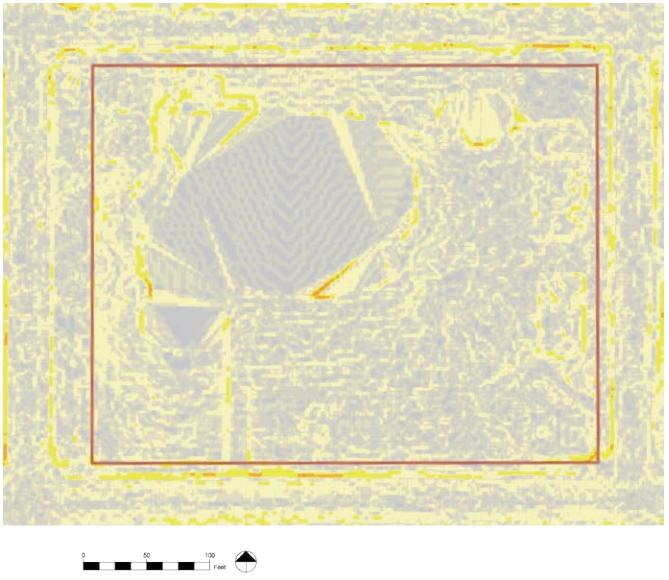
Stormwater
Sanitary Sewer
Water

Figure 4.185 Woodrow Wilson utilities

Data from Riley County Community GIS Viewer

- The utility lines follow the perimeter of the site property line and will not affect the planting of trees.

Slope Study



0 5 10 15 21 31 →up to 90

Figure 4.186 Woodrow Wilson site slope

Data from ArcGIS Terrain: Slope Map

- The steepest slope of the site is **below 10%**, so there is no need to consider the subsequent maintenance difficulties caused by the slope.

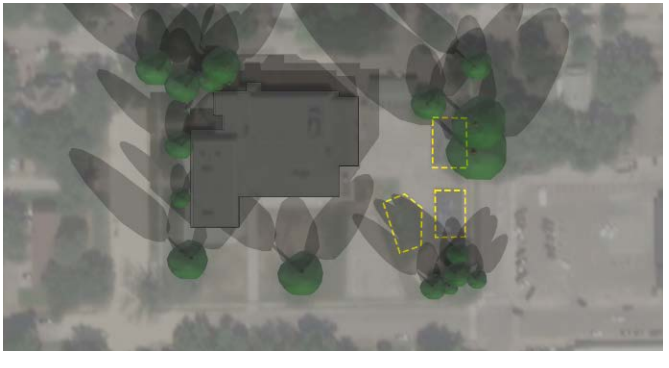
Shade Study

Shade pattern from 9 am to 3 pm on Mar. 21

Shade pattern from 9 am to 3 pm on Jun. 21

Shade pattern from 9 am to 3 pm on Sept. 21

Shade pattern from 9 am to 3 pm on Dec. 21



Playground equipment areas

- Existing trees on site and surrounding street trees can provide shade for student activity areas.
- The playground in the northeast will be converted into a parking lot due to the future modification of the school ground. The rest of the student activity areas lack shade.

Figure 4.187 Woodrow Wilson shade study

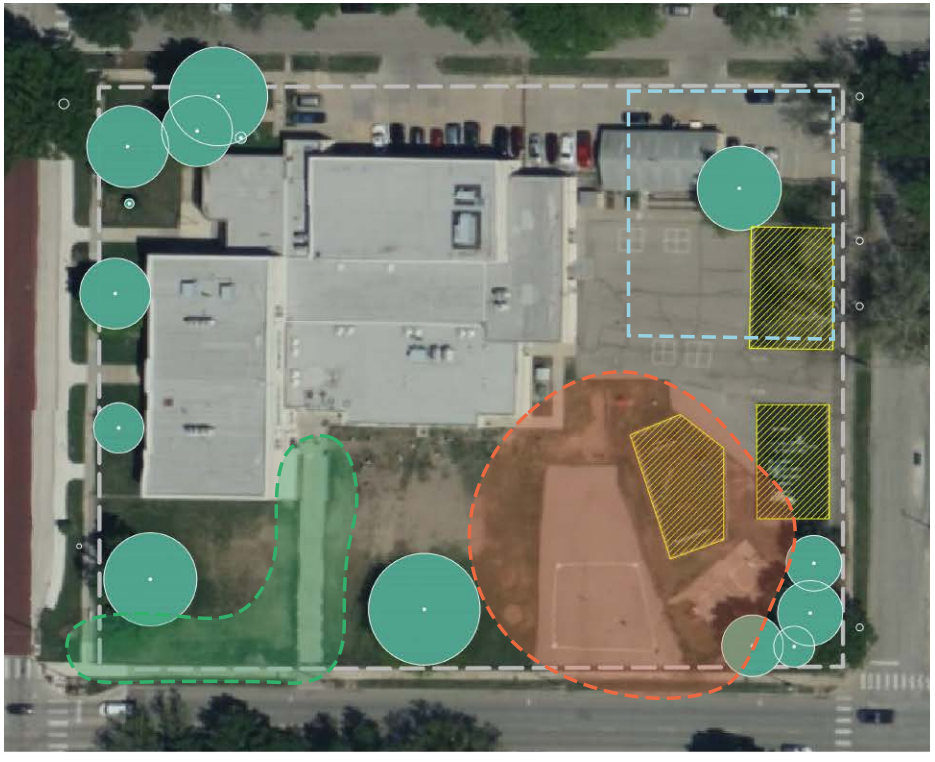


Figure 4.188 Potential tree placement locations at Woodrow Wilson

Issues

- According to the school's 2022 site plan update, the playground in the northeast will be converted into a parking lot, and the hardscape play area will be expanded. The remaining trees cannot cover the new playground area.
- Elm and ash trees on site are susceptible to known pests and will likely die. Please refer to the Woodrow Wilson i-Tree Ecosystem Analysis Report (Appendix 10) for more information.

Opportunities for new Trees

- Students would benefit from adding shade around the playground.
- Since the new playground is adjacent to the street, trees could also be planted in the public right of way to provide shade for the activity areas.
- The open space in the south of the school can be used to build an outdoor classroom and trees can be planted around it.
- Trees can be added at the schoolyard's boundary to increase the space enclosure.

4.2 Precedent study

4.21 Precedent Information

To understand how other schools are working to increase tree planting, four notable examples of existing tree planting programs/ projects/ initiatives were studied. Findings from the precedent studies were summarized and considered for applicability to the USD 383 district.

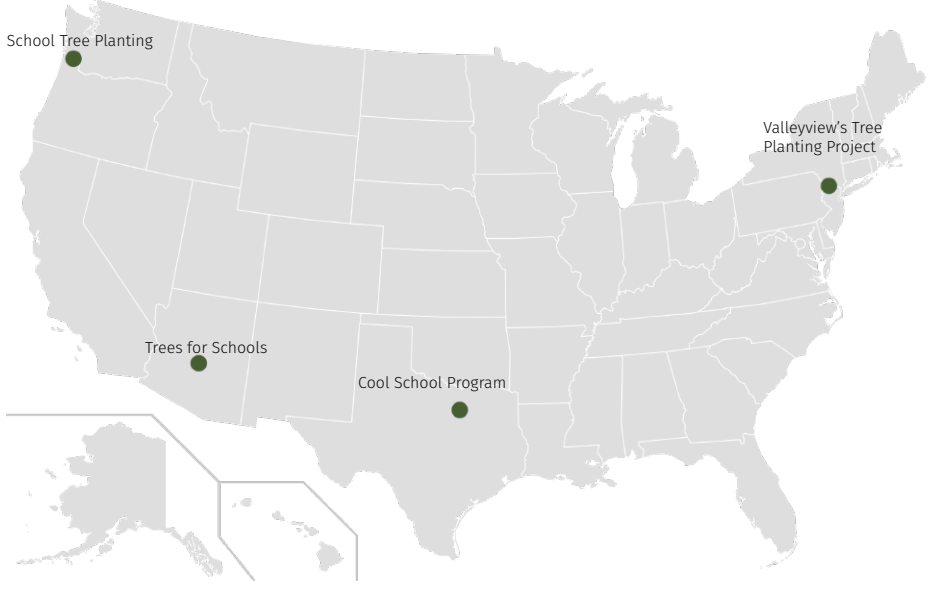
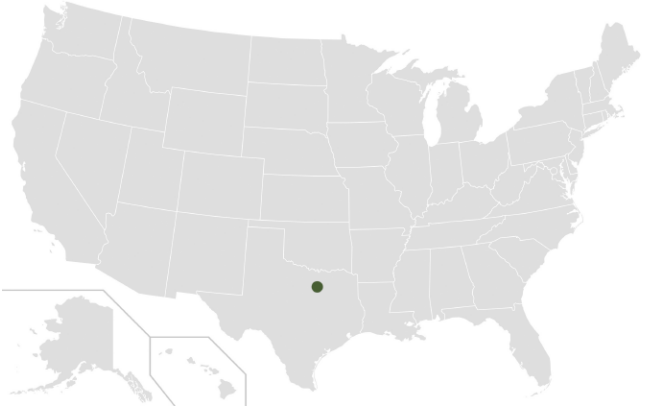


Figure 4.2 The locations of studied precedents

Precedent 1: Cool School Program



Background

Dallas has one of the most challenging urban climates in the United States and has been ranked 8th by the American Lung Association for the worst air quality in the nation for ozone and non-attainment for the EPA's National Ambient Air Quality Standards. This air quality situation affects over 89,000 children in Dallas. School campuses in Dallas are some of the hottest and least shaded urban heat islands in North Texas.

Texas Tree Foundation launched Cool School Program for the health and well-being of Dallas ISD students and to provide solutions to deal with the effects of the urban heat island effect in the area. Presently, 70% of Dallas area elementary schools have less than seven percent tree canopy, while a minimum of 27% tree canopy is recommended to reduce exposure to harmful ultraviolet rays and air pollution. Texas Trees Foundation's State of the Dallas Urban Forest Report confirmed that area school campuses are in dire need of improved tree canopies (Texas Tree Foundation 2022).

Location: Dallas, Texas

Scale / scope

Cool Schools Program launched in 2016 with Dallas Independent School District (Dallas ISD) featuring two pilot schools, where 176 trees were planted. This resulted in $227,290 of ecosystem services over a 40-year period, that includes: carbon sequestration, air pollution removal, energy savings, and stormwater savings.

Ten schools within the Dallas Independent School District (Dallas ISD) have received trees to date. An additional twenty schools are designated for planting through 2024. Appropriately 80-100 trees are planted at each school site(Texas Tree Foundation 2022).

Year established

From 2016 until now, and planned to complete planting at 2024.

Goals and objectives

- Texas Trees Foundation's goal is to enhance the landscapes

and outdoor learning opportunities of 150+ elementary school campuses in Dallas ISD, and expand the Cool Schools model to surrounding regional school districts and across the state of Texas.

- Cool Schools connect students and teachers to nature by planting trees and creating fun and engaging outdoor experiential learning areas. These spaces cultivate children's knowledge and awareness of the natural environment (Texas Tree Foundation 2022).

Administrative structure and partnership

Texas Tree Foundation: The Texas Trees Foundation (Texas Trees) is a large-scale organization in North Texas through transformational, research-based plans that educate and mobilize the public to activate the social, economic, environmental, and health benefits trees and urban forestry provide. Cool School Program is a subsidiary program of Texas Trees partnered with

Dallas Independent School District (Dallas ISD)

and

Dallas Parks and Recreation Department, Trust for Public Land

Funding and budget

Funding: Sponsorship, project-by-project basis funding

Components of sponsorship investment include: Speaking opportunities; Name and/or logo branding; Company recognition through marketing/media; Other opportunities based on specific needs. Full sponsorship amount must be in place before a school project can be started.

Budget started at $35,000

- Landscape design and graphics
- Project coordination and launch
- School Green Team facilitation
- Trees and shrubs
- Curriculum, educational supplies and teacher training/Tree Trunk
- Planting/Celebration Day Planning, Coordination and Implementation

Care and maintenance

People from Texas Tree Foundation monitor and water new trees until established.

Education and outreach

- **Establish a Green Team of teachers and staff.** This group will lead environmental projects at their school.
- **Create landscape plan tailored to each school.** Students and teachers contribute their ideas during the design process.
- **Provide educational resources to teachers and students.** Provides STEM-based/TEKS-aligned curriculum,

educational resources, and hands-on learning activities to engage students in Cool Schools outdoor learning areas.

- **Organize Planting Day** with students, faculty, volunteers, and partners, so everyone participates to plant and mulch the new trees at their school.
- **Monitor and water new trees until established.** Texas Trees Foundation care for the new trees until they can care for themselves.
- **Measure short and long-term educational and environmental impacts.** Texas Trees Foundation check on participation in the curriculum and record tree growth.
- **Promote Celebration Day.** Everyone celebrates their hard work and achievement with an event at the school featuring student activities, art, and music.
- **Convert the schoolyard into a public park.** After hours and on weekends, allowing the community to enjoy the new playground, walking trail and benches.

(Texas Tree Foundation 2022).

Lesson learned from Cool School Program

The program is well structured and clearly organized, from design to implementation to subsequent maintenance. Landscape architects played an important role in publicizing the project by making a series of diagrams to show the benefits of planting trees in the schoolyards and showing trees' placement. Landscape plans and diagrams made the project goals and objectives much easier to understand by the public and made the project more attractive.

This precedent is well explained that a powerful organization drives project success. Texas Tree, as a large organization, is thoughtful and capable of implementing every project step. However, in Manhattan, KS, no such organization has the capability to take on everything of this kind of project. Therefore, in planning the Manhattan Elementary School's tree-planting initiative, it is necessary to clarify the procedure of the project and the tasks that need to be completed to guide the school and related organizations in planting and maintenance. Then distribute the duties to various parties and let them collaborate on the tree planting initiative. The purpose is to use multi-party cooperation to replace large organizations.

Texas Trees have planted approximately 80-100 at each school site. This is a very large, well organized and funded program. The proposed tree planting initiative for Manhattan would be much smaller in scope. A total tree planting goal for each site would be important.

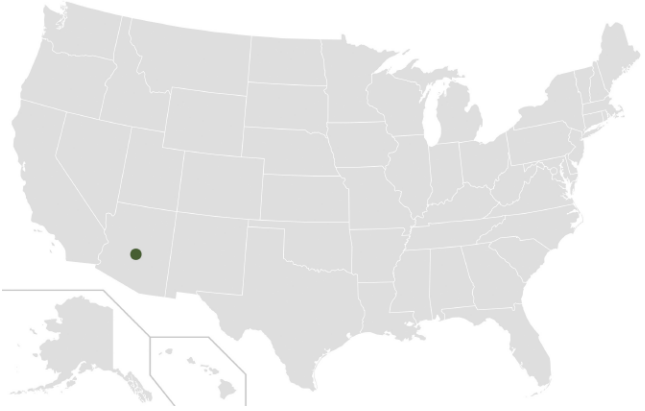
The Cool School Program explicitly states that trees require long-term monitoring and maintenance to ensure survival, which was also crucial in the design of this initiative. The dead, newly planted maple trees on the playground of Lee Elementary School are an example of what happens without dedicated follow-up maintenance.

One of the best parts about the Cool School Program that can be applied to Manhattan's tree planting initiative is its education and outreach. Texas Trees offers three different educational pathways. The first point is that students, teachers, and staff directly participate in planting trees and establish an emotional connection with the trees they planted by themselves, to increase the awareness of campus trees. The second point is to provide a STEM-based/TEKS-aligned curriculum that increases the frequency of tree topics in everyday education and makes students notice the trees around them. The third point is to hold celebration days after the tree planting event. Everyone celebrates their hard work and achievement with an event at the school featuring student activities, art, and music. So that the campus tree planting is not just a one-time event but a celebration festival that is revisited every year.

Summary: What makes this project successful?

- Texas Tree Foundation has clear goals and objectives.
- Texas Tree Foundation has a stable administrative structure and partnership: Texas Tree Foundation is a large tree-related organization.
- Texas Tree Foundation has sufficient budget from sponsorship: project starts after full sponsorships are received.
- Landscape architects involved in the Coll School Program: They produce diagrams and plans to indicate the number of trees and location they will place.
- Guaranteed follow-up maintenance is provided by Texas Trees: Texas Tree Foundation maintains newly planted trees until established, measure the short-term and long-term benefits.
- Texas Tree Foundation provides a variety of educational activities: on-site education during planting days, a STEM-based/TEKS-aligned curriculum guideline, celebration day.

Precedent 2: Trees for Schools



Background

"Planting Trees in Schools, While Fostering Youth Stewardship"

Trees for Schools, a program from Trees Matter, aims to get more tree infrastructure into schools alongside teaching staff and students on the importance of trees and tree care. It goes beyond simply planting the tree--the maintenance and care of the tree that follows is critical to the success of the tree. Trees Matter is determined to educate schools on this by having the students, staff, and maintenance crews be an integral part of not only the planting itself, but also the education that informs them on how to care for their new trees in the long term (Trees Matter 2022).

Location: Phoenix, Arizona

Scale / scope

At school districts within the Phoenix, total sixteen schools were planted, number of trees from 3~ 35.

Year established

From 2016 until now

Goals and Objectives

- Get more tree infrastructures into schools.
- Educate schools on tree and tree care by having the students, staff, and maintenance crews be an integral part of not only the planting itself, but also the education that informs them on how to care for their new trees in the long term (Trees Matter 2022).

Administrative structure and partnership

Trees Matter: Trees Matter is a Phoenix-based 501(c)(3) environmental education nonprofit, whose mission is to inspire and promote an increased tree canopy. Trees for School is a subsidiary program of Trees Matter.

partners with

School districts within the Phoenix

Maricopa County Public Health office of Epidemiology

and Data Services: created a map for this program by using poverty rate, number of heat deaths, heat illness, cardiovascular disease hospitalizations that prioritize schools in the district.

Funding and Budget

Funding: Project-by-project basis, Trees Matter determines the priority of the school.

Care and Maintenance

Tree Matter value the importance of maintenance on newly planted trees and mentioned that maintenance is a part of the information they provided to the school.

Education and Outreach

Provide an activity guide corresponding to 3rd-grade level science standards.

Educate schools on tree and tree care by having the students, staff, and maintenance crews tree planting and caring for the new trees in the long term.

Provide subscription to Trees for Schools Educator Newsletter, created by Trees Matter. This newsletter highlights various environmental education resources, primarily from Tree Matters' database on tree-related education material.

How Program Works

- Maricopa County Public Health office of Epidemiology and Data Services: created a map for this program by using poverty rate, number of heat deaths, heat illness, cardiovascular disease hospitalizations that prioritize schools in the district.
- Schools within this geographic region meet the program's scope and are able to apply the planting projects from the Trees Matter's website.
- Special consideration will be considered regarding schools that are located in areas with less tree canopy and contain vulnerable communities. Trees matter will also consider applications by the order they are received.
- Plantings will occur in the Fall and Spring as these are the best time to plant trees.

(Trees Matter 2022).

Lesson learned from Trees for Schools

Judging from the tree planting data of each school, Trees Matter planted 3~35 trees in each school, which is more similar to the project scale of the elementary schools in Manhattan, KS, than Texas Tree which planted 80~100 trees in each school. Like the Cool School Program, Trees for School is led by the large organization Tree Matters. Its organizational capabilities and resources are what Manhattan, KS lacks.

Unlike Texas Tree, Trees Matter mentioned how they judge the need for trees in schools. Trees Matter worked with an agency (Maricopa County Public Health Office of Epidemiology and Data Services) to obtain the poverty rate, number of heat deaths, heat illness, and cardiovascular disease hospitalizations that created a map to prioritize schools in the district. Even with the order, Trees Matter did not take the initiative to plant trees in the school but provided a form on its website for the school to fill out. After the school has ensured that tree planting activities can be organized, Trees Matter will take action.

In Manhattan, KS, there is no existing organization that can help plan for tree planting within the city or at the schools. Therefore, establishing a dedicated project team can better seek cooperation in arranging all aspects of resources. As for picking a school to plant, there is no need to prioritize it through various data like Trees Matter because this project's scope is only eight elementary schools. Eight schools can start the tree planting initiative simultaneously and negotiate a specific tree planting date.

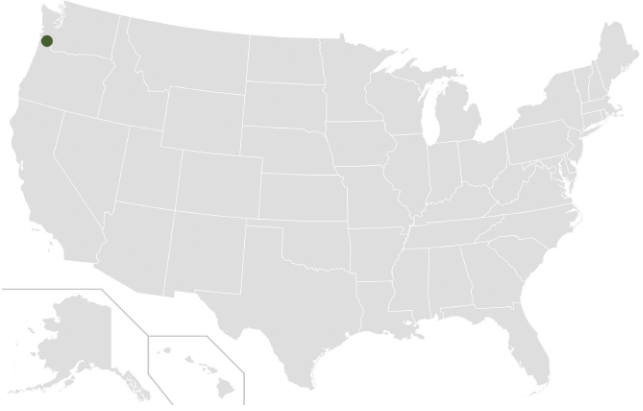
Trees Matter emphasized "informs students, staff, and maintenance crews on how to care for their new trees in the long term" but did not point out if they would send people for follow-up care of trees planted on campus as Texas Trees does. The difference between the two organizations results in two different maintenance methods. One is the maintenance by special personnel from outside the school, and it is necessary to consider what kind of tools the maintenance team needs. If it is on-campus maintenance, it is needed to consider whether there are corresponding facilities for the schoolyard landscape. For example, off-campus maintenance might need a removable water tank for watering, while on-campus maintenance would allow water and plumbing to reach where the trees are planted.

Not mentioned in other precedents and unique to Trees Matter is the "Provide subscription to Trees for Schools Educator Newsletter" through the subscribe email. People interested in this project can receive progress tracking and tree-related educational information. This model is also possible at the tree planting initiative in Manhattan, KS, including but not limited to using emails, social platforms, or USD383's official website for public tree-related activities and follow-up information. Even observation reports of trees can be used as part of the teaching content, allowing students to express the changes of trees in different ways to increase students' perception of natural changes and seasons.

Summary: What makes this project successful?

- Trees Matter has clear goals and objectives.
- After schools submitted the application, prioritize schools by using the map created by Maricopa County Public Health Office of Epidemiology and Data Services.
- Trees Matter has a stable administrative structure and partnership: Tree Matters is a large tree-related non-profit organization.
- Trees Matter has sufficient budget from organization.
- Trees Matter informs the important of maintenance to school members.
- Trees Matter offers a variety of educational sources: on-site education during planting days, an activity hand book, email s subscription.

Precedent 3: School Tree Planting



Background

Each year, the City's Urban Forestry Program works with a variety of public and private schools throughout the City of Vancouver to provide and plant trees. School Tree Planting projects help connect students to the benefits of trees and foster environmental stewardship. These projects also support our larger community effort to help grow Vancouver's tree canopy.

These School Tree Planting projects connect students to the benefits of trees and foster environmental stewardship. Tree planting is a great way to increase student interest in their local environment and achieve academic goals. Each school tree planting provides educators with the opportunity to inspire school administrators, faculty and students to affect positive change at their schools and, in turn, their communities (City of Vancouver 2022).

Location: Vancouver, Washington

Year established

Each year

Goals and Objectives

- Connect students to the benefits of trees and foster environmental stewardship
- Support the larger community effort to help grow city's tree canopy.

Administrative structure and partnership

City's Forestry: city -lead project

partners with

Variety of public and private schools throughout the city

Funding and Budget

Funding: Urban Forestry provides the needed tools and trees, as well as technical assistance for each approved project, leading up to and on the day of the planting. Project-by-project, application basis.

Care and Maintenance

Schools that participate in the program must commit to watering their new trees for a minimum of two years following planting.

Education and Outreach

- Teachers use the planting process to discuss the benefits trees provide, while including many subjects that their classes are studying.
- Students serve as the primary planters, giving them a sense of ownership and increasing their knowledge of trees.

How Program Works

- Project applications are accepted, reviewed, and approved throughout the year in conjunction with the respective school district. Keep in mind that tree planting is normally scheduled between October and April, so this may be a factor to consider along with the school calendar in making application. Urban Forestry provides the needed tools and trees, as well as technical assistance for each approved project, leading up to and on the day of the planting. With support of Urban Forestry staff, students serve as the primary planters, giving them a sense of ownership and increasing their knowledge of trees. Schools that participate in the program must commit to watering their new trees for a minimum of two years following planting.
- Urban Forestry is interested in working with principals, teachers or staff at K-12 schools in Vancouver interested in adding approximately five or more trees to school property.
- Urban Forestry recognizes that not all schools may be participating in the program at any given time. Some districts may have pre-identified areas or schools where planting projects can be allowed. In addition, proposed project organizers must agree to help plant trees and commit to a two-year maintenance plan following the tree planting. To provide a successful partnership in planting and growing healthy trees, each proposed project must meet with the approval of the school principal and/or facilities department.
- To qualify for the free trees and assistance, approved School Tree projects are asked to help grow our City's tree canopy by meeting a requirement of at least 60 percent shade and native trees and no more than 40 percent ornamental or understory trees. This requirement may be waived for special projects.
- Once approved, successful project organizers – which may include teachers, principals, and/or student groups – will meet with Urban Forestry staff for a project planning orientation several months in advance. They will work with Urban Forestry staff to select tree species and planting locations on the school campus and to develop a maintenance schedule. Leading up to the event, various tree activities are available to engage students, including learning about the species of trees they will be planting, learning how to properly handle and plant trees, and understanding the value of trees (City of Vancouver 2022).

Lesson learned from School Tree Planting

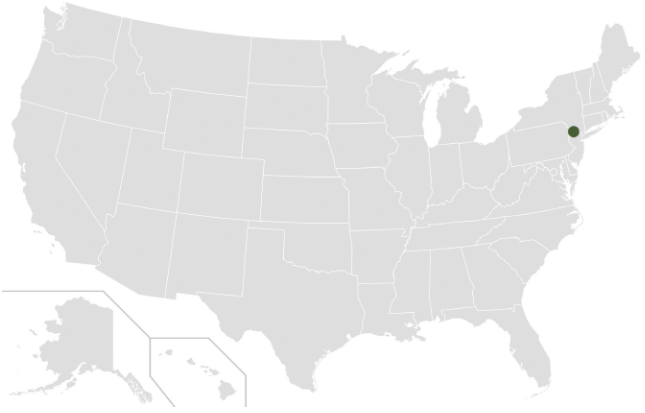
The most important part of this precedent is how the program works and how to apply. Unlike larger tree-related organizations such as Texas Trees and Trees Matter, this precedent was led by Urban Forestry. Its collaborative model and project process can be applicable for Manhattan, KS.

First, the Kansas Forest Service offices are located in Manhattan, KS, not far from the eight elementary schools in this project. Kansas Forest Service also has full-time tree professionals who can advise on relevant knowledge. Kansas Forest Service cultivates certain species of trees each year for residents to purchase at a low price and plant as conservation trees. The Kansas Forest Service office has the equipment needed for tree planting and may be able to rent out tree planting activities. Kansas Forest Service can be a strong partner for the tree planting initiative by providing tree material, planting tools, professional guides, and knowledge about tree planting maintenance.

Summary: What makes this project successful?

- City of Vancouver has clear goals and objectives.
- City of Vancouver has a stable administrative structure and partnership: city-lead program
- Urban forestry has budget for School Tree Planting program from City of Vancouver.
- Urban forestry requires school members to do two years maintenance. Project organizers Urban Forestry staff to select tree species and planting locations on the school campus and to develop a maintenance schedule.
- School Tree Planting is a long-term planning project: Project organizers meet with Urban Forestry staff for a project planning orientation several months in advance.
- Urban forestry provides educational sources: Under the help of Urban Forestry staff, project organizers learn leading the event, various tree activities engaging students, including learning about the species of trees they will be planting, learning how to properly handle and plant trees, and understanding the value of trees.

Precedent 4: Valleyview's Tree Planting Project



Background

On October 18th, 2021, Valleyview's teachers and students rolled up their sleeves and got to work on tree planting. The Tree Planting Project's goals were to improve the schoolyard habitat and address climate action; the new trees also enhance the improved AJ Spinola Athletic Fields.

The Project was a success due to the tremendous support of nearly 20 staff volunteers and over 100 students, including members of Valleyview's Builders Club, Student Green Team, STEAM Club, Girls Soccer Team, Boys Soccer Team, and Cross Country Team.

The community supporters include Dave Sipple (Denville's Beautification Committee) for generously sharing his time and assistance, Denville's Green Sustainability Committee for the donation of the redbud, and Cerbo's Greenhouses of Parsippany for helping select the perfect trees.

The Tree Planting Project was largely made possible through NJ Natural Gas' 2021 "Picture This, Caption That!" Energy Conservation Contest, which was won last year by Valleyview's Erin Nangle. The Contest provided $1,000 for Valleyview to pursue an environmental project (Denville Township School District 2021).

Location: Denville, New Jersey

Scale / scope

Single school with 6 trees planted.

Year established

2021

Goals and Objectives

- Improve the schoolyard habitat and address climate action
- The new trees enhance their athletic fields.

Administrative structure and partnership

Denville Township School District: school spontaneity project

partners with

Community supporters: Denville's Beautification Committee, Denville's Green Sustainability Committee, and Cerbo's Greenhouses of Parsippany.

Funding and Budget

Budget: NJ Natural Gas' 2021 "Picture This, Caption That!" Energy Conservation Contest, The Contest provided $1,000 for Valleyview to pursue an environmental project

Education and Outreach

Students participate to plant new trees at their school.

Lesson learned from Valleyview's Tree Planting Project

Schoolyard tree planting initiatives are possible even with minimal funding. The reason for choosing this precedent is to open up ideas for finding parties and partners for school planting projects. In the absence of strong organizational leadership, schools still have the ability to organize their tree planting activity. In addition to seeking financial support, schools can also fill the resources needed to drive tree planting initiatives by effectively using multiple resources.

In this precedent the school invited the school's club to participate, ensuring sufficient volunteers for the running event. The school also seeks help from various social organizations, with resources including assistance, knowledge, and planting tree material from community supporters.

Summary: What makes this project successful?

- School seeks help from various social organizations, with resources including assistance, knowledge, and planting tree material from community supporters.
- School has dedicate budget for this project.

4.22 Precedent Study Synthesis

Goals and Objectives

Trees bring many different benefits. It should be determined early in the project which benefits are most important in the schoolyard tree planting initiative and where they are most needed, in order to set clear goals and objectives

The direct beneficiaries of the school's tree planting should first consider the school's users, which are students, staff, and teachers. Additional beneficiaries depend on the project's design, such as volunteers involved in tree planting and people who use the schoolyards after hours. The range of beneficiaries vary with the size of the project.

The goals and objectives of tree planting precedents led by different organizations are different. For a large tree organization like the Texas Tree Foundation that focuses more on multi-party cooperation and community participation, its goals include getting its projects to a larger audience, so the goal Included is converting the schoolyard into a public park. Another example is Vancouver City's Forestry, which focuses more on trees' environmental benefits and the maintenance that schools can bring to newly planted trees. Therefore, the goals and the objectives depend more on the project leader, admin structure, and the partners.

Administrative structure

From four precedents, it is easy to notice that the larger the organization, the more capable and resourceful a well-organized tree planting initiative is. Ideally, a team with multi-party cooperation led a tree planting initiative to carry out the long-term operation.

Build a project team:

Everyone wants trees they plant to survive and provide long-lasting, multi-year benefits. To ensure that plans are fully implemented and monitored. A regularly, stable, ongoing, and active support is essential. A stable organization maintains communication between partners, monitors progress, tracks milestones, and drives change when needed—ideally initiated by, or in partnership with, a large environment-related organization such as the Texas Tree Foundation. The Texas Tree Foundation clearly states that they, as the initiator of tree planting activities, will maintenance as part of their responsibilities. Currently there is no large organization for the USD 383 school district to help maintain the trees. The project is more likely to start with an informal group and then gradually become a more robust and stable as the project grows. The USD 383 tree-planting initiative is more likely to be district-based than an affiliate project of a larger organization independent project.

Project Champion:

Except for the last precedent, the remaining three precedents are not led by the school. Organizations with tree-related knowledge and resources are better positioned to lead such tree-planting initiatives. However, the project's leading team does not need to start from a large organization. Regardless of the team's ability to provide sources, the essence of start

the initiative is only need a person as the Project Champion who is enthusiastic about planting trees in schoolyards. Then, this person can start communicate with school district.

District-level Project Coordinator:

For the schoolyard tree planting initiative in Manhattan, KS, the projects take place in schools all belong to the USD 383 school district. Therefore, having a district-level project coordinator makes project coordinators easier to allocate various resources and establish cooperation with outside groups and organization.

School-level project team:

Regardless of goals and objectives, the tree planting initiative takes place in the individual school. Therefore, the school must have a dedicated team to connect with the district-level project team, professionals and volunteers from outside groups, and organizations to jointly promote the project's implementation.

Partnership

Different parties value schoolyard trees differently and have different views on the tree planting initiative. The more important their perception is to them and the project itself, the easier the project is supported, funded, implemented, and sustained. Thus, looking for a partner should consider what the collaborators can bring to the tree planting initiative and what benefits the tree planting initiative can offer them.

Organization / Agency	What can they do?	What they get?
School district	Actively promote the development of the project	Attracts students and applicants, creates environment conducive to learning
School communities (teachers, staff, clubs, PTO)	Instructor, volunteer, Help on tree planting	Greener, healthier, more resilient school environment
Public Park & Rec	Provide sources in the public space around schools	Improved urban environments
Forest department	Provide professional knowledge and guidance, Instructor, Plant material	Increased tree canopy
City Commission	Commit to trees as solution to problems (e.g. urban heat island, energy use)	Greener, healthier, more resilient communities
Local business groups	Support and invest in the project	Increase popularity, increased sales
Universities	Schoolyard design, volunteer group , Demonstrate exemplary practices	Special learning experience
Faith-based groups	Neighborhood revitalization ,Advocate for equitable distribution of green assets	Greener, healthier, more resilient school environment
Conservation groups, tree groups	Allies, sources of technical support, funding	Improved urban environments
Neighborhood groups	Constituents and potential community stewards	Share of important benefits from trees

Table 4.21 The win-win partnership relationship

Funding and budget

Funding sources:

For the project to get started and run smoothly, the initiative on a funded project-by-project basis seems more feasible. Both the Texas Tree Foundation and Tree Matters are funded based on project-by-project. Texas Tree Foundation makes it more evident that they do so through sponsorship investment. The component includes speaking opportunities, name and logo branding, company recognition through marketing and media, and other options based on specific needs. Co-branding sponsorship is also possible, but the total sponsorship amount must be in place before starting a school project.

It is safe to start a project after receiving sufficient funding, but trees require long-term maintenance. Therefore, the cost of follow-up maintenance should be considered when formulating the plan, and long-term planning and long-term budget should be made.

The amount of funding can also be adjusted according to the school's own goals. The most basic activities of the Schoolyard tree planting initiative should include tree plantings, education, and teacher training. Going a step further can add outdoor learning seating and presentation area, different learning themes, and playground improvement.

Here is the budget list provided by Texas Tree Foundation and used for the Cool School Project:

- Landscape design and graphics
- Project coordination and launch
- School team facilitation
- Plant materials and other landscape materials
- Curriculum, educational supplies, and teacher training
- Planting/Celebration Day Planning, Coordination, and Implementation
- Follow-up monitor and maintenance

(Texas Tree Foundation 2022)

For the tree planting initiative, there is no need for such a long list of expenses. The budget list is based on the cost of the Texas Tree Foundation as a large organization leading tree planting activities in schools.

Part of the materials for the tree planting initiative in Manhattan, KS, has been provided in this project. The remaining part mainly relies on various organizations' win-win cooperation and community stewardship.

First, the landscape design and graphics have been completed in this project. The school needs to do is to make minor adjustments to the plan according to the actual situation before planting trees. Curriculum and educational supplies can be developed through the education and outreach examples suggested in this project. Teacher training is available through partnerships with Manhattan Parks &Rec and the Kansas Forest Service. Project coordination and launch and school team facilitation procedures are also provided. The district and schools can follow the guideline to implement independently, rather

than paying others to assist in the formation. Similarly, planning, coordination, and implementation of planting and celebration day can also be completed by teams formed within the school.

Therefore, The following is an anticipated list of expenses for the tree planting initiative in Manhattan, KS,

- Plant materials and other landscape materials
- Follow-up monitor and maintenance

Education and Outreach

There are four ways of receiving education and outreach in four precedents, which take place at different stages of the project.

1. Provide relevant knowledge training to school

Instructor: Professionals from the project leading team or tree organization

Audience: School staff, school teachers, and volunteer representative who will engage the tree planting event and follow-up maintenance

Location: On-site or remote meeting

When: Before planting

Contents:

- Assist in arranging the activities at the tree planting day. Provide curriculum guidelines, educational resources, and hands-on learning activities to engage students in the planting event.
- Introduce the location and species of trees to be planted, and the precautions when planting.
- Inform the monitor and maintenance requirements after the trees are planted.

The information conveyed in this section is the basis of the entire tree planting initiative. The focus of the content is to determine the information communicated by the project team and the school before trees are planted. The purpose is to give the school and project team a general understanding of the process and responsibilities of the tree planting initiative. Embody in precedents as Texas Trees establishes a Green Team of teachers and staff. Proposed project by Vancouver City's Forestry organizers must agree to help plant trees and commit to a two-year maintenance plan following the tree planting, meet with Urban Forestry staff for a project planning orientation several months in advance, and work with Urban Forestry staff to select tree species and planting locations on the school campus and develop a maintenance schedule.

2. Impart knowledge to students during tree planting

Instructor: Professionals from the project leading team or tree organization, school teachers

Audience: Students, volunteers, and other participants

Location: on-site

When: During planting

Contents: Tree planting and maintenance

- Lead students, staff, volunteers, and partners to participate planting, watering, and mulching the new trees
- Introduce the species of trees they will be planting
- Educate how to properly handle and plant trees
- Explain the value of trees

This section is the highlight of the tree planting initiative. The most lively time of the whole project is definitely the process of planting trees into the soil. Trees need to be properly planted under professional guidance to ensure their survival. All four precedents mentioned that professionals were present to guide the planting.

3. Impart knowledge to students in daily teaching activities

Instructor: School teachers

Audience: Students

Location: on-site

When: Anytime

Contents: Courses, units, or activities related to trees

Planting trees in schoolyards should not be a one-time event but rather expect a long-term impact. After the students got involved and planted the tree by themselves, an emotional connection will be established between students and trees. Increasing courses related to trees can enrich the course content and increase students' awareness of trees. For example, Texas Trees provides a STEM-based/ TEKS-aligned curriculum, educational resources, and hands-on learning activities to engage students in outdoor learning areas. Tree Matters provides an activity guide corresponding to 3rd-grade level science standards. These learning materials help school teachers to develop courses, units, or activities related to trees.

4. Follow-up knowledge

Instructor: Project leading team

Audience: People who would ;like to get more information about the project

Location: social media, email subscription

When: After planting

Contents: Tree planting program progress, follow-up reports, and more information related tree planting programs

It has been mentioned many times in the previous chapters that tree planting activities do not stop at the tree planted. Frequent updates of the initiative's information can ensure continuous attention to the project. The online platform is a good way to report and track the planted trees' follow-up, maintain the project's freshness, and expand its popularity. In addition, the progress can also be released with some tree-related knowledge to educate the public. The publicity of project progress can play a role in public supervision. Students' participation in tree-related activities, courses, and creations can also be presented to the public as the content published on the platform, attracting people to invest in or participate in projects in the future.

Tree planting initiative framework	Summary of important aspects from precedents	Aspects applicable for USD 383 planting initiative
Goals and Objectives	Clear goals and objectives: • Enhance the landscapes and outdoor learning opportunities, engage outdoor experiential learning, cultivate children's knowledge and awareness of the natural environment (Texas Tree Foundation) • Add more tree infrastructures, educate schools on tree and tree care (Trees Matter) • Connect students to the benefits of trees and foster environmental stewardship, grow city's tree canopy (Vancouver Urban Forestry) • Improve the schoolyard habitat and address climate action (Denville Township School District)	• Expand students' interactions with trees • Increase students' awareness and education of the natural environment • Foster environmental stewardship • Grow city's canopy • Improve schoolyard habitat and environment
Administrative structure and Partnership	Stable administrative structure and partnership: • Large environmental organization partners with schools (Texas Tree Foundation and Trees Matter) • City's Forestry (Vancouver Urban Forestry) • School-organized itself (Denville Township School District)	Forestry department: • Forestry section Manhattan Parks & Rec • Kansas Forest Service
Funding and Budget	Secure funding: • Project sponsorship and co-sponsorships (Texas Tree Foundation) • Donation to the organization (Trees Matter) • City funding (Vancouver Urban Forestry) • School budget (Denville Township School District)	Donation
Care and Maintenance	• Guaranteed follow-up maintenance: • Volunteers from organization (Texas Tree Foundation) • School (Trees Matter) • School, under the help of forestry staff (Vancouver Urban Forestry)	School team, under the help of tree professionals
Education and Outreach	Various educational sources: • Planting day on-site participation and education (all four precedents) • Curriculum guideline (Texas Tree Foundation and Trees Matter) • Celebration day at the school featuring student activities, art, and music(Texas Tree Foundation) • Email subscription of tree related knowledge (Trees Matter)	• Planting day on-site participation and education • Curriculum guideline • Celebration day at the school featuring student activities, art, and music • Email subscription of tree related knowledge
Others	Landscape architects produce diagrams and plans. (Texas Tree Foundation)	Site information from inventory and site plans are provided.

Table 4.22 Summary of important aspects from precedents

4.3 Survey

A total of four responses were received in the survey sent to the principals of eight primary schools, and all four principals agreed that there is a need for additional trees to be planted at their school site. When asked if they would welcome the support of an outside community volunteer group to help fund, plant, and care for new trees, the four principals all show a welcoming attitude. In addition, principals pointed out that school communities such as teachers, staff, clubs, and PTO may be interested in engaging students in planting and caring for new trees on site. Therefore, planting trees through multi-party cooperation in schools is feasible and can be supported by the principal.

Outdoor learning space is a topic of interest to all principals. Out of 4 responses, one school has an unshaded outdoor learning space, one is developing an outdoor learning space, and the remaining two schools are interested in developing an outdoor learning space.

Three principals said they were aware of existing lessons or study units related to trees in their schools, but one principal was unsure. They both indicated a lesson or study unit focused on trees could be incorporated.

Regarding where to plant the trees, the survey gives options that are near the playground, in the open lawn area, along with the site's edges/along the perimeter, near the parking lots, near the building, and at building entrances and exits. Every principal gave a different answer. This will be used as a reference for individual site design.

4.4 Interview

After contacting the Department of Maintenance of the school district by email several times, there was no reply from any maintenance crew. Therefore, to ensure this project could move to the next stage, the design guideline on the site relies mainly on information from the documents provided on the district website.

4.5 Document Review

USD 383 Facilities Manual:

www.usd383.org/home/showpublisheddocument/23489/637036245842070000

According to the USD 383 Facilities Manual, the application procedure of planting trees in the school yard is

- Complete a REQUEST FOR MODIFICATION OR ADDITION TO DISTRICT GROUNDS REQUEST FORM, then the manual suggest
- Request a meeting with Facilities and Growth Committee to present proposal.
- Develop the plan for planting trees to illustrate
    - When will the project begin
    - Who is responsible for oversight of the project
    - Where will the trees be planted
    - When will the trees be planted
    - Who will care for and water the trees after they are planted, and custodial or maintenance staff may not be able to carry this duty.

For specific site design, . The requirements are as follows

- Call Dig Safe to mark underground utilities
- Contact IT Services about any fiber optics locations at the building
- Contact district maintenance manager about maintenance related issues

1. Underground utility locations that Dig Safe does not mark

    Placement should be where the mature canopy grows no closer than 20' from underground lines

2. Underground drainage locations installed by district

    Placement should be where the mature canopy grows no closer than 20' from underground lines

3. Conflicts with above ground utilities

    Placement should be where the mature canopy grows no closer than 20' from overhead lines

4. Spacing from objects and buildings to allow access of mowing machines

    At least 8' of clearance is needed for the small mower, taking into consideration the size of the mature trees

    At least 20' of clearance is needed for the large mower, taking into consideration the size of the mature trees

    Large/Tall trees with large root systems should be no closer than 35' from the building to prevent roof damage, storm damage, and debris on the roofs

Manhattan- Ogden USD 383 Master Plan 2017 and information related to Bond Construction:

www.usd383.org/district/bond-construction

This document was reviewed to understand the school's future development plans, focusing on additions, removals, and modifications to the school's grounds, buildings and hardscape.

This master plan provides site improvement plan of district site and recommended time periods for current and forecasted improvements over a 20 year period. By comparing the USD 383 Bond Construction project timeline provided on the district's website, the district will build and upgrade school facilities with reference to this master plan from September 2019 to the end of 2024. The content includes providing necessary classrooms at existing sites, constructing high-wind shelters at some schools, building and expanding appropriate space for program enhancements, multipurpose rooms at small schools, parking and bus drop-off areas, etc.

Through the publicity of the bond construction process on the site inventory and the school website, the base maps used by this tree planting initiative have been or are about to complete the bond construction. To ensure that the location of tree planting does not conflict. The site development information obtained from this document is reflected in the design of the next chapter. The modified school sites will be used as the base map instead of using the current condition for the planting plan.

City of Manhattan Spring Street Tree Planting Program:

www.mhkprd.com/216/Forestry

During the site analysis, it was found that some trees around the school provide shade for the activity areas in the schoolyards. Most of the trees around these schools are public trees. Therefore, this document was reviewed to find the potential public tree source.

Regarding this project, the City of Manhattan Parks and Rec official website only provides a form for applicants to fill in the street information they want to plant trees, and there is no additional information. However, this could provide a possible source of plant material for this project. Perhaps by working with Manhattan Parks and Rec to increase the number of trees around the school while also benefiting the schoolyard.

MANHATTAN DEVELOPMENT CODE (MDC):

online.encodeplus.com/regs/manhattan-udo/doc-viewer.aspx#secid-446

The site development of landscaping should refer to MANHATTAN DEVELOPMENT CODE (MDC): Division 26-7C. Landscaping, Screening, and Buffering

If there are conflicts between the tree planting initiative and the MDC, the initiative should be revised according to the standards stipulated by the MDC.

Documents from Kansas Forest Service

By reviewing and summarizing documents provide by Kansas Forest Service, tree documents were selected to use as reference to generate a recommended tree species list.

Preferred Trees for Northeast Kansas: This document suggest the tree that is suitable for growing at northeast Kansas. It include charts show the tolerances of individual trees to various environmental conditions as well as the

major landscape attributes of each tree.

www.kansasforests.org/community_forestry/community_docs/NE%20Kansas%20Preferred%20Trees.pdf

Trees and Shrubs for Difficult Sites: This document provide a lists of trees and shrubs for dry and wet locations. The purpose is to select trees that can survive in harsh environments for schools, improve trees' survival rate, and reduce the frequency of tree maintenance.

bookstore.ksre.ksu.edu/pubs/MF2205.pdf

Trees and Shrubs That Attract Songbirds and Wildlife: This document provides a list of trees and shrubs that attract wildlife. Information includes the quality and season of food, cover and nesting quality, plant range, habitat, and general remarks about the plant. The purpose is to select trees with characteristics that attract students' attention in a particular season as potential educational material.

https://bookstore.ksre.ksu.edu/pubs/L845.pdf

The primary reason for choosing these three documents is that they design for the environmental condition in Manhattan, KS. Climatically suitable trees have a higher survival rate and therefore require less maintenance. The trees recommended in these three documents are ideal for planting in Manhattan, KS.

Not all trees in these three documents are included in the recommended planting table for this project. Because one of the primary purposes of the trees planted in this project is to provide shade, the preferred trees are primarily large. Due to the space available for planting, large trees are not suitable for all places, so some small and medium-sized trees are also included in the recommended list.

To reduce tree maintenance, most of the trees on the list are drought resistant. In addition, the tree's resistance to sun, light shade, high PH, wetness, and pests is also marked in the list, which can be selected according to the actual situation.

Watching the trees change throughout the year is very fun and educational. All trees on the list are decadent trees to create large shade and have an apparent seasonal variation. All trees have more or less desirable flowers, showy fruit, autumn foliage color, or ornamental bark.

Recommend tree species list for USD 383 elementary schools

Common name	Scientific name	Tolerant of					
		Full sun	Light Shade	High pH	Drought	Wet	Pests
Chinkapin Oak*	Quercus muehlenbergii	Good		Good	Good		Good
River Birch	Betula nigra	Good				Good	Fair
Ginkgo	Ginkgo biloba	Good		Good	Good		Good
Kentucky Coffeetree*	Gymnocladus dioicus	Good		Good	Good	Fair	Good
Sweetgum	Liquidambar styraciflua	Good				Good	
Black Gum	Nyssa sylvatica	Good	Fair			Good	
London Planetree	Platanus x acerifolia	Good	Fair	Good	Fair	Good	
Swamp White Oak*	Quercus acutissima	Good			Fair	Good	Fair
Shingle Oak*	Quercus imbricaria	Good			Good	Fair	Fair
Bur Oak*	Quercus macrocarpa	Good		Good	Good	Fair	
Willow Oak	Quercus phellos	Good			Fair	Fair	Good
Shumard Red Oak*	Quercus shumardii	Good		Fair	Fair	Fair	Fair
Baldcypress	Taxodium distichum	Good			Good	Good	Good
Lacebark Elm	Ulmus parvifolia	Good	Fair	Good	Good	Fair	Fair
Hackberry*	Celtis occidentalis	Good	Fair	Good	Good	Good	
Honeylocust*	Gleditsia triacanthos	Good	Fair	Good			
Japanese Tree Lilac	Syringa reticulata)	Good		Good	Fair		Fair
Flowering Crabapple	Malus spp.	Good		Fair	Fair		
Eastern Redbud*	Cercis canadensis	Good	Fair	Good	Fair		Fair

***Native to NE Kansas region**

Good: the tree is strongly tolerant of the characteristic indicated.

Fair: the tree shows some tolerance.

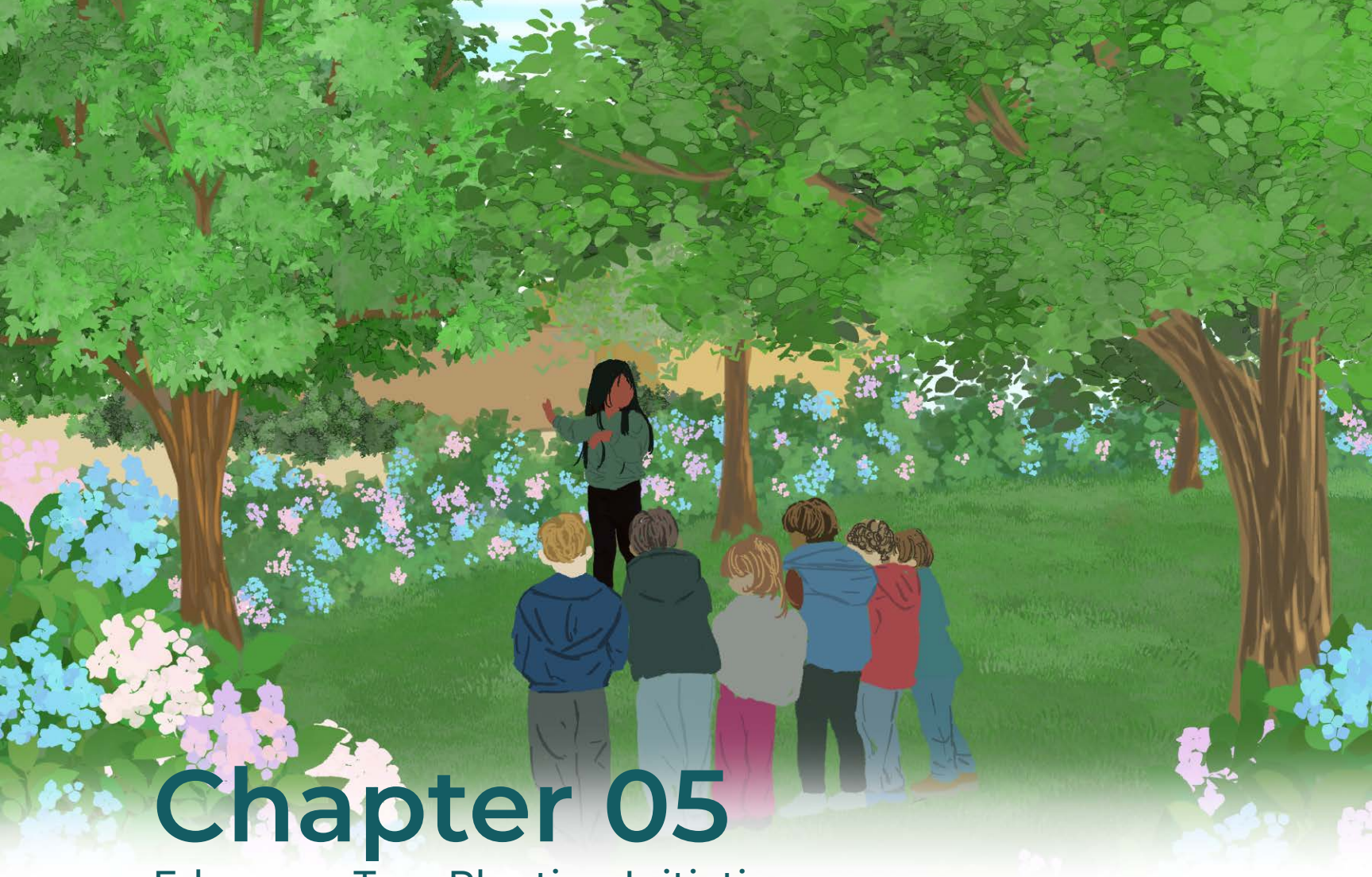
Alkaline Soil:
Good: tree may tolerate soils with a pH up to 8.0 or more.
Fair: tree will tolerate an alkaline soil up to a pH of 7.5.
Blank: tree may not tolerate alkaline soils; do not plant in alkaline soils to avoid the problem of iron or manganese chlorosis.

Pests:
Good: tree is usually free of insect and disease problems.
Fair: tree encounters insect or disease pests on an infrequent basis and often is not permanently damaged.
Blank: tree may suffer from pests which may permanently damage or kill the tree and/or the tree may exhibit minor insect and disease problems on a frequent basis which may affect the aesthetics of the tree or insects may commonly be a nuisance.

Table 4.5 The recommend tree species list for USD 383 elementary schools

Common name	Scientific name	Landscape Attributes					
		Mature height	Mature spread	Desirable flowers	Showy or useful fruit	Autumn foliage color	Ornamental bark
Chinkapin Oak*	Quercus muehlenbergii	35-40+	40-45		Fair	Fair	
River Birch	Betula nigra	40-60	40-50	Fair		Fair	Good
Ginkgo	Ginkgo biloba	50-60+	25-40			Good	Fair
Kentucky Coffeetree*	Gymnocladus dioicus	50-60+	30-45		Fair	Fair	Fair
Sweetgum	Liquidambar styraciflua	50-75	50-75		Fair	Good	Fair
Black Gum	Nyssa sylvatica	30-50	20-30			Good	Good
London Planetree	Platanus x acerifolia	60-80	50-60		Fair		Good
Swamp White Oak*	Quercus acutissima	50-60	40-60		Fair	Good	Fair
Shingle Oak*	Quercus imbricaria	50-60	40-60		Fair	Fair	
Bur Oak*	Quercus macrocarpa	60-80	50-70		Fair		
Willow Oak	Quercus phellos	40-60	30-40			Fair	
Shumard Red Oak*	Quercus shumardii	60-80	40-60		Fair	Good	
Baldcypress	Taxodium distichum	50-70+	20-50		Fair	Good	Fair
Lacebark Elm	Ulmus parvifolia	40-60	35-50		Fair	Fair	Good
Hackberry*	Celtis occidentalis	50-100	50-100		Fair		
Honeylocust*	Gleditsia triacanthos	50-75	50-75				
Japanese Tree Lilac	Syringa reticulata)	20-25	15-25	Good			Good
Flowering Crabapple	Malus spp.	varies	varies	Good	Good		Fair
Eastern Redbud*	Cercis canadensis	20-25	20-25	Good		Fair	Fair

Table 4.5 The recommend tree species list for USD 383 elementary schools. (cont.)



Chapter 05

Edugreen Tree Planting Initiative

Edugreen Tree Planting Initiative

Informed by the findings from the methods, this project proposes a district-wide 5-year tree planting initiative that includes phased goals and a tree planting plan for eight elementary schools in Manhattan, KS. It is divided into three main points,

1. Develop a tree planting initiative and timeline to guide the implementation and care for new trees

To make the Edugreen Tree Planting Initiative feasible, a framework and a timeline are provided in this chapter to explain the procedures and details from initiative initiation, to the project team formation, to initiative implementation and ongoing maintenance.

The administrative structure of this initiative mainly consists of three parts. The first is the program champion who initiates the initiative. The second is the project coordinator at the USD 383 School District level to oversee the project implementation. The third is individual elementary school project team that will champion the implantation and care for new trees. The responsibilities of these people and teams involved in each step of the initiative are further described later in this chapter.

In addition, the contents in Chapters 1, 2, and 4 also informative for the Edugreen Tree Planting Initiative. The following table explains the various information provided in this project for reference.

2. Create a tree planting plan for each site

One of the purposes of Edugreen Tree Planting Initiative is to increase shade for student activity areas to create comfortable outdoor spaces. All site plans in this chapter prioritize planting trees adjacent to student activity areas. In addition, all site plans consider important site information from the USD 383 Facilities Manual, the Manhattan- Ogden USD 383 Master Plan 2017 provided in the USD 383 bond construction project, and the MANHATTAN DEVELOPMENT CODE to ensure that the location of proposed trees feasible base on existing and future site plans.

3. Expand students' interaction with trees to increase their awareness and education.

Education and outreach are structured in two parts. The first part relates to actual tree planting and the second part provides resources about trees, which can be used as a reference for school teachers to design tree-related courses. In addition, for those interested in this project and who want to continue to develop or conduct in-depth research, some research directions and suggestions are given at the end of the chapter.

5.1 Edugreen Tree Planting Initiative Framework

Location: Manhattan, KS

Scale / scope

- A 5-yr program that seeks to plant a total of 137 trees across eight elementary school sties.
- The tree planting initiative has the potential to continue past 5 years

Mission

The Edugreen Tree Planting Initiative seeks to expand students' interactions with trees and increase their awareness and education of the natural environment by increasing the number of trees at the elementary schoolyards.

Goals and objectives

Edugreen Tree Planting Initiative seeks to plant 137 new trees across eight elementary schools in the USD 383 School District in five years. The tree planting activity in the elementary school will expand students' interactions with trees and increase students' awareness and education of the natural environment. This initiative fosters community support for the campus tree program and encourages good tree management on school properties. The trees added by this initiative also enhance schoolyard canopy cover and will provide shade and create comfort for children while playing outdoors.

Administrative structure

Project Champion:

Role: Initiate, organize, and champion the Edugreen Tree Planting Initiative.

Responsibility: This person proposes the tree planting initiative to the district and convenes individual school Tree Teams. This person can take on an administrative role of project manager, or they can convene a team of volunteers to facilitate in the overall project management.

Project Coordinator (District):

Role: Oversee the overall Edugreen Tree Planting Initiative.

Responsibility: At the district level, an individual is needed to champion and oversee the overall USD383 Tree Planting Initiative, and to provide individual guidance and support to each schools' Tree Team.

This individual will be in-charge of broader community outreach, district wide tree event programming, publicizing events, and fundraising. Project coordinator will meet with each schools' Tree Team at the start of each academic year and as needed throughout the year.

Tree Team (Individual Schools):

Role: Implement the Edugreen Tree Planting Initiative and care for new trees.

Responsibility: For this project to be successful, a dedicated team of teachers, staff, parents (PTO), and students needs to be formed at each elementary school site. Each schools' "Tree Team" will be knowledgeable about their site's opportunities and constraints and can champion the implementation and care for new trees. This team will also be responsible for encouraging their schools' curriculum includes a connection to trees. It is envisioned that this team have a consistent leader year to year, but that members may change annually, at the start of each new academic year.

School principal:

One of the principal's most important roles is to deliver messages to all parties in the school. Principals know more about their school's resources and can communicate the Edugreen Tree Planting Initiative with the district project coordinator, or assign a person in charge who is familiar with the school's condition. Organizations such as School clubs and PTO can coordinate directly with the principal. These organizations can be the main component of volunteers and the main part of donors to the initiative.

School teachers and staff:

School teachers and staff participate in planting activities as leaders and educators of students. They can provide tree-related education through curriculum and activities.

USD383 Maintenance Department:

The implementation of Edugreen Tree Planting Initiative should actively coordinate with the district's maintenance department to ensure potential maintenance issues are understood and proactively addressed.

School Communities:

The groups most closely associated with the school, including but not limited to PTO, school clubs, teachers, staff, etc., are likely to be willing to help with this initiative for fundraising and volunteering.

Partnership

The project coordinator should invite partners and establish long-term cooperation from outside groups and organizations to help with the tree planting initiative. Potential partners like K-State University, Kansas Forest Service, and Manhattan Parks & Rec are needed to be involved in every planting event.

Manhattan Parks & Rec:

The City forestry staff may be willing to become the planting day facilitators.

Kansas Forest Service:

- Kansas Forest Service has the state forester, program coordinators, statewide specialists, and support staff. The staff may be willing to become the planting day instructor, assistant, or provide consulting and educational sources for the initiative.
- The office of Kansas Forest Service is close to the schools in the USD 383, and there are full-time employees and professional tree equipment. Perhaps after reaching cooperation, tree planting initiative team can borrow tree planting equipment from the office.
- Kansas Forest Service has Conservation Tree Planting Program offering tree seedlings and other items for use in conservation plantings. Orders are accepted December 1 through May 1 and September 1 to October 15. The distribution time matches the school time of the elementary school. Maybe ask Kansas Forest Service if they can grow the saplings for the schoolyard tree planting initiative.

Kansas State University:

Many departments at the university may be able to help with the tree planting initiative:

- Students from Landscape Architecture who are good at gathering site information and producing demonstration plans.
- Students in the Horticulture department may be able to provide some information on plants.
- Students in the School of Leadership Study can give relevant advice on organizing activities.

The project team might reach out to these departments at the university or student organizations in the college to see if a faculty or student leader could lead a collaborative project to help plant trees on schoolyards.

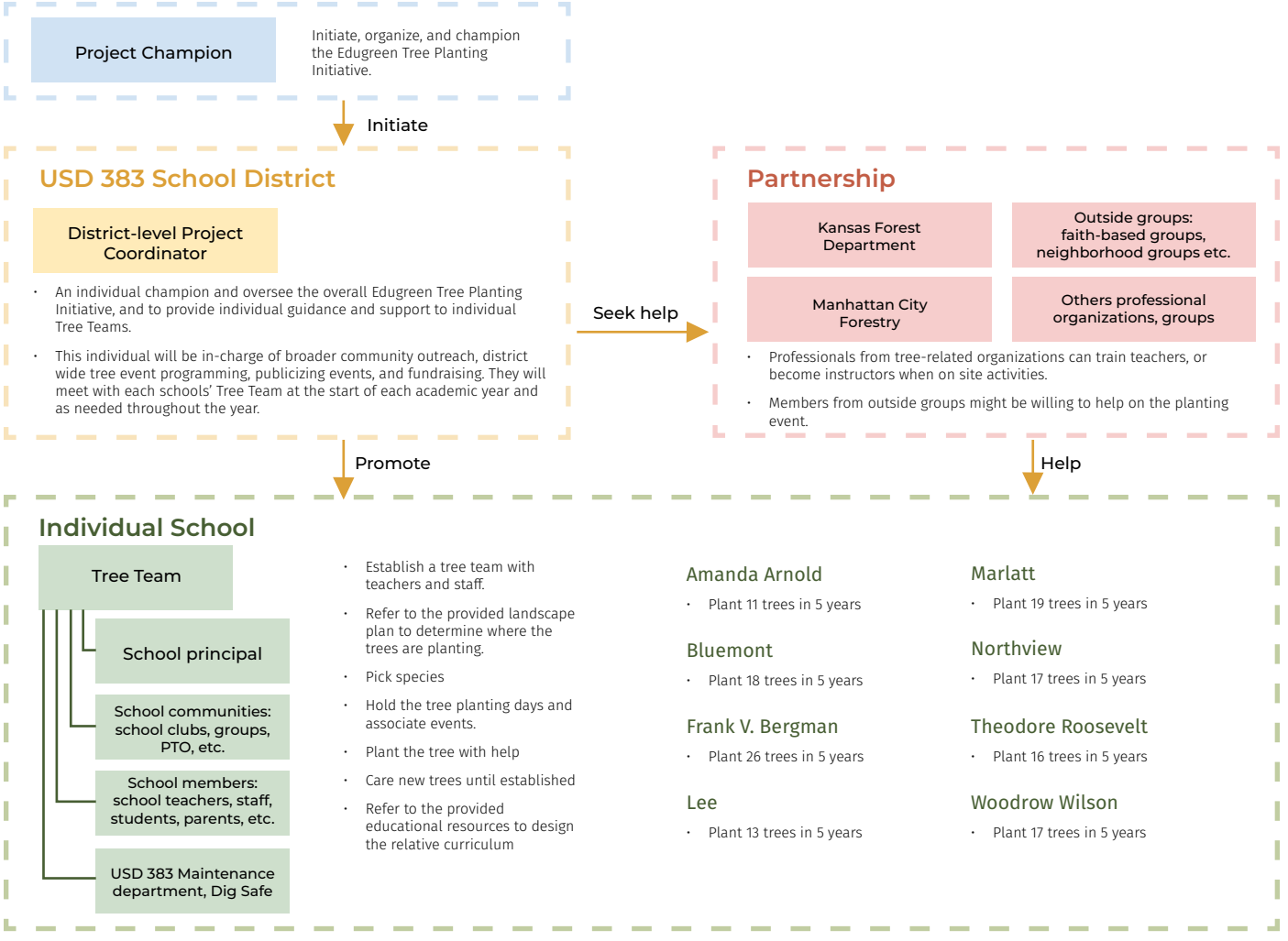


Figure 5.1 Edugreen Tree Planting Initiative administrate structure and partnership relationship

Funding and budget

The first step in this initiative is to secure funding. Once the payment is received, the project can start.

Funding sources:

Considering that the project started with a small, informal organization led by an individual, the funding for the project would not be as plentiful as a project led by a larger organization. Donations from parents, community members, and other organizations may be used as the first funding to start a project. If feasible, the same funding model could be replicated the following year. Other funding sources could consider some special funds, such as the Elementary and Secondary School Emergency Relief (ESSER) Fund, which is dedicated funding for preventing, preparing for, or responding to the COVID-19 pandemic.

Due to this tree planting initiative proposes a 5 year period, and people are always more enthusiastic at the beginning of the project, thus School Tree Team must have a long-term plan for the funds received.

Budget list:

As mentioned in the previous chapter, the anticipated list of expenses for the tree planting initiative in Manhattan, KS, are

- Plant materials and other landscape materials
- Follow-up monitor and maintenance

Tree size for planting consideration:

The tree size recommended for planting in the schoolyard should be governed not only by the budget but by the irrigation capabilities after planting, site drainage, weed control and mulch management, and storm history.

- Irrigation capabilities: If irrigation cannot be provided for the recommended period after planting, choose smaller nursery stock to ensure survival.
- Site drainage: Large-sized nursery trees (more than 2 inches in trunk diameter) may be poorly suited for wet sites because roots in the bottom portion of the root ball could become submerged in water. This can stress the tree by killing the deeper roots in the root ball.
- Weed control and mulch management: If weed growth is not controlled chemically or with mulch application around the tree during the establishment period, small nursery stock may be the best choice.
- Storm history: Small-size nursery stock establishes faster than large-sized nursery stock. This may allow small nursery stock to become wind-firm sooner than larger-sized nursery stock (University of Florida 2015).

To sum up, choosing smaller nursery stock (less than 2 inches in trunk diameter) is more suitable for on-site planting for the Manhattan elementary schools tree planting initiative. A reference price from Blueville Nursery Inc. (A complete landscape company in Manhattan, KS) shows the 1-1.5” caliper deciduous tree costs $225 and a 1.5-2.0” caliper deciduous tree costs $275. This price could use as a reference for schools to set their goal to collect the funding.

Criterion	Small-sized nursery stock (Less than 2.0" caliper)	Large-sized nursery stock (More than 2.0" caliper)
Establishment period	Quick	Slow
Irrigation period after planting	Brief	Extended
Susceptible to drought or flood	Briefly after planting	For an extended period
Number of trees planted per dollar	Large	Small
Pruning needs	High	Moderate
Cost of nursery stock	Inexpensive	More expensive
Suitability for compacted or poorly drained soils	Well-suited	Could be poorly suited

Table 5.1 Tree size for planting consideration, adapted from University of Florida 2015.

Care and Maintenances

Planting trees is not the end of the initiative, ongoing monitoring and maintenance are needed to ensure survival. Tree Teams at each school are responsible for care for new trees until established, which will take at least three years. The School Tree Team should meet with professionals to develop a maintenance schedule.

Others

Tree planting plans for each school.

Individual Tree Teams can refer to the provided tree planting plan in this chapter to determine where and when trees should be planted.

The tree planting plans referred to information on slopes, utilities, buildings, development plans, and the potential tree size to make the tree planting locations feasible with existing and future site conditions. The planting plans also considered activity areas and parking lots to prioritize planting locations that can cover more users' activities.

The trees are mainly planted for three reasons:

- **Plant for shade:** Trees are planted in the student activity area, providing shade for students and teachers, and parents waiting aside. Trees are planted in the parking lot areas providing shade for vehicles.
- **Plant for space enclosure:** A buffer adjacent to the site boundary or between the student activity area and the parking lot, a driveway for separating spaces.
- **Plant for microclimate modification:** Trees mainly shade the impervious paving around the hardscape play area, reducing the surface temperature in hot weather.

The first priority focuses on the playground area, with planting planned to be completed within one to two years. The plan of rest years is to move to the schoolyard lawn, parking lot, site boundary, and other areas.

Recommended tree species list

The species and expected growing size of the trees are provided in Chapter 4 so that the readers can have a general understanding of the characteristics of the trees.

Educational resources to teachers and students.

Relevant sources are provided within this chapter and guide students in their direct or indirect contact with trees, enrich the school curriculum to increase students' awareness of trees and nature environment.

The date of planting day and celebration day.

The Planting day can be held in conjunction with Arbor Day to highlight the festival's significance. A celebration day could be at Earth Day, following Arbor Day with events in schools featuring student activities, art and music to celebrate the hard work and achievements of all initiative participants.

Benefits of completing Edugreen Tree Planting Initiative

After completing the tree planting initiative, every school can get benefits.

- Students will have more chances to interact with trees and be aware of the surrounding trees and natural environment.
- There will be more shade around student activity areas and parking lots.
- The trees added will offer more environmental benefits.
- School Tree Team will care for the new trees and encourage good tree management on school properties, as well as reduce the maintenance effort from the district maintenance department.
- The trees added enhance schoolyard canopy cover and will help to contribute urban tree canopy.

5.2 Edugreen Tree Planting Initiative Timeline

	Tasks	Administrative stage												Implentation Stage (Repeat each year)												Completion
		Anticipate one year												Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	After 5 years
1	Edugreen Tree Planting Initiative starts with a passionate person, the Project Champion.																									
2	Project Champion appoints a district-level Project Coordinator who starts administrate tasks.																									
3	Project Coordinator helps organize the Tree Teams at individual schools.																									
4	Individual Tree Teams plan for the implantation of 5-year tree planting initiative.																									
5	Individual Tree Teams prepare submit their tree planting plans for district approval.																									
6	Official kick-off of the tree planting initiative																									
1	Individual Tree Teams prepare for the year's tree planting.																									
2	Individual Tree Teams hold the tree planting days and associated events.																									
3	School adds tree-related courses, curriculum, and units.																									
4	Individual Tree Teams provide maintenance and care to the planted trees.																									

Figure 5.2 Edugreen Tree Planting Initiative timeline

Initiative administrative stage

Step 1: Edugreen Tree Planting Initiative starts with a passionate person, the Project Champion.

- Project champion prepares the initiative proposal and initial plan that contains the current condition and the potential benefits of the tree planting initiative.
- Project champion contacts USD 383 School District to discuss the possibility of the tree planting initiative.

Step 2: Project Champion appoints a district-level Project Coordinator who starts administrate tasks.

- Project coordinator posts the initial thoughts to inform the public to notice the initiative. Prepare in advance for the follow-up looking for funding and volunteering.
- Project coordinator contacts the relevant organizations and departments such as Kansas Forest Service and Manhattan Parks & Rec to ask about starting a collaborative partnership.
- Establish cooperation between the district and various departments and organizations, and invite people from various departments and organizations to join the project team.

Step 3: Project Coordinator helps organize the Tree Teams at individual schools.

- Project coordinator meets with individual schools to talk about the willingness to undertake the tree planting initiative.
- Principal recommends the person in charge of the initiative in the school, or asks the principal to recommend people in the school who are interested in this project and willing to take charge.
- Principal publicizes the intentions of the tree planting initiative to relevant teachers, staff, and communities in the school and helps with fundraising .
- School Tree Team posts information on school social media platform to outside groups, seeking help with fund raising and volunteering.

Step 4: Individual Tree Teams plan for the implementation of 5-year tree planting initiative. (This step may require multiple meetings before and after step 5).

- Each school Tree Team is responsible for determining:
  - When will the project begin
  - Who is responsible for oversight of the project
  - Where the trees be planted
  - When the trees be planted
  - Who will care for and water the trees after they are planted, and custodial or maintenance staff may not be able to carry this duty.
- The Tree Team receives input from outside partners to select tree species and plant trees.

- The Tree Team receives input from outside partners to develop a tree care (maintenance) plan.
- The Tree Team receives input from outside partners to measure the benefits of the planted trees.

Step 5: Individual Tree Teams prepare and submit their tree planting plans for district approval.

- School Tree Team completes a REQUEST FOR MODIFICATION OR ADDITION TO DISTRICT GROUNDS REQUEST FORM
- School Tree Team requests a meeting with Facilities and Growth Committee to present proposal.
- Individual school tree planting initiative approved by the school district and approved for implementation.

Step 6: Official kick-off of the tree planting initiative.

- School Tree Team officially publicizes project information on the project's website or social media accounts, school district website, and partners' websites, including the tree planting plan, seeking help with funding and volunteering.
- The tree planting initiatives of the eight schools will not necessarily be implemented at the same time. Once a school has met the prerequisites for project implementation, publicity can begin to increase the popularity of the entire tree planting initiative. Subsequent projects can therefore gain more public support.

Initiative implementation stage (Repeat each year)

Step 1: Individual Tree Teams prepare for the year's tree planting.

- Preparation starts at the beginning of the school year (mid-August).
- School Tree Team seeks help with funding and volunteering.
- School Tree Team confirm the tree placement location
  - Call Dig Safe to mark underground utilities
  - Contact IT Services about any fiber optics locations at the building
  - Contact district maintenance manager about maintenance related issues
  - Soil testing
  - Mark the tree planting location
- School Tree Team confirms the activity process with school teachers, staff, volunteer representatives, and instructors.
- Project team prepares the planting materials.
- Project team contact all participants to join the first planting day.
- School Tree Team publicize the planting day agenda of the planting day, include the participants and planned activities.

Step 2: Individual Tree Teams hold the tree planting days and associated events.

- Planting day can be held in conjunction with Arbor Day in March.
- After the tree planting day, a celebration day can be held to celebrate their hard work on planting trees, such as Earth Day after Arbor Day.
- School Tree Team concludes and publicizes the tree planting initiative on social platforms, websites, or provides email subscriptions
- School Tree Team invites parents and community members to participate in the celebration to raise funds for tree planting activities in the coming year.

Anytime: School adds tree-related courses, curriculum, and units.

- School teachers and staff refer to the provided educational resources to design the relative curriculum at chapter 5.5.

After tree planting day: Individual Tree Teams provide maintenance and care to the planted trees.

- School Tree Team follows the results discussed with the professionals, Project Coordinator, and district maintenance department in step 4, then
  - Watering newly planted trees for 3 years
  - Pruning trees
- Monitor to determine if additional maintenance is needed.

Project Staff	Key Information	Chapter	Useful for
Project Champion	The issues and importance of schoolyard trees	1	Introducing Edugreen Tree Planting Initiative to USD 383 District.
	The benefits of schoolyard trees and green schoolyard	2	Explaining to the USD 383 District the importance of trees in the schoolyard.
	Tree planting initiative framework and timeline	5	A guide for Project Champion implement the initiative.
Project Coordinator	What is the tree planting initiative and how it works	2	Explaining the tree initiative to individual Tree Teams.
	What is the community stewardship and how it works	2	Explaining community stewardship to individual Tree Teams.
	The importances of tree species and follow-up maintenance when planting new trees	2	Explaining the importance of tree species and follow-up maintenance to individual Tree Teams.
	Precedent study findings	4	Making the Edugreen Tree Planting Initiative framework easier to understand.
	Tree planting initiative framework and timeline	5	A guide for the Project Coordinator implements the initiative.
Individual Tree Teams	Site analysis: Information of existing schoolyard trees (location, species, size, condition, i-Tree Ecosystem Analysis Result), utility, slope, shade, issues, and opportunity for new trees.	4	Understanding the current situation of their school.
	Overview documents related to trees	4	A reference for individual Tree Teams implement the initiative.
	Recommended tree species list	4	A reference for individual Tree Teams implement the initiative.
	Tree planting initiative framework and timeline	5	A guide for individual Tree Teams implement the initiative.
	Tree planting plans for individual schools	5	Plans for individual Tree Teams confirm the tree placement location and priorities.
	Education, outreach, and other information	5	• Additional references for individual uses to lead planting day. • School teachers use to add tree-related curriculum. • Suggestions for people who want to continue to develop or conduct in-depth research on the schoolyard tree planting initiatives.

Table 5.2 Key information for project staff

5.3 Tree Planting Plan

Guidelines for tree planting are provided for each school site. These guidelines take into consideration the characteristics of each site, learned through site analysis, document review, and results from the survey of school principals.

Notes about planting on site

- Obtain approvals. Prior to any tree planting, Dig Safe must be called to mark underground utilities; IT services must be contacted to mark fiber optics; and, USD 383 must be notified for final approval. Each school's Tree Team must ensure these tasks are completed.
- Spacing between utilities and drainage: The Utility locations used in this project came from Riley County GIS. The mature canopy size of all trees should be kept **at least 20' away from utilities.**
- Spacing for mowers: Leave **at least 8' between trees and other objects** for small mowers. Also, consider the large mower's travel path and leave **at least 20'** for it.
- Spacing between buildings: The large trees should be planted **at least 35' away from the buildings**. When selecting a tree species, consult the Tree Species Recommendation list (see Table 4.5) to see its mature canopy spread size.

5.31 Amanda Arnold Tree Planting Plan

Goal:

Plant 11 trees in 5 years

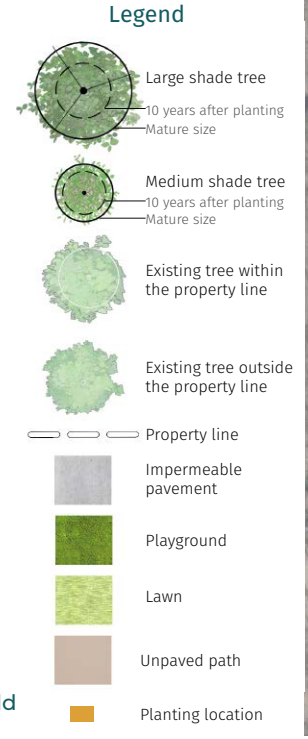


Figure 5.311 Amanda Arnold tree planting location

Tree planting priorities

First priority:

- **Plant for shade:** Newly planted trees provide shade for children using the playground and for parents and teachers waiting around the playground.

Year 1: Tree #1, 2, 6

Year 2: Tree #3, 4, 5

Total 6 trees

6 Large shade trees (#1-6)

Second priority:

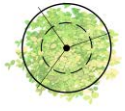
- **Plant for shade:** Newly planted trees are located on the south side of the parking lot, which can provide shade for parked vehicles.

Year 3: Tree #7, 8

Year 4: Tree #9, 10

Year 5: Tree #11

Total 5 trees



5 Large shade trees (#7-11)

Benefits of completing the Edugreen Tree Planting Initiative

- After five years, Amanda Arnold Elementary School will fill the tree canopy gap around playgrounds and southern parking lot.

Newly planted trees (#3, 4) provide shade for children using the playground and for parents and teachers waiting around the playground.

Figure 5.312 Amanda Arnold rendering 1

Three large trees (#1, 3, 4) create comfortable rest areas.

Figure 5.313 Amanda Arnold rendering 2

5.32 Bluemont Tree Planting Plan

Figure 5.321 Bluemont tree planting location

Goal:

Plant 18 trees in 5 years

Tree planting priorities

First priority

- **Plant for shade:** Newly planted trees provide shade for children using the playground and for parents and teachers waiting around the playground. Proposed trees (#1, 2) add to existing trees to form a large shade area, shown as dashed areas on the map. This area is a good place to build a new playground or an outdoor classroom.
- **Plant for spatial enclosure:** Newly planted trees (#3~7) create a barrier between the playground and the new driveway to improve safety.
- **Plant for microclimate temperature modification:** Newly planted trees will shade the hardscape play area, helping to reduce the surface temperature of the paving.

Year 1: Plant 4 Trees #1, 2, 6, 7

Year 2: Plant 3 Trees #3, 4, 5

Total 7 trees

4 Large shade trees (#1, 2, 3, 4)

3 Medium shade trees (#5, 6, 7)

Second priority

- **Plant for shade:** Newly planted trees (#8~10) provide shade for vehicles science a new parking will be added.
- **Plant for spatial enclosure:** Newly planted trees (#18, 17) create a barrier between the schoolyard and the public road to reduce the disturbance of busy traffic.

Year 3: Tree #8, 9, 10

Year 4: Tree #13, 14, 15

Year 5: Tree #16, 17

Total 8 trees

5 Large shade trees (#8, 9, 10, 16, 17)

3 Medium shade trees (#13, 14, 15)

Street Trees

Tree #11, 12, 18

- Street tree planting is not included in the Edugreen Tree Planting Initiative, however it is still recommended to request the city plant trees along the public right of way.

Benefit of completing the Edugreen Tree Planting Initiative

- After five years, Bluemont Elementary School will have doubled the number of trees on its site.

Newly planted trees (#3, 4, 5, 6) create a benificial buffer between the playground and the drop-off area.

Figure 5.322 Bluemont rendering 1

Existing stree trees will continue provide shade to the new hardscape play area.

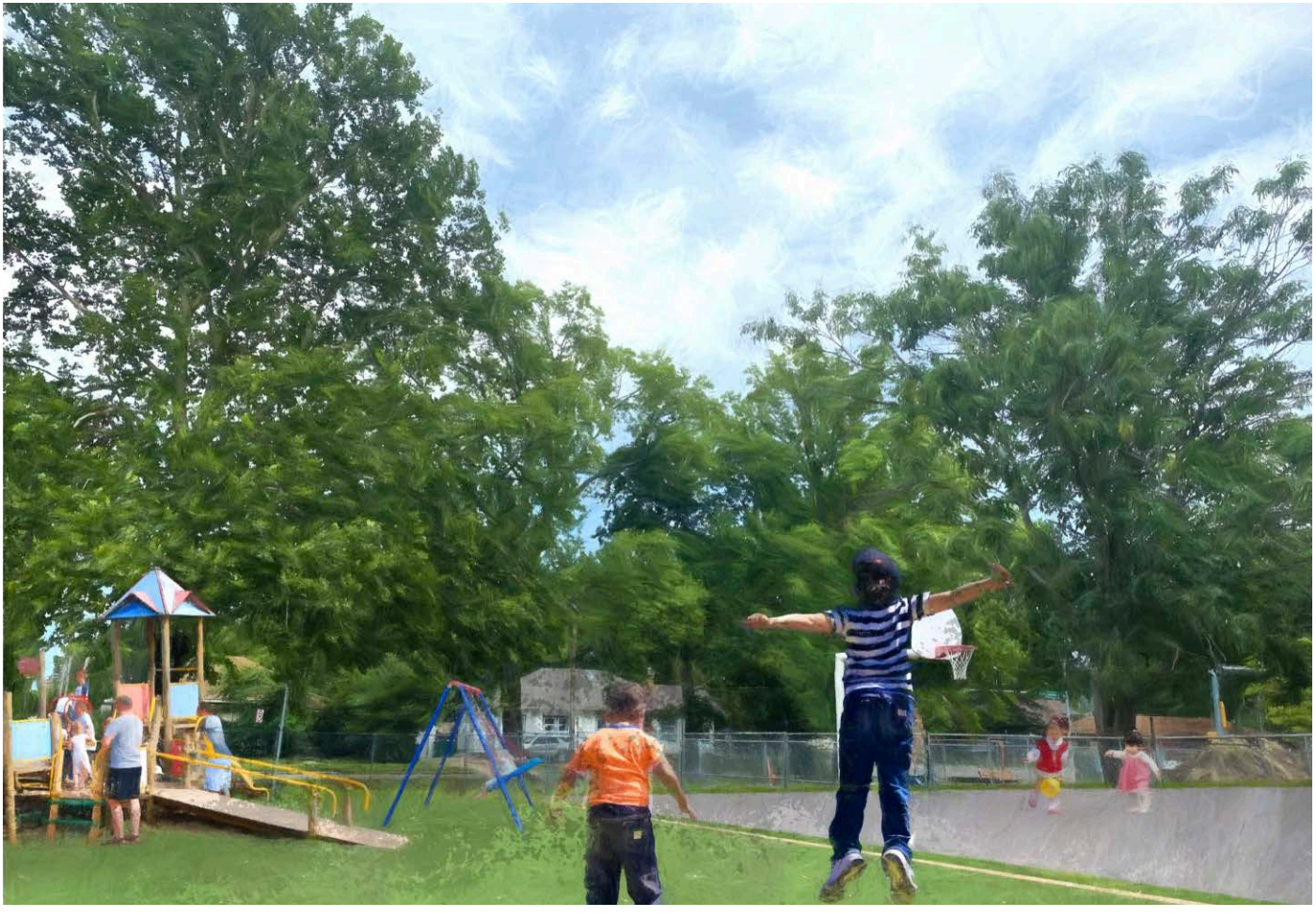


Figure 5.323 Bluemont rendering 2

5.33 Frank V. Bergman Tree Planting Plan

Figure 5.331 Frank V. Bergman tree planting location

Goal:

Plant 25 trees in 5 years

Tree planting priorities

First priority

- **Plant for shade:** Newly planted trees (#1-7) provide shade for children using the playground and for parents and teachers waiting around the playground. Proposed trees (#8-12) provide shade for people around the basketball court area.
- **Plant for microclimate temperature modification:** Newly planted trees will shade the hardscape play area, helping to reduce the surface temperature of the paving.

Year 1: Tree #1, 2, 3, 4, 5, 6, 7

Year 2: Tree #8, 9, 10, 11, 12

Total 12 trees

12 Large shade trees (#1-12)

Second priority

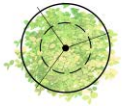
- **Plant for filling the planting beds:** Newly planted trees within landscape islands make the parking lot feel more welcoming and cooler.
- **Plant for shade:** Newly planted trees provide shade for parked vehicles.
- **Plant for spatial enclosure:** Use newly planted trees to create a barrier between the schoolyard and the adjacent road.

Year 3: Tree #13, 14, 17, 18, 19

Year 4: Tree #15, 16, 20, 21, 22

Year 5: Tree #23, 24, 25

Total 13 trees



4 Large shade trees (#13-16)

9 Medium shade trees (#17-25)

Benefit of completing the Edugreen Tree Planting Initiative

- After five years, Frank V. Bergman Elementary School will fill the tree canopy gap around the playgrounds and in the parking lot.

Newly planted trees (#5, 6, 7) provide shade for children using the playground and for parents and teachers waiting around the playground.

Figure 5.332 Frank V. Bergman rendering 1

Two large trees (#1, 2) create a comfortable shaded area.

Figure 5.333 Frank V. Bergman rendering 2

5.34 Lee Tree Planting Plan

Figure 5.341 Lee tree planting location

Goal:

Plant 13 trees in 5 years

Tree planting priorities

First priority

- **Plant for shade:** Newly planted trees provide shade for children using the playground and for parents and teachers waiting around the playground.
- **Plant for spatial enclosure:** Newly planted trees create a barrier between the schoolyard and the adjacent road to reduce the disturbance of busy traffic.
- **Plant for microclimate temperature modification:** Newly planted trees will shade the hardscape play area, helping to reduce the surface temperature of the paving.

Year 1: Tree #1, 2, 3, 4

Year 2: Tree # 5, 6

Year 3: Tree #7, 8

Total 8 trees

5 Large shade trees (#4-8)

3 Medium shade trees (#1-3)

Second priority

- **Plant to fill the planting beds.**

Year 4: Tree #9, 10, 11

Year 5: Tree #12, 13

Total 5 trees

2 Large shade trees (#12, 13)

3 Medium shade trees (9-11)

Benefit of completing the Edugreen Tree Planting Initiative

- After five years, Lee Elementary School will fill the tree canopy gap around the playgrounds and in the parking lot.

Newly planted trees (#3, 4, 7, 8) provide shade for children using the playground and for parents and teachers waiting around the playground.

Figure 5.342 Lee rendering 1

Four trees (#3, 4, 7, 8) increase shade areas next to the playgrounds and form a buffer between the schoolyard and adjacent road.

Figure 5.343 Lee rendering 2

5.35 Marlatt Tree Planting Plan

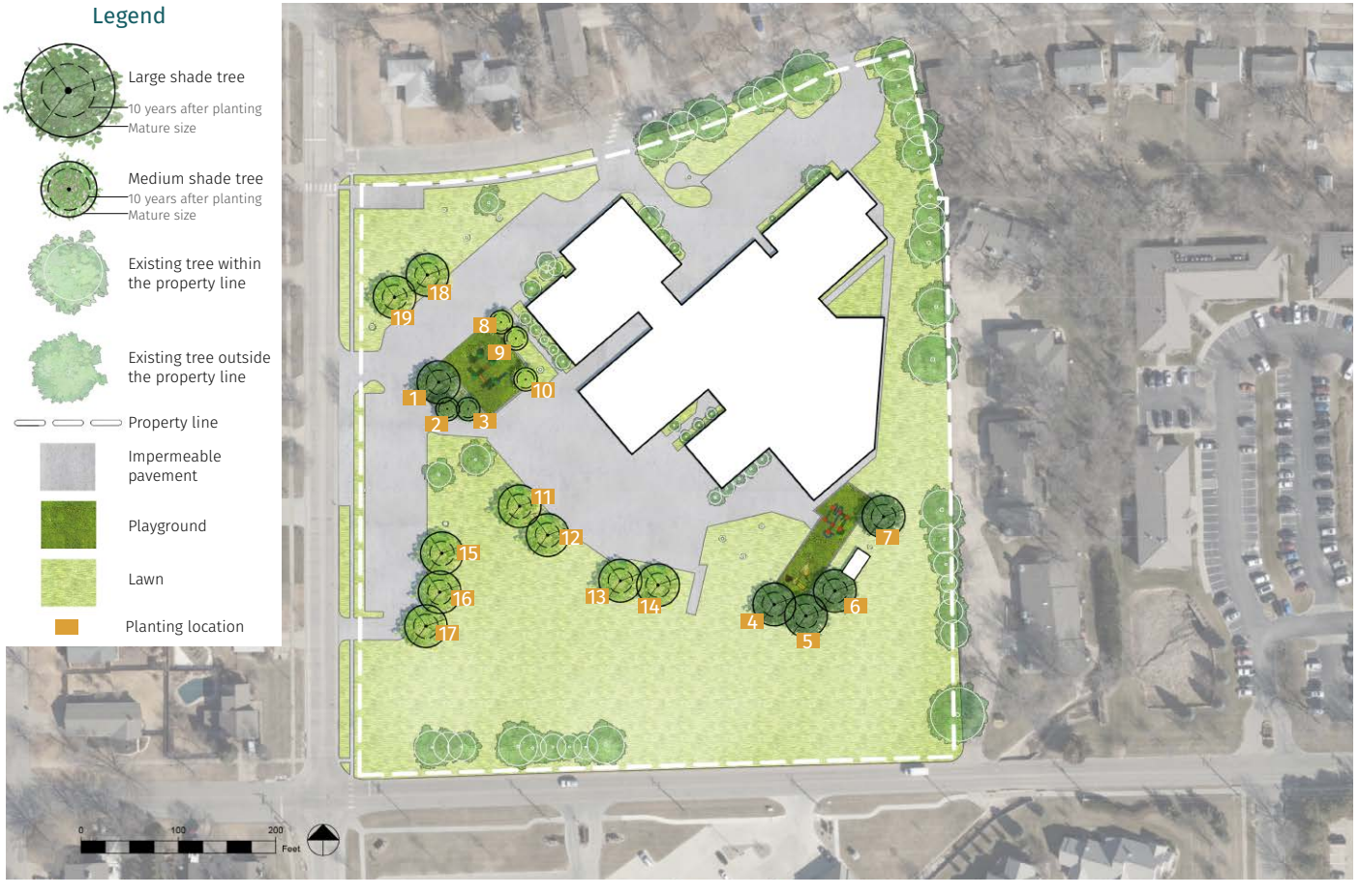


Figure 5.351 Marlatt tree planting location

Goal:

Plant 19 trees in 5 years

Tree planting priorities

First priority

- **Plant for shade:** Newly planted trees provide shade for children using the playground and for parents and teachers waiting around the playground.

Year 1: Tree #1, 2, 3, 4, 5, 6, 7

Total 7 trees

5 Large shade trees (#1, 4-7)

3 Medium shade trees (#2-4)

Second priority

- **Plant for shade:** Newly planted trees (#11-14) provide shade for children using the hardscape play area and for parents and teachers waiting around the hardscape play area.
- **Plant for microclimate temperature modification:** Newly planted trees (#11-14) will shade the hardscape play area, helping to reduce the surface temperature of the paving.
- **Plant for shade:** Newly planted trees (#15-19) provide shade for vehicles.
- **Plant for spatial enclosure:** Newly planted trees (#15-19) connect existing trees to form a buffer between the lawn and parking lot.
- **Plant for aesthetic:** Add ornamental trees (#8, 9, 10) in the high foot traffic area to enhance the aesthetics of the schoolyard.

Year 2: Tree #11, 12, 13, 14

Year 3: Tree #8, 9, 10

Year 4: Tree #15, 16, 17

Year 5: Tree #18, 19

Total 12 trees

9 Large shade trees (#11-19)

3 Medium shade trees (#8-10)

Benefit of completing the Edugreen Tree Planting Initiative

- After five years, Marlatt Elementary School will fill the tree canopy gap around playgrounds and add more trees around the parking lot.

Newly planted trees (#1, 2, 3) provide shade for children using the playground and for parents and teachers waiting around the playground.

Figure 5.352 Marlatt rendering 1

Newly planted trees (#11, 12) around the hardscape play area reduce the temperature of the concrete paving.

Figure 5.353 Marlatt rendering 2

5.36 Northview Tree Planting Plan

Legend

Large shade tree
10 years after planting
Mature size

Medium shade tree
10 years after planting
Mature size

Existing tree within the property line

Existing tree outside the property line

Property line

Impermeable pavement

Playground

Lawn

Unpaved path

Planting location

Figure 5.361 Northview tree planting location

Goal:

Plant 17 trees in 5 years

Tree planting priorities

First priority

- **Plant for shade:** Newly planted trees provide shade for children using the playground and for parents and teachers waiting around the playground.
- **Plant for microclimate temperature modification:** Newly planted trees will shade the hardscape play area, helping to reduce the surface temperature of the paving.

Year 1: Tree #1, 2, 3, 4, 5

Total 5 trees

5 Large shade trees (#1-5)

Second priority

- **Plant for shade:** Newly planted trees (#6-8) provide shade for children using the playground and hardscape play area and for parents and teachers waiting around these areas.
- **Plant for microclimate temperature modification:** Newly planted trees will shade the hardscape play area, helping to reduce the surface temperature of the paving.
- **Plant for spatial enclosure:** Newly planted trees (#9-17) connect existing trees to form a buffer at edge of the schoolyard.
- **Plant for aesthetic:** Add ornamental trees (#11, 12, 14, 15, 16, 17) in the high foot traffic area to enhance the aesthetics of the schoolyard.

Year 2: Tree #6, 7, 8

Year 3: Tree #11, 12, 13, 14

Year 4: Tree #15, 16, 17

Year 5: Tree #9, 10

Total 12 trees

6 Large shade trees (#6-10, 13)

6 Medium shade trees (#11, 12, 14-17)

Benefit of completing the Edugreen Tree Planting Initiative

- After five years, Northview Elementary School will fill the tree canopy gap around playgrounds and add more trees around the parking lot.

Newly planted trees (#1, 2, 3, 4) provide shade for children using the playground and for parents and teachers waiting around the playground.

Figure 5.362 Northview rendering 1

Two large trees (#6, 7) provide shade areas for schoolyard users.

Figure 5.363 Northview rendering 2

5.37 Theodore Roosevelt Tree Planting Plan

Figure 5.371 Theodore Roosevelt tree planting location

Goal:

Plant 16 trees in 5 years

Tree planting priorities

First priority

- **Plant for shade:** Newly planted trees provide shade for children using the playground and for parents and teachers waiting around the playground.

Year 1: Tree #1, 2

Total 2 trees

2 Large shade trees (#1, 2)

Second priority

- **Plant for shade:** Newly planted trees (#6-10) form large shade areas, shown as dashed areas on the map, which is a good place to build a new playground or outdoor learning area.
- **Plant for spatial enclosure:** Newly planted trees (#11, 12) form a buffer at edge of the schoolyard.
- **Plant for aesthetic:** Add ornamental trees (#13, 14, 15) in the high foot traffic area to enhance the aesthetics of the schoolyard.

Year 1: Tree #6, 7, 8

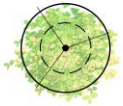
Year 2: Tree #9, 10

Year 3: Tree #11, 12

Year 4: Tree #13, 14

Year 5: Tree #15, 16

Total 14 trees



5 Large shade trees (#8-12)

6 Medium shade trees (#6, 7, 13-16)

Street Trees

Tree 3, 4, 5

- Street tree planting is not included in the Edugreen Tree Planting Initiative, however it is still recommended to request the city plant trees along the public right of way.

Benefits of completing the Edugreen Tree Planting Initiative

- After 5 years, Theodore Roosevelt Elementary School will have doubled the number of trees on its site.

Newly planted trees (#1, 2, 3, 4) form a large shade areas, which is a good place to build an outdoor classroom.

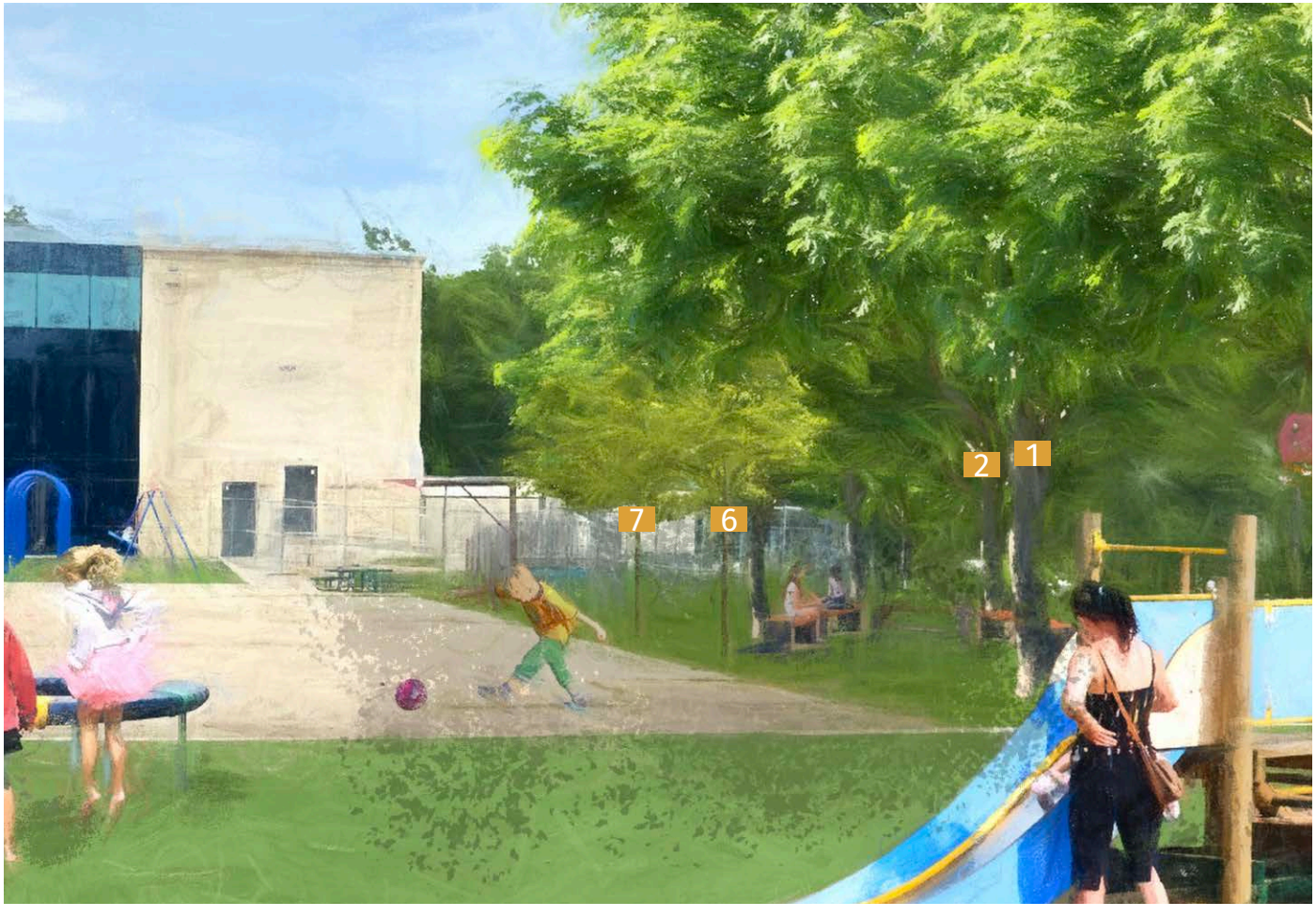


Figure 5.372 Theodore Roosevelt rendering 1

Adding street trees (#3, 4, 5) will benefit the school yard users.

Figure 5.373 Theodore Roosevelt rendering 2

5.38 Woodrow Wilson Tree Planting Plan

Figure 5.381 Woodrow Wilson tree planting location

Goal:

Plant 17 trees in 5 years

Tree planting priorities

First priority

- **Plant for shade:** Newly planted trees provide shade for children using the playground and for parents and teachers waiting around the playground.
- **Plant for microclimate temperature modification:** Newly planted trees (#6-8) will shade the hardscape play area, helping to reduce the surface temperature of the paving.

Year 1: Tree #1, 2, 3, 4

Total 4 trees

2 Large shade trees (#1, 4)

2 Medium shade trees (#2, 3)

Second priority

- **Plant for shade:** Newly planted trees (#11-14) connect the existing trees to form large shade areas, shown as dashed areas on the map, which is a good place to build a new playground or outdoor learning area.
- **Plant for spatial enclosure:** Newly planted trees (#15-17) create a barrier between the schoolyard and the public road to reduce the disturbance of busy traffic.

Year 2: Tree #11, 12

Year 3: Tree #13, 14

Year 4: Tree #15, 16

Year 5: Tree #17

Total 7 trees

3 Large shade trees (#11, 16, 17)

4 Medium shade trees (#12-15)

Street Trees

Tree 7, 8, 9, 10

- Street tree planting is not included in the Edugreen Tree Planting Initiative, however it is still recommended to request the city plant trees along the public right of way.

Benefit of completing the Edugreen Tree Planting Initiative

- After 5 years, Woodrow Wilson elementary school will have doubled the number of trees on its site.

Newly planted trees (#4, 11) form a large shade areas, which is a good place to build an outdoor classroom.

Figure 5.382 Woodrow Wilson rendering 1

Newly planted trees (#1, 2) provide shade for children using the playground and for parents and teachers waiting around the playground.

Figure 5.383 Woodrow Wilson rendering 2

5.4 Education, Outreach and Other Information

5.41 Information related to tree planting

Kansas Forest Service Resources

Pages contain publications, videos, podcast episodes and educational articles related to trees in the Kansas.

https://www.kansasforests.org/resources/

Selecting and Planting a Tree

This document was developed by K-State Extension and provided by Kansas Forest Service. It includes the recommendations for selecting and planting different types of trees, including the method and frequency of mulch and watering.

https://bookstore.ksre.ksu.edu/pubs/L870.pdf

Arbor Day Foundation

Arbor Day Foundation has grown over the last 50 years to become the largest member nonprofit organization dedicated to planting trees. A wide variety of information related to trees can be found on the foundation's official website.

https://www.arborday.org/

5.42 Educational sources for developing tree-related curriculum

My Tree Activity Book

An activity guide developed that corresponds with 3rd grade level science standards. Provided by Tree Matters for the Trees for Schools project.

https://treesmatter.org/Trees-for-Schools

USDA Forest Service Kids

Contains a series of natural environment education websites and videos for children, suitable as a reference for the development of tree-related units, courses, and curriculum.

https://www.fs.usda.gov/learn/kids

USDA Forest Service Kids

Contains a series of natural environment education websites and videos for children, suitable as a reference for the development of tree-related units, courses, and curriculum.

https://www.fs.usda.gov/learn/kids

Tree Campus K–12 at arborday.org

Tree Campus K-12 inspires collaboration between schools, students, and communities to facilitate experiences with trees as a learning tool. The program encourages schools and educators to create purposeful opportunities for students to interact with trees by offering resources as well as a framework for becoming recognized and celebrating their efforts with their community.

https://www.arborday.org/programs/tree-campus-k-12/

Project Learning Tree(PLT)

Project Learning Tree is an initiative of the Sustainable Forestry Initiative. It uses trees and forests as windows on the world to increase students' understanding of the environment and actions they can take to conserve it. It helps develop students' awareness, knowledge, and appreciation of the environment, builds their skills and ability to make informed decisions, and encourages them to take personal responsibility for sustaining the environment and our quality of life that depends on it.

The PLT program is characterized by three equally important components:

- high-quality instructional materials for grades PreK-12,
- carefully designed professional development, and
- an extensive distribution and support network.

PLT's instructional materials for early childhood through grade 12 can be used with students in formal school settings and with youth in nonformal settings. The hands-on activities make teaching and learning fun. They connect children to nature, engage students in learning, improve student achievement, and grow 21st century skills – including the ability to think critically and solve problems.

https://www.fs.usda.gov/learn/kids

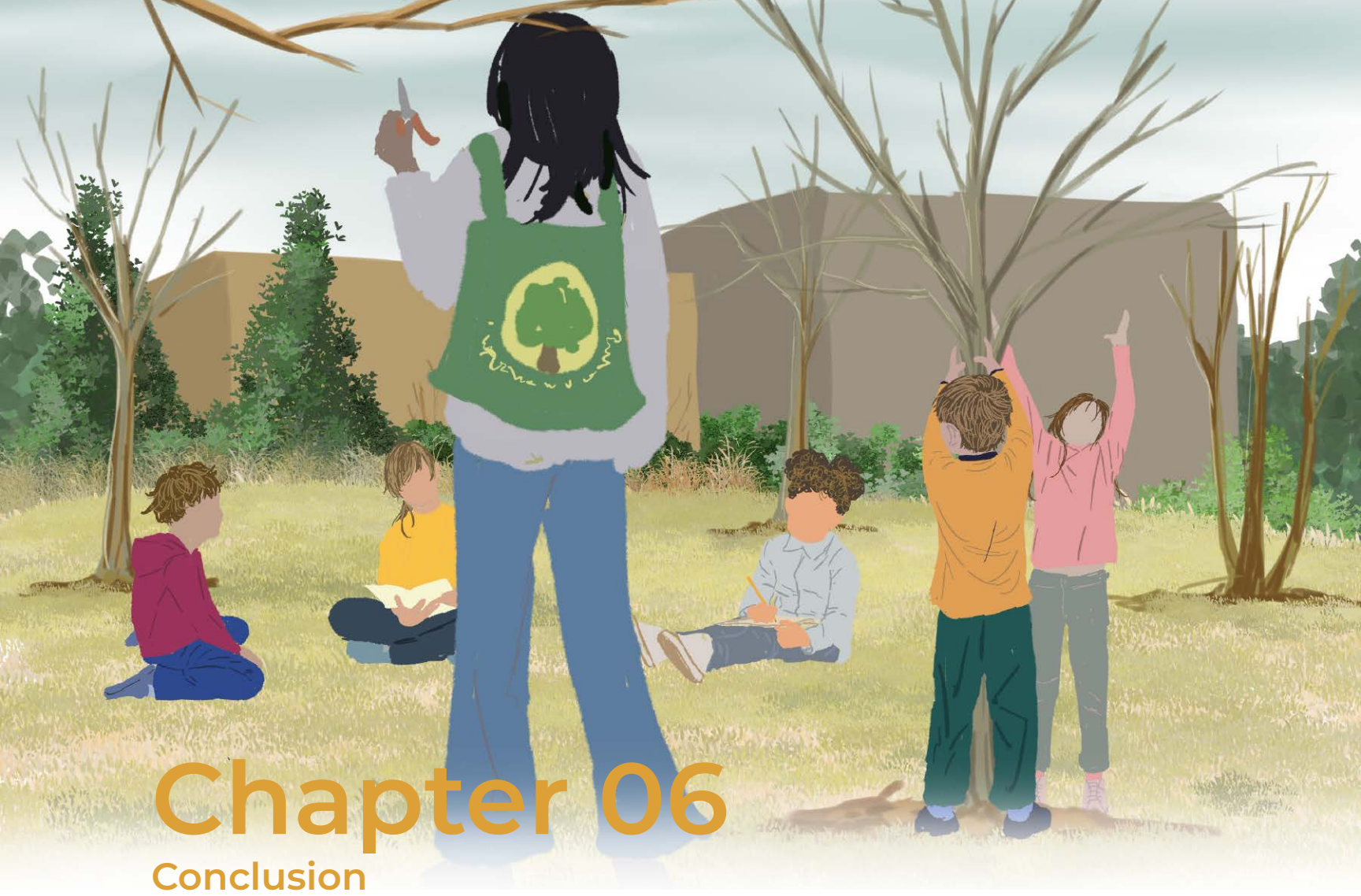
5.43 Information for further research

i-Tree Design

For people interested in measuring the benefits of newly added trees, the i-Tree Design tool helps estimate individual tree benefits in terms of carbon dioxide, air pollution, stormwater impacts, and energy savings.

i-Tree Design estimates tree benefits for the current year and up to 99 years in the future. Total benefits to date based on estimated tree age are also provided. Multiple trees and buildings can be modeled.

https://www.arborday.org/programs/tree-campus-k-12/



Chapter 06

Conclusion

Conclusion

6.1 Project Summary

By implementing the 5-year Edugreen Tree Planting Initiative a total of 137 trees can be planted on eight elementary school sites in Manhattan, KS. This will significantly increase beneficial shade and create an opportunity for children to have a more enjoyable and safer experience within the school yard.

Edugreen Tree Planting Initiative was created by doing a site analysis of eight elementary school sites in Manhattan, Kansas, a precedent study of schoolyard tree planting programs, a survey of eight principles, an interview of the district maintenance department, and a document review. Outcomes include a student-involved, community-supported tree planting initiative framework and a timeline, individual school planting plans, and educational resource suggestions. For people who want to add trees to these eight schoolyards, this five-year tree planting initiative shows the possibility of adding trees to the schoolyard without putting landscape funding and maintenance pressures on the school district.

Like many tree planting initiatives, in order for Edugreen to succeed, it will require the support of many dedicated individuals. These individuals must champion and support tree implementation and maintenance at each school. The need for maintenance, including watering and pruning, is also essential. Planting the trees is the easy part, ensuring they survive is harder.

Student-involved tree planting activities can expand students' interactions with trees and create an emotional connection between them and the trees they planted, finally increasing students' awareness and education of the natural environment. The initiative fosters community support for the campus tree program and encourages good tree management on school properties. The trees added by this initiative also enhance schoolyard canopy cover and will help to contribute to the urban tree canopy.

The initiative begins to address the lack of trees in schools with an informed step in the right direction. Making slight changes every year, like planting a tree or two, can make a qualitative and quantitative difference in the schoolyard five years later. A popular Chinese proverb that says: "The best time to plant a tree was 20 years ago. The second-best time is now."

6.2 Limitation of the Study

This initiative seeks to plant trees that benefit students and schoolyard users but may be biased because respondents to the survey only selected the principal of each school. The gathering of information should be expanded to a broader population. To increase the diversity of participants, teachers and school staff should be the target population since they spend more time with students and are familiar with the school curriculum and daily activities.

Waiting for responses to the surveys and subsequent extraction and application of the obtained information to the design was time-consuming. Due to time constraints and an unclear process for district approval for studies conducted for USD 383 School District, the results cannot be published directly. They cannot be a clear representation of individual schools' perceptions of shade and tree planting.

Additionally, requests for interviews of the USD 383 maintenance department staff were unanswered, despite multiple follow-ups. All the information related to the schoolyard maintenance is from Manhattan-Ogden USD 383 Maintenance and Facilities Procedures document and not first hand knowledge from employees. It is unclear about the attitude of the maintenance crews to planting trees in the schoolyards and letting others help plant and maintain trees.

6.3 Potential of Future Study

This initiative assumes an ideal situation. In practice, convincing the district to start the initiative and getting support from the district and the school was one of the biggest challenges. Awareness of the importance and benefits of trees in the schoolyard is the basis for driving the tree planting initiative started. Team formation, finding partners, and moving the initiative forward require more detailed consideration. To ensure this initiative is fulfilled, community support is essential. Help should be sought from different types of partners according to the needs of the initiative.

The initiative framework and timeline in this project were explicitly created for the eight elementary schools in Manhattan, KS, in the USD 383 Manhattan- Ogden School District. Other schools in the district, state, or nation may see this as possible for them. After some adjustments, other schools interested in planting trees in the schoolyard may be able to use the information for a situation outside of the project sites.

This initiative opens many possibilities for planting trees in the schoolyard, making the school landscape a part of community responsibility and students' knowledge acquisition. Making the tree planting initiative possible is a process of multi-party consultation. The future direction of efforts is to integrate as many resources as possible and conduct more in-depth research on the effective ways to engage people to participate in schoolyard tree planting and maintenance. Furthermore, while this project provides

the initiative framework, timeline, and planting plans for schools, studies can be conducted to gain more insight into students' experience of planting activities and tree-related courses. To enable students to gain long-term awareness and education about trees and the environment through participation in tree planting activities and related practices.

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KANSAS STATE UNIVERSITY | University Research Compliance Office

TO: Jessica Canfield
Landscape Archit & Comm Plan
Manhattan, KS 66506

Proposal Number: IRB-11006

FROM: Rick Scheidt, Chair
Committee on Research Involving Human Subjects

DATE: 02/01/2022

RE: Proposal Entitled, "EDUGREEN-A Tree Planting Initiative and Management Plan for Manhattan, Kansas' Elementary Schools."

The Committee on Research Involving Human Subjects / Institutional Review Board (IRB) for Kansas State University has reviewed the proposal identified above and has determined that it is EXEMPT from further IRB review. This exemption applies only to the proposal - as written – and currently on file with the IRB. Any change potentially affecting human subjects must be approved by the IRB prior to implementation and may disqualify the proposal from exemption.

Based upon information provided to the IRB, this activity is exempt under the criteria set forth in the Federal Policy for the Protection of Human Subjects, **45 CFR §104(d), category:Exempt Category 2 Subsection ii.**

Certain research is exempt from the requirements of HHS/OHRP regulations. A determination that research is exempt does not imply that investigators have no ethical responsibilities to subjects in such research; it means only that the regulatory requirements related to IRB review, informed consent, and assurance of compliance do not apply to the research.

Any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Committee on Research Involving Human Subjects, the University Research Compliance Office, and if the subjects are KSU students, to the Director of the Student Health Center.

Electronically signed by Rick Scheidt on 02/01/2022 5:33 PM ET

203 Fairchild Hall, Manhattan, KS 66502 | (785) 532-3224 | fax: (785) 532-3278

Interview of USD 383 Landscape Maintenance Staff

My name is Jia Cheng, I am a graduate student in the Landscape Architecture program at Kansas State University. I am currently working on my master's project & report, which is about the landscape design of local elementary schoolyards, with a focus on trees.

To inform my work, I have several specific questions regarding the landscape maintenance of the USD 383 elementary schools, which I hope you can answer for me. It is anticipated to take 10 - 15 minutes of your time. The information you provide will help inform my proposed landscape design project and may be included in my final written report.

Your participation in my graduate project is voluntary, and you do not have to answer any questions you do not want to. Answers collected as part of this project will not be used in other projects. Should you have questions, please contact my advisor, Associate Professor Jessica Canfield (jesscan@ksu.edu)

Because I intend to include the answers in my final written report, I must ask for consent to include your name. Please note however, that because your name is listed on a public website as an employee of USD 383, I cannot ensure full anonymity between your identity and your answers.

____I consent to associating my name with my answers (your name will be included in the final written report).

____I do not consent to associating my name with my answers (your name will not be included in the final written report. However full anonymity cannot be ensured because your name appears on a public website).

Thank you for your consideration and time in support of my graduate project.

I am hoping you can reply by **Friday, February 11th, 2022**. I will reach out again with a reminder email if I do not hear back from you.

Questions

1. How many employees conduct landscape maintenance at the USD383 elementary school sites?

2. What are the typical landscape maintenance tasks done at the elementary school sites, and how frequent are they done?

3. Does maintenance staff conduct any regular tree care practices (pruning, pests, mulching, watering, etc.)?

4. Does the maintenance department ever contract out any tree care practices?

5. How are decisions made regarding the landscape design at the elementary school sites?

6. How and who determines if new trees will be planted at the elementary school sites? Does each school oversee decisions at their own sites, or is there any district level approval needed?

7. When a new tree is planted at an elementary school site, who determines where it will be planted? Who provides initial establishment care for it (watering, mulching, etc.)?

8. Would the district be supportive of a community volunteer group dedicated to helping plant and care for new trees?

9. What are some challenges related to maintaining the current schoolyards and trees?

10. What is your opinion about increasing the number of trees at the elementary schools?

11. Is there anything else you would like to share regarding the landscape maintenance and tree care for the elementary schools?

Thank you very much for your time.

KANSAS STATE UNIVERSITY | University Research Compliance Office

TO: Jessica Canfield
Landscape Archit & Comm Plan
Manhattan, KS 66506

Proposal Number: IRB-11042

FROM: Rick Scheidt, Chair
Committee on Research Involving Human Subjects

DATE: 02/15/2022

RE: Proposal Entitled, "EDUGREEN-A Tree Planting Initiative and Management Plan for Manhattan, Kansas' Elementary Schools Part-2 Survey of Principals."

The Committee on Research Involving Human Subjects / Institutional Review Board (IRB) for Kansas State University has reviewed the proposal identified above and has determined that it is EXEMPT from further IRB review. This exemption applies only to the proposal - as written – and currently on file with the IRB. Any change potentially affecting human subjects must be approved by the IRB prior to implementation and may disqualify the proposal from exemption.

Based upon information provided to the IRB, this activity is exempt under the criteria set forth in the Federal Policy for the Protection of Human Subjects, **45 CFR §104(d), category:Exempt Category 2 Subsection ii.**

Certain research is exempt from the requirements of HHS/OHRP regulations. A determination that research is exempt does not imply that investigators have no ethical responsibilities to subjects in such research; it means only that the regulatory requirements related to IRB review, informed consent, and assurance of compliance do not apply to the research.

Any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Committee on Research Involving Human Subjects, the University Research Compliance Office, and if the subjects are KSU students, to the Director of the Student Health Center.

Electronically signed by Rick Scheidt on 02/15/2022 2:56 PM ET

203 Fairchild Hall, Manhattan, KS 66502 | (785) 532-3224 | fax: (785) 532-3278

Graduate Student Project on Schoolyard Trees

Introduction to Participants

This graduate research project has IRB approval from Kansas State University, #IRB-11042. Your participation in this project is voluntary and you may end your participation at any time, without penalty. There are no anticipated risks in participating, and you do not have to answer any questions you do not want to. Answers collected will not be used in other research projects. By agreeing to participate, you consent to your name and answers being included in my final written report.

Should you have questions, please contact my advisor, Associate Professor Jessica Canfield

(jesscan@ksu.edu).

Do you agree to participate?

- Yes
- No

Q1. Your Name:

Q2. Your School:

- Amanda Arnold Elementary School
- Bluemont Elementary School
- Frank V. Bergman Elementary School
- Lee Elementary School
- Marlatt Elementary School
- Northview Elementary School
- Ogden Elementary School
- Oliver Brown Elementary School
- Theodore Roosevelt Elementary School
- Woodrow Wilson Elementary School

Q3. How many years have you been principal at your school? 3. How many years have you been principal at your school?

Q4. Please select all student activities that occur outside at your school. (Check all that apply)

Recess

Lunch

Assemblies or special events

Physical education class

Classroom educational activities

Informal social gatherings

Extended day activities

Intermural or intramural athletic events

Other

Q5. When students participate in outdoor activities, do you think there is adequate shade afforded to them on sunny days?

Definitely yes

Probably yes

Probable not

Definitely not

Unsure

Q6. If you think there is inadequate shade afforded to students on sunny days, to what extent do you think a lack of shade impacts students' abilities to fully enjoy and participate in outdoor activities?

Very impacted

Moderately impacted

Somewhat impacted

Slightly impacted

Not impacted

Unsure

Q7. Do you think there is a need for additional trees to be planted at your school site?

Definitely yes

Probably yes

Probable not

Definitely not

Unsure

Q8. If you think there is a need for additional trees, please indicate where on site they are needed and the level of priority for the need.

Near playground equipment

In open lawn areas

Along the site's edges/along the perimeter

Near the parking lots

Near the building

At building entrances and exits

Other

Q9. If new trees were to be added to your school site, who makes this determination and what approvals are needed? Please briefly describe the process for a landscape improvement project at your school.

Q10. Please indicate the level of interest you think your school community might have in engaging students in the planting and care of new trees on site.

School teachers

School staff

School clubs

PTO

Other

Q11. Would your school welcome the support of an outside community volunteer group to help fund, plant, and care for new trees?

Definitely yes

Probably yes

Probable not

Definitely not

Unsure

Q12. Are you aware of any existing lessons/study units in your school related to trees?

Yes

No

Unsure

Q13. Do you think a lesson/study unit focused on trees could be incorporated?

Definitely yes

Probably yes

Probable not

Definitely not

Unsure

N/A - we already have a lesson/study unit focusing on trees

Q14. In terms of a designated outdoor classroom space, please check all that are true of your school site.

We have outdoor classroom space.

Our outdoor classroom space is shaded.

Our outdoor classroom space is unshaded.

We do not currently have an outdoor classroom space.

We are currently developing an outdoor classroom space.

We have an interest in developing an outdoor classroom space.

Q15. Is there anything else you would like to share regarding your school's trees and/or landscape designs trees and/or landscape design that would be helpful for me to understand?

i-Tree Ecosystem Analysis

Amanda

Urban Forest Effects and Values
March 2022

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Amanda urban forest was conducted during 2022. Data from 70 trees located throughout Amanda were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 70
- Tree Cover: 8.0 %
- Most common species of trees: Eastern red cedar, elm spp, oak spp
- Percentage of trees less than 6" (15.2 cm) diameter: 5.7%
- Pollution Removal: 48.8 pounds/year ($137/year)
- Carbon Storage: 44.29 tons ($7.55 thousand)
- Carbon Sequestration: 1511 pounds ($129/year)
- Oxygen Production: 2.015 tons/year
- Avoided Runoff: 1.871 thousand cubic feet/year ($125/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Replacement values: $164 thousand

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control.

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I. Tree Characteristics of the Urban Forest

The urban forest of Amanda has 70 trees with a tree cover of 8.0 percent. The three most common species are Eastern red cedar (54.3 percent), elm spp (11.4 percent), and oak spp (7.1 percent).

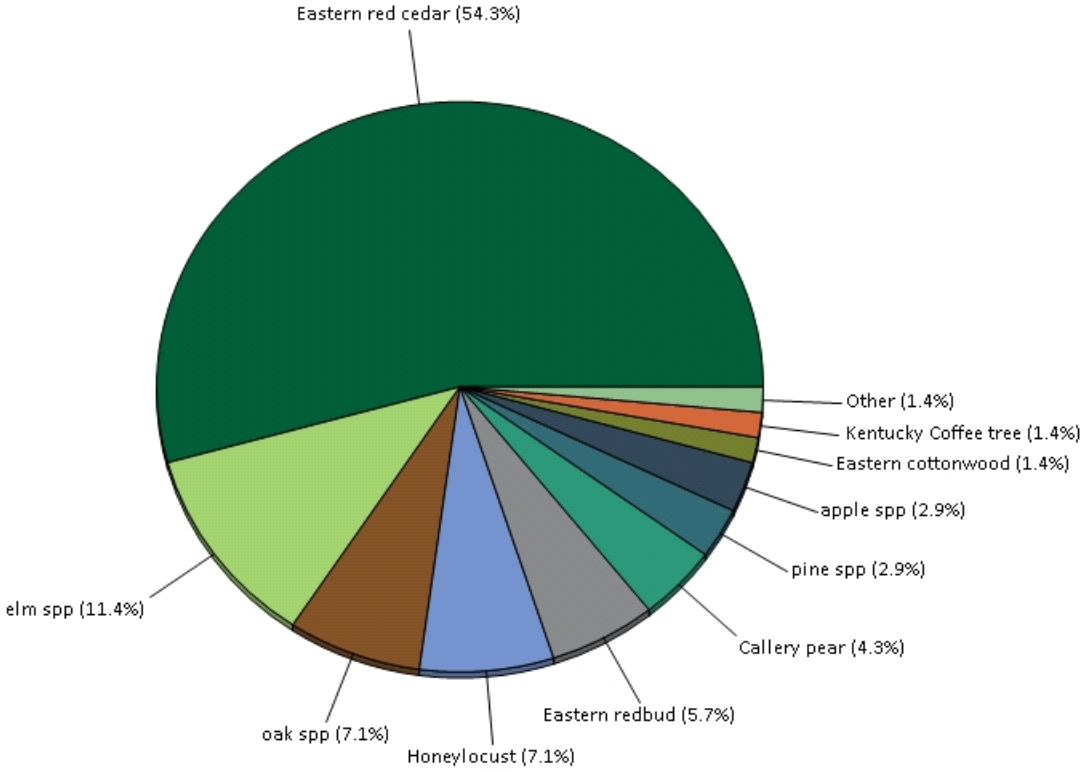


Figure 1. Tree species composition in Amanda

The overall tree density in Amanda is 7 trees/acre (see Appendix III for comparable values from other cities).

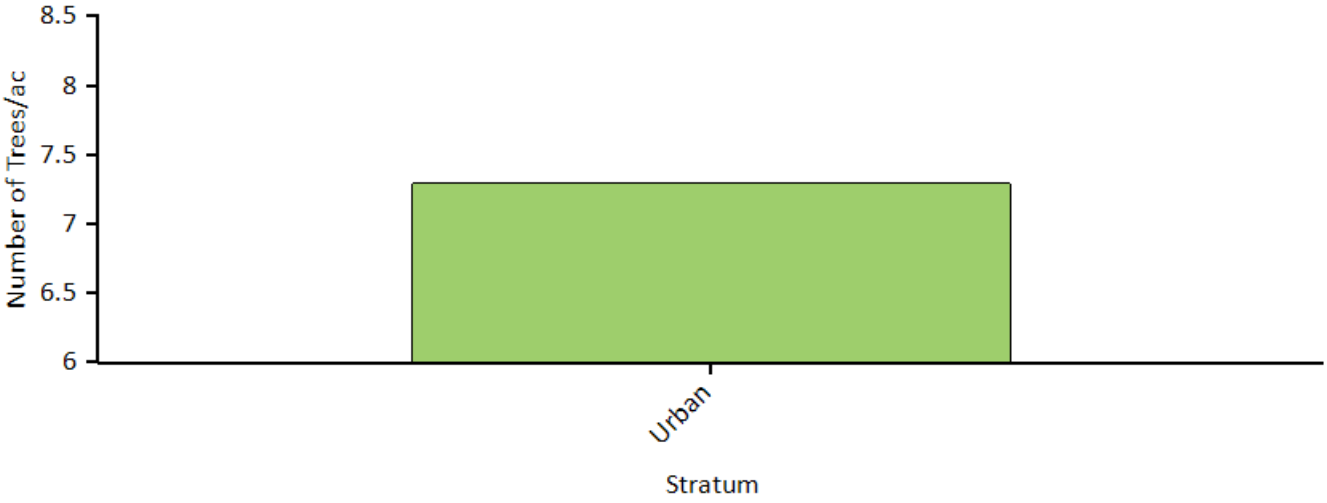


Figure 2. Number of trees/ac in Amanda by stratum

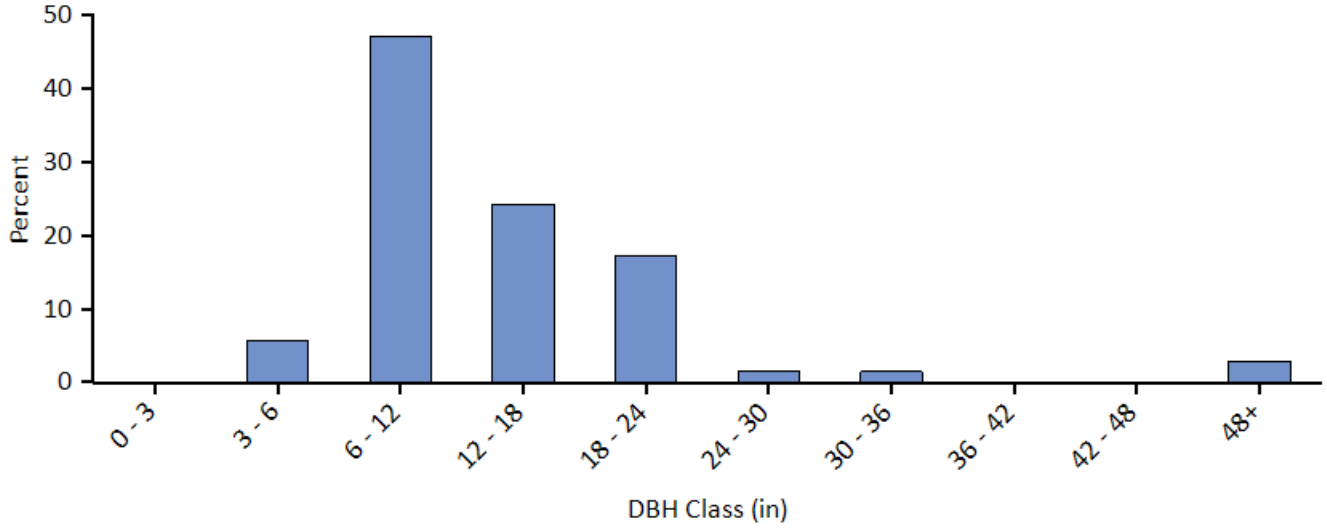


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Amanda, about 70 percent of the trees are species native to North America, while 69 percent are native to Kansas. Species exotic to North America make up 30 percent of the population. Most exotic tree species have an origin from North America + (26 percent of the species).

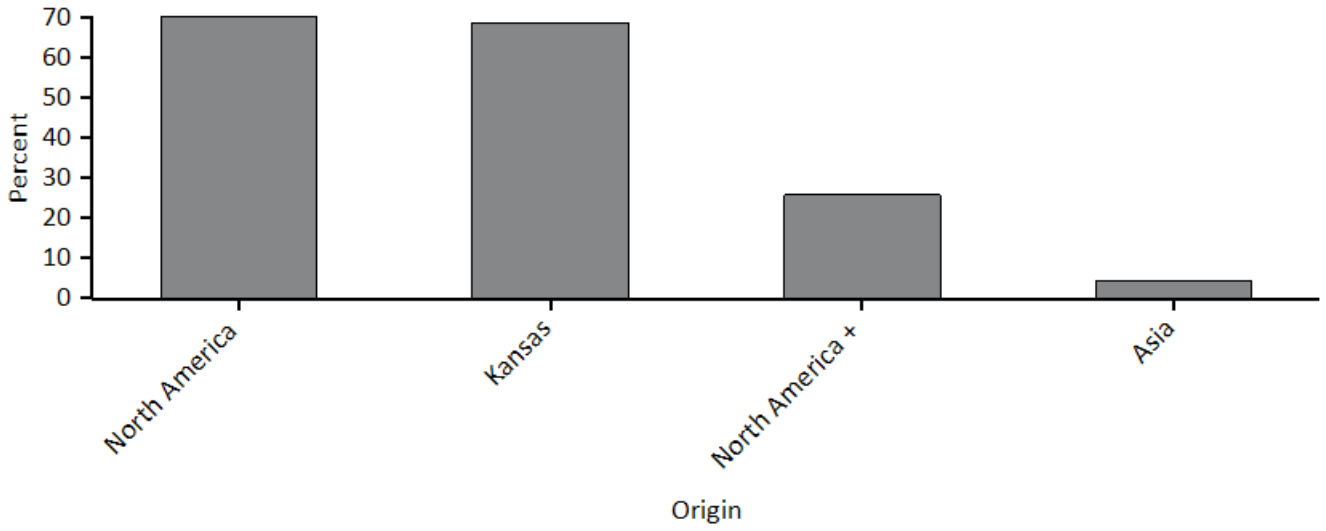


Figure 4. Percent of live tree population by area of native origin, Amanda

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. One of the 11 tree species in Amanda are identified as invasive on the state invasive species list (Kansas Native Plant Society 2006). This invasive species (Callery pear) comprises 4.3 percent of the tree population though it may only cause a minimal level of impact (see Appendix V for a complete list of invasive species).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 8 percent of Amanda and provide 3.967 acres of leaf area. Total leaf area is greatest in Urban.

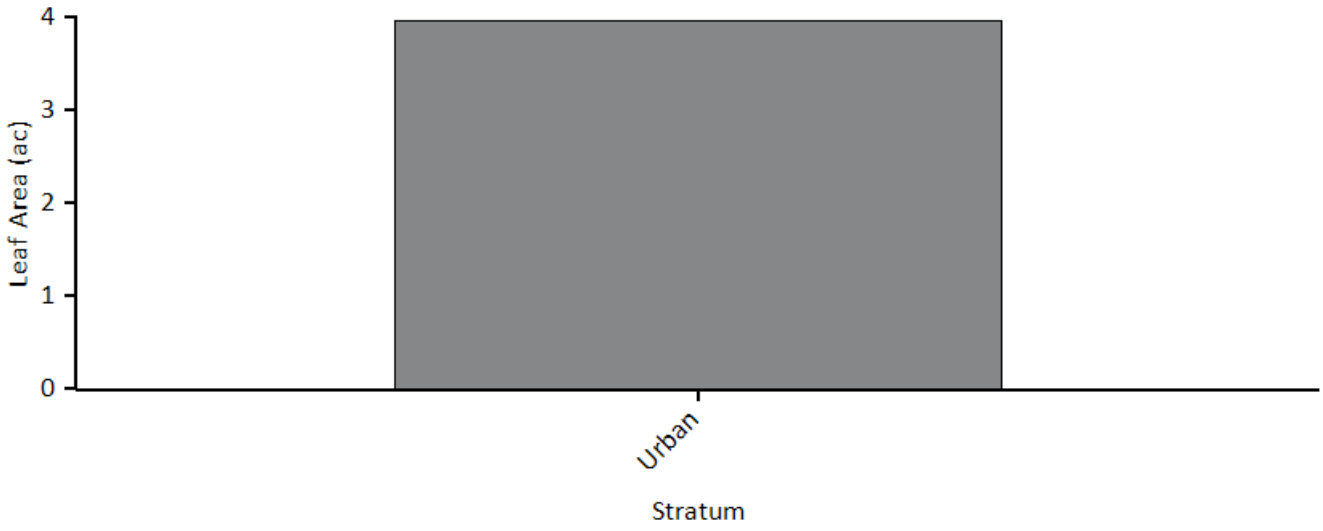


Figure 5. Leaf area by stratum, Amanda

In Amanda, the most dominant species in terms of leaf area are Eastern red cedar, oak spp, and Honeylocust. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Amanda

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Eastern red cedar	54.3	32.2	86.5
elm spp	11.4	13.5	24.9
oak spp	7.1	16.1	23.3
Honeylocust	7.1	14.9	22.0
Callery pear	4.3	7.5	11.8
Eastern cottonwood	1.4	7.1	8.5
Eastern redbud	5.7	2.7	8.4
pine spp	2.9	3.3	6.1
apple spp	2.9	0.8	3.7
Kentucky Coffee tree	1.4	1.2	2.6

Common ground cover classes (including cover types beneath trees and shrubs) in Amanda are not available since they are configured not to be collected.

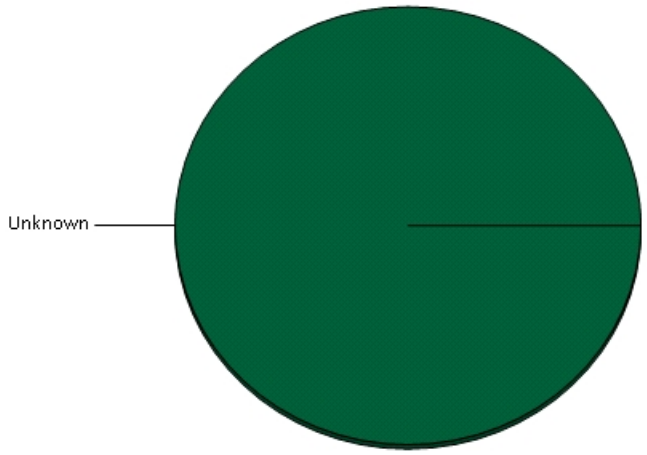


Figure 6. Percent of land by ground cover classes, Amanda

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in Amanda was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 48.8 pounds of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), particulate matter less than 10 microns and greater than 2.5 microns (PM10*)[2], and sulfur dioxide (SO2)) per year with an associated value of $137 (see Appendix I for more details).

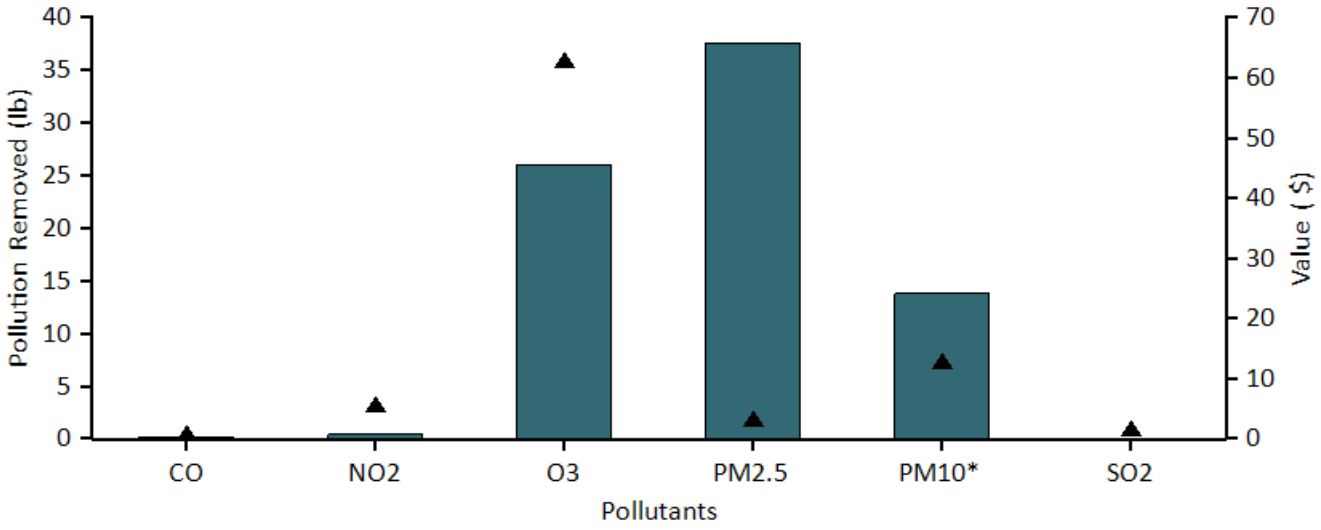


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Amanda

[1] PM10* is particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is particulate matter less than 2.5 microns. If PM2.5 is not monitored, PM10* represents particulate matter less than 10 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces. This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2022, trees in Amanda emitted an estimated 49.75 pounds of volatile organic compounds (VOCs) (23.72 pounds of isoprene and 26.03 pounds of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Seventy- seven percent of the urban forest's VOC emissions were from oak spp and Eastern red cedar. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Amanda trees is about 1511 pounds of carbon per year with an associated value of $129. See Appendix I for more details on methods.

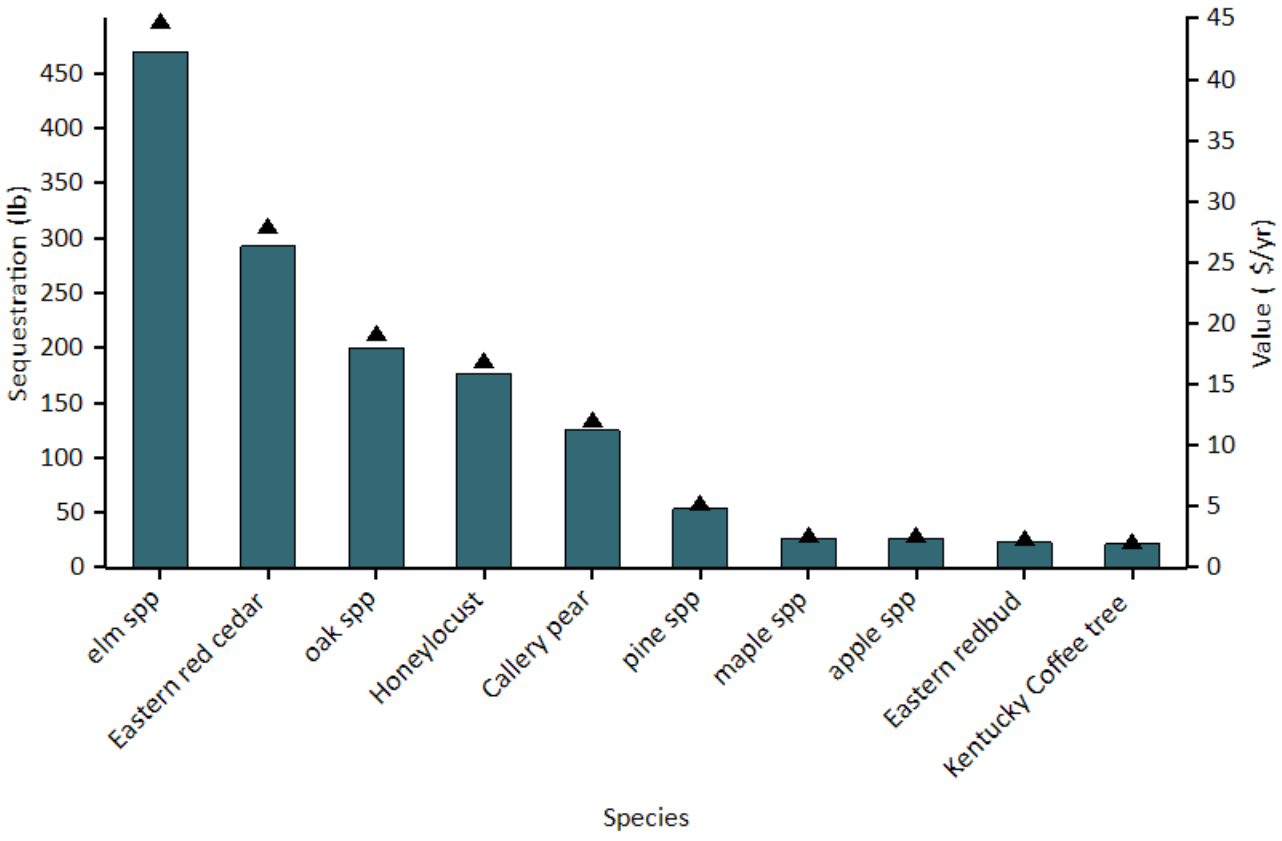


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Amanda

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Amanda are estimated to store 44.3 tons of carbon ($7.55 thousand). Of the species sampled, elm spp stores and sequesters the most carbon (approximately 26.4% of the total carbon stored and 32.8% of all sequestered carbon.)

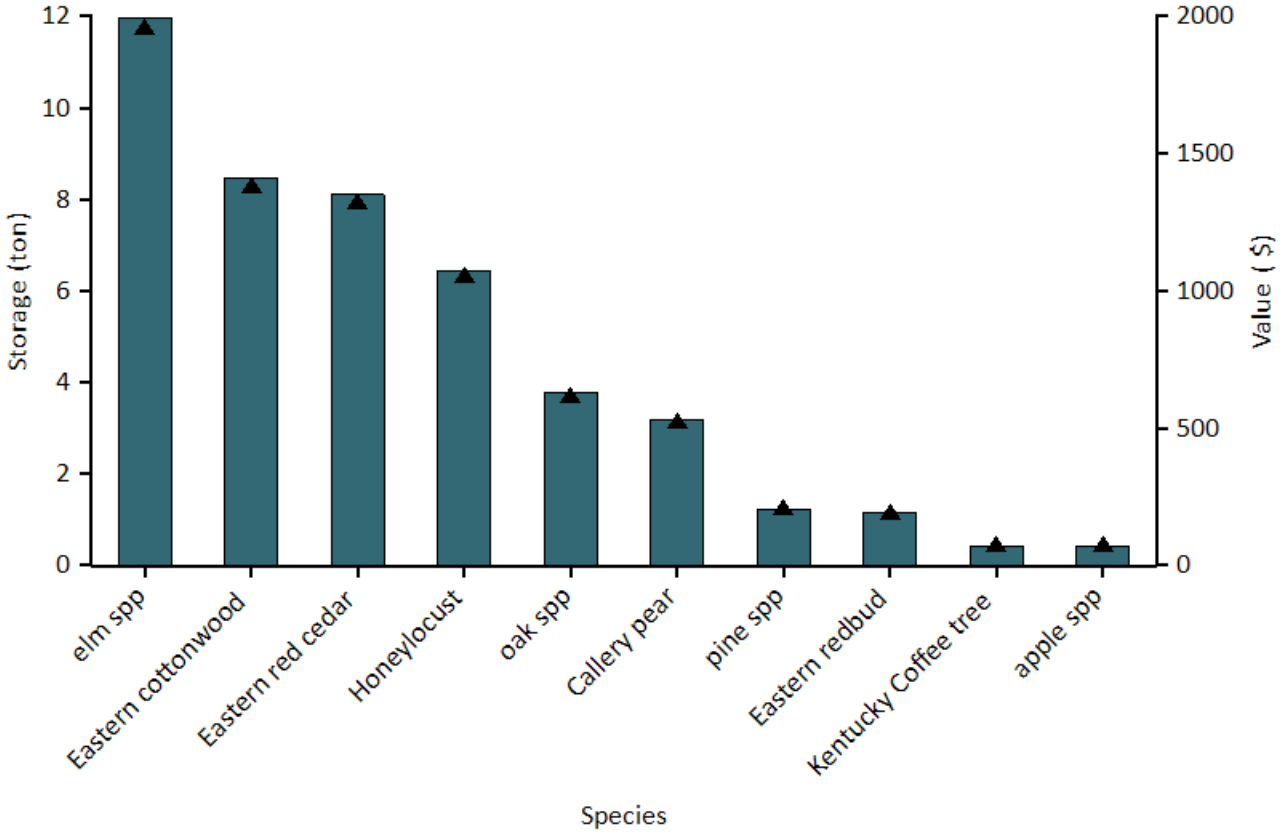


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Amanda

V. Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Amanda are estimated to produce 2.015 tons of oxygen per year.[4] However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 11 oxygen production species.

Species	*Oxygen (pound)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (acre)*
elm spp	1,322.61	495.98	8	0.53
Eastern red cedar	824.29	309.11	38	1.28
oak spp	563.92	211.47	5	0.64
Honeylocust	496.78	186.29	5	0.59
Callery pear	352.24	132.09	3	0.30
pine spp	149.81	56.18	2	0.13
maple spp	74.32	27.87	1	0.03
apple spp	73.64	27.61	2	0.03
Eastern redbud	64.90	24.34	4	0.11
Kentucky Coffee tree	60.07	22.53	1	0.05
Eastern cottonwood	47.78	17.92	1	0.28

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Amanda help to reduce runoff by an estimated 1.87 thousand cubic feet a year with an associated value of $130 (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Amanda, the total annual precipitation in 2019 was 44.7 inches.

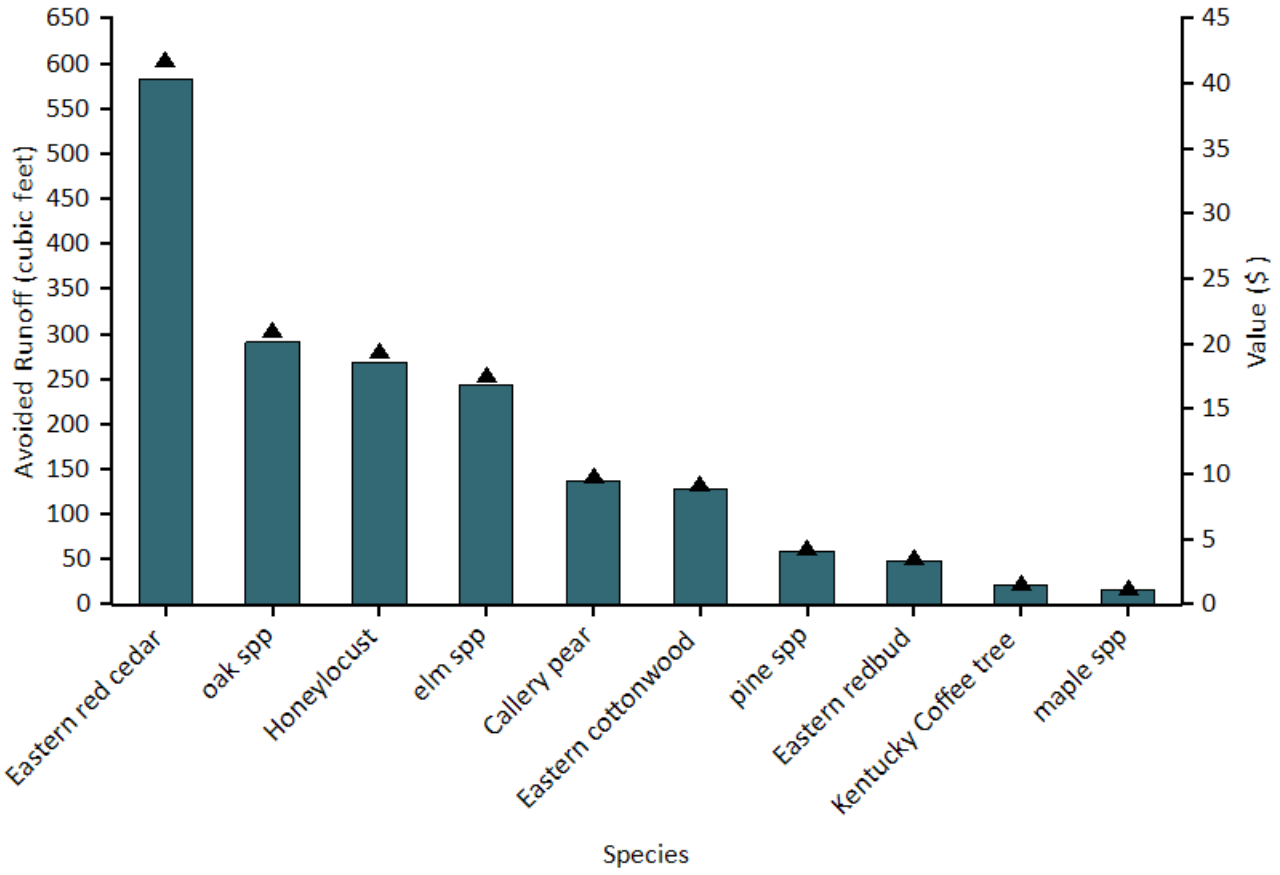


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Amanda

VII. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Because energy-related data were not collected, energy savings and carbon avoided cannot be calculated.

Table 3. Annual energy savings due to trees near residential buildings, Amanda

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (pounds)	0	0	0

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, Amanda

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of $130.2 per MWH and $11.3442000317562 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Replacement and Functional Values

Urban forests have a replacement value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The replacement value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Amanda have the following replacement values:

- Replacement value: $164 thousand
- Carbon storage: $7.55 thousand

Urban trees in Amanda have the following annual functional values:

- Carbon sequestration: $129
- Avoided runoff: $125
- Pollution removal: $137
- Energy costs and carbon emission values: $0

(Note: negative value indicates increased energy cost and carbon emission value)

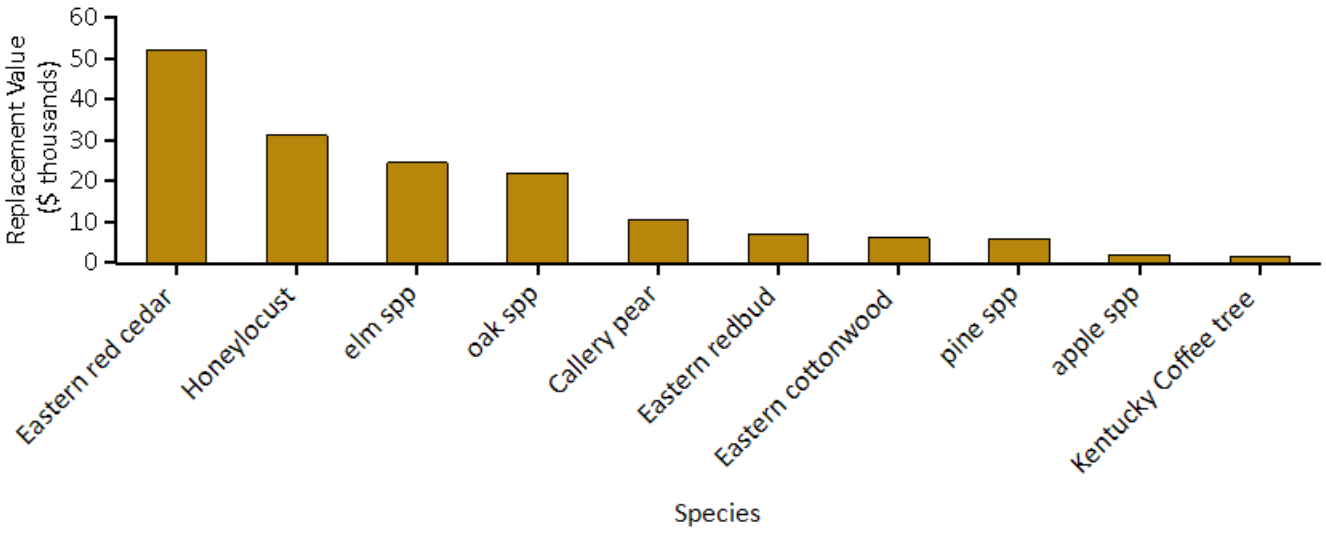


Figure 11. Tree species with the greatest replacement value, Amanda

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, replacement value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Riley County. One of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

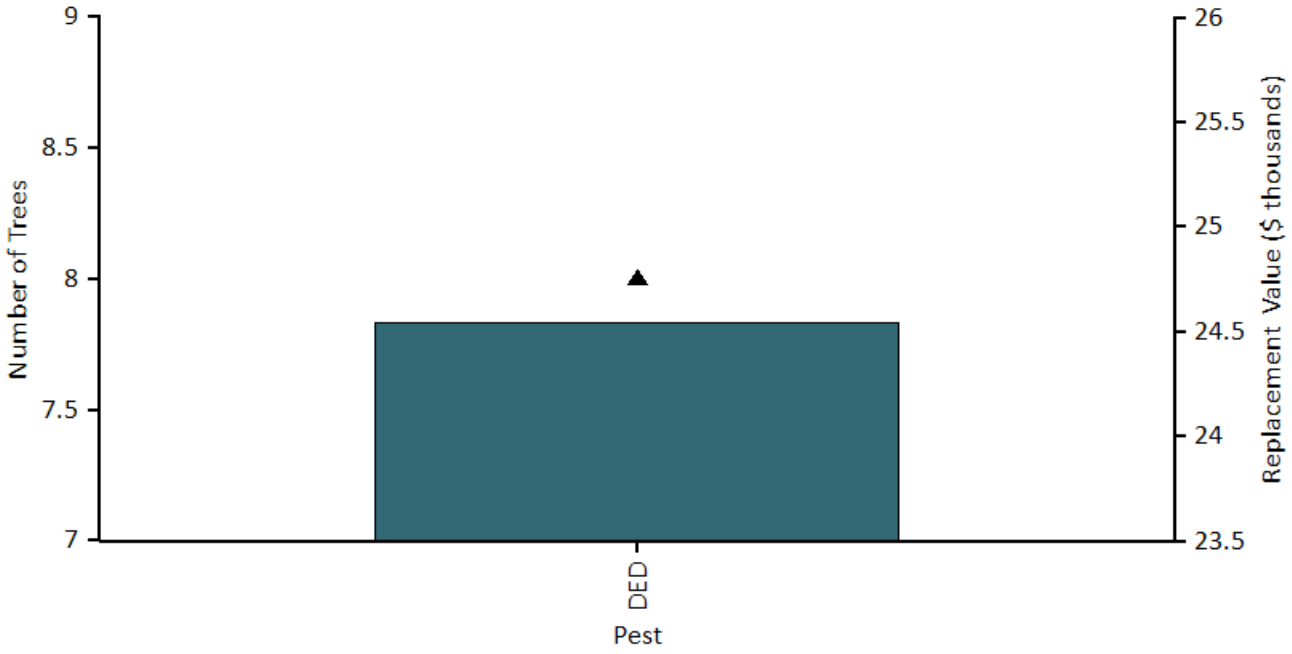


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, Amanda

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Amanda could possibly lose 11.4 percent of its trees to this pest ($24.5 thousand in replacement value).

Appendix I. i-Tree Eco Model and Field Measurements

i-Tree Eco is designed to use standardized field data and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Replacement value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Kansas Native Plant Society 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter less than 2.5 microns, and particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces (Nowak et al 2013). This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to

the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 and PM10* removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 and PM10* concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 and PM10* but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,443 per ton (carbon monoxide), $2,544 per ton (ozone), $456 per ton (nitrogen dioxide), $180 per ton (sulfur dioxide), $81,055 per ton (particulate matter less than 2.5 microns), $6,781 per ton (particulate matter less than 10 microns and greater than 2.5 microns).

Carbon Storage and Sequestration:

Carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak 1994). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition (Nowak et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of $0.07 per ft^3.

Building Energy Use:

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

For this analysis, energy saving value is calculated based on the prices of $130.20 per MWH and $11.34 per MBTU.

Replacement Values:

Replacement value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Replacement values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Replacement value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in Amanda provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Amanda in 0 days
- Annual carbon (C) emissions from 31 automobiles
- Annual C emissions from 13 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 0 automobiles
- Annual carbon monoxide emissions from 0 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 0 automobiles
- Annual nitrogen dioxide emissions from 0 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 4 automobiles
- Annual sulfur dioxide emissions from 0 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Amanda in 0.0 days
- Annual C emissions from 0 automobiles
- Annual C emissions from 0 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (Nowak 1995):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (Nowak 2000). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include (Nowak 2000):

Strategy	*Result*
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Kansas invasive species list (Kansas Native Plant Society 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ac)*	*Percent Leaf Area*
Callery pear	3	4.3	0.3	7.5
Total	**3**	**4.29**	**0.30**	**7.53**

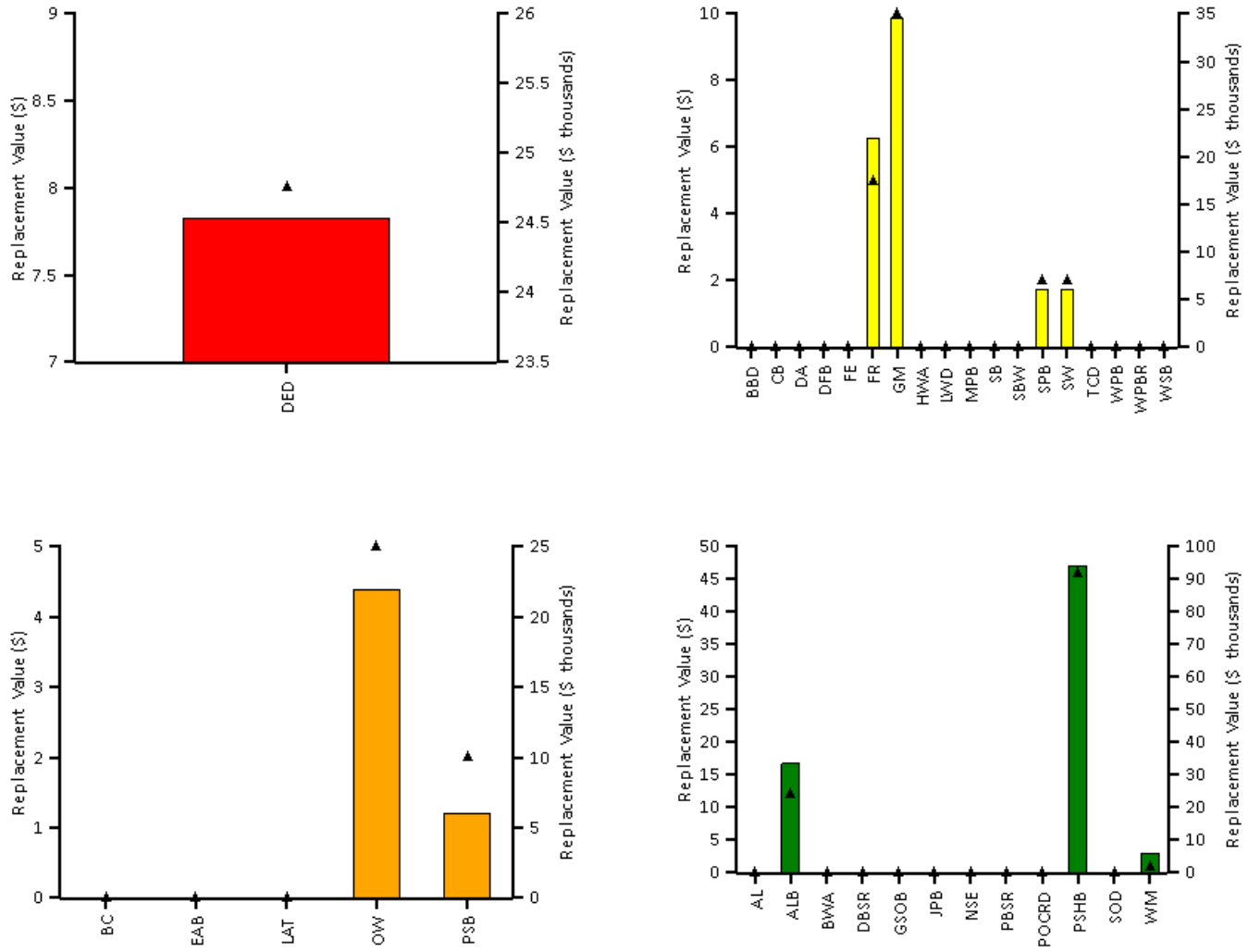
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ thousands)
AL	Phyllocnistis populiella	Aspen Leafminer	0	0.00
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	12	33.52
BBD	Neonectria faginata	Beech Bark Disease	0	0.00
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	0	0.00
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	0	0.00
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	8	24.54
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	0	0.00
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	5	21.98
GM	Lymantria dispar	Gypsy Moth	10	34.53
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	0	0.00
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	5	21.98
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	0	0.00
PSB	Tomicus piniperda	Pine Shoot Beetle	2	6.06
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	46	94.07
SB	Dendroctonus rufipennis	Spruce Beetle	0	0.00
SBW	Choristoneura fumiferana	Spruce Budworm	0	0.00
SOD	Phytophthora ramorum	Sudden Oak Death	0	0.00
SPB	Dendroctonus frontalis	Southern Pine Beetle	2	6.06
SW	Sirex noctilio	Sirex Wood Wasp	2	6.06
TCD	Geosmithia morbida	Thousand Canker Disease	0	0.00
WM	Operophtera brumata	Winter Moth	1	6.11
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	0	0.00
WSB	Choristoneura occidentalis	Western Spruce Budworm	0	0.00

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Replacement value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
	7	oak spp																																				
	7	pine spp																																				
	5	elm spp																																				
	3	Callery pear																																				
	3	apple spp																																				
	2	Eastern cottonwood																																				
	1	Eastern red cedar																																				
	1	Honeylocust																																				
	1	maple spp																																				

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Riley county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Riley county
- Green indicates pest is outside of these ranges

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i-Tree Ecosystem Analysis

Bluemont

Urban Forest Effects and Values
March 2022

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Bluemont urban forest was conducted during 2022. Data from 16 trees located throughout Bluemont were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 16
- Tree Cover: 7.5 %
- Most common species of trees: pine spp, Eastern red cedar, Eastern redbud
- Percentage of trees less than 6" (15.2 cm) diameter: 25.0%
- Pollution Removal: 16.45 pounds/year ($51.8/year)
- Carbon Storage: 11.38 tons ($1.94 thousand)
- Carbon Sequestration: 530 pounds ($45.2/year)
- Oxygen Production: 1413 pounds/year
- Avoided Runoff: 664 cubic feet/year ($44.4/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Replacement values: $60.6 thousand

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control.

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I. Tree Characteristics of the Urban Forest

The urban forest of Bluemont has 16 trees with a tree cover of 7.5 percent. The three most common species are pine spp (18.8 percent), Eastern red cedar (18.8 percent), and Eastern redbud (18.8 percent).

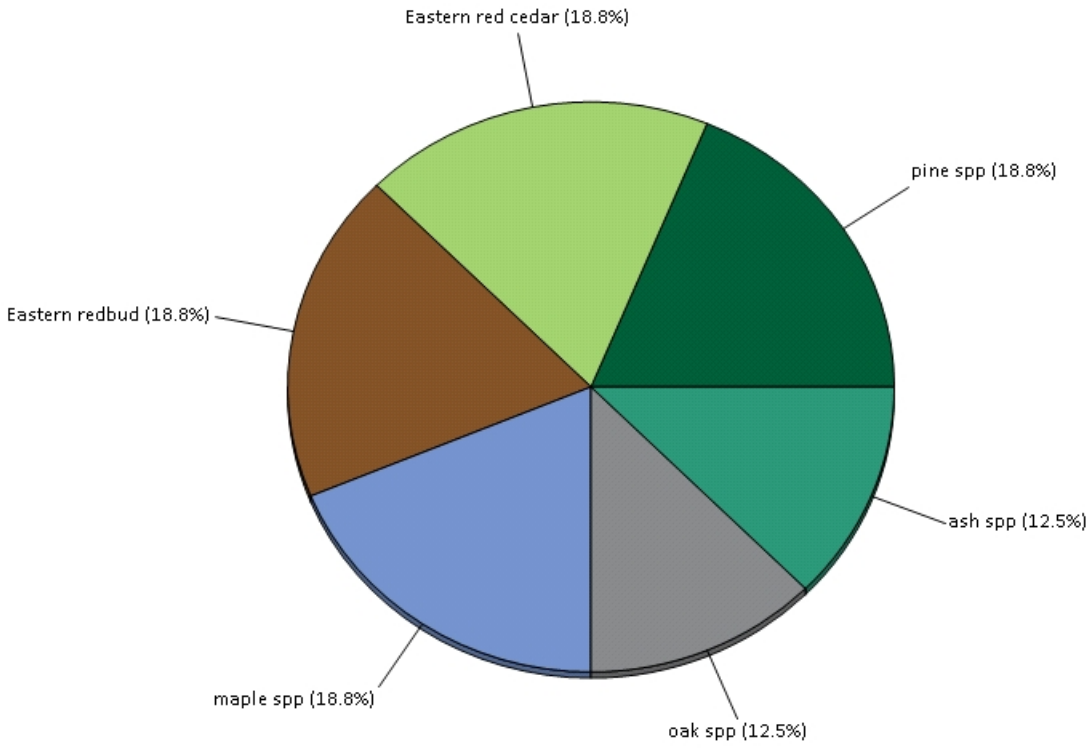


Figure 1. Tree species composition in Bluemont

The overall tree density in Bluemont is 6 trees/acre (see Appendix III for comparable values from other cities).

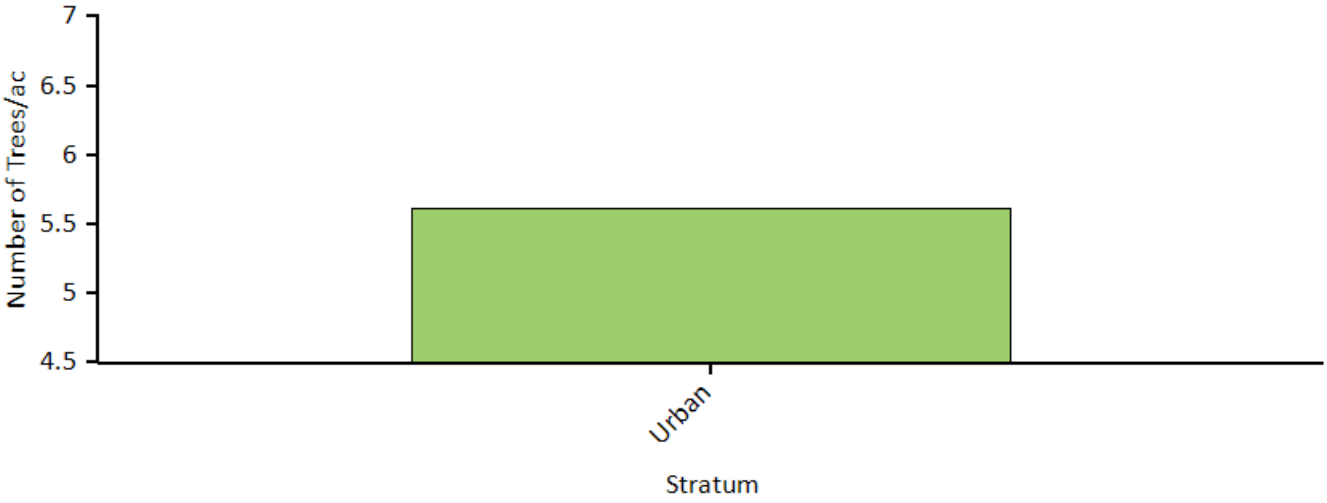


Figure 2. Number of trees/ac in Bluemont by stratum

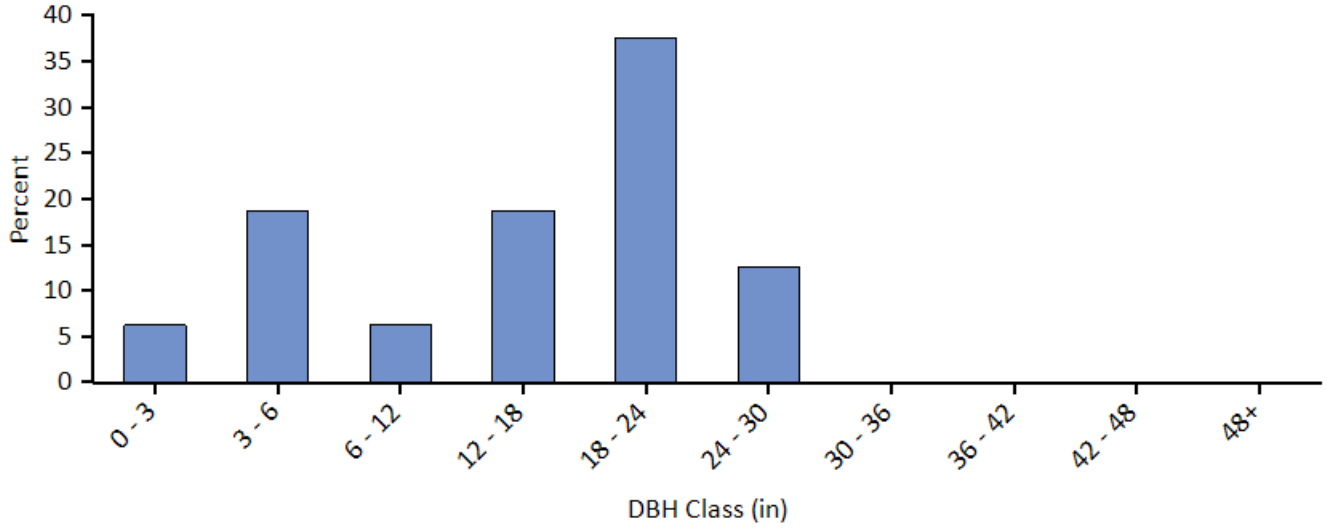


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Bluemont, about 38 percent of the trees are species native to North America, while 38 percent are native to Kansas. Species exotic to North America make up 63 percent of the population. Most exotic tree species have an origin from North America + (63 percent of the species).

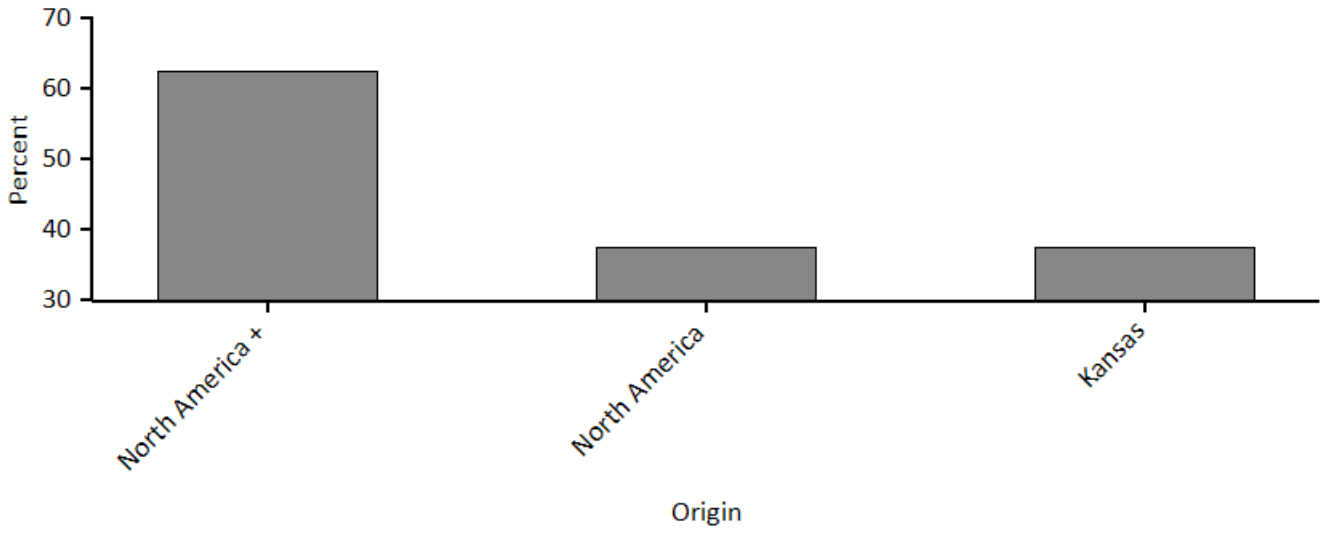


Figure 4. Percent of live tree population by area of native origin, Bluemont

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. Zero of the 6 tree species in Bluemont are identified as invasive on the state invasive species list (Kansas Native Plant Society 2006).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 7.5 percent of Bluemont and provide 1.507 acres of leaf area. Total leaf area is greatest in Urban.

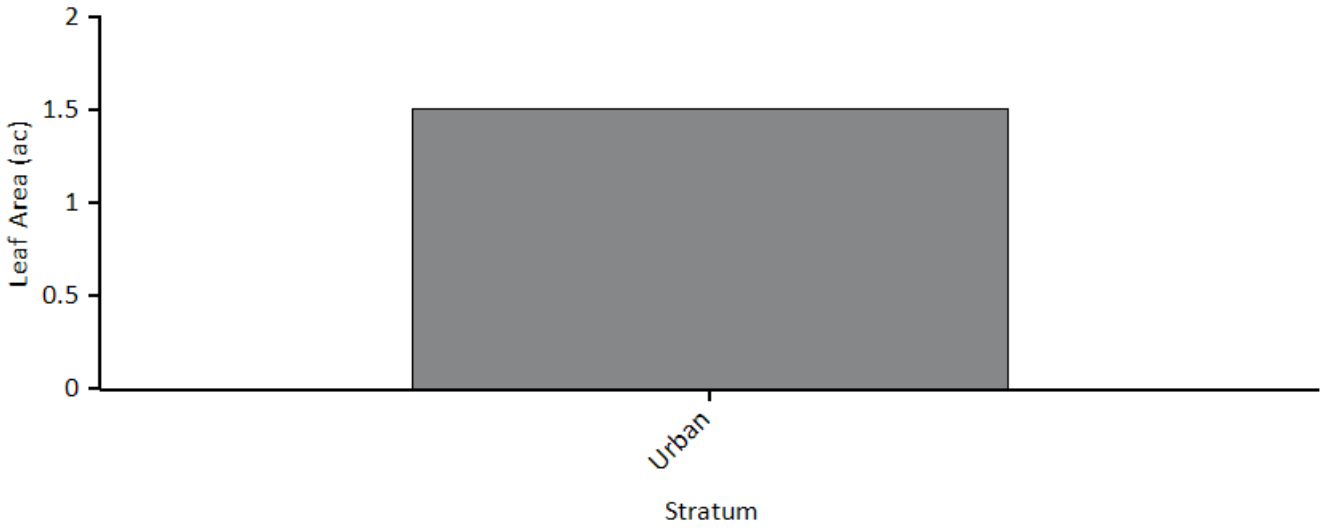


Figure 5. Leaf area by stratum, Bluemont

In Bluemont, the most dominant species in terms of leaf area are Eastern red cedar, ash spp, and pine spp. The 6 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Bluemont

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Eastern red cedar	18.8	30.1	48.9
pine spp	18.8	17.5	36.3
ash spp	12.5	19.1	31.6
oak spp	12.5	17.4	29.9
Eastern redbud	18.8	9.2	27.9
maple spp	18.8	6.7	25.5

Common ground cover classes (including cover types beneath trees and shrubs) in Bluemont are not available since they are configured not to be collected.

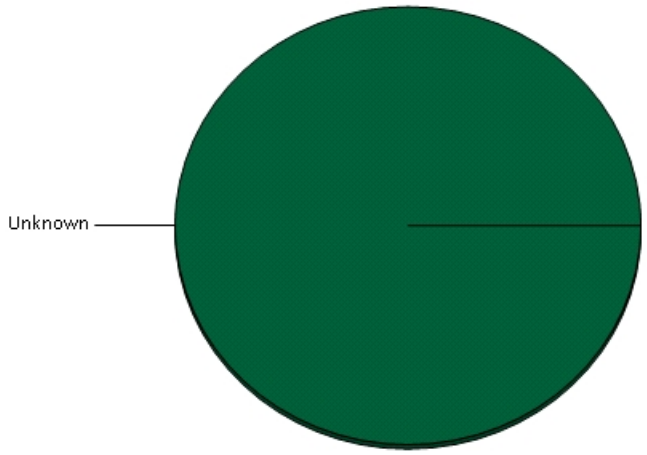


Figure 6. Percent of land by ground cover classes, Bluemont

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in Bluemont was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 16.45 pounds of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), particulate matter less than 10 microns and greater than 2.5 microns (PM10*)[2], and sulfur dioxide (SO2)) per year with an associated value of $51.8 (see Appendix I for more details).

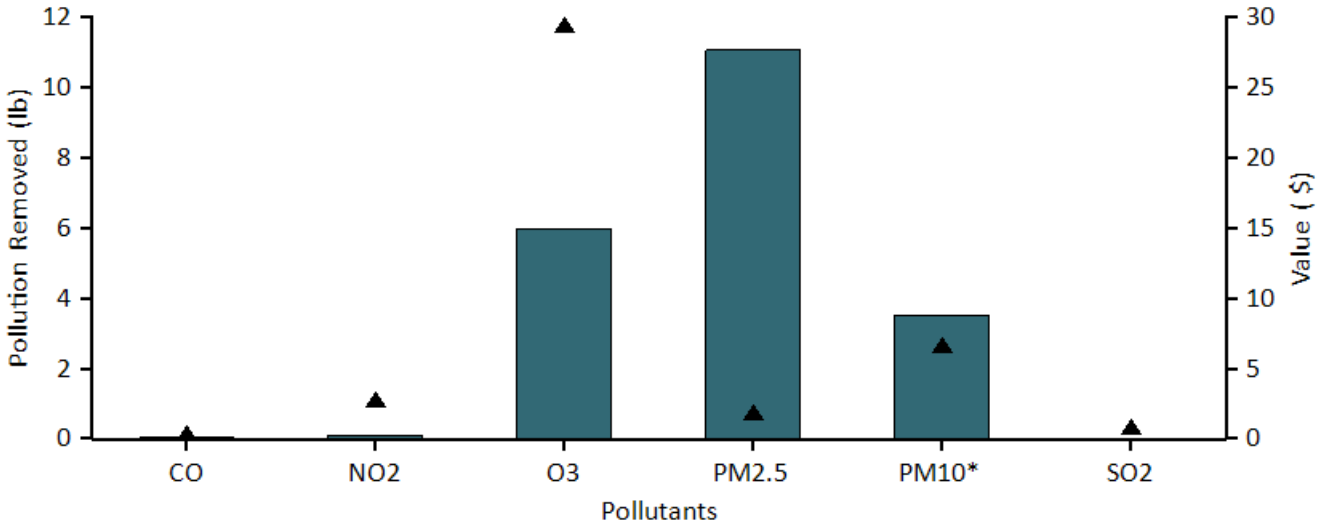


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Bluemont

[1] PM10* is particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is particulate matter less than 2.5 microns. If PM2.5 is not monitored, PM10* represents particulate matter less than 10 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces. This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2022, trees in Bluemont emitted an estimated 16.74 pounds of volatile organic compounds (VOCs) (5.271 pounds of isoprene and 11.47 pounds of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Eighty- three percent of the urban forest's VOC emissions were from oak spp and Eastern red cedar. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Bluemont trees is about 530 pounds of carbon per year with an associated value of $45.2. See Appendix I for more details on methods.

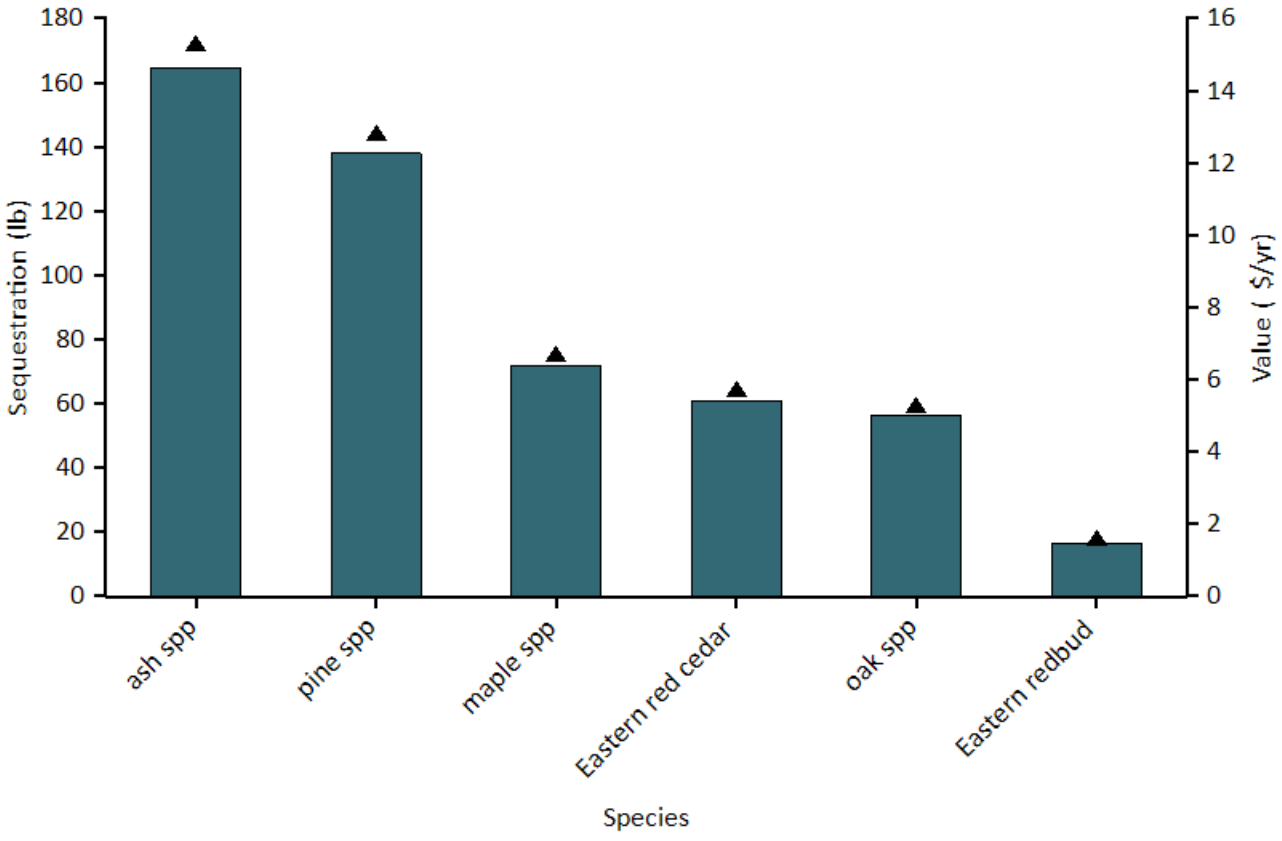


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Bluemont

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Bluemont are estimated to store 11.4 tons of carbon ($1.94 thousand). Of the species sampled, ash spp stores and sequesters the most carbon (approximately 28.5% of the total carbon stored and 32.4% of all sequestered carbon.)

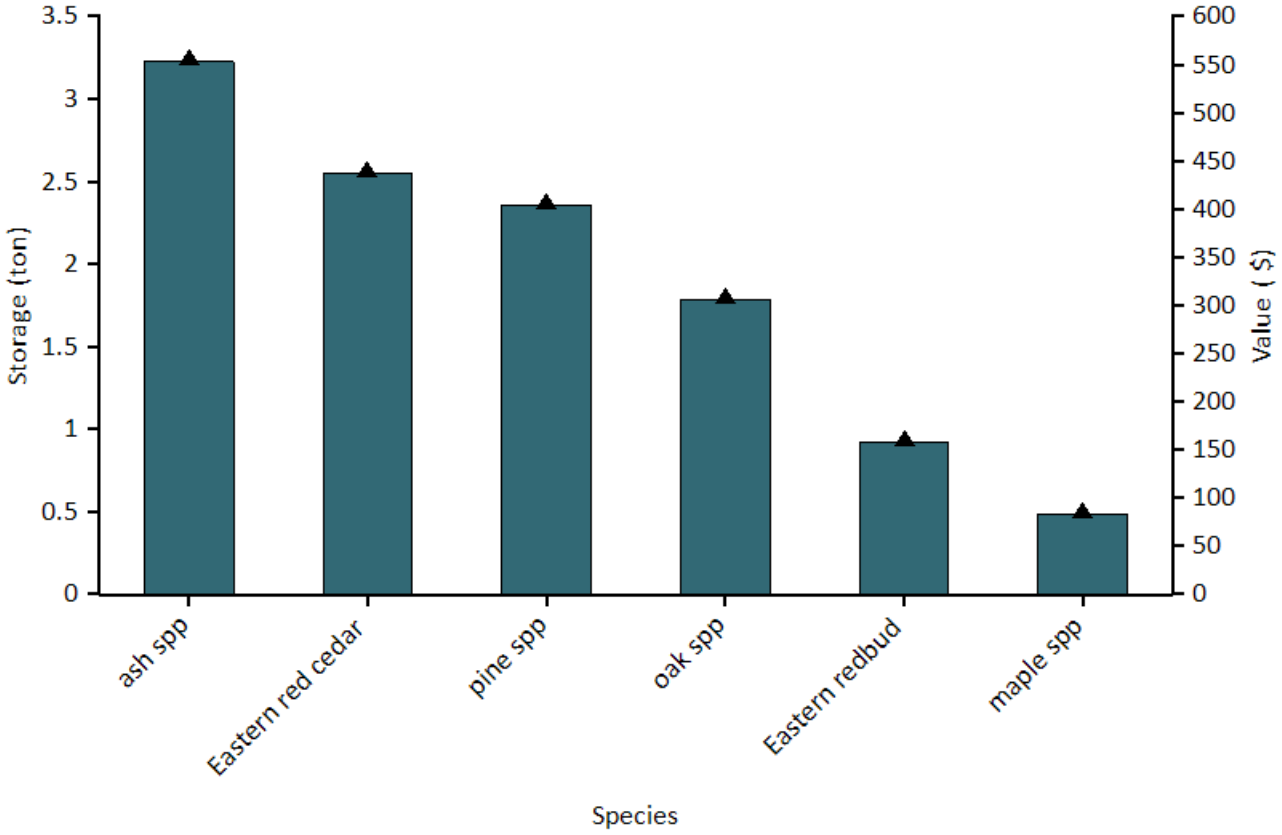


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Bluemont

V. Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Bluemont are estimated to produce 1413 pounds of oxygen per year.[4] However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 6 oxygen production species.

Species	*Oxygen (pound)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (acre)*
ash spp	458.00	171.75	2	0.29
pine spp	383.42	143.78	3	0.26
maple spp	199.27	74.73	3	0.10
Eastern red cedar	169.60	63.60	3	0.45
oak spp	157.10	58.91	2	0.26
Eastern redbud	45.92	17.22	3	0.14

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Bluemont help to reduce runoff by an estimated 664 cubic feet a year with an associated value of $44 (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Bluemont, the total annual precipitation in 2019 was 44.7 inches.

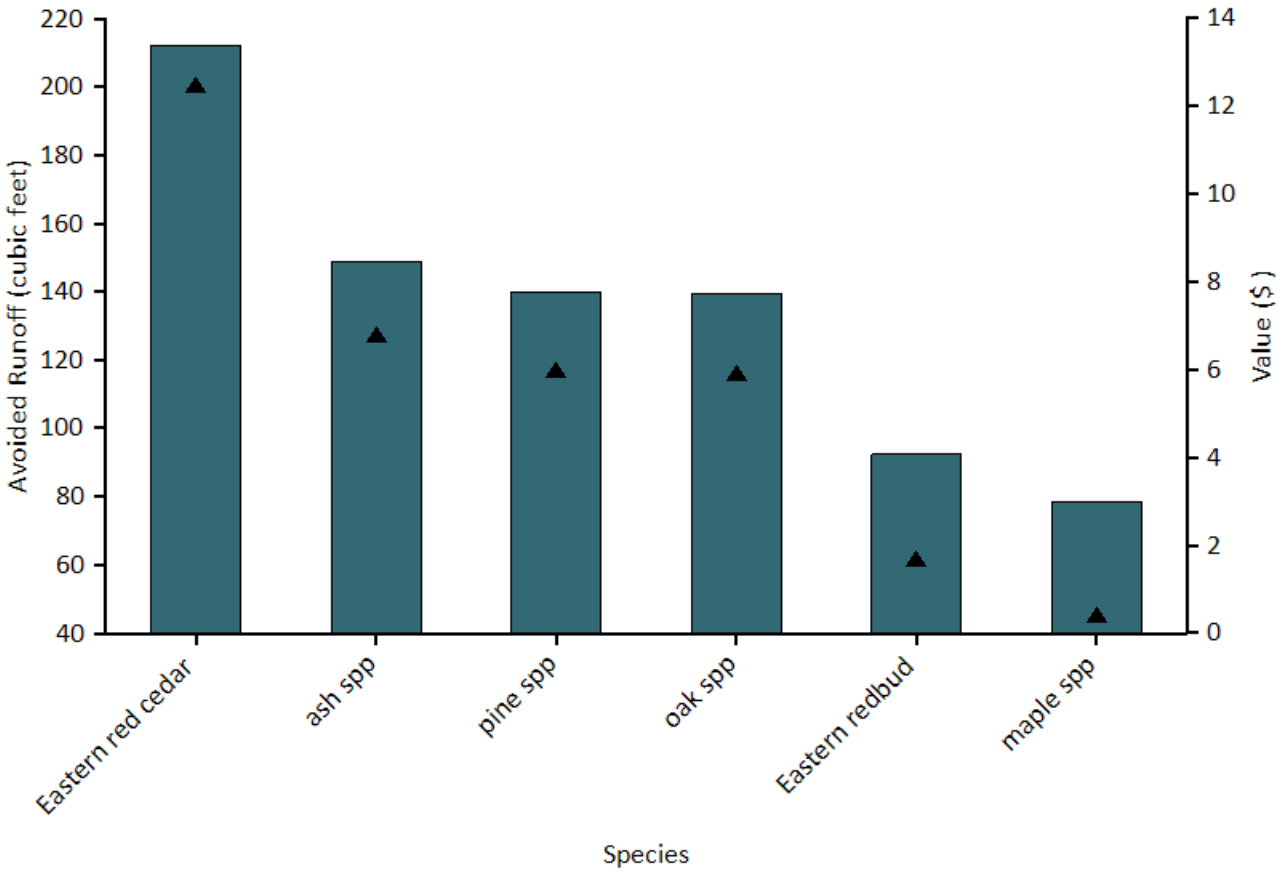


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Bluemont

VII. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Because energy-related data were not collected, energy savings and carbon avoided cannot be calculated.

Table 3. Annual energy savings due to trees near residential buildings, Bluemont

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (pounds)	0	0	0

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, Bluemont

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of $130.2 per MWH and $11.3442000317562 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Replacement and Functional Values

Urban forests have a replacement value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The replacement value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Bluemont have the following replacement values:

- Replacement value: $60.6 thousand
- Carbon storage: $1.94 thousand

Urban trees in Bluemont have the following annual functional values:

- Carbon sequestration: $45.2
- Avoided runoff: $44.4
- Pollution removal: $51.8
- Energy costs and carbon emission values: $0

(Note: negative value indicates increased energy cost and carbon emission value)

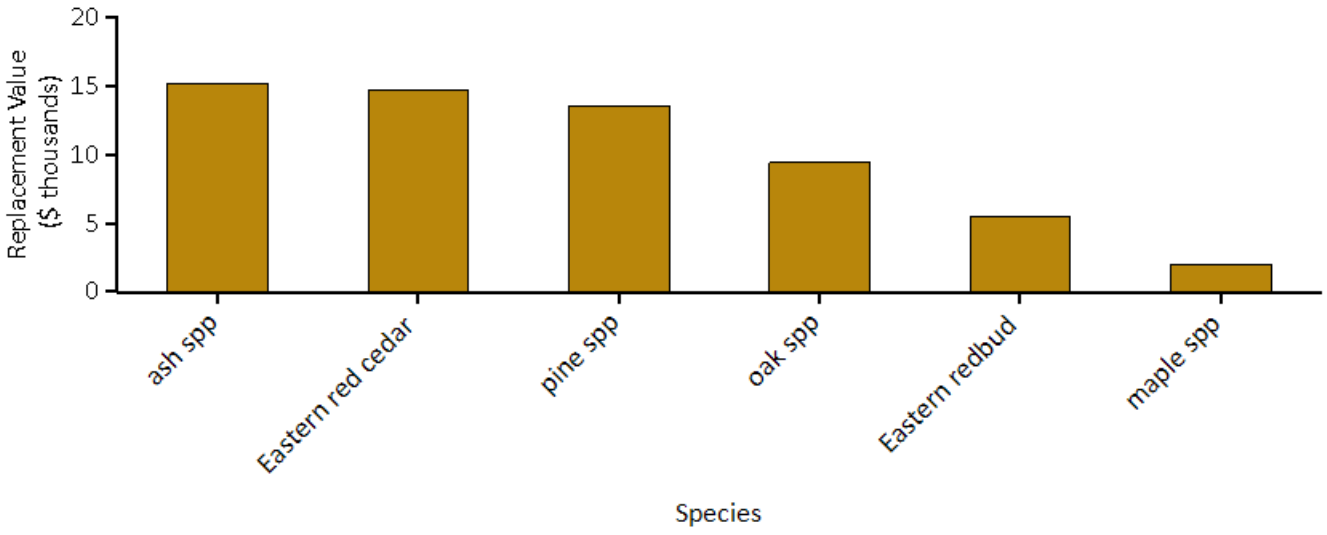


Figure 11. Tree species with the greatest replacement value, Bluemont

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, replacement value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Riley County. One of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

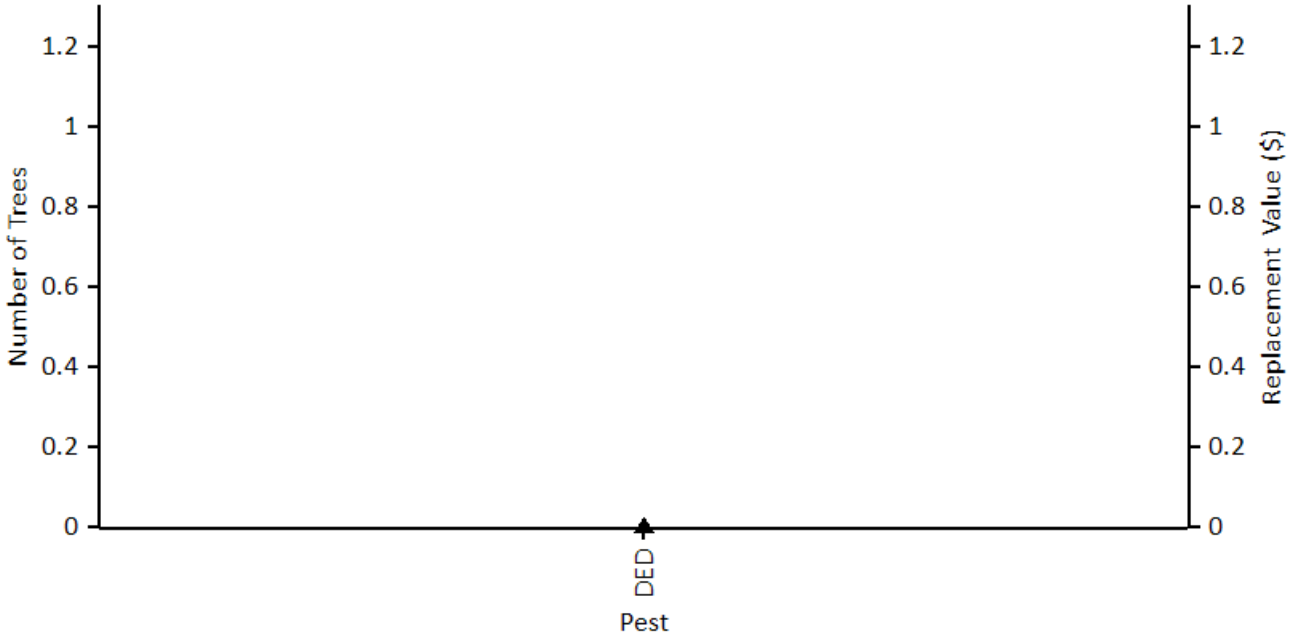


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, Bluemont

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Bluemont could possibly lose 0.0 percent of its trees to this pest ($0 in replacement value).

Appendix I. i-Tree Eco Model and Field Measurements

i-Tree Eco is designed to use standardized field data and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Replacement value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Kansas Native Plant Society 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter less than 2.5 microns, and particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces (Nowak et al 2013). This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to

the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 and PM10* removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 and PM10* concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 and PM10* but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,443 per ton (carbon monoxide), $2,552 per ton (ozone), $449 per ton (nitrogen dioxide), $176 per ton (sulfur dioxide), $82,349 per ton (particulate matter less than 2.5 microns), $6,781 per ton (particulate matter less than 10 microns and greater than 2.5 microns).

Carbon Storage and Sequestration:

Carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak 1994). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition (Nowak et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of $0.07 per ft^3.

Building Energy Use:

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

For this analysis, energy saving value is calculated based on the prices of $130.20 per MWH and $11.34 per MBTU.

Replacement Values:

Replacement value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Replacement values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Replacement value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in Bluemont provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Bluemont in 0 days
- Annual carbon (C) emissions from 8 automobiles
- Annual C emissions from 3 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 0 automobiles
- Annual carbon monoxide emissions from 0 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 0 automobiles
- Annual nitrogen dioxide emissions from 0 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 1 automobiles
- Annual sulfur dioxide emissions from 0 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Bluemont in 0.0 days
- Annual C emissions from 0 automobiles
- Annual C emissions from 0 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (Nowak 1995):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (Nowak 2000). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include (Nowak 2000):

Strategy	*Result*
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Kansas invasive species list (Kansas Native Plant Society 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ac)*	*Percent Leaf Area*
Total	**0**	**0.00**	**0.00**	**0.00**

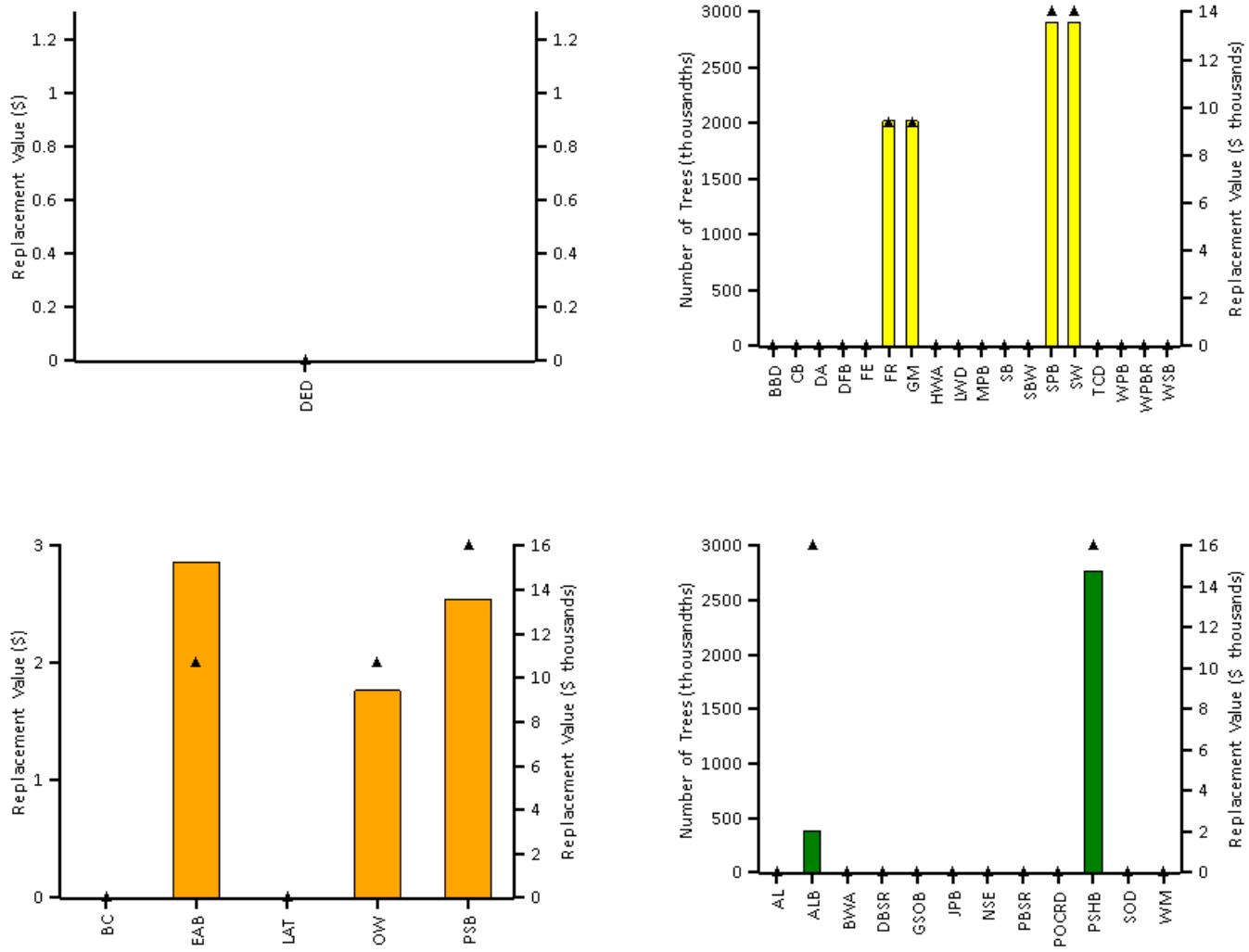
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ thousands)
AL	Phyllocnistis populiella	Aspen Leafminer	0	0.00
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	3	2.01
BBD	Neonectria faginata	Beech Bark Disease	0	0.00
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	0	0.00
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	0	0.00
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	0	0.00
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	2	15.25
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	2	9.44
GM	Lymantria dispar	Gypsy Moth	2	9.44
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	0	0.00
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	2	9.44
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	0	0.00
PSB	Tomicus piniperda	Pine Shoot Beetle	3	13.59
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	3	14.75
SB	Dendroctonus rufipennis	Spruce Beetle	0	0.00
SBW	Choristoneura fumiferana	Spruce Budworm	0	0.00
SOD	Phytophthora ramorum	Sudden Oak Death	0	0.00
SPB	Dendroctonus frontalis	Southern Pine Beetle	3	13.59
SW	Sirex noctilio	Sirex Wood Wasp	3	13.59
TCD	Geosmithia morbida	Thousand Canker Disease	0	0.00
WM	Operophtera brumata	Winter Moth	0	0.00
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	0	0.00
WSB	Choristoneura occidentalis	Western Spruce Budworm	0	0.00

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Replacement value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
	7	pine spp																																				
	7	oak spp																																				
	3	ash spp																																				
	1	Eastern red cedar																																				
	1	maple spp																																				

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Riley county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Riley county
- Green indicates pest is outside of these ranges

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i-Tree Ecosystem Analysis

Frank V Bergman

Urban Forest Effects and Values

February 2022

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Frank V Bergman urban forest was conducted during 2022. Data from 13 trees located throughout Frank V Bergman were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 13
- Tree Cover: 1.4 %
- Most common species of trees: pine spp, Callery pear, oak spp
- Percentage of trees less than 6" (15.2 cm) diameter: 0.0%
- Pollution Removal: 8.355 pounds/year ($25.6/year)
- Carbon Storage: 5.049 tons ($861)
- Carbon Sequestration: 464 pounds ($39.6/year)
- Oxygen Production: 1237 pounds/year
- Avoided Runoff: 332.4 cubic feet/year ($22.2/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Replacement values: $32.8 thousand

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control.

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I. Tree Characteristics of the Urban Forest

The urban forest of Frank V Bergman has 13 trees with a tree cover of 1.4 percent. The three most common species are pine spp (53.8 percent), Callery pear (30.8 percent), and oak spp (7.7 percent).

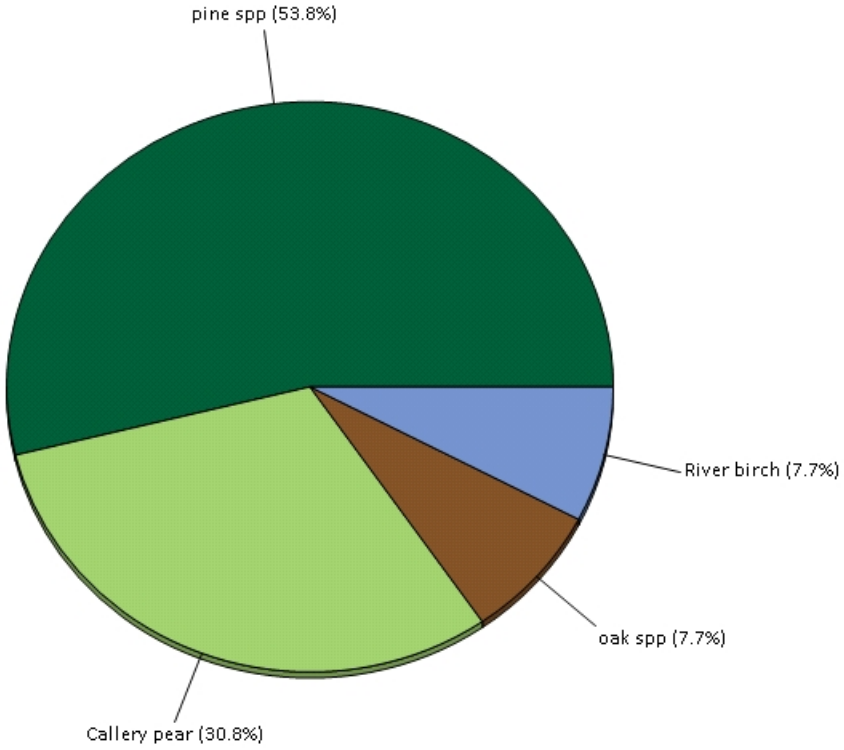


Figure 1. Tree species composition in Frank V Bergman

The overall tree density in Frank V Bergman is 2 trees/acre (see Appendix III for comparable values from other cities).

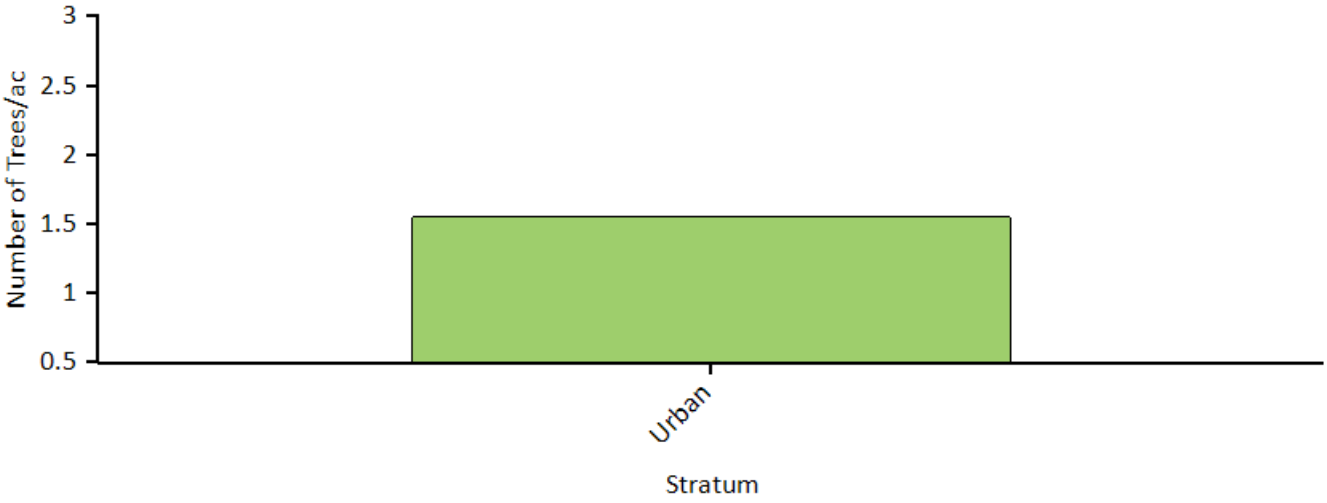


Figure 2. Number of trees/ac in Frank V Bergman by stratum

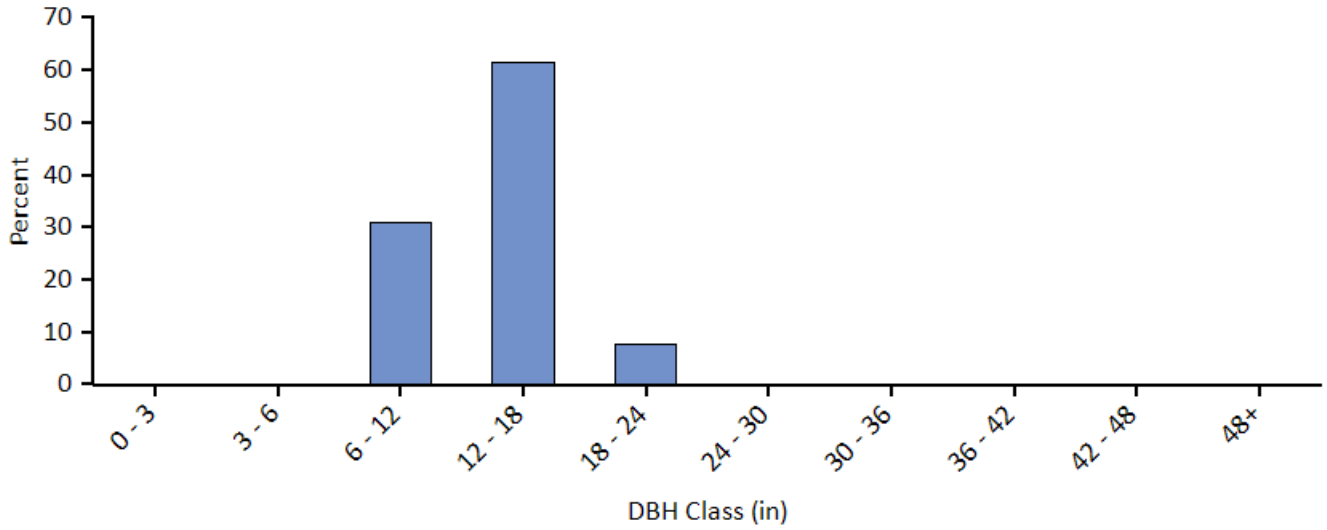


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Frank V Bergman, about 8 percent of the trees are species native to North America, while 8 percent are native to Kansas. Species exotic to North America make up 92 percent of the population. Most exotic tree species have an origin from North America + (62 percent of the species).

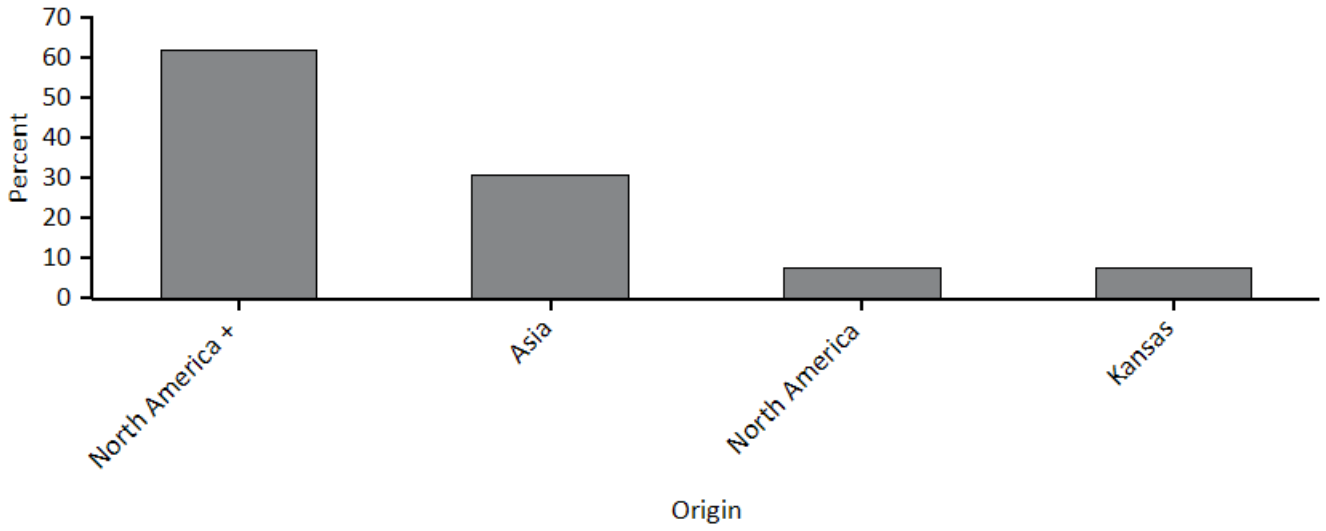


Figure 4. Percent of live tree population by area of native origin, Frank V Bergman

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. One of the 4 tree species in Frank V Bergman are identified as invasive on the state invasive species list (Kansas Native Plant Society 2006). This invasive species (Callery pear) comprises 30.8 percent of the tree population though it may only cause a minimal level of impact (see Appendix V for a complete list of invasive species).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 1.4 percent of Frank V Bergman and provide 0.7381 acres of leaf area. Total leaf area is greatest in Urban.

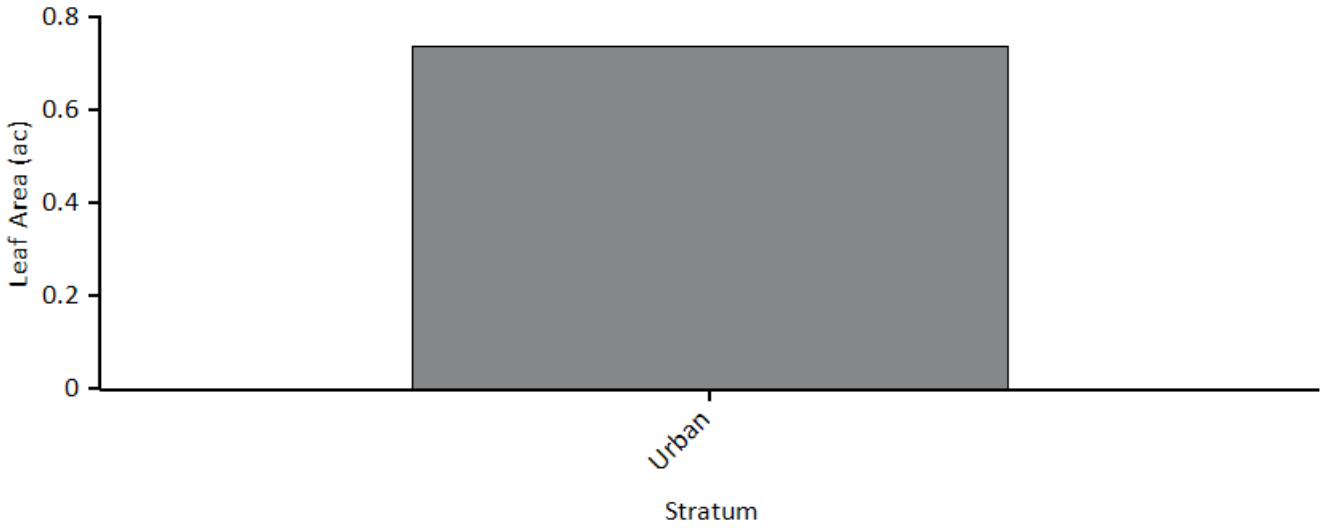


Figure 5. Leaf area by stratum, Frank V Bergman

In Frank V Bergman, the most dominant species in terms of leaf area are pine spp, Callery pear, and River birch. The 4 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Frank V Bergman

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
pine spp	53.8	44.7	98.6
Callery pear	30.8	31.0	61.8
River birch	7.7	16.3	24.0
oak spp	7.7	7.9	15.6

Common ground cover classes (including cover types beneath trees and shrubs) in Frank V Bergman are not available since they are configured not to be collected.

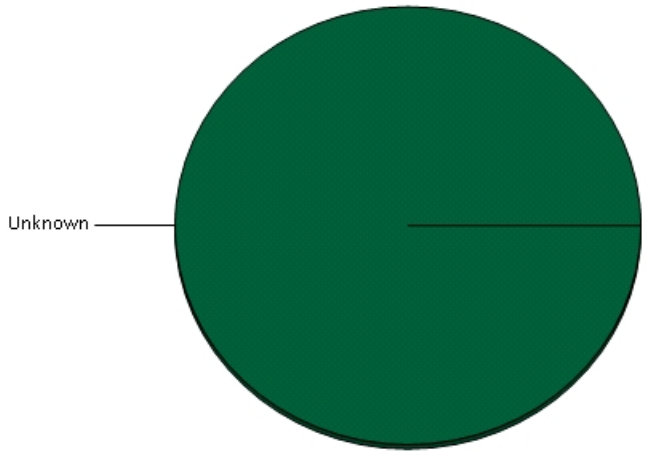


Figure 6. Percent of land by ground cover classes, Frank V Bergman

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in Frank V Bergman was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 8.355 pounds of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), particulate matter less than 10 microns and greater than 2.5 microns (PM10*)[2], and sulfur dioxide (SO2)) per year with an associated value of $25.6 (see Appendix I for more details).

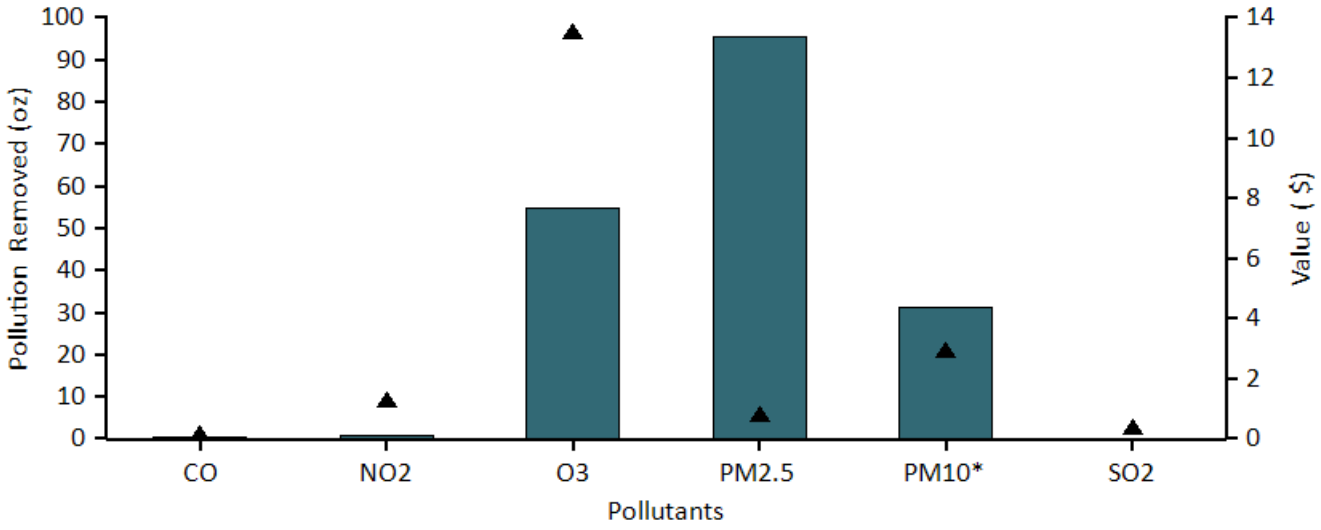


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Frank V Bergman

[1] PM10* is particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is particulate matter less than 2.5 microns. If PM2.5 is not monitored, PM10* represents particulate matter less than 10 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces. This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2022, trees in Frank V Bergman emitted an estimated 6.459 pounds of volatile organic compounds (VOCs) (1.263 pounds of isoprene and 5.196 pounds of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Ninety- one percent of the urban forest's VOC emissions were from pine spp and oak spp. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Frank V Bergman trees is about 464 pounds of carbon per year with an associated value of $39.6. See Appendix I for more details on methods.

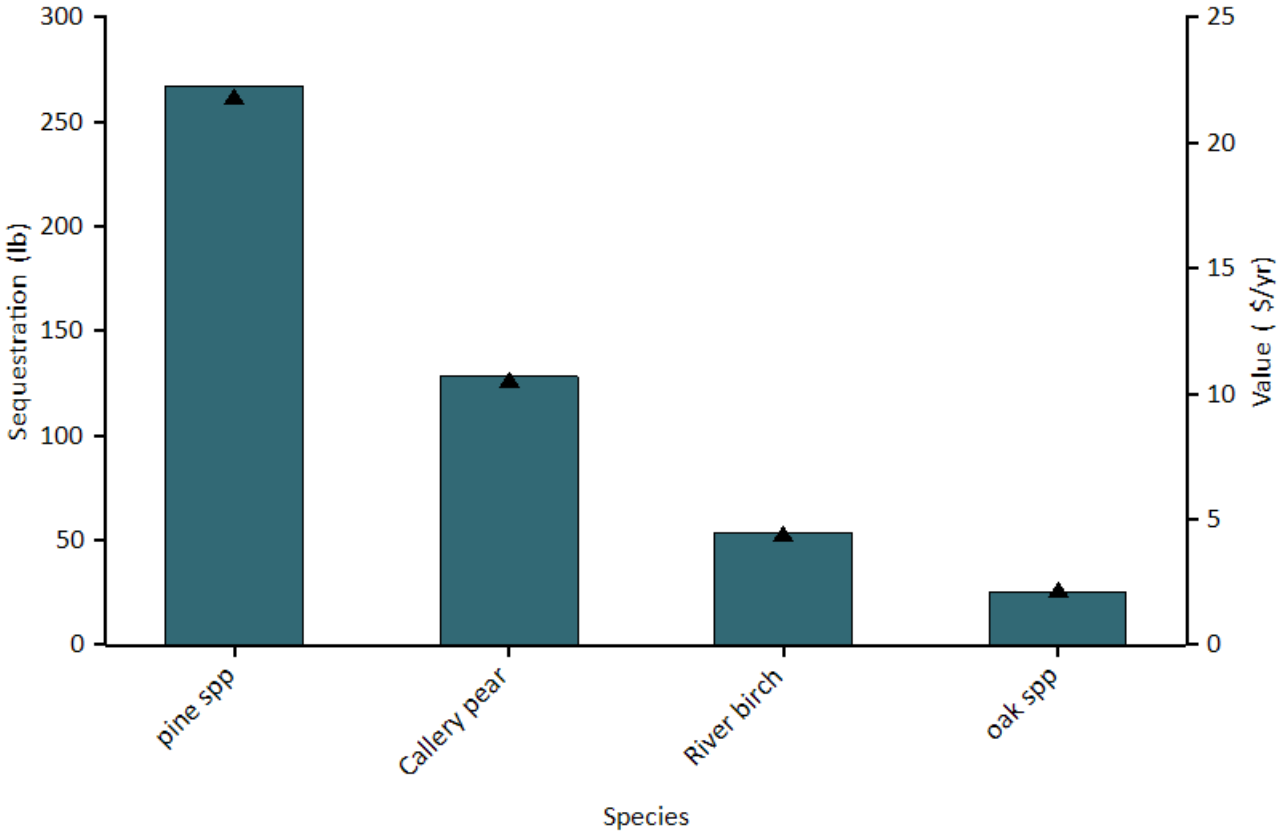


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Frank V Bergman

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Frank V Bergman are estimated to store 5.05 tons of carbon ($861). Of the species sampled, pine spp stores and

sequesters the most carbon (approximately 66.3% of the total carbon stored and 56.3% of all sequestered carbon.)

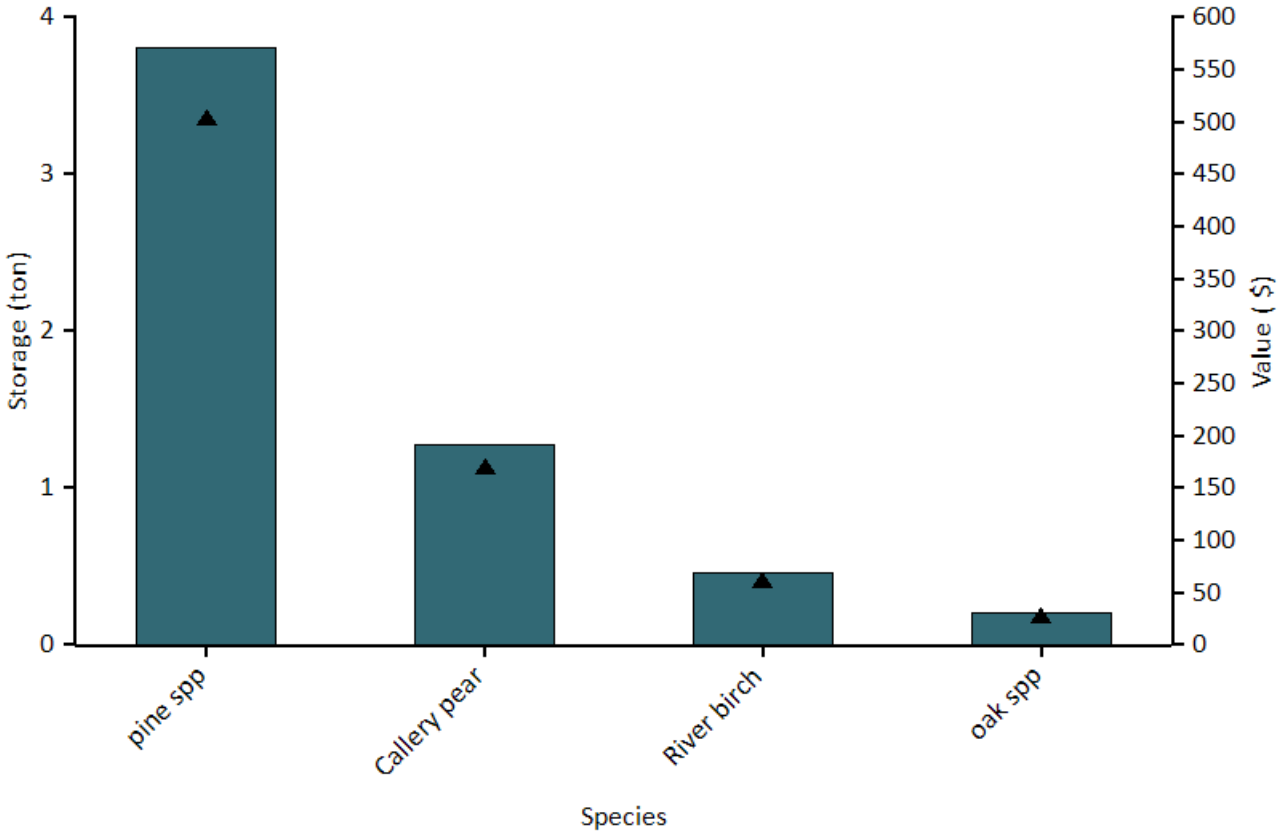


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Frank V Bergman

V. Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Frank V Bergman are estimated to produce 1237 pounds of oxygen per year.[4] However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 4 oxygen production species.

Species	*Oxygen (pound)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (square feet)*
pine spp	696.84	261.32	7	0.01
Callery pear	334.20	125.33	4	0.01
River birch	139.79	52.42	1	0.01
oak spp	66.45	24.92	1	0.00

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Frank V Bergman help to reduce runoff by an estimated 332 cubic feet a year with an associated value of $22 (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Frank V Bergman, the total annual precipitation in 2019 was 44.7 inches.

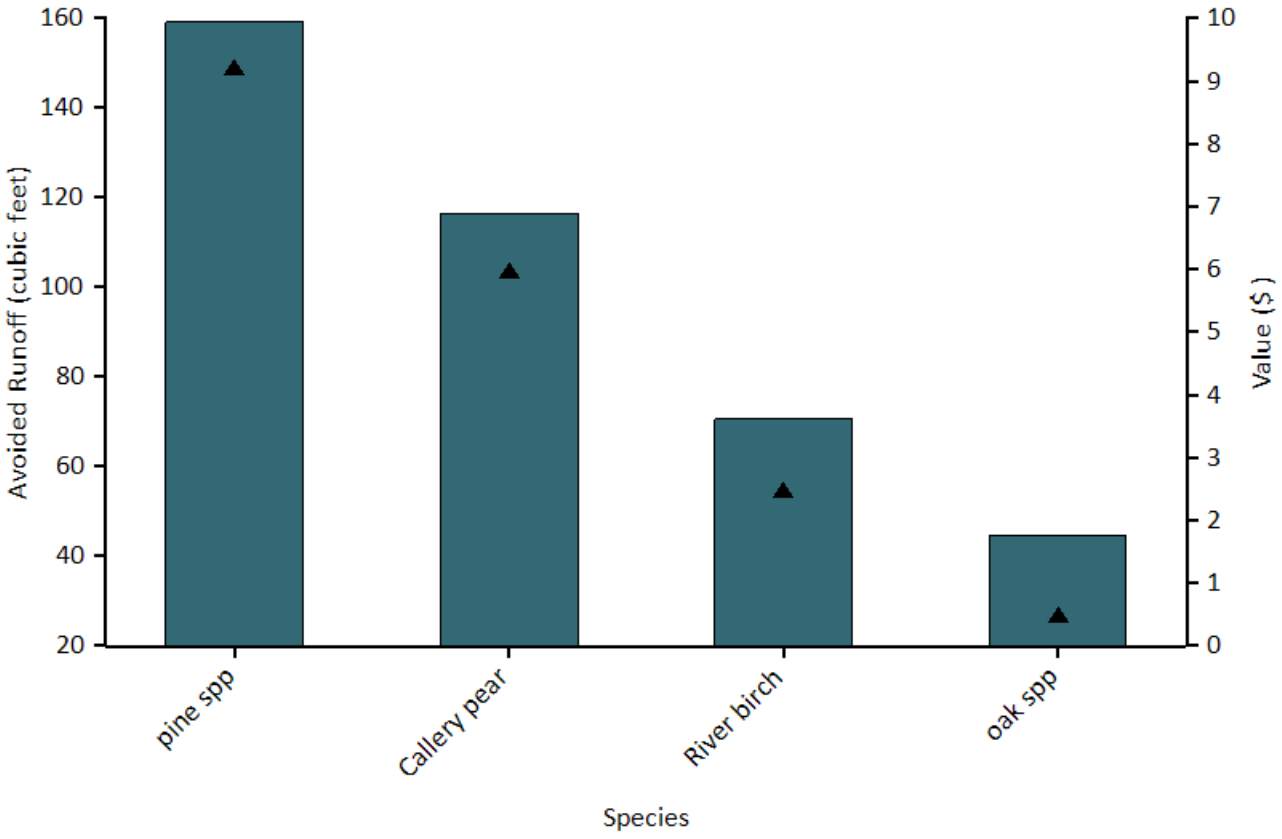


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Frank V Bergman

VII. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Because energy-related data were not collected, energy savings and carbon avoided cannot be calculated.

Table 3. Annual energy savings due to trees near residential buildings, Frank V Bergman

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (pounds)	0	0	0

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, Frank V Bergman

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of $130.2 per MWH and $11.3442000317562 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Replacement and Functional Values

Urban forests have a replacement value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The replacement value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Frank V Bergman have the following replacement values:

- Replacement value: $32.8 thousand
- Carbon storage: $861

Urban trees in Frank V Bergman have the following annual functional values:

- Carbon sequestration: $39.6
- Avoided runoff: $22.2
- Pollution removal: $25.6
- Energy costs and carbon emission values: $0

(Note: negative value indicates increased energy cost and carbon emission value)

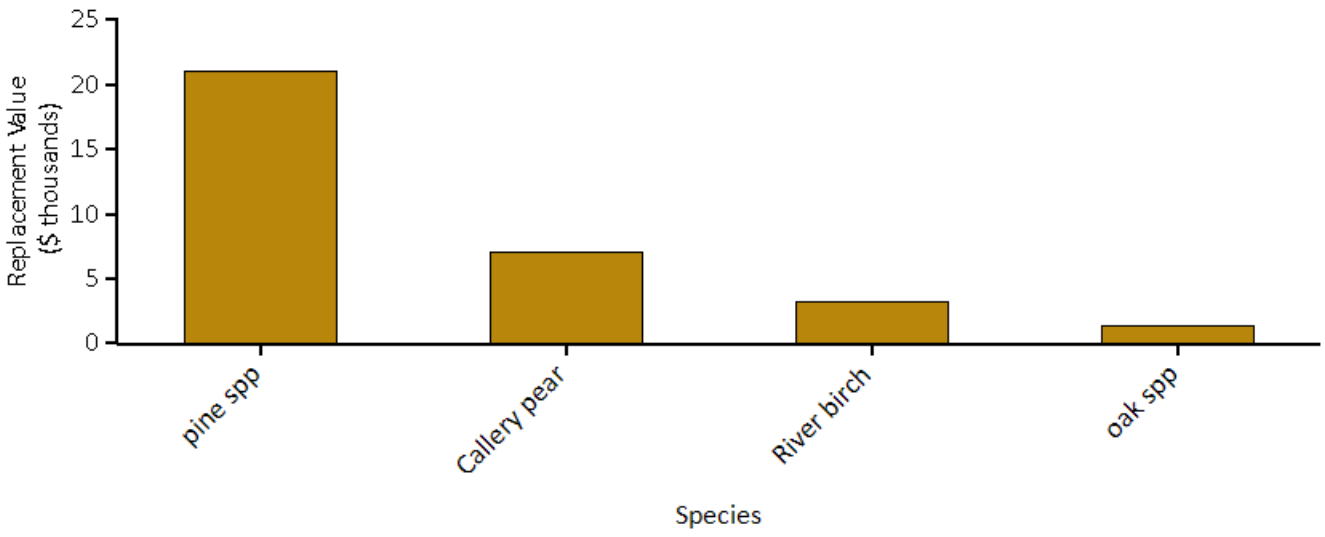


Figure 11. Tree species with the greatest replacement value, Frank V Bergman

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, replacement value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Riley County. One of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

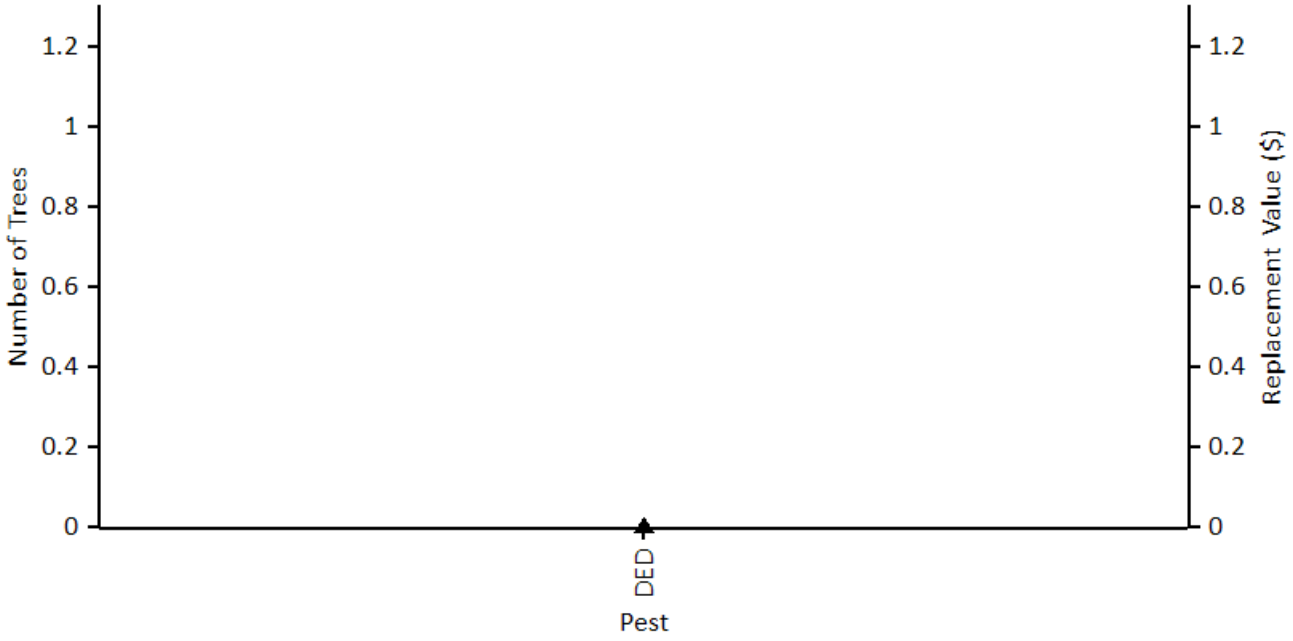


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, Frank V Bergman

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Frank V Bergman could possibly lose 0.0 percent of its trees to this pest ($0 in replacement value).

Appendix I. i-Tree Eco Model and Field Measurements

i-Tree Eco is designed to use standardized field data and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Replacement value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Kansas Native Plant Society 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter less than 2.5 microns, and particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces (Nowak et al 2013). This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to

the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 and PM10* removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 and PM10* concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 and PM10* but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,443 per ton (carbon monoxide), $2,553 per ton (ozone), $450 per ton (nitrogen dioxide), $177 per ton (sulfur dioxide), $82,390 per ton (particulate matter less than 2.5 microns), $6,781 per ton (particulate matter less than 10 microns and greater than 2.5 microns).

Carbon Storage and Sequestration:

Carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak 1994). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition (Nowak et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of $0.07 per ft^3.

Building Energy Use:

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

For this analysis, energy saving value is calculated based on the prices of $130.20 per MWH and $11.34 per MBTU.

Replacement Values:

Replacement value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Replacement values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Replacement value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in Frank V Bergman provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Frank V Bergman in 0 days
- Annual carbon (C) emissions from 4 automobiles
- Annual C emissions from 1 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 0 automobiles
- Annual carbon monoxide emissions from 0 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 0 automobiles
- Annual nitrogen dioxide emissions from 0 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 1 automobiles
- Annual sulfur dioxide emissions from 0 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Frank V Bergman in 0.0 days
- Annual C emissions from 0 automobiles
- Annual C emissions from 0 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (Nowak 1995):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (Nowak 2000). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include (Nowak 2000):

Strategy	*Result*
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Kansas invasive species list (Kansas Native Plant Society 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ft²)*	*Percent Leaf Area*
Callery pear	4	30.8	0.0	31.0
Total	**4**	**30.77**	**0.01**	**31.04**

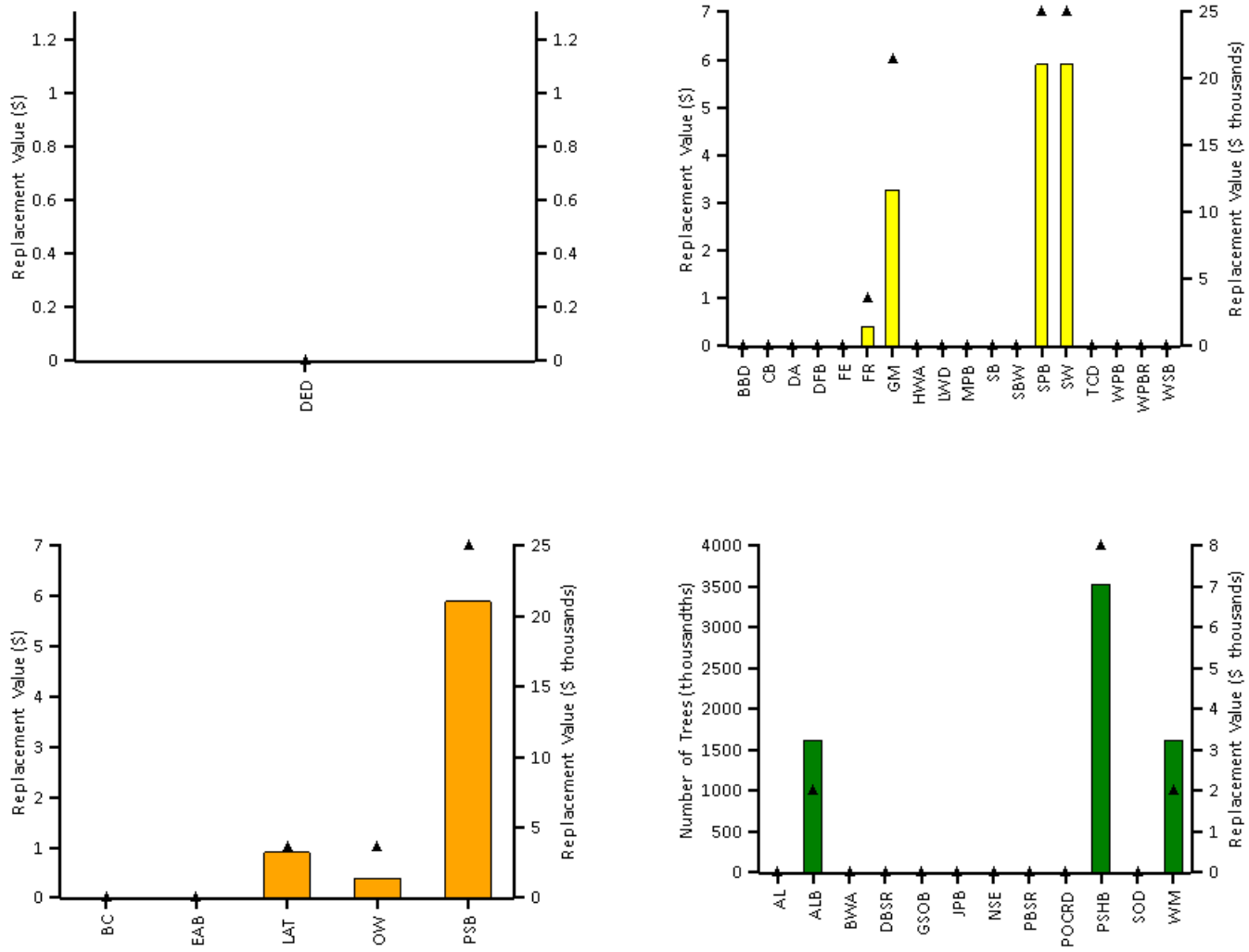
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ thousands)
AL	Phyllocnistis populiella	Aspen Leafminer	0	0.00
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	1	3.25
BBD	Neonectria faginata	Beech Bark Disease	0	0.00
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	0	0.00
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	0	0.00
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	0	0.00
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	0	0.00
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	1	1.40
GM	Lymantria dispar	Gypsy Moth	6	11.71
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	1	3.25
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	1	1.40
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	0	0.00
PSB	Tomicus piniperda	Pine Shoot Beetle	7	21.06
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	4	7.07
SB	Dendroctonus rufipennis	Spruce Beetle	0	0.00
SBW	Choristoneura fumiferana	Spruce Budworm	0	0.00
SOD	Phytophthora ramorum	Sudden Oak Death	0	0.00
SPB	Dendroctonus frontalis	Southern Pine Beetle	7	21.06
SW	Sirex noctilio	Sirex Wood Wasp	7	21.06
TCD	Geosmithia morbida	Thousand Canker Disease	0	0.00
WM	Operophtera brumata	Winter Moth	1	3.25
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	0	0.00
WSB	Choristoneura occidentalis	Western Spruce Budworm	0	0.00

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Replacement value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
	7	pine spp																																				
	7	oak spp																																				
	7	River birch																																				
	3	Callery pear																																				

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Riley county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Riley county
- Green indicates pest is outside of these ranges

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i-Tree Ecosystem Analysis

Lee

Urban Forest Effects and Values
March 2022

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Lee urban forest was conducted during 2022. Data from 24 trees located throughout Lee were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 24
- Tree Cover: 2.2 %
- Most common species of trees: maple spp, elm spp, Japanese tree lilac
- Percentage of trees less than 6" (15.2 cm) diameter: 66.7%
- Pollution Removal: 6.662 pounds/year ($18.4/year)
- Carbon Storage: 3.788 tons ($646)
- Carbon Sequestration: 388.3 pounds ($33.1/year)
- Oxygen Production: 1035 pounds/year
- Avoided Runoff: 292.5 cubic feet/year ($19.6/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Replacement values: $19.9 thousand

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control.

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I. Tree Characteristics of the Urban Forest

The urban forest of Lee has 24 trees with a tree cover of 2.2 percent. The three most common species are maple spp (41.7 percent), elm spp (20.8 percent), and Japanese tree lilac (8.3 percent).

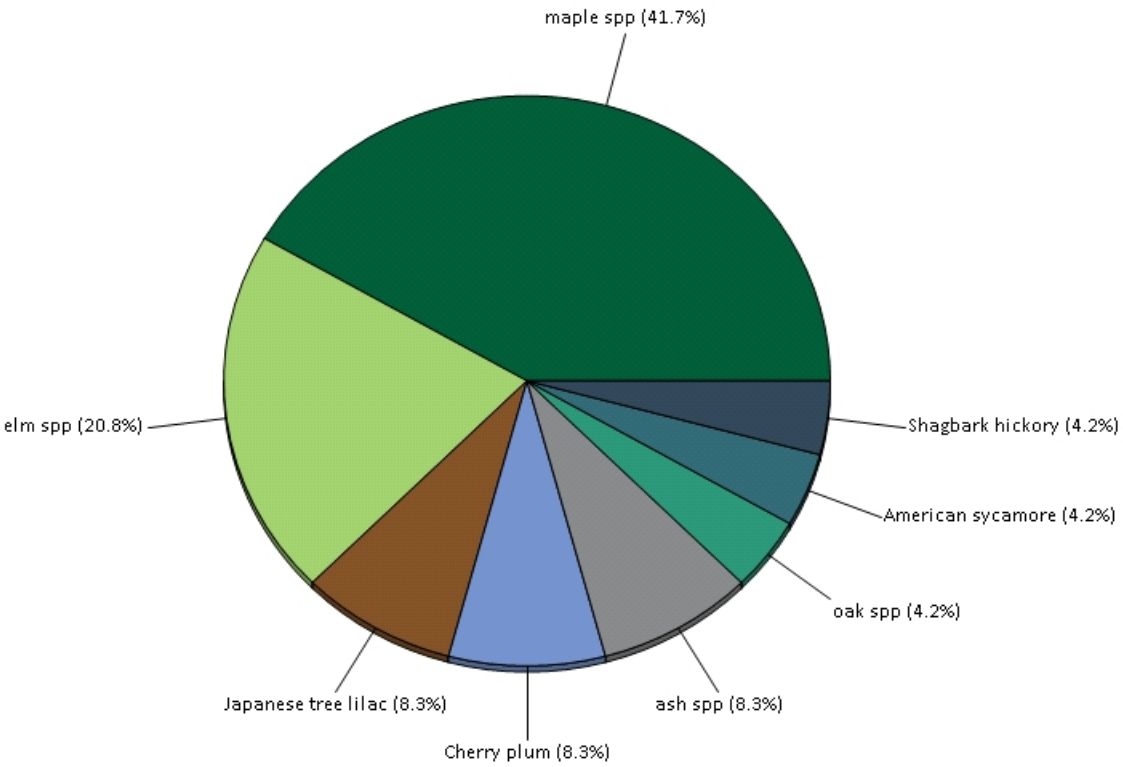


Figure 1. Tree species composition in Lee

The overall tree density in Lee is 4 trees/acre (see Appendix III for comparable values from other cities).

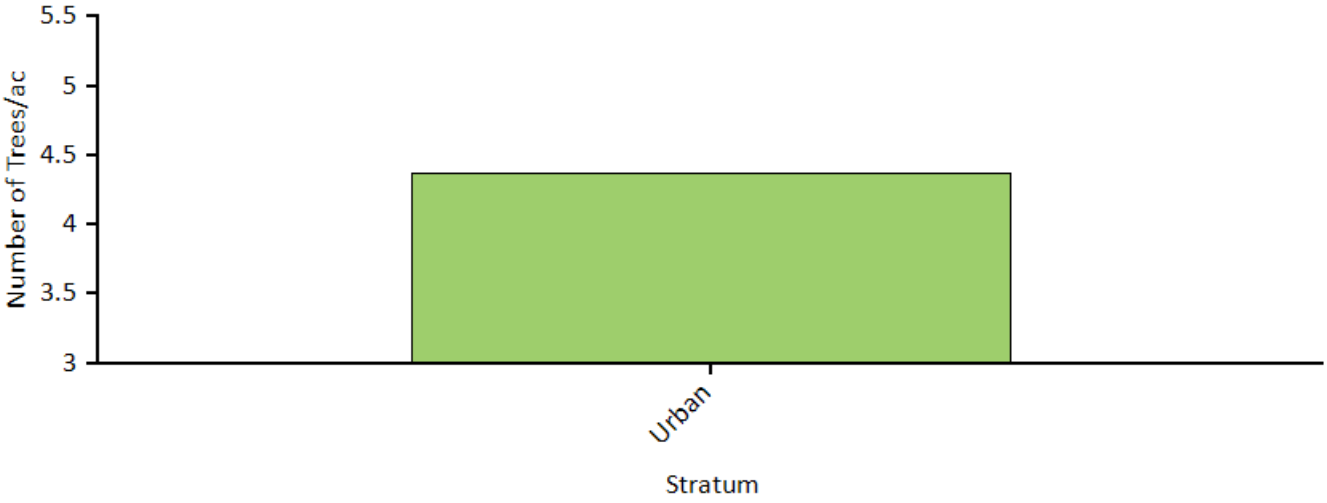


Figure 2. Number of trees/ac in Lee by stratum

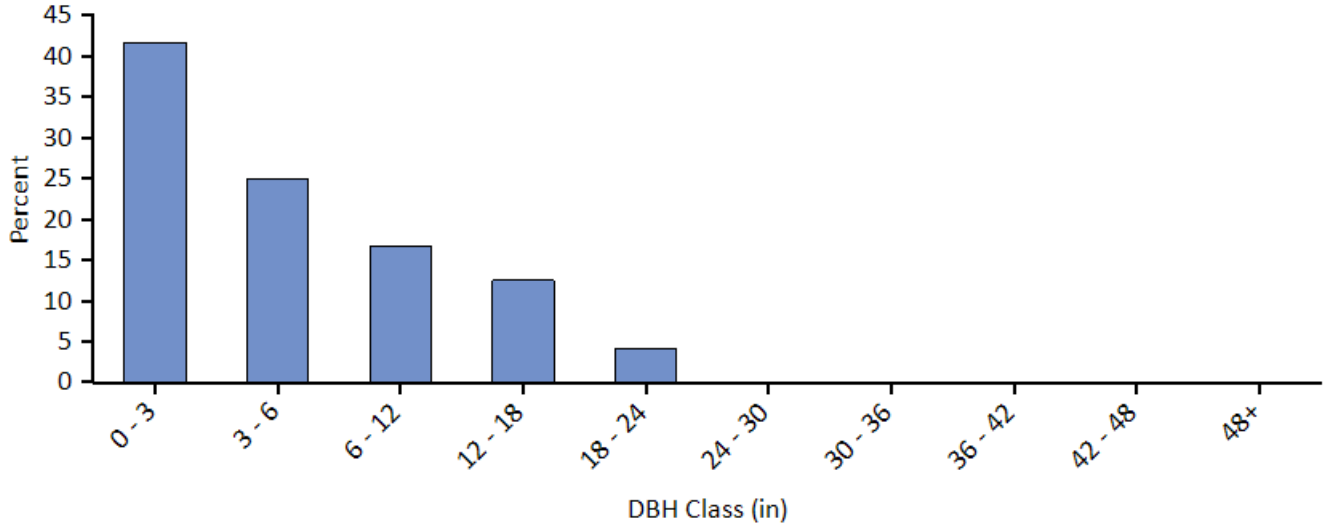


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Lee, about 8 percent of the trees are species native to North America, while 8 percent are native to Kansas. Species exotic to North America make up 92 percent of the population. Most exotic tree species have an origin from North America + (75 percent of the species).

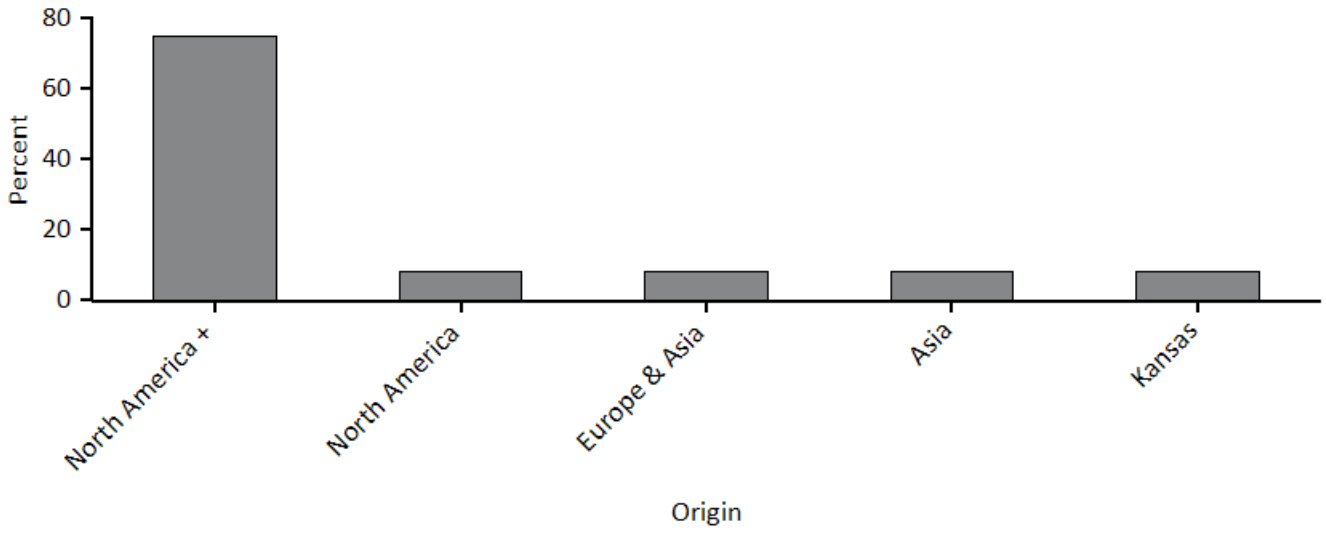


Figure 4. Percent of live tree population by area of native origin, Lee

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. Zero of the 8 tree species in Lee are identified as invasive on the state invasive species list (Kansas Native Plant Society 2006).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 2.2 percent of Lee and provide 0.7858 acres of leaf area. Total leaf area is greatest in Urban.

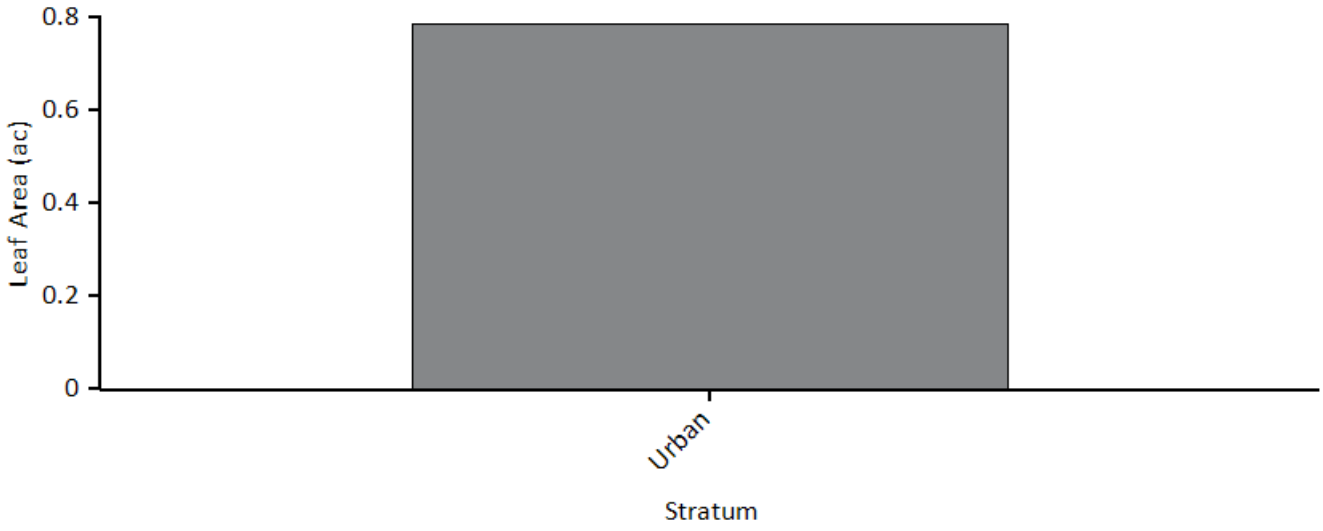


Figure 5. Leaf area by stratum, Lee

In Lee, the most dominant species in terms of leaf area are ash spp, maple spp, and oak spp. The 8 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Lee

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
maple spp	41.7	27.2	68.8
ash spp	8.3	36.0	44.3
oak spp	4.2	23.5	27.7
elm spp	20.8	6.7	27.5
American sycamore	4.2	5.6	9.7
Japanese tree lilac	8.3	0.7	9.0
Cherry plum	8.3	0.4	8.7
Shagbark hickory	4.2	0.0	4.2

Common ground cover classes (including cover types beneath trees and shrubs) in Lee are not available since they are configured not to be collected.

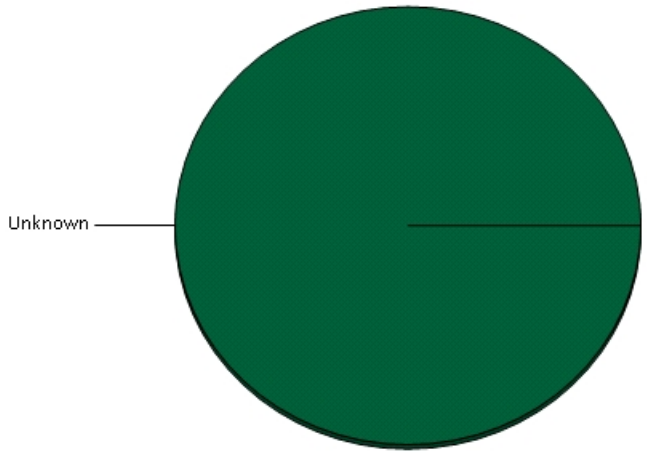


Figure 6. Percent of land by ground cover classes, Lee

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in Lee was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 6.662 pounds of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), particulate matter less than 10 microns and greater than 2.5 microns (PM10*)[2], and sulfur dioxide (SO2)) per year with an associated value of $18.4 (see Appendix I for more details).

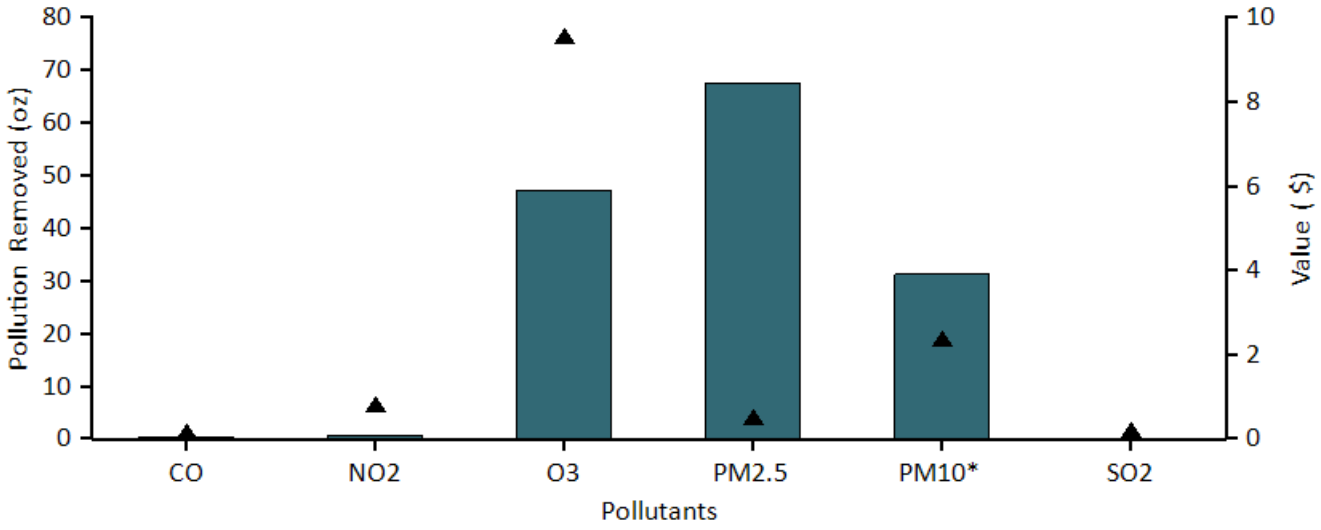


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Lee

[1] PM10* is particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is particulate matter less than 2.5 microns. If PM2.5 is not monitored, PM10* represents particulate matter less than 10 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces. This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2022, trees in Lee emitted an estimated 8.986 pounds of volatile organic compounds (VOCs) (4.344 pounds of isoprene and 4.642 pounds of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Ninety- five percent of the urban forest's VOC emissions were from oak spp and maple spp. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Lee trees is about 388.3 pounds of carbon per year with an associated value of $33.1. See Appendix I for more details on methods.

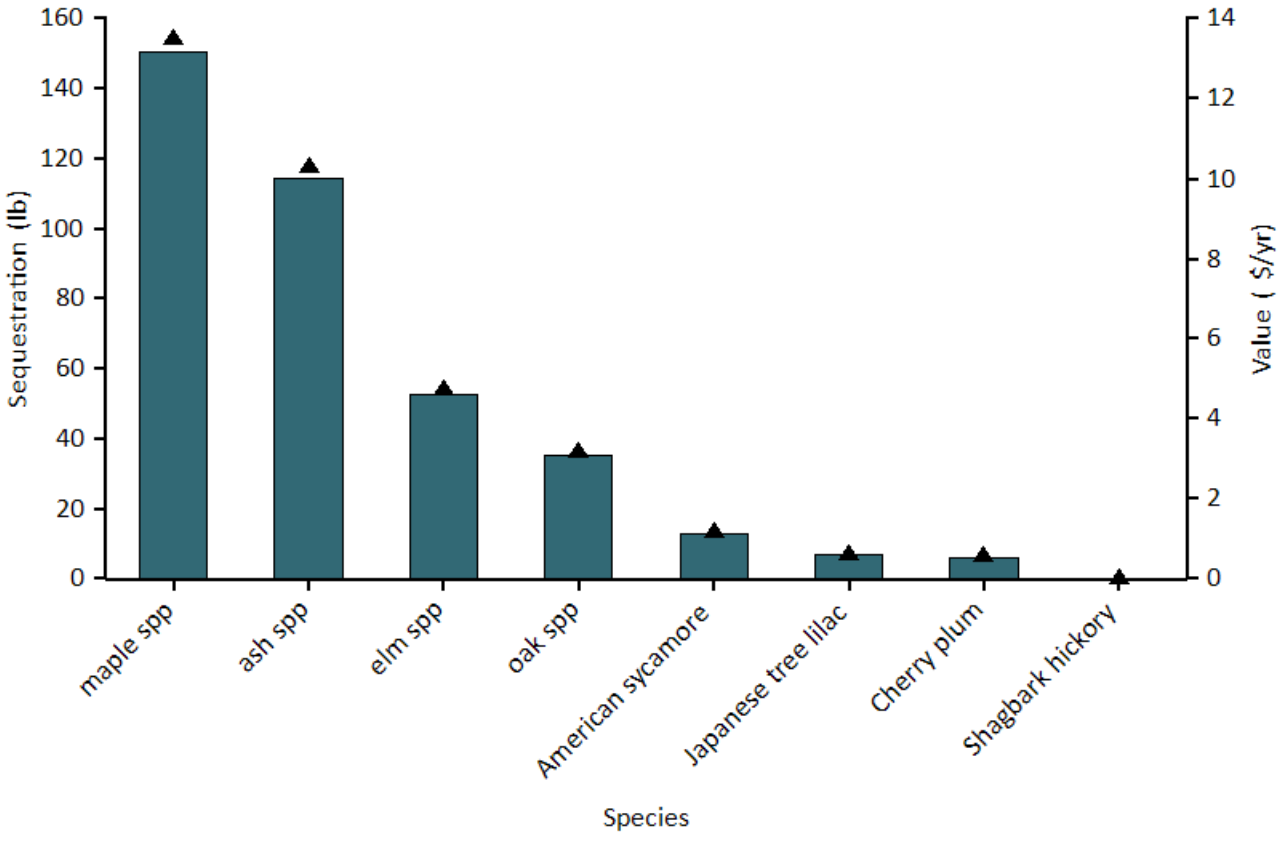


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Lee

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Lee are estimated to store 3.79 tons of carbon ($646). Of the species sampled, ash spp stores the most carbon (approximately 33.6% of the total carbon stored) and maple spp sequesters the most (approximately 39.7% of all

sequestered carbon.)

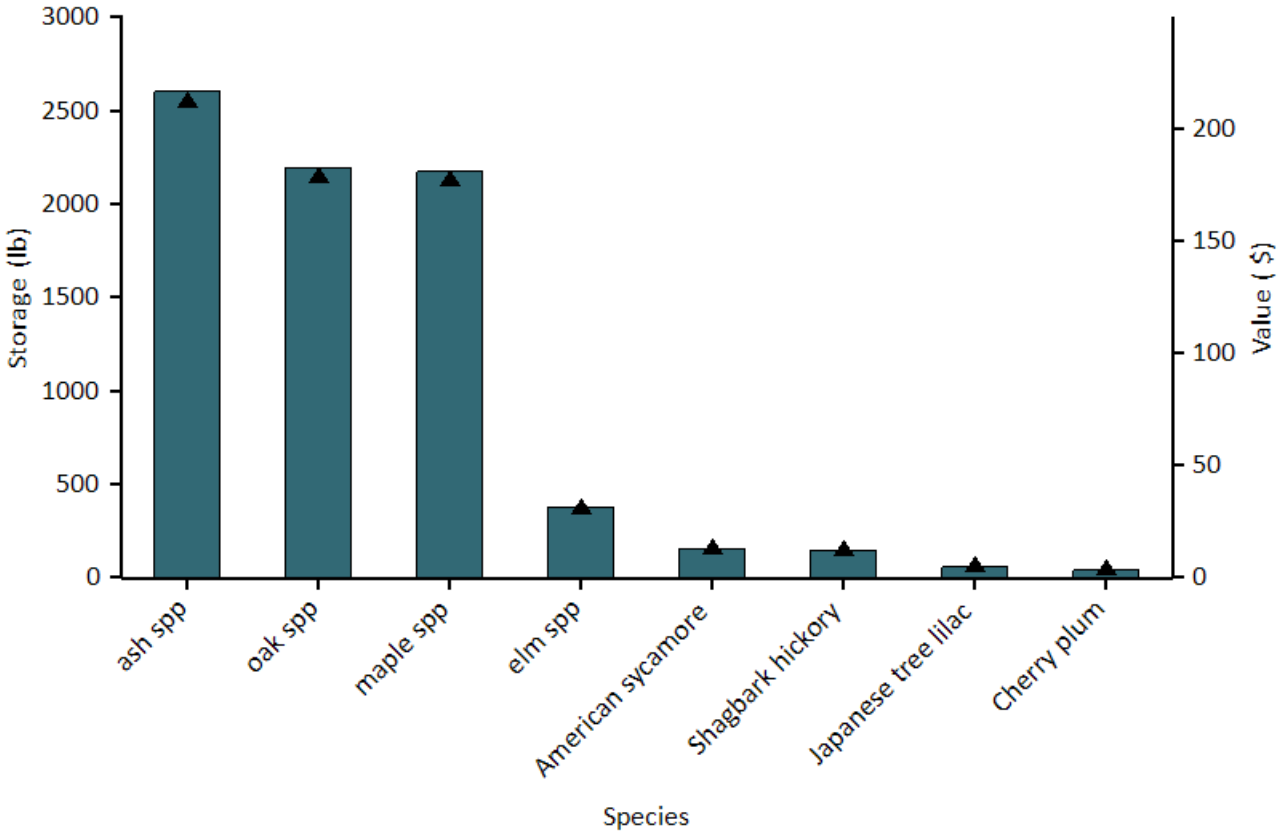


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Lee

V. Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Lee are estimated to produce 1035 pounds of oxygen per year.[4] However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 8 oxygen production species.

Species	*Oxygen (pound)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (square feet)*
maple spp	411.34	154.25	10	0.01
ash spp	313.08	117.41	2	0.01
elm spp	143.39	53.77	5	0.00
oak spp	96.44	36.16	1	0.01
American sycamore	35.36	13.26	1	0.00
Japanese tree lilac	18.88	7.08	2	0.00
Cherry plum	16.58	6.22	2	0.00
Shagbark hickory	0.31	0.11	1	0.00

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Lee help to reduce runoff by an estimated 293 cubic feet a year with an associated value of $20 (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Lee, the total annual precipitation in 2019 was 44.7 inches.

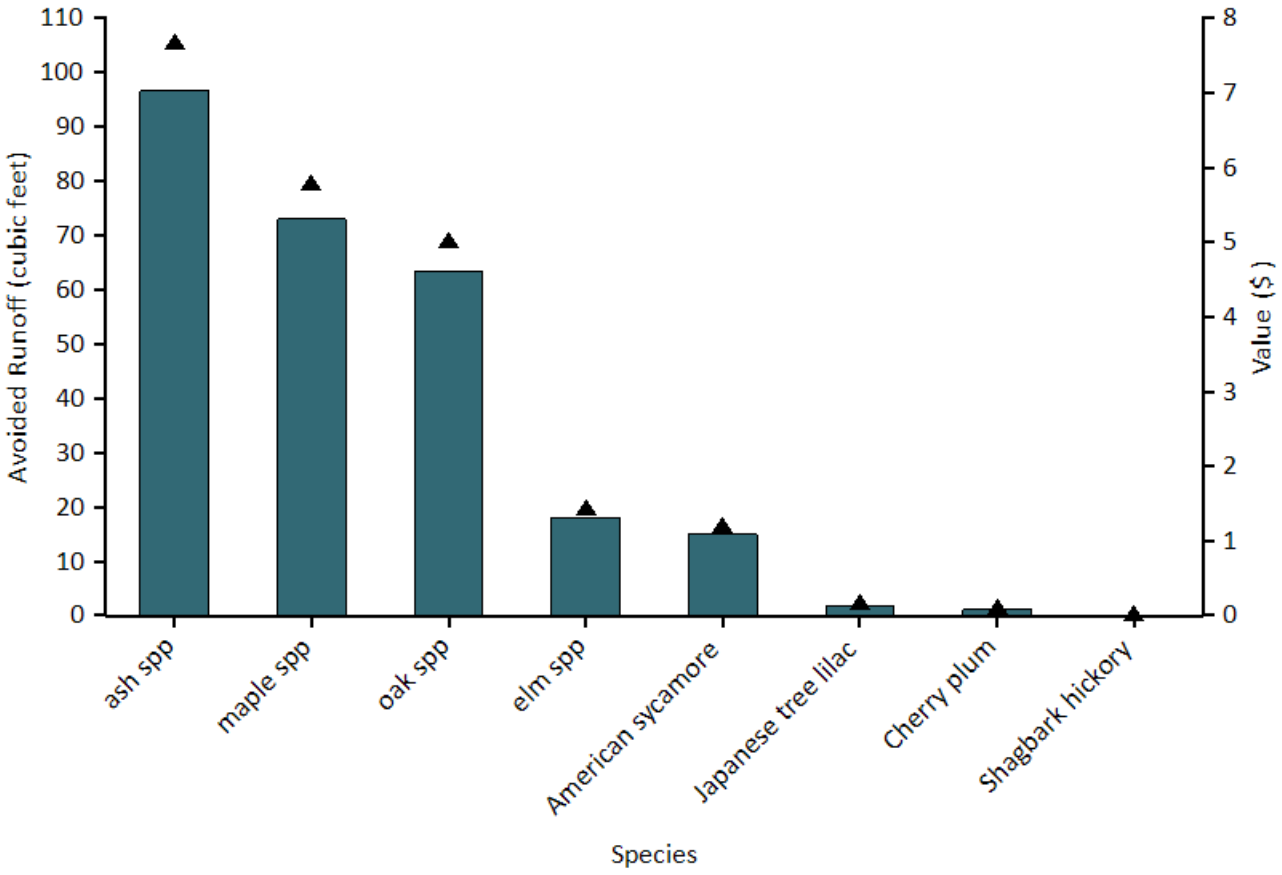


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Lee

VII. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Because energy-related data were not collected, energy savings and carbon avoided cannot be calculated.

Table 3. Annual energy savings due to trees near residential buildings, Lee

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (pounds)	0	0	0

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, Lee

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of $130.2 per MWH and $11.3442000317562 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Replacement and Functional Values

Urban forests have a replacement value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The replacement value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Lee have the following replacement values:

- Replacement value: $19.9 thousand
- Carbon storage: $646

Urban trees in Lee have the following annual functional values:

- Carbon sequestration: $33.1
- Avoided runoff: $19.6
- Pollution removal: $18.4
- Energy costs and carbon emission values: $0

(Note: negative value indicates increased energy cost and carbon emission value)

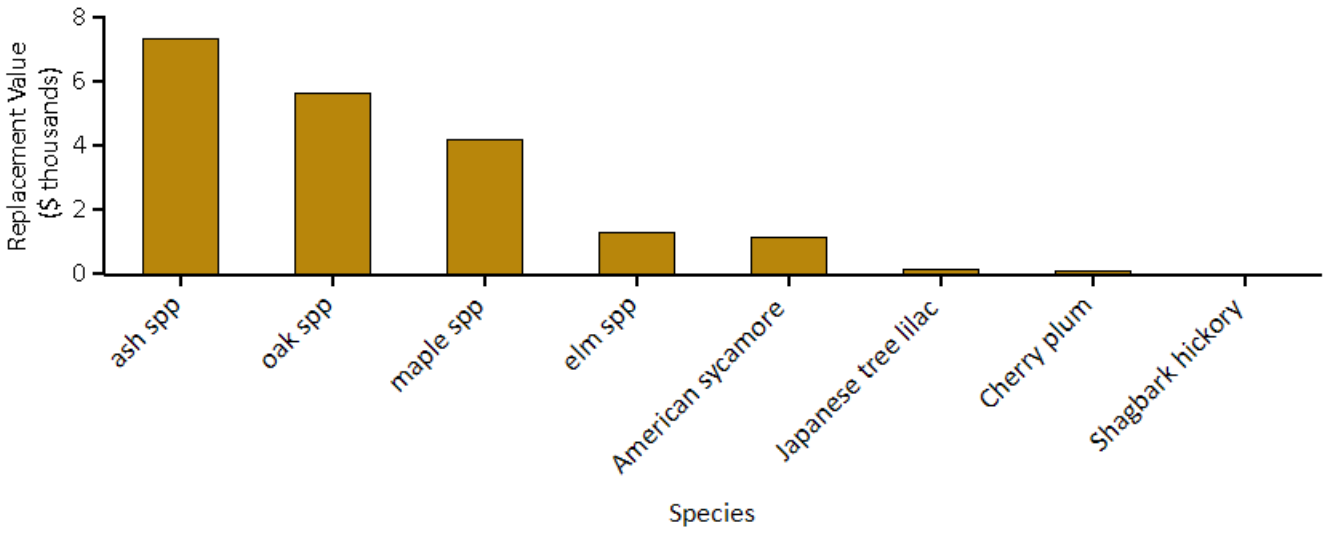


Figure 11. Tree species with the greatest replacement value, Lee

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, replacement value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Riley County. One of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

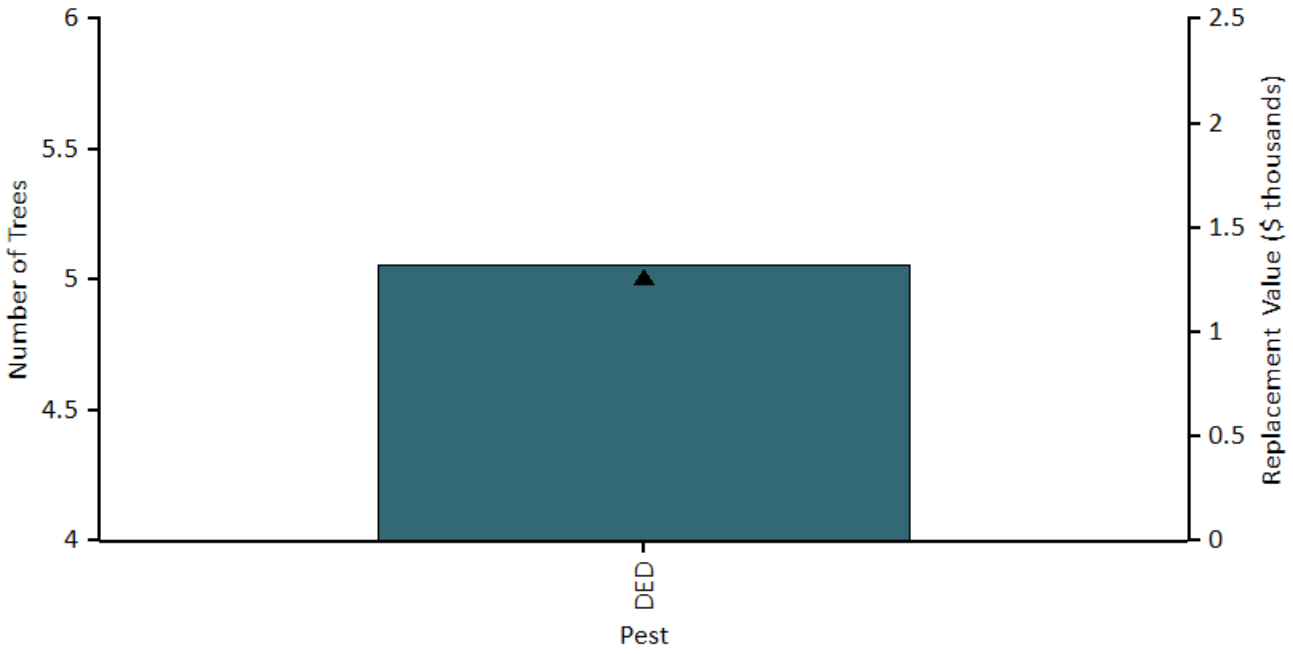


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, Lee

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Lee could possibly lose 20.8 percent of its trees to this pest ($1.32 thousand in replacement value).

Appendix I. i-Tree Eco Model and Field Measurements

i-Tree Eco is designed to use standardized field data and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Replacement value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Kansas Native Plant Society 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter less than 2.5 microns, and particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces (Nowak et al 2013). This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to

the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 and PM10* removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 and PM10* concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 and PM10* but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,443 per ton (carbon monoxide), $2,487 per ton (ozone), $480 per ton (nitrogen dioxide), $209 per ton (sulfur dioxide), $74,859 per ton (particulate matter less than 2.5 microns), $6,781 per ton (particulate matter less than 10 microns and greater than 2.5 microns).

Carbon Storage and Sequestration:

Carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak 1994). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition (Nowak et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of $0.07 per ft^3.

Building Energy Use:

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

For this analysis, energy saving value is calculated based on the prices of $130.20 per MWH and $11.34 per MBTU.

Replacement Values:

Replacement value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Replacement values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Replacement value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in Lee provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Lee in 0 days
- Annual carbon (C) emissions from 3 automobiles
- Annual C emissions from 1 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 0 automobiles
- Annual carbon monoxide emissions from 0 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 0 automobiles
- Annual nitrogen dioxide emissions from 0 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 0 automobiles
- Annual sulfur dioxide emissions from 0 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Lee in 0.0 days
- Annual C emissions from 0 automobiles
- Annual C emissions from 0 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (Nowak 1995):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (Nowak 2000). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include (Nowak 2000):

Strategy	*Result*
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Kansas invasive species list (Kansas Native Plant Society 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ac)*	*Percent Leaf Area*
Total	**0**	**0.00**	**0.00**	**0.00**

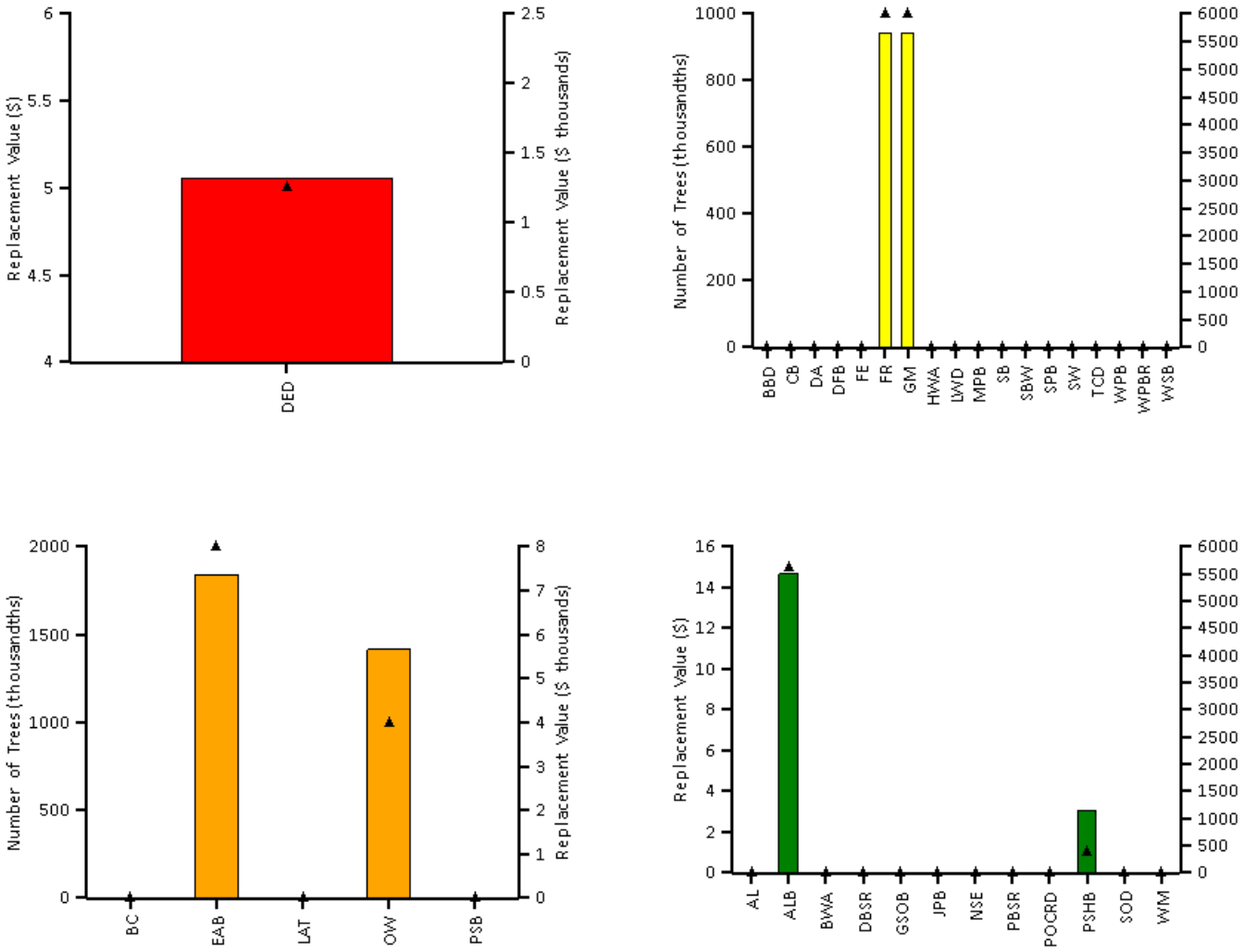
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($)
AL	Phyllocnistis populiella	Aspen Leafminer	0	0.00
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	15	5,501.20
BBD	Neonectria faginata	Beech Bark Disease	0	0.00
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	0	0.00
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	0	0.00
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	5	1,319.44
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	2	7,351.33
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	1	5,662.23
GM	Lymantria dispar	Gypsy Moth	1	5,662.23
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	0	0.00
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	1	5,662.23
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	0	0.00
PSB	Tomicus piniperda	Pine Shoot Beetle	0	0.00
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	1	1,151.59
SB	Dendroctonus rufipennis	Spruce Beetle	0	0.00
SBW	Choristoneura fumiferana	Spruce Budworm	0	0.00
SOD	Phytophthora ramorum	Sudden Oak Death	0	0.00
SPB	Dendroctonus frontalis	Southern Pine Beetle	0	0.00
SW	Sirex noctilio	Sirex Wood Wasp	0	0.00
TCD	Geosmithia morbida	Thousand Canker Disease	0	0.00
WM	Operophtera brumata	Winter Moth	0	0.00
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	0	0.00
WSB	Choristoneura occidentalis	Western Spruce Budworm	0	0.00

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Replacement value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
	7	oak spp																																				
	5	elm spp																																				
	3	ash spp																																				
	1	maple spp																																				
	1	American sycamore																																				

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Riley county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Riley county
- Green indicates pest is outside of these ranges

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i-Tree Ecosystem Analysis

Marlatt

Urban Forest Effects and Values
March 2022

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Marlatt urban forest was conducted during 2022. Data from 73 trees located throughout Marlatt were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 73
- Tree Cover: 9.3 %
- Most common species of trees: Callery pear, maple spp, pine spp
- Percentage of trees less than 6" (15.2 cm) diameter: 32.9%
- Pollution Removal: 47.47 pounds/year ($128/year)
- Carbon Storage: 36.48 tons ($6.22 thousand)
- Carbon Sequestration: 1759 pounds ($150/year)
- Oxygen Production: 2.346 tons/year
- Avoided Runoff: 1.886 thousand cubic feet/year ($126/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Replacement values: $161 thousand

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control.

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I. Tree Characteristics of the Urban Forest

The urban forest of Marlatt has 73 trees with a tree cover of 9.3 percent. The three most common species are Callery pear (13.7 percent), maple spp (13.7 percent), and pine spp (12.3 percent).

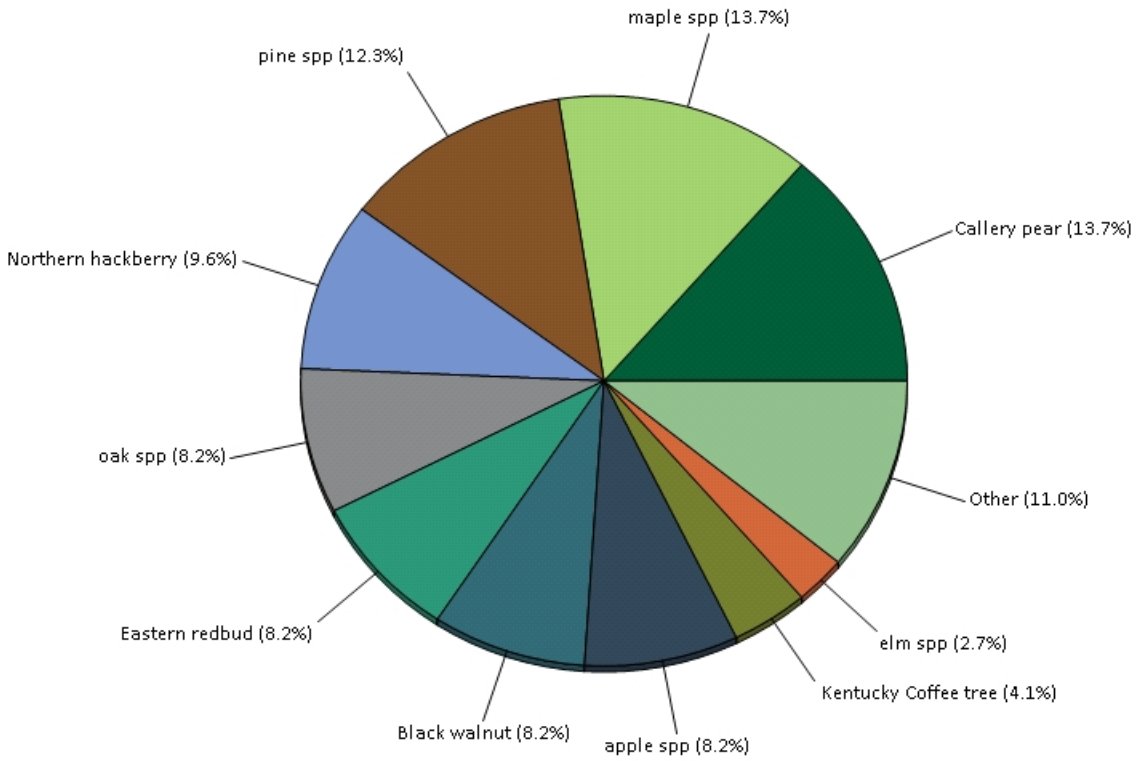


Figure 1. Tree species composition in Marlatt

The overall tree density in Marlatt is 8 trees/acre (see Appendix III for comparable values from other cities).

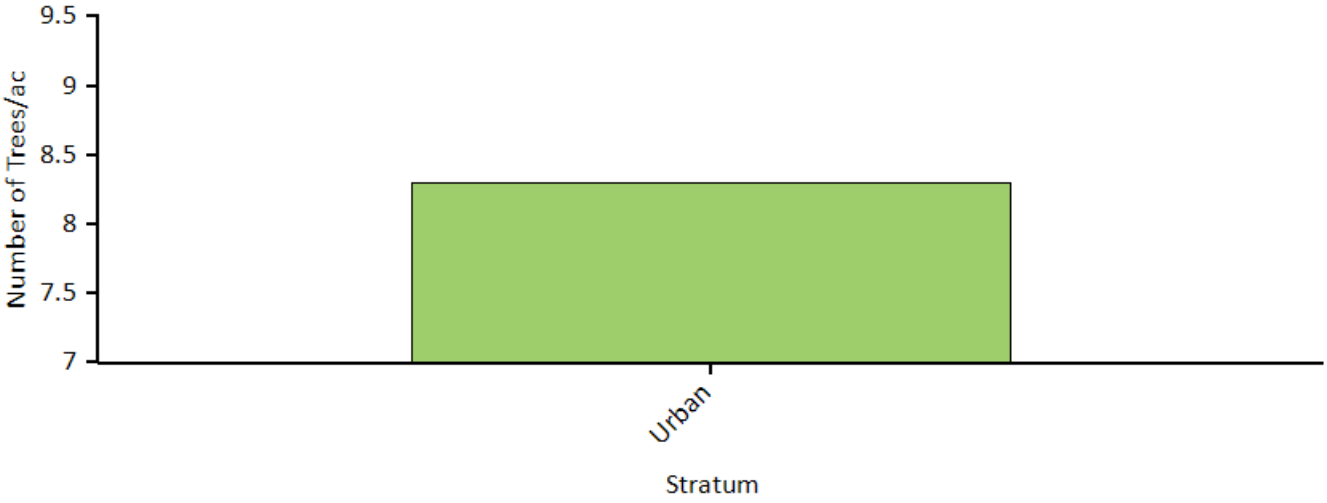


Figure 2. Number of trees/ac in Marlatt by stratum

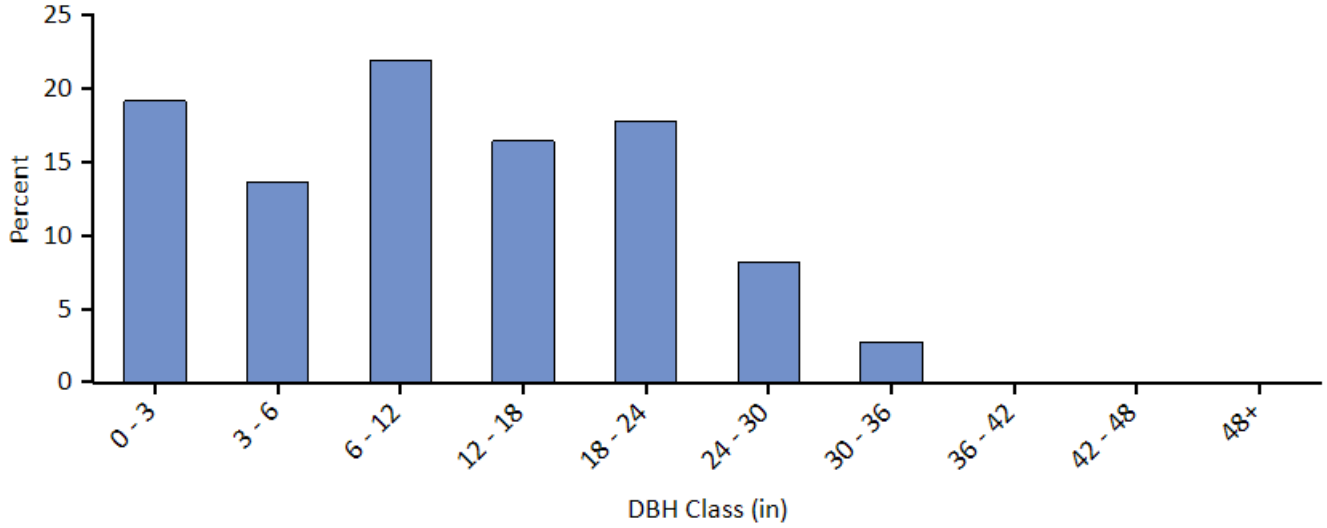


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Marlatt, about 40 percent of the trees are species native to North America, while 32 percent are native to Kansas. Species exotic to North America make up 60 percent of the population. Most exotic tree species have an origin from North America + (47 percent of the species).

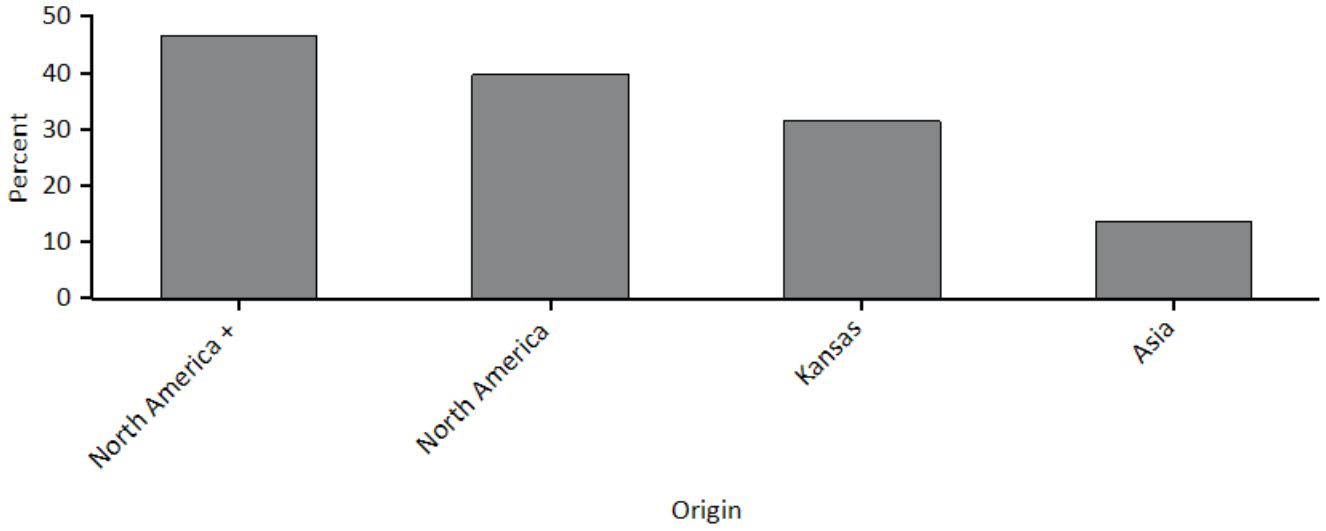


Figure 4. Percent of live tree population by area of native origin, Marlatt

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. One of the 17 tree species in Marlatt are identified as invasive on the state invasive species list (Kansas Native Plant Society 2006). This invasive species (Callery pear) comprises 13.7 percent of the tree population though it may only cause a minimal level of impact (see Appendix V for a complete list of invasive species).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 9.3 percent of Marlatt and provide 4.228 acres of leaf area. Total leaf area is greatest in Urban.

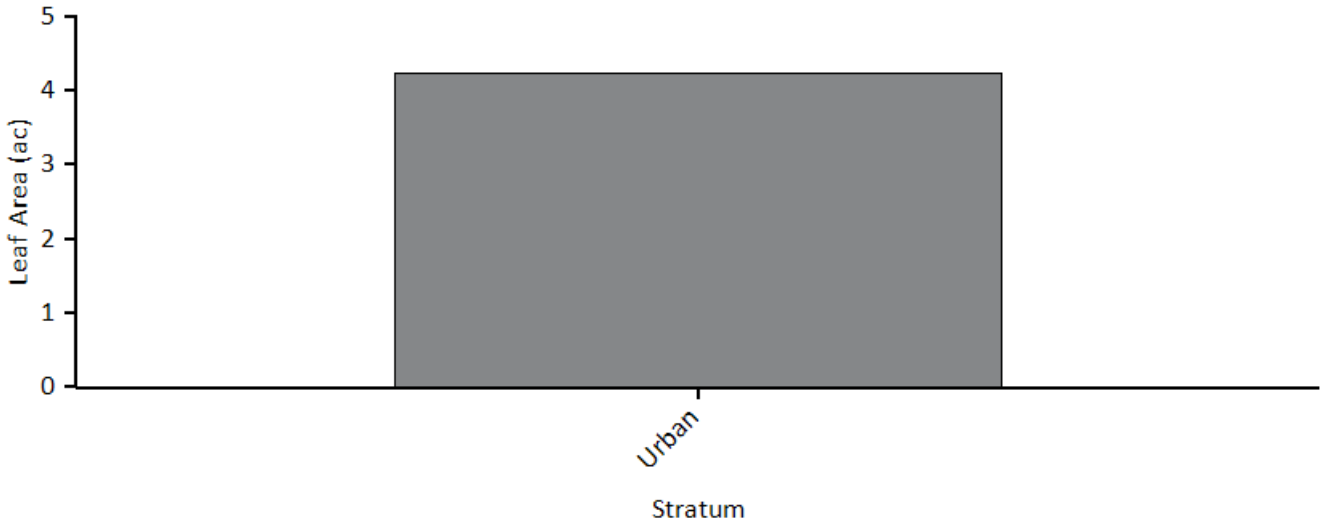


Figure 5. Leaf area by stratum, Marlatt

In Marlatt, the most dominant species in terms of leaf area are pine spp, Black walnut, and Callery pear. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Marlatt

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
pine spp	12.3	18.9	31.2
Callery pear	13.7	16.2	29.9
Black walnut	8.2	18.5	26.7
Northern hackberry	9.6	15.8	25.3
maple spp	13.7	6.1	19.8
oak spp	8.2	8.3	16.6
Eastern redbud	8.2	1.8	10.0
apple spp	8.2	0.6	8.8
elm spp	2.7	4.0	6.7
Northern catalpa	1.4	3.3	4.7

Common ground cover classes (including cover types beneath trees and shrubs) in Marlatt are not available since they are configured not to be collected.

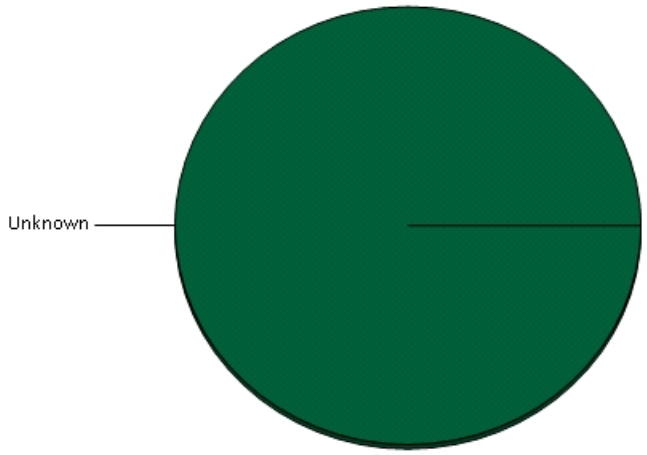


Figure 6. Percent of land by ground cover classes, Marlatt

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in Marlatt was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 47.47 pounds of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), particulate matter less than 10 microns and greater than 2.5 microns (PM10*)[2], and sulfur dioxide (SO2)) per year with an associated value of $128 (see Appendix I for more details).

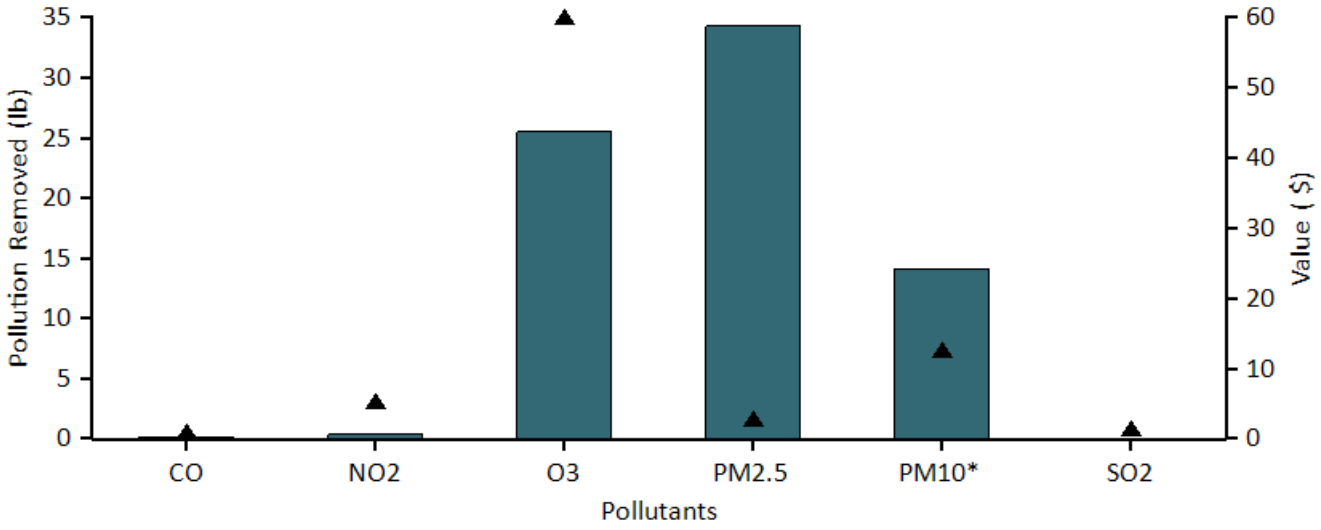


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Marlatt

[1] PM10* is particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is particulate matter less than 2.5 microns. If PM2.5 is not monitored, PM10* represents particulate matter less than 10 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces. This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2022, trees in Marlatt emitted an estimated 33.7 pounds of volatile organic compounds (VOCs) (9.051 pounds of isoprene and 24.65 pounds of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Seventy- four percent of the urban forest's VOC emissions were from oak spp and pine spp. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Marlatt trees is about 1759 pounds of carbon per year with an associated value of $150. See Appendix I for more details on methods.

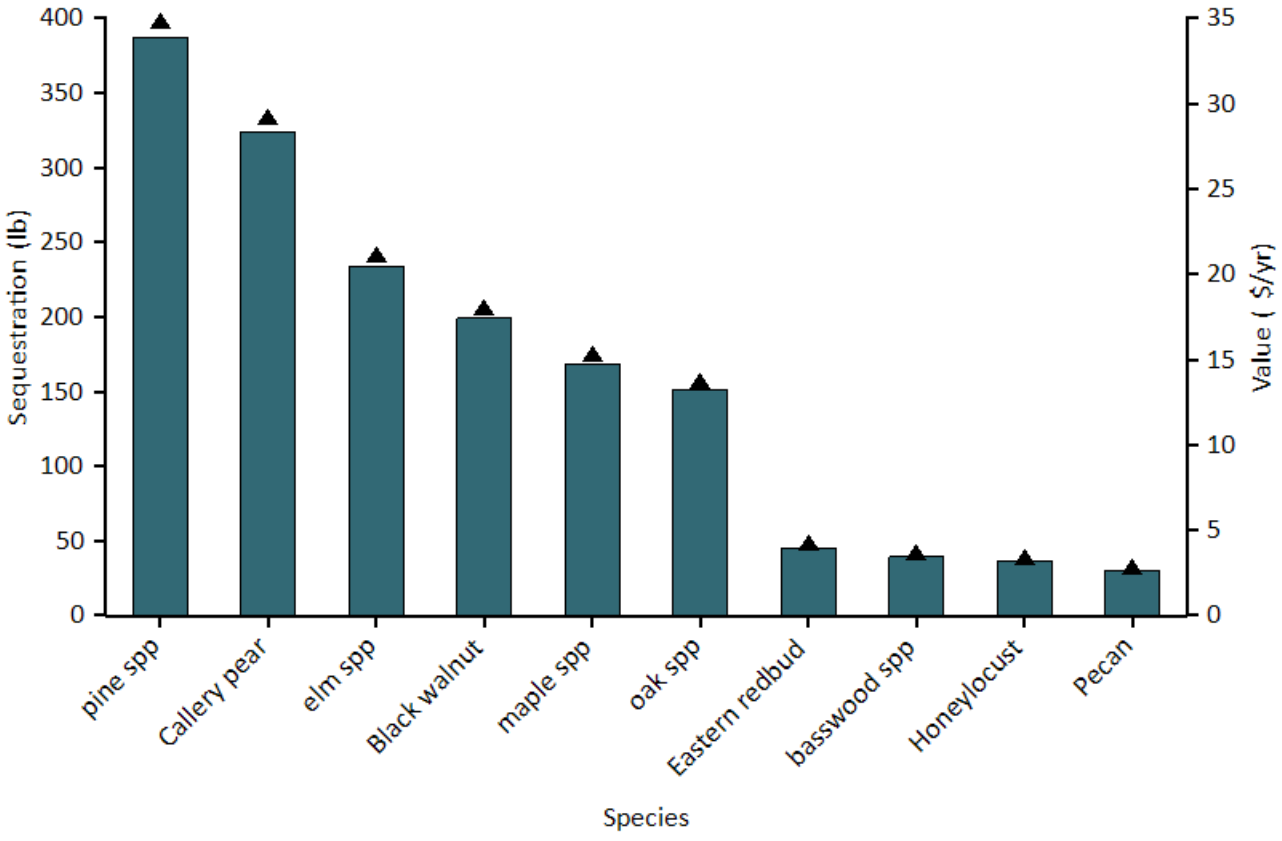


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Marlatt

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Marlatt are estimated to store 36.5 tons of carbon ($6.22 thousand). Of the species sampled, elm spp stores the most carbon (approximately 27.3% of the total carbon stored) and pine spp sequesters the most (approximately 22.6% of

all sequestered carbon.)

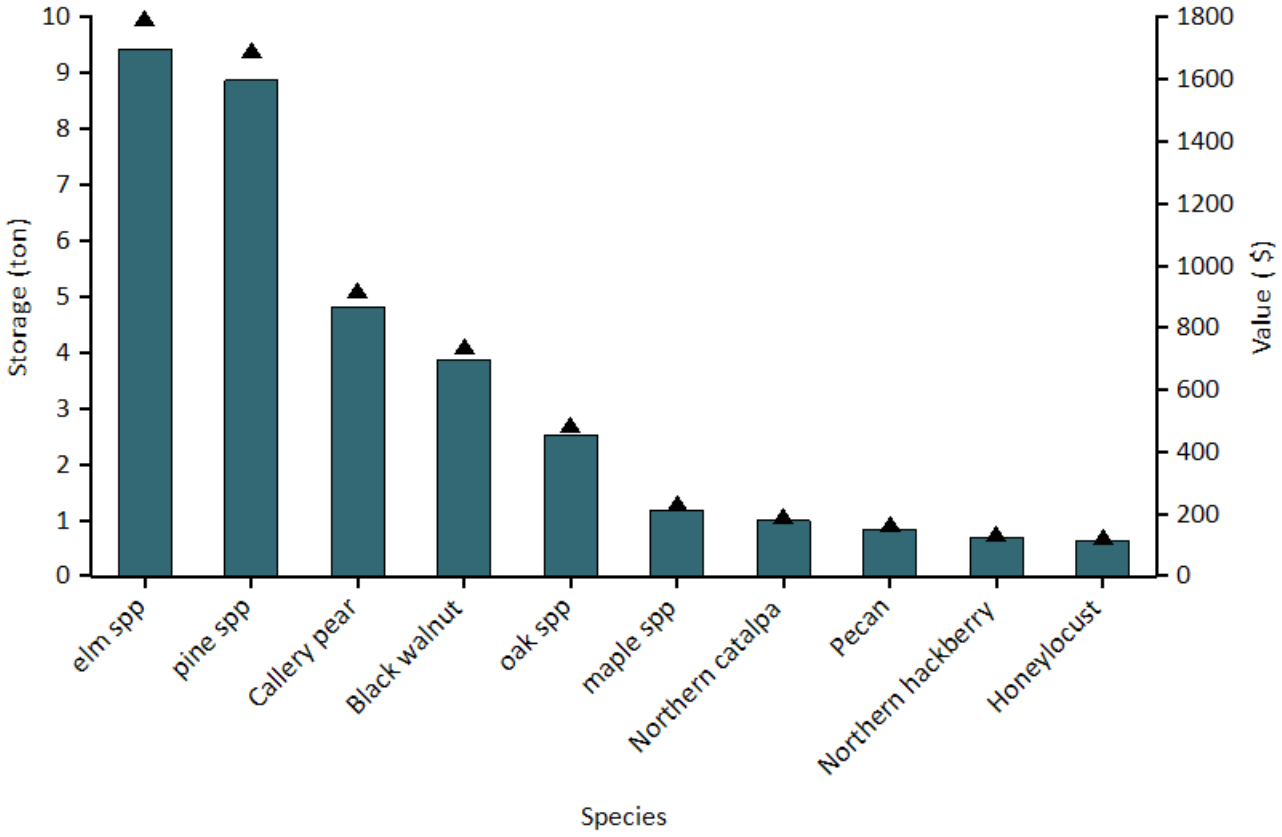


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Marlatt

V. Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Marlatt are estimated to produce 2.346 tons of oxygen per year.[4] However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 17 oxygen production species.

Species	*Oxygen (pound)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (acre)*
pine spp	1,059.50	397.31	9	0.80
Callery pear	886.57	332.46	10	0.68
elm spp	639.86	239.95	2	0.17
Black walnut	545.37	204.51	6	0.78
maple spp	461.88	173.20	10	0.26
oak spp	413.87	155.20	6	0.35
Eastern redbud	124.65	46.74	6	0.07
basswood spp	107.53	40.33	1	0.05
Honeylocust	100.00	37.50	1	0.11
Pecan	83.08	31.16	1	0.10
Northern catalpa	79.25	29.72	1	0.14
apple spp	71.78	26.92	6	0.03
Northern hackberry	64.44	24.16	7	0.67
Eastern red cedar	18.28	6.86	2	0.01
Kentucky Coffee tree	17.40	6.52	3	0.00
Tulip tree	9.19	3.44	1	0.00
Blue spruce	8.41	3.15	1	0.00

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Marlatt help to reduce runoff by an estimated 1.89 thousand cubic feet a year with an associated value of $130 (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Marlatt, the total annual precipitation in 2019 was 44.7 inches.

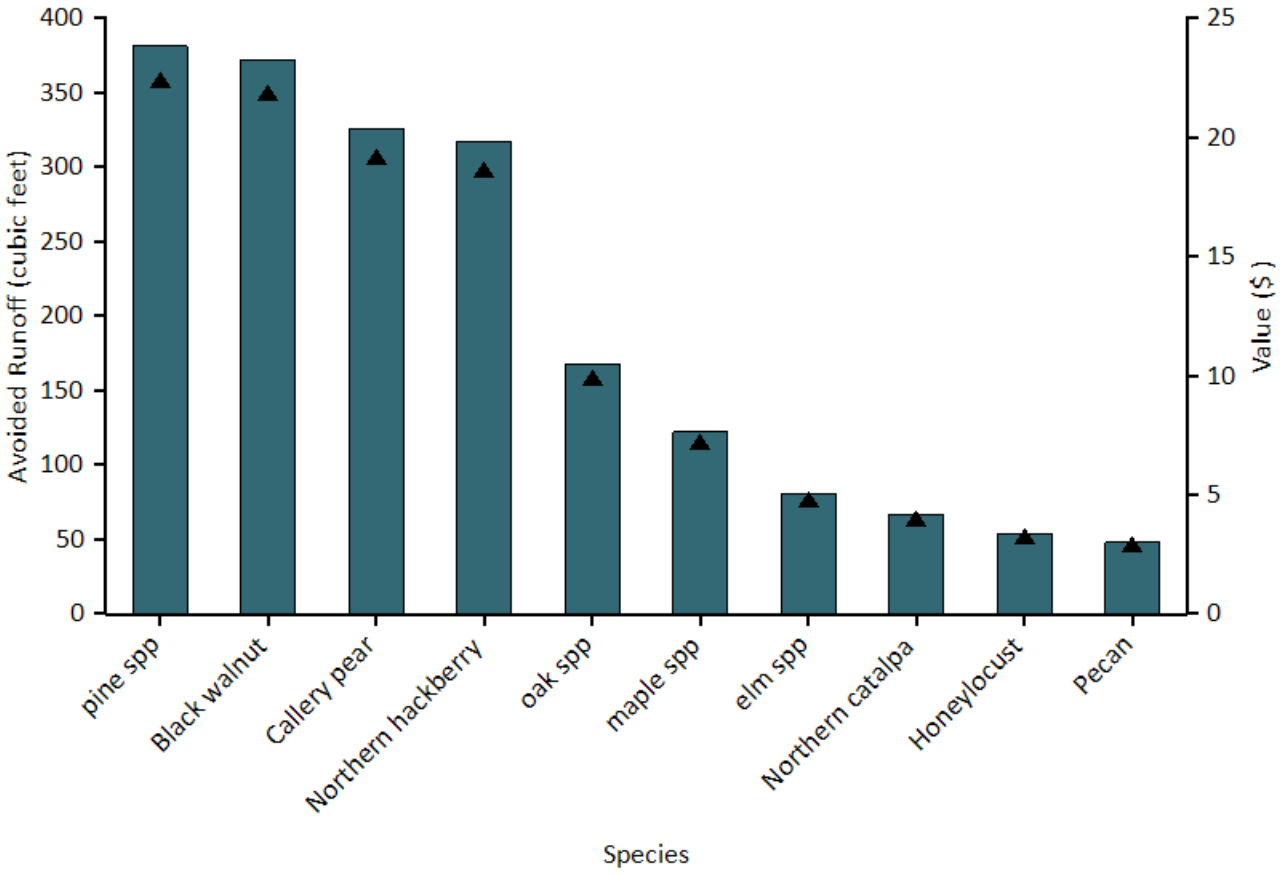


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Marlatt

VII. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Because energy-related data were not collected, energy savings and carbon avoided cannot be calculated.

Table 3. Annual energy savings due to trees near residential buildings, Marlatt

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (pounds)	0	0	0

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, Marlatt

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of $130.2 per MWH and $11.3442000317562 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Replacement and Functional Values

Urban forests have a replacement value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The replacement value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Marlatt have the following replacement values:

- Replacement value: $161 thousand
- Carbon storage: $6.22 thousand

Urban trees in Marlatt have the following annual functional values:

- Carbon sequestration: $150
- Avoided runoff: $126
- Pollution removal: $128
- Energy costs and carbon emission values: $0

(Note: negative value indicates increased energy cost and carbon emission value)

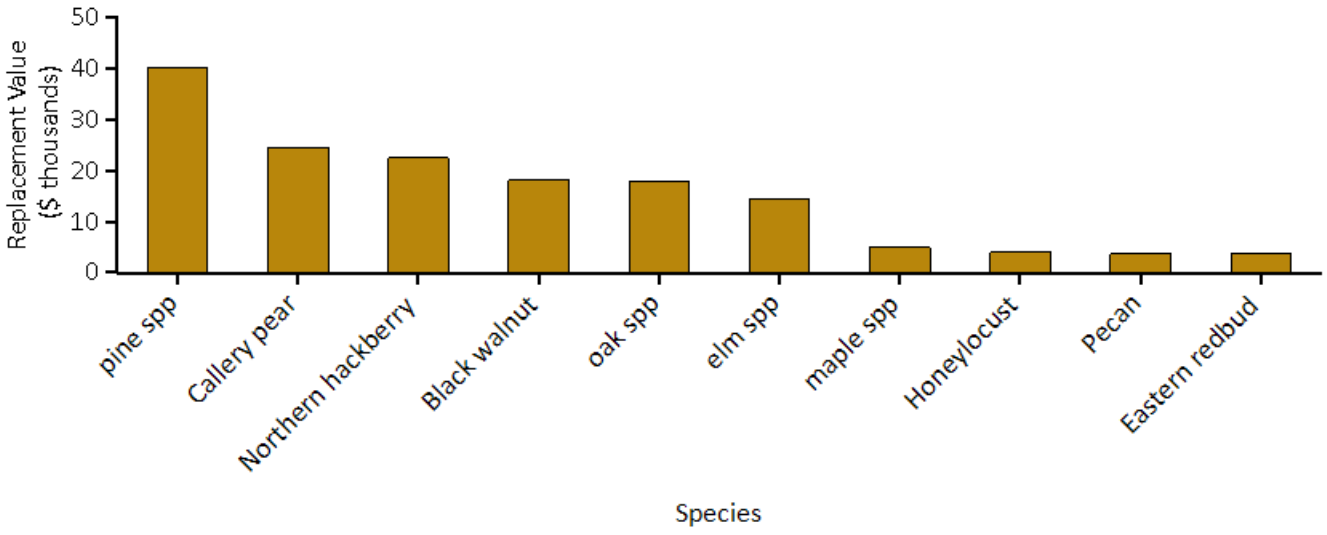


Figure 11. Tree species with the greatest replacement value, Marlatt

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, replacement value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Riley County. One of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

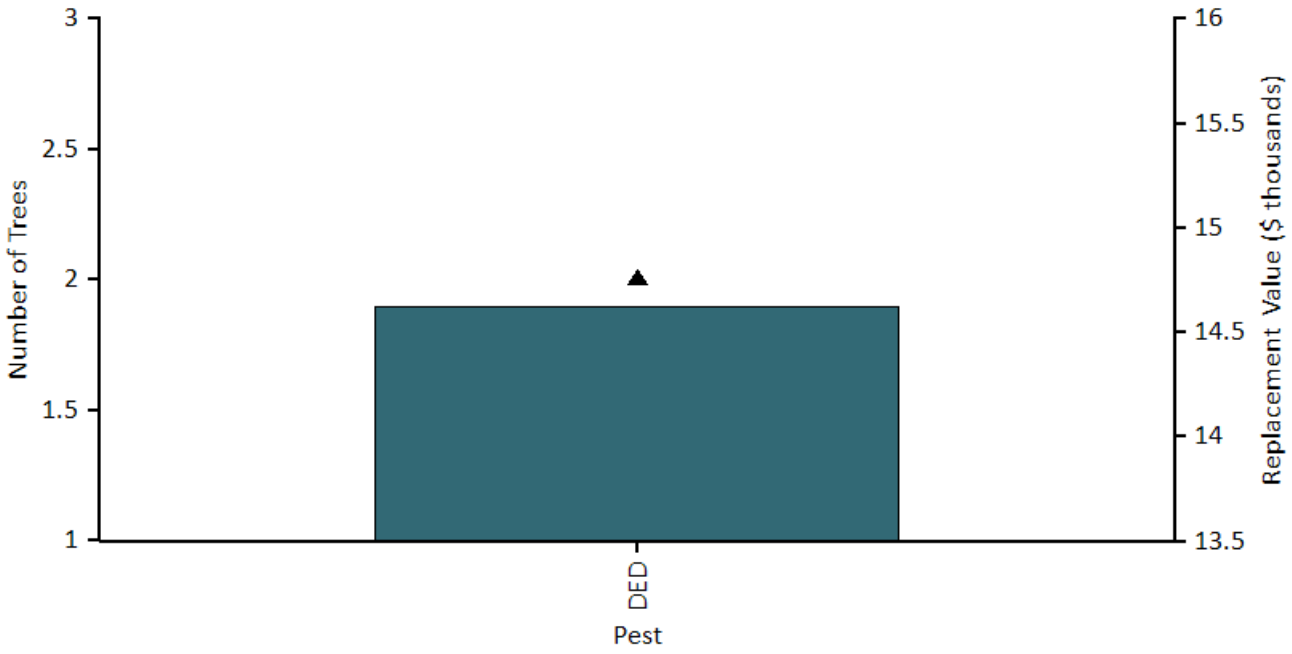


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, Marlatt

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Marlatt could possibly lose 2.7 percent of its trees to this pest ($14.6 thousand in replacement value).

Appendix I. i-Tree Eco Model and Field Measurements

i-Tree Eco is designed to use standardized field data and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Replacement value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Kansas Native Plant Society 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter less than 2.5 microns, and particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces (Nowak et al 2013). This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to

the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 and PM10* removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 and PM10* concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 and PM10* but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,443 per ton (carbon monoxide), $2,515 per ton (ozone), $462 per ton (nitrogen dioxide), $187 per ton (sulfur dioxide), $78,653 per ton (particulate matter less than 2.5 microns), $6,781 per ton (particulate matter less than 10 microns and greater than 2.5 microns).

Carbon Storage and Sequestration:

Carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak 1994). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition (Nowak et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of $0.07 per ft^3.

Building Energy Use:

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

For this analysis, energy saving value is calculated based on the prices of $130.20 per MWH and $11.34 per MBTU.

Replacement Values:

Replacement value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Replacement values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Replacement value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in Marlatt provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Marlatt in 0 days
- Annual carbon (C) emissions from 26 automobiles
- Annual C emissions from 11 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 0 automobiles
- Annual carbon monoxide emissions from 0 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 0 automobiles
- Annual nitrogen dioxide emissions from 0 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 4 automobiles
- Annual sulfur dioxide emissions from 0 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Marlatt in 0.0 days
- Annual C emissions from 0 automobiles
- Annual C emissions from 0 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (Nowak 1995):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (Nowak 2000). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include (Nowak 2000):

Strategy	*Result*
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Kansas invasive species list (Kansas Native Plant Society 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ac)*	*Percent Leaf Area*
Callery pear	10	13.7	0.7	16.2
Total	**10**	**13.70**	**0.68**	**16.17**

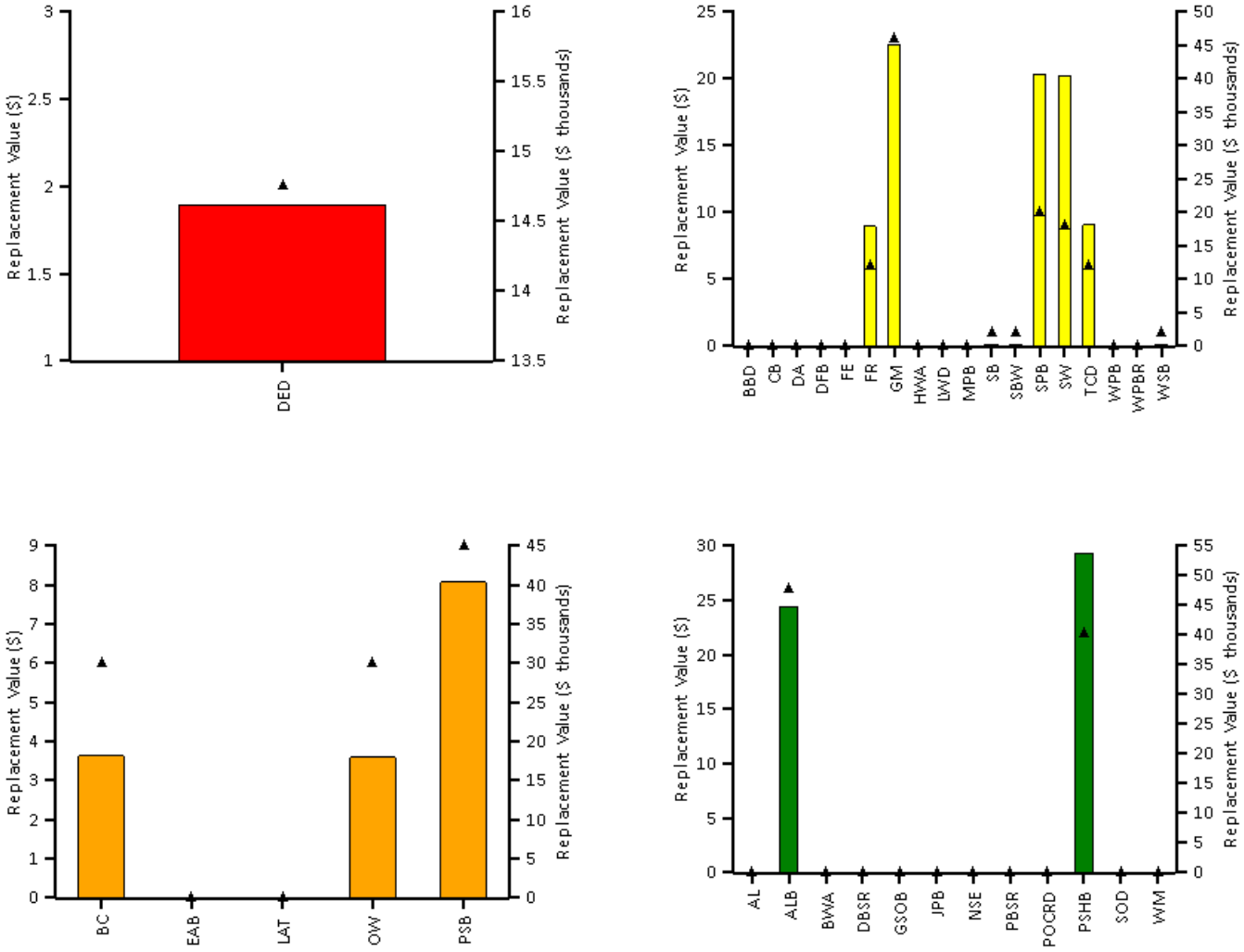
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ thousands)
AL	Phyllocnistis populiella	Aspen Leafminer	0	0.00
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	26	44.78
BBD	Neonectria faginata	Beech Bark Disease	0	0.00
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	6	18.14
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	0	0.00
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	2	14.62
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	0	0.00
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	6	17.95
GM	Lymantria dispar	Gypsy Moth	23	45.21
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	0	0.00
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	6	17.95
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	0	0.00
PSB	Tomicus piniperda	Pine Shoot Beetle	9	40.39
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	22	53.80
SB	Dendroctonus rufipennis	Spruce Beetle	1	0.29
SBW	Choristoneura fumiferana	Spruce Budworm	1	0.29
SOD	Phytophthora ramorum	Sudden Oak Death	0	0.00
SPB	Dendroctonus frontalis	Southern Pine Beetle	10	40.68
SW	Sirex noctilio	Sirex Wood Wasp	9	40.39
TCD	Geosmithia morbida	Thousand Canker Disease	6	18.14
WM	Operophtera brumata	Winter Moth	0	0.00
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	0	0.00
WSB	Choristoneura occidentalis	Western Spruce Budworm	1	0.29

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Replacement value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
	8	Blue spruce																																				
	7	pine spp																																				
	7	oak spp																																				
	6	Black walnut																																				
	5	elm spp																																				
	3	Callery pear																																				
	3	apple spp																																				
	3	basswood spp																																				
	1	maple spp																																				
	1	Northern hackberry																																				
	1	Eastern red cedar																																				
	1	Pecan																																				
	1	Northern catalpa																																				
	1	Honeylocust																																				
	1	Tulip tree																																				

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Riley county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Riley county
- Green indicates pest is outside of these ranges

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i-Tree Ecosystem Analysis

Northview

Urban Forest Effects and Values
March 2022

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Northview urban forest was conducted during 2022. Data from 26 trees located throughout Northview were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 26
- Tree Cover: 1.7 %
- Most common species of trees: Honeylocust, maple spp, Baldcypress
- Percentage of trees less than 6" (15.2 cm) diameter: 19.2%
- Pollution Removal: 12.89 pounds/year ($34.8/year)
- Carbon Storage: 10.16 tons ($1.73 thousand)
- Carbon Sequestration: 717.6 pounds ($61.2/year)
- Oxygen Production: 1914 pounds/year
- Avoided Runoff: 555.4 cubic feet/year ($37.1/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Replacement values: $58.4 thousand

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control.

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I. Tree Characteristics of the Urban Forest

The urban forest of Northview has 26 trees with a tree cover of 1.7 percent. The three most common species are Honeylocust (19.2 percent), maple spp (19.2 percent), and Baldcypress (15.4 percent).

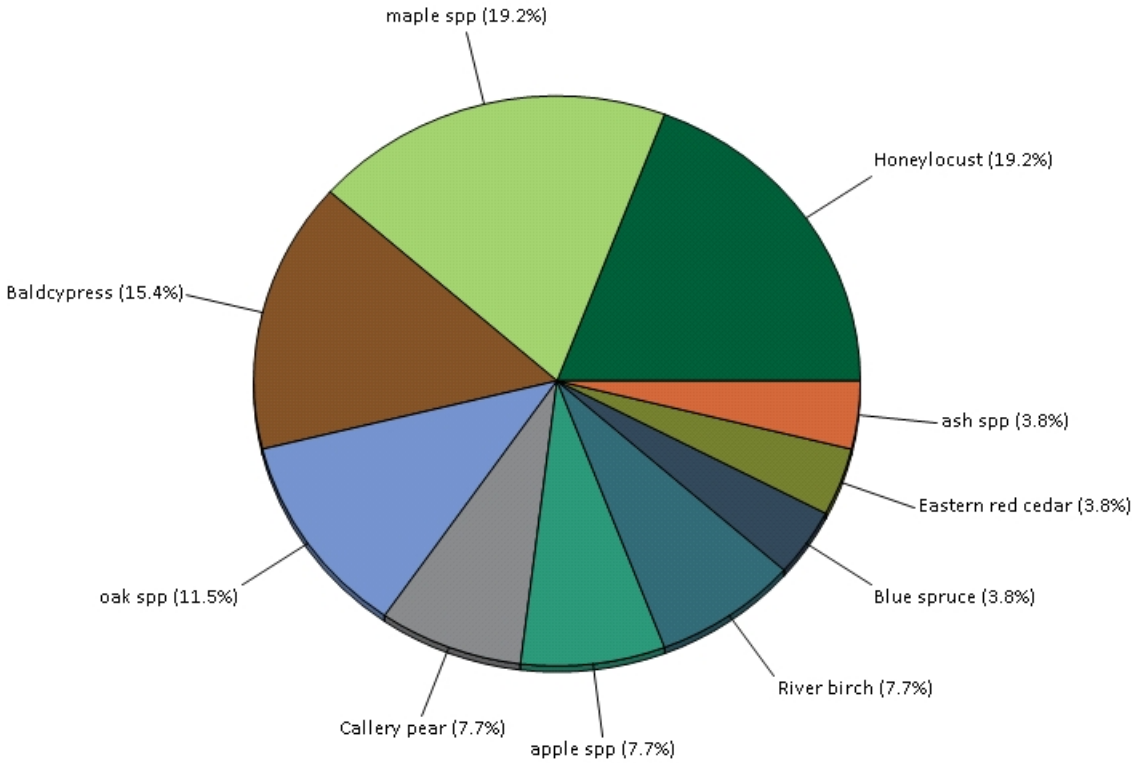


Figure 1. Tree species composition in Northview

The overall tree density in Northview is 2 trees/acre (see Appendix III for comparable values from other cities).

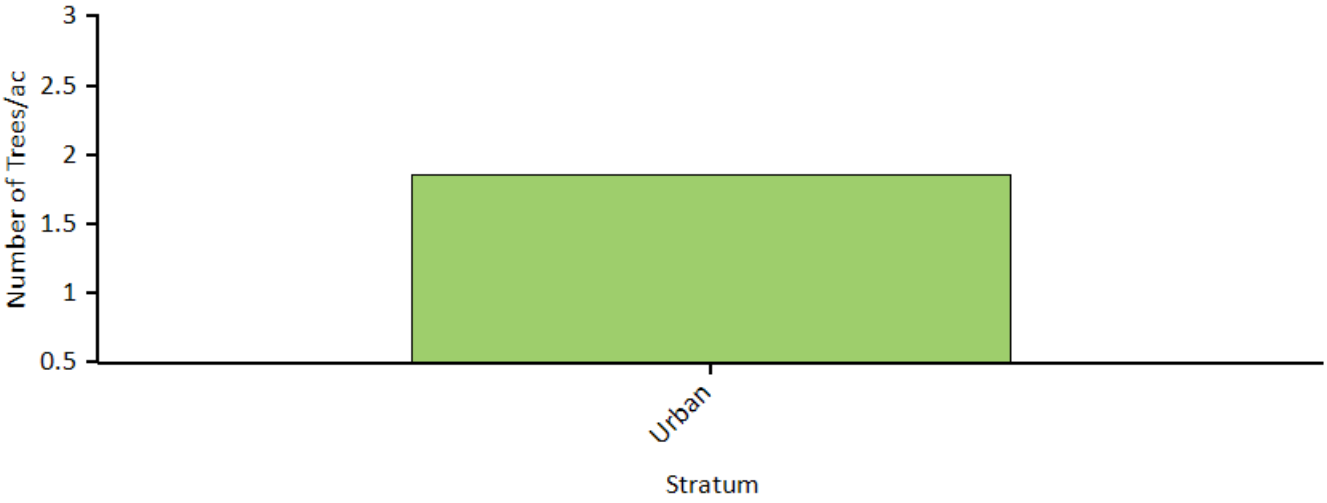


Figure 2. Number of trees/ac in Northview by stratum

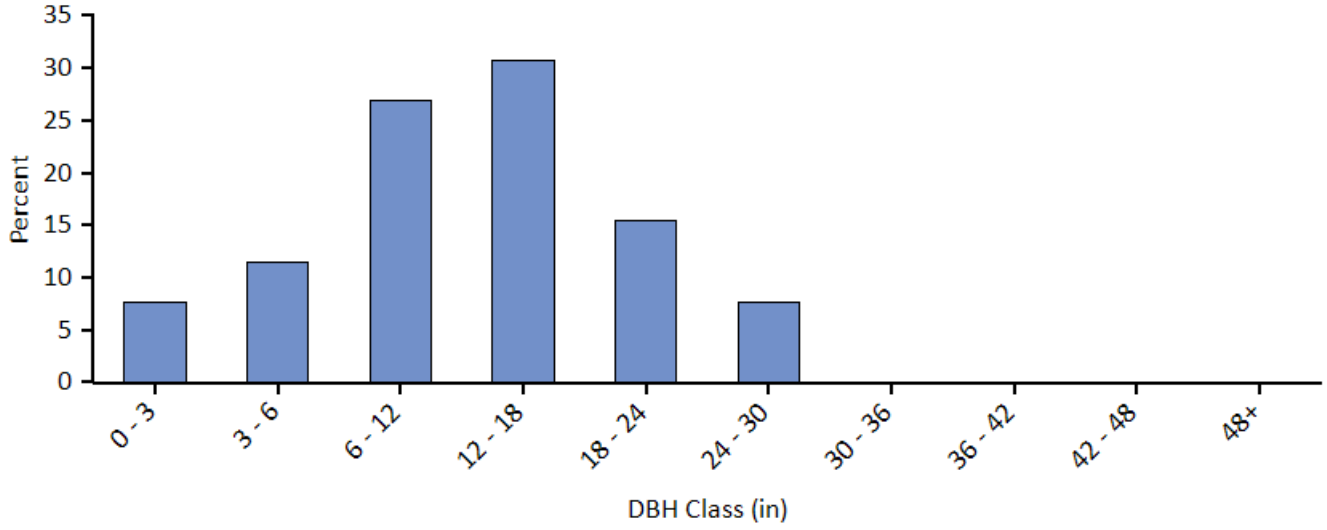


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Northview, about 48 percent of the trees are species native to North America, while 28 percent are native to Kansas. Species exotic to North America make up 52 percent of the population. Most exotic tree species have an origin from North America + (44 percent of the species).

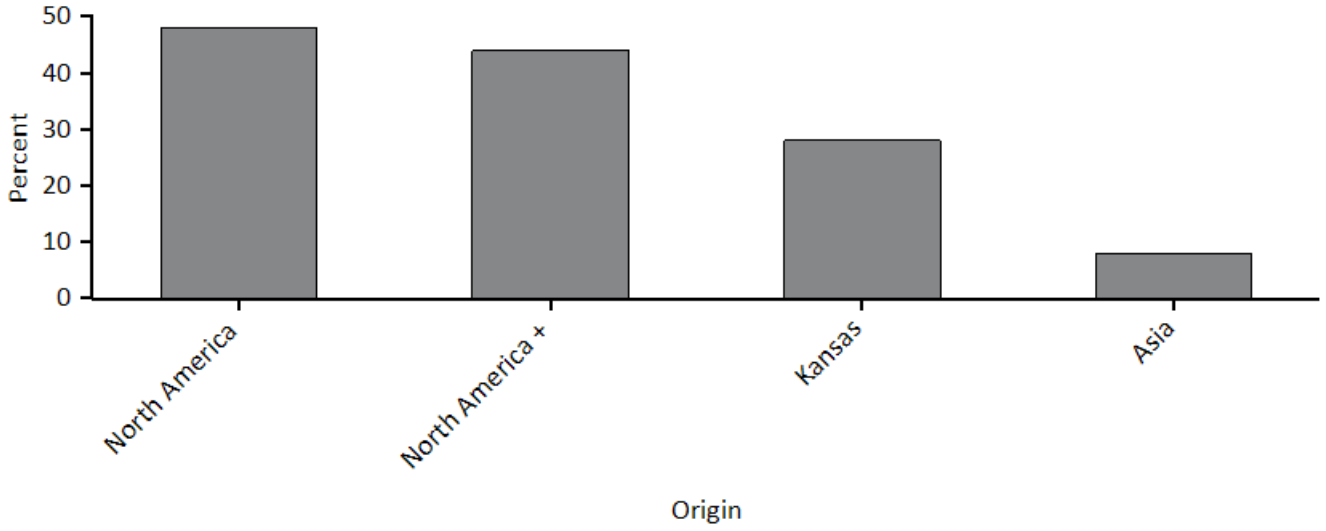


Figure 4. Percent of live tree population by area of native origin, Northview

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. One of the 10 tree species in Northview are identified as invasive on the state invasive species list (Kansas Native Plant Society 2006). This invasive species (Callery pear) comprises 7.7 percent of the tree population though it may only cause a minimal level of impact (see Appendix V for a complete list of invasive species).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 1.7 percent of Northview and provide 1.397 acres of leaf area. Total leaf area is greatest in Urban.

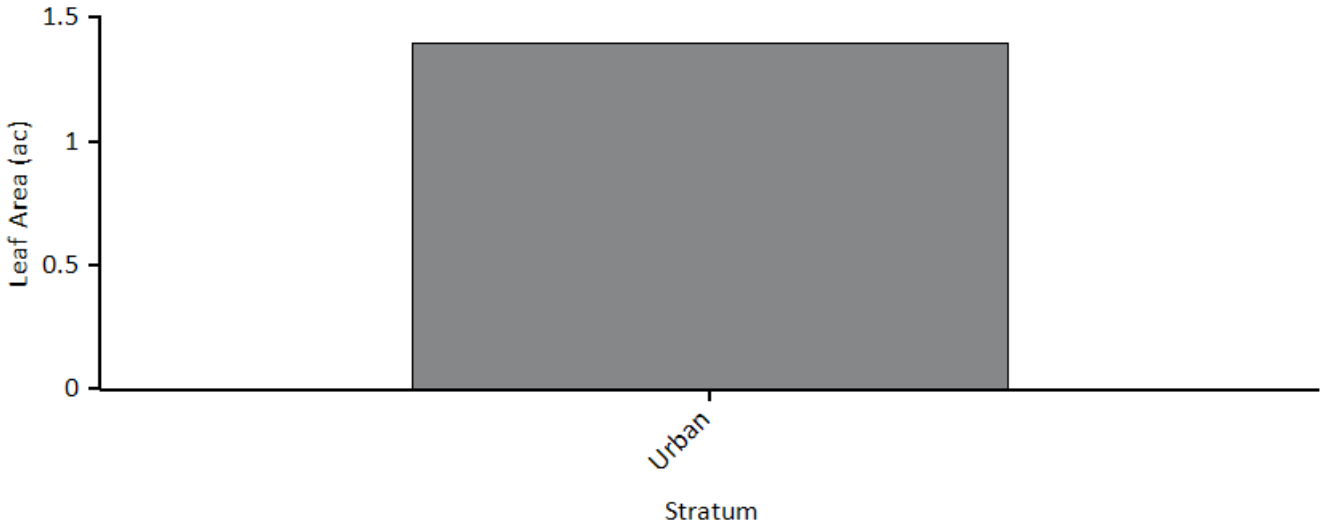


Figure 5. Leaf area by stratum, Northview

In Northview, the most dominant species in terms of leaf area are Baldcypress, maple spp, and Callery pear. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Northview

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Baldcypress	15.4	31.6	47.0
maple spp	19.2	13.5	32.8
Honeylocust	19.2	12.1	31.4
oak spp	11.5	11.0	22.5
Callery pear	7.7	12.7	20.4
ash spp	3.8	11.9	15.7
apple spp	7.7	2.2	9.9
River birch	7.7	1.7	9.4
Eastern red cedar	3.8	3.0	6.8
Blue spruce	3.8	0.3	4.1

Common ground cover classes (including cover types beneath trees and shrubs) in Northview are not available since they are configured not to be collected.

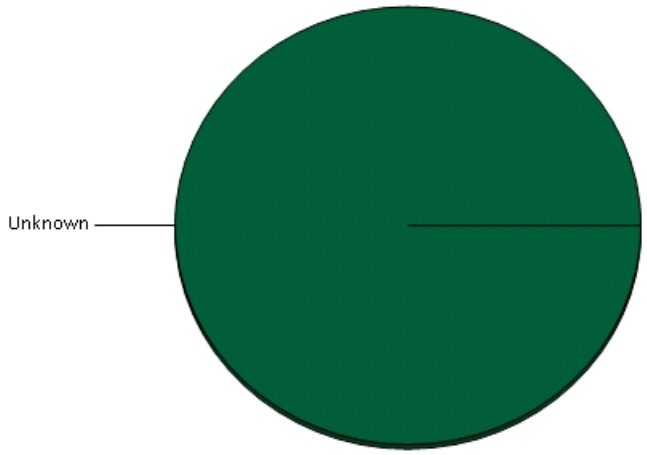


Figure 6. Percent of land by ground cover classes, Northview

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in Northview was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 12.89 pounds of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), particulate matter less than 10 microns and greater than 2.5 microns (PM10*)[2], and sulfur dioxide (SO2)) per year with an associated value of $34.8 (see Appendix I for more details).

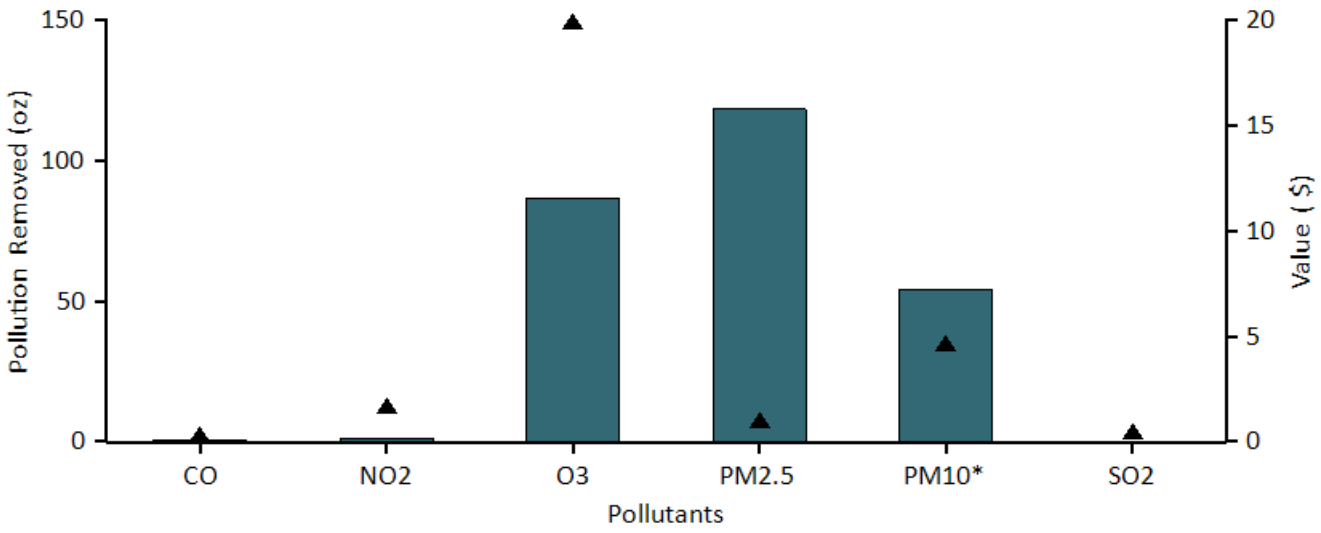


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Northview

[1] PM10* is particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is particulate matter less than 2.5 microns. If PM2.5 is not monitored, PM10* represents particulate matter less than 10 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces. This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2022, trees in Northview emitted an estimated 10.32 pounds of volatile organic compounds (VOCs) (3.61 pounds of isoprene and 6.714 pounds of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Eighty- six percent of the urban forest's VOC emissions were from oak spp and Baldcypress. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Northview trees is about 717.6 pounds of carbon per year with an associated value of $61.2. See Appendix I for more details on methods.

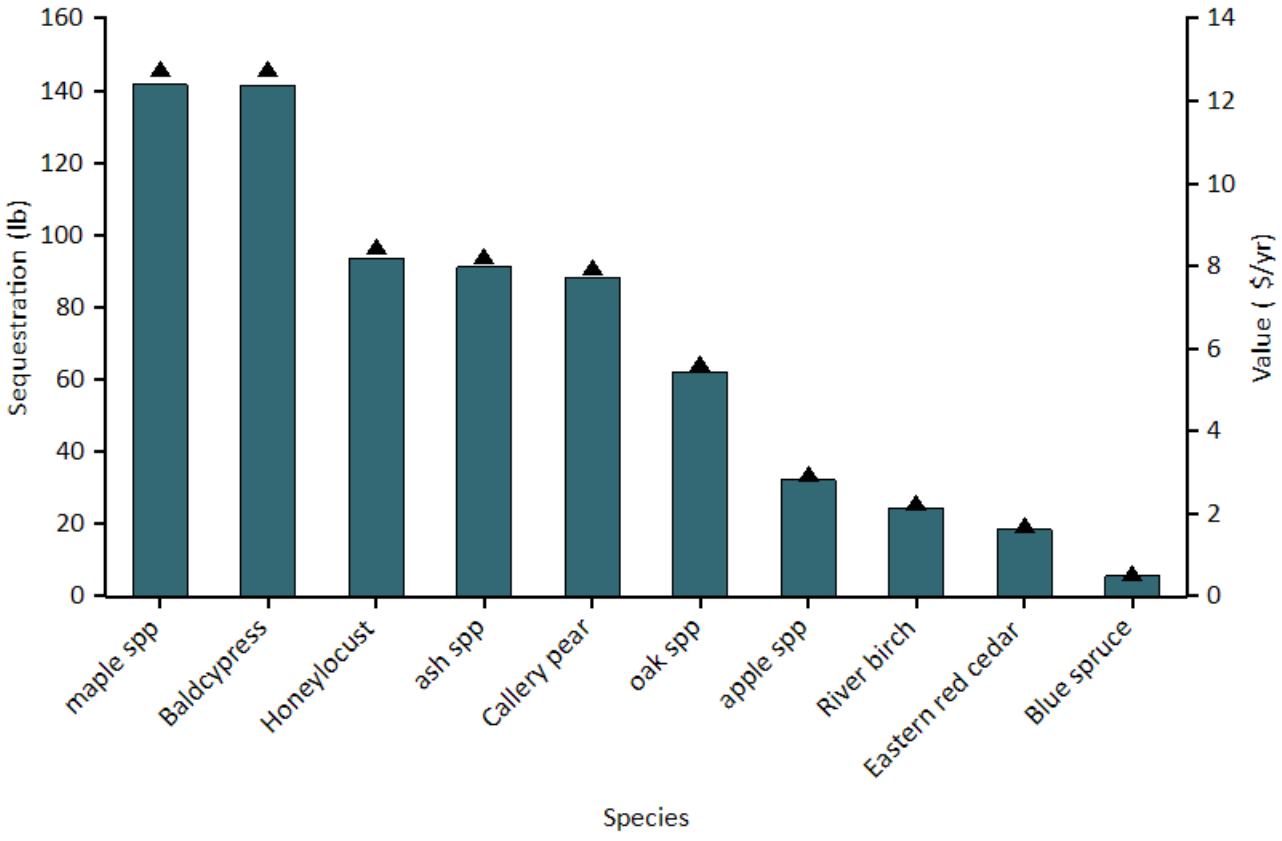


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Northview

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Northview are estimated to store 10.2 tons of carbon ($1.73 thousand). Of the species sampled, Callery pear stores the most carbon (approximately 22.5% of the total carbon stored) and maple spp sequesters the most

(approximately 20.3% of all sequestered carbon.)

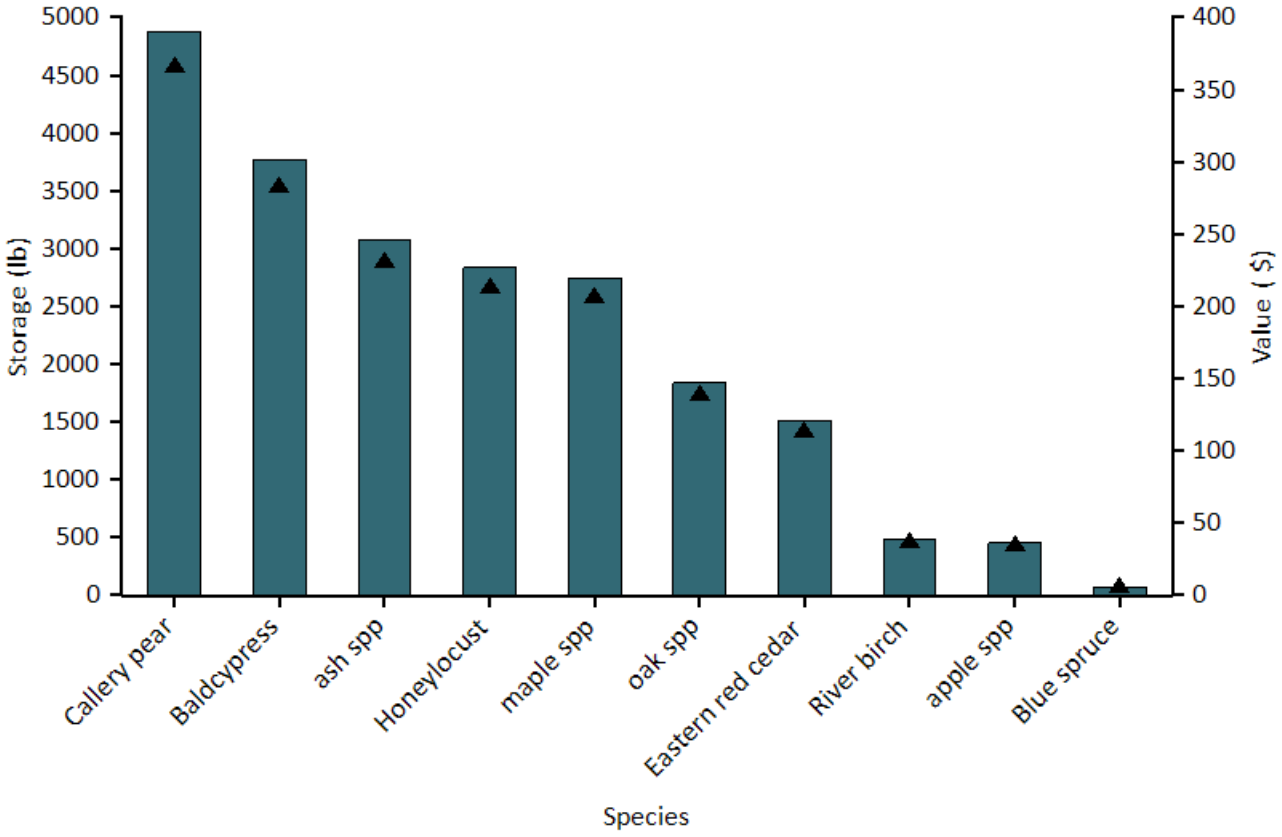


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Northview

V. Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Northview are estimated to produce 1914 pounds of oxygen per year.[4] However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 10 oxygen production species.

Species	*Oxygen (pound)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (square feet)*
maple spp	387.96	145.48	5	0.01
Baldcypress	387.35	145.26	4	0.02
Honeylocust	256.22	96.08	5	0.01
ash spp	249.58	93.59	1	0.01
Callery pear	241.45	90.54	2	0.01
oak spp	170.12	63.79	3	0.01
apple spp	88.08	33.03	2	0.00
River birch	66.87	25.08	2	0.00
Eastern red cedar	50.42	18.91	1	0.00
Blue spruce	15.51	5.82	1	0.00

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Northview help to reduce runoff by an estimated 555 cubic feet a year with an associated value of $37 (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Northview, the total annual precipitation in 2019 was 44.7 inches.

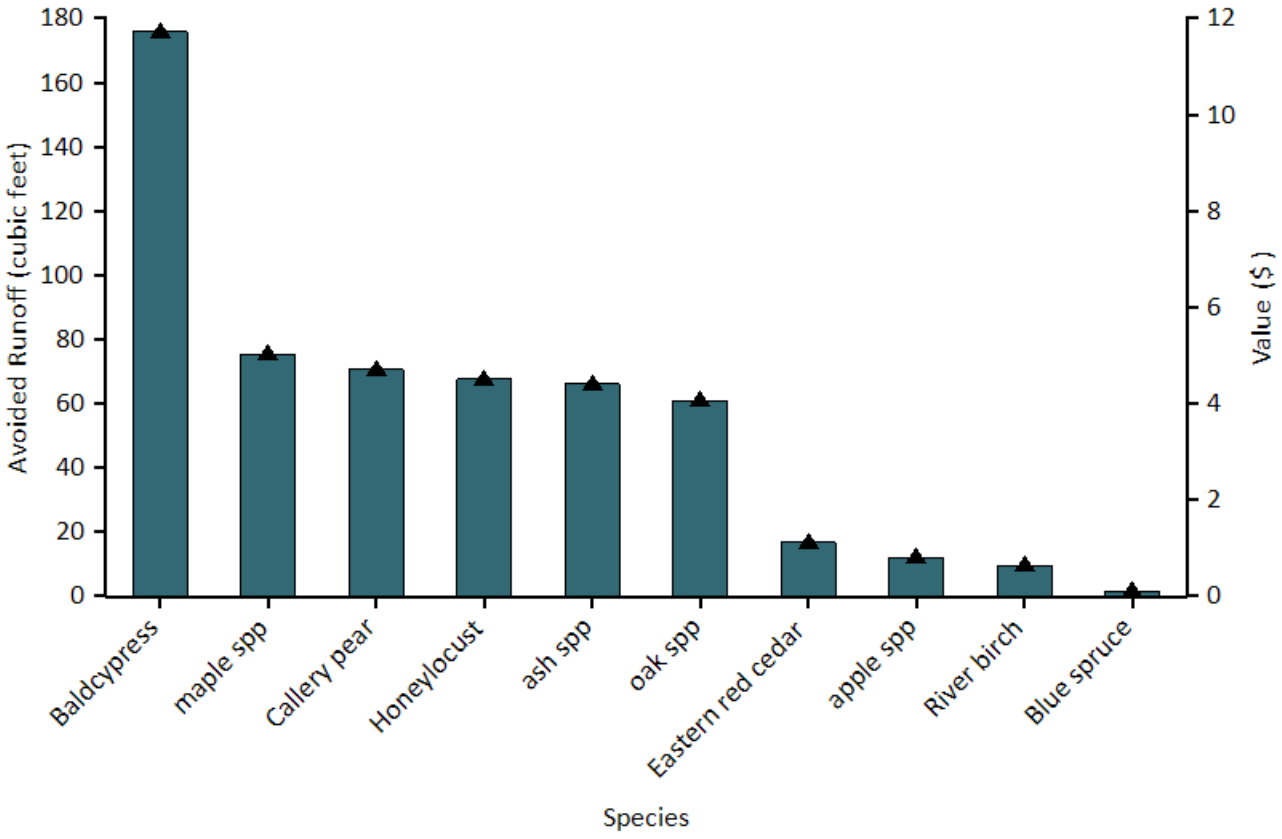


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Northview

VII. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Because energy-related data were not collected, energy savings and carbon avoided cannot be calculated.

Table 3. Annual energy savings due to trees near residential buildings, Northview

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (pounds)	0	0	0

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, Northview

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of $130.2 per MWH and $11.3442000317562 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Replacement and Functional Values

Urban forests have a replacement value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The replacement value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Northview have the following replacement values:

- Replacement value: $58.4 thousand
- Carbon storage: $1.73 thousand

Urban trees in Northview have the following annual functional values:

- Carbon sequestration: $61.2
- Avoided runoff: $37.1
- Pollution removal: $34.8
- Energy costs and carbon emission values: $0

(Note: negative value indicates increased energy cost and carbon emission value)

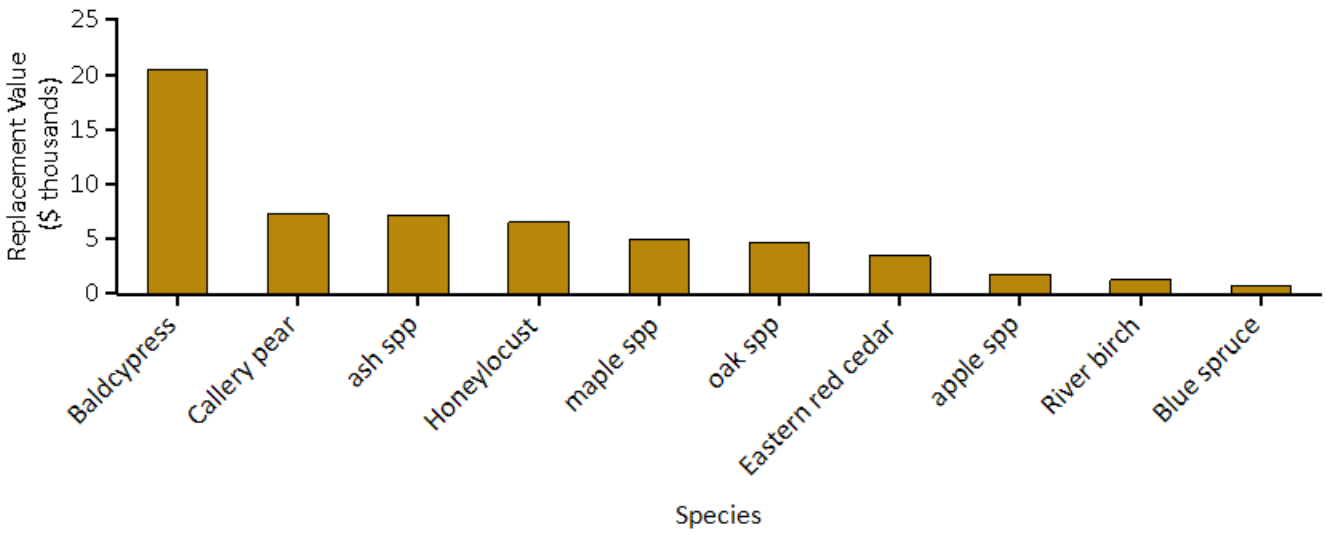


Figure 11. Tree species with the greatest replacement value, Northview

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, replacement value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Riley County. One of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

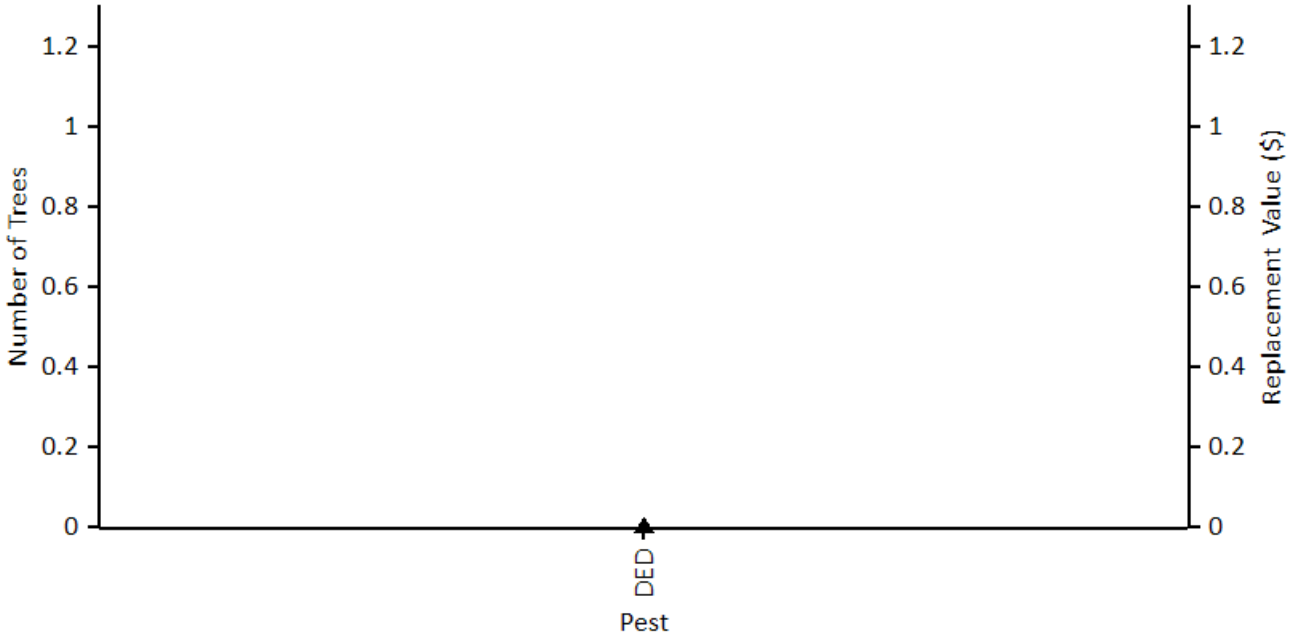


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, Northview

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Northview could possibly lose 0.0 percent of its trees to this pest ($0 in replacement value).

Appendix I. i-Tree Eco Model and Field Measurements

i-Tree Eco is designed to use standardized field data and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Replacement value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Kansas Native Plant Society 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter less than 2.5 microns, and particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces (Nowak et al 2013). This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to

the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 and PM10* removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 and PM10* concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 and PM10* but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,443 per ton (carbon monoxide), $2,483 per ton (ozone), $475 per ton (nitrogen dioxide), $202 per ton (sulfur dioxide), $75,636 per ton (particulate matter less than 2.5 microns), $6,781 per ton (particulate matter less than 10 microns and greater than 2.5 microns).

Carbon Storage and Sequestration:

Carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak 1994). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition (Nowak et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of $0.07 per ft^3.

Building Energy Use:

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

For this analysis, energy saving value is calculated based on the prices of $130.20 per MWH and $11.34 per MBTU.

Replacement Values:

Replacement value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Replacement values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Replacement value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in Northview provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Northview in 0 days
- Annual carbon (C) emissions from 7 automobiles
- Annual C emissions from 3 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 0 automobiles
- Annual carbon monoxide emissions from 0 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 0 automobiles
- Annual nitrogen dioxide emissions from 0 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 1 automobiles
- Annual sulfur dioxide emissions from 0 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Northview in 0.0 days
- Annual C emissions from 0 automobiles
- Annual C emissions from 0 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (Nowak 1995):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (Nowak 2000). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include (Nowak 2000):

Strategy	*Result*
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Kansas invasive species list (Kansas Native Plant Society 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ft²)*	*Percent Leaf Area*
Callery pear	2	7.7	0.0	12.7
Total	**2**	**7.69**	**0.01**	**12.69**

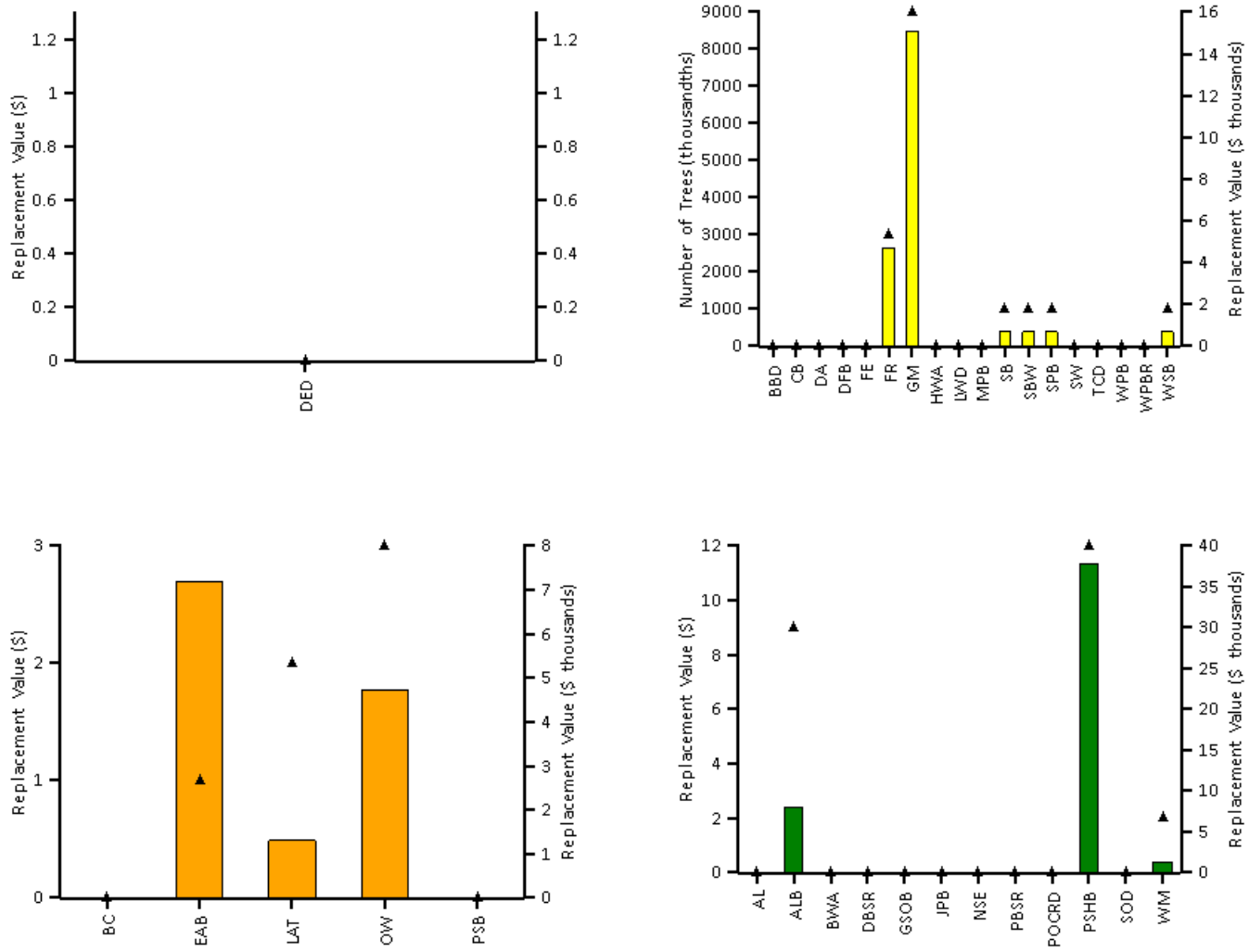
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ thousands)
AL	Phyllocnistis populiella	Aspen Leafminer	0	0.00
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	9	8.03
BBD	Neonectria faginata	Beech Bark Disease	0	0.00
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	0	0.00
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	0	0.00
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	0	0.00
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	1	7.20
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	3	4.72
GM	Lymantria dispar	Gypsy Moth	9	15.08
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	2	1.31
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	3	4.72
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	0	0.00
PSB	Tomicus piniperda	Pine Shoot Beetle	0	0.00
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	12	37.79
SB	Dendroctonus rufipennis	Spruce Beetle	1	0.68
SBW	Choristoneura fumiferana	Spruce Budworm	1	0.68
SOD	Phytophthora ramorum	Sudden Oak Death	0	0.00
SPB	Dendroctonus frontalis	Southern Pine Beetle	1	0.68
SW	Sirex noctilio	Sirex Wood Wasp	0	0.00
TCD	Geosmithia morbida	Thousand Canker Disease	0	0.00
WM	Operophtera brumata	Winter Moth	2	1.31
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	0	0.00
WSB	Choristoneura occidentalis	Western Spruce Budworm	1	0.68

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Replacement value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
	8	Blue spruce																																				
	7	oak spp																																					
	7	River birch																																					
	3	Callery pear																																					
	3	apple spp																																					
	3	ash spp																																					
	1	Honeylocust																																					
	1	maple spp																																					
	1	Baldcypress																																					
	1	Eastern red cedar																																					

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Riley county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Riley county
- Green indicates pest is outside of these ranges

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i-Tree Ecosystem Analysis

Theodore Roosevelt

Urban Forest Effects and Values
March 2022

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Theodore Roosevelt urban forest was conducted during 2022. Data from 14 trees located throughout Theodore Roosevelt were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 14
- Tree Cover: 8.3 %
- Most common species of trees: ash spp, elm spp, Japanese tree lilac
- Percentage of trees less than 6" (15.2 cm) diameter: 21.4%
- Pollution Removal: 12.26 pounds/year ($32.2/year)
- Carbon Storage: 12.68 tons ($2.16 thousand)
- Carbon Sequestration: 458.6 pounds ($39.1/year)
- Oxygen Production: 1223 pounds/year
- Avoided Runoff: 492.3 cubic feet/year ($32.9/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Replacement values: $54.7 thousand

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control.

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I. Tree Characteristics of the Urban Forest

The urban forest of Theodore Roosevelt has 14 trees with a tree cover of 8.3 percent. The three most common species are ash spp (21.4 percent), elm spp (7.1 percent), and Japanese tree lilac (7.1 percent).

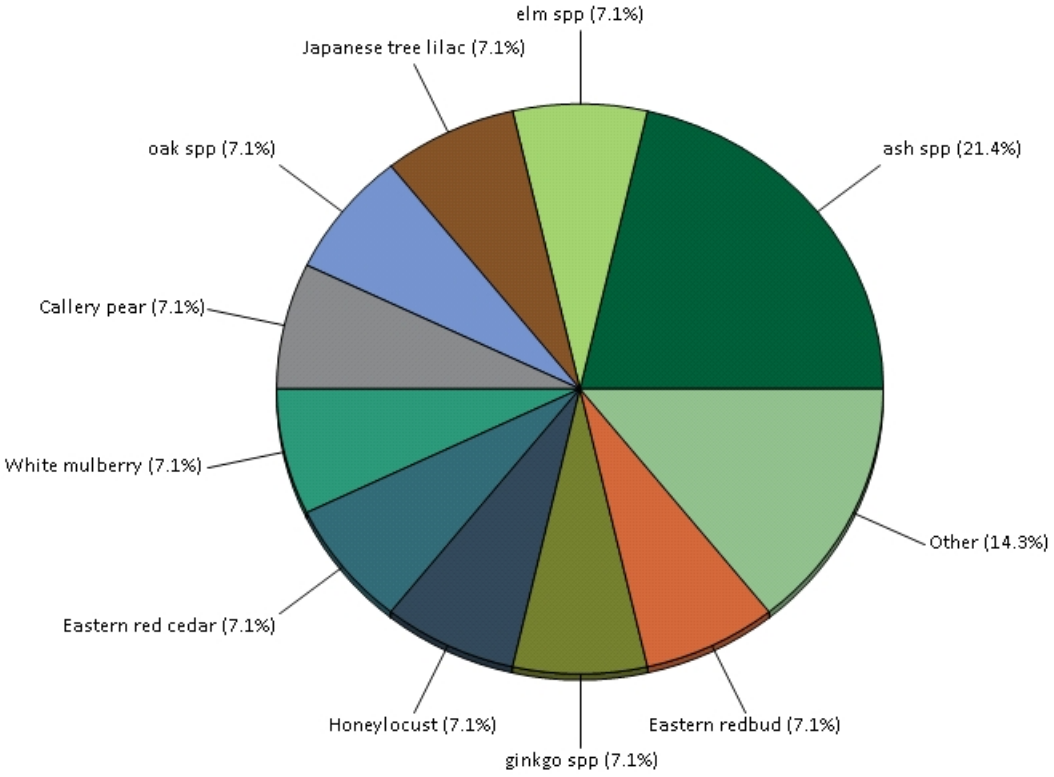


Figure 1. Tree species composition in Theodore Roosevelt

The overall tree density in Theodore Roosevelt is 5 trees/acre (see Appendix III for comparable values from other cities).

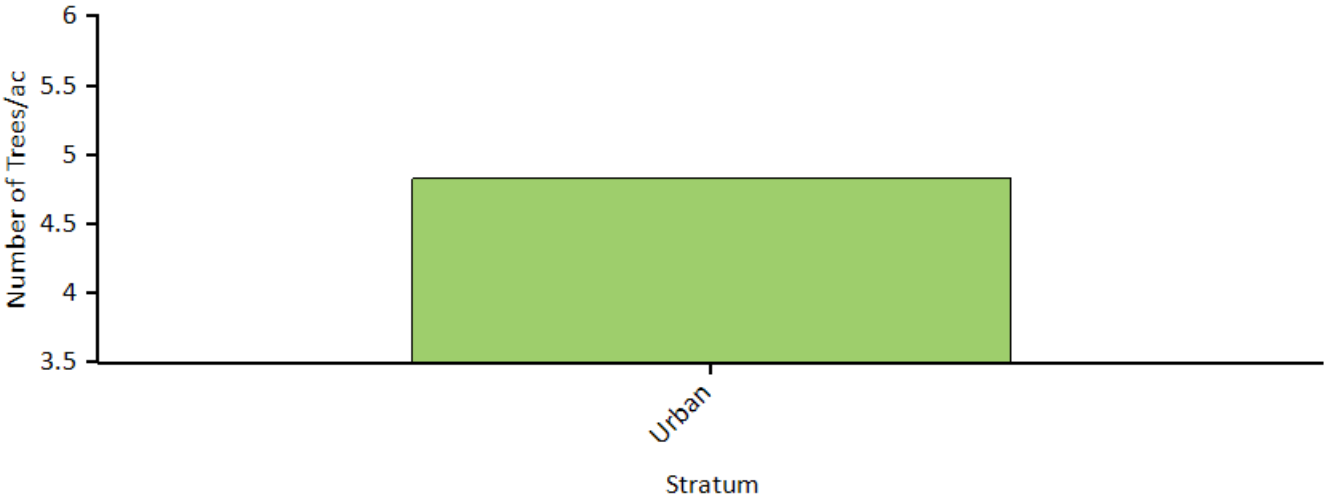


Figure 2. Number of trees/ac in Theodore Roosevelt by stratum

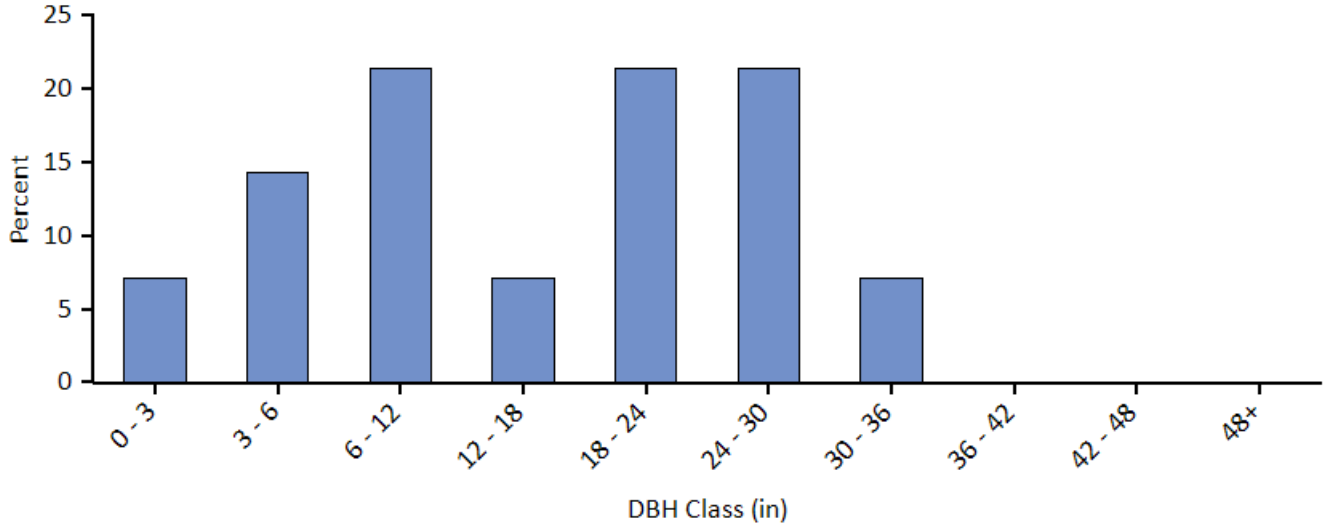


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Theodore Roosevelt, about 29 percent of the trees are species native to North America, while 21 percent are native to Kansas. Species exotic to North America make up 71 percent of the population. Most exotic tree species have an origin from North America + (43 percent of the species).

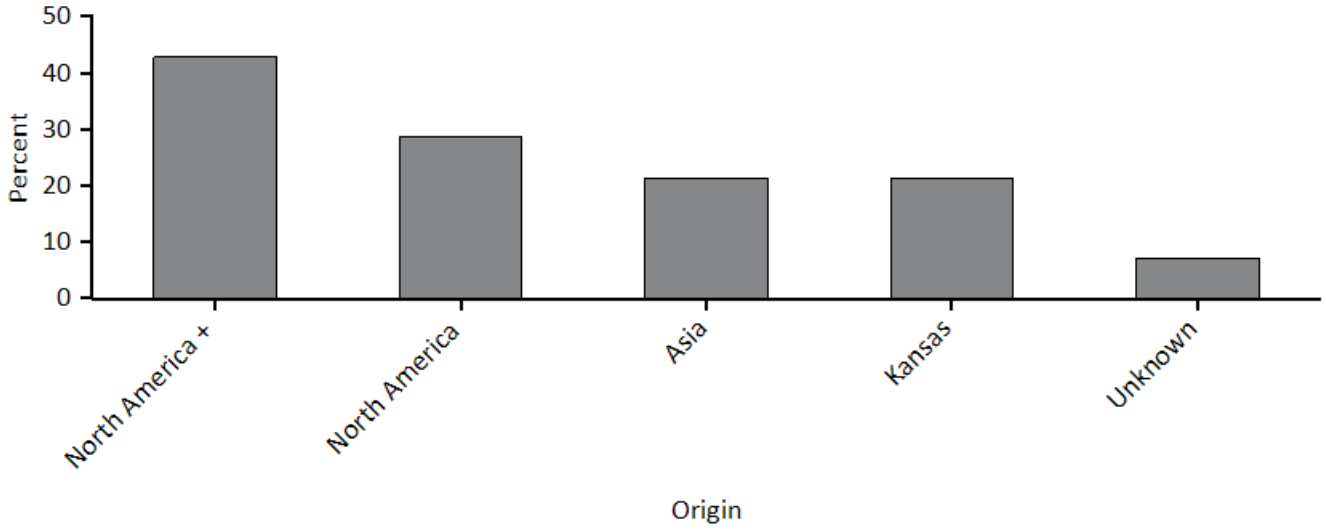


Figure 4. Percent of live tree population by area of native origin, Theodore Roosevelt

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. One of the 12 tree species in Theodore Roosevelt are identified as invasive on the state invasive species list (Kansas Native Plant Society 2006). This invasive species (Callery pear) comprises 7.1 percent of the tree population though it may only cause a minimal level of impact (see Appendix V for a complete list of invasive species).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 8.3 percent of Theodore Roosevelt and provide 1.131 acres of leaf area. Total leaf area is greatest in Urban.

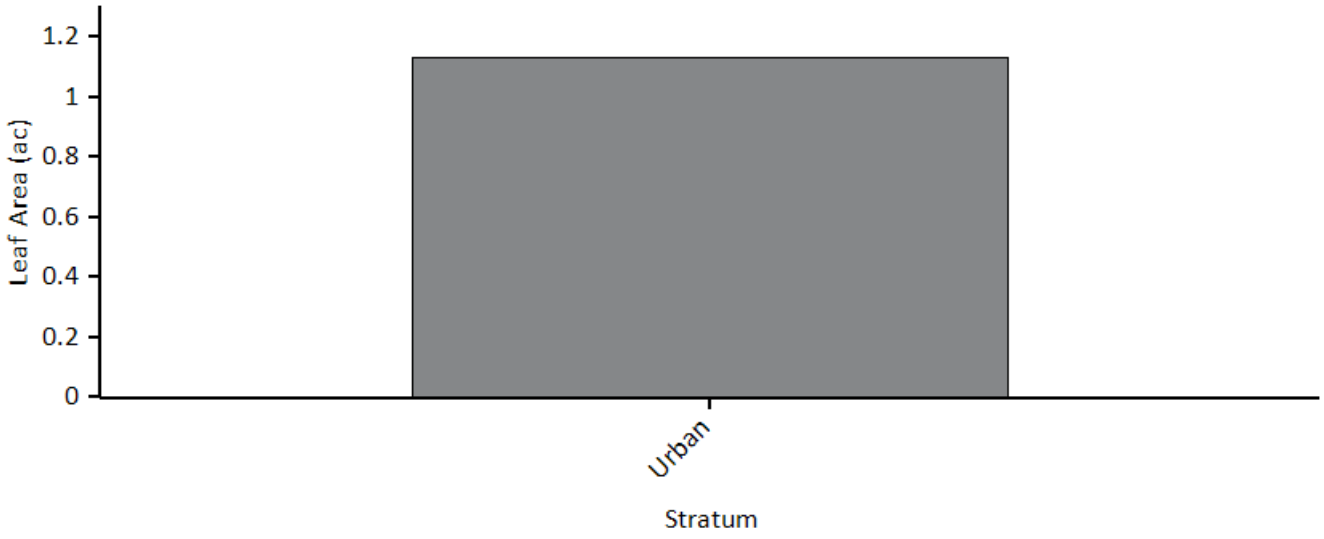


Figure 5. Leaf area by stratum, Theodore Roosevelt

In Theodore Roosevelt, the most dominant species in terms of leaf area are ash spp, Callery pear, and White mulberry. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Theodore Roosevelt

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
ash spp	21.4	38.7	60.1
Callery pear	7.1	13.5	20.7
White mulberry	7.1	10.8	17.9
Honeylocust	7.1	10.7	17.8
Northern catalpa	7.1	8.8	15.9
Eastern red cedar	7.1	6.1	13.2
oak spp	7.1	6.0	13.2
elm spp	7.1	2.0	9.1
maple spp	7.1	1.4	8.5
Eastern redbud	7.1	1.2	8.4

Common ground cover classes (including cover types beneath trees and shrubs) in Theodore Roosevelt are not available since they are configured not to be collected.

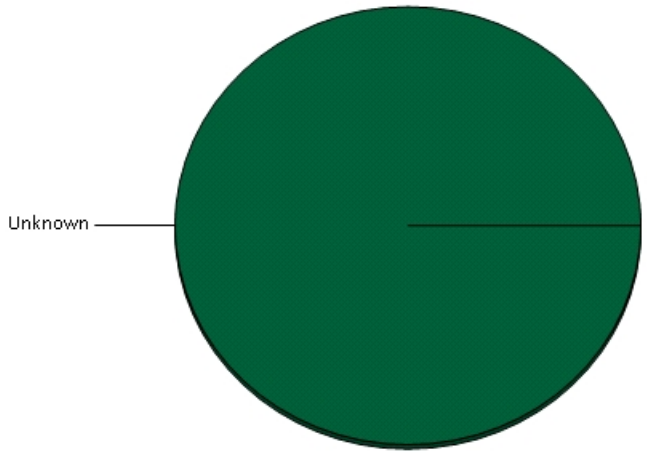


Figure 6. Percent of land by ground cover classes, Theodore Roosevelt

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in Theodore Roosevelt was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 12.26 pounds of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), particulate matter less than 10 microns and greater than 2.5 microns (PM10*)[2], and sulfur dioxide (SO2)) per year with an associated value of $32.2 (see Appendix I for more details).

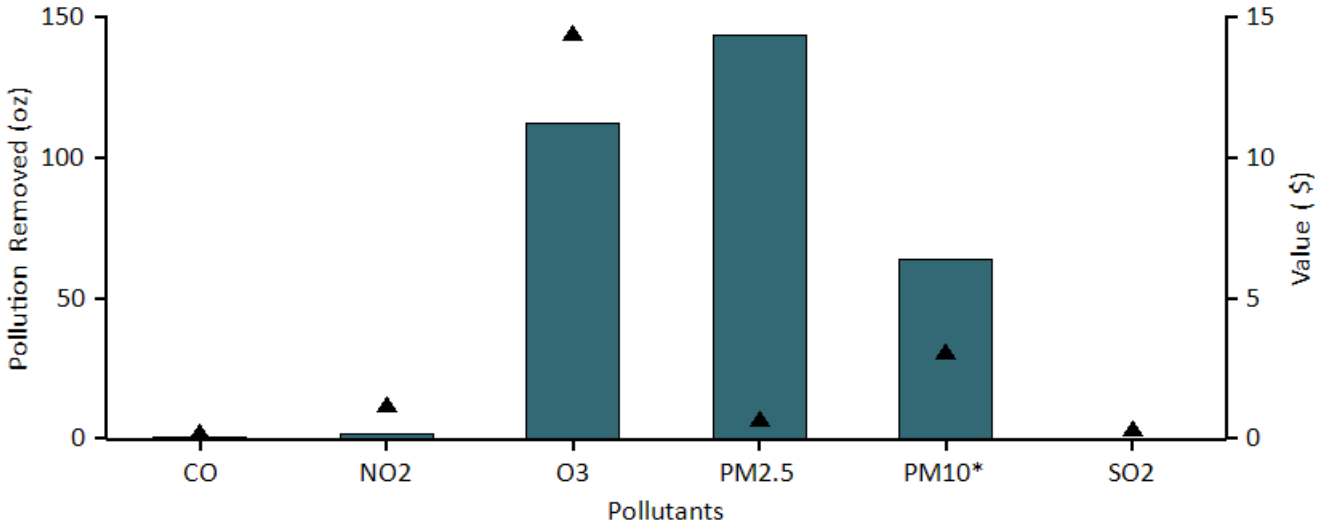


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Theodore Roosevelt

[1] PM10* is particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is particulate matter less than 2.5 microns. If PM2.5 is not monitored, PM10* represents particulate matter less than 10 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces. This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2022, trees in Theodore Roosevelt emitted an estimated 4.455 pounds of volatile organic compounds (VOCs) (1.864 pounds of isoprene and 2.591 pounds of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Eighty- five percent of the urban forest's VOC emissions were from oak spp and Eastern red cedar. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Theodore Roosevelt trees is about 458.6 pounds of carbon per year with an associated value of $39.1. See Appendix I for more details on methods.

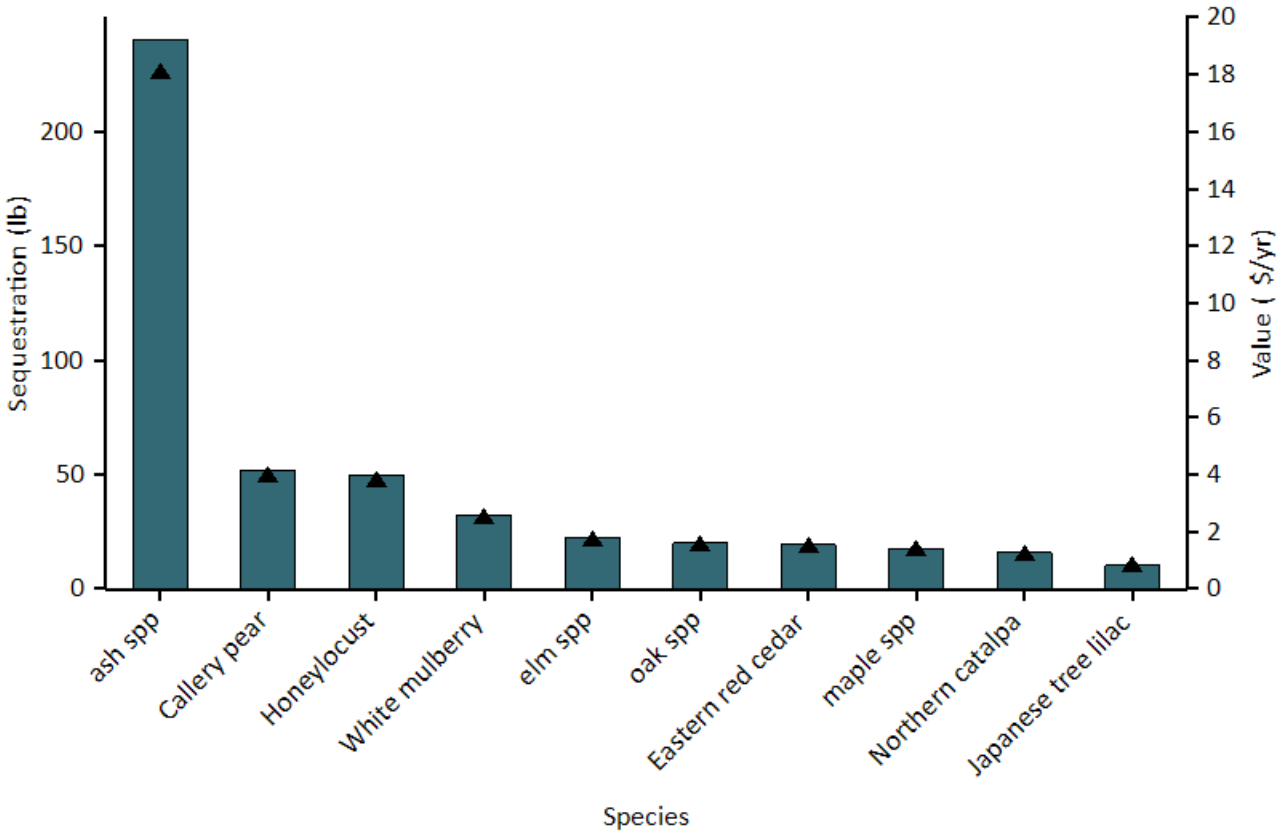


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Theodore Roosevelt

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Theodore Roosevelt are estimated to store 12.7 tons of carbon ($2.16 thousand). Of the species sampled, ash spp

stores and sequesters the most carbon (approximately 51.2% of the total carbon stored and 49.2% of all sequestered carbon.)

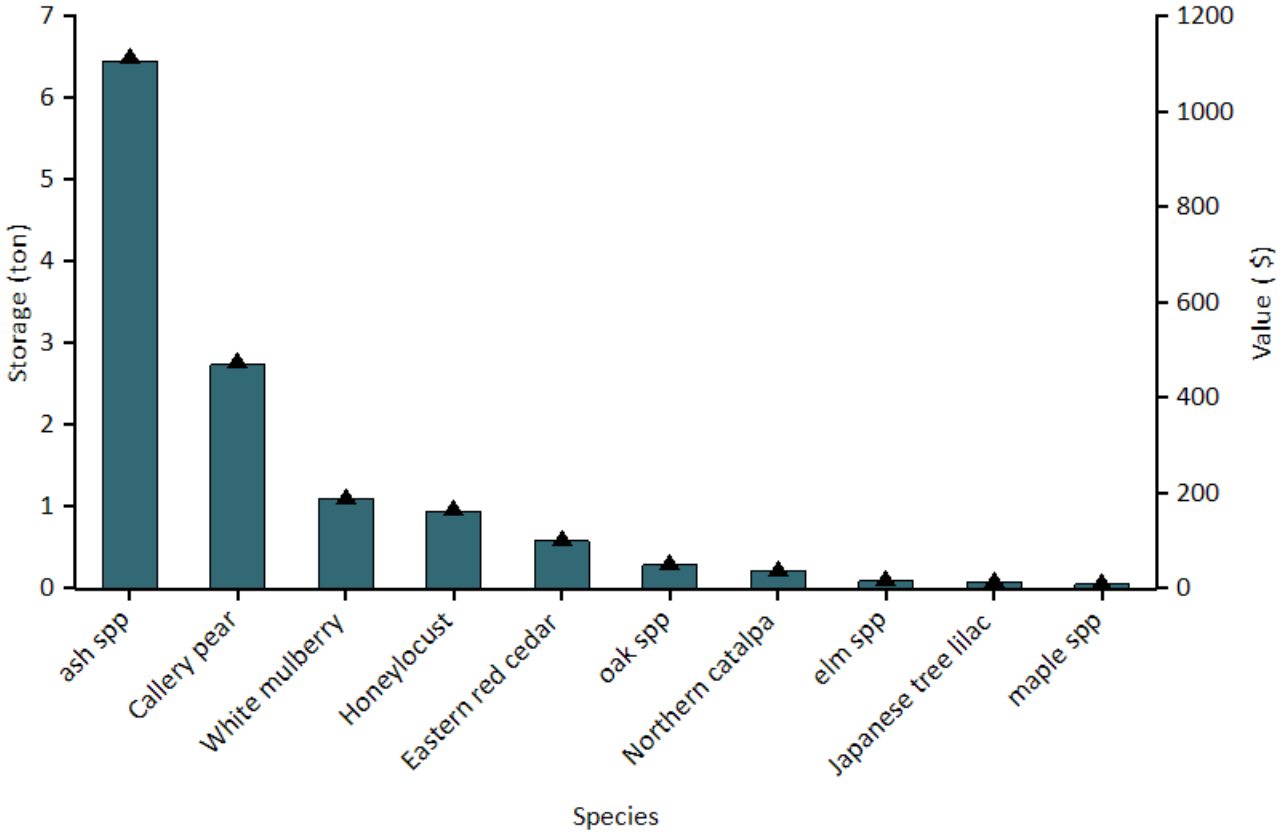


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Theodore Roosevelt

V. Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Theodore Roosevelt are estimated to produce 1223 pounds of oxygen per year.[4] However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 12 oxygen production species.

Species	*Oxygen (pound)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (square feet)*
ash spp	601.51	225.57	3	0.02
Callery pear	130.42	48.91	1	0.01
Honeylocust	125.08	46.90	1	0.01
White mulberry	81.37	30.51	1	0.01
elm spp	56.69	21.26	1	0.00
oak spp	50.28	18.86	1	0.00
Eastern red cedar	48.75	18.28	1	0.00
maple spp	44.05	16.52	1	0.00
Northern catalpa	40.05	15.02	1	0.00
Japanese tree lilac	25.43	9.54	1	0.00
Eastern redbud	15.58	5.84	1	0.00
ginkgo spp	3.67	1.38	1	0.00

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Theodore Roosevelt help to reduce runoff by an estimated 492 cubic feet a year with an associated value of $33 (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Theodore Roosevelt, the total annual precipitation in 2019 was 44.7 inches.

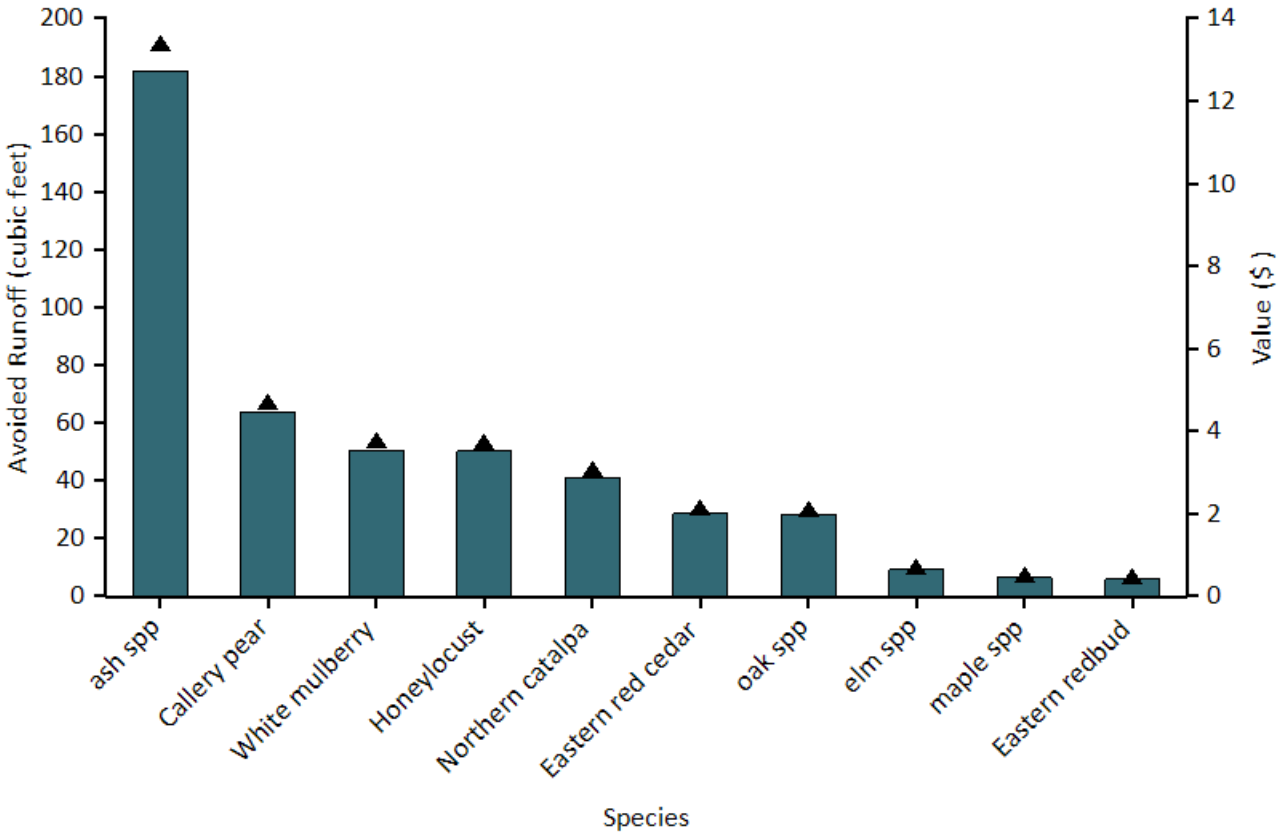


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Theodore Roosevelt

VII. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Because energy-related data were not collected, energy savings and carbon avoided cannot be calculated.

Table 3. Annual energy savings due to trees near residential buildings, Theodore Roosevelt

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (pounds)	0	0	0

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, Theodore Roosevelt

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of $130.2 per MWH and $11.3442000317562 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Replacement and Functional Values

Urban forests have a replacement value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The replacement value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Theodore Roosevelt have the following replacement values:

- Replacement value: $54.7 thousand
- Carbon storage: $2.16 thousand

Urban trees in Theodore Roosevelt have the following annual functional values:

- Carbon sequestration: $39.1
- Avoided runoff: $32.9
- Pollution removal: $32.2
- Energy costs and carbon emission values: $0

(Note: negative value indicates increased energy cost and carbon emission value)

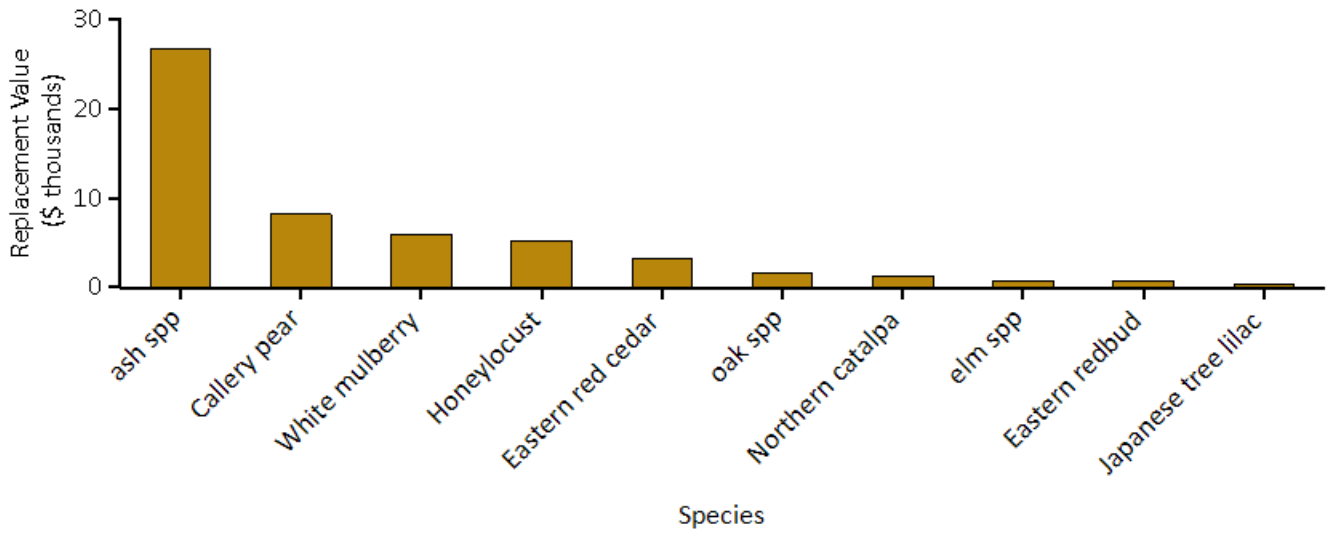


Figure 11. Tree species with the greatest replacement value, Theodore Roosevelt

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, replacement value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Riley County. One of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

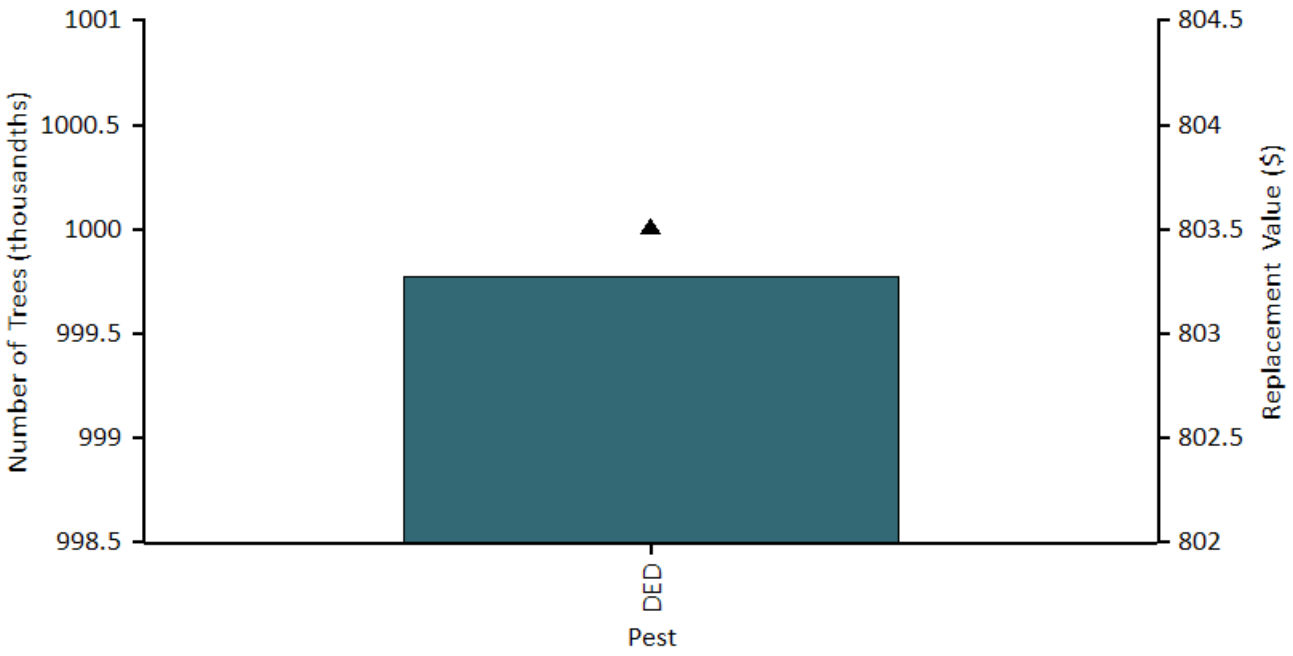


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, Theodore Roosevelt

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Theodore Roosevelt could possibly lose 7.1 percent of its trees to this pest ($803 in replacement value).

Appendix I. i-Tree Eco Model and Field Measurements

i-Tree Eco is designed to use standardized field data and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Replacement value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Kansas Native Plant Society 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter less than 2.5 microns, and particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces (Nowak et al 2013). This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to

the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 and PM10* removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 and PM10* concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 and PM10* but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,443 per ton (carbon monoxide), $2,497 per ton (ozone), $478 per ton (nitrogen dioxide), $198 per ton (sulfur dioxide), $75,354 per ton (particulate matter less than 2.5 microns), $6,781 per ton (particulate matter less than 10 microns and greater than 2.5 microns).

Carbon Storage and Sequestration:

Carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak 1994). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition (Nowak et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of $0.07 per ft^3.

Building Energy Use:

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

For this analysis, energy saving value is calculated based on the prices of $130.20 per MWH and $11.34 per MBTU.

Replacement Values:

Replacement value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Replacement values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Replacement value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in Theodore Roosevelt provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Theodore Roosevelt in 0 days
- Annual carbon (C) emissions from 9 automobiles
- Annual C emissions from 4 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 0 automobiles
- Annual carbon monoxide emissions from 0 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 0 automobiles
- Annual nitrogen dioxide emissions from 0 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 1 automobiles
- Annual sulfur dioxide emissions from 0 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Theodore Roosevelt in 0.0 days
- Annual C emissions from 0 automobiles
- Annual C emissions from 0 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (Nowak 1995):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (Nowak 2000). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include (Nowak 2000):

Strategy	*Result*
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Kansas invasive species list (Kansas Native Plant Society 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ft²)*	*Percent Leaf Area*
Callery pear	1	7.1	0.0	13.5
Total	**1**	**7.14**	**0.01**	**13.55**

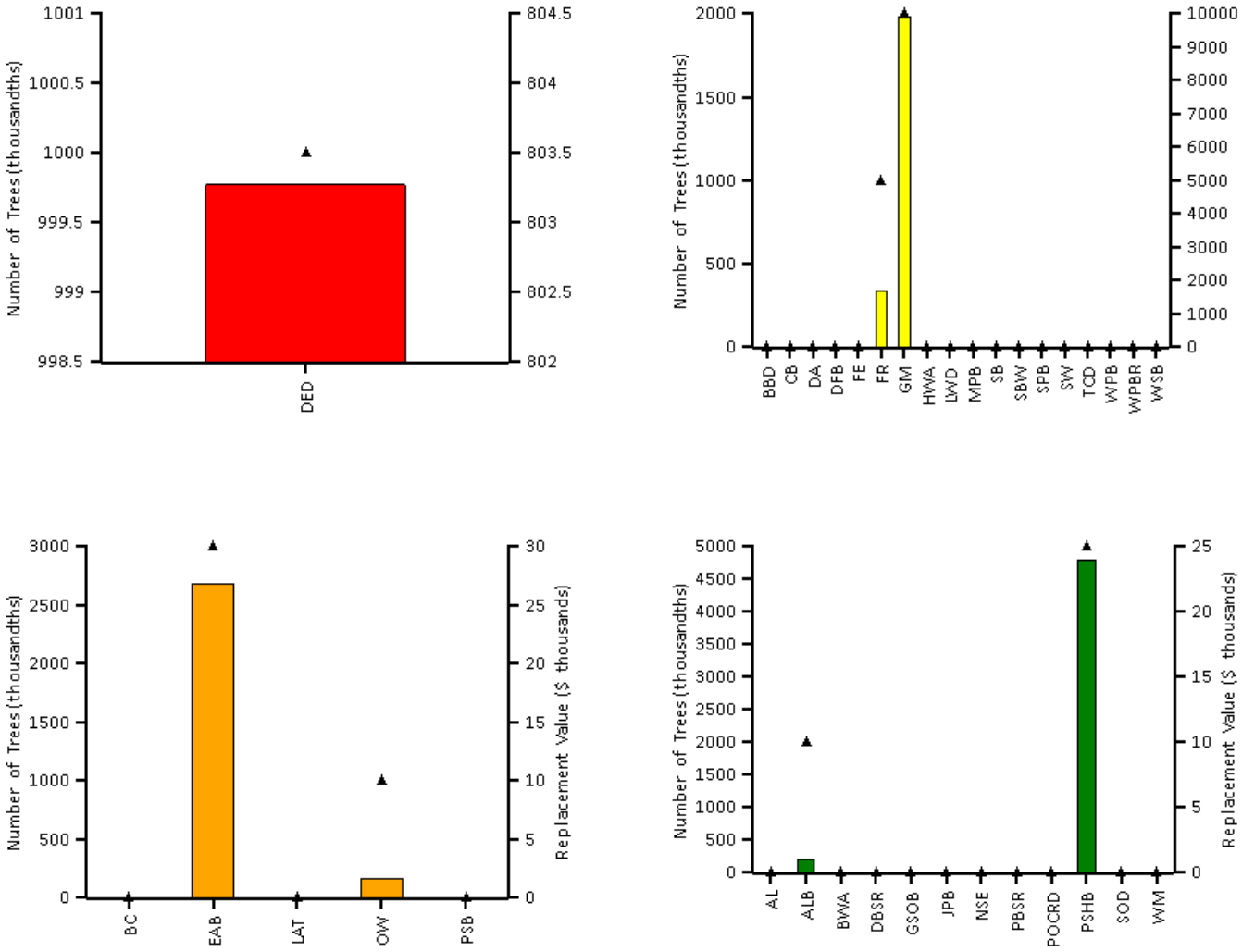
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ thousands)
AL	Phyllocnistis populiella	Aspen Leafminer	0	0.00
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	2	1.06
BBD	Neonectria faginata	Beech Bark Disease	0	0.00
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	0	0.00
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	0	0.00
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	1	0.80
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	3	26.85
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	1	1.68
GM	Lymantria dispar	Gypsy Moth	2	9.92
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	0	0.00
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	1	1.68
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	0	0.00
PSB	Tomicus piniperda	Pine Shoot Beetle	0	0.00
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	5	23.97
SB	Dendroctonus rufipennis	Spruce Beetle	0	0.00
SBW	Choristoneura fumiferana	Spruce Budworm	0	0.00
SOD	Phytophthora ramorum	Sudden Oak Death	0	0.00
SPB	Dendroctonus frontalis	Southern Pine Beetle	0	0.00
SW	Sirex noctilio	Sirex Wood Wasp	0	0.00
TCD	Geosmithia morbida	Thousand Canker Disease	0	0.00
WM	Operophtera brumata	Winter Moth	0	0.00
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	0	0.00
WSB	Choristoneura occidentalis	Western Spruce Budworm	0	0.00

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Replacement value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
	7	oak spp																																				
	5	elm spp																																				
	3	ash spp																																				
	3	Callery pear																																				
	1	White mulberry																																				
	1	Eastern red cedar																																				
	1	Honeylocust																																				
	1	Northern catalpa																																				
	1	maple spp																																				

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Riley county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Riley county
- Green indicates pest is outside of these ranges

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i-Tree Ecosystem Analysis

Woodrow Wilson

Urban Forest Effects and Values
March 2022

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Woodrow Wilson urban forest was conducted during 2022. Data from 14 trees located throughout Woodrow Wilson were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 14
- Tree Cover: 6.8 %
- Most common species of trees: American elm, Japanese tree lilac, Callery pear
- Percentage of trees less than 6" (15.2 cm) diameter: 21.4%
- Pollution Removal: 11.19 pounds/year ($30.7/year)
- Carbon Storage: 9.681 tons ($1.65 thousand)
- Carbon Sequestration: 590.4 pounds ($50.3/year)
- Oxygen Production: 1574 pounds/year
- Avoided Runoff: 470.8 cubic feet/year ($31.5/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Replacement values: $42.5 thousand

Ton: short ton (U.S.) (2,000 lbs)
Monetary values $ are reported in US Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control.

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I. Tree Characteristics of the Urban Forest

The urban forest of Woodrow Wilson has 14 trees with a tree cover of 6.8 percent. The three most common species are American elm (14.3 percent), Japanese tree lilac (14.3 percent), and Callery pear (14.3 percent).

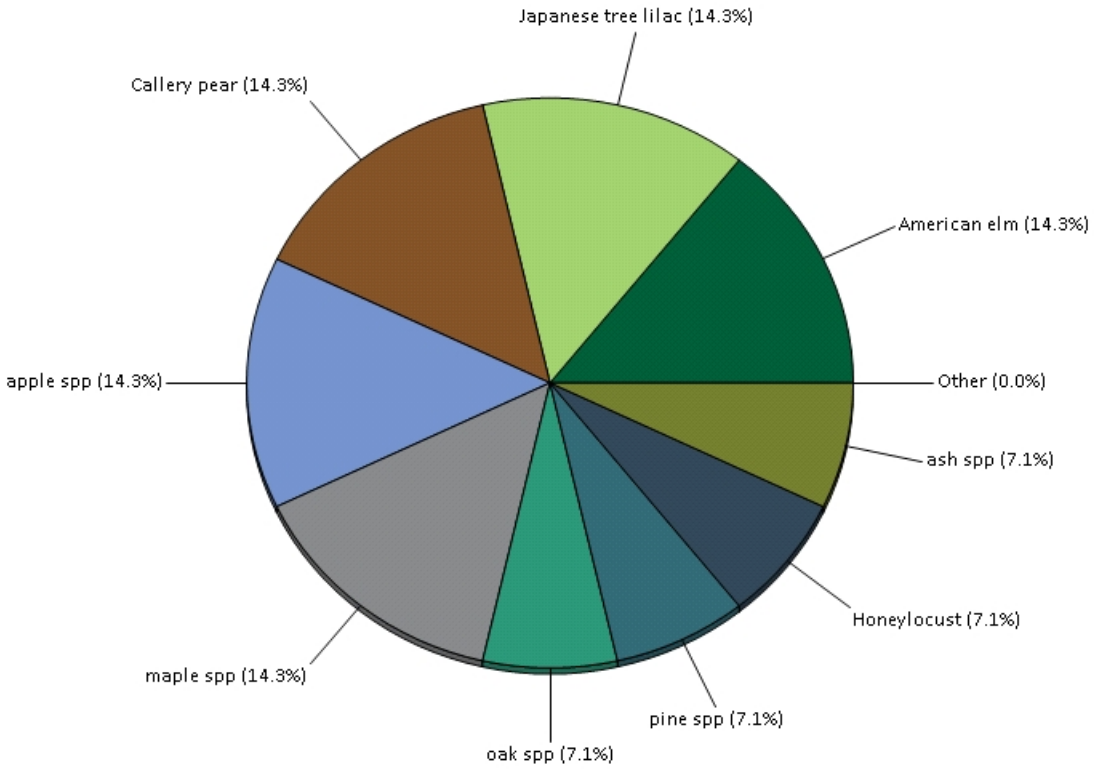


Figure 1. Tree species composition in Woodrow Wilson

The overall tree density in Woodrow Wilson is 5 trees/acre (see Appendix III for comparable values from other cities).

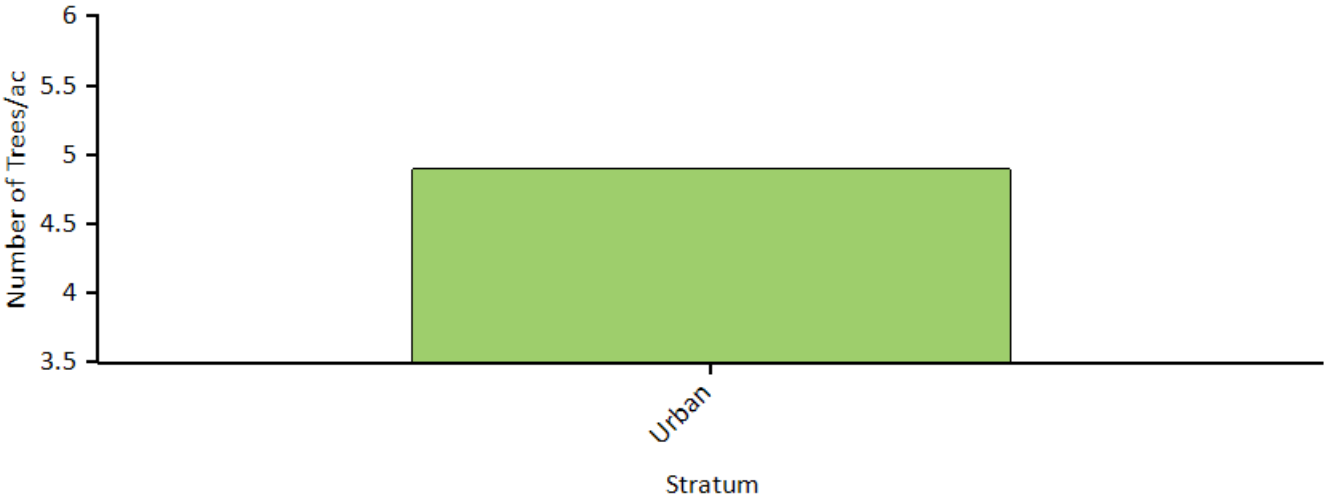


Figure 2. Number of trees/ac in Woodrow Wilson by stratum

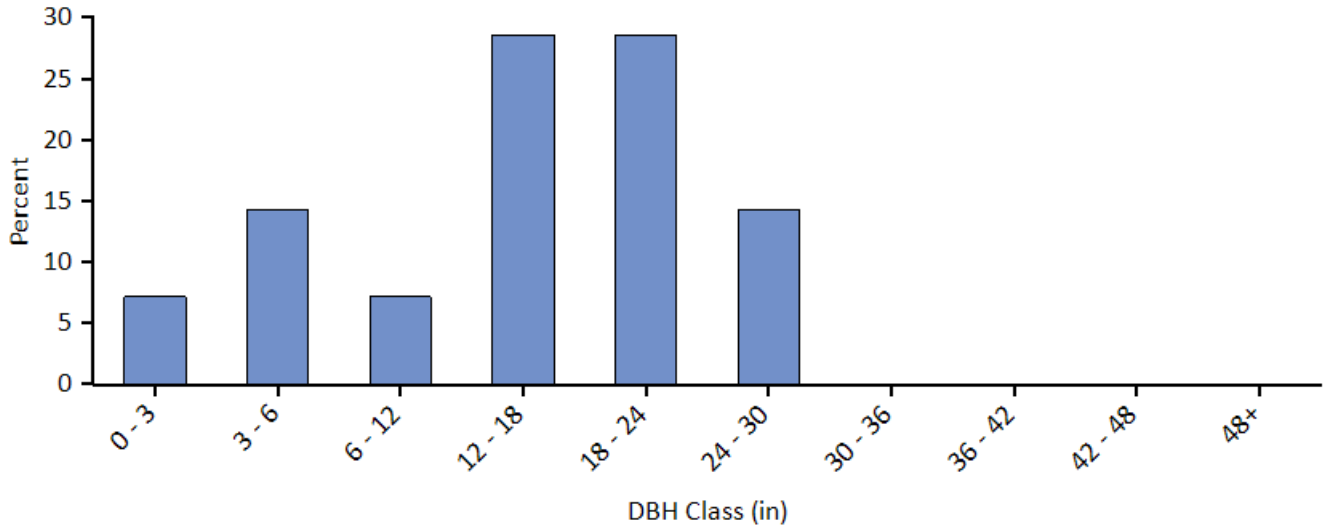


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 4.5 feet)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Woodrow Wilson , about 21 percent of the trees are species native to North America, while 21 percent are native to Kansas. Species exotic to North America make up 79 percent of the population. Most exotic tree species have an origin from North America + (50 percent of the species).

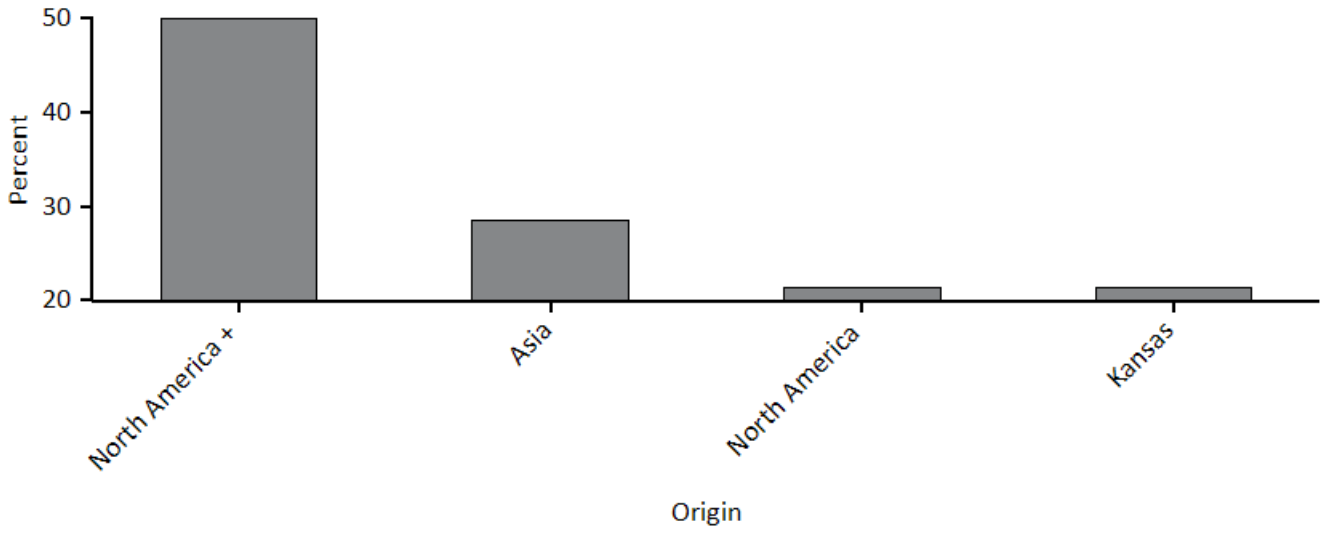


Figure 4. Percent of live tree population by area of native origin, Woodrow Wilson

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas. One of the 9 tree species in Woodrow Wilson are identified as invasive on the state invasive species list (Kansas Native Plant Society 2006). This invasive species (Callery pear) comprises 14.3 percent of the tree population though it may only cause a minimal level of impact (see Appendix V for a complete list of invasive species).

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 6.8 percent of Woodrow Wilson and provide 1.142 acres of leaf area. Total leaf area is greatest in Urban.

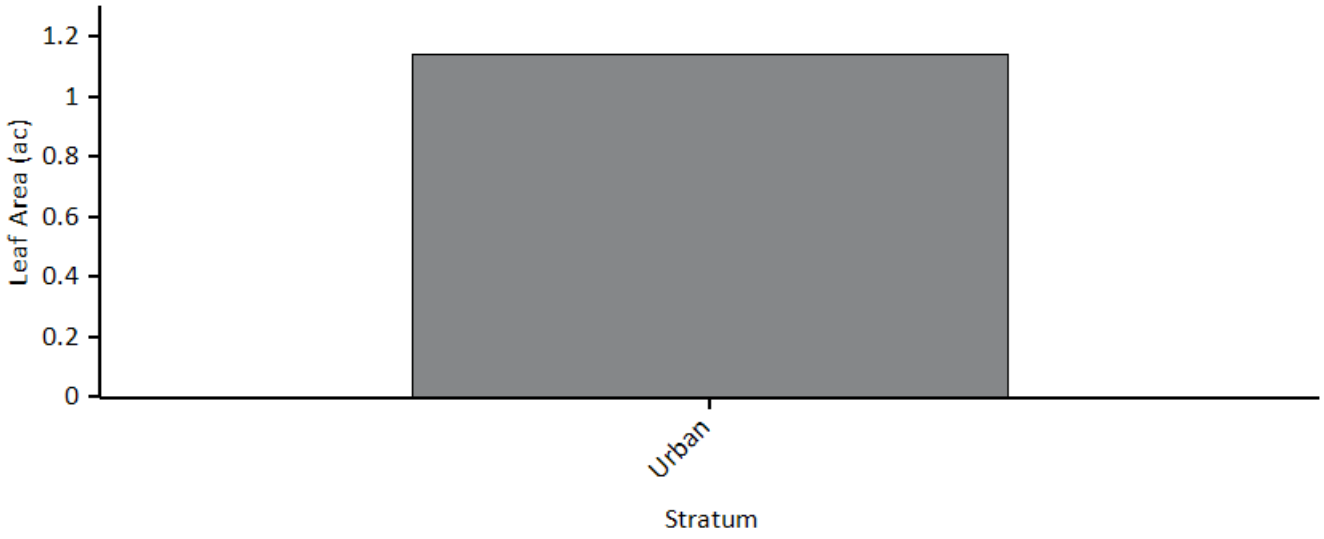


Figure 5. Leaf area by stratum, Woodrow Wilson

In Woodrow Wilson , the most dominant species in terms of leaf area are maple spp, oak spp, and Callery pear. The 9 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Woodrow Wilson

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
maple spp	14.3	23.7	38.0
Callery pear	14.3	14.7	29.0
American elm	14.3	11.2	25.4
oak spp	7.1	17.2	24.3
ash spp	7.1	10.7	17.8
pine spp	7.1	10.4	17.6
Honeylocust	7.1	9.7	16.8
apple spp	14.3	1.9	16.2
Japanese tree lilac	14.3	0.5	14.8

Common ground cover classes (including cover types beneath trees and shrubs) in Woodrow Wilson are not available since they are configured not to be collected.

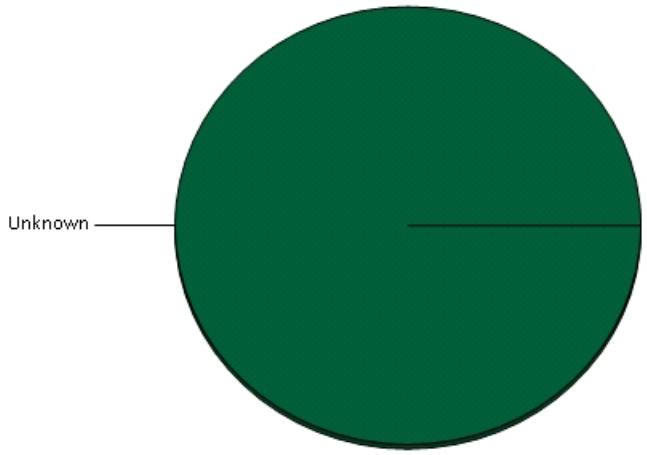


Figure 6. Percent of land by ground cover classes, Woodrow Wilson

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in Woodrow Wilson was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 11.19 pounds of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), particulate matter less than 10 microns and greater than 2.5 microns (PM10*)[2], and sulfur dioxide (SO2)) per year with an associated value of $30.7 (see Appendix I for more details).

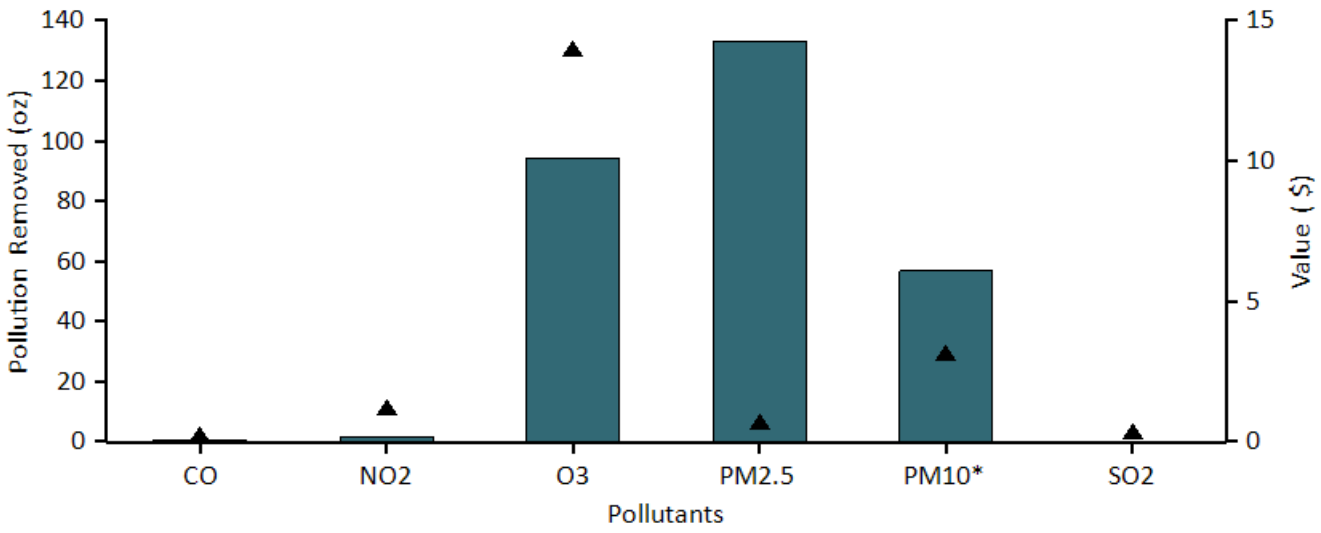


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Woodrow Wilson

[1] PM10* is particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is particulate matter less than 2.5 microns. If PM2.5 is not monitored, PM10* represents particulate matter less than 10 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces. This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2022, trees in Woodrow Wilson emitted an estimated 11.49 pounds of volatile organic compounds (VOCs) (4.566 pounds of isoprene and 6.927 pounds of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Eighty- eight percent of the urban forest's VOC emissions were from oak spp and pine spp. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Woodrow Wilson trees is about 590.4 pounds of carbon per year with an associated value of $50.3. See Appendix I for more details on methods.

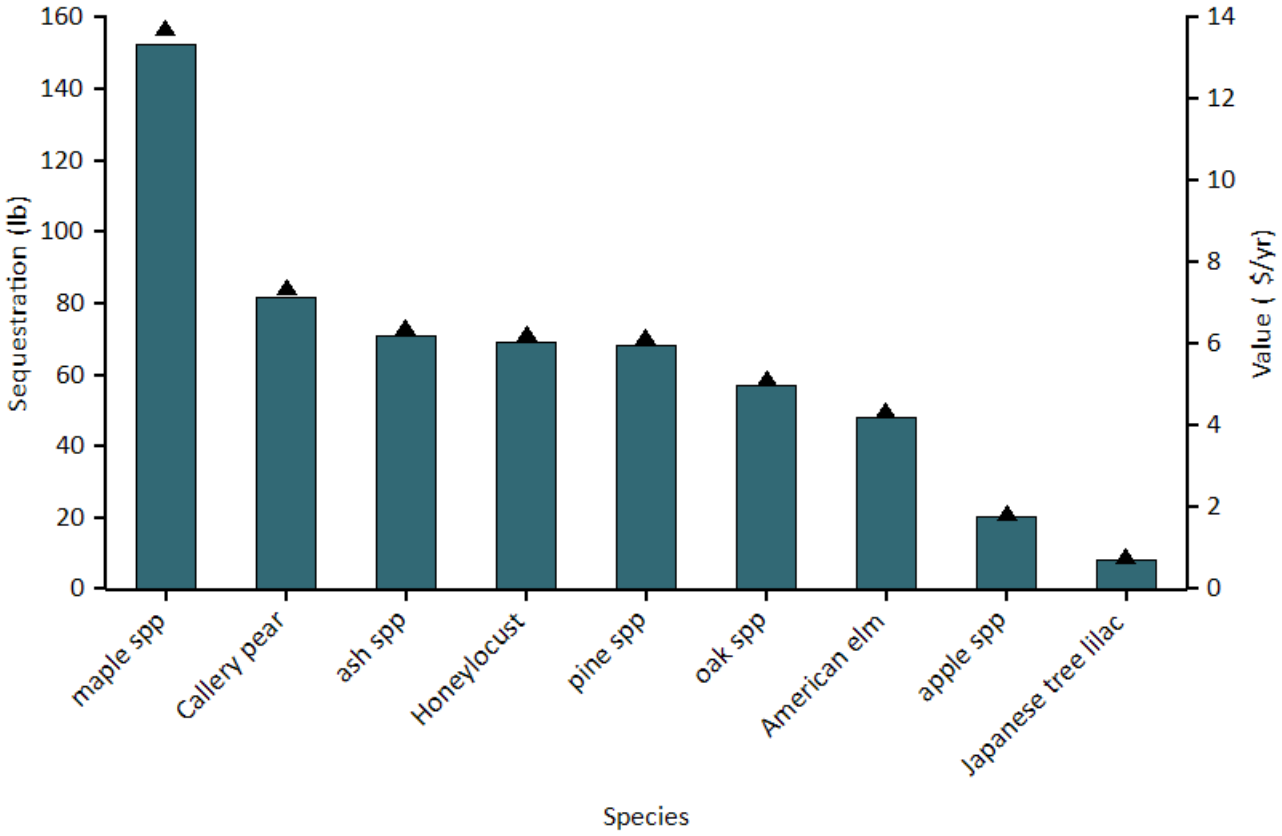


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Woodrow Wilson

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Woodrow Wilson are estimated to store 9.68 tons of carbon ($1.65 thousand). Of the species sampled, maple spp

stores and sequesters the most carbon (approximately 21.1% of the total carbon stored and 26.5% of all sequestered carbon.)

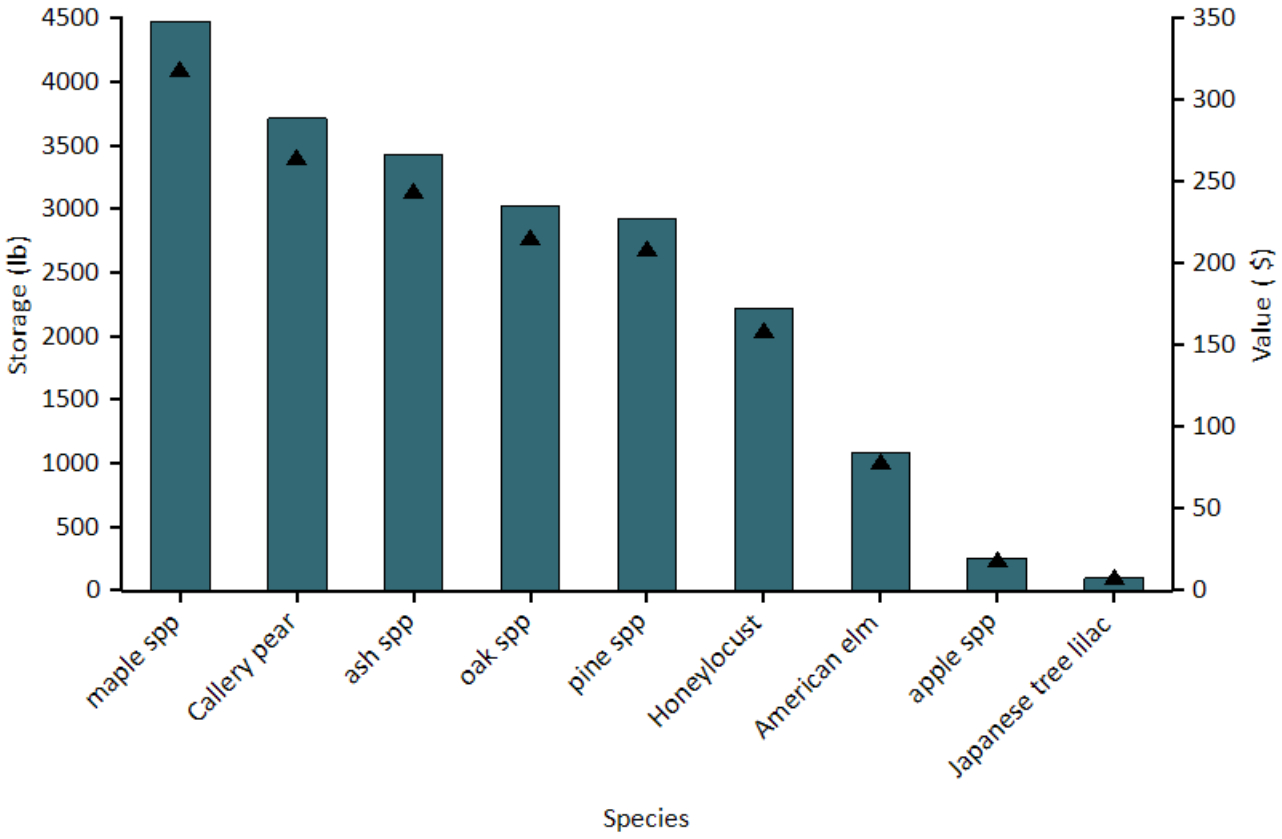


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Woodrow Wilson

V. Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Woodrow Wilson are estimated to produce 1574 pounds of oxygen per year.[4] However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 9 oxygen production species.

Species	*Oxygen (pound)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (square feet)*
maple spp	416.92	156.34	2	0.01
Callery pear	223.72	83.89	2	0.01
ash spp	193.68	72.63	1	0.01
Honeylocust	189.36	71.01	1	0.00
pine spp	186.12	69.79	1	0.01
oak spp	155.52	58.32	1	0.01
American elm	131.54	49.33	2	0.01
apple spp	54.93	20.60	2	0.00
Japanese tree lilac	22.53	8.45	2	0.00

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Woodrow Wilson help to reduce runoff by an estimated 471 cubic feet a year with an associated value of $31 (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Woodrow Wilson , the total annual precipitation in 2019 was 44.7 inches.

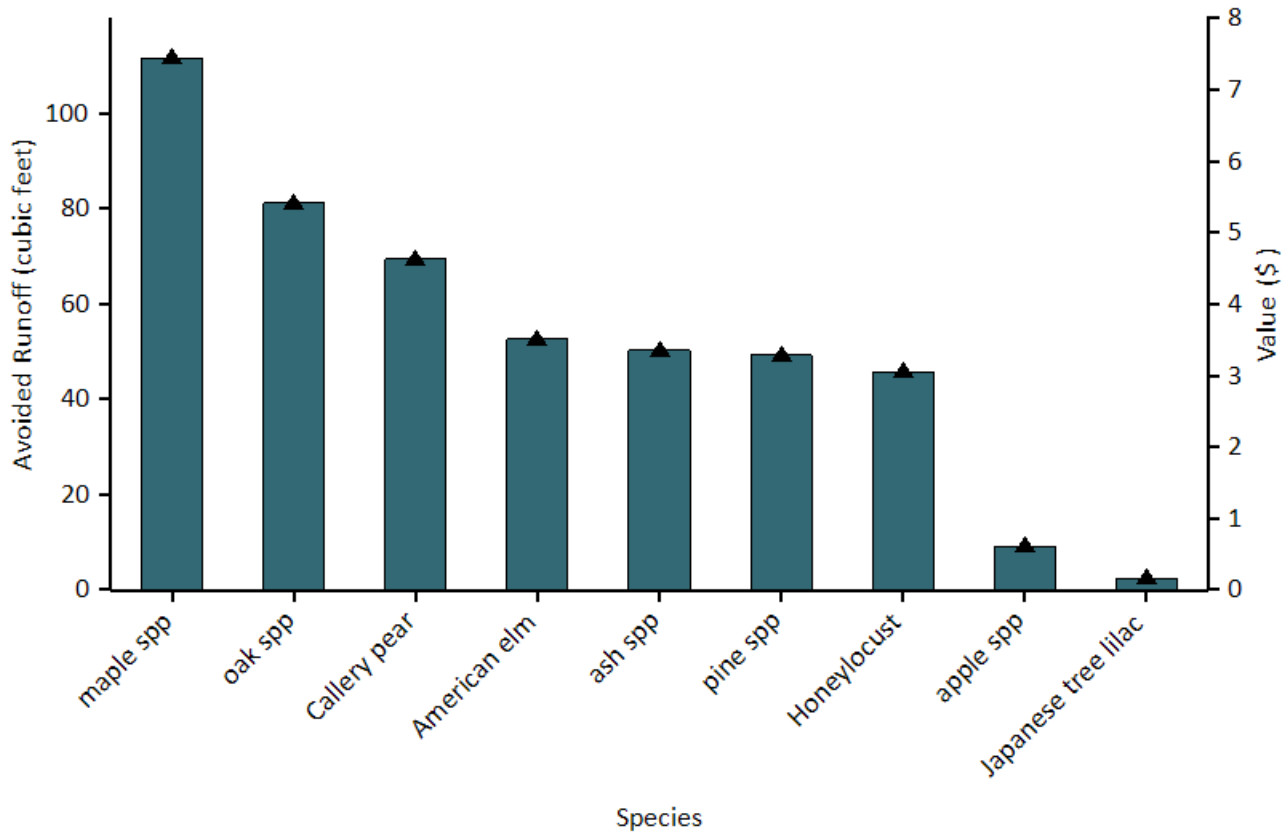


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Woodrow Wilson

VII. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Because energy-related data were not collected, energy savings and carbon avoided cannot be calculated.

Table 3. Annual energy savings due to trees near residential buildings, Woodrow Wilson

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (pounds)	0	0	0

[a]MBTU - one million British Thermal Units

[b]MWH - megawatt-hour

Table 4. Annual savings [a]($) in residential energy expenditure during heating and cooling seasons, Woodrow Wilson

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of $130.2 per MWH and $11.3442000317562 per MBTU (see Appendix I for more details)

[c]MBTU - one million British Thermal Units

[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Replacement and Functional Values

Urban forests have a replacement value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The replacement value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Woodrow Wilson have the following replacement values:

- Replacement value: $42.5 thousand
- Carbon storage: $1.65 thousand

Urban trees in Woodrow Wilson have the following annual functional values:

- Carbon sequestration: $50.3
- Avoided runoff: $31.5
- Pollution removal: $30.7
- Energy costs and carbon emission values: $0

(Note: negative value indicates increased energy cost and carbon emission value)

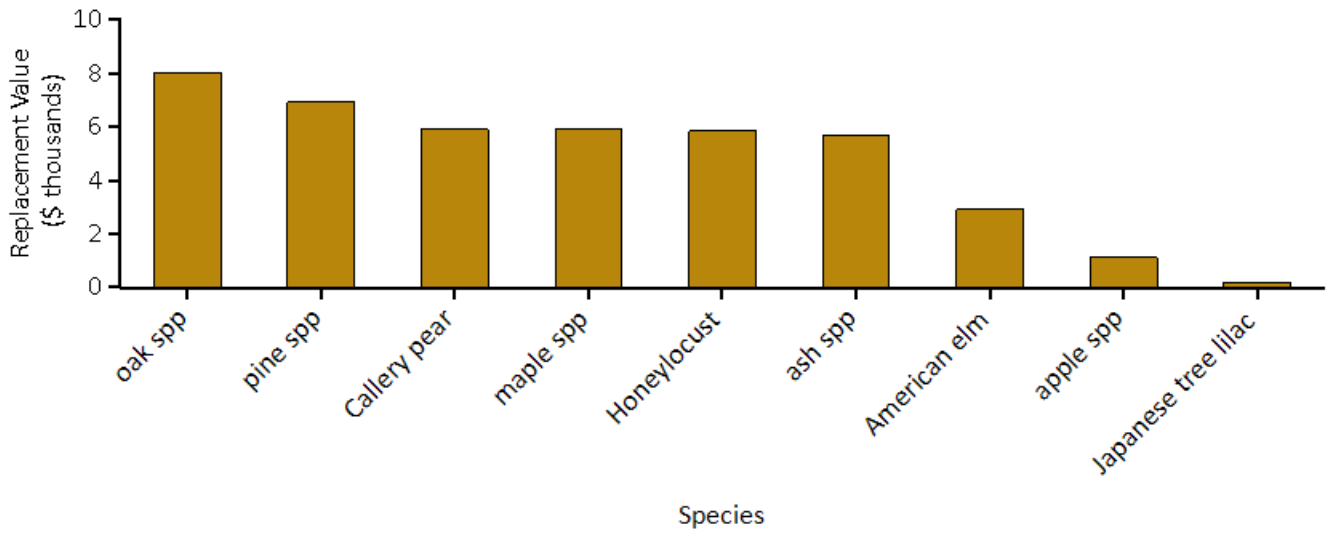


Figure 11. Tree species with the greatest replacement value, Woodrow Wilson

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, replacement value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact and compared with pest range maps (Forest Health Technology Enterprise Team 2014) for the conterminous United States to determine their proximity to Riley County. One of the thirty-six pests analyzed are located within the county. For a complete analysis of all pests, see Appendix VII.

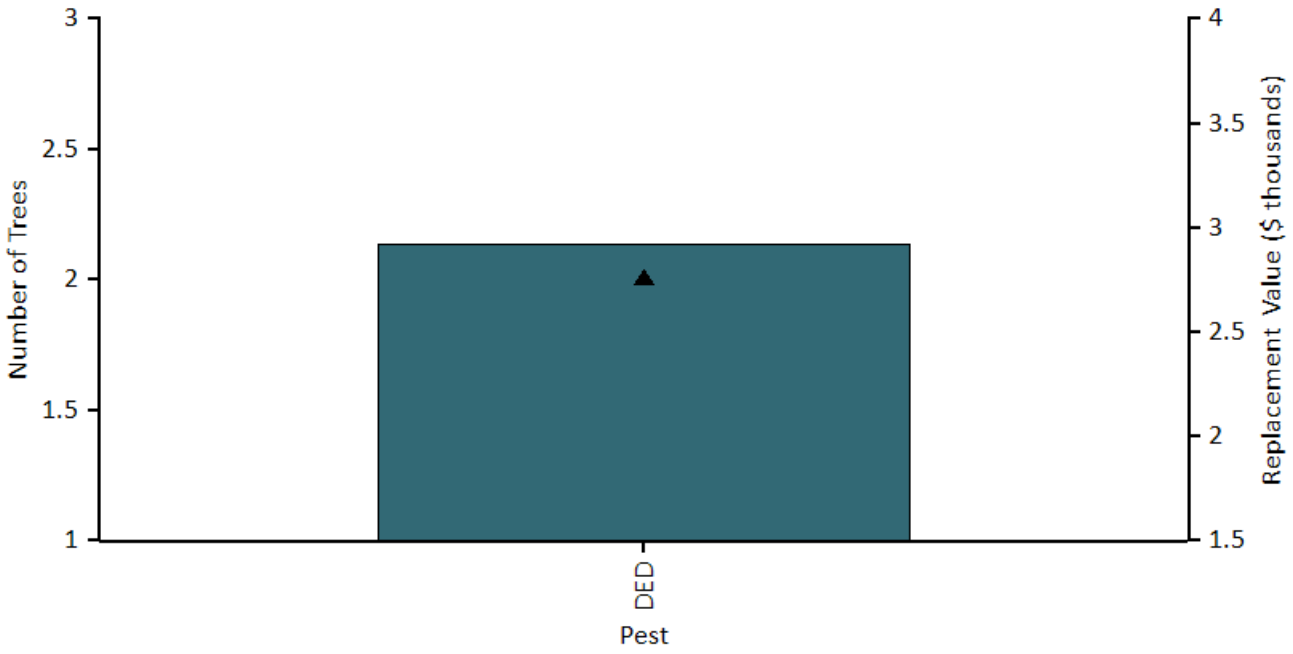


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) for most threatening pests located in the county, Woodrow Wilson

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Woodrow Wilson could possibly lose 14.3 percent of its trees to this pest ($2.92 thousand in replacement value).

Appendix I. i-Tree Eco Model and Field Measurements

i-Tree Eco is designed to use standardized field data and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Replacement value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

Tree Characteristics:

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list (Kansas Native Plant Society 2006)for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

Air Pollution Removal:

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter less than 2.5 microns, and particulate matter less than 10 microns and greater than 2.5 microns. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 and PM10* when particulate matter is deposited on leaf surfaces (Nowak et al 2013). This deposited PM2.5 and PM10* can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to

the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 and PM10* removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 and PM10* concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 and PM10* but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of $1,443 per ton (carbon monoxide), $2,492 per ton (ozone), $464 per ton (nitrogen dioxide), $193 per ton (sulfur dioxide), $77,181 per ton (particulate matter less than 2.5 microns), $6,781 per ton (particulate matter less than 10 microns and greater than 2.5 microns).

Carbon Storage and Sequestration:

Carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak 1994). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on $171 per ton.

Oxygen Production:

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition (Nowak et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of $0.07 per ft^3.

Building Energy Use:

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

For this analysis, energy saving value is calculated based on the prices of $130.20 per MWH and $11.34 per MBTU.

Replacement Values:

Replacement value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Replacement values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Replacement value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 250 miles of the county edge, is between 250 and 750 miles away, or is greater than 750 miles away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in Woodrow Wilson provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in Woodrow Wilson in 0 days
- Annual carbon (C) emissions from 7 automobiles
- Annual C emissions from 3 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 0 automobiles
- Annual carbon monoxide emissions from 0 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 0 automobiles
- Annual nitrogen dioxide emissions from 0 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 1 automobiles
- Annual sulfur dioxide emissions from 0 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in Woodrow Wilson in 0.0 days
- Annual C emissions from 0 automobiles
- Annual C emissions from 0 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (tons)*	*Carbon Sequestration (tons/yr)*	*Pollution Removal (tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,221,000	51,500	2,099
Atlanta, GA	36.7	9,415,000	1,344,000	46,400	1,663
Los Angeles, CA	11.1	5,993,000	1,269,000	77,000	1,975
New York, NY	20.9	5,212,000	1,350,000	42,300	1,676
London, ON, Canada	24.7	4,376,000	396,000	13,700	408
Chicago, IL	17.2	3,585,000	716,000	25,200	888
Phoenix, AZ	9.0	3,166,000	315,000	32,800	563
Baltimore, MD	21.0	2,479,000	570,000	18,400	430
Philadelphia, PA	15.7	2,113,000	530,000	16,100	575
Washington, DC	28.6	1,928,000	525,000	16,200	418
Oakville, ON , Canada	29.1	1,908,000	147,000	6,600	190
Albuquerque, NM	14.3	1,846,000	332,000	10,600	248
Boston, MA	22.3	1,183,000	319,000	10,500	283
Syracuse, NY	26.9	1,088,000	183,000	5,900	109
Woodbridge, NJ	29.5	986,000	160,000	5,600	210
Minneapolis, MN	26.4	979,000	250,000	8,900	305
San Francisco, CA	11.9	668,000	194,000	5,100	141
Morgantown, WV	35.5	658,000	93,000	2,900	72
Moorestown, NJ	28.0	583,000	117,000	3,800	118
Hartford, CT	25.9	568,000	143,000	4,300	58
Jersey City, NJ	11.5	136,000	21,000	890	41
Casper, WY	8.9	123,000	37,000	1,200	37
Freehold, NJ	34.4	48,000	20,000	540	22

II. Totals per acre of land area

City	*Number of Trees/ac*	*Carbon Storage (tons/ac)*	*Carbon Sequestration (tons/ac/yr)*	*Pollution Removal (lb/ac/yr)*
Toronto, ON, Canada	64.9	7.8	0.33	26.7
Atlanta, GA	111.6	15.9	0.55	39.4
Los Angeles, CA	19.6	4.2	0.16	13.1
New York, NY	26.4	6.8	0.21	17.0
London, ON, Canada	75.1	6.8	0.24	14.0
Chicago, IL	24.2	4.8	0.17	12.0
Phoenix, AZ	12.9	1.3	0.13	4.6
Baltimore, MD	48.0	11.1	0.36	16.6
Philadelphia, PA	25.1	6.3	0.19	13.6
Washington, DC	49.0	13.3	0.41	21.2
Oakville, ON , Canada	78.1	6.0	0.27	11.0
Albuquerque, NM	21.8	3.9	0.12	5.9
Boston, MA	33.5	9.1	0.30	16.1
Syracuse, NY	67.7	10.3	0.34	13.6
Woodbridge, NJ	66.5	10.8	0.38	28.4
Minneapolis, MN	26.2	6.7	0.24	16.3
San Francisco, CA	22.5	6.6	0.17	9.5
Morgantown, WV	119.2	16.8	0.52	26.0
Moorestown, NJ	62.1	12.4	0.40	25.1
Hartford, CT	50.4	12.7	0.38	10.2
Jersey City, NJ	14.4	2.2	0.09	8.6
Casper, WY	9.1	2.8	0.09	5.5
Freehold, NJ	38.3	16.0	0.44	35.3

Appendix IV. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (Nowak 1995):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (Nowak 2000). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include (Nowak 2000):

Strategy	*Result*
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix V. Invasive Species of the Urban Forest

The following inventoried tree species were listed as invasive on the Kansas invasive species list (Kansas Native Plant Society 2006):

Species Name[a]	*Number of Trees*	*% of Trees*	*Leaf Area (ft²)*	*Percent Leaf Area*
Callery pear	2	14.3	0.0	14.7
Total	**2**	**14.29**	**0.01**	**14.71**

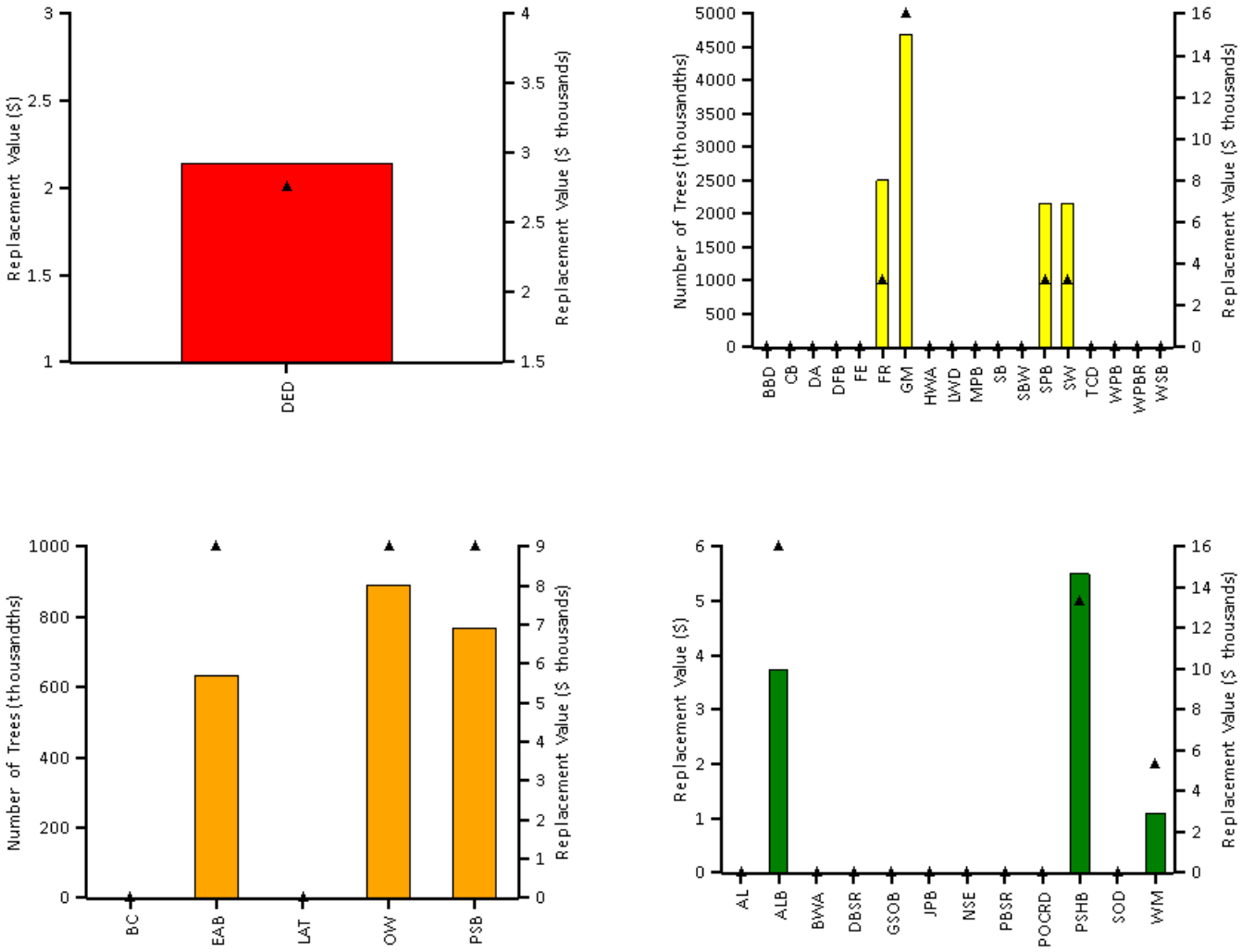
[a]Species are determined to be invasive if they are listed on the state's invasive species list

Appendix VI. Potential Risk of Pests

Thirty-six insects and diseases were analyzed to quantify their potential impact on the urban forest. As each insect/disease is likely to attack different host tree species, the implications for {0} will vary. The number of trees at risk reflects only the known host species that are likely to experience mortality.

Code	Scientific Name	Common Name	Trees at Risk (#)	Value ($ thousands)
AL	Phyllocnistis populiella	Aspen Leafminer	0	0.00
ALB	Anoplophora glabripennis	Asian Longhorned Beetle	6	9.94
BBD	Neonectria faginata	Beech Bark Disease	0	0.00
BC	Sirococcus clavigignenti juglandacearum	Butternut Canker	0	0.00
BWA	Adelges piceae	Balsam Woolly Adelgid	0	0.00
CB	Cryphonectria parasitica	Chestnut Blight	0	0.00
DA	Discula destructiva	Dogwood Anthracnose	0	0.00
DBSR	Leptographium wageneri var. pseudotsugae	Douglas-fir Black Stain Root Disease	0	0.00
DED	Ophiostoma novo-ulmi	Dutch Elm Disease	2	2.92
DFB	Dendroctonus pseudotsugae	Douglas-Fir Beetle	0	0.00
EAB	Agrilus planipennis	Emerald Ash Borer	1	5.70
FE	Scolytus ventralis	Fir Engraver	0	0.00
FR	Cronartium quercuum f. sp. Fusiforme	Fusiform Rust	1	8.02
GM	Lymantria dispar	Gypsy Moth	5	15.04
GSOB	Agrilus auroguttatus	Goldspotted Oak Borer	0	0.00
HWA	Adelges tsugae	Hemlock Woolly Adelgid	0	0.00
JPB	Dendroctonus jeffreyi	Jeffrey Pine Beetle	0	0.00
LAT	Choristoneura conflictana	Large Aspen Tortrix	0	0.00
LWD	Raffaelea lauricola	Laurel Wilt	0	0.00
MPB	Dendroctonus ponderosae	Mountain Pine Beetle	0	0.00
NSE	Ips perturbatus	Northern Spruce Engraver	0	0.00
OW	Ceratocystis fagacearum	Oak Wilt	1	8.02
PBSR	Leptographium wageneri var. ponderosum	Pine Black Stain Root Disease	0	0.00
POCRD	Phytophthora lateralis	Port-Orford-Cedar Root Disease	0	0.00
PSB	Tomicus piniperda	Pine Shoot Beetle	1	6.92
PSHB	Euwallacea nov. sp.	Polyphagous Shot Hole Borer	5	14.67
SB	Dendroctonus rufipennis	Spruce Beetle	0	0.00
SBW	Choristoneura fumiferana	Spruce Budworm	0	0.00
SOD	Phytophthora ramorum	Sudden Oak Death	0	0.00
SPB	Dendroctonus frontalis	Southern Pine Beetle	1	6.92
SW	Sirex noctilio	Sirex Wood Wasp	1	6.92
TCD	Geosmithia morbida	Thousand Canker Disease	0	0.00
WM	Operophtera brumata	Winter Moth	2	2.92
WPB	Dendroctonus brevicomis	Western Pine Beetle	0	0.00
WPBR	Cronartium ribicola	White Pine Blister Rust	0	0.00
WSB	Choristoneura occidentalis	Western Spruce Budworm	0	0.00

In the following graph, the pests are color coded according to the county's proximity to the pest occurrence in the United States. Red indicates that the pest is within the county; orange indicates that the pest is within 250 miles of the county; yellow indicates that the pest is within 750 miles of the county; and green indicates that the pest is outside of these ranges.



Note: points - Number of trees, bars - Replacement value

Based on the host tree species for each pest and the current range of the pest (Forest Health Technology Enterprise Team 2014), it is possible to determine what the risk is that each tree species in the urban forest could be attacked by an insect or disease.

Spp. Risk	Risk Weight	Species Name	AL	ALB	BBD	BC	BWA	CB	DA	DBSR	DED	DFB	EAB	FE	FR	GM	GSOB	HWA	JPB	LAT	LWD	MPB	NSE	OW	PBSR	POCRD	PSB	PSHB	SB	SBW	SOD	SPB	SW	TCD	WM	WPB	WPBR	WSB
	7	American elm																																					
	7	oak spp																																					
	7	pine spp																																					
	3	Callery pear																																					
	3	apple spp																																					
	3	ash spp																																					
	1	maple spp																																					
	1	Honeylocust																																					

Note:
Species that are not listed in the matrix are not known to be hosts to any of the pests analyzed.

Species Risk:

- Red indicates that tree species is at risk to at least one pest within county
- Orange indicates that tree species has no risk to pests in county, but has a risk to at least one pest within 250 miles from the county
- Yellow indicates that tree species has no risk to pests within 250 miles of county, but has a risk to at least one pest that is 250 and 750 miles from the county
- Green indicates that tree species has no risk to pests within 750 miles of county, but has a risk to at least one pest that is greater than 750 miles from the county

Risk Weight:
Numerical scoring system based on sum of points assigned to pest risks for species. Each pest that could attack tree species is scored as 4 points if red, 3 points if orange, 2 points if yellow and 1 point if green.

Pest Color Codes:

- Red indicates pest is within Riley county
- Red indicates pest is within 250 miles county
- Yellow indicates pest is within 750 miles of Riley county
- Green indicates pest is outside of these ranges

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