

Envisioning kansas state university as an accredited arboretum with a climate-ready tree
collection

by

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Abstract

Climate change poses a significant threat to the survival and prosperity of trees in Kansas and beyond (Esperon-Rodriguez et al. 2021, Matthews et al. 2018, Mao 2021). As the climate becomes increasingly unpredictable and extreme, numerous tree species will find it challenging to adapt and manage the emerging threats and changing conditions. Anticipated rapid changes in conditions include; drought, shifting hardiness zones, heat zones, increased growing degree days, severe storms, and the emergence of new pests and diseases (Esperon-Rodriguez et al. 2021, Matthews et al. 2018, Primack and Miller-Rushing 2009, Rakow and Lee 2011). Given Kansas's changing climatic conditions and uncertainty about the long-term survival of its existing, regionally adapted trees, there is a pressing need to develop and study an expanded palette of suitable tree species.

This project aims to create recommendations for the establishment of an accredited arboretum with a dedicated climate-ready tree collection at Kansas State University (KSU) to disseminate groundbreaking knowledge about trees tailored to Kansas's anticipated end-of-century climatic projections. This study included precedent studies of notable University arboreta were conducted to understand their arboretum components. A survey of subject matter experts from the Kansas Forest Service to understand the current and future challenges, public concerns, and research needs regarding trees in Kansas. A site inventory was performed to understand factors within each of the five K-State campus landscape typologies investigated that could inform the future species selection and placement of new trees within each typology. A climate evaluation examined recent and projected variables related to tree growth and survival across the United States to understand the implications for Kansas by the end of the century and to identify regions that recently exhibit the climatic projections for Kansas. By identifying regions with

recent similar climatic conditions, informed decisions were made regarding selecting tree species suited for Kansas' future.

These findings offer insight into what efforts are needed to establish an accredited arboretum with a climate-ready tree collection at Kansas State University. This work provides recommendations that would reinforce KSU's commitment to its land-grant mission by serving as a platform for propagating novel tree information and exemplifying its dedication to education and outreach.

ENVISIONING KANSAS STATE UNIVERSITY
AS AN ACCREDITED ARBORETUM WITH A
CLIMATE-READY TREE COLLECTION



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ABSTRACT

Climate change poses a significant threat to the survival and prosperity of trees in Kansas and beyond (Esperon-Rodriguez et al. 2021, Matthews et al. 2018, Mao 2021). As the climate becomes increasingly unpredictable and extreme, numerous tree species will find it challenging to adapt and manage the emerging threats and changing conditions. Anticipated rapid changes in conditions include; drought, shifting hardiness zones, heat zones, increased growing degree days, severe storms, and the emergence of new pests and diseases (Esperon-Rodriguez et al. 2021, Matthews et al. 2018, Primack and Miller-Rushing 2009, Rakow and Lee 2011). Given Kansas's changing climatic conditions and uncertainty about the long-term survival of its existing, regionally adapted trees, there is a pressing need to develop and study an expanded palette of suitable tree species.

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These findings offer insight into what efforts are needed to establish an accredited arboretum with a climate-ready tree collection at Kansas State University. This work provides recommendations that would reinforce KSU's commitment to its land-grant mission by serving as a platform for propagating novel tree information and exemplifying its dedication to education and outreach.

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KEY TERMS

Accession: an individual plant (single taxon) from one source at the same time; assigned a code or number for tracking purposes (Rakow and Lee 2011).

Accessioning: the act of adding a new item to a collection (Rakow and Lee 2011).

Acquisition: a plant or propagule that has been brought to the garden to be accessioned and cataloged (Gratzfeld 2016, Rakow and Lee 2011).

Arboreta: the plural form of arboretum.

Arboretum: an arboretum is a place where woody plants are grown, displayed, and studied for scientific, educational, or ornamental purposes (Rakow and Lee 2011, Wyman 1960).

Climate-Ready Trees: trees selected for their adaptability to current and projected climatic conditions.

Collection: a group of plants that have been brought together for a specific purpose (Rakow and Lee 2011).

Curator: an individual who manages and/or maintains one or more collections of plant specimens for study and research purposes (Gratzfeld 2016, Rakow and Lee 2011).

Curation: the act of selecting, organizing, and caring for the plants in a collection (Rakow and Lee 2011).

Phenology: the study of the timing of natural events, such as the first leaf break, the first flower opening, peak flowering, and so on. Phenology also applies to the timing of animal species' migration (Rakow and Lee 2011).

CHAPTER 1
INTRODUCTION





Figure 1.1 View of Kansas State University Anderson Hall (by author).

INTRODUCTION

IMPORTANCE

Arboreta are places where people intentionally grow, study, and display woody plants for educational, scientific, and ornamental purposes (ArbNet n.d., Rakow and Lee 2011, Wyman 1960). Numerous arboreta are situated worldwide, with sizes ranging from small cemeteries to vast national parks. They can also be in nature reserves, historic properties, botanical gardens, and universities (ArbNet n.d.). Arboreta on university and college campuses are becoming one of the fastest-growing segments of public horticulture (Klett et al., 2014, Rakow and Lee 2011). There are various compelling reasons why universities establish arboreta. These include promoting campus unity, facilitating university research, and serving as gateways to the broader community. For example, at the University of California, Davis, the GATEways (Gardens, Art, and Environment) Project uses the UC Davis Arboretum as the front entrance to the campus (UC Davis 2022). By incorporating an arboretum, a campus can feature a central design component that harmonizes the surrounding environment. Most importantly, it can foster intellectual unification among the university community members (Rakow and Lee 2011, Gratzfeld in 2016).

Campus arboreta have traditionally served as living laboratories to enrich undergraduate and graduate education through hands-on learning and observation of plant growth, diversity, development, and adaptation. These arboreta offer a natural setting for students to conduct research projects, collect data, and apply scientific methods. Arboreta on or associated with land grant institutions are particularly valuable because they can support mission-driven activities and outreach efforts, including walking tours, classes, workshops, or other continuing education events for broad audiences (Rakow and Lee 2011). These arboreta can enhance student learning in various disciplines such as horticulture, landscape design, plant pathology, entomology, landscape architecture, agriculture, plant breeding, forestry, plant identification, ecology, and environmental science. Campus Arboreta have the potential to foster a culture of stewardship and conservation among students, faculty, staff, and visitors. Moreover, arboretum personnel may collaborate with other institutions, research extension agencies, state and federal forest service departments, and K-12 schools or community organizations to further expand educational opportunities.

KANSAS STATE UNIVERSITY

Kansas State University (KSU) is a designated land-grant institution whose mission is to “foster excellent teaching, research, and service that develop a highly skilled and educated citizenry necessary to advancing the well-being of Kansas, the nation, and the international community” (KSU 2008). In 1863, the University became the nation’s first land-grant university under the Morrill Act. Then, called the Kansas State Agricultural College, one of its primary foci was researching the types of plants that could be cultivated and grown in the Kansas prairie landscape and disseminating the findings to the public (KSU 2008, Vireo and Ayers Saint Gross 2012). Since the initial founding of the University, its campus grounds have served as a living laboratory

for students, faculty, and the public (Vireo and Ayers Saint Gross 2012). Selected plants were labeled for public display, making the college landscape an excellent way to educate students and the public about woody plants (Brokesh 2019). Over time, the campus developed, hosting an extensive array of trees once described by K-State as an arboretum. The arboretum, which contained an extensive display of trees and shrubs, boasted the state's most extensive variety of such plants. However, during the mid-20th century, tree and shrub species decreased due to development expansion and construction of new buildings (Brokesh 2019). Today, the campus grounds of KSU still hold a diverse display of trees that create a picturesque landscape.

While the Kansas State University campus has a history of cultivating trees since its inception, it has the potential to transform into something prominent - an accredited arboretum with a dedicated climate-ready collection. This transformation would require strategic and intentional efforts to curate, research, and exhibit woody plants for scientific, academic, and aesthetic purposes. With key elements such as a well-defined purpose, a dedicated administrative body, a comprehensive collection policy, established tree care and management practices, identified collections, robust outreach programs, and active research initiatives crucial for this evolution, KSU can become an accredited arboretum. Achieving accreditation would not only validate and enhance these efforts but also provide a framework for growth, collaboration, and recognition in the broader scientific and academic community. The pursuit of ArbNet accreditation is not just a critical step but a beacon of possibility for KSU to fully realize its potential as a living laboratory and educational resource for generations to come, contributing to the well-being of Kansas and beyond.

DILEMMA

Climate change poses a significant threat to the survival and prosperity of trees in Kansas and beyond (Esperon-Rodriguez et al. 2021, Matthews et al. 2018, Mao 2021). Trees, being rooted, are unable to adapt swiftly in response to rapidly changing climate conditions. While tree populations can shift geographically, this process occurs slowly over time and depends on seed dispersal (USDA and U.S. Forest Service, 2023). As the climate becomes increasingly unpredictable and extreme, numerous tree species will find it challenging to adapt and manage the emerging threats and changing conditions. Anticipated rapid changes in conditions include; drought, shifting hardiness zones, heat zones, increased growing degree days, severe storms, and the emergence of new pests and diseases (Esperon-Rodriguez et al. 2021, Matthews et al. 2018, Primack and Miller-Rushing 2009, Rakow and Lee 2011).

Given Kansas's changing climatic conditions and uncertainty about the long-term survival of its existing, regionally adapted trees, there is a pressing need to develop and study an expanded palette of suitable tree species. Kansas State University, a land grant institution committed to disseminating novel knowledge in Kansas and the region, with a history of plant cultivation and public education, is uniquely positioned to establish such an arboretum (KSU 2008). This arboretum would be a vital resource for disseminating groundbreaking knowledge about trees tailored to Kansas's anticipated end-of-century climatic projections. Establishing an accredited arboretum with a dedicated climate-ready tree collection would reinforce KSU's commitment to its land-grant mission by serving as a platform for propagating groundbreaking tree information and exemplifying the university's dedication to education and outreach.

RESEARCH QUESTION
How can Kansas State University develop an accredited arboretum with a dedicated “climate-ready” tree collection to demonstrate the viability of species most suitable for Kansas’s changing climate?

PROJECT GOALS

- Learn the history of the KSU campus trees.
- Identify Kansas tree experts' current and future concerns, issues, and research needs.
- Investigate the administrative and structural components of accredited arboreta.
- Study the KSU campus to identify its various landscape typologies and to develop suggestions for future tree placement and species selection.
- Gain insight into the anticipated climate conditions in Kansas by the end of the Century.
- Compile a list of climate-ready trees for Kansas’s future climate.
- Provide Kansas State University with recommendations for establishing an accredited arboretum on campus.

CHAPTER 2

BACKGROUND





Figure 2.1 Scotch Pines on the K-State campus quad north of Hale Library (by author).

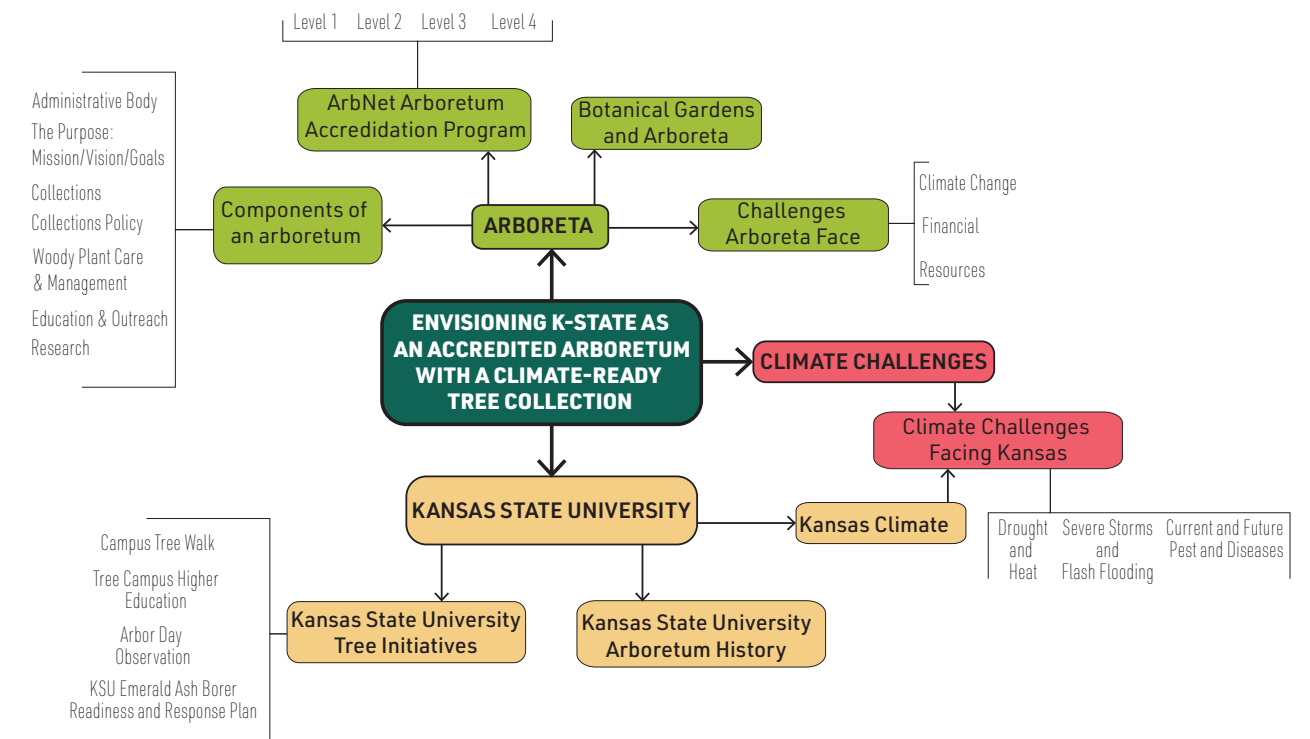


Figure 2.2 Literature Map (by author).

BACKGROUND ARBORETA

An arboretum is a place where woody plants are grown, displayed, and studied for scientific, educational, or ornamental purposes (Rakow and Lee 2011, Wyman 1960). Today, there are hundreds of arboreta across the United States, ranging from small community gardens to large national parks. An arboretum may be part of a botanical garden, a university institution, or a public park. An arboretum usually has a collection of living specimens, including different species, varieties, or cultivars of plants. An arboretum may also have exhibits, trails, or programs that showcase the diversity and importance of trees and plants in the natural environment and human culture (Rakow and Lee 2011, Gratzfeld 2016).

An arboretum houses systematically organized collections of woody plants, wherein each plant family is allocated its distinct area. The placement of plants is thoughtfully done, considering their individual needs and purposes (Rakow and Lee 2011, Gratzfeld 2016). Experts label, maintain, and document plant collections for conservation, research, and educational development. An arboretum's primary objective is to ensure advancements in the understanding of woody plants (Rakow and Lee 2011, Gratzfeld 2016, Wyman 1960).

The history of arboreta in the United States dates to the colonial era when European settlers established some of the earliest botanical gardens. One of the first arboreta in the country was the Bartram's Garden in Philadelphia, founded by John Bartram in 1728. Bartram collected and cultivated many native and exotic plants, and his garden became a center of scientific inquiry and exchange (Smithsonian 2019). Another influential arboretum was the Arnold Arboretum in Boston, founded by Charles Sprague Sargent in 1872. Sargent was a pioneer of dendrology, the study of trees, and he amassed an extensive collection of living specimens from around the world. The Arnold Arboretum is now part of Harvard University and one of the country's oldest and most renowned arboretum (Rakow and Lee 2011, Smithsonian 2019, Wyman 1960). Today, there are hundreds of arboreta across the United States, ranging from small community gardens to large national parks. They serve as valuable conservation, education, research, and recreation resources and showcase woody plants' diversity and beauty (Rakow and Lee 2011).

Differences between Botanical Gardens and Arboreta

A botanical garden and an arboretum are places where plants are grown and displayed for scientific, educational, and aesthetic purposes (Rakow and Lee 2011, Gratzfeld 2016). However, there are some key differences between them. A botanical garden typically exhibits a wide range of plants, including flowers, herbs, vegetables, aquatic plants, and tropical plants (Wyman 1960). Some botanical gardens may have greenhouses or special sections for plants from different regions of the world (Rakow and Lee 2011). A botanical garden may also have specialized small gardens, such as rose gardens, rock gardens, or Japanese gardens. On the other hand, an arboretum is a specialized botanical garden that focuses on woody plants, such as trees, shrubs, and vines (Gratzfeld 2016, Wyman 1960). An arboretum may exist independently or as part of a more extensive botanical garden. An arboretum may also have plants grouped according to their scientific relationships or geographic origins. An arboretum plays a vital role in the conservation and research of woody plants. Therefore, the main difference between a botanical garden and an arboretum is the diversity and type of plants they display. A botanical garden has a broader range of plants than an arboretum, which concentrates on woody plants.

COMPONENTS OF AN ARBORETUM
ADMINISTRATIVE BODY

An arboretum's Administrative Body is a cornerstone of its success. This body is typically a diverse team of highly skilled professionals, each bringing their unique expertise in fields such as education, research, administration, resource management, and governance (Gratzfeld 2016, Wyman 1960). It's worth noting that the terminology used to describe this body can vary depending on the institution. They may be referred to as the "Governing Body," "Arboretum Committee," "Organizational Group," or other similar terms and are used interchangeably.

The Administrative Body is entrusted with the responsibility of setting the strategic direction, ensuring financial sustainability, and overseeing the operations of the arboretum. They are the catalysts for innovation, problem solvers, strategists, and resource acquirers, all of which are crucial for the growth and development of the arboretum. The roles and titles within the governing body may vary, reflecting the specific objectives and needs of the arboretum (Gratzfeld 2016, Rakow and Lee 2011).

In the early stages of an arboretum's development, the governing body might be small, with individuals taking on multiple roles and responsibilities. These early pioneers wear many hats, from fundraising and planning to education and conservation. The size and structure of the governing body often evolve as the arboretum grows and secures more resources.

Arboreta, whether accredited or not, has governing bodies. However, the structure and responsibilities of these bodies can differ significantly. For accredited arboreta, the governing body's expectations increase with the level of accreditation. For instance, at Level IV, the highest level of accreditation, the governing body is expected to employ well-qualified tree scientists, manage living tree collections for conservation purposes, and actively support tree conservation (Arbnet 2022). For non-accredited arboreta, the governing body still plays a vital role, although the expectations may not be as clearly defined. These bodies often focus on the local needs and objectives of the arboretum, which can include education, conservation, and community engagement.

In essence, an arboretum's administrative body, whether accredited or not, is more than just a group of individuals overseeing its operations. It is the driving force behind the arboretum's growth, progression, and contribution to tree science and conservation (Arbnet 2022, Gratzfeld 2016, Rakow and Lee 2011). Its passion, dedication, and interdisciplinary expertise enable an arboretum to thrive and serve its purpose effectively.

THE PURPOSE: MISSION/VISION/GOALS

Arboreta use missions and visions to guide their work and communicate their values to the public. These missions and visions help steer their goals, strategies, and activities related to their collections research and education. A mission statement is an actionable statement that describes what the arboretum does, whom it serves, and why it exists. A vision statement is an aspirational statement that describes what the arboretum hopes to achieve or become in the future (Croneberger 2020, Gratzfeld 2016, Rakow and Lee 2011). Having a purpose for an arboretum helps to define its identity, scope, and direction and to communicate its value and relevance to the public. Establishing or revamping an arboretum starts with a clear and compelling purpose (Gratzfeld 2016, Rakow and Lee 2011). It can also inspire and motivate an arboretum's staff, volunteers, donors, and partners to support its work and contribute to its success. By providing a clearly defined set of objectives, an arboretum can better fulfill its roles, effectively communicate its purpose to visitors, and establish itself as a valuable resource within the community.

COLLECTIONS

Arboreta collections consist of well-documented woody plants and embody an institution's mission and goals (Hohn 2004, Wyman 1960). The defining characteristic distinguishing a tree in an arboretum from its counterpart in a park is its extensive documentation. This record-keeping is a hallmark of arboreta collections, underscoring their unique value and importance. A collection's value is not confined to the woody plants it comprises but extends to the accompanying information. Without sufficient documentation, the collections' storytelling potential is limited, and their reference value is diminished.

These collections are not merely physical objects but also conceptual constructs. Their defining themes often intersect, allowing plants from one collection to be integrated into the themes of another. How a collection is conceptually organized influences its public display, management, and utilization (Hohn 2004, Wyman 1960).

Diversity and Development of Collections

The diversity and development of collections in an arboretum can greatly vary, influenced by factors such as the institution's size, focus, and available resources. For example, collections vary across arboreta, from testing the hardiness of new varieties to offering recreational walks or drives (Rakow and Lee 2011, Wyman 1960). It is important to note that the number or type of collections is not uniform across all arboretums. Similarly, the number of woody plants within a single collection is inconsistent. Some arboretums may house fewer collections with more species within each. In contrast, others might concentrate on a specific type of tree or woody plant, resulting in fewer but more specialized collections (Hohn 2004).

Collections are developed through various acquisition methods, including bequests, purchases, field collections, transfers, exchanges, gifts, and loans. Each method contributes uniquely to the growth and diversity of the collections (Hohn 2004). Curators are pivotal in determining a collection but do not operate in isolation. They work alongside a governing board and other key contributors, all guided by the institution's comprehensive collections policy (President and Fellows of Harvard College 2022). Together, they ensure the collection is diverse, well-curated, and aligns with the institution's mission.

Collection Documentation

Documentation is the cornerstone of collections management in arboreta. It serves multiple functions, from validating ownership and legal status to tracking vital information such as the source, historical background, and condition of the collections. This record-keeping enhances intellectual access, providing detailed insights into the collections' identity, classification, importance, and relationships (President and Fellows of Harvard College 2022). Moreover, documentation plays a pivotal role in the care and management of collections. It monitors their location, movement, preservation status, and usage patterns, ensuring their longevity and integrity (Rakow and Lee 2011).



Figure 2.3 Flowering Crabapple Tree Collection at the Kansas Landscape Arboretum (by author).

It is important to note that the approach to documentation can vary significantly from one institution to another. Each arboretum or public garden may have unique guidelines and procedures for documenting their collections, reflecting their specific goals, resources, and constraints (President and Fellows of Harvard College 2022, Rakow and Lee 2011, Wyman 1960). Furthermore, documentation supports a range of activities, including research, education, exhibitions, and public engagement, by providing essential information that facilitates the interpretation and use of collections (Wyman 1960). Experts meticulously label and maintain these collections in arboreta to advance conservation efforts, scientific progress, and educational initiatives. Each collection is curated to deepen our knowledge of woody plants and foster their ongoing survival and prosperity (President and Fellows of Harvard College 2022). Ultimately, the documentation process is fundamental to the effective management and meaningful use of collections. It establishes a record of ownership, traces the collections' history, aids in their care, and promotes their use and interpretation, making the collections meaningful and utilizable (President and Fellows of Harvard College 2022, Rakow and Lee 2011, Wyman 1960).

Information Commonly Documented in a Collection

In the realm of botanical gardens and arboreta, the documentation associated with each item in a collection can vary significantly. This variation is influenced by several factors, including the size of the institution, its primary focus, and the resources at its disposal.

According to "Curational Practices for Botanical Gardens" by Timothy Hohn the following information is commonly documented for each item in a collection (Hohn 2004).

- Accession number: A unique identifier assigned to each item in the collection.
- Plant name: The scientific and common name of the plant.
- Verification: The process and results of confirming the plant's identity and authenticity.
- Accession date: When the plant was formally accepted into the collection.
- Condition upon receipt: The physical state and health of the plant material.
- Source: The immediate and original origin of the plant material, such as a nursery, a collector, or a donor.
- Lineage: The genetic history and parentage of the plant, particularly for hybrids and cultivars.
- Deaccession date: The date the plant was formally removed from the collection.
- Current condition: The current physical state and health of the plant, including any changes or problems.
- Preservation and other activities: Records of any treatments, interventions, or events that affect the plant, such as pruning, pest control, or propagation.
- Conservation data: Information on the conservation status, threats, and actions for plants, especially rare and endangered species.
- Control data: Information on the inventory, location, labeling, and distribution of the plant within and outside the garden.
- Historical data: Information on the plant's historical significance, cultural value, and uses.
- Miscellaneous descriptive data: Any other relevant information not covered by the above categories, such as phenology, morphology, ecology, etc.

This comprehensive documentation is crucial for the effective management and meaningful use of the collections (Hohn 2004).

COLLECTION TYPES

Woody plants are grouped into collections based on various criteria, such as family association, region of origin, functionality, conservation, trials, or plant needs. Each arboretum has its own mission and way of categorizing collections. It's worth noting that a plant can be a part of multiple collections if it meets the criteria of each one (Hohn 2004, Rakow and Lee 2011).

Thematic Collections

Collections with specific themes highlight concepts in human culture, geography, and ecological necessities. These themes may encompass historical eras, design aesthetics, and cultural significance, such as conservation and education (Rakow and Lee 2011). An example of this can be seen at the Morton Arboretum in Lisle, Illinois. The arboretum has numerous themed collections, including a collection called "Collections and Creations and Human + Nature exhibit". These collections showcase interactive sculptures and benches that encourage visitors to perceive the plants uniquely (Morton Arboretum 2023).

Taxonomic Collections

In collections based on taxonomy, plants are grouped based on their scientific classification, which includes family, genus, and species. The Arnold Arboretum at Harvard University has six accredited taxonomic collections through the American Public Gardens Association's Plant Collection Network. These collections include Acer for maples, Carya for hickories, Fagus for beeches, Magnolia, Syringa for lilacs, and Tsuga for hemlocks (President and Fellows of Harvard College 2022).

Geographic Collections

These collections consist of plants from a particular region, country or worldwide. The United States National Arboretum in Washington, D.C., presents various geographic collections, such as the Asian Collections, featuring plants from Japan, China, and Korea. The Friendship Garden displays plants from countries with diplomatic relations with the U.S., while the Grove of State Trees showcases official trees from every state (U.S. National Arboretum n.d.).

Conservation Collections

A conservation collection refers to a selection of living plants nurtured and preserved to safeguard rare or endangered species, specifically native ones. These collections are crucial for ex-situ (off-site) conservation, which involves protecting plants outside their natural environment. Ex-situ conservation can work alongside in-situ (on-site) conservation, which involves protecting plants within their natural habitat. Additionally, ex-situ conservation can serve as a backup resource for research, education, display, and restoration purposes.

The Arnold Arboretum has collaborated with the Center for Plant Conservation (CPC) since 1984. The Center for Plant Conservation curates a comprehensive conservation collection of over 2,200 endangered native plant species throughout America, which is expertly managed by a network of world-class botanical gardens and arboreta. Nine species currently reside in the Arnold Arboretum, including the pinkshell azalea (*Rhododendron vaseyi*) and the Florida torreyia (*Torreya taxifolia*). This collaboration is focused on conserving species under a changing climate, a significant concern for the Arnold Arboretum (President and Fellows of Harvard College 2023).

Display Collections

A display collection at an arboretum is a group of woody plants cultivated for scientific and educational purposes and for aesthetic appeal. A display collection may showcase plants from a specific region, family, genus, or species or highlight plants with specific traits, such as flowering, fruiting, or fall color. An example of a display collection at an arboretum is the Nationally Accredited Cornus Collection™ at the Cheekwood Estate & Gardens in Nashville, Tennessee. This collection features more than 230 dogwoods (*Cornus* spp.) of different types, including native and exotic species, cultivars, and hybrids. The gardens create a beautiful display of flowers in the spring and foliage in the fall, serving as a research and conservation center for these plants (Cheekwood Estate & Gardens n.d.).

Trial Collections

Trial collections evaluate performance, suitability, and value under specific environmental conditions. Trial collections help researchers, breeders, and growers to identify the best plants for different regions and purposes. For example, the Texas Tree Trials Database by the UC Davis Arboretum & Public Garden is testing a collection of about 45 tree species from west and central Texas that are of interest because of their novelty and potential for the Sacramento Valley region as they adapt to a changing climate. The trees are being tested for their drought tolerance, pest resistance, and adaptability (McAdow 2021).

Research Collections

Research collections at an arboretum are groups of plants grown and maintained for scientific purposes. They may include rare, endangered, or native species and plants with specific traits or uses. In the past, researchers would gather these plants without considering their future once the project was done. However, collections with thorough records may be considered valuable for research purposes. (Rakow and Lee 2011, Wyman 1960).

COLLECTIONS POLICY

A Collections Policy is a strategic document that articulates the purpose, scope, and standards of a botanical garden or arboretum's living collections. It acts as a blueprint, guiding what an institution collects and how it manages the acquisition, documentation, preservation, and utilization of its collections (ArbNet 2022, Gratzfeld 2016, President and Fellows of Harvard College 2022). "If no such policy is in place, collections can easily stray from their intended purposes" (Gratzfeld 2016). This policy ensures that the collections align with the institution's mission and goals, maintaining their relevance, meaning, and ethical integrity (Gratzfeld 2016, Hohn 2004, Smith College 2018).

The relationship between a collection and its policy is symbiotic. The policy provides the framework for developing and managing the collections and setting the standards and procedures for their care. Conversely, the collections are the tangible embodiment of the policy, each element reflecting and reinforcing the other (Hohn 2004).

COMMON COMPONENTS OF A COLLECTIONS POLICY

While reviewing collections policies from a range of arboreta, including the Arnold Arboretum, the Colorado State University Arboretum, the UC Davis Public Garden and Arboretum, and the "Curational Practices for Botanical Gardens" document, it's evident that the framework of a Collections Policy is often consistent, though not universally so. The specific structure, content, and details of these policies are customized to each institution's unique needs and objectives. Furthermore, the nature of these policies can vary significantly depending on the size and capacity of the arboretum, reflecting the diverse ways in which different institutions approach the management and care of their collections.

The following components have been identified as generally contained within a Collections Policy, although specific details may vary from one institution to another:

Introduction and Purpose

This section clarifies the policy's objective and scope, which is often to steer the development and upkeep of the plant collections.

Acquisitions

This section illustrates the requirements and procedures for obtaining new plants for the collections, including ethical and legal considerations.

Plant Records/Accessions

This section outlines the guidelines and techniques for maintaining accurate and comprehensive records of all plant materials in the collections, including database management and labeling.

Evaluations/Inventory

This section specifies the frequency and components of conducting an inventory of the collections, which involves evaluating the plants' condition, location, and identity.

Maintenance

This section defines the necessary maintenance operations and practices to protect and enhance the collections' health and beauty, such as pest control, fertilizing, pruning, and irrigation. Many arboreta have a separate plan for the care of the woody plants.

Deaccessioning/Disposal

This section explains the reasons and methods for removing plants from the collections, whether by transferring them to other parties or destroying them.

Access and Use

This section regulates and encourages the educational and research use of the collections by various groups, such as instructors, researchers, students, and visitors. It also prohibits the unauthorized introduction or collection of plants.

WOODY PLANT CARE AND MANAGEMENT

Arboreta are home to diverse trees and woody plants. Caring for them is crucial for their continued growth and survival. Proper care and management of woody plants in arboreta are necessary to preserve their biodiversity, ensure their survival and growth, and promote a healthy environment for visitors. Woody plant care generally involves pruning, watering, fertilizing, pest control, and protecting them from environmental stressors. Each of these plant care tasks contributes towards maintaining the health and vitality of the plants in the arboretum. Pruning involves the selective removal of branches or parts of a plant to promote healthy growth and improve its overall appearance. Watering and fertilizing are essential to provide the necessary nutrients and moisture for the plants to thrive. Pest control measures are implemented to prevent or control disease outbreaks and infestations that can negatively impact the overall health of the plants. Arboreta are often subject to environmental stressors such as extreme temperatures, wind, and drought. Therefore, it is essential to take protective measures to safeguard the plants from these factors. The level of management and care for arboreta can differ between institutions. Some university arboreta have established arboriculture management plans focusing on specific plant groups or the entire plant collection. Other arboreta have plans and guidelines to ensure that arboriculture tasks are properly considered and resourced, making it easier to predict and address any issues that may arise (Gratzfeld 2016).

RESEARCH

Arboretum research advances the understanding of plant diversity, ecology, evolution, and conservation. These living laboratories provide researchers access to various plant species from different regions and detailed records of their origin, cultivation, and phenology (Hetrick 2018, President and Fellows of Harvard College 2022). Researchers can use arboreta to study various aspects of plant biology, including genetics, physiology, morphology, development, interactions with other organisms, and responses to environmental changes. The range of research conducted by university arboreta has significantly expanded in recent times, encompassing fields such as conservation genetics, DNA barcoding, plant biochemistry, ethnobotany, seed biology, ecological restoration, and arboriculture science (Gratzfeld 2016, Hetrick 2018). University-affiliated arboreta are more likely to conduct direct research and provide higher education teaching than those affiliated with other institutions (Gratzfeld 2016). Despite the importance of research, it is not a given that every university arboretum supports research.

Recent arboretum research has provided valuable insights into various aspects of plant biology (Hetrick 2018). For instance, a molecular phylogenetic study of oaks at the UC Davis Arboretum revealed the evolutionary relationships among different species of this important genus (Murphy and Potter 2018). A study at the same Arboretum also explored the nectar-associated microbial communities within California fuchsia and other native plants and how these microbes affect plant-pollinator interactions and plant fitness (Russell and McFrederick 2022). Furthermore, another study at UC Davis Arboretum analyzed the nutritional composition of acorns of approximately 100 oak taxa to evaluate their horticultural potential as a commercial animal feed crop (Hetrick 2018). These studies highlight arboreta pivotal role as focal points for research and expanding knowledge in plant biology. In conclusion, the research conducted at arboreta can inform conservation strategies and management practices for preserving plant diversity and promoting sustainable use of plant resources, making them valuable resources for the scientific community (Hetrick 2018, President and Fellows of Harvard College 2022). Overall, arboreta are vital in advancing research, conservation, and education in plant biology.

EDUCATION & OUTREACH

Arboreta are noteworthy for their emphasis on education and outreach. These institutions offer a platform for individuals to learn about plant biodiversity, ecology, and the conservation of their habitats (Gratzfeld 2016). In addition, arboreta are engaged in education on various themes of plant science, including climate change, invasive species, pollination, and restoration (ArbNet n.d., President and Fellows of Harvard College, 2022). Arboreta contribute to education and outreach by engaging in citizen science initiatives such as monitoring plant phenology, collecting plant specimens, and reporting plant observations (Smith College 2018). By teaming up with state agencies, community institutions, and citizens, arboreta can share their knowledge and resources to achieve their goals.

Arboreta provide a range of educational and outreach programs tailored to different groups, including school groups, families, professionals, and the general public. Education and outreach at arboreta can take various forms, such as guided tours, workshops, lectures, demonstrations, exhibits, publications, online resources, citizen science projects, volunteer programs, and partnerships with schools and other organizations (UC Davis 2022, CSU 2020). Arboreta can also use social media platforms to engage with its audiences and share information about its activities, events, collections, and research (CSU 2020). Moreover, developing educational materials like tip books and brochures that simplify vital subjects and make learning enjoyable is a common approach. Another outreach strategy is hosting special events like festivals, exhibits, guided tours, and art shows that showcase plants' beauty and cultural significance. In addition, some arboreta donate fresh produce from their harvest gardens to local food banks and use gardens to inspire visitors to discover and learn (Hicks 2022). In conclusion, education and outreach at arboreta are essential for fulfilling their mission and vision and enhancing public value and relevance.

ARBNET ARBORETUM ACCREDITATION PROGRAM

In 2011, the Morton Arboretum established the ArbNet Arboretum Accreditation Program, the only arboreta accreditation program in the world. The program was established to facilitate an international, interactive community of arboreta towards a common goal of plant conservation, research, and education. Its goal is to unify the arboreta community and set professional standards for institutions in the field. Arboreta achievement levels are established in accordance with industry-recognized standards. The entire program is free of charge, and any arboretum or public garden that has a significant emphasis on woody plants is eligible to apply (ArbNet 2022).

ArbNet's mission is to promote the establishment and development of arboreta, identify those capable of participating in scientific, collection, or conservation activities, and advance the planting and preservation of woody plants. ArbNet offers helpful resources for improving arboreta operations, research, conservation, and education to fulfill this mission. It also provides arboretum-focused news and events, opportunities for collaboration with other arboreta in scientific, collection, and conservation activities, a broad network to support trees' planting, care, and conservation, and an online forum for tree discussions. Accredited arboreta are encouraged to become leaders and serve as models to promote professional development and engagement with other arboreta (ArbNet 2022).

Accreditation

Accreditation is granted based on a self-assessment and documentation of an arboretum's adherence to accreditation standards. Accreditation levels are granted based on the number of labeled woody plants, governance, strategic documents, education opportunities, research, and conservation efforts, and more. There are four levels of accreditation, with IV being the most accomplished. Each level is defined by a set of criteria that describe the degree of development, professionalism, capacity, and quality of the program. Accredited arboreta are encouraged to seek and achieve higher professional standards and progress through the levels (ArbNet 2022).

ACCREDITATION LEVELS (ArbNet 2022).
The text below refers to the accreditation requirements for Levels 1-4, as outlined in Table 2.1 and on the ArbNet Program website.

Level 1

Level I arboreta are sites with at least 25 labeled woody plants, a few staff or volunteers, and documentation that defines the arboretum purpose and audience(s), specifies plant types, outlines plant care, and establishes the organization's ongoing operation.

Level 2

Level II arboreta has at least 100 labeled woody plants, employs paid staff, and has enhanced public education programs and a documented collections policy.

Level 3

Level III arboreta have 500+ labeled woody plants, a collections curator, educational programming, collaborations, publicized collections, and participate in tree science and conservation.

Level 4

Arboreta, with Level IV accreditation, is the highest level. They have well-qualified tree scientists who publish advanced research, manage living tree collections for conservation purposes, and actively support tree conservation via the Global Trees Campaign. These arboreta are globally recognized as woody plant-focused institutions.

ArbNet Arboretum Accreditation Criteria

	Level I	Level II	Level III	Level IV
Arboretum Plan	•	•	•	•
Organizational or governance group	•	•	•	•
Labeled tree and woody plant taxa				
25+	•			
100+		•		
500+			•	•
Staff or volunteer support				
Volunteer or paid	•			
Paid Management		•	•	•
Curator			•	•
Scientific or conservation staff				•
Public dimension				
Public access and atleast one event per year	•	•	•	•
Enhanced public & educational program		•	•	•
Substantial educational programming			•	•
Collections policy		•	•	•
Collaboration with other arboreta			•	•
Collections data sharing with networked collections			•	•
Agenda for tree science, planting, and conservation			•	•
Collection conservation				•
Conservation role in Global Trees Campaign				•

Table 2.1 ArbNet accreditation criteria levels 1-4 (adapted from ArbNet 2022).

CHALLENGES FACING ARBORETA
Financial and Resources Challenges Arboreta Face

Arboreta possess the expertise and plant collections to advance woody plant findings significantly. However, they often encounter financial and resource challenges that significantly impact research efforts. Arboreta often face financial difficulties due to their limited or inconsistent cash flow. Managing their income and expenses can be challenging, particularly for those relying on seasonal or unpredictable revenue sources, such as donations, grants, or visitor fees. Additionally, arboreta have high fixed costs such as staff salaries, utilities, and maintenance, which makes it even more challenging to maintain a stable financial position. To overcome these challenges, arboreta can create a sensible budget, track their spending, diversify their income streams, and explore ways to reduce costs or increase efficiency.

Arboreta may also face the significant challenge of lacking resources to deal with unexpected situations like natural disasters, pest infestations, vandalism, or equipment malfunctions. To ensure that such issues do not disrupt the arboreta' operations, arboreta must take proactive measures, such as establishing an emergency fund and purchasing adequate insurance coverage. To secure more capital, arboreta must develop a clear and compelling vision, identify potential funding sources, cultivate relationships with stakeholders, and demonstrate their impact and value. These steps can help them to be prepared and avoid financial strains caused by unforeseen emergencies.



Figure 2.4 Storm damage to numerous trees on the north end of K-State's campus in 2022 (by author).

Climate Challenges Facing Arboreta

The impact of climate change on plant species is becoming more and more evident, and it is crucial that arboreta take action to prevent plant species extinctions (Gratzfeld 2016, Primack et al., 2021, Primack and Miller-Rushing 2009). In this regard, arboreta have a significant responsibility in addressing the challenges posed by climate change. Some of the climatic challenges facing Arboreta are plant diversity and management operations.

Climate change is expected to increase numerous plant species' extinction risk (Gratzfeld 2016, Primack et al. 2021, Primack and Miller-Rushing 2009). To address this issue, arboreta must find solutions to a variety of challenges. One challenge is monitoring and predicting plant species' phenological responses to climate change across different plant hardiness zones, heat zones, biomes, and continents. Another challenge is to evaluate the anatomical and functional traits associated with phenological responses to climate change. The third challenge is to preserve plant diversity and genetic resources while facing the challenges posed by climate change. Climate change may also affect the horticultural management, plant health and biosecurity, and environmental sustainability of botanic gardens (Primack et al. 2021, Primack and Miller-Rushing 2009). For example, climate change may alter arboreta' water availability, pest and disease pressure, and energy demand (Gratzfeld 2016, Primack et al. 2021).

Amidst the various challenges posed by climate change, arboreta can play a crucial role in raising public awareness about the impact of climate change on plants and ecosystems. Arboreta can effectively maximize their societal impact by educating the public about the effects of climate change and demonstrating sustainable practices to adapt to and mitigate its impact (Gratzfeld 2016, Primack et al. 2021).

KANSAS CLIMATE

Kansas has a varied climate. Based on the 1991 - 2020 normals, the amount of annual precipitation ranges from over 45 inches in the southeast to less than 18 inches in the southwest. This pattern is influenced by weather systems that move from the Gulf of Mexico (KSU n.d.). The annual snowfall in Kansas follows a gradient from northwest to southeast. The northwest region receives the highest snowfall of 28 to 42 inches, while the southeast region receives the lowest amounts of less than 12 inches. However, snowfall amounts may vary significantly yearly (KSU n.d.).

The annual mean temperature in Kansas follows a north-south pattern. The southern region experiences the warmest temperatures, averaging around 58 °F, while the northwest region experiences the coolest temperatures of less than 52 °F (KSU n.d.).

CLIMATE CHALLENGES FACING KANSAS

Drought and Heat

Drought is a decrease in precipitation over an extended period, typically a season or more, resulting in a water shortage that can adversely affect vegetation, animals, and people (Coder and Warnell 2009, NOAA 2018). Drought can develop relatively quickly and last a short period, exacerbated by extreme heat and wind, or span multiple years or even decades. It is important to distinguish drought from aridity, a permanent climate characteristic found in areas where low precipitation is the norm. Aridity refers to a permanent climate feature in regions that experience low precipitation regularly, while drought can be exacerbated by human activities like water usage and management in a given area (Coder and Warnell 2009, NOAA 2006, NOAA 2018).

A heat wave is a prolonged period of unusually high temperatures for a region, causing increased heat stress (Robinson 2001). Most plants grow best in temperatures ranging from 59°–86°F. When temperatures above 86°F are sustained for long periods, plant growth is slowed, and some plants may begin to show signs of stress (Matthews et al. 2018). Above 104°F, plants will show different signs of heat stress depending on plant type, plant maturity, and factors often associated with high temperatures, such as drought or wind (Esperon-Rodriguez et al. 2021, Gilles 2021).

Droughts and heat waves pose a significant threat to the trees of Kansas, impacting their growth and survival (Allen et al. 2015, Coder and Warnell 2009). Climate change may exacerbate this threat, leading to more frequent and intense droughts and heat waves (Allen et al. 2015, Coder and Warnell 2009, NOAA 2006, NOAA 2018).

Drought and heat stress cause various physiological and biochemical changes in woody plants. For instance, they can lead to reduced photosynthesis, the process by which trees convert light energy into chemical energy. Photosynthesis is sensitive to high temperatures and water deficits (Coder and Warnell 2009, Dutky 2006, Esperon-Rodriguez et al. 2021, Ghirardo et al. 2022). Another response of trees to heat and drought is the regulation of transpiration, the process by which trees lose water vapor through their leaves. Transpiration is essential for cooling the leaves and transporting nutrients. However, transpiration also exposes trees to water loss and dehydration (Coder and Warnell 2009, Ghirardo et al. 2022).

Heat and drought stress also affect nutrient uptake and allocation, the processes by which trees acquire and distribute essential elements for their metabolism. Nutrient uptake and allocation depend on water and energy availability, which are reduced during heat and drought stress. As a result, trees may experience nutrient deficiencies or imbalances, which can affect their growth and quality (Allen et al. 2015, Coder and Warnell 2009, Ghirardo et al. 2022).

The effects of drought on trees depend on several factors, such as the intensity, duration, and frequency of the water deficit, the tree species, the age and size of the tree, and the interactions with other environmental factors (Allen et al. 2015, Coder and Warnell 2009, Ghirardo et al. 2022). When trees experience water deficit, they may show symptoms such as yellowing or wilting of leaves, leaf scorch, early leaf drop, reduced shoot growth, and susceptibility to pests and diseases (Allen et al. 2015, Coder and Warnell 2009, Dutky 2006). In some cases, drought can also cause tree mortality (Allen et al. 2015, Coder and Warnell 2009, Esperon-Rodriguez et al. 2022). Heat and drought stress can significantly impact trees' physiological processes (Coder and Warnell 2009, Dutky 2006, Esperon-Rodriguez et al. 2021, Ghirardo et al. 2022). These impacts can affect trees' health, especially under the projected climate change scenarios described in Chapter 4. To cope with these challenges, Kansas must adopt more adaptive and resilient practices, such as diversifying woody plants, improving irrigation efficiency, and using drought-tolerant varieties.



Figure 2.5 Mature trees in the K-State B2 parking lot north of Haymaker Hall were severely damaged by high winds (by author).

Severe Storms and Flash Flooding

Another climatic challenge facing Kansas is the occurrence of severe thunderstorms that can produce large hail, high winds, and tornadoes. These storms, with their unpredictable behavior due to climate change, can cause injuries, fatalities, power outages, infrastructure damage, and the loss of trees. Kansas ranks among the top states regarding tornado frequency and intensity (EPA 2016, Li et al. 2022, NOAA 2023). Some studies suggest that climate change may lead to thunderstorms that are more violent in Kansas, while others indicate that there may be fewer but stronger storms (EPA 2016, Li et al. 2022).

Since the beginning of the 20th century, temperatures in KS have warmed by 1.5 degrees Fahrenheit (EPA 2016). The soil is becoming drier, rainstorms are becoming more intense, and floods are becoming more severe. Warming winters and changes in the timing and size of rainfall events have altered crop yields. In the coming decades, summers will likely become increasingly hot and dry, creating problems for agriculture and possibly human health (EPA 2016, Li et al. 2022). Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others (EPA 2016, Li et al. 2022, NOAA 2023).

Flash flooding is another climatic phenomenon that is becoming increasingly prevalent in Kansas due to the ongoing changes in the global climate (EPA 2016, KSU 2019, Li et al. 2022, NOAA 2023). These floods can develop within minutes or hours, depending on the intensity and duration of the rain, the topography, soil conditions, and ground cover (Li et al. 2022, NOAA 2023). They can roll boulders, tear out trees, destroy buildings and bridges, and scour new channels (NOAA 2023). In Kansas, heavy rains have caused localized flooding in some areas, leading to the immediate destabilization of trees and the deposition of significant amounts of silt on the root system. This not only affects the stability of the trees but also their overall health and longevity (KSU 2019, NOAA 2023).

Future climate simulations predict an increase in the occurrence of flash floods across most of the United States, including Kansas. The Central US, where Kansas is located, will likely see an 8.6% predicted increase in flash flooding (EPA 2016, Li et al. 2022). The impact of these flash floods on trees is particularly concerning. Flash floods can cause rapid soil erosion, leading to the destabilization of trees (KSU 2019). Additionally, the deposition of significant amounts of silt on the root system can affect the nutrient absorption capacity of the trees, potentially leading to stunted growth or even tree death (KSU 2019). This increase in flash floods significantly threatens the state's infrastructure, economy, and natural ecosystems (EPA 2016, Kloesel et al. 2018, KSU 2019, Li et al. 2022).

CURRENT PESTS AND DISEASE THREATS IN KANSAS

Trees will face a rise in pest and disease problems in future climates (McDowell and Allen 2015, Rennenberg et al. 2006, Usman et al. 2021). Rising temperatures will lead to a geographic expansion of pathogen and vector distributions, thereby increasing the number of potential hosts (McDowell and Allen 2015). Pathogen and pest evolution may also be more rapid and overcome the resistance of plants. Entomologists predict that a continual increase in temperature may contribute to rapid growth, development, and survival, and extend the distribution ranges of pests (Usman et al. 2021). Trees need water to produce food, fight off pests, and heal from injuries (Rennenberg et al. 2006). The increase in drought and heat waves weakens trees making them more vulnerable to pest infestations (Allen et al. 2015, Ghirardo et al. 2022, Rennenberg et al. 2006). Some pests, such as borers that tunnel into the inner bark and outer wood of trees, can cause more damage in dry years than in wet years (Rennenberg et al. 2006, Coder and Warnell 2009). Drought also affects the pest populations, as some pests may thrive or decline under high temperatures and low moisture conditions (Coder and Warnell 2009). Below, some of the current and future pests and diseases threats of trees in Kansas are described.



Figure 2.6 The following Kansas counties have reported the presence of Emerald Ash Borer as of 2022 and are highlighted in green (by author).

Emerald Ash Borer

The Emerald Ash Borer (EAB) is an exotic invasive beetle from northeastern Asia and eastern Russia that was brought into the United States in infested packing material. (Kansas State University 2018). This beetle threatens urban and riparian forests by killing North American ash species (*Fraxinus* sp.) and their cultivars. At least 70 million ash trees have already been destroyed due to the EAB, and it estimated that the nearly 9 billion North American ash trees will eventually be functionally eliminated from the continent. The Emerald Ash Borer (*Agrilus planipennis* Fairmaire) was first discovered in the North America, in Michigan and Ontario in 2002 and has expanded further into Canada and from the Midwest to the eastern part of the United States (Kansas State University 2018). The borer has now been identified in at least 24 states, including Kansas in 2012. The EAB has now been found in 12 Kansas counties; Wyandotte (2012), Johnson (2013), Leavenworth (2014), Douglas (2015), Jefferson (2015), Atchinson (2016), Doniphan (2017), Shawnee (2017), Miami (2019), Jackson (2019), Osage (2022), and Brown (2022) (Kansas Forest Service 2022).

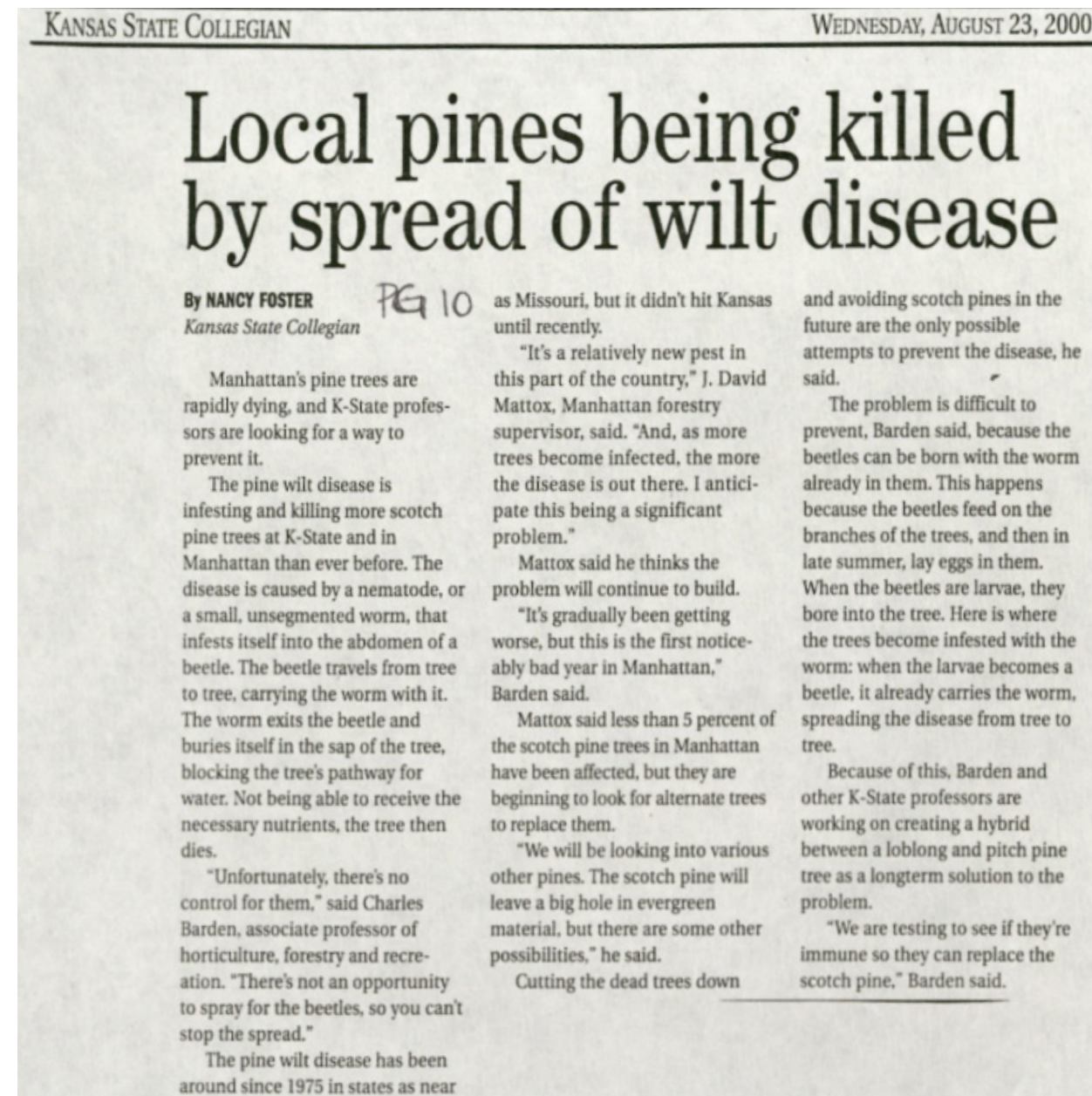


Figure 2.7 Kansas State Collegian article from August 2000 reports the spread of wilt disease killing pine trees on the K-State campus and across the city of Manhattan, Kansas (Kansas State Collegian 2000).

Pine Wilt

Pine Wilt is caused by the pinewood nematode but is transmitted from tree to tree by the pine sawyer beetle. The disease has caused extensive damage and losses to exotic pine species in the Midwest, Great Plains and especially Scotch Pines and on the Kansas State University main campus (Kansas Forest Service 2022).

Dutch Elm Disease

Dutch elm disease (DED) is a systemic vascular wilt disease of elm (*Ulmus* spp.) caused by two closely related fungi, which are spread by bark beetles and through root grafts. The fungi have been spreading across North America since the 1920s, and it made its way to Kansas in 1957 killing most of the native elm trees in the United States over the past century (Kansas Forest Service 2022).

Oak Wilt

Oak wilt is a mortal disease caused by a fungal pathogen. The oak wilt fungus is spread from diseased oaks to healthy ones through aboveground transmission by insect vectors or through connected root systems. This disease is found throughout the eastern and central U.S and more than 33 species of oaks are known to be susceptible (USDA 2016).

EMERGING PESTS & DISEASE THREATS IN KANSAS

Thousand Cankers Disease of Walnut

“Thousand cankers disease (TCD) is caused by a combination of a fungus (*Geosmithia morbida*) and the walnut twig beetle (*Pityophthorus juglandis*)” (Kansas Forest Service 2022). Black walnut (*Juglans nigra*) is native to the eastern Great Plains and has been widely planted throughout the region. The disease now threatens black walnuts throughout the Great Plains (USDA 2016). According to the Kansas State Forest Service, Black walnut (*Juglans nigra*), is the most valuable native species to the state and is the most susceptible of the *Juglans* species to this disease (Kansas Forest Service 2022).

Asian Longhorned Beetle

The Asian longhorned beetle (ALB) is an exotic insect that is a major threat to America's hardwood trees. There is no current cure, therefore early identification and eradication are critical to its control. The ALB currently infests areas in Massachusetts, New York and Ohio. If this pest were to become established in the US it would become one of the most destructive and costly pests threatening industry, forest and neighborhood resources valued at billions of dollars (USDA 2022). It is suspected that the Asian Longhorned Beetle (*Anoplophora glabripennis*) arrived in the U.S. via wood packing material from Asia (Kansas Forest Service 2022). “The ALB has the potential to cause more damage than Dutch elm disease, chestnut blight and gypsy moths combined, destroying millions of acres of America's treasured hardwoods” (USDA 2022). This beetle feeds on a wide variety of hardwood tree species that are native or planted in Kansas, becoming a significant threat to its trees.

Asian Gypsy Moth

The Asian Gypsy Moths (AGM) are exotic pests first detected in Washington in 1991. Ongoing and completed eradication of various sites in the U.S. has so far prevented the establishment of this generalist feeder. In the US, ongoing and completed site eradications have prevented the major establishment of the moth AGM. The AGM is largely destructive due to its broad range of hosts, and the female moths are active fliers (Kansas Forest Service 2022).

Sudden Oak Death

Sudden Oak Death (SOD) is caused by *Phytophthora ramorum*, a water mold pathogen. SOD was first detected in the San Francisco Bay Area in the mid-1990s (USDA 2022). The SOD pathogen is considered especially dangerous because it affects a wide variety of woody species and there is currently no known cure. The pathogen has killed millions of tanoaks and coast live oak trees along the central California coast into the southern part of Oregon (USDA 2022). In June of 2019, the water mold pathogen of SOD was detected in plants that originated from Park Hill Plants Nursery in Oklahoma, and plants from that nursery were shipped to 60 Walmart stores across Kansas (Kansas Forest Service 2022).

KANSAS STATE UNIVERSITY

Kansas State University (KSU) is a public research university in Manhattan, Kansas, serving students, Kansas, the nation, and the world. Established in 1863, KSU is recognized as the first land-grant institution in the United States under the Morrill Act (KSU 2008). The university, with its agricultural and research facilities, stretches across over 2,320 acres. Of this, the main campus occupies an area of approximately 664 acres (Vireo and Ayers Saint Gross 2012).



Figure 2.8 This Eastern Redcedar was originally planted as part of the fence line on the original farmland that became KSU (by author).



Figure 2.9 shows the city of Manhattan, Kansas, within Riley County, where Kansas State University is located (by author).

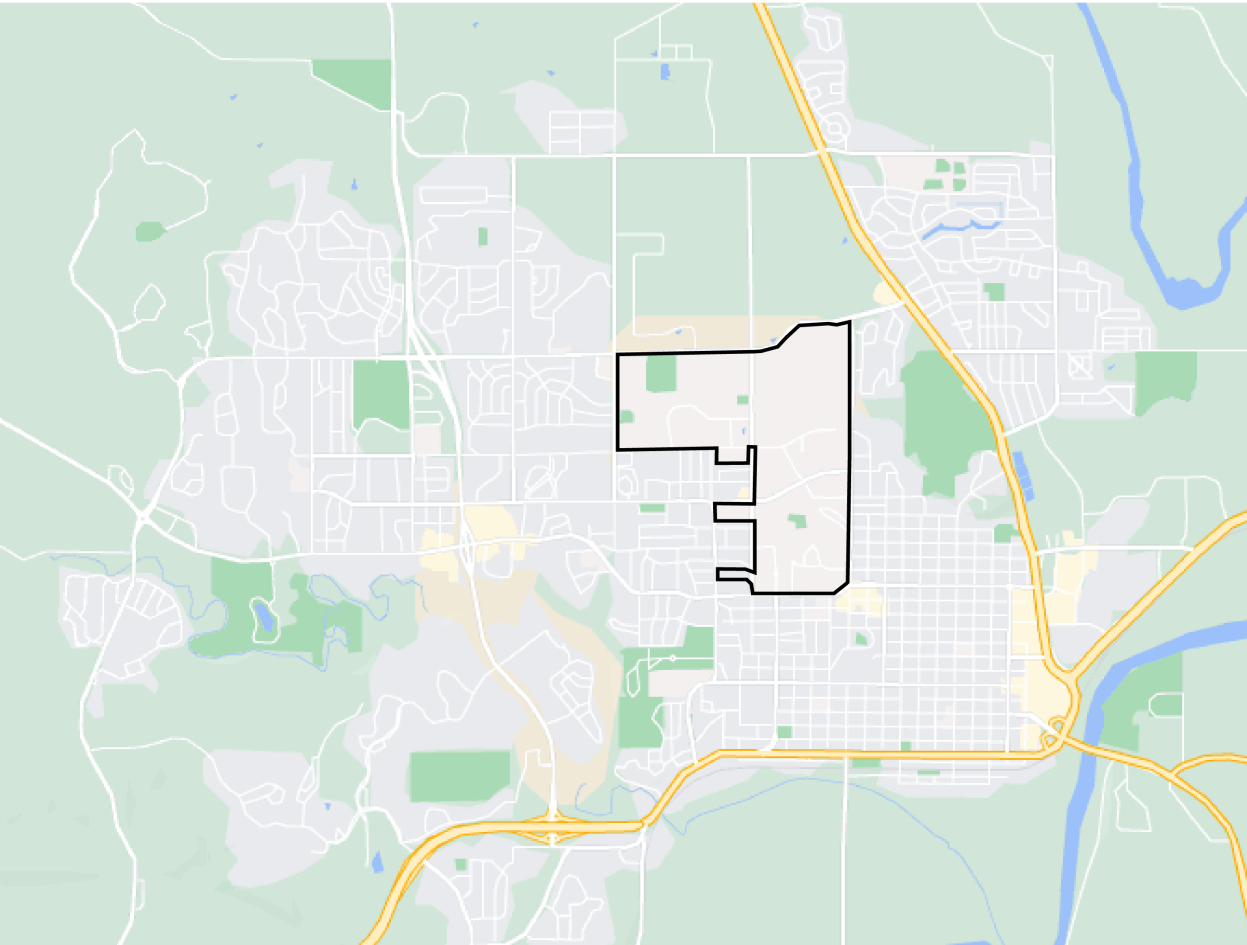


Figure 2.10 Map of the developed urban area of Manhattan, Kansas, showing the K-State University campus outlined in black(Snazzy Maps 2023).

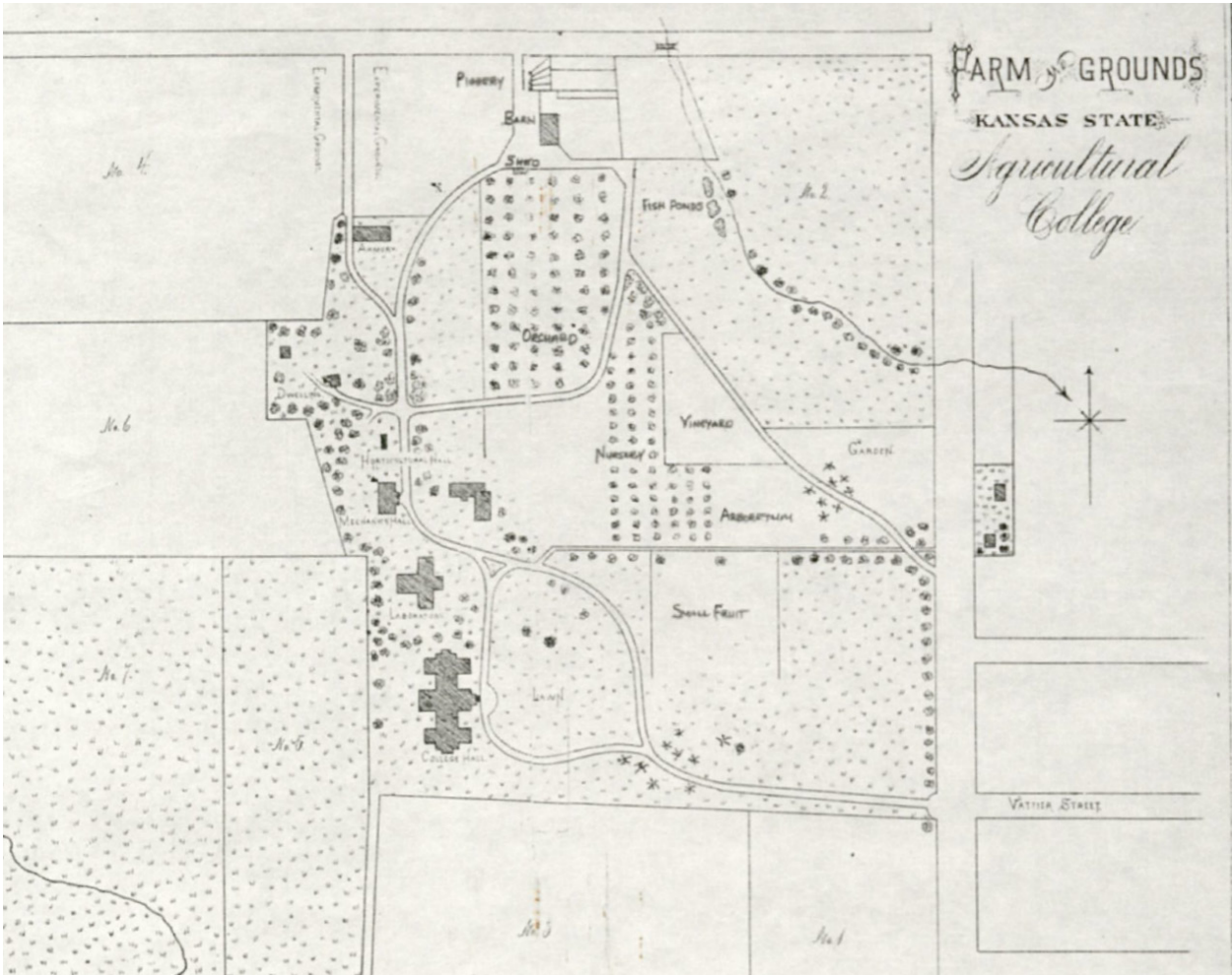


Figure 2.11 Plan of the Farm and Grounds of Kansas State University a Report of the Professor of Agriculture Experiments 1883-1885. This early plan of the K-State University shows what was once the site of the K-State Campus Arboretum (Kansas State University Hale Library Special Collections 1885).

HISTORY OF THE KANSAS STATE UNIVERSITY ARBORETUM

For several decades, the K-State campus was renowned for its stunning landscape, which once boasted over 700 different species of woody plants (K-Stater 1989). Under the leadership of Reverend Elbridge Gale (1870-1879), Professor E. A. Popenoe (1879-1895), and Professor L. R. Quinlan (1927-1963), the campus was transformed into an arboretum (KSU Arboretum n.d.). As a result of their efforts, a number of oaks, maple, walnut, pine, and ash tree groves were planted in Kansas to serve as a source of lumber and firewood. In addition, fruit trees and grapevines were planted to cover the plains with orchards. Moreover, seed-bearing plants were sown to attract birds and create a bird sanctuary (KSU Arboretum n.d.).



Figure 2.12 The content of the only document held in the Hale Library archives' Arboretum Vertical Files that is dedicated solely to describing Kansas State University as a Campus Arboretum (KSU Arboretum n.d.).

The arboretum is believed to have been established with the arrival of over 100 species of hardy, exotic trees and shrubs from the Arnold Arboretum of Harvard University (Mercury 1985, The Manhattan Mercury 1984). It flourished under Professor. L.R. Quinlan, an Arnold Arboretum-trained expert with an M.L.A. degree from Harvard University (Mercury 1985). "He kept detailed records of 4,000 campus trees, established a shrub collection of 358 species, and cultivars, and an evergreen collection of over 90 accessions" (Mercury 1985).

The arboretum, which contained an extensive collection of trees and shrubs, boasted the state's most extensive variety of such plants. Selected plants were labeled for public display, making the college landscape an excellent way to educate students and the public about woody plants (Brokesh 2019). At its peak, the campus arboretum contained 4,000 specimens representing 700 species of trees and shrubs, according to the accounts of Frank Gibbons, assistant professor of horticulture at K-State (The Manhattan Mercury 1984). In fact, at one point, it was considered one of the finest arboretum campuses in the Midwest (The Manhattan Mercury 1984).



Figure 2.13 An article from 1984 in the Manhattan Mercury described KSU's campus as one of the best arboretum campuses in the Midwest (The Manhattan Mercury 1984).

A Proposed Vision to Restore the Arboretum

In the mid-20th century, the number of tree and shrub species diminished due to the expansion of buildings, roads, and paths (The Manhattan Mercury 1984). With only 225 species left and a large number of older trees nearing the end of their life cycles on the K-State campus, University administrators and supporters found it essential and urgent to invest in the replacement and revitalization of the campus arboretum to restore and enrich the legacy of K-State's beautiful campus (K-Stater 1989). "These numbers have dwindled to approximately 225 species due to the many new buildings, parking lots, and sidewalks that have been added to the campus, Gibbons said" (The Manhattan Mercury 1984).

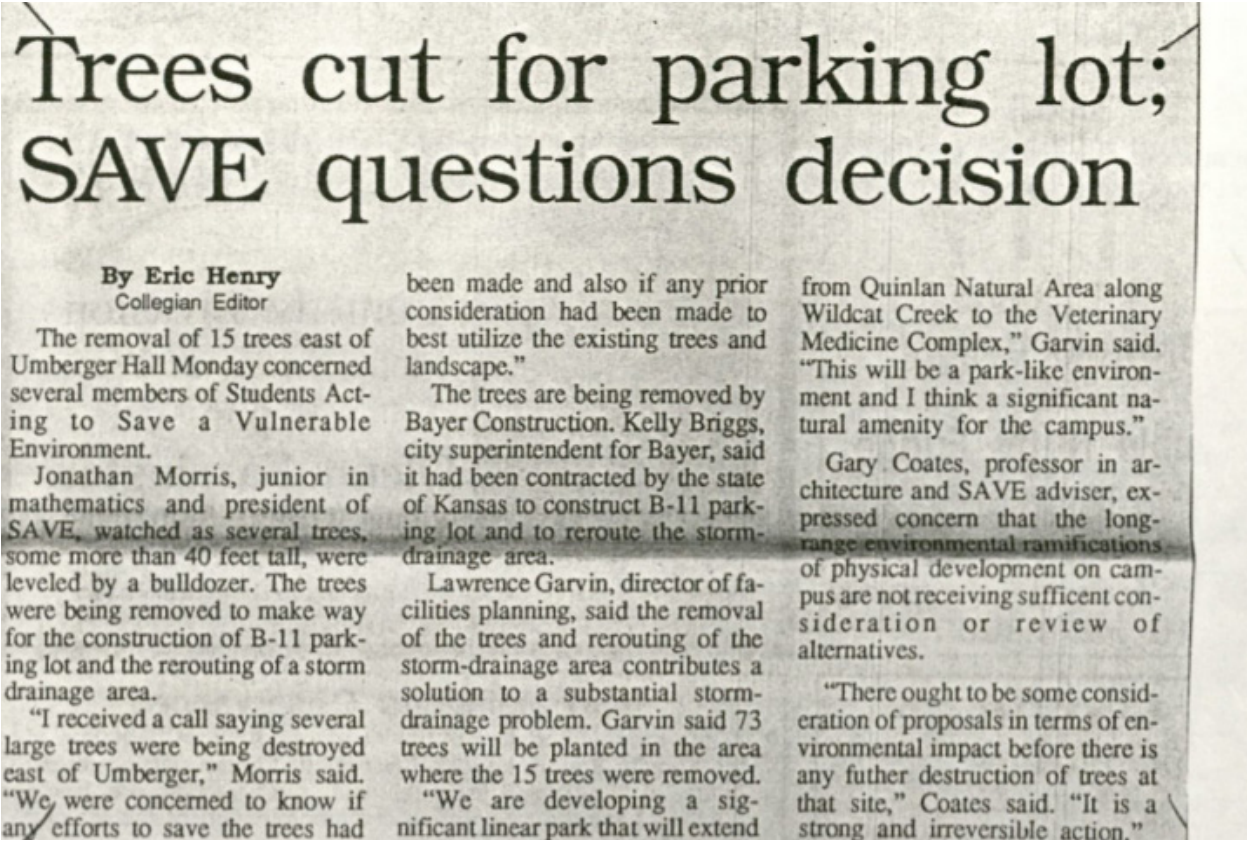


Figure 2.14 According to a 1990 Collegian article, the removal of 15 trees for a parking lot sparked concerns about environmental impact and the potential destruction of more trees on campus (Collegian 1990).



Figure 2.15 The KSU Arboretum was at its prime under Prof. Quinlan's leadership, but new constructions and parking lots threatened its survival (Mercury 1985).



Figure 2.16 In 1989, an article warned about the potential loss of diversity in K-State's campus arboretum. To address this, a \$5.8 million project was proposed to restore and enrich the campus landscape with new woody plants (K-Stater 1989).

In an effort to renew the campus arboretum, contributions were being accepted at one point in time. The goal of the \$5.8 million fund-raising drive was to restore the campus arboretum through private donations (KSU Arboretum n.d.). The proposed Campus Beautification-Reforestation Project, which was part of the long-range plan, included six major tree planting areas at campus entrances and on-campus locations, as well as a campus perimeter buffer of trees. This project called for about 4,500 woody plants (K-Stater 1989). The allocated funds were intended to purchase trees that would enhance the educational programs and the aesthetics of the campus. However, it remains unknown as to how these funds were utilized. The plan aimed to triple the number of tree species, increase the number of flowering and showy trees, and create a better environment for the bird sanctuary (KSU Arboretum n.d.). To revitalize the campus arboretum with new trees and shrubs, hundreds of plantings were required (KSU Arboretum n.d.).



Figure 2.17 Shows a cavity in an Eastern Red Cedar tree filled with concrete. While this was once thought to stop decay and support the tree, experts now advise against filling cavities unless necessary. These concerted efforts were made to preserve and protect the K-State campus trees (by author).

KANSAS STATE UNIVERSITY CURRENT TREE INITIATIVES

Kansas State University is committed to maintaining and enhancing the trees on campus. These trees provide various benefits to the university community and the surrounding area. They not only improve the aesthetic appeal but also help to enhance air quality, reduce energy consumption, and provide habitat for wildlife. The Department of Grounds Maintenance, with the help of volunteers and donors, takes care of maintaining these trees. The university also organizes various tree-related events and activities, such as tree tours, tree plantings, tree care workshops, and Arbor Day celebrations.

Campus Tree Walk

The Kansas State University Campus Tree Walk is a self-guided tour that allows visitors to explore diverse and beautiful trees. The tour covers about 1.5 miles and includes 100 trees, some predating 1875. The tour also provides historical and botanical information about the trees and the campus. The Campus Tree Walk was created to showcase the results of agricultural research and landscape design conducted at the university since its founding in 1863. The campus was originally a barren site with few native trees, has been transformed, and now holds thousands of trees planted for various purposes, such as windbreaks and ornamental landscaping. The Campus Tree Walk is a great opportunity to learn about the trees that grow in Kansas and how they contribute to the beauty and ecology of the campus. The tour can be done at any time of the year, but it is especially enjoyable in spring when many of the trees are in bloom or in fall when the leaves change color (KSU 2011).



Figure 2.18 Shows the Austrian Pine that is number 11 in the self guided campus tree walk. This tree was transported by horse and sled and replanted during winter in 1882 (by author).

Tree Campus Higher Education

The Tree Campus Higher Education program, established by the Arbor Day Foundation, is designed to acknowledge, and recognize colleges and universities for their efforts in promoting effective urban forest management practices and encouraging student involvement in pursuing tree campus goals. Kansas State University's Manhattan campus has been recognized as a Tree Campus by the Arbor Day Foundation since 2013 for its commitment to urban forestry and environmental stewardship. The university has met the five core recognition standards: maintaining a tree advisory committee, having a campus tree-care plan, dedicating annual expenditures for its campus tree program, hosting an Arbor Day observance, and having a student service-learning project. The Tree Campus program aims to inspire students to become better stewards of the environment and create a healthier planet for us all (Arbor Day Foundation n.d.).

Arbor Day Observation

Arbor Day is a special day to celebrate and promote the planting and care of trees. Arbor Day is celebrated in Kansas on the last Friday of April each year. As part of the Arbor Day celebration, K-State's students plant new trees yearly. In 2023, KSU planted four trees: a Sawtooth Oak for President Richard and First Lady Sally Linton near Eisenhower Hall; a Zig-Zag Redbud on the south lawn of Dykstra Hall; a Tulip tree on the back lawn of the President's Residence; and a Wildfire Black Gum on the south lawn area of Hale Library. They hosted a tree educational display table and demonstrated tree climbing techniques in the Water Hall's quad. Activities such as Arbor Day show K-State's commitment to enhancing the beauty and canopy of its campus landscape and educating its students and community about the benefits and challenges of urban forestry. Arbor Day is an excellent opportunity to appreciate and protect the trees that enrich our lives and environment (Lavis 2023).

KSU Emerald Ash Borer Readiness and Response Plan

The Emerald ash borer response plan for Kansas State University is a document that outlines the strategies and actions to deal with the threat of the emerald ash borer (EAB). This invasive insect kills ash trees by feeding on their inner bark. The plan aims to reduce the EAB's ecological, economic, and aesthetic impacts on the university's campuses and properties, with 251 ash trees on the KSU Manhattan campus. The plan proposes a five-year ash management strategy that includes removing dead and poor trees and trees in poor locations; treating notable and historic trees and other good condition trees with insecticides; planting new trees to replace the removed ones; using solid ash logs for campus construction or instruction; and communicating with the university community about the EAB issue. The plan is based on the best-known science of the time. It seeks to minimize the cost and liability for the university while protecting people from hazardous trees and maintaining the beauty of the campus landscape (Bomberger and Kansas Forest Service 2018).



Figure 2.19 In 2022, students planted three trees donated by the Rotary Club on the west side of McCain on April 29, Arbor Day in Kansas. Students also discussed and demonstrated proper tree planting, guided by Dr. Catherine Lavis (Canfield 2022).

CHAPTER 3
METHODOLOGY



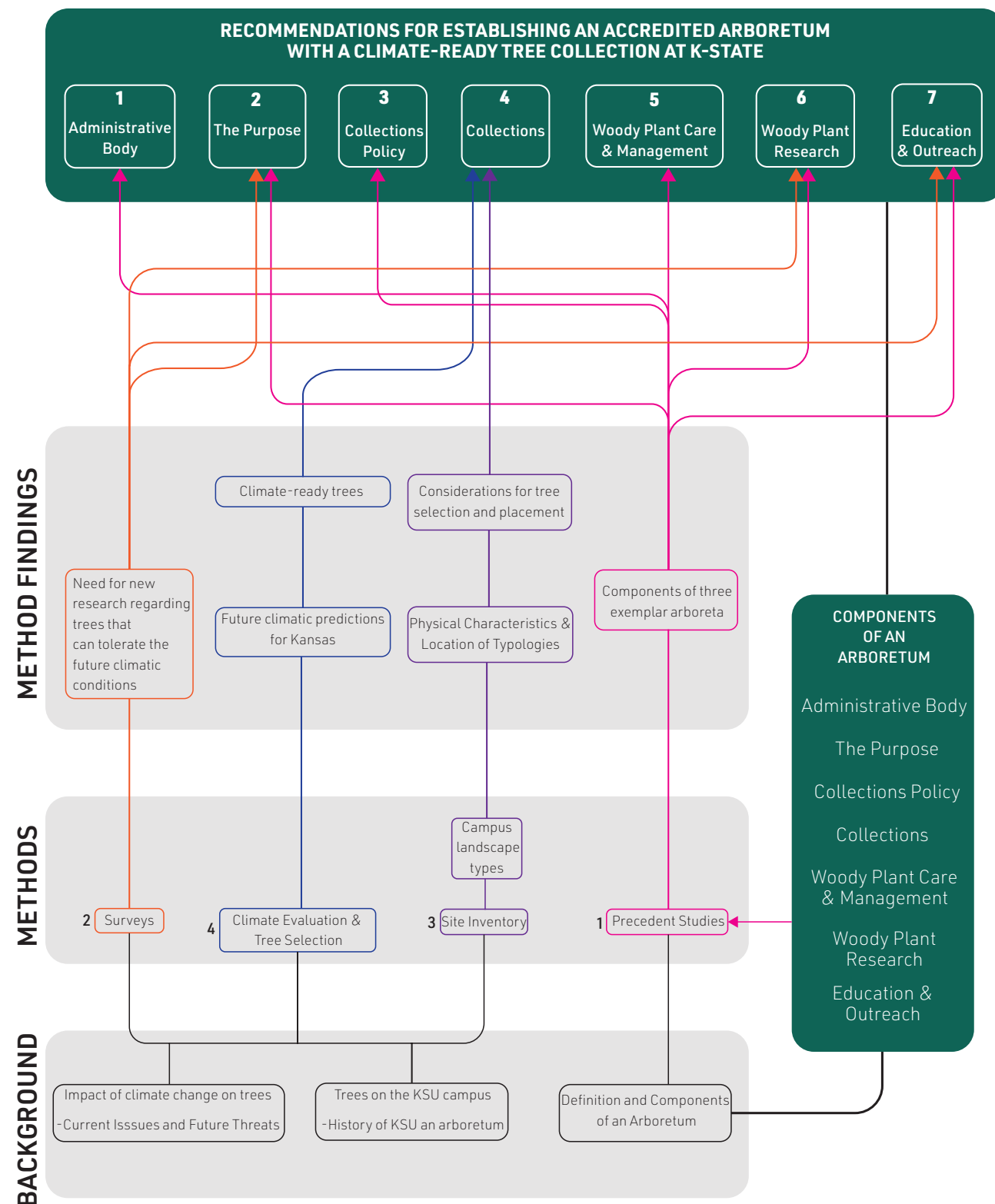


Figure 3.1 Project Research Methodology Process (by author).

METHODOLOGY

To answer the research question: How can Kansas State University develop an accredited arboretum with a dedicated “climate-ready” tree collection to demonstrate the viability of species most suitable for Kansas’s changing climate? This research project employed a mixed-methods approach, encompassing surveys of subject matter experts, precedent studies of notable university arboreta, climate evaluation of current and future conditions, a site inventory of K-State campus landscape typologies, and a tree species selection method for selecting climate-ready trees for a collection tailored to Kansas's anticipated end-of-century climatic projections.

The research findings informed recommendations for establishing the necessary arboretum components for an accredited arboretum at K-State with a specialized climate-ready collection. These include an administrative body, a mission, collections, collections policy, tree care management practices, research pursuits, and educational outreach initiatives.

1. PRECEDENT STUDIES

Purpose

Precedent studies of exemplary University arboreta were conducted to understand the components of university arboreta. Three were chosen for the precedent study after a preliminary review of 96 arboreta associated with higher education institutions. The three were chosen because they possess the necessary arboretum components with qualities and practices that could apply to establishing a notable accredited arboretum at K-State.

PRECEDENTS

1. COLORADO STATE UNIVERSITY ARBORETUM

Location: Fort Collins, CO

Description: The Colorado State University (CSU) Campus Arboretum embodies CSU’s land-grant heritage and mission by offering an engaging learning laboratory environment for students, employees, and community visitors. The arboretum manages approximately 10,000 trees, diverse in age, class, and species, distributed over three campuses, comprising 2,400 acres of land (CSU 2022).

2. THE UNIVERSITY OF CALIFORNIA DAVIS ARBORETUM & PUBLIC GARDEN

Location: Davis, CA

Description: The land-grant University of California at Davis (UC Davis) Arboretum was founded in 1936 to support teaching and research at the University. The Arboretum occupies 96-acres displaying collections that include over 22,000 trees and plants that grow and thrive in California’s Central Valley, where extreme summer heat, drying winds, heavy soils, and often poor water quality pose challenges (ArbNet n.d., UC Davis Arboretum 2022). The Arboretum is the main source of horticultural information for inland California and is a leader in proactive educational tree programs and activities for students and communities.

3. ARNOLD ARBORETUM OF HARVARD UNIVERSITY

Location: Boston, MA

Description: The Arnold Arboretum of Harvard University living collections account for 15,000 accessioned plants, representing almost 4,000 unique taxa that include 2,100 species (President and Fellows of Harvard College 2022). The living collection does not only support the Arnold Arboretum’s mission by serving key research, education, and conservation roles, but in its entirety represents one of the very best examples of arboretums in the world (President and Fellows of Harvard College 2022).

Process

The three precedents selected were studied in terms of the components of an arboretum noted below. A review of documents from various sources was conducted for each arboretum component. These documents included tree care plans, site plans, collection policies, research publications, landscape management plans, and horticulture documents. Web blogs and arbNet application forms were also utilized. To obtain in-house documents and information, a representative of the arbNet program was contacted for guidance and referrals.

Components of an Arboretum

Background

- 1) Administrative Body
- 2) The Purpose
- 3) Collection Policy
- 4) Woody Plant Care & Management
- 5) Collection(s)
- 6) Woody Plant Research
- 7) Education & Outreach

The results of each component of the arboretum were summarized, and the main takeaways were extracted to create recommendations for the components of an arboretum at K-State.

2.SURVEYS

Purpose

A survey of subject matter experts, professionals from the Kansas Forest Service, was used to gain insight into the current state of forestry/trees in Kansas. Specifically,

- What current threats/issues related to trees are experts observing in their service area
- What future threats/issues do experts foresee occurring in their service area
- What common issues/concerns does the public have about trees
- What research related to trees in Kansas is lacking/ needed to better inform future planting

These professionals were chosen because they serve citizens of the state, communities, and arboriculture industries through training, education, technical assistance, and management of trees.

Survey Design

Survey subjects were identified through the Kansas State Forest website, which in 2022 listed eleven individuals with the titles of Community and Rural Foresters. Thus, these individuals were considered subject matter experts in forestry and trees within Kansas.

The survey questionnaire included five open-ended questions.

Questions

1. Within the area you serve, what are the most significant threats/issues related to trees that you are currently seeing?
2. What future threats/issues do you foresee for trees in your service area?
3. What are the most common issues/concerns that the public reaches out to you for, regarding trees?
4. What future research on trees in Kansas do you believe is needed to provide better information to the public in next century?
5. Is there anything else, regarding trees in Kansas, that would be helpful for me to know?

A description of the study and questionnaire was emailed to all eleven Kansas State Forest Service Foresters. They were requested to reply to the email and answer the open-ended questions within 3 weeks. Follow-up emails were sent to those who had not responded after the first deadline. In total, four individuals completed the questionnaire, which is a 36% response rate.

3. SITE INVENTORY

Purpose

The site inventory's purpose was to identify key factors within each campus landscape typology that could inform the future species selection and placement of new trees within each typology.

LANDSCAPE TYPOLOGIES

The landscape typologies from the 2012 KSU Landscape Guidelines document used in this project were quadrangles, campus green, plazas, surface parking, and the campus corridor. The document presents several typologies, but only five were considered as they make up most of the arboretum site for this project.

- Quadrangles
- Plazas
- Campus Green
- Campus Corridor
- Surface Parking

What was created and compiled?

- A color-coded map inventory of the campus landscape typologies.
- A written description of the physical characteristics of the five landscape typologies specific to K-State’s campus.
- Photographs of the five landscape typologies were collected to understand their physical characteristics.

How was it compiled?

The map inventory of the landscape typologies was compiled using a Google Earth aerial image and was color-coded using Adobe Illustrator. The photographs of the five landscape typologies were documented through on-site visits using a camera to capture the physical characteristics. The written description was through documenting the physical characteristics of each typology. The physical characteristics of each typology specific to K-State were documented in writing through on-site visits and referencing the map inventory and site pictures.

How was it analyzed?

The site photos, inventory map, and physical characteristics descriptions were used to develop considerations for tree placement and selection specific to each of the five landscape typologies.

4. CLIMATE EVALUATION

Purpose

This climate evaluation examined recent and projected variables related to tree growth and survival across the United States to understand the implications for Kansas by the end of the century and to identify regions that recently exhibit the climatic projections for Kansas. By identifying regions with recent similar climatic conditions, informed decisions can be made regarding the selection of tree species suited for Kansas’ future.

What was collected?

Recent and projected maps of change throughout the century for the conterminous United States for plant hardiness zones, heat zones, and growing degree days were collected. Each pair of maps presented in Chapter Four compares recent conditions (1980-2009) to potential conditions under a scenario of high greenhouse gas emissions at the end of the century (2070-2099, RCP 8.5; high level of emissions over the next several decades). The high emissions scenario was chosen because of the dramatic projections for fossil fuel consumption in the world’s developing economies and the unlikelihood of policy mechanisms controlling greenhouse gas (GHG) emissions (Matthews et al. 2018).

How was it collected?

These maps were retrieved via the ArcGIS Story Maps Application Tool developed by The USDA Forest Service Office of Sustainability and Climate. Additional climate data was collected from the report: Assessing Potential Climate Change Pressures Across The Conterminous United States: Mapping Plant Hardiness Zones, Heat Zones, Growing Degree Days, And Cumulative Drought Severity Throughout This Century by Stephen Matthews, Louis Iverson, Matthew Peters, and Anantha Prasad (Matthews et al. 2018).

Why was it collected?

Climatic information on plant hardiness zones, growing degree days, and heat zones was collected because these variables directly impact tree growth and survival. By examining the recent and projected data maps across the United States, regions with recent similar climatic conditions can be identified to understand the implications for Kansas, enabling informed decisions regarding tree selection.

Plant hardiness zones (PHZs) can indicate the extent of winter stress that plants experience due to cold temperatures. These zones are based on the average annual extreme minimum temperatures, and this information is used to evaluate the cold hardiness of plants (Climate 2022). The value in these maps is the absolute minimum temperature achieved for each year and reported as the 30-year mean. Due to their cold tolerance, hardiness zones reflect the range limits of many plant species, including woody ones. The warming temperatures in the future will cause zonal variations that can be useful in identifying niche constraints and the range potential of plant species (Matthews et al. 2018). The maps in Chapter Four delineate plant hardiness zones and subzones according to the USDA definitions, which break the geography into zones by 10 °F (5.56 °C) increments from zone 1 (-55 to -45.6 °C) to zone 13 (15.7 to 22 °C) of annual extreme minimum temperature (Matthews et al. 2018). To determine the coldest day of the year, researchers identified the daily minimum temperature from July 1 to June 30, with the nominal year assigned to the first six months (Matthews et al. 2018).

Heat zones: The distribution of potential heat stress for plants is mapped using heat zones. Heat zones map the number of days with a maximum daily temperature greater than ≥86°F. This metric only indicates changes in "hot" conditions, as each plant species has unique adaptations to tolerate various conditions. Each year, the number of days surpassing the 86°F threshold is tallied and summed, and the mean number of days per year is reported for 30 years (Matthews et al. 2018). The ≥86°F value is a general temperature threshold at which photosynthesis can be negatively affected for trees (Matthews et al. 2018, Rennenberg et al. 2006). Extended periods of high temperatures above these thresholds, particularly when accompanied by prolonged dry conditions, can cause decreased tree performance and mortality (Allen et al. 2015, Matthews et al. 2018).

(GDD): Growing degree days describe the season available for plant growth and development based on temperature accumulation. This metric measures the accumulation of growing degree days at or above 41 °F (5 °C), as growth is limited below 41 °F (Matthews et al. 2018).

How was it analyzed?

The three maps displaying the predicted conditions for Kansas in the current regions of the US were superimposed. The maps were analyzed by examining the overlaid conditions to determine regions where all three climatic factors were recently displayed simultaneously to research the coinciding regions for potential climate-ready trees for KS.

TREE SPECIES SELECTION

Purpose

A Climate-Ready Tree Collection is a curated assortment of species that demonstrate exceptional adaptability to current climatic conditions, particularly those exhibiting drought tolerance and heat resistance. These trees are not only adapted to the present climate but are also expected to flourish under future climatic projections due to their inherent traits, such as drought tolerance and heat resistance, which favor survival and growth in changing environmental conditions.

This method sought to select tree species for a Climate-Ready Tree Collection specifically tailored to the state of Kansas. It comprises tree species that are well-adapted to Kansas's current climate and those anticipated to withstand its future climatic conditions. These future conditions include shifts in hardiness zones and heat zones, the prevalence of drought, and an increase in growing degree days, which suggests a greater number of hotter days per year than currently experienced.

After the proposed list of climate-ready trees was completed, the trees were assigned into five palettes, one for each of the KSU landscape typologies, using the considerations for tree selection and placement from the site inventory.

Process

STEP 1: SELECTION OF TREE LISTS

After a background search of notable lists of drought-tolerant trees from Kansas and Texas, the states identified in the climate evaluation, the K-State Drought Tolerant Trees for South-Central Kansas and the Texas Tree Trial database were selected to compile a list of climate-ready trees suited for Kansas's end-of-century climatic projections. The two lists were chosen because they each possess trees with notable attributes, such as drought tolerance, heat resistance, and compatibility with Kansas's recent and projected hardiness zones for Kansas.

The K-State Drought-Tolerant Trees for South-Central Kansas

The K-State Drought-Tolerant Trees for South-Central Kansas list publicized in 2015, is a valuable resource for selection for Kansas. This list was created by horticulturists at the K-State John C. Pair Horticultural Center, who have evaluated trees and shrubs in south-central Kansas for over 40 years. The list was selected because it includes 72 trees that have proven themselves to survive in south-central Kansas with only natural precipitation. These species have natural protection from ordinary seasonal drought, and some can withstand severe, prolonged drought conditions. By choosing plants from this list, arboretum managers can reduce the risk of tree failure due to lack of water (Griffin 2015).

Texas Tree Trial Database | UC Davis Arboretum & Public Garden

The Texas Tree Trials Database publicized in 2021, is a valuable resource for horticulturists, arborists, and researchers interested in 45 trees that have the potential for Kansas as it adapts to a changing climate. By testing the drought and heat tolerance of new and underutilized tree species from the west and central Texas, the trials provide long-term research needed to adapt. The region's hot and dry climate offers numerous tree species that are not currently utilized in the horticultural industry of Kansas. Therefore, expanding the selection by incorporating these trees would enhance the diversity and durability of the campus arboretum against the anticipated climatic changes (McAdow 2021, UC Davis 2021).

STEP 2. TREE CHARACTERISTICS FOR SELECTION AND PLACEMENT

The selection of tree species for the landscape typologies at KSU was an informed decision, focusing on specific traits associated with each tree. This decision-making process was guided by insights drawn from the site inventory regarding the considerations for tree selection across the five landscape typologies.

Three critical traits were identified as paramount in this process: branch strength, potential for root damage, and tolerance to salt spray. These traits were deemed critical based on the findings from the site inventory and were studied using the comprehensive SelecTree database.

In addition to these traits, the suggested uses and optimal planting sites for each tree species were also explored. This information was used to make strategic designations that would enhance both the aesthetics and functionality of the KSU campus.

Species Characteristics

- Scientific Name
- Common Name
- Foliage Type
- Height at Maturity
- Spread at Maturity
- Hardiness Zone
- Aesthetic Characteristics
- Sun Exposure
- Potential Issues

Characteristics to Inform Palette Designation

- Branch Strength: Weak, Medium, Strong
- Root Damage: Low, Moderate, High
- Salt Spray Tolerance: Low, Moderate, High
- Suggested Use(s) and or Planting Site:

Branch Strength:

Branch strength refers to a tree branch’s capacity to support weight without breaking. It depends on factors like species, age, health, diameter, and branch angle. Assessing branch strength is crucial to evaluate the risk of failure and potential damage. While SelecTree rates branch strength as strong, medium, or weak based on a tree’s ability to withstand wind and snow loads, the source does not provide a specific definition (UFEI, n.d.).

Root Damage Potential:

Root damage potential measures how likely a tree’s roots are to cause damage to sidewalks, foundations, pipes, or other structures. It is based on factors such as root size, depth, spread, and growth rate. A tree with a high root damage potential may require root barriers to prevent conflicts with infrastructure. A tree with a low root damage potential may be more suitable for planting near buildings or pavement. SelecTree rates the potential for root damage as low, moderate, or high but does not provide definitions for each rating (UFEI, n.d.).

Salt Spray Tolerance:

Salt spray tolerance refers to a plant’s ability to withstand salt in the soil, which can harm growth and appearance. Some plants are more sensitive to salt and may exhibit symptoms like leaf scorch, defoliation, reduced flowering, or even death. Salt spray tolerance is vital when selecting trees for roadside landscapes or places with de-icing products. SelecTree rates this tolerance as low, moderate, or high, although the source does not provide specific definitions (UFEI, n.d.).

Suggested Use:

The Missouri Botanical Garden Plant Finder uses the term "suggested use" to recommend ways to utilize the various plants in their database. This includes their applications in landscaping, medicinal purposes, culinary uses, or other specific functions. The website aims to provide comprehensive information about the plants, including their characteristics and potential uses, to assist in decision-making (Missouri Botanical Garden, n.d.).

Planting Site:

The Morton Arboretum uses the term "planting site" to refer to the recommended planting location, which considers environmental conditions such as sunlight, moisture, and space, which are crucial for the plant's growth and health (Morton Arboretum, n.d.).

How was it collected?

The information above was collected through comprehensive research on each tree species. Sources used in the research included the Manual of Woody Landscape Plants (Dirr 2009), The Tree Book (Dirr and Warren 2019), the Missouri Botanical Garden online plant finder (n.d.), Morton Arboretum plant finder (n.d.), SelecTree an online tree selection guide (UFEI n.d.), and University Research Extension resources. The information noted above was investigated for each tree and organized in Excel tables.

How was it analyzed?

STEP 3. FILTERING PROCESS

In this step, a comprehensive background search was conducted on the trees listed in both the Texas Tree Trial Database and the K-State Drought-Tolerant Trees for South-Central Kansas. The objective was to identify and exclude trees with potential invasiveness and those posing critical human health hazards. By filtering out such trees it was ensured that the climate-ready collection is suited for the KSU campus.

STEP 4: TREE PALETTE ASSIGNMENT RATIONALE

The climate-ready trees were thoughtfully categorized into specific landscape typology palettes based on their unique characteristics, practical considerations, recommended suggested use, and planting sites. Each species could belong to one or more of the landscape typology palettes. Below is the rationale used for developing the landscape typology tree species palettes.

SelecTree Information:

Branch Strength: Weak, Medium, Strong

Root Damage Potential: Low, Moderate, High

Salt Spray Tolerance: Low, Moderate, High

Surface Parking

Trees should be able to withstand the harsh conditions of the parking lot, such as salt, pollution, and compacted soil. They should also have a high canopy, a small root zone, and a noninvasive root system.

Tree species with the following attributes were included in the surface parking palette.

Branch Strength: Medium, Strong

Root Damage Potential: Low, Moderate

Salt Spray Tolerance: Moderate, High

Quadrangles

The quadrangle’s palette should include a variety of trees that tolerate salt and those that can’t tolerate such conditions. The palette can also include trees with varying trees, such as deciduous and evergreens, and variability in root damage potential, according to SelecTree.

Tree species with the following attributes were included in the quadrangle’s palette.

Branch Strength: Medium, Strong

Root Damage Potential: Low, Moderate, High

Salt Spray Tolerance: Low, Moderate, High

Campus Green

Trees on the campus green should include a variety of trees that tolerate harsh conditions, including salt and compacted soil, and those that can’t tolerate such conditions. Trees in this area can include trees with varying root systems and heights, widths, and shapes in canopies, and litter.

Tree species with the following attributes were included in the campus green palette.

Branch Strength: Weak, Medium, Strong

Root Damage Potential: Low, Moderate, High

Salt Spray Tolerance: Low, Moderate, High

Plazas

The trees selected for plazas should tolerate harsh conditions, including salt and compacted soil. They should also produce insignificant litter. Deciduous trees should have a high canopy, a small root zone, and a non-invasive root system.

Tree species with the following attributes were included in the plaza palette.

Branch Strength: Medium, Strong

Root Damage Potential: Low, Moderate

Salt Spray Tolerance: Moderate, High

Campus Corridor

The campus corridor palette includes trees with unique characteristics not accounted for in the other landscape typologies. Given the physical characteristics of the campus corridor and its minimal pedestrian traffic compared to other typologies, trees in this area can have varying root systems, heights, widths, shapes in canopies, and significant litter.

Tree species with the following attributes were included in the campus corridor palette.

Branch Strength: Weak, Medium, Strong

Root Damage Potential: Low, Moderate, High

Salt Spray Tolerance: Low, Moderate, High

CHAPTER 4

FINDINGS



PRECEDENT STUDIES



Figure 4.1 Arnold Arboretum of Harvard University Aerial (by author using satellite imagery from Google Earth 2022).

ARNOLD ARBORETUM OF HARVARD UNIVERSITY

BACKGROUND

Accreditation Level & Year Obtained: Not accredited through the ArbNet program.
Land Grant: No
Size: 281 acres

ADMINISTRATIVE BODY

People are involved in all aspects of the arboretum there are administration, curation, education and public programs, greenhouse nursery and plant production, horticulture, information technology, institutional advancement, library, archives, and research in addition, the organization welcomes visiting scholars, visiting fellows, and associates (President and Fellows of Harvard College 2022).

THE PURPOSE: MISSION/VISION/GOALS

MISSION

“The Arnold Arboretum of Harvard University discovers and disseminates knowledge of the plant kingdom to foster greater understanding, appreciation, and stewardship of Earth’s botanical diversity and its essential value to humankind through research, horticulture and education” (President and Fellows of Harvard College 2022).

GOALS

- “Increase “phylogenetic breadth” within clades
- Increase “biological breadth” within clades
- Create a unique identity in conservation biology
- Create a unique identity in woody plant genomics
- Prioritize acquisition of taxa within geographically disjunct clades
- Increase “phylogenetic breadth” within clades
- Reassert horticultural leadership in accessioning marginally hardy species” (Arnold Arboretum 2016).

COLLECTIONS POLICY

Per Arnold Arboretum's Living Collections Policy, the institution develops, manages, and enhances its living collections, including all plants that fall under its scope (Arnold Arboretum 2016, Dosmann 2007).

Purpose of the Living Collection

The Collections Policy of the Arnold Arboretum policy guides the development, management, and enhancement of the living collections, which are essential for research, education, and conservation of woody plants (Dosmann 2007).

Purpose of the Collection

The Arnold Arboretum's Living Collections is integral to its mission as a research institution focused on woody plants. These collections support scientific study, education, and other vital roles (Dosmann 2007).

Record Keeping

“Records for each accession in the collection are housed in BG-BASE, a PC-based database. Intensely curated, BG-BASE stores plant information including:

- Source of origin
- Specific provenance
- Date of acquisition
- Accepted botanical names and its synonyms
- Size upon receipt as well as at intervals throughout its history
- Number of specimens
- Map location on the grounds
- Presence of any vouchers in the cultivated herbarium or photographic images
-

Additional data may include; performance observations, unique ornamental characteristics, growth and survival rates, hardiness potential, specific propagation techniques, a botanical description, and taxonomic verifications. Further information regarding storm damage, vulnerability to pests and diseases, and experimental data in the form of supplementary notes are included. The Arboretum carefully observes its plant collections, and any formal assessments are recorded in the Arboretums Plant Inventory Operations Manual (President and Fellows of Harvard College 2022).

Legal and Ethical Considerations

The Arboretum adheres to plant acquisition and distribution laws and regulations and manages invasive plants to prevent environmental harm. Additionally, the Arboretum respects the rights and interests of source countries and communities and conserves their biodiversity (Dosmann 2007).

WOODY PLANT CARE AND MANAGEMENT

A staff of eight horticulturists, horticultural technologists, two arborists, and two gardeners manage the Living Collections. Additionally, up to 12 summer interns assist with these activities during the summer. equipment” (Director of Operations, Manager of Horticulture, and Assistant Manager of Horticulture, the team’s responsibilities include; planting and transplanting plants from the nursery to the grounds, turf care, monitoring for insects and diseases, applying pesticides and biological controls, pruning, removing dead or declining trees, chipping brush, watering, fertilizing, applying soil amendments, removing volunteer plants and invasives, rejuvenating planting beds, mulching, removing litter, plowing snow, and maintaining equipment”(President and Fellows of Harvard College 2022). The Arboretum also has a Landscape Management Plan that divides the Arboretum into 71 zones based on location, environmental characteristics, and collections. Horticulturists are assigned to a set of zones to become experts and improve the quality of care they provide (President and Fellows of Harvard College 2022).

Plant Inventory Operations Manual

- The manual describes the procedures and standards for conducting inventory field checks of the living collections at the Arnold Arboretum.
- Curatorial staff perform inventory field checks every five years to systematically and routinely review accessioned plants, their labels, maps, and records.
- The manual outlines the workflow of inventory field checks, which consists of eight steps: notify horticulturist, gather materials and tools, preview and audit records and maps, conduct field work, complete office tasks, accomplish follow-up tasks, summarize work with horticulturists and managers, and archive work materials.
- The manual offers guidance and suggestions on how to conduct field checks on plants. Any person can do these and should be recorded in BG-BASE or submitted to the curatorial department.
- The manual includes appendices with resources, such as operationally defined plant conditions, inventory timeline and regions, label standards and source guide, emergency procedure, and tutorials for data management systems.

COLLECTION(S)

“The Living Collections are divided into three primary categories: Core, Historic, and Miscellaneous Collections; within each are secondary collections. This organization allows priority to be assigned to all extant, as well as potential, accessions within each category, thus guiding collections development, management, and enhancement decisions. In addition, it is important to note that some woody plants at the Arnold Arboretum are grown only for research and experimentation purposes and are not included in the Living Collections Policy” (President and Fellows of Harvard College 2022).

1. Core Collections
 - a. Biogeographic Collections
 - b. NAPPC Collections
 - c. Conservation Collections
 - d. Synoptic Collections
2. Historic Collections
 - a. Arnold Arboretum accessions
 - b. Nurseries and Horticulturalists
 - c. Distinctive Cultivar Collections
 - d. Cultivars with names proposed prior to 1953
 - e. Arnold Arboretum Cultivars Introductions
 - f. Larz Anderson Bonsai Collection
3. Miscellaneous Collections
 - a. Display collections
 - b. Natural areas
 - c. Spontaneous Flora
 - d. Dana Greenhouse and Nursery Collections

(Dosmann 2007).

WOODY PLANT RESEARCH

Plant biology questions can be answered at the Arnold Arboretum by utilizing world-class research facilities among over 16,000 living specimens (2,100 species) (President and Fellows of Harvard College 2022). The scientists’ research ranges from organismic and evolutionary biology, molecular and developmental biology, plant physiology, and ecological, environmental, and biodiversity studies. The arboretum’s library and archives contain a specialized research collection devoted to temperate woody plants, with works on botany, horticulture, flora, landscape studies, garden history, and dendrology. The arboretum offers a variety of woody plant resources, such as living collections that display a wide range of specimens, research facilities with advanced technology, and libraries and archives (President and Fellows of Harvard College 2022).

EDUCATION & OUTREACH
Elementary Plant Education

Children from Boston Area schools’ benefit from nature and introductory plant science instruction by arboretum educators and volunteers. Preschool and elementary children and their teachers can participate in varied nature programs focused on plant science. Furthermore, school groups may plan self-guided trips and participate in numerous educational opportunities, including tours and family activities in the landscape and the Hunnewell Visitor Center (President and Fellows of Harvard College 2022).

Virtual Learning

Virtual nature learning is offered for Grades K-5 students. They can download Google Slides to observe and discuss nature and find fun ways to explore it outdoors. The slides have teacher notes that last for 30 minutes (President and Fellows of Harvard College 2022).

Arboretum Young Scientist Program

The program offers hands-on learning on the Arboretum grounds. Students can explore the Arboretum landscape, conduct field studies, collect data, and interact with scientists, horticulturists, and other professionals. The program aims to inspire the next generation of scientists and plant enthusiasts (President and Fellows of Harvard College 2022).

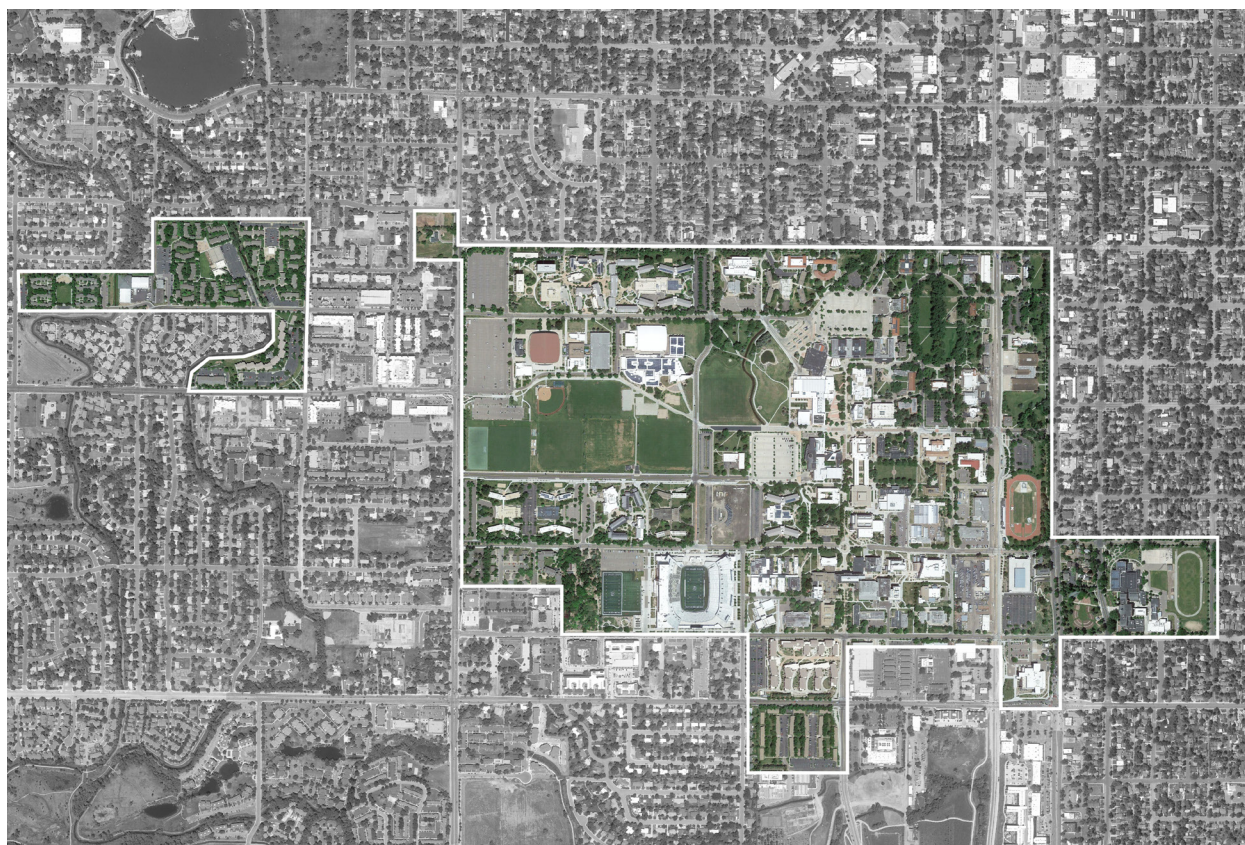


Figure 4.2 Colorado State University Campus Arboretum Aerial (by author using satellite imagery from Google Earth 2022).

COLORADO STATE UNIVERSITY ARBORETUM

BACKGROUND

Accreditation Level & Year Obtained: Level 3 Accreditation obtained 2019

Land Grant: Yes

Size: Approximately 2,400 acres

ADMINISTRATIVE BODY

The responsibility for the Campus Tree Care Plan, Tree Collections Management, and Campus as Arboretum rests with the Facilities Management Department, under the direction of the Vice President for University Operations.

Campus Arboretum Committee

The Campus Arboretum Committee leads all efforts for the Campus Arboretum and includes the following representatives:

- CSU University Planner
- CSU Campus Landscape Architect
- CSU Campus Arborist
- CSU Outdoor Services Manager
- CSU Horticulture and Landscape Architecture Department representative
- CSFS Community Forestry Program Manager
- Fort Collins City Forester
- CSU Student representative
- Fort Collins community member
- GIS Specialist
- Program Assistant, Facilities Management (CSU, n.d.).

THE PURPOSE: MISSION/VISION/GOALS

MISSION

"Inspired by its land-grant heritage, Colorado State University is committed to excellence, setting the standard for public research universities in teaching, research, service and extension for the benefit of the citizens of Colorado, the United States and the world." (CSU, n.d.)

GOALS

"Oval Preservation: To obtain resources to increase the frequency of pruning in the historic pre-1922 American elm Oval area.

Inventory: The goal is continuous maintenance of the GIS inventory.

Increase species representation: Using the GIS tree inventory as a benchmark, increase the percentage of underrepresented species, especially in the historic areas of campus.

Tree replacement: Implement tree replacement and damage assessment policies as outlined in the Campus Tree Care Plan.

Staff Support: Adjust current position descriptions in Facilities Management to include specific duties related to curation and management of the campus arboretum" (CSU, n.d.).

COLLECTIONS POLICY

The CSU Arboretum has a Collection Management Manual with a living Collection Policy section briefly detailing the curational history, collection preservation and collection management which discusses the Plant Inventory Database that is discussed under the Collection Record Management Systems Component. The Living Collections Policy section discusses curation history, plant inventory database and collection preservation (CSU 2022).

Collection Record Management

The CSU Campus Arboretum uses ArcGIS: The attributes listed within the GIS Tree Database include: ID, common name, genus, cultivar, diameter at breast height, deciduous or conifer, notes, status, creation date, condition, memorial, observation, and tree care (CSU n.d.).

WOODY PLANT CARE AND MANAGEMENT

“Ongoing tree care activities, both in-house and by outside contractors, are overseen by the Campus Arborist within the Outdoor Services Group. The University Landscape Architect has the primary role within Facilities Management in species selection, tree placement, and the enforcement of tree protection during construction” (CSU 2022). The CSU Arboretum has a Campus Tree Care Plan with the following items below that ensure the successful management of the campus arboretum (CSU 2022).

Management Best Practices

- Tree Removal Policy
- Wood Utilization
- Recommended Species
- Prohibited Species
- Managing for Catastrophic Events
- Protection and Preservation Policies
- Emerald Ash Borer - Plan for Treatment of Trees
- Tree Damage Assessment
- Prohibited Practices

COLLECTION(S)

“CSU has approximately 294 tree species and over 1,000 woody plant species in its collection. The Oval elm collection dating from 1881, is preserved for the long-term benefit of the university and has continuing research value in finding efficacious treatments for evolving exotic pests of elm”(CSU 2022).

“The Heritage Garden & Arboretum Collection is about 6.0 acres and was established over forty years ago. It has the largest collection of woody plants in the region with over 1,154 different taxa represented. The main objectives of the Heritage Arboretum and demonstration garden are to determine which woody plants are best suited for growing in the Rocky Mountain area and to display these plants for public and teaching purposes” (CSU 2022).

WOODY PLANT RESEARCH

Shrub Water Use Study

A shrub water use study was conducted to determine the response of four shrub species to different irrigation levels. The study was conducted at the Fort Collins W.D. Holly Plant

Environmental Research Center during the 2010 growing season. Two experimental methods were used in this study: one in the field and one in a lysimeter. As part of the study, various plant characteristics were measured, including height, width, water potential, leaf area, and biomass. Identifying shrubs with low water demands for urban plantings was the purpose of this study (CSU 2018)

Plant Select®

The Colorado State University Arboretum is also one of three founding partners of Plant Select®, which was established in 1997. This partnership brings together Colorado State University, Denver Botanic Garden, landscape professionals, and public gardens in seven western states to test, develop, and distribute superior plants, including woody plants (CSU, n.d.).

Plant Trial Research

Plant trials have been conducted at CSU for more than 40 years, and numerous articles have been published on more adaptable woody plants in national, regional, and state publications. In addition, research has been incorporated into Extension Fact Sheets regarding recommended woody plants for Colorado, as well as the Rocky Mountain and High Plains regions (CSU, n.d.).

Graduate Student Peer-reviewed Findings

Several graduate students in the Department of Horticulture and Landscape Architecture have published their findings in peer-reviewed scientific journals regarding proper tree planting techniques (CSU, n.d.).

EDUCATION & OUTREACH

Arbor Day

As part of the Arbor Day tree planting celebration, held each spring by the Tree Campus USA Committee, students and community members learn more about trees and their important role in our environment (CSU, n.d.).

Outreach to University

The Department of Public Relations informs the university community about CSU's involvement in the Tree Campus USA program. This article is featured in a news email that reaches students and staff twice a week. CSU's social media accounts on Facebook, Twitter, and Google also share arboretum news (CSU, n.d.).

Experiential Learning and Outreach

CSU students and community members can participate in one to two experiential learning opportunities in urban and community forestry each semester. The activities involved in these opportunities include inventorying trees and caring for them. A course in Urban and Community Forestry (HORT 466) is also available during the fall term (during odd-numbered years) (CSU, n.d.).

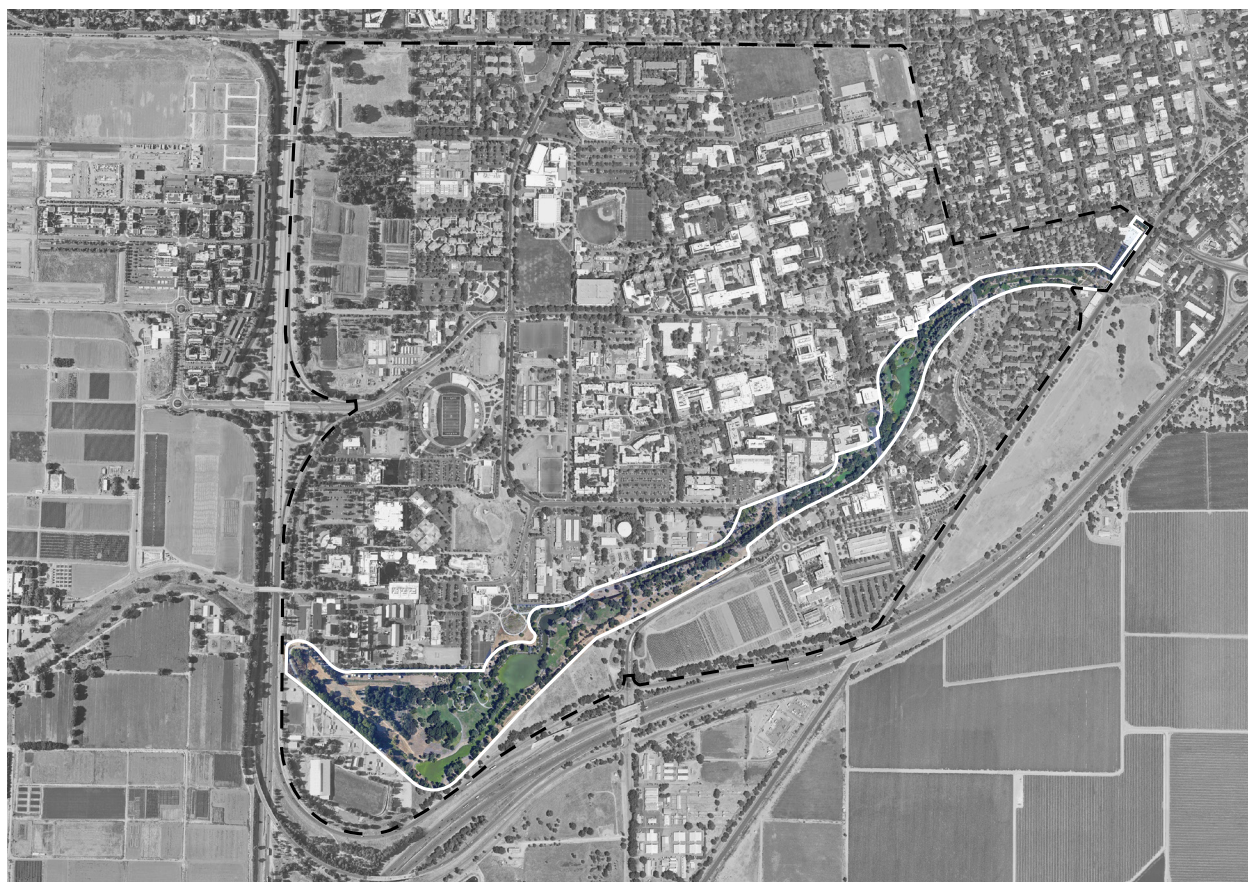


Figure 4.3 University of California Davis Main Campus and Arboretum Aerial (by author using satellite imagery from Google Earth 2022).

THE UNIVERSITY OF CALIFORNIA DAVIS ARBORETUM & PUBLIC GARDEN

BACKGROUND

Accreditation Level & Year Obtained: Level 3 ArbNet accreditation was obtained in 2019.

Land Grant: Yes

Size: 96 acres

Geographic Location: Central Valley, California

ADMINISTRATIVE BODY

"The UC Davis Arboretum and Public Garden is under the governance of the Office of Campus Planning and Environmental Stewardship in the Finance, Operations and Administration unit at UC Davis" (UC Davis 2022).

THE PURPOSE: MISSION/VISION/GOALS

MISSION

"To inspire human potential to help people and environments thrive" (UC Davis 2022).

GOALS

1. Provide an exemplary place of beauty, learning, and environmental stewardship as a UC Davis campus emblem.
2. Inspire and educate visitors about the natural world and appropriate horticulture in the Central Valley.
3. Strengthen the Arboretum's Museum function and scientific and academic value.
4. Disseminate the expertise of UC Davis to the regional community and promote environmental responsibility as a primary outreach arm of UC Davis" (UC Davis 2022).

COLLECTIONS POLICY

In the UC Davis Collections Policy, the following information is detailed:

Botanical and Horticultural Goals for the Living Collection

This section outlines the primary purposes and benefits of the living collection, such as providing learning, stewardship, and outreach opportunities.

Acquisition Policy and Priorities

Explains how the living collection is acquired, curated, and managed, with a focus on plants adapted to a Mediterranean climate and the Central Valley of California. It also lists the current collection development priorities and criteria.

Care of the Living Collection

Refer to the woody plant care section.

Plant Record Management

Details how the plant records information is maintained in IrisBG and ArcGIS Online and how the UC Davis Herbarium staff manages herbarium specimens.

Horticultural Evaluation and Conservation of the Collection

This heading emphasizes the need for regular horticultural evaluation of all plant collections and highlights the importance of conservation reviews and grants for the most important ones.

Collection Use

The UC Davis Arboretum's Collection is extensively used for formal and informal education, with a wide range of groups using the collection for teaching and research. The curatorial and horticultural staff often receive requests for plant samples and work directly with those requesting the material. Propagation materials of unique plants are shared with other botanical gardens and nurseries, with precautions taken to prevent the distribution of potentially invasive species.

Legal and Ethical Considerations

This section affirms compliance with all relevant laws, policies, and directives regarding plant collection, propagation, and distribution and their components. It also expresses the commitment to abide by international conventions and collaborative efforts for plant conservation.

National and International Collaboration

The document highlights the partnership with other botanical institutions nationally and internationally to further the aims of various plant conservation strategies and initiatives. (UC Davis 2022).

WOODY PLANT CARE AND MANAGEMENT

“Oversight, management, care, and conservation of the Living Collection falls primarily to the horticultural staff at the UC Davis Arboretum and Public Garden. Current staff positions at the UC Davis Arboretum with responsibility for the direct care of the collections include the Director of GATEways Horticulture and Teaching Gardens, the Director of Public Horticulture and Engagement, three GATEways Horticulturists, and three GATEways Gardening Specialists. Additional support is provided for the care of the Living Collection through the Grounds and Landscape Services subunit of the Arboretum and Public Garden. Grounds and Landscape Services work teams provide specialized services and collection management activities, including turf mowing, tree trimming and removal, pest and weed management, and other services that require large equipment” (UC Davis 2022).

COLLECTION(S)

Collections at UC Davis Arboretum are divided into three categories (a plant may belong to more than one category):

- Taxonomic collections (e.g., Quercus, Eucalyptus, Ceanothus)
- Eco-geographic collections (e.g., Southwest US and Mexico, North Coast Collection)
- Thematic collections (e.g., White Flower Garden, home demonstration gardens)

(UC Davis 2022).

WOODY PLANT RESEARCH

Texas Tree Trial Research Project

This project is being conducted by the UC Davis Arboretum and Public Garden to evaluate the suitability of 40 species of trees native to Texas for the Sacramento Valley region, which faces increased temperatures and drought conditions due to climate change. This project seeks to identify and promote trees that will be resilient and diverse in the face of climate change, in order to enhance the urban tree canopy at UC Davis and in the surrounding communities. Seeds from Texas are collected, propagated at the Arboretum Headquarters Nursery, and planted at different trial sites around campus. In addition to monitoring and updating the performance and characteristics of each tree species, the project seeks to inform students and the public about these new plants. (McAdow 2021).

Climate-Ready Tree Study

This project aims to identify and test tree species that are capable of adapting to the challenges posed by climate change in urban areas. As part of the study, different species of trees were planted and monitored in three climate zones in California, and their growth, survival, and

ecosystem services will be evaluated. Ultimately, the study aims to provide urban foresters and landscapers with science-based information and recommendations that will help them create healthier and more resilient urban forests in the future. (McPherson et al. 2016).

EDUCATION & OUTREACH

The UC Davis Arboretum and Public Garden is open 365 days a year to the public. The Arboretum & Public Garden offers a wide range of educational programs and activities to the campus and community, and over 100 classes use it each year (UC Davis 2022). Below are notable manifestations of education and outreach hosted at the University.

GATEway (Gardens, Arts and The Environment) Project

The UC Davis GATEways Project is intended to connect the campus and the community through environmental education, research, and outreach. In this project, thematic gardens, trails, and exhibits showcase the diversity of plants and ecosystems in California and around the world. As a result of the partnership with campus departments, the project creates educational and leadership opportunities for students. They plan and implement outreach initiatives, beautification efforts, educational events for K-12 students and campus visitors, and stewardship practices (UC Davis 2022).

Learning by Leading™ (LxL)

The Learning by Leading™ program grants opportunities for undergraduate students to gain hands-on experience in environmental leadership and education. The program offers various internships that focus on different aspects of the Arboretum, such as horticulture, ecology, community engagement, and education. The interns work in teams with mentors and staff to design and implement projects that benefit the Arboretum and the campus community (UC Davis 2022).

Urban Tree Stewardship

The Urban Tree Stewardship program aims to educate and train students and interns on the benefits and challenges of urban forestry. The program covers topics such as tree identification, planting, pruning, pest management, and climate change adaptation. The program also involves hands-on activities such as inventorying, mapping, and monitoring campus trees. The program's goal is to enhance the health and diversity of the campus tree canopy and to foster a sense of stewardship among the participants (Hetrick 2020).

Arboretum & Public Garden All-Stars

The Arboretum & Public Garden All-Stars is a program that showcases 100 species of reliable plants that have been tested on-site and are well-adapted to the climate and soil conditions of the Central Valley. These plants are selected for their beauty, drought tolerance, pest resistance, impressive qualities, and ease of care. The UC Davis Arboretum and Public Garden aims to promote these plants, shrubs, vines, and trees as examples of sustainable landscaping for the region (UC Davis 2022).

TAKEAWAYS
ADMINISTRATIVE BODY

Kansas State University stands to gain significantly by forming an arboretum committee of experienced professionals akin to those at CSU’s Arboretum and the Arnold Arboretum. The CSU Arboretum’s successful model includes representatives from a diverse range of departments, such as the University Planner, Campus Landscape Architect, Campus Arborist, Outdoor Services Manager, Horticulture and Landscape Architecture Department, Community Forestry Program Manager, City Forester, a student representative, a community member, a GIS Specialist, and a Program Assistant from Facilities Management. Furthermore, for KSU Arboretum to fortify its standing in woody plant research and education, it’s essential to bring on board experienced professionals such as research and education coordinators, much like those at the Arnold Arboretum. Such a group of professionals would ensure the smooth functioning and advancement of the KSU Arboretum’s objectives, ultimately contributing to its growth and development.

THE PURPOSE

In crafting KSU’s mission, it’s crucial to emulate CSU’s Arboretum, whose mission and goals embody its dedication to excellence as a public land-grant research university. This involves formulating a mission statement acknowledging KSU’s land-grant legacy and its commitment to disseminating knowledge to Kansas and beyond.

COLLECTIONS

In the same manner that the Arnold Arboretum categorizes its collection into three primary categories, KSU can follow a similar technique. Like the Arnold Arboretum, KSU should pursue a historic collection category, and the other two KSUs shall pursue a taxonomic category to include its existing trees on campus and, finally, a specialized Kansas climate-ready tree collection. Learning from the University of California Davis Arboretum and Public Garden, KSU could learn to select tree species adapted to Kansas’s projected climate conditions, considering trees from regions with similar or warmer climates. The selection of climate-ready trees should be based on current and projected hardiness zones, heat zones, and drought tolerance. Exploring resources like the UC Davis Texas tree trials database could provide valuable insights into novel tree species that could thrive in Kansas’s changing climate. In summary, adopting these collections’ takeaways could significantly enhance the future growth of KSU’s arboretum.

COLLECTIONS POLICY

For the KSU Arboretum to be successful, it is important to establish a comprehensive collections policy that mirrors the notable precedents of the Arnold Arboretum and UC Davis Arboretum. Such a policy would guide the development, management, and refinement of its collections. This policy should outline the scope of the collections, acquisition, deaccession, curation, and management procedures, as well as access and use of the collections, and articulate how it supports KSU’s missions.

In addition, investing in collections software, such as IrisBG, can streamline plant record-keeping and data management. It enables record creation and updating, data filtering, report generation, and information sharing with other institutions. Integrating this with geographic information systems like ArcGIS or BG-MAP can generate precise, interactive maps of the plant inventory, enhancing efficiency and outreach. Platforms like ArcGIS Online allow access to various data sources, customization of map appearance and functionality, and collaboration with other arboreta. This can help KSU showcase its collections, monitor their health, and engage visitors interactively, thereby contributing significantly to the arboretum’s success.

WOODY PLANT CARE & MANAGEMENT

The Arnold Arboretum and the Colorado State University Arboretum owe their plant care and management success to implementing a landscape plan, a campus tree-care plan, and an inventory manual. These woody plant care and management strategies provide valuable insights for Kansas State University’s establishment. The development of a plant inventory operation manual akin to the one used by the Arnold Arboretum would standardize the procedures for cataloging collections at KSU. As demonstrated by CSU, by developing a Campus Tree Care Plan that adheres to the ANSI A300 Standards and leverages resources from the International Society of Arboriculture, which outlines best practices for tree care operations, KSU could ensure the arboretum’s proper maintenance and management.

WOODY PLANT RESEARCH

Based on the research being conducted at the UC Davis Arboretum, the KSU Arboretum could benefit from experimenting with diverse tree species, particularly those native to hot and arid climates like Texas. Monitoring their performance over time would provide valuable data on their growth, health, water use, and aesthetic value. Learning from the experiences of other horticulturists and arborists who have planted or observed these trees in different conditions could further enhance KSU’s understanding. Sharing the results and lessons learned with other arboreturns and communities could contribute to creating climate-ready communities.

EDUCATION & OUTREACH

Drawing from the three notable precedents, the KSU Arboretum could fortify its education and outreach by leveraging digital platforms, fostering environmental stewardship through experiential learning, and facilitating student interaction with the arboretum landscape and professionals. In conjunction with collaborations with other arboreturns, research extensions, and horticulturists’ strategic use of on-site and virtual platforms can promote superior woody plants and effectively inform the community about various initiatives. Partnerships with campus departments and community entities can substantially amplify the impact of educational initiatives. By immersing students in real-world environmental challenges, they can acquire vital skills and experiences, thereby enriching their educational journey and leadership potential.

SURVEYS

These surveys were conducted in the fall of 2022.

QUESTION 1: Within the area you serve, what are the most significant threats/issues related to trees you currently see?

RESPONDENT 1

- Bush honeysuckle is displacing native flora in the understory of rural and community forests. It is so abundant now that I don't see that a grip can be ever made on it.
- Callery pear has also escaped cultivation and like bush honeysuckle, will overtake the native flora in the forest system and out compete it. It's also showing up in grazing lands and fire won't control it so unless a landowner or land manager undertakes mechanical means to kill it, it's likely to get way out of hand, more than it already is.
- The emerald ash borer has been found in 2 new Kansas counties, bringing the total of counties with known detections to 12. Those counties are Wyandotte, Johnson, Miami, Leavenworth, Atchison, Doniphan, Brown, Jackson, Jefferson, Douglas, Osage and Shawnee.
- Climate extremes. Prolonged stretches of drought followed by fast falling rainfall that doesn't soak in as well as slower rain events would. Temperature extremes, such as going from 69 degrees one afternoon to 19 degrees the next morning in fall, before plants go fully dormant. Or early warmups in the spring followed by damaging cold temps.
- Storm severity

RESPONDENT 2

- Community canopies that lack age and species diversity, an aging mature to over-mature. The canopies have been further degraded by repetitive storm events. Typically, top 3 species represent 50% of total canopy.
- Most communities need to look at removals and replanting.
- Most communities have ordinances that require the homeowner to be responsible for pruning and removals within the city easement. The city regulates the easement but is homeowners' responsibility.
- Everyone wants fast growing trees.

RESPONDENT 3

The most significant threats to individual trees tend to be abiotic (environmental) stresses, and in some cases impact from insects and diseases such as Emerald Ash Borer. The most significant threats to forests continue to be pressure from invasive plants (especially bush honeysuckle), lack of active management (leading to forest stand conversion to shade-tolerant species and overmature/overstocked stands), and degradation of riparian forests and forestland conversion adjacent to developing areas.

RESPONDENT 4

I would add wildfires and concerns with the urban tree canopy. Wildfires are becoming more severe and larger than they have been. These fires often clear trees out of areas where they had invaded, such as native prairie, but they also are impacting more and more into areas that previous had not burned such as riparian forests. All too often such fire damaged stands of trees are not replaced. There have been several studies around the country as well as here in Kansas which show that the urban tree canopy is declining due to several of the same factors Respondent 3 listed for the rural forest canopy as well as the additional stresses of the urban environment such as age of the trees, increased heat, soil compaction, physical damage (i.e. impact from cars, mowers, etc.). Like with the fire damaged trees the urban canopy is by and large not being replaced as it dies out and/or has to be removed for public safety reasons.

QUESTION 2: What future threats/issues do you foresee for trees in your service area?

RESPONDENT 1

- Asian long horned beetle. Not found in Kansas but has been detected in Massachusetts, NY, Ohio and South Carolina. Unlike the EAB, ALB has a wide host range. All it would take would be the transportation of firewood with ALB in it for it to spread to other states.
- Thousand cankers disease of walnut. Not found in Kansas but detected in several states east and west of Kansas. While black walnut is not overly abundant in most communities, it is found in all. It would be devastating to the rural forests where black walnut is more abundant. Black walnut is also our most economically important rural tree.
- Sudden oak death. The pathogen of SOD was carried in to Kansas on nursery stock and while plant vendors who received those shipments were notified and told to destroy the plants, there is a chance that the disease could escape into the community and rural forests. There was a huge amount of press around this, but again, there's a chance that not every infected plant was destroyed and it could impact thousands to millions of oak trees in Kansas. It too, has a large host range.
- See more future threats at https://www.kansasforests.org/forest_health/emerging_threats/
- Climate extremes will also be a future threat, especially if global warming intensifies.

RESPONDENT 2

- Current and impending insect and disease threats. ie: EAB
- Hazard and defective trees, both public and private.
- Declining budgets and staff. Grey infrastructure is more important.

RESPONDENT 3

Accelerating impact from the issues identified above, along with new introductions of damaging pests and diseases that are not yet in Kansas. These include Asian Longhorned Beetle, Thousand Cankers Disease of Black Walnut, Spotted Lanternfly, Spongy Moth (formerly Gypsy Moth), Sudden Oak Death, and more. There is also an increasing risk that non-resident landowners may have trouble connecting with local resource professionals to get practical technical assistance in managing their forest lands, leading to undesirable outcomes.

RESPONDENT 4

To this one I would not add too much more to what has been listed above and in question.

QUESTION 3: What are the most common issues/concerns that the public reaches out to you for, regarding trees?

RESPONDENT 1

My role is not to assist private individuals, but I have received several emails and calls over the years. A large majority of contact is for opinions about the condition of their tree(s) or to find out what’s going on with their tree(s). If I can’t answer that very easily, I send them to their county extension agent, whose role is to help the private individual. I’ve been contacted about trees being bulldozed out for development, about what a neighbor did to their tree, for tree ID, for insect and disease questions, etc.

RESPONDENT 2

- Tree health, insect and disease issues
- Tree species selection
- Need for species that are climate adaptive and resilient.
- Cities have reached out about their downtown pit planted trees, I have drawn a few plans for replacements and suggest that they do not remove the old trees all at once. I have a couple of communities that are not replacing the trees- too temporary. One is putting in lights and another is doing shrubs- great!!!!!!

RESPONDENT 3

Drought stress, defoliation from bagworms, "what tree will do best in my county?", timber marketing challenges, windbreak establishment and renovation, and more.

RESPONDENT 4

To this list added by Respondent 3 I would add those who are interested in what is the value of their trees. This is for a variety of reasons ranging from damaged trees that need appraised for recuperation of damages, to the landowner having been approached by a timber buyer (logger) and the landowner wants to verify the offered price, to land that is changing hands and the timber value is part of the transaction, to an urban citizen trying to save their favorite tree or park by impressing on the local government the value of the tree(s).

QUESTION 4: What future research on trees in Kansas do you believe is needed to provide better information to the public in the next century?

RESPONDENT 1

In our community forestry program, we have spent a lot of time and effort working to make people aware of the many different types of trees that can grow in Kansas. Largely in part because of the threats and issues mentioned above. If you’ve been with me in class, you’ve heard me talk about our demonstration arboretum here where we have planted some rare and uncommon species of trees. My intent is to watch the rare and uncommons for at least 10 years to find out how they perform. If they can live and do well enough here, then I feel more confident recommending small plantings in nearby communities. I would really like to see more demonstration sites in Kansas testing material. And we will need a strong partnership with nursery growers and retail centers to obtain and sell stock that is less known. This is an area where my interest is the strongest. Others in my agency likely will have differing opinions.

RESPONDENT 2

- Continues tree species trails.
- Concentrated effort on tree species seed sources.
- Climate adaptive species. It is our weather extremes that make it tough.
- Not necessarily a complete dynamic change to natives only, we require the exotics to attain proper diversity. But we do need to be prudent with exotics and trial for invasiveness, etc. ie: Flowering pear. Trialing is imperative.....

RESPONDENT 3

We need to be able to continue to provide more and more confident answers to the question of what kinds of forests, what kinds of trees, and where those trees should be, looking forward for the next 20- 100 years through the lens of climate change impacts. This would include recommendations for working forests that provide sustainable, resilient economic and ecosystem benefits for landowners -- and carbon storage may play an increasing role in that discussion.

RESPONDENT 4

N/A

QUESTION 5: Is there anything else, regarding trees in Kansas, that would be helpful for me to know?

RESPONDENT 1

Our trees are a tremendous asset to our state, not just from an aesthetic standpoint, but from an economic, social, environmental and health standpoint. I could talk your leg off about that. Here are a few resources that discuss and quantify the tree and forest resource in the NE part of the state.

RESPONDENT 2

N/A

RESPONDENT 3

Kansas is in the heart of the Great Plains, where there has always been a equilibrium and tension between fire, grass, water, and trees. These are all interconnected across the mosaic of landscapes, and we need to engage in active management of our land in order to ensure things don't get too far out of balance within those systems.

RESPONDENT 4

As it is with the management of any natural resource, management of trees need to be a cooperative endeavor with foresters, arborists, fire managers, range managers, ranchers, farmers, citizens, on and on all feeling that they are valued, respected, and heard when it comes to discussions of how best to manage trees/forests in Kansas.

QUESTION 1: Within the area you serve, what are the most significant threats/issues related to trees you currently see?

QUESTION 1: Responses Summary

In the areas the Respondents serve, the most significant threats/issues to trees they see are from insects and diseases, lack of diversity in age and species among canopies, extreme climatic events, and lack of proactive management. Insects like the Emerald Ash Borer, now identified in 12 Kansas counties, pose a growing threat to community tree cover throughout the state. While invasive plants like the Asian bush honeysuckle are gradually dominating different Kansas landscapes such as forest edges and riparian areas, the invasive tree Callery pear, known to grow and spread rapidly, is often overpowering the growth of native trees. One of the respondents raised a concern about the lack of diversity in the age and species of trees in several communities in Kansas, in which the top three species make up 50% of the total canopy in most urban forests. Most canopies are mature or over-mature, and repeated storm events have only deteriorated their condition. Extreme climate events like prolonged droughts, sudden heavy rainfall, and dramatic temperature changes exacerbate these worsened conditions, increasing Respondents' concerns. Respondent 2 also highlights that communities seek trees with a fast growth rate. Proactive measures like active management, planting, and tree removal are necessary to address these issues.

QUESTION 2: What future threats/issues do you foresee for trees in your service area?

QUESTION 2: Responses Summary

Kansas Foresters anticipate many potential threats to trees in their service area, including insects and diseases such as the Asian Long Horned Beetle, Emerald Ash Borer, Thousand Cankers disease, Sudden Oak disease, Gypsy Moth, and others. Respondents are concerned that if climate change intensifies, the state will experience more frequent and severe weather events, such as heat waves, droughts, floods, and storms. Such climate extremes could further devastate forest health, human health, and the state economy. An additional future concern is that non-resident landowners may struggle to access local resource professionals for practical technical assistance in managing their forest lands. These threats/issues increase the risk of undesirable outcomes.

QUESTION 3: What are the most common issues/concerns that the public reaches out to you for, regarding trees?

QUESTION 3: Responses Summary

People often contact the Kansas Forester respondents about common tree-related concerns, such as insect and disease issues, tree health, and tree species selection. They also seek recommendations on climate-adaptive and resilient species.

QUESTION 4: What future research on trees in Kansas do you believe is needed to provide better information to the public in the next century?

QUESTION 4: Responses Summary

The survey respondents have recommended that future research on trees in Kansas should concentrate on identifying and evaluating rare and uncommon tree species, creating additional demonstration sites, collaborating with nursery growers and retail centers, developing species that can adapt to changing climates, and testing nonnative species for invasiveness. The respondents stress the importance of confidently determining which trees to plant, where to plant them, and what types of forests to develop, particularly for the next 20-100 years.

QUESTION 5: Is there anything else, regarding trees in Kansas, that would be helpful for me to know?

QUESTION 5: Responses Summary

The respondents highlighted the importance of trees in Kansas from various perspectives, including aesthetic, economic, social, environmental, and health. They emphasized the need for active land management to maintain balance, which requires cooperation among stakeholders such as foresters, arborists, farmers, and citizens.

SURVEY TAKEAWAYS COLLECTIONS

- Tree species trials are needed to test the performance and suitability of rare and uncommon tree species in different Kansas climates and landscapes. Respondent 1 and Respondent 2 both suggested this as a need for future research.
- Climate adaptive and resilient species are in high demand, as people seek trees that can withstand the weather extremes and environmental stresses that are expected to increase with climate change. Respondent 2 and Respondent 3 both mentioned this as a common concern among the public.
- Diversity in age and species is important for maintaining healthy and sustainable urban and rural forests. Many Kansas communities have canopies dominated by a few species, making them vulnerable to pests, diseases, and storms. Respondent 2 and Respondent 4 both highlighted this as a significant issue.

WOODY PLANT RESEARCH

- Forest management and planning are crucial factors for successful tree planting and growing. However, the respondents in a recent study emphasized that more research is needed to provide more confident answers to the question of what kinds of forests, what kinds of trees, and where those trees should be planted, looking forward to the next 20-100 years. Respondents 3 and 4 emphasized the importance of the research for successful tree planting and growth.
- The survey participants recommended conducting further research to evaluate the adaptability and growth performance of rare, uncommon tree species in various Kansas climates and landscapes. Both Respondent 1 and Respondent 2 highlighted this area of interest.
- The survey participants expressed the need for further investigation to identify and assess tree species capable of enduring harsh weather conditions and environmental strains likely to intensify due to climate change. They also recommended examining the invasive potential and possible advantages of uncommon species. Respondent 2 and Respondent 3 both highlighted this as a shared anxiety among the public.

EDUCATION & OUTREACH

- The respondents highlighted the importance of trees in Kansas from various perspectives, such as aesthetic, economic, social, environmental, and health. Providing education opportunities to the public about the multiple benefits of trees could help increase appreciation and support for tree planting and management.
- Non-resident landowners may require assistance in connecting with local resource professionals to manage their forest lands. Outreach efforts should be made to provide landowners with relevant information and guidance. Respondent 3 mentioned this as a potential future threat.

SITE INVENTORY

The site inventory aimed to identify key factors within each campus landscape typology that could inform the future species selection and placement of new trees within each typology. The tree placement and selection considerations for each landscape typology were developed using site photos, inventory maps, and physical characteristic descriptions.

MAPPED CAMPUS LANDSCAPE TYPOLOGIES

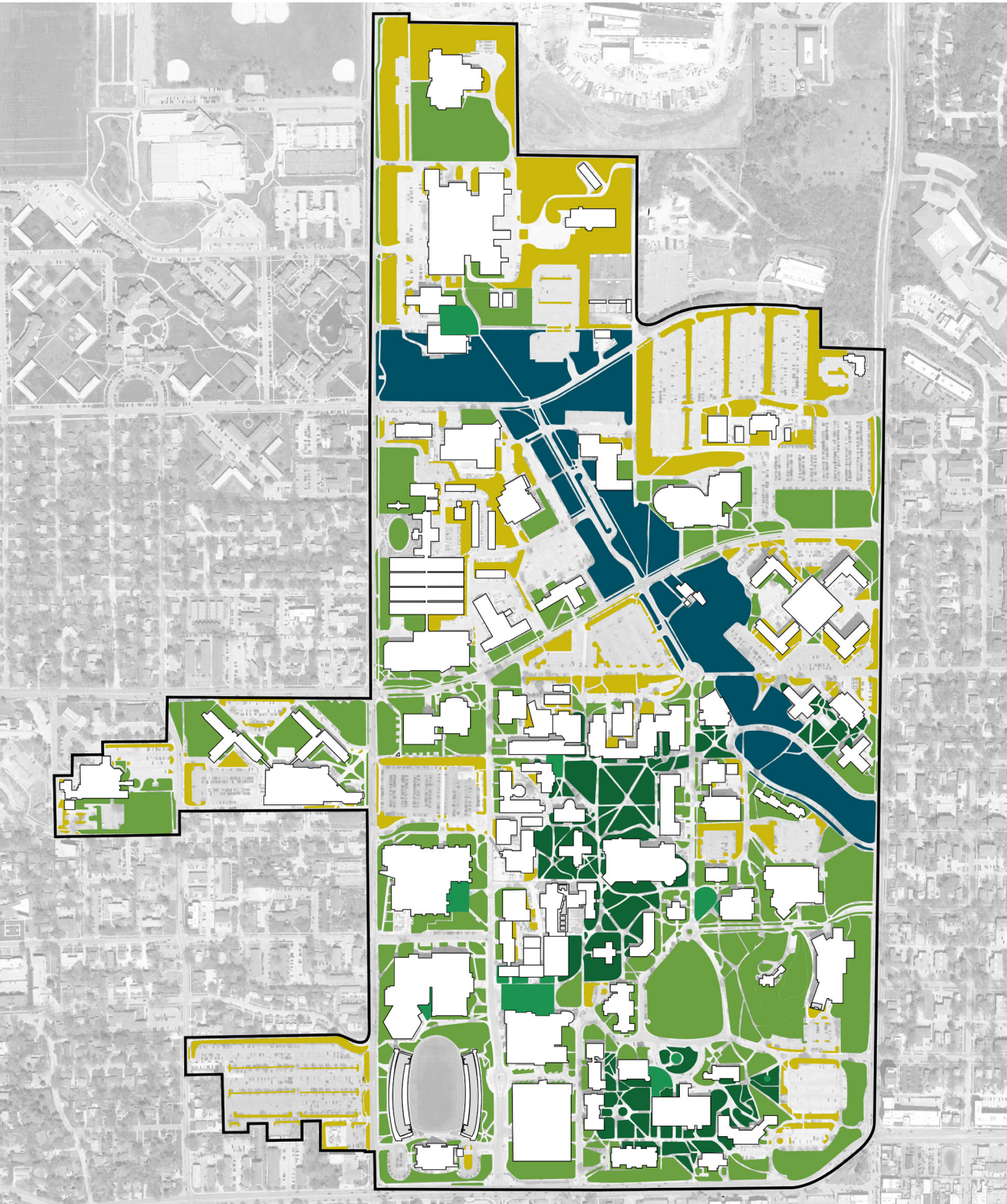


Figure 4.4 Kansas State University Main Campus Landscape Typologies (by author using satellite imagery from Google Earth 2022).

LEGEND

- | | | |
|--------------|-------------|-----------------|
| Campus Green | Quadrangles | Campus Corridor |
| Buildings | Plazas | Surface Parking |

Plan not to scale ⓘ

SURFACE PARKING
Physical Characteristics

Surface parking lots on campus are paved areas usually located adjacent to a building or a street and used for campus vehicle parking. Campus surface parking lots vary in size, shape, design, and function.

Surface parking lots on campus range in size from lots that accommodate a few dozen vehicles to large lots that can hold hundreds. The size and shape of the parking lots depend on the available land and the layout of the parking spaces and traffic lanes. Some contain large planter strips between rows, like the ones at B16, B17, and B3, while others have small islands for plantings and trees, like D1, A3, and A17. Some are strictly devoted to vehicles with no planting, like A11 and A12. Existing vegetation in parking lots typically consists of some shrubs acting as barriers and islands covered with turf. Additionally, some islands feature trees of varying sizes and species to provide essential shade.

Considerations for Tree Placement

Soil Quality:

The soil in parking lot planter strips may not be very root-friendly, as it may be compacted, contaminated, or poorly drained. Soil quality can limit tree growth and survival; however, soil volume, meaning the amount of space for tree roots to grow, is of primary concern.



MAPPED SURFACE PARKING LOCATIONS

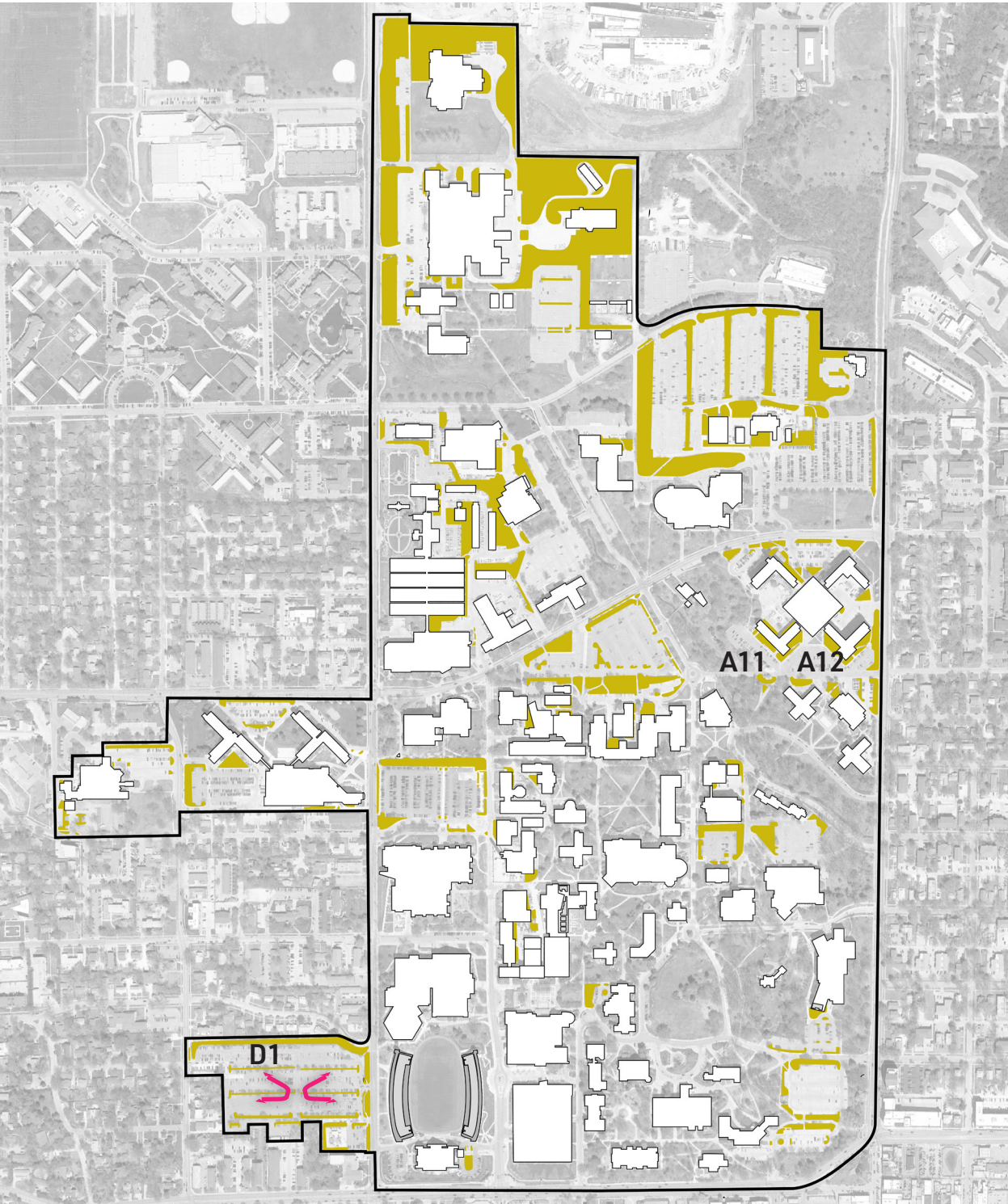


Figure 4.5 Illustrates the locations of the surface parking landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

Surface Parking

Plan not to scale

Water and Heat Stress:

Paved surfaces are engineered to shed water quickly, often depriving plants of adequate soil moisture or leaving their roots submerged in excess water. Paved surfaces also absorb and radiate heat, increasing the temperature and evaporation rate in the parking lot. These factors can cause water and heat stress on trees.

Limited Soil Volumes:

Limited soil volumes confine roots, restrict root growth, and often supply inadequate moisture and nutrients, affecting trees' health and stability.

Root vs. Pavement Conflict:

The lateral growth of shallow tree roots can cause sidewalks to crack and heave, creating uneven displacement of adjoining concrete sections. This can damage the pavement and create tripping hazards.

Winter Salting Stress:

Parking lots are often salted in the winter, which can further stress trees by increasing soil salinity.



MAPPED SURFACE PARKING LOCATIONS

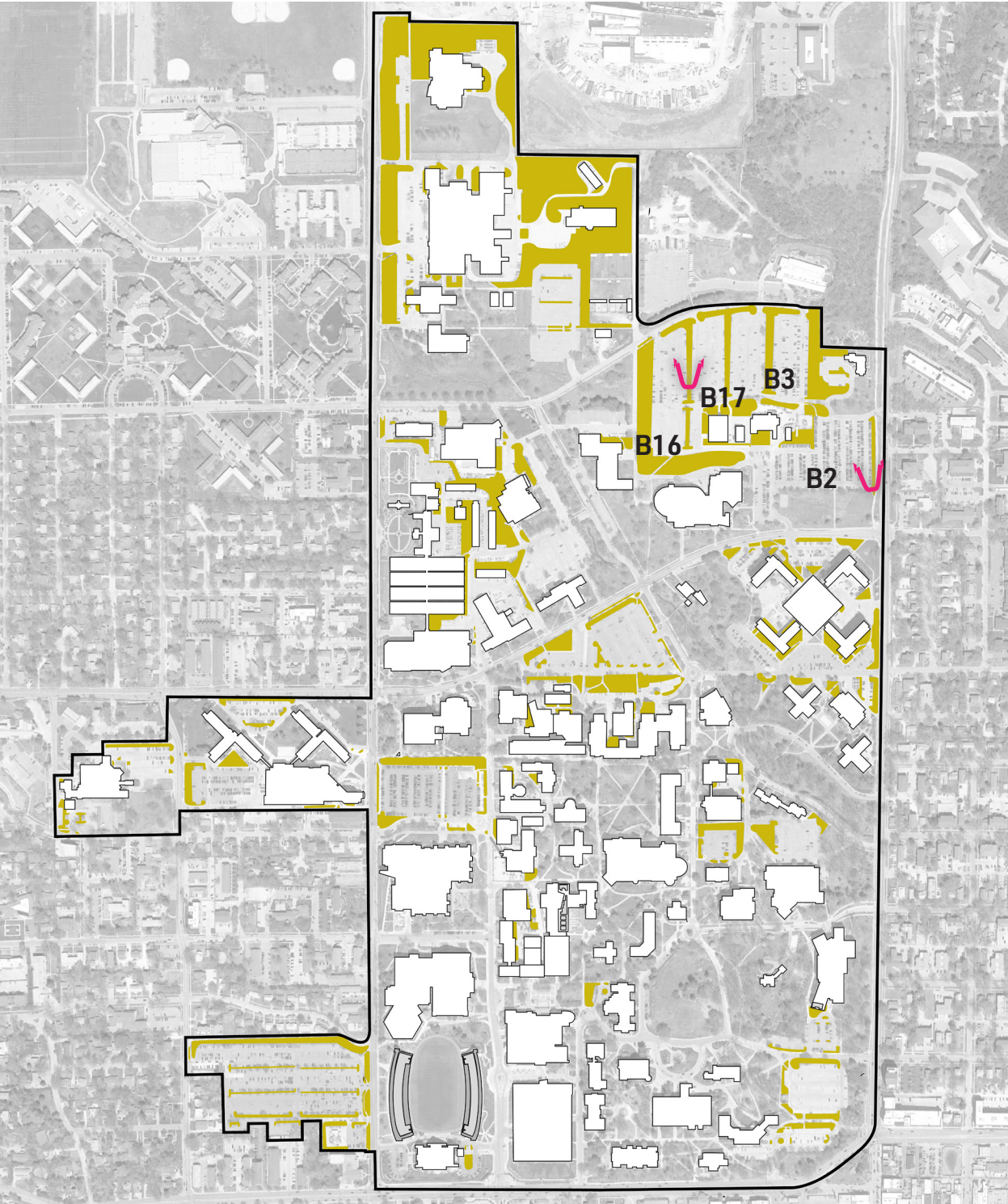


Figure 4.6 Illustrates the locations of the surface parking landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

Surface Parking

Plan not to scale

Site Limitations:

Planting sites in surface parking lots may be limited, and not every space is suitable for trees. Factors such as underground utilities, sight lines, and maintenance may restrict the size of trees.

Visibility:

In surface parking lots, trees should be placed to avoid obstructing sightlines and signage and should not interfere with loading zones or emergency vehicle routes.

Provide Tree Canopy:

Trees can provide shade, cooling, and beauty to surface parking lots. They can also reduce runoff, improve air quality, and sequester carbon. Trees should be planted along the edges or corners of the parking lot or on islands within the parking lot.

Considerations for Tree Selection

Select Trees for Durability:

Trees for surface parking lots should be chosen for their durability, adaptability, and suitability for the site. They should be able to withstand the harsh conditions of the parking lot, such as heat, salt, pollution, and compacted soil. They should also be low-maintenance and produce minimal litter. Trees should have a high canopy, a small to moderate root zone, and a non-invasive root system.



MAPPED SURFACE PARKING LOCATIONS

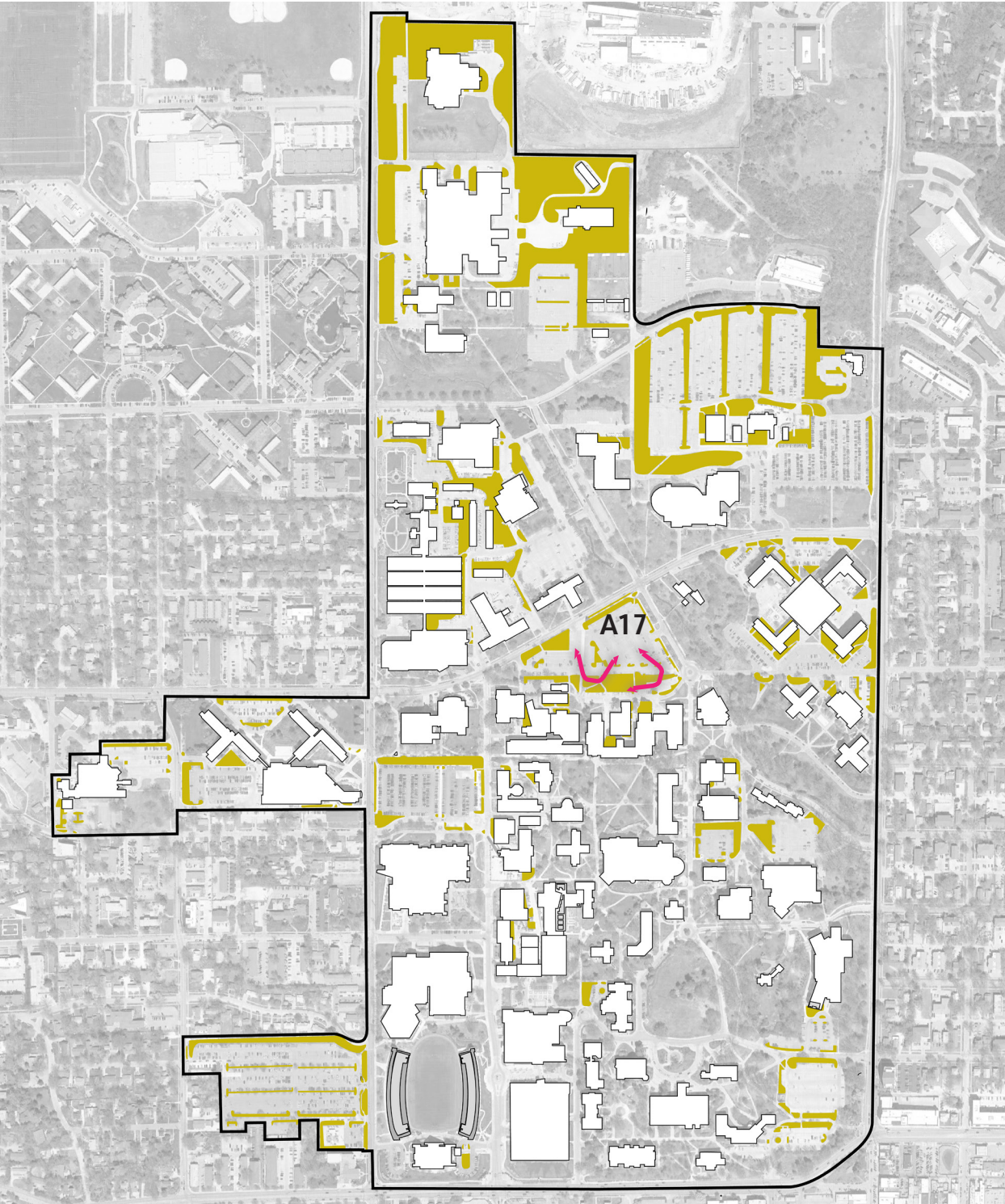


Figure 4.7 Illustrates the locations of the surface parking landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

Surface Parking

Plan not to scale

PLAZAS
Physical Characteristics

Kansas State University campus plazas are open, public spaces that serve as gathering places for people and events. They are usually located in the heart of a campus, such as Bosco Plaza, the plaza east of Durland Hall, and the plaza west of Bluemont Hall. These K-State plazas can vary in size, shape, design, and function, but they typically have some common features, such as expanse concrete surfaces, seating, landscaping, and lighting.

K-State plazas can range from large rectangular areas such as Bosco Plaza to more organic ones like the plaza west of Bluemont Hall. Their shape is often compatible with the surrounding buildings and contexts, providing space for flexible use. Existing landscape planting in these campus plazas varies but typically consists of shade trees and ornamental trees, shrubs, ground cover, and turf. Plazas vary in use and activity; for example, Bosco Plaza is a highly flexible space that supports programming year-round, including art installations, concerts, and markets, and the plaza west of Bluemont Hall is a more intimate plaza with seating.



MAPPED CAMPUS PLAZAS LOCATIONS

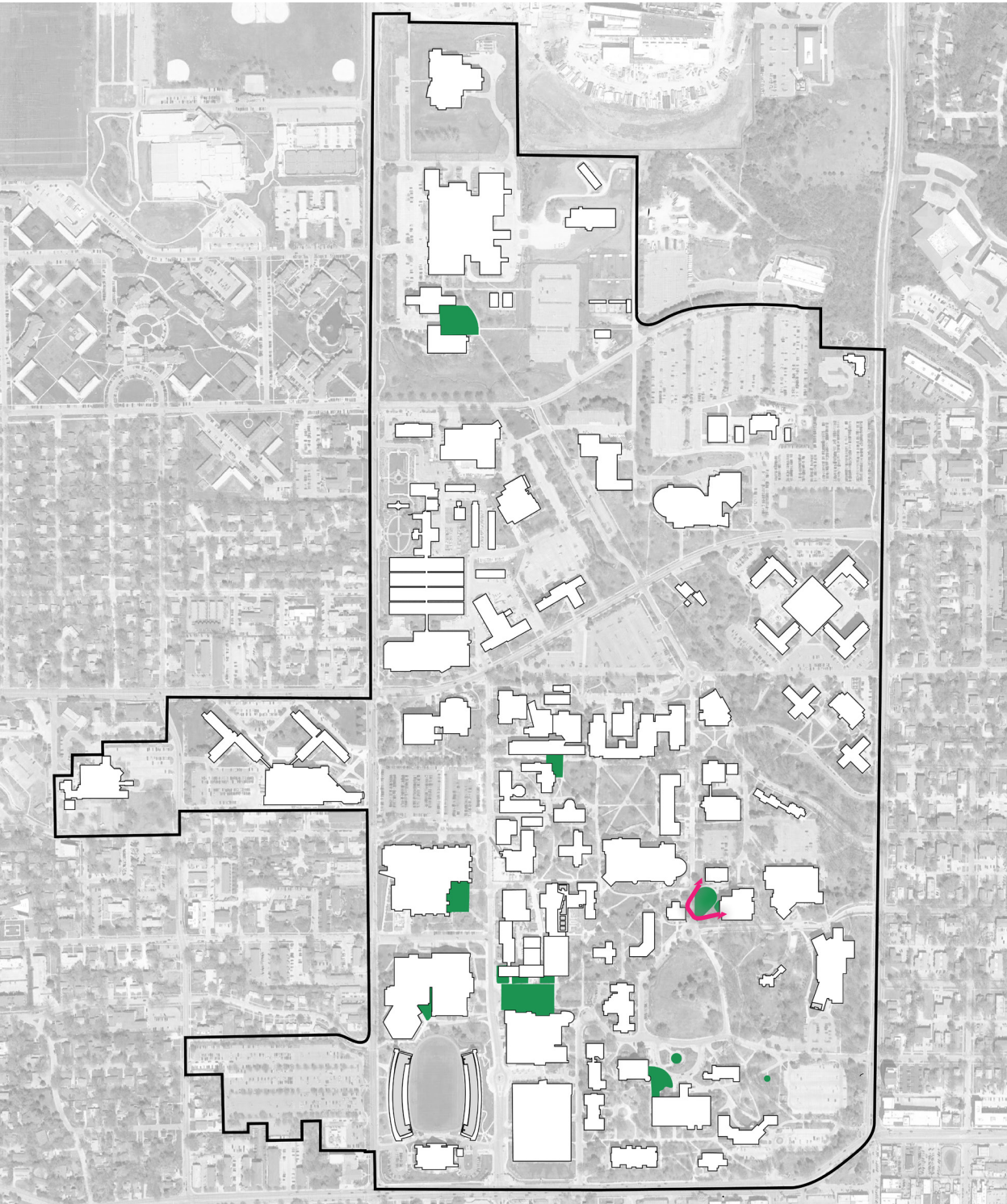


Figure 4.8 Illustrates the locations of the plaza landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

Plazas

Plan not to scale ⓘ



MAPPED CAMPUS PLAZAS LOCATIONS

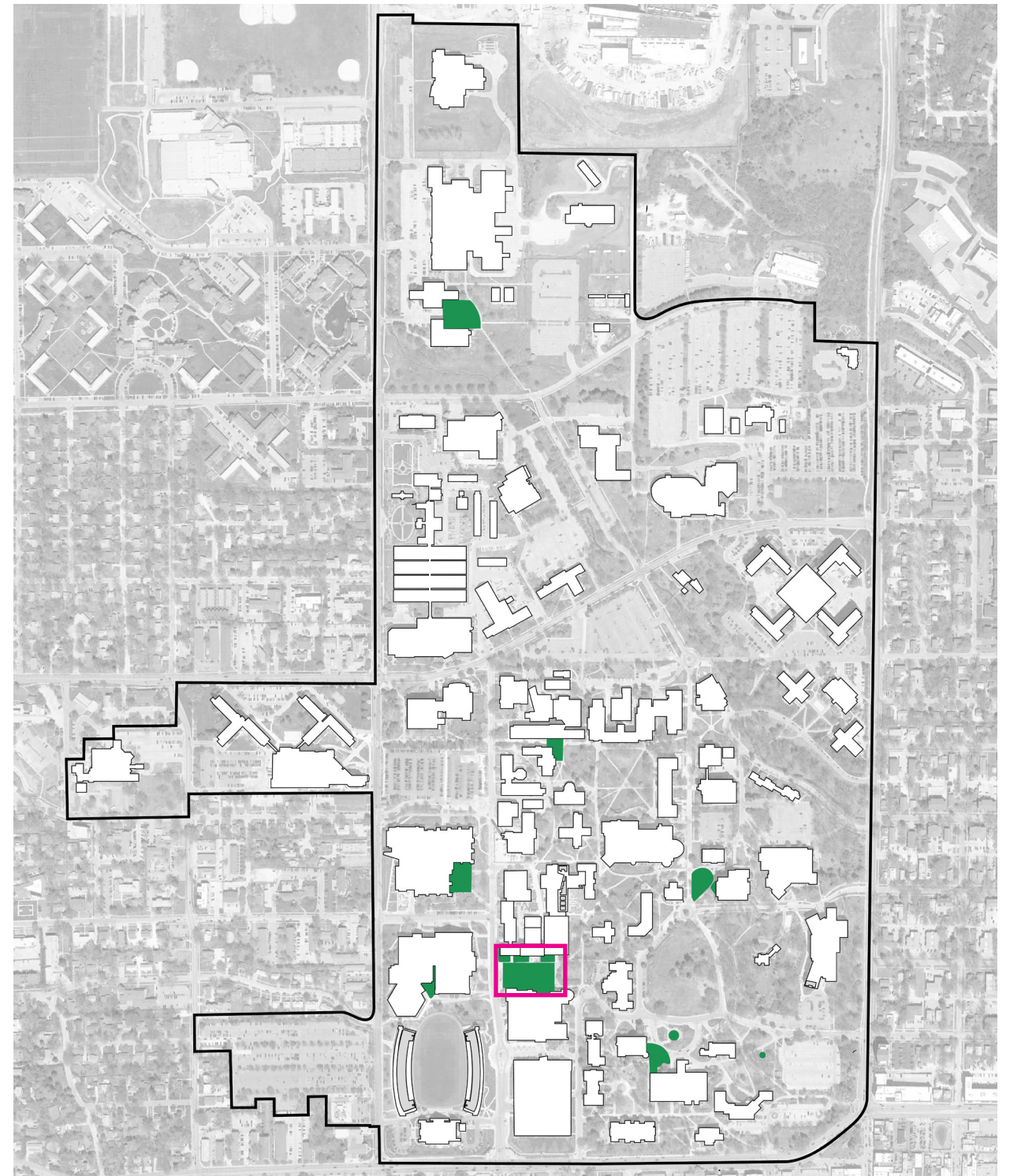


Figure 4.9 Illustrates the locations of the plaza landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

■ Plazas

Plan not to scale ⓘ

Considerations for Tree Placement

Water and Heat Stress:

Paved surfaces are engineered to shed water quickly, often depriving plants of adequate soil moisture or leaving their roots submerged in excess water. Paved surfaces also absorb and radiate heat, increasing the temperature and evaporation rate in the parking lot. These factors can cause water and heat stress on trees.

Limited Soil Volumes:

Limited soil volumes may be a constraint, especially in plazas with raised planters, as limited soil volumes confine roots, restricting root growth and often supplying inadequate moisture and nutrients. This can affect the health and stability of trees.

Root vs. Pavement Conflict:

The lateral growth of shallow tree roots can cause sidewalks to crack and heave, creating uneven displacement of adjoining sections of concrete. This can damage the pavement and create tripping hazards.

Winter Salting Stress:

Plazas are often salted in the winter, which can further stress trees by increasing soil salinity.



MAPPED CAMPUS PLAZAS LOCATIONS

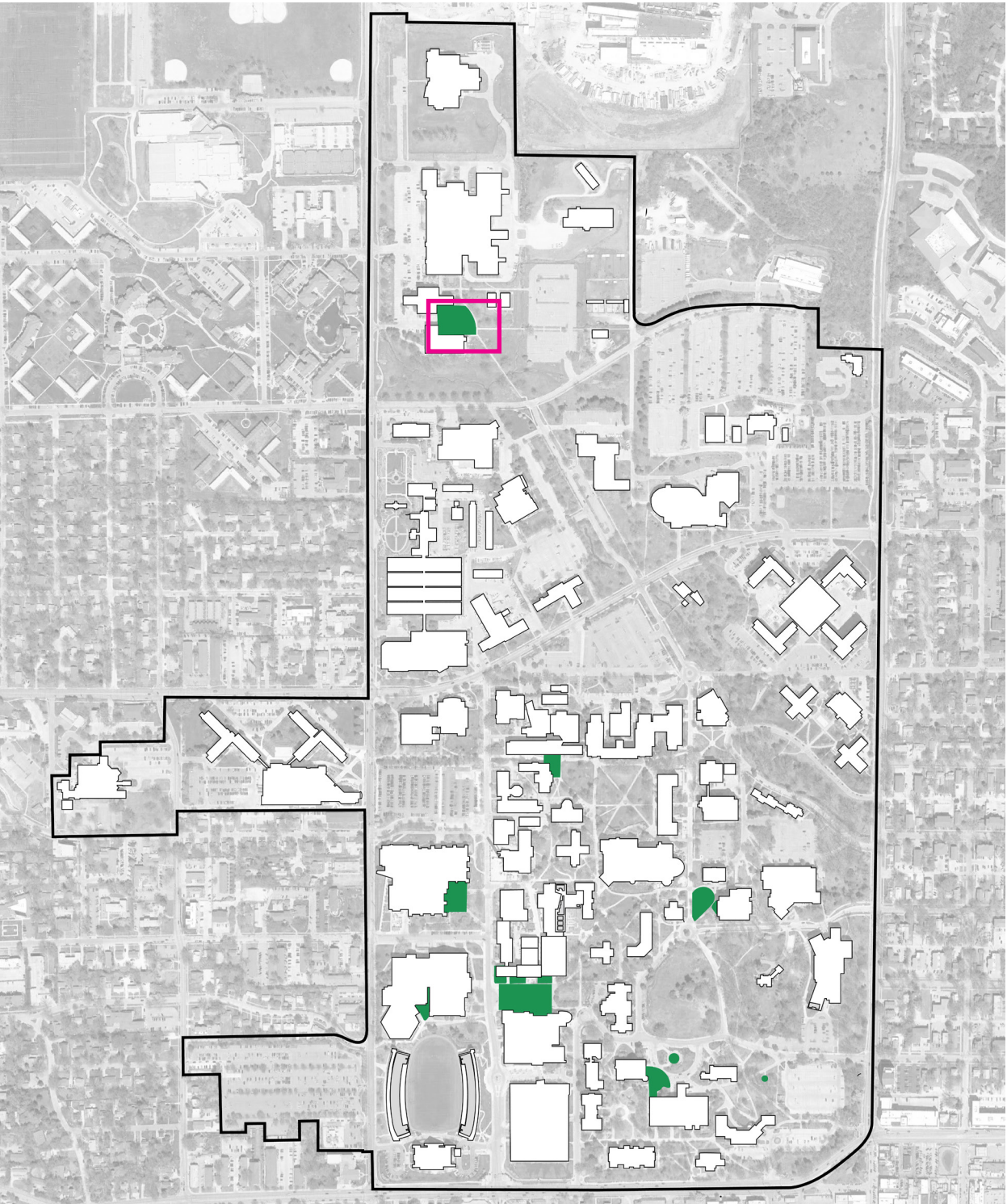


Figure 4.10 Illustrates the locations of the plaza landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

Plazas

Plan not to scale ⓘ

Access and Circulation:

Tree placement should ensure clear access for emergency vehicles and not hinder gathering events, as well as flexible programming.

Site Limitations:

Planting sites in plazas may be limited, and not every space is suitable for trees. Factors such as underground utilities, sight lines, security, flexible programming, and maintenance may restrict the location and size of trees planted.

Provide Tree Canopy:

Trees can provide shade, cooling, and beauty to campus plazas. They can also reduce runoff, improve air quality, and sequester carbon. Trees should be planted along the edges or corners of the plaza or on islands and planters within the plaza. The islands should be large enough to accommodate the tree roots and provide adequate soil volume.

Architectural features:

K-State plazas feature elements like fountains, sculptures, stages, signs, and pavilions that enhance aesthetics and interaction. Tree placement near these features requires careful consideration. For example, when placing a tree near a water feature, consider the maintenance implications, such as the potential for fallen leaves clogging the water flow.

Functionality:

Plaza tree placement should consider programmed activities in these spaces. Opt for species with broad canopies for larger spaces and smaller trees for intimate areas. Coordinate the placement of trees with seating areas, tables, and other amenities.



MAPPED CAMPUS PLAZAS LOCATIONS

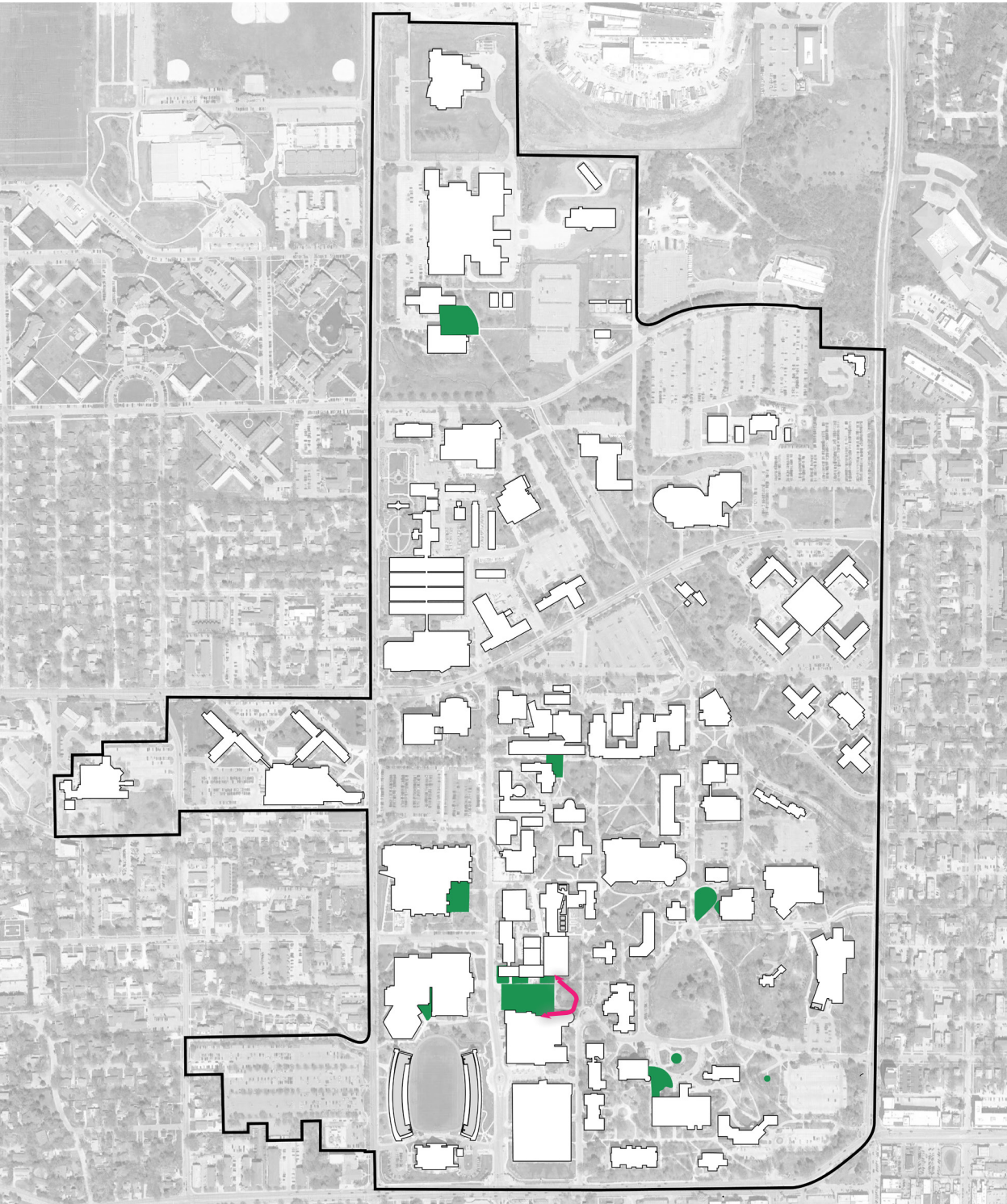


Figure 4.11 Illustrates the locations of the plaza landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

Plazas

Plan not to scale

Considerations for Tree Selection

Select Trees for Durability:

Trees for Plazas should be chosen for their durability, adaptability, and suitability for the site. They should be able to withstand the conditions of those plazas with salt, pollution, and compacted soil. They should also be low-maintenance and produce minimal litter. Trees should have a high canopy, a small to moderate root zone, and a non-invasive root system.

Allergen Consideration:

Consider any potential allergenic properties of certain tree species, especially if the plaza is a high-traffic area frequented by students, faculty, and visitors.

Seasonal Interest:

Look for trees that offer visual interest throughout the year, including colorful foliage in autumn, blossoms in spring, and attractive bark or structure in winter.

Aesthetic Appeal:

Choose trees that enhance the overall visual appeal of the campus plazas. Consider factors such as foliage color, texture, and form.



MAPPED CAMPUS PLAZAS LOCATIONS

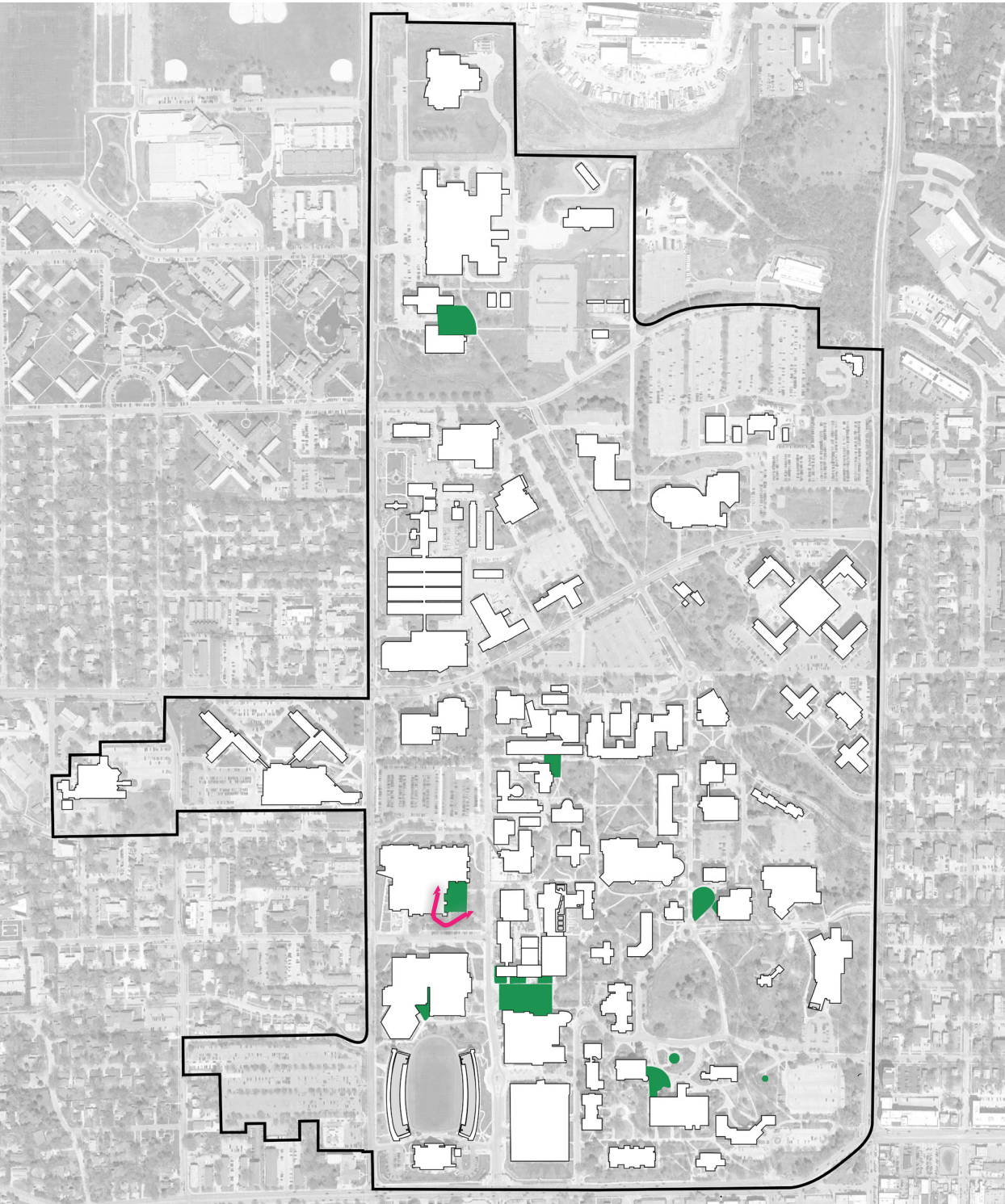


Figure 4.12 Illustrates the locations of the plaza landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

Plazas

Plan not to scale

QUADRANGLES
Physical Characteristics

On the K-State campus, quadrangles, colloquially known as quads, are formal open green spaces that take on either a rectangular or square shape. These spaces are partially or completely enclosed by surrounding university buildings and trees. Quads are typically oriented along a cardinal direction, such as north-south or east-west, serving as central hubs connecting various campus buildings. In addition to their functional role, these spaces may offer outdoor studying, recreation, and social interaction opportunities. Landscapes on quadrangles are characterized by large lawns that may be used for recreation, relaxation, or events. The edges of the quadrangle may feature garden plantings and shade trees, which provide enclosure and visual interest. Quadrangles typically have trees along the edges to provide shade and scale the buildings and alongside sidewalks to provide shade and comfort.

The K-State quadrangle, located at the heart of the campus, is surrounded by Leasure Hall, Waters Hall, Willard Hall, and Hale Library. This area serves as the academic hub of the campus and experiences a high volume of pedestrian traffic during class hours. The quadrangle is designed formally, featuring an open, sunlit lawn bordered by large-canopy trees along its outer edge. Numerous sidewalks crisscross the area, providing pedestrians easy access to the surrounding academic buildings.

The quadrangle situated between Boyd Hall, Van Zile, and Putnam Hall functions as a communal space for students, linking dorm rooms and dining facilities. This area is characterized by an open lawn with minimal tree coverage, creating a spacious and welcoming environment for students to connect and relax.



MAPPED QUADRANGLE LOCATIONS

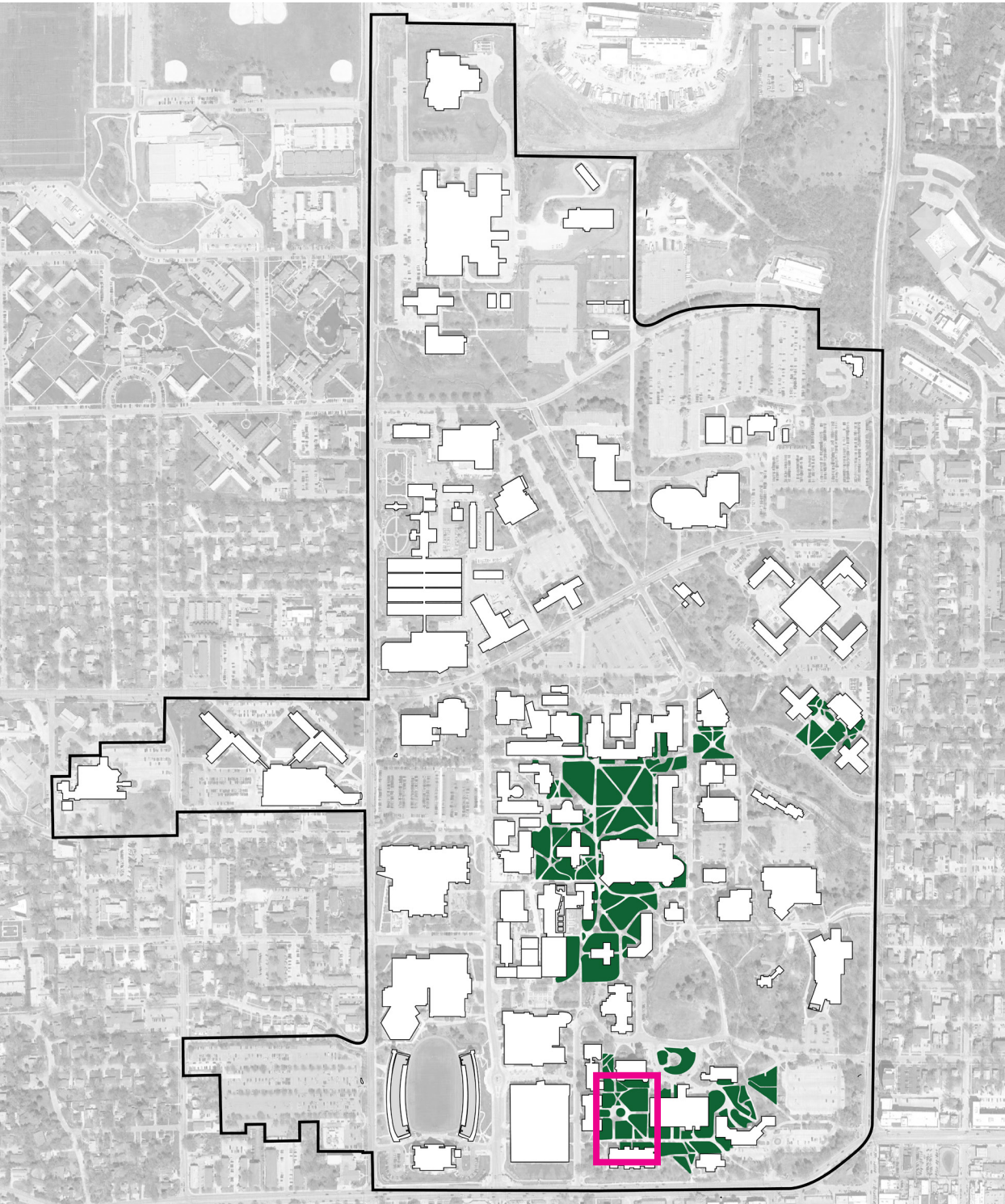


Figure 4.13 Illustrates the locations of the quadrangle landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

■ Quadrangles

Plan not to scale ⓘ

Considerations for Tree Placement

Root vs. Pavement Conflict:

The lateral growth of shallow tree roots can cause sidewalks and pavements to crack and heave, creating uneven displacement of adjoining concrete sections. This can damage the pavement and create tripping hazards. Therefore, placement needs to be considered when planting a new tree, such as a tree near a concrete walk; the tree's root system should be noninvasive.

Functionality:

Consider the size and species of trees to be planted. Larger trees can provide a natural canopy for larger gatherings, while smaller trees can create intimate spaces for smaller groups. The placement of trees should allow for flexible use of space. Plant large canopy trees along paths to provide shade for pedestrians and cyclists and reduce heat gain from pavement.

Considerations for Tree Selection

Allergen Consideration:

Consider any serious allergenic properties of certain tree species.

Provide Tree Canopy:

Trees can shade, cool, and beautify quadrangles. They can also reduce runoff, improve air quality, and sequester carbon.



MAPPED QUADRANGLE LOCATIONS

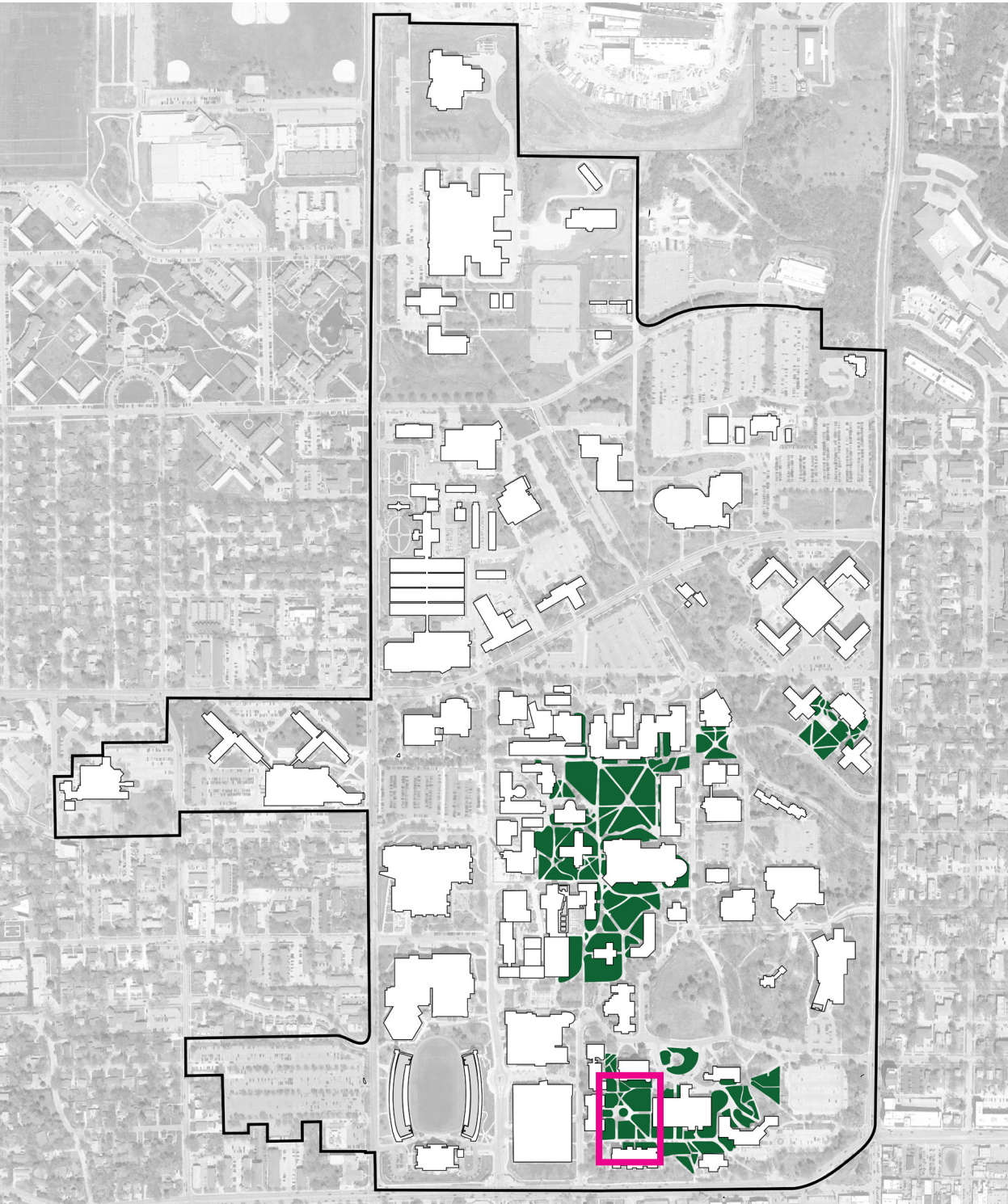


Figure 4.14 Illustrates the locations of the quadrangle landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

■ Quadrangles

Plan not to scale ⓘ



MAPPED QUADRANGLE LOCATIONS

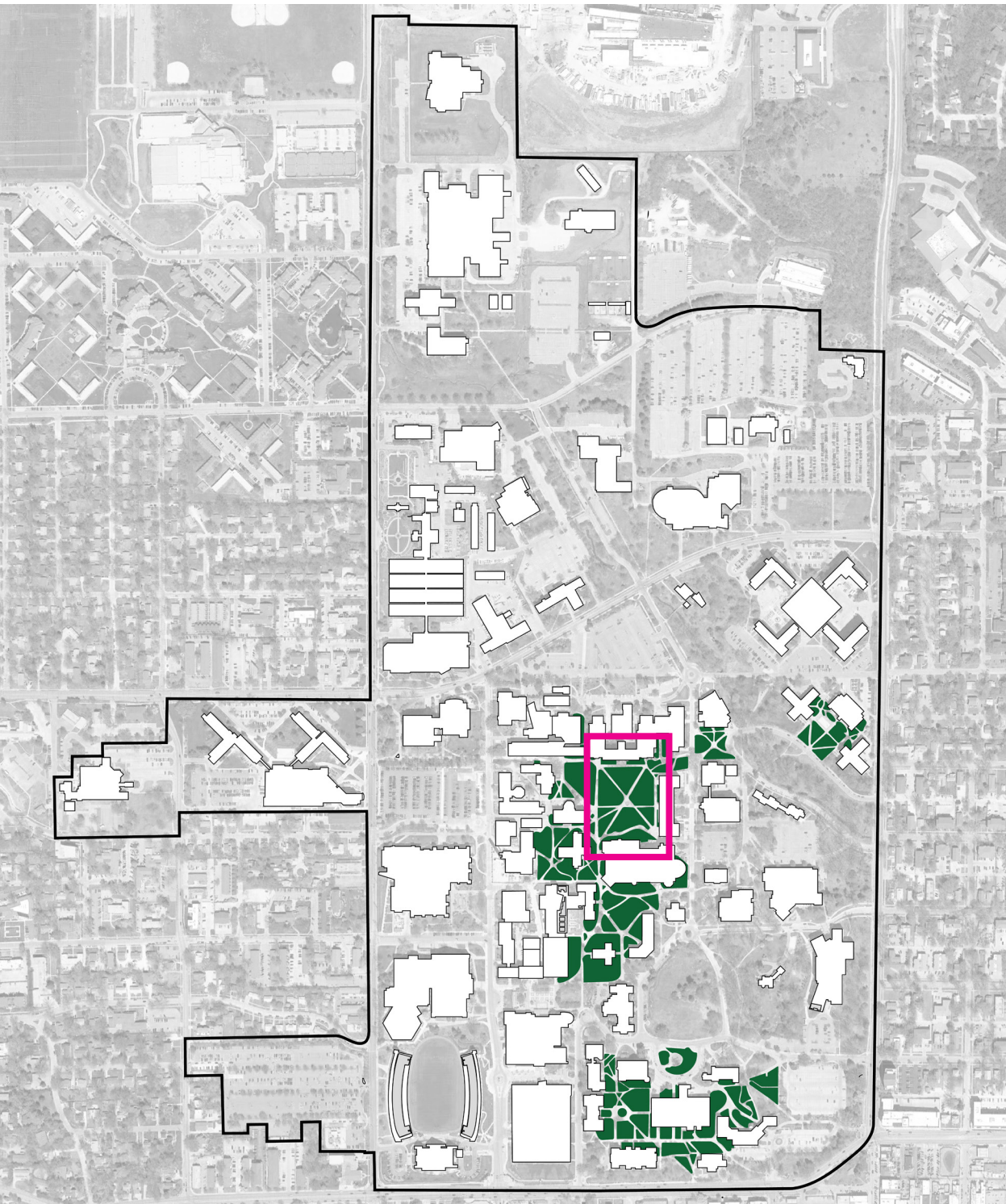


Figure 4.15 Illustrates the locations of the quadrangle landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

■ Quadrangles

Plan not to scale ⓘ



MAPPED QUADRANGLE LOCATIONS

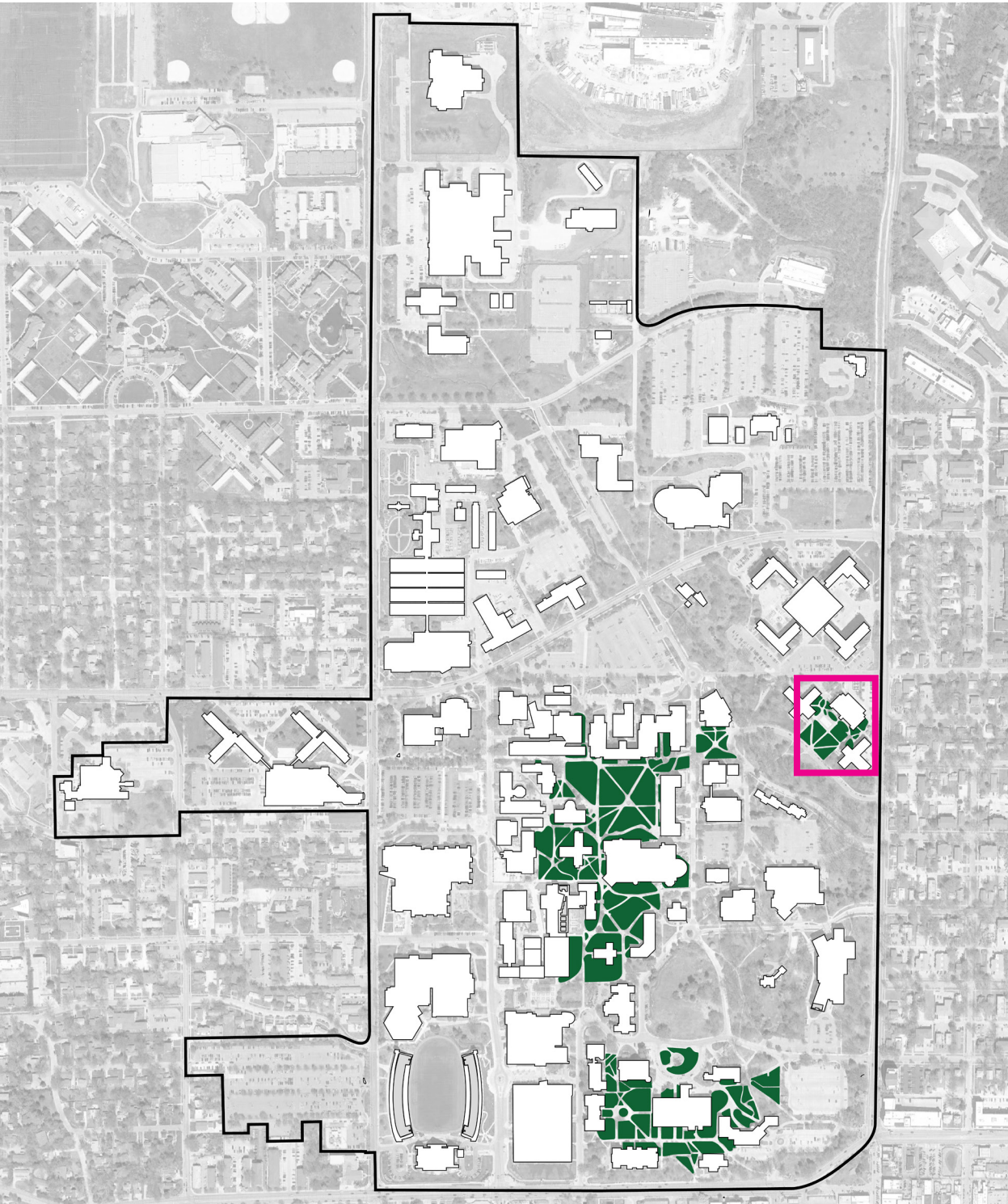


Figure 4.16 Illustrates the locations of the quadrangle landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

■ Quadrangles

Plan not to scale ⓘ

CAMPUS GREEN
Physical Characteristics

Campus greens at K-State are open and informal spaces that are either quality landscapes preserved as the campus is developed or undeveloped areas with minimal landscaping. These campuses open green spaces have a mix of sunny and shady areas and may resemble quadrangles or plazas, depending on their location and use. The campus greens at K-State serve as versatile open spaces, offering a blend of both preserved landscapes and minimally landscaped areas.

The size and shape of the campus green greatly depends on the available space and the layout of landscaped areas. Some greens are large expanses of lawn, such as Anderson Lawn, which is a space composed of primarily turf and large mature deciduous trees; this lawn frames the front of Anderson Hall and is used for large gatherings and events by K-State. Most of the K-State campus greens are unnamed but consist of lawns interspersed with a mix of deciduous and evergreen trees, varying in sizes and ages, and other campus green locations simply consist of small, landscaped areas with only turf. The campus features additional green areas designed to capture stormwater. These include rain gardens and bio-swales, often strategically located to reduce runoff, thereby enhancing water quality.



MAPPED CAMPUS GREEN LOCATIONS

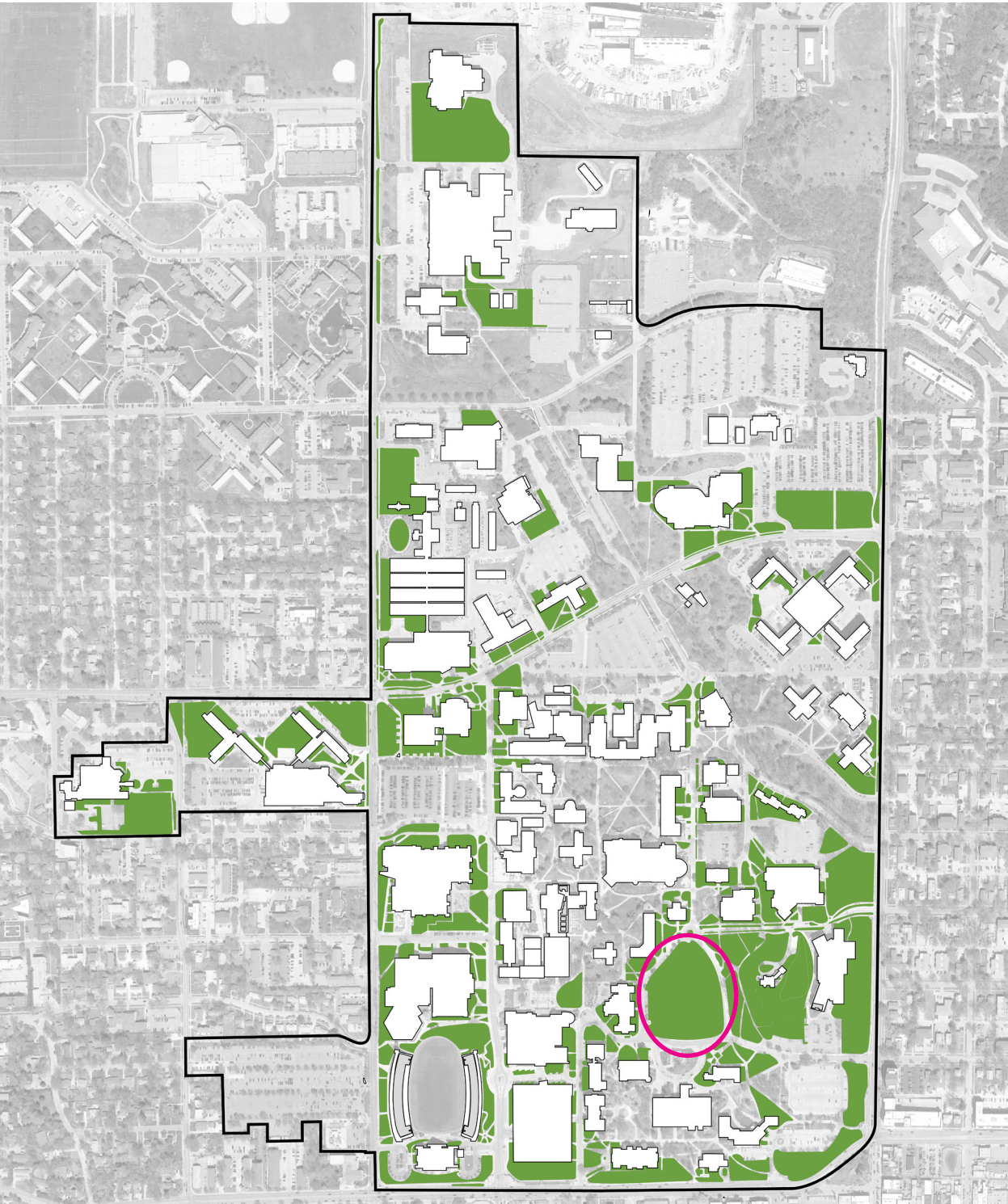


Figure 4.17 Illustrates the locations of the campus green landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

■ Campus Green

Plan not to scale ⓘ



MAPPED CAMPUS GREEN LOCATIONS

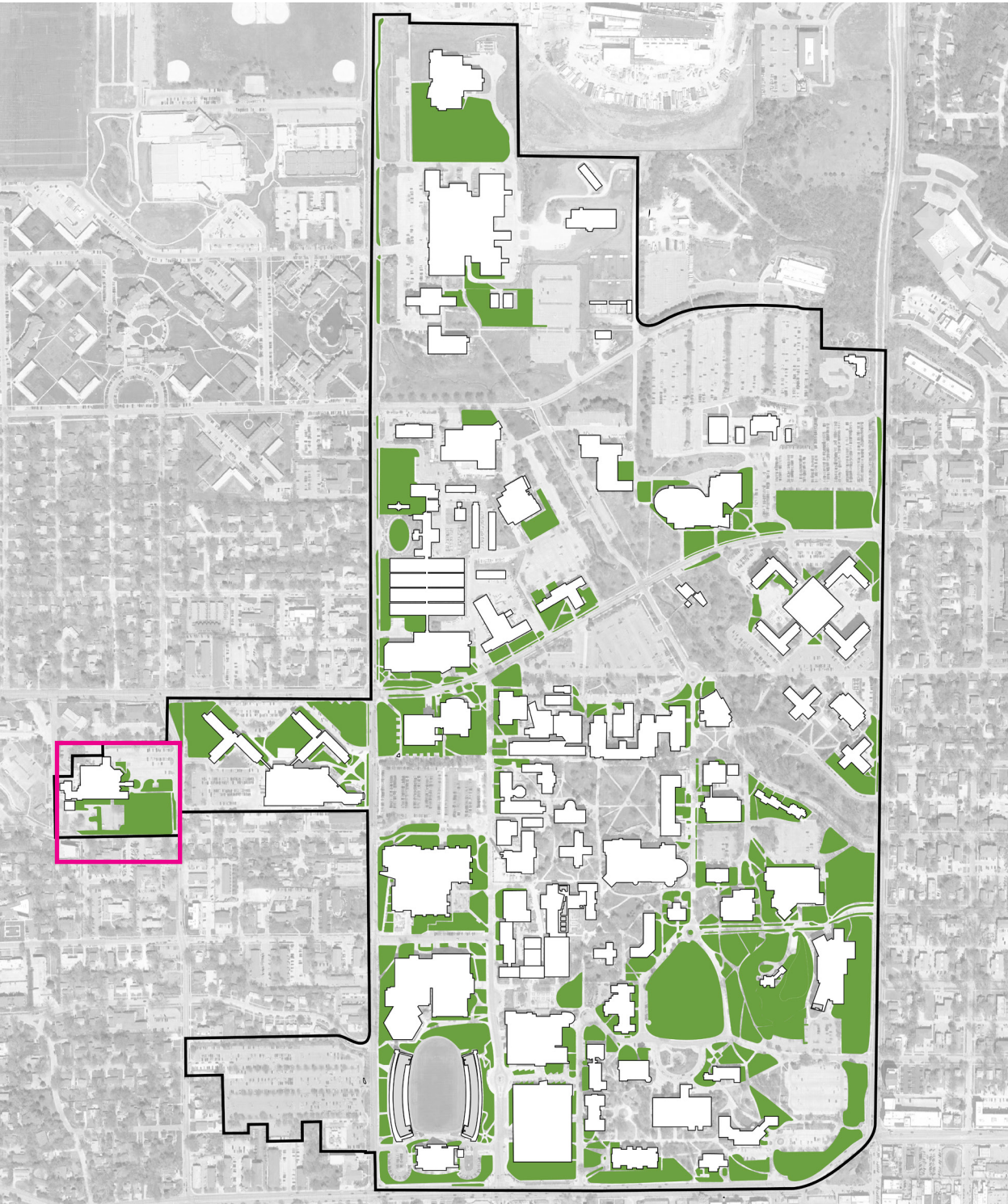


Figure 4.18 Illustrates the locations of the campus green landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

■ Campus Green

Plan not to scale ⓘ

Considerations for Tree Placement

Soil Quality:

The soil quality across the campus greens may not be conducive to root growth in certain areas, as it could be either compacted or poorly drained. This issue can restrict tree growth and survival. Therefore, the trees' tolerance to compacted soils should be considered.

Limited Space:

Some campus green spaces may have limited space for planting trees due to the presence of overhead and underground utilities. These factors may restrict the location and size of planting areas and the height and spread of trees. Therefore, the tree's size and shape should be compatible with the available space.

Root vs. Pavement Conflict:

The lateral growth of shallow tree roots can cause sidewalks and pavements to crack and heave, creating uneven displacement of adjoining sections of concrete. This can damage the infrastructure and create tripping hazards. Therefore, the tree's root system should be noninvasive when planting a tree near a concrete walk.

Allergen Consideration:

Consider any potential allergenic properties of certain tree species, especially if the campus green is a high-traffic area frequented by students, faculty, and visitors.

Considerations for Tree Selection

Provide Tree Canopy:

Trees can provide shade, cooling, and beauty to the campus green.



MAPPED CAMPUS GREEN LOCATIONS

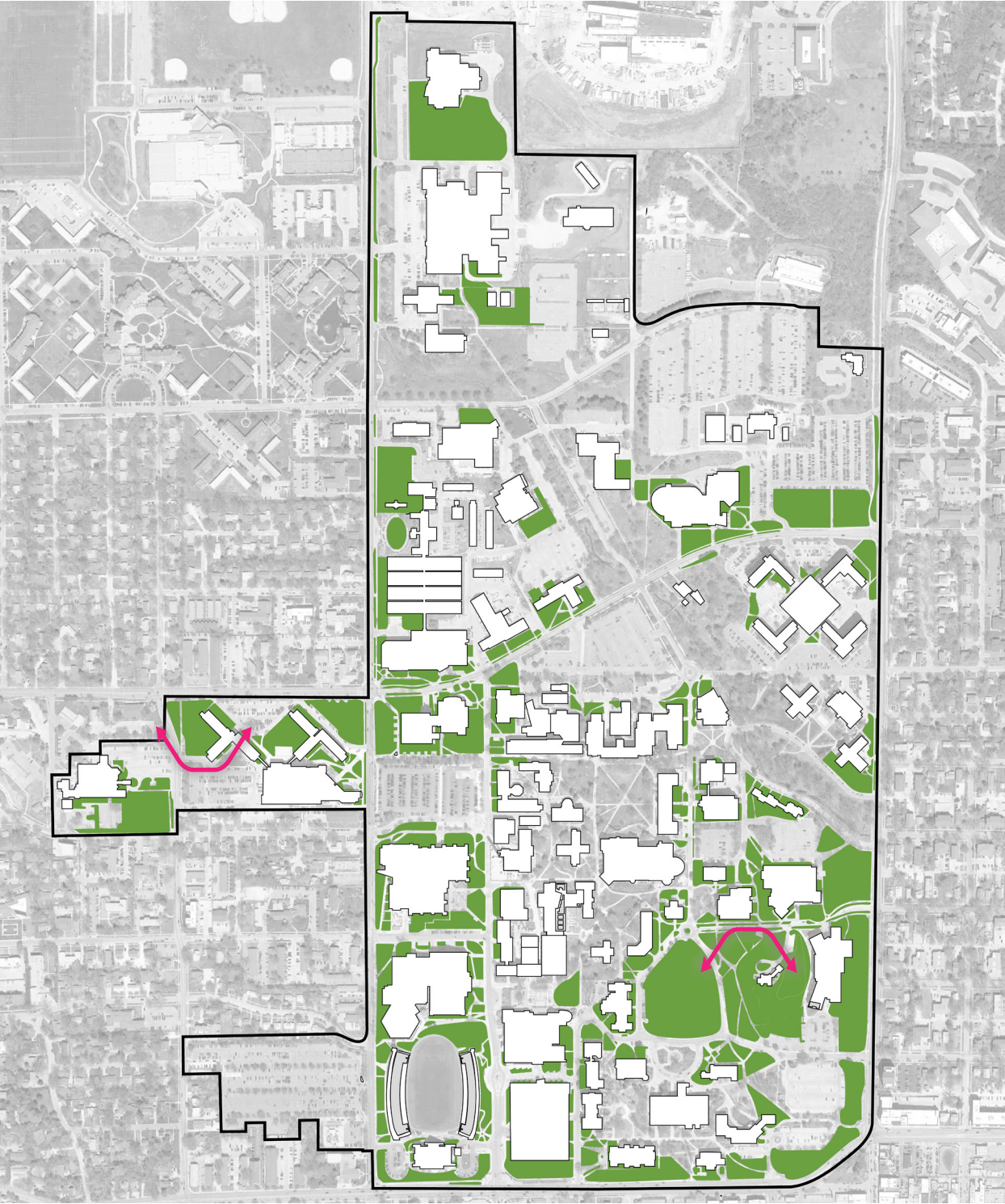


Figure 4.19 Illustrates the locations of the campus green landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

Campus Green

Plan not to scale



MAPPED CAMPUS GREEN LOCATIONS

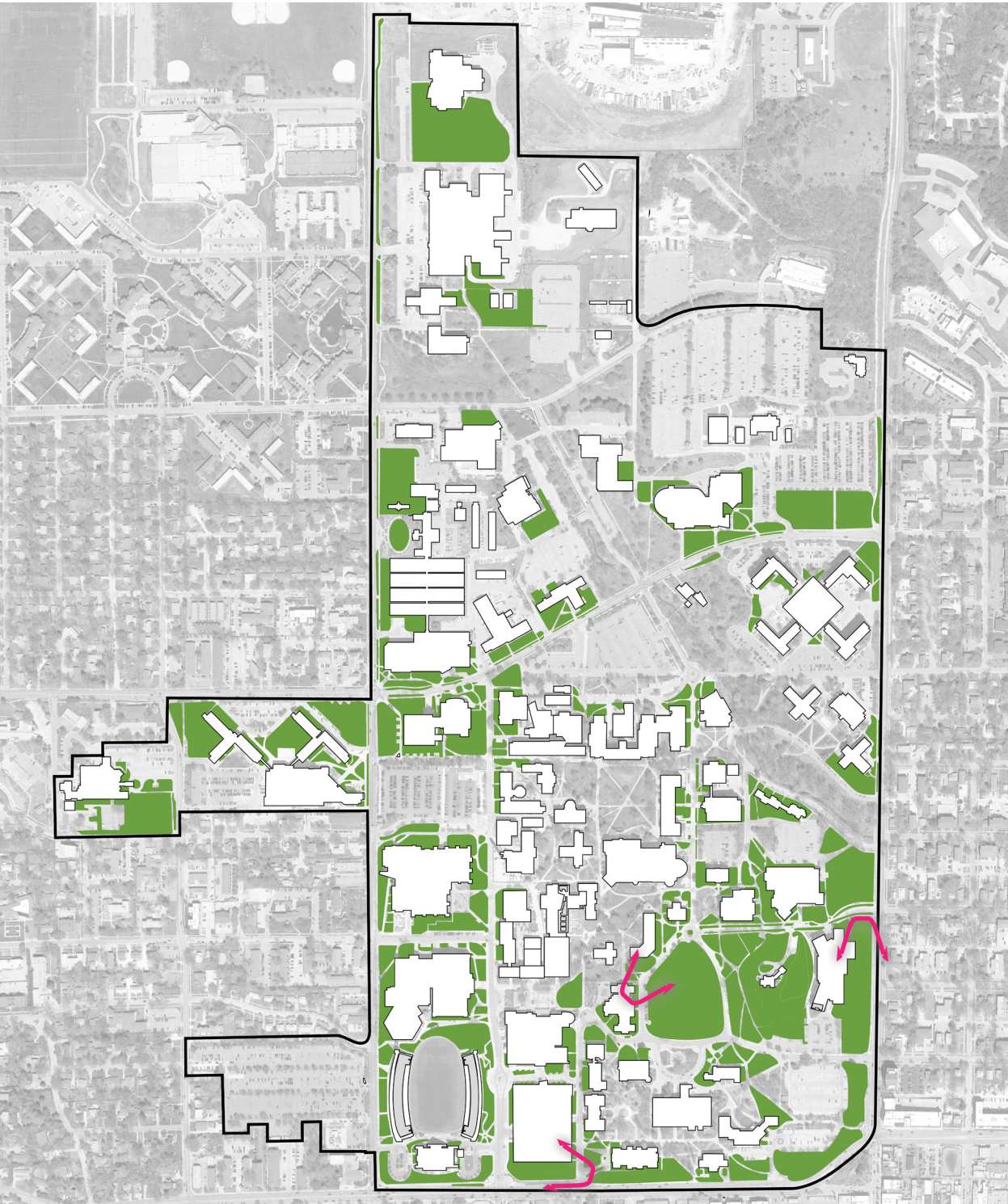


Figure 4.20 Illustrates the locations of the campus green landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

Campus Green

Plan not to scale

CAMPUS CORRIDOR
Physical Characteristics

The K-State Campus Corridor, a unique landscape typology of the university, offers a contrast to the more structured and organized spaces across the campus. This landscape is characterized by heavily wooded areas interspersed with meandering creeks, creating a picturesque environment. In contrast, other spaces within the campus corridor are not densely wooded. Instead, they feature a variety of trees and shrubs of different sizes, ages, and types, set against large expanses of open lawns like the vastness of a prairie. This particular landscape typology stands out for its less manicured areas and dominance in woody plants, distinguishing it from other landscape typologies inventoried in this method.

Considerations for Tree Placement

Consider replacing ash trees that are mature or dying to maintain the health and aesthetics of the landscape.

When planning the placement of trees, consider the location of future building projects, utilities, and potential creek restoration.

Seize the opportunity to plant memorial trees and select species interesting for tree walks.



MAPPED CAMPUS CORRIDOR LOCATIONS

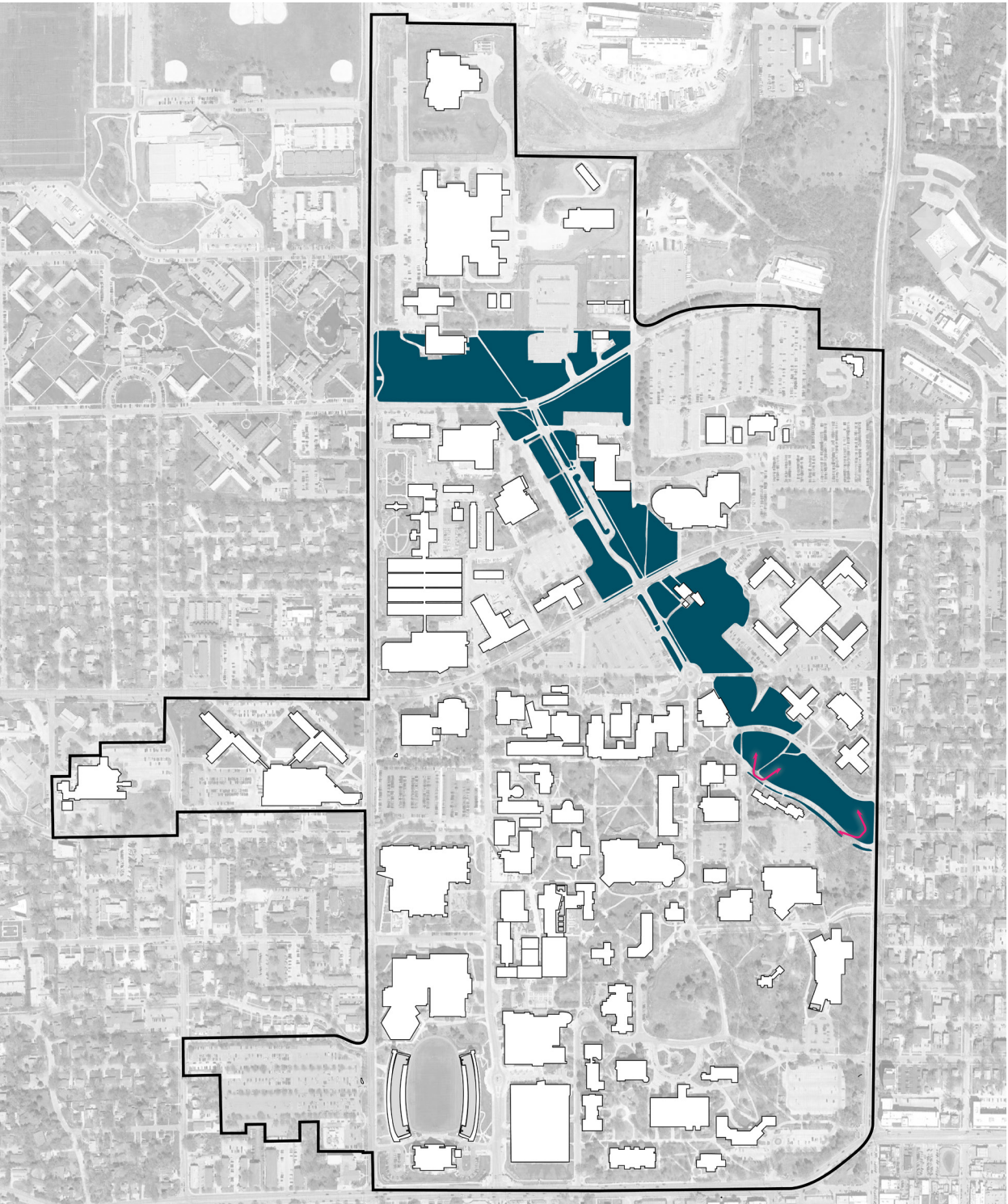


Figure 4.21 Illustrates the locations of the campus corridor landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

■ Campus Corridor

Plan not to scale ⓘ

Considerations for Tree Selection

Flooding:

Several key factors must be considered when selecting trees for the campus corridor, especially in areas near water or prone to frequent flooding. First and foremost, the species chosen must be able to endure periodic flooding and adapt to waterlogged soils. Secondly, it's advantageous to opt for plants with robust root systems. Such plants serve a dual purpose - stabilizing creek banks and preventing erosion, offering a natural and effective solution to this widespread issue. In addition, the selected trees must be able to tolerate sediment deposition. This unique trait enables them to flourish even when soil composition changes. Finally, it's worth considering trees that can efficiently manage stormwater. These trees, capable of effectively absorbing water or stabilizing banks, are an excellent choice for areas susceptible to heavy flooding.



MAPPED CAMPUS CORRIDOR LOCATIONS

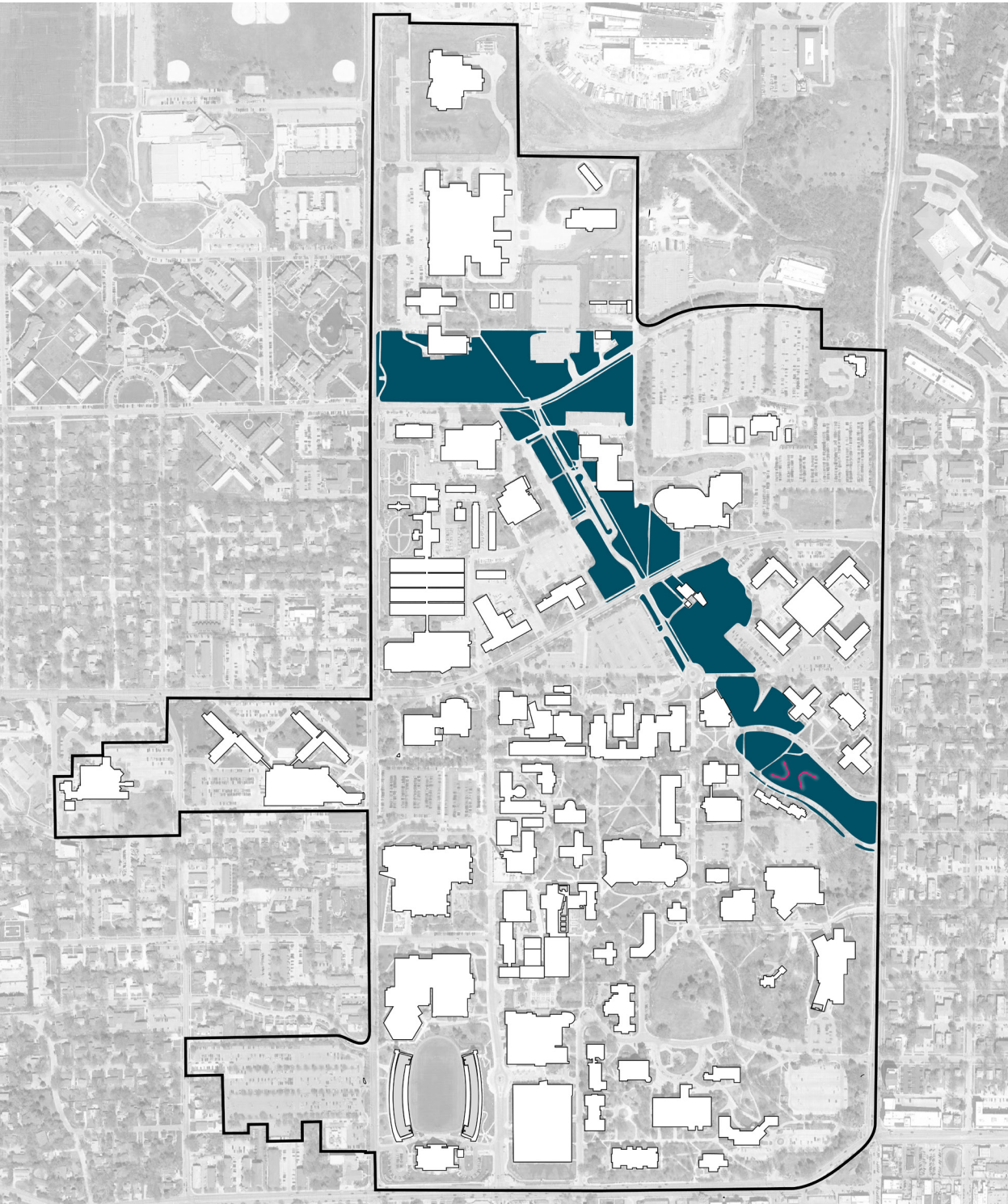


Figure 4.22 Illustrates the locations of the campus corridor landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

Campus Corridor

Plan not to scale ⓘ



MAPPED CAMPUS CORRIDOR LOCATIONS

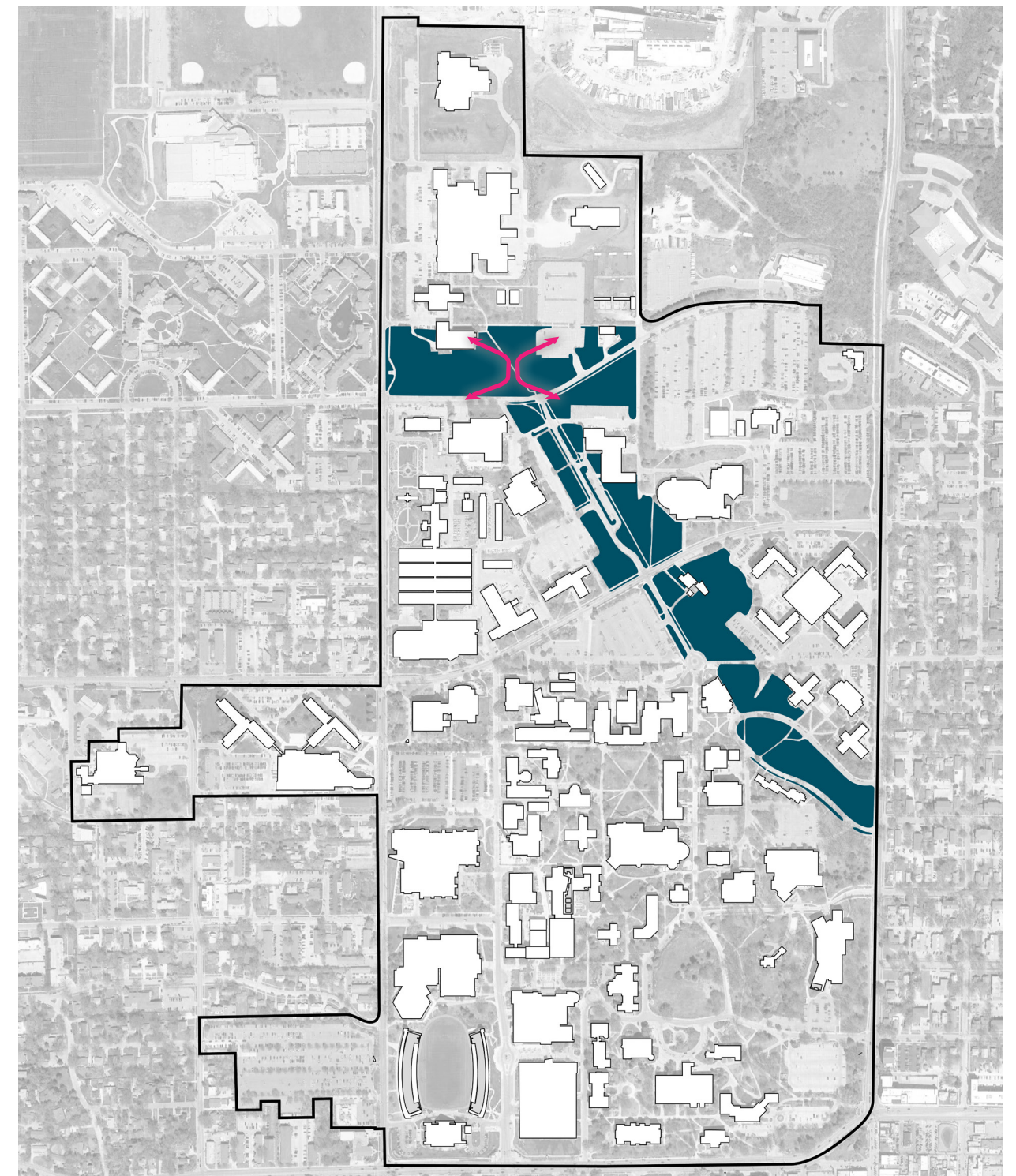


Figure 4.23 Illustrates the locations of the campus corridor landscape typology at Kansas State University (by author using satellite imagery from Google Earth 2022).

LEGEND

■ Campus Corridor

Plan not to scale ⓘ

CLIMATE EVALUATION

The climate evaluation shows predictions for the Kansas climate by the end of the 21st century and which areas in the US currently match those predicted conditions. The study examined two sets of maps for the conterminous United States for each metric, one showing recent conditions (1980-2009) and the other showing potential conditions (2070-2099) under a high emission scenario. The high emissions scenario, also known as RCP 8.5, represents a future where greenhouse gas emissions continue to rise throughout the 21st century without effective control policies. This scenario is characterized by increasing fossil fuel consumption and the absence of climate change mitigation policies (Matthews et al. 2018).

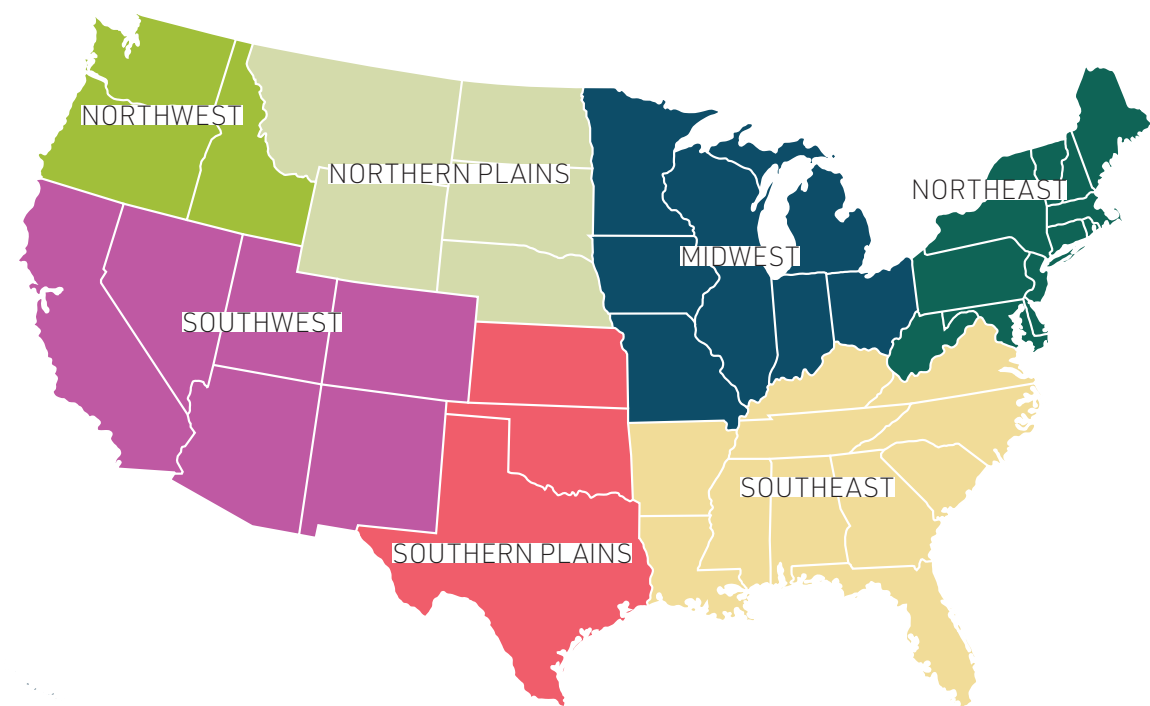


Figure 4.24 Regions of the conterminous United States as defined in the report: Assessing Potential Climate Change Pressures across the Conterminous United States:Mapping Plant Hardiness Zones, Heat Zones,Growing Degree Days, and Cumulative Drought Severity throughout this Century and used in this climate evaluation method (by author).

PLANT HARDINESS ZONES (1980-2009)

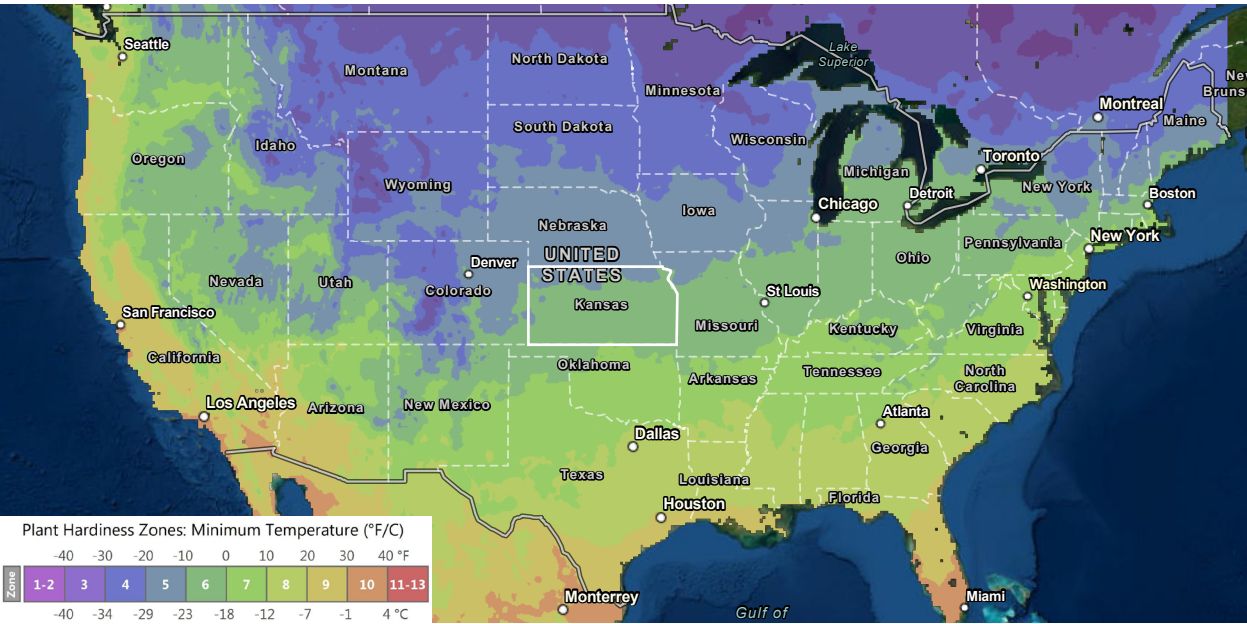


Figure 4.25 Recent Plant Hardiness Zones 1980-2009 Map (Climate 2022, Matthews et al. 2018).

Plant hardiness zones (PHZs) can indicate the extent of winter stress that plants experience due to cold temperatures. These zones are based on the average annual extreme minimum temperatures, and this information is used to evaluate the cold hardiness of plants (Climate 2022). The value in these maps is the absolute minimum temperature achieved for each year and reported as the 30-year mean. Due to their cold tolerance, hardiness zones reflect the range limits of many plant species, including woody ones. These maps delineate plant hardiness zones and subzones according to the USDA definitions, which break the geography into zones by 10 °F (5.56 °C) increments from zone 1 (-55 to -45.6 °C) to zone 13 (15.7 to 22 °C) of annual extreme minimum temperature (Matthews et al. 2018).

The Plant Hardiness Zones of the Southern Plains region extend from zone 5 in northern Kansas to zone 9 in southern Texas. Oklahoma is mostly in PHZ 7, except for its northern border, which is in PHZ 6. Kansas falls under Hardiness Zones 5 and 6, with a minimum temperature range of -28 to -17.8 degrees Celsius (Matthews et al. 2018). As of 2023, Manhattan, Kansas, is in zone 6, according to the 2023 USDA Plant Hardiness Zone Map (USDA 2023).

PROJECTED PLANT HARDINESS ZONES (2070-2099) (RCP 8.5)

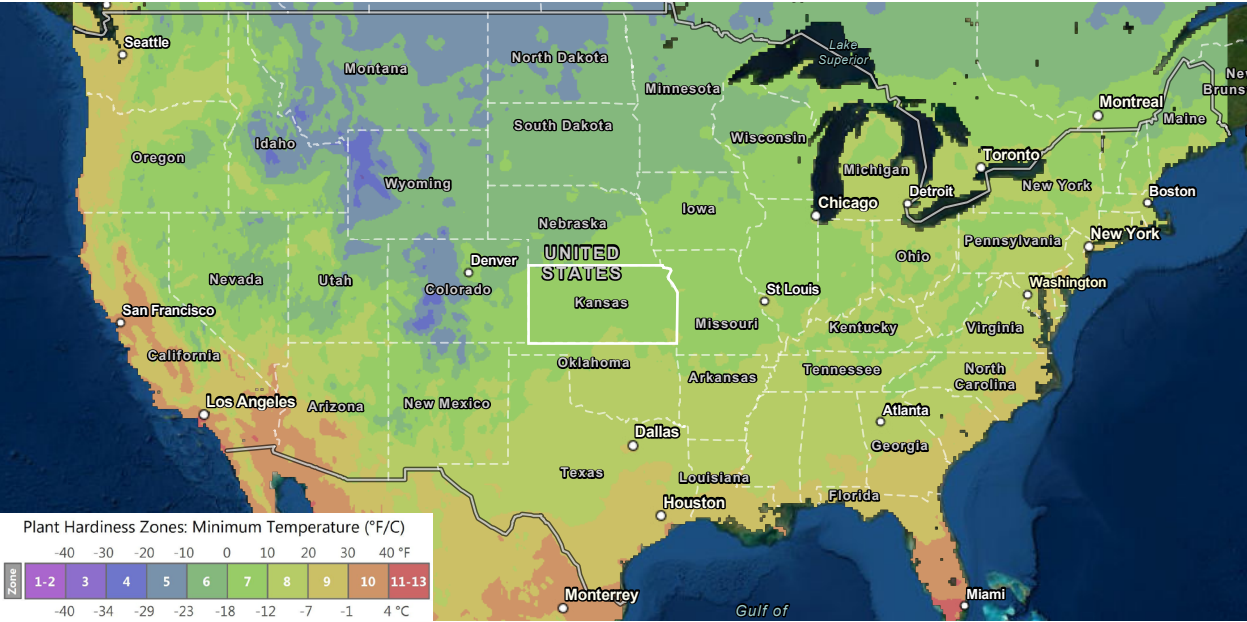


Figure 4.26 Projected Plant Hardiness Zones Under the High Emissions Scenario 2070-2099 RCP 8.5 Map. (Climate 2022, Matthews et al. 2018).

The high emissions scenario depicts a potential for significant temperature increases across all regions of the conterminous United States. By the end of the century, under the high scenario, minimum temperatures are projected to increase by at least 5 °C across the midwest, northeast, northern plains, and northwest regions. The minimum temperature in the Northeast and Midwest regions is forecasted to rise by at least 8-9°C, shifting towards warmer conditions throughout the entire distribution. The Southern Plains PHZ projections range from Zone 10 in South Texas to Zone 7 in Kansas. Most of Oklahoma is projected as zone 8, with some areas in zone 7.

- According to the projections, Kansas PHZs are expected to range from Zone 7 in most parts of the state to Zone 8 in a portion of the south-central region. Therefore, the minimum temperature across Kansas will fall between -17.7°C to -6.7°C under this scenario(Matthews et al. 2018).

PLANT HARDINESS ZONE 7-8 (1980-2009)

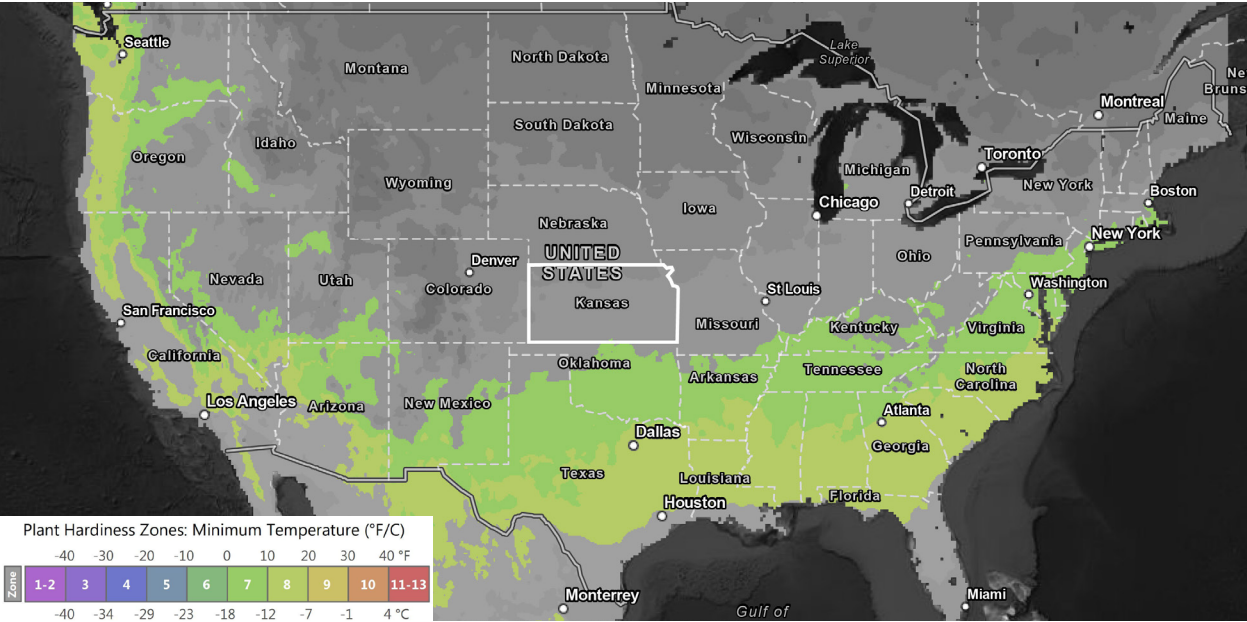


Figure 4.27 Highlighted regions in 1980-2009 that are the projected Plant Hardiness Zones for Kansas under the high emissions scenario for 2070-2099 (RCP8.5) (Climate 2022, Matthews et al. 2018).

PLANT HARDINESS ZONES TAKEAWAYS

A significant change in the plant hardiness zone for a state can adversely affect the survival and growth of many tree species. The warming temperatures in the future will result in zonal variations that can be utilized to identify the potential range of plant species. The temperature change can impact the survival, growth rate, and timing of developmental stages of trees, such as flowering and fruiting. It can also influence the abundance and types of pests and diseases in an area, affecting tree health(Matthews et al. 2018).

Therefore, it is essential to reassess the selection of tree species and choose those adapted to the projected hardiness zone 7 and 8 for the state of Kansas.

HEAT ZONES (1980-2009)

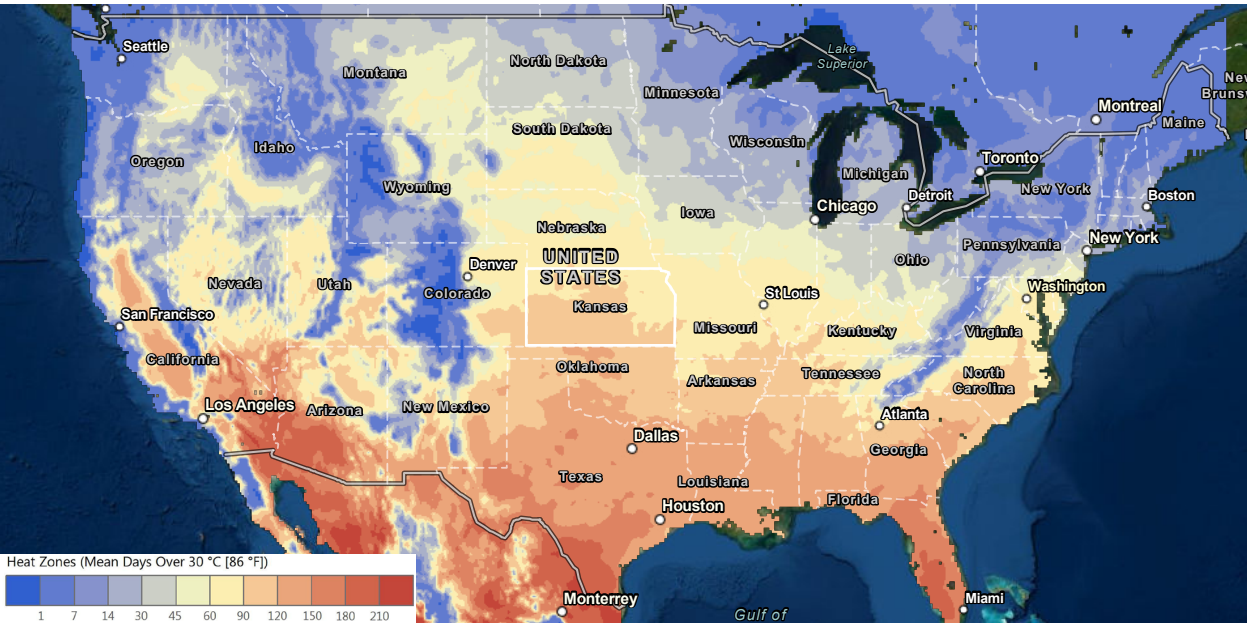


Figure 4.28 Historical 1980-2009 Heat Zones Map (Climate 2022, Matthews et al. 2018).

The distribution of potential heat stress for plants is mapped using heat zones. Heat zones are the number of days with a maximum daily temperature greater than $\geq 86^{\circ}\text{F}$. This metric only indicates changes in "hot" conditions, as each plant species has unique adaptations to tolerate various conditions. Each year, the number of days surpassing the 86°F threshold is tallied and summed, and the mean number of days per year is reported for 30 years (Matthews et al. 2018). The $\geq 86^{\circ}\text{F}$ value is a general temperature threshold at which photosynthesis can be negatively affected for woody plants (Matthews et al. 2018, Rennenberg et al. 2006).

- According to the recent heat zones map, the Southern Plains experience 123 days annually with temperatures exceeding 86°F .
- Between 1980 and 2009, Kansas averaged 61-120 days per year with a maximum temperature of at least 86°F , while Manhattan, KS, averaged 61-90 days.

PROJECTED HEAT ZONES (2070-2099) (RCP 8.5)

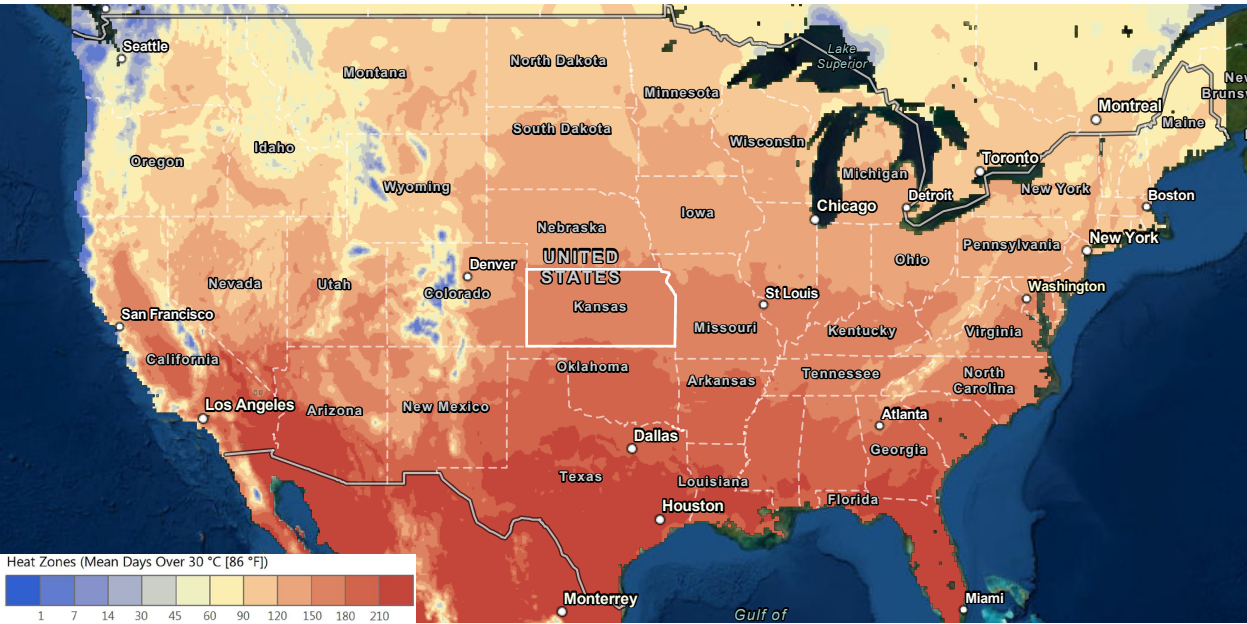


Figure 4.29 2070-2099 RCP 8.5 Heat Zones Map (Climate 2022, Matthews et al. 2018).

Profound changes are expected under the high emissions (RCP8.5) scenario. It is predicted that 53% of the land in the Southern Plains will experience an increase of 80 days with hot temperatures. In the Midwest and Northeast, over 50% of their landscapes are anticipated to exceed the 100-day increase threshold (Matthews et al. 2018).

- Kansas is expected to have 151-180 days per year with temperatures above 30°C (86°F) with a small area in south-central Kansas projected to have 181-210 days per year with temperatures above 30°C (86°F) (Matthews et al. 2018).
- Most of Texas is expected to have more than 210 days yearly with temperatures above 30°C (86°F).

HEAT ZONES 151-210 DAYS IN (1980-2009)

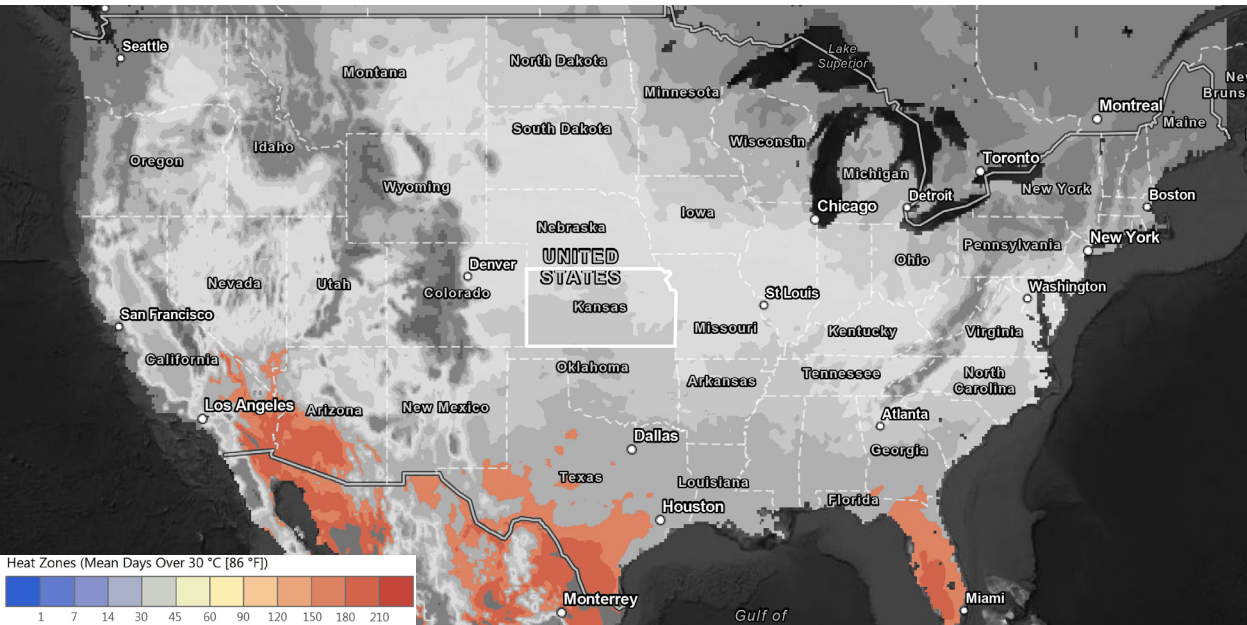


Figure 4.30 Highlighted regions in 1980-2009 that are the projected Heat Zones for Kansas under the high emissions scenario for 2070-2099 (RCP8.5) (Climate 2022, Matthews et al. 2018).

HEAT ZONE TAKEAWAYS

The conterminous United States, with recent conditions of 151-180 days with temperatures above 86°F, are central and southern parts of Texas and Florida, with glimpses of such days in south California and southwest Arizona. The conterminous United States, with recent conditions of 181-210 days a year surpassing the 86°F threshold, is shown in south Texas Florida, and glimpses in south Arizona and California.

- The projected increase of Kansas from 61-120 days in 1980-2009 to 151-210 days in 2070-2099, in a year where the maximum daily temperature is above 86°F, is a significant concern for the woody plants in the area.

Extended periods of high temperatures above the 86°F value threshold, particularly when accompanied by prolonged dry conditions, can cause decreased tree performance and mortality (Allen et al. 2015, Matthews et al. 2018).

With the shift of heat zones, selecting woody plants that can thrive under the projected heat zone conditions is essential. Choosing the appropriate tree species is of utmost importance, as it is necessary to identify those that can adapt to the anticipated future climate conditions, including higher temperatures and potentially modified precipitation patterns. It is imperative to ensure that the selected tree species are well-suited to the projected climate conditions to guarantee their growth and survival.

GROWING DEGREE DAYS (1980-2009)

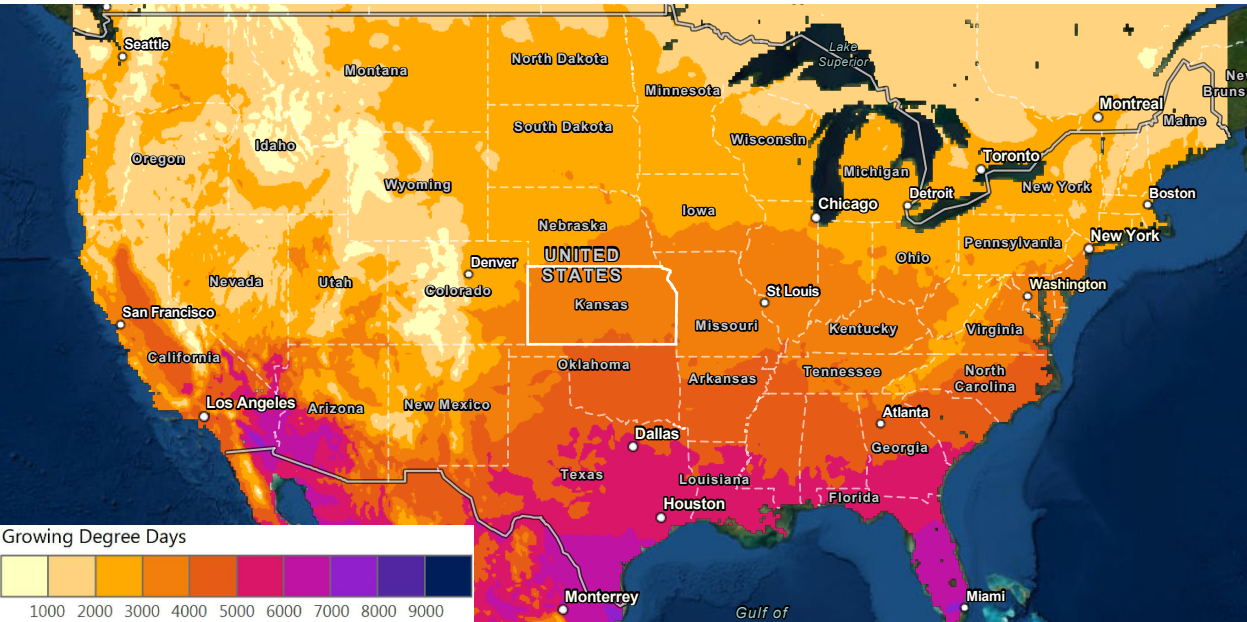


Figure 4.31 Map of the mean number of growing degree days for the conterminous United States. The map shows an accumulation of growing degree days for the recent conditions of the 1980-2009 period (Climate 2022, Matthews et al. 2018).

Plant growth patterns are defined by growing degree days (GDD) accumulated during the growing season. This metric offers a detailed insight into determining the potential for the growing season. In this study, the evaluation of the accumulation of growing degree days at or above 41°F (5°C) is based on the assumption that limited growth occurs below 41°F (Matthews et al. 2018). The process involves calculating growing degree days by determining the average daily temperature based on the projected maximum and minimum daily temperatures. The difference between each mean value and 41°F is then accumulated for all days each year, yielding positive difference values (Matthews et al. 2018).

The highest values were observed in Florida, south Texas, southwestern Arizona, and southeastern California.

- The state of Kansas experienced 3,000-3,999 GDD, with the southern part of the state having 4,000-4,999 GDD. The GDD of the southern plains ranges from 3,000-3,999 GDD in Kansas to 6,000-6,999 GDD in south Texas, with Oklahoma mainly in the range of 4,000-4,999 GDD.

PROJECTED GROWING DEGREE DAYS (2070-2099) (RCP 8.5)

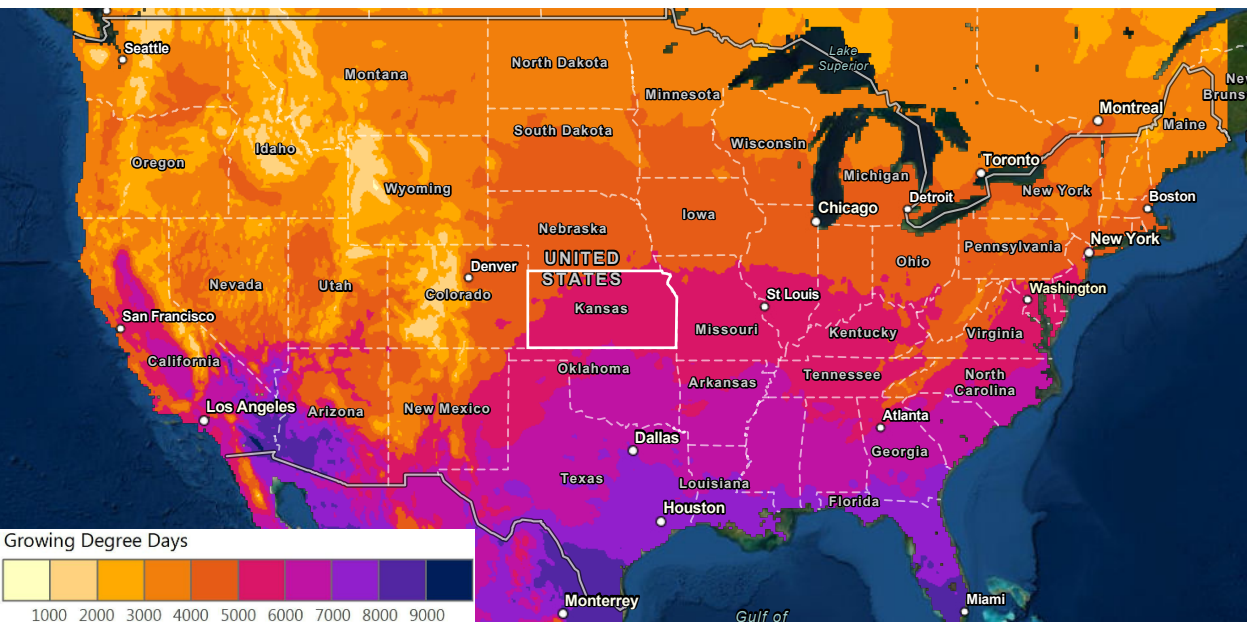


Figure 4.32 Map of projected mean growing degree days accumulation in the contiguous United States for the late 2070-2099 period using high climate scenario (RCP 8.5) (Climate 2022, Matthews et al. 2018).

Projections of Growing Degree Days (GDD) throughout the century indicate a widespread increase throughout the United States. This increase is illustrated in the figure above, which shows the mean GDD for the conterminous United States by the 30 years of 2070-2099. The Northeast region will also see a rise in GDD, but it will be slightly lower than the rest of the country. On the other hand, the southern part of the United States is expected to experience a much more significant increase in GDD, particularly under the high scenario.

- Under this high emission scenario displayed above, the state of Kansas is expected to have a predominantly uniform range of growing degree days (GDD) between 5,000 and 5,999. However, the GDD will likely fall between 4,000 and 4,999 in Kansas’s northwest region.
- Moving on to the southern plains, the GDD ranges from 4,000 to 4,999 in the northeast corner of Kansas, while in south Texas, it reaches a high of 8,000 to 8,999 GDD.

GROWING DEGREE DAYS 4,000-5,999 IN (1980-2009)

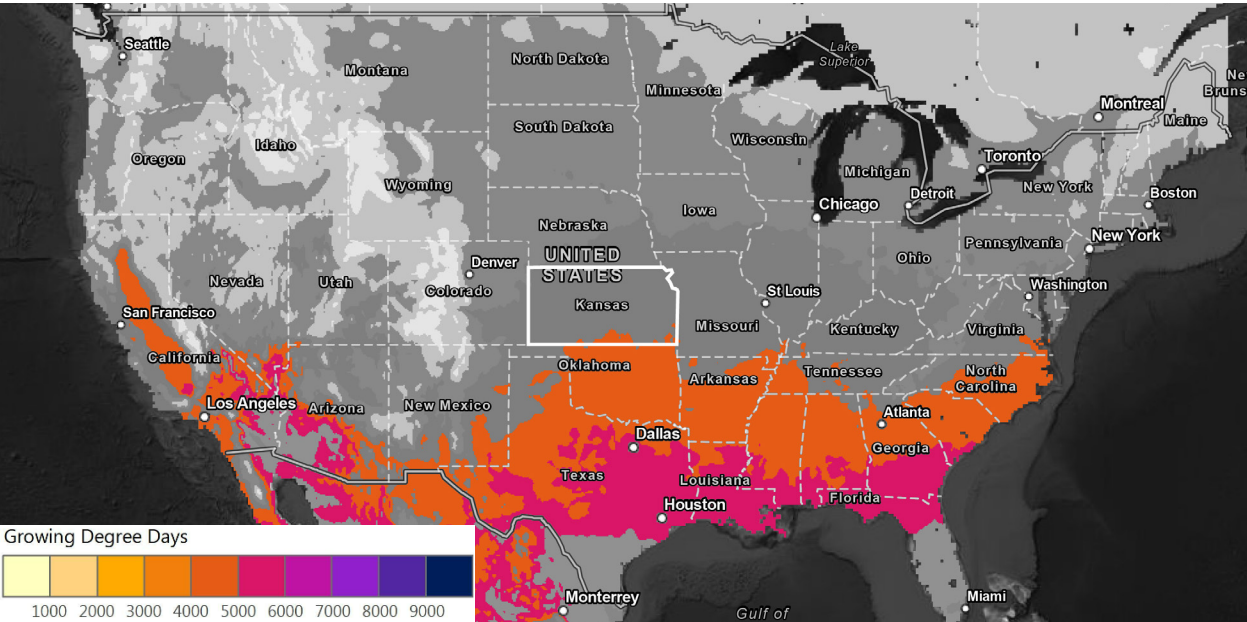


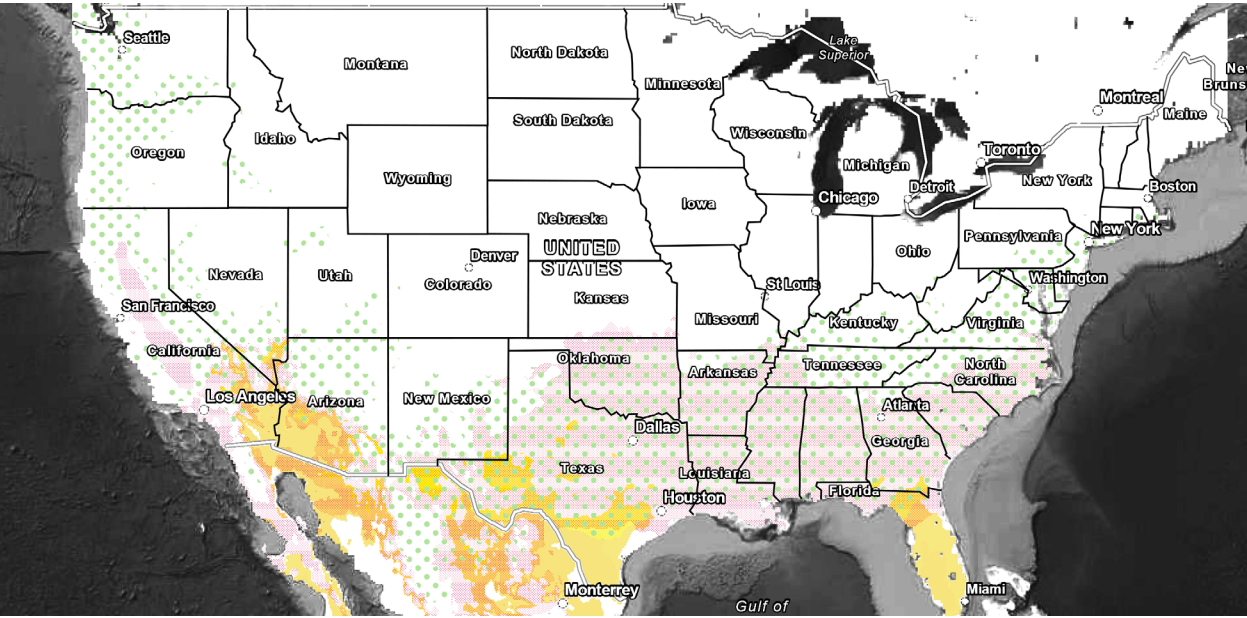
Figure 4.33 highlights the growing degree days range of 4,000-4,999 and 5,000-5,999, the GDD range Kansas is projected to have under the high emission scenario period of 2070-2099, using the recent condition maps of 1980-2009. Kansas is projected to have mostly 5,000-5,999 days in its state region, with the northwest corner of the state at 4,000-4,999 (Climate 2022, Matthews et al. 2018).

GROWING DEGREE DAYS TAKEAWAYS

The conterminous United States, with recent conditions of 5,000-5,999 GDDs, includes a large part of Texas, most of Louisiana, southern portions of Mississippi, Alabama, Georgia, South Carolina, and north Florida, along with some parts of the southern half of California and Arizona.

When selecting tree species, it's crucial to consider the projected Growing Degree Days (GDD) for Kansas. While GDD can indicate the amount of heat accumulation during the growing season, it doesn't account for the uncertainties in climate change modeling concerning precipitation estimates. The impact of climate change on precipitation patterns could lead to more extended drought periods and an uneven distribution of rainfall, with reduced amounts of precipitation in the later months of summer and autumn. This increase in moisture stress and higher temperatures can intensify plant stress and surge plant mortality rates (Matthews et al. 2018, US EPA 2021). Therefore, selecting tree species well-suited to the projected GDD with notable drought tolerance characteristics for Kansas can increase their chances of survival amidst changing climatic conditions.

HIGHLIGHTED REGIONS IN 1980-2009 THAT ARE THE PROJECTED PHZ's, HEAT ZONES AND GDD FOR KANSAS UNDER THE HIGH EMISSIONS SCENARIO FOR 2070-2099 (RCP8.5)



LEGEND

Plant Hardiness Zones Heat Zones Growing Degree Days

Figure 4.34 This map shows regions with PHZs, Heat Zones, and GDDs from 1980-2009, which reflect Kansas's future under the high emission scenario for 2070-2099 (adapted by author using Photoshop) (Climate 2022, Matthews et al. 2018).

APPLICABLE TAKEAWAYS

Given the anticipated shifts in plant hardiness zones, heat zones, and growing degree days for Kansas, selecting tree species that can adapt to these changing conditions is vital. The climatic evaluation conducted in this study examined recent and projected variables related to tree growth and survival across the United States to understand the implications for Kansas by the end of the century.

Central Texas and a portion of Northwest Florida are the two states with projected regions overlapping GDDs, PHZ, and Heat zones that Kansas is predicted to have, with Texas displaying the greater land mass area with these three criteria present. While portions of Arizona and Florida exhibit overlap of all three metrics, only Texas has consistent overlap through a large portion of the state. Therefore, Texas emerges as a key reference for tree selection. Its current hardiness zones 7 and 8 align with Kansas's future projections, and it has recently exhibited the projected heat zones and growing degree days that Kansas is expected to experience under the high emissions scenario.

Moreover, portions of the south-central region of Kansas have already recently experienced the high emission scenario projected growing degree days (Climate 2022, Matthews et al. 2018). Therefore, when selecting climate-ready trees for Kansas, it's important to align species selection to both current and projected Kansas zones.

Choosing the appropriate tree species is of utmost importance, as it is necessary to identify those that can adapt to the anticipated climate conditions, including higher temperatures. However, this project did not investigate precipitation patterns, as the report referenced did not contain this data. The referenced report, "Assessing Potential Climate Change Pressures Across The Conterminous United States: Mapping Plant Hardiness Zones, Heat Zones, Growing Degree Days, And Cumulative Drought Severity Throughout This Century," suggests that precipitation will manifest as larger, more extreme events and with increased irregularity in its seasonality (Matthews et al. 2018).

It is imperative to select tree species well-adapted to the current climate conditions and the projected climatic changes, ensuring their potential for growth and survival. In this regard, trees that have shown significant drought tolerance in both Kansas and Texas are promising candidates. The selection of trees from Kansas is informed by the fact that parts of the state's south-central region have already experienced the high emission scenario projected growing degree days (Climate 2022, Matthews et al. 2018). Therefore, when selecting climate-ready trees for Kansas, it is vital to align species selection with Kansas's recent and projected climatic variables.

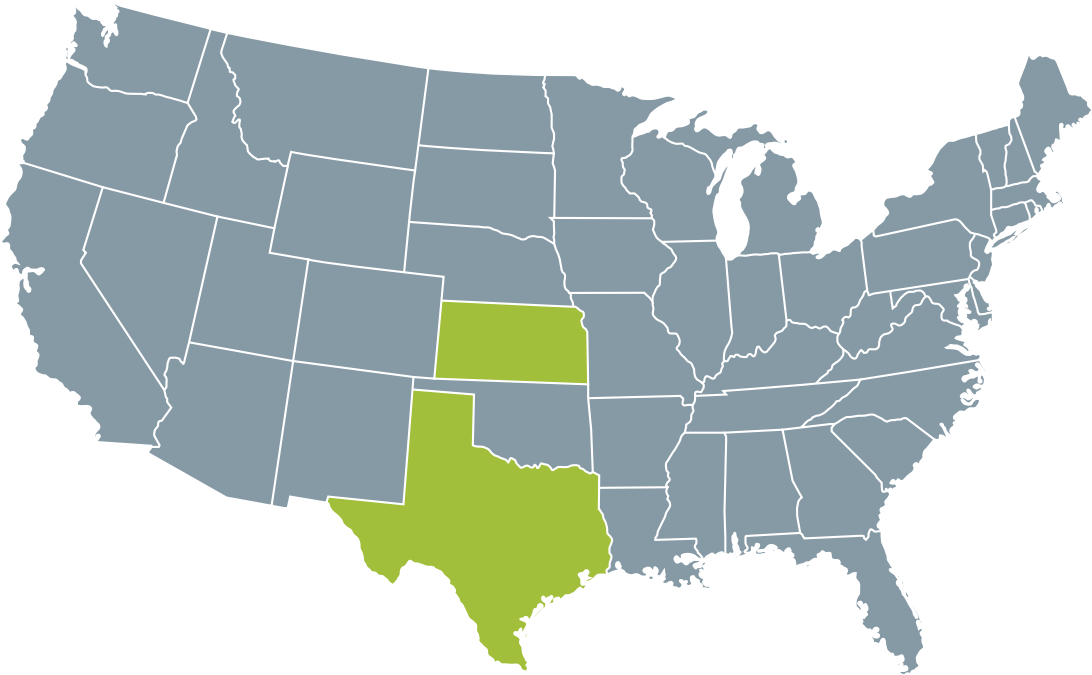


Figure 4.35 United States Map with the states identified in the climate evaluation that were chosen to trees from for the KSU climate-ready tree collection (by author).

TREE SPECIES SELECTION
CLIMATE-READY TREES FOR KANSAS

This method involved the comprehensive review of notable drought-tolerant tree lists from Kansas and Texas, states specifically identified during the climate evaluation. Two key lists were deliberately selected: the K-State Drought Tolerant Trees for South-Central Kansas and the UC Davis Arboretum Texas Tree Trial database. The two lists were selected because they each possess trees with notable attributes, such as drought tolerance, heat resistance, and compatibility with Kansas's recent and projected hardiness zones for Kansas. Initially, the combined total of trees from both lists was 117. However, after eliminating duplicates and filtering the list, the number of pertinent trees was narrowed to 96.

The objective was to assemble a robust Kansas Climate-Ready Tree List tailored to the state's current climate and anticipated future conditions. These future conditions encompass shifts in hardiness and heat zones, increased prevalence of drought, and a rise in growing degree days, indicating more hot days per year than currently experienced.

PALETTE ASSIGNMENT

The climate-ready trees were categorized into specific landscape typology palettes based on their species characteristics and practical considerations. Each species could belong to one or more of the typologies. Below is the rationale behind the development of the tree species palettes.

Comprehensive information on tree suggested use and planting site recommendations, as well as select data on branch strength, root damage potential, and salt spray tolerance, was harnessed for informed decision-making when placing trees into the KSU five palettes. For full definitions of these criteria, see page 60:

- Branch Strength: Weak, Medium, Strong
- Root Damage Potential: Low, Moderate, High
- Salt Spray Tolerance: Low, Moderate, High

Surface Parking
Trees should be able to withstand the harsh conditions of the parking lot, such as salt, pollution, and compacted soil. They should also have a high canopy, a small root zone, and a noninvasive root system.

- Tree species with the following attributes were included in the surface parking palette.
- Branch Strength: Medium, Strong
 - Root Damage Potential: Low, Moderate
 - Salt Spray Tolerance: Moderate, High

The data for the branch strength, root damage potential, and salt spray tolerance criteria was obtained from SelecTree, which employs a qualitative ranking scale.

Quadrangles

The quadrangle’s palette should include a variety of trees that tolerate salt and those that can’t tolerate such conditions. The palette can also include varying trees, such as deciduous and evergreens, and variability in root damage potential, according to SelecTree.

Tree species with the following attributes were included in the quadrangle’s palette.
Branch Strength: Medium, Strong
Root Damage Potential: Low, Moderate, High
Salt Spray Tolerance: Low, Moderate, High

Campus Green

Trees on the campus green should include a variety of trees that tolerate harsh conditions, including salt, and those that can’t tolerate such conditions. Trees in this area can include trees with varying root systems and heights, widths, and shapes in canopies, and litter.

Tree species with the following attributes were included in the campus green palette.
Branch Strength: Weak, Medium, Strong
Root Damage Potential: Low, Moderate, High
Salt Spray Tolerance: Low, Moderate, High

Plazas

The trees selected for plazas should tolerate harsh conditions, including salt and compacted soil. They should also produce insignificant litter. Deciduous trees should have a high canopy, a small root zone, and a non-invasive root system.

Tree species with the following attributes were included in the plaza palette.
Branch Strength: Medium, Strong
Root Damage Potential: Low, Moderate
Salt Spray Tolerance: Moderate, High

Campus Corridor

The campus corridor palette includes trees with unique characteristics not accounted for in the other landscape typologies. Given the physical characteristics of the campus corridor and its minimal pedestrian traffic compared to other typologies, trees in this area can have varying root systems, heights, widths, shapes in canopies, and significant litter.

Tree species with the following attributes were included in the campus corridor palette.
Branch Strength: Weak, Medium, Strong
Root Damage Potential: Low, Moderate, High
Salt Spray Tolerance: Low, Moderate, High

THE K-STATE CLIMATE-READY TREE COLLECTION

NOTE: Trees with an asterisk are native to Kansas. Refer to Appendices for tree profiles.

	SURFACE PARKING	QUADRANGLES	CAMPUS GREEN	PLAZAS	CAMPUS CORRIDOR
SCIENTIFIC NAME					
Acer buergerianum	•	•	•	•	•
Acer campestre		•	•	•	•
Acer grandidentatum		•	•	•	•
Acer miyabei		•	•	•	•
Acer saccharum ‘John Pair’*		•	•	•	•
Acer saccharum ‘Legacy’*		•	•	•	•
Acer saccharum Oregon Trail*	•	•	•	•	•
Acer truncatum	•	•	•	•	•
Arbutus xalapensis			•		•
Bauhinia lunarioides			•		•
Calocedrus decurrens		•	•	•	•
Carpinus betulus	•	•	•	•	•
Carya illinoensis*			•		•
Catalpa bignonioides			•		•
Catalpa speciosa*			•		•
Cedrus atlantica			•		•
Celtis laevigata					•
Celtis lindheimeri			•		•
Celtis occidentalis*	•		•		•
Cercis canadensis var. texensis	•	•	•	•	•
Cercis canadensis*	•	•	•	•	•

THE K-STATE CLIMATE-READY TREE COLLECTION - CONTINUED

SCIENTIFIC NAME	SURFACE PARKING	QUADRANGLES	CAMPUS GREEN	PLAZAS	CAMPUS CORRIDOR
Chionanthus retusus	•	•	•	•	•
Cotinus coggygria			•		•
Cotinus obovatus	•	•	•	•	•
Crataegus ambigua					•
Crataegus viridis 'Winter King'	•	•	•	•	•
Cupressus arizonica			•		•
Dermatophyllum secundiflorum (Sophora secundiflora)					•
Diospyros texana			•		•
Diospyros virginiana*					•
Eucommia ulmoides	•	•	•	•	•
Euonymus bungeanus			•		•
Ginkgo biloba	•	•	•	•	•
Gleditsia triacanthos var. inermis*	•		•		•
Gymnocladus dioicus*			•		•
Heptacodium miconioides		•	•	•	•
Hesperocyparis arizonica	•	•	•	•	•
Juglans major					•
Juglans microcarpa					•
Juniperus chinensis	•	•	•	•	•
Juniperus deppeana			•		•
Koelreuteria paniculata		•	•		•

THE K-STATE CLIMATE-READY TREE COLLECTION - CONTINUED

SCIENTIFIC NAME	SURFACE PARKING	QUADRANGLES	CAMPUS GREEN	PLAZAS	CAMPUS CORRIDOR
Leucaena retusa					•
Liquidambar styraciflua			•		•
Maackia amurensis		•	•		•
Maclura pomifera*					•
Magnolia grandiflora			•		•
Morus microphylla					•
Pinus bungeana			•		•
Pinus cembroides		•	•	•	•
Pinus flexilis			•		•
Pinus ponderosa		•	•		•
Pinus ponderosa var. scopulorum		•	•		•
Pinus remota					•
Pinus strobiformis			•		•
Pistacia chinensis			•		•
Pistacia mexicana					•
Platanus x acerifolia			•		•
Platycladus orientalis			•		•
Prunus mexicana					•
Prunus serotina var. eximia					•
Prunus serotina var. virens					•
Quercus arizonica			•		•

THE K-STATE CLIMATE-READY TREE COLLECTION - CONTINUED

	SURFACE PARKING	QUADRANGLES	CAMPUS GREEN	PLAZAS	CAMPUS CORRIDOR
SCIENTIFIC NAME					
Quercus bicolor*			•		•
Quercus buckleyi		•	•		
Quercus graciliformis (Quercus canbyi)	•	•	•		•
Quercus gravesii					•
Quercus grisea					•
Quercus imbricaria*		•	•		•
Quercus laceyi					•
Quercus macrocarpa*		•	•		•
Quercus mohriana					•
Quercus muehlenbergii*		•	•		•
Quercus nigra					•
Quercus nuttallii			•		•
Quercus oblongifolia			•		•
Quercus phellos		•	•		•
Quercus robur		•	•		•
Quercus rubra*		•	•		•
Quercus shumardii*		•	•		•
Quercus stellata			•		•
Quercus vaseyana					•
Sapindus drummondii*					•
Senegalia wrightii			•		•

THE K-STATE CLIMATE-READY TREE COLLECTION - CONTINUED

	SURFACE PARKING	QUADRANGLES	CAMPUS GREEN	PLAZAS	CAMPUS CORRIDOR
SCIENTIFIC NAME					
Styphnolobium affine			•		•
Styphnolobium japonicum					•
Syringa reticulata	•	•	•	•	•
Taxodium distichum			•		•
Tilia americana var. caroliniana			•		•
Ulmus americana*		•	•		•
Ulmus crassifolia			•		•
Ulmus davidiana var. japonica			•		•
Ulmus parvifolia	•	•	•	•	•
Ungnadia speciosa					•
x Chitalpa tashkentensis	•	•	•	•	•
Zelkova serrata	•	•	•	•	•

TAKEAWAYS

The Kansas Climate-Ready Tree List was compiled from the K-State Drought Tolerant Trees for South-Central Kansas list and the UC Davis Arboretum Texas Tree Trial database. In addition to future climatic conditions, this list considers the physical characteristics of the KSU campus landscape typologies, the distinct physical attributes of the tree species, and placement requirements.

CHAPTER 5

RECOMMENDATIONS



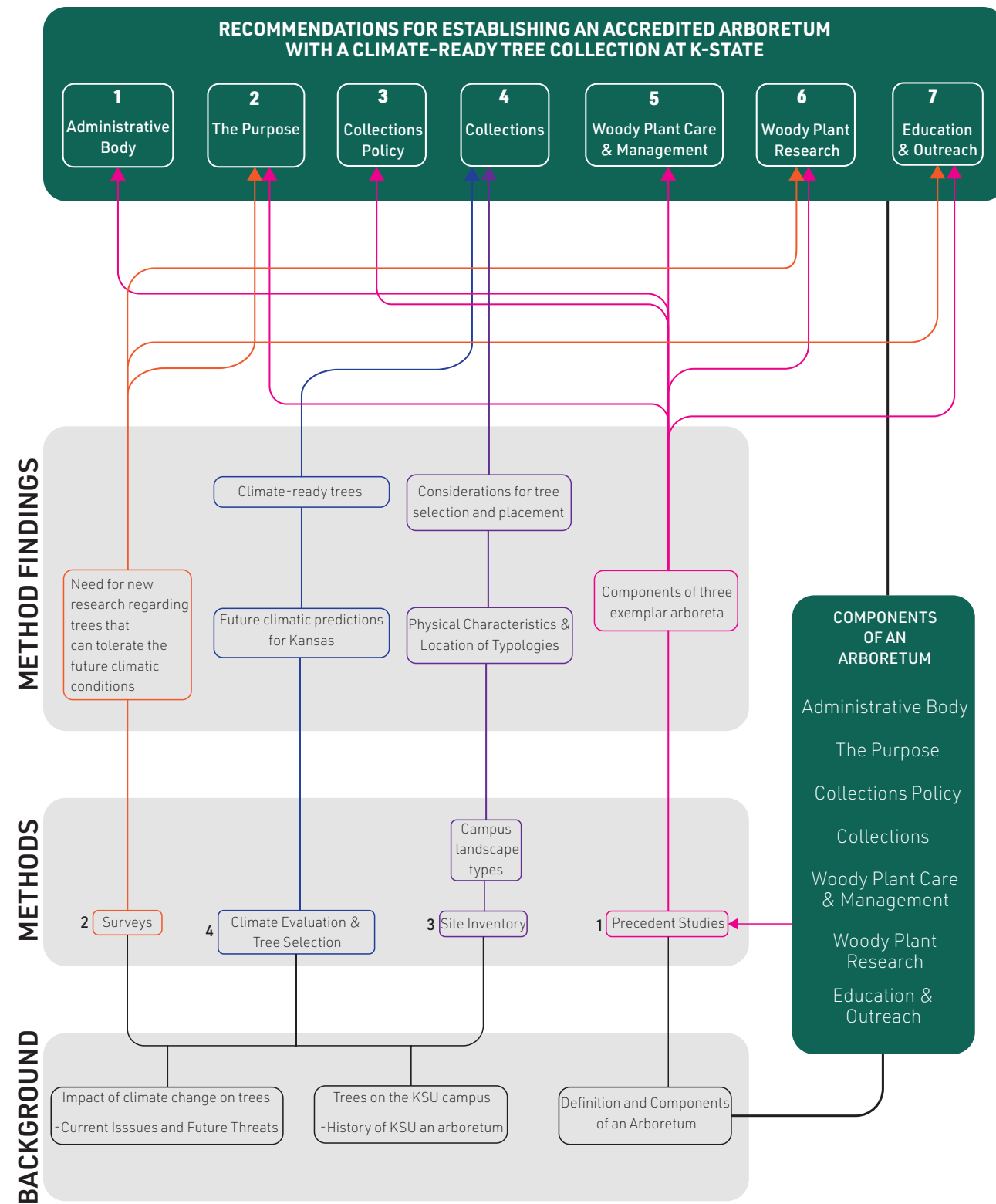


Figure 5.1 Methodology for creating recommendations for the establishment of K-States Accredited Arboretum (by author).

RECOMMENDATIONS

Insights from background research, precedent studies, surveys, site inventory, and climate evaluation, coupled with tree species selection, pave the way for KSU to establish an accredited arboretum with a dedicated climate-ready tree collection. These findings lead to the following recommendations:

1. Establish an arboretum advisory committee.
2. Define the arboretum's purpose.
3. Create a collections policy.
4. Define existing and proposed collections.
5. Develop tree care and management practices.
6. Develop research pursuits that concentrate on trees.
7. Commence education and outreach initiatives.

By implementing these recommendations collectively, KSU can achieve arboretum accreditation while also possessing a specialized climate-ready tree collection for Kansas. This comprehensive approach would underscore KSU's dedication to its land-grant mission, the propagation of novel tree information, and its commitment to education and outreach.

1. ESTABLISH AN ARBORETUM ADVISORY COMMITTEE

For KSU, the purpose of the Arboretum Advisory Committee will be to organize, maintain, and advance the establishment of the Arboretum. It is recommended that the committee be overseen by a single individual serving as Managing Director. Other core committee positions should be Collections Curator, Research Coordinator, Education and Outreach Coordinator, Arborist, and Landscape Architect. Ideally, different people will fill the positions; however, if staffing is limited, responsibilities can be shared across roles. In addition to the core committee, it is recommended that the advisory committee include supporting members. Members will serve as resources and support the work of the core committee.

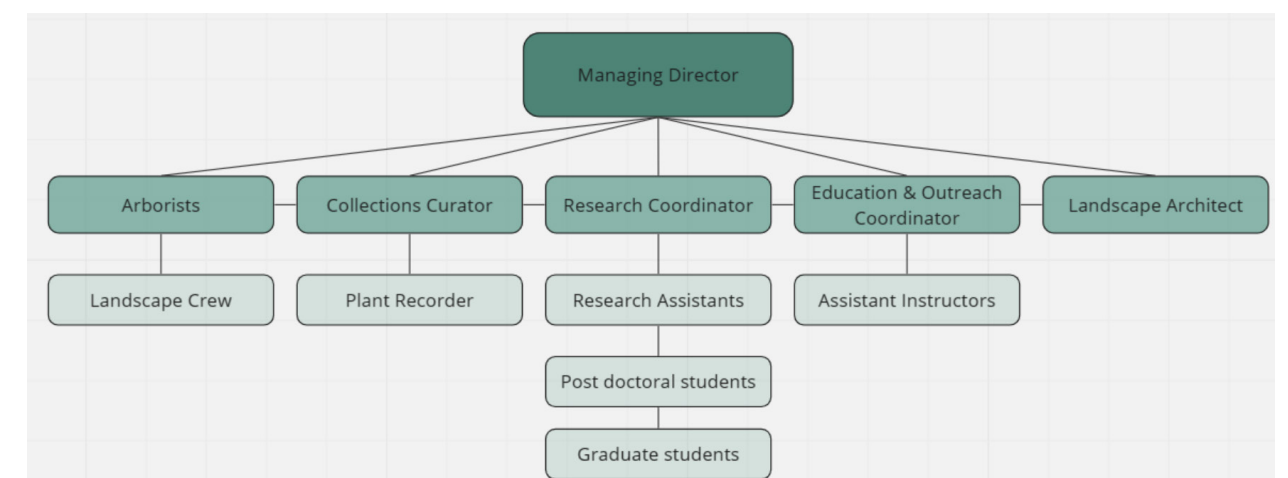


Figure 5.2 Proposed arboretum advisory committee structure for the KSU arboretum (by author).

RECOMMENDED CORE POSITIONS
MANAGING DIRECTOR

The managing director is one of the most highly qualified staff members, possibly the most senior staff member responsible for the daily smooth operation of the Arboretum. Usually, the director serves as a leader and may assign operational and management responsibilities to others. Directors are responsible for creating the mission, vision, and plans for its arboretum in collaboration with the advisory committee. Directors are also responsible for ensuring that the organization and its staff function effectively to achieve the arboretum's mission and goals. This role also entails fundraising efforts, promotion, and positioning within the arboretum profession and the local community to advance the arboretum (Gratzfeld 2016, Rakow and Lee 2011).

Recommendations for K-State

The position of managing director of the Kansas State University Arboretum requires academic, administrative, and leadership skills. The ideal candidate should have a master's degree or higher in horticulture, botany, landscape architecture, or a related field, with experience managing public gardens and/or arboreturns. The candidate should also have experience in fundraising, budgeting, staff supervision, and community outreach. Most importantly, the candidate should demonstrate a passion for woody plants, research, and education, as well as a vision for the future development of the Arboretum.

COLLECTIONS CURATOR

Curators are responsible for the development and care of collections over time. "Curators develop plant collections policy, acquire plants for the collections, arrange appropriate record keeping and labeling, ensure proper horticultural care and protection, conduct evaluations of plant performance, and arrange access to the collections for study or use by others (Rakow and Lee 2011)."

Recommendations for K-State

The curator of a plant collection must have substantial knowledge of plants and horticulture, and a passion for the subject (Gratzfeld 2016, Rakow and Lee 2011). Therefore, a KSU horticulture or landscape architecture faculty member with specialized knowledge of woody plants would best perform curatorial duties. In addition to a curator, a highly qualified plant recorder, also known as a GIS specialist at some arboreturns, will be needed to support curator tasks, specifically in establishing the GIS coordinates for each accession as the Arboretum grows. (CSU 2020 Gratzfeld 2016, Rakow and Lee 2011). It is highly recommended that a faculty member in the geography, landscape architecture, and or planning department take on the role of a plant recorder as an additional task to their departmental duties.

RESEARCH COORDINATOR

Various arboreturns are devoted to science; many conduct scientific research as part of their mission. There has been an increase in arboretum science programs in recent years due to environmental concerns (Gratzfeld 2016, Rakow and Lee 2011). In most cases, it is advised that the scientific program is led by a head, director, or vice president of research. Research Coordinators at arboreturns, such as those at Harvard University's Arnold Arboretum, often

specialize in taxonomy and systematics, conservation, genetics, genomics, or the breeding of plants. Their research is supported by postdoctoral scientists, graduate students, research associates, laboratory and field assistants, and other researchers with specialized academic qualifications (President and Fellows of Harvard College 2022).

Recommendations for K-State

A Research Coordinator for an arboretum should have a strong background in botany, ecology, horticulture, and conservation. A professor who teaches and conducts research in these fields would be best recommended to be a Research Coordinator at the Arboretum.

EDUCATION & OUTREACH COORDINATOR

Education coordinators plan the arboretum's educational programs in accordance with the arboretum's mission and the interests and needs of the audience. Education coordinators collaborate with instructors to conduct classes, tours, and activities and may perform such duties directly.

Recommendations for K-State

A professor in education or a horticultural expert may be a suitable candidate for the role of education coordinator if there is a special interest in the subject matter and is experienced in delivering educational programs in a formal or informal setting.

ARBORIST

A professional arborist is required to care for the woody plants in an arboretum. Among other tasks, the arborist plants, weeds, waters, prunes, and otherwise cultivates plants in the collections. An understanding of plants and horticulture, acquired through experience and academic study, is required. It is common for arboriculturists to interact with visitors who are interested in their work, and they may share their knowledge informally or formally through the arboretum's educational programs (Rakow and Lee 2011).

Recommendations for K-State

Currently, KSU has one certified arborist on staff responsible for conducting regular inspections, pruning, planting, and removals. However, a second certified arborist is recommended because of the campus's size, the number of existing trees, and additional trees for the arboretum. This will help maintain and improve the quality of the campus trees. In addition to arborists, a highly qualified landscape maintenance crew is needed to perform tree care tasks.

LANDSCAPE ARCHITECT

A Landscape Architect for an arboretum is vital because they play a crucial role in overseeing all landscape and arboretum projects. For example, at Vanderbilt University, the Landscape Architect is responsible for guiding the institution's principles, which include respecting the institution's historical identity, making the campus more walkable and bikeable, ensuring sustainability, preserving, and expanding the campus' park-like setting, community engagement, and outdoor enhancements (Vanderbilt University 2023). Landscape Architects develop strategic plans for the

campus outdoor spaces and establish long-term goals and targets for the university landscape and arboretum. A University Landscape Architect at KSU's Arboretum can play a pivotal role in shaping the university's aesthetic character while promoting education and sustainability.

Recommendations for K-State

KSU needs to hire a landscape architect for the campus immediately. The ideal candidate would be a licensed landscape architect with experience working with arboreta. They should be well-versed in woody plants and able to create strategic plans for the campus grounds, including setting long-term goals for the campus arboretum. Additionally, the candidate should be a community-engaged landscape architect who can create educational and welcoming spaces that benefit the university and the public for years. The landscape architect must also ensure that the university's historic identity is respected and incorporated into the arboretum. This role would suit an existing or former faculty member from the Landscape Architecture & Regional Community Planning Department.

2. DEFINE THE PURPOSE OF THE ARBORETUM

An arboretum's purpose should align with the vision and mission of the organization that owns or manages it. It should also reflect the needs and interests of the advisory committee and beneficiaries of the arboretum, such as researchers, educators, visitors, donors, or partners. The purpose of an arboretum should be communicated clearly and consistently in its development and upkeep. Here are some recommendations to consider while creating the mission for the arboretum.

- Identify the primary purpose and goals of the arboretum, such as promoting research, education, conservation, or recreation.
- Highlight the unique features and values of the existing campus trees, such as their purpose, history, diversity, or aesthetics.
- Define the target audience and stakeholders, such as students, faculty, donors, volunteers, or visitors.
- Express the commitment to stewardship and sustainability of the arboretum and its plant collections.
- Provide a clear and concise summary of the mission statement that reflects the vision and values.

Draft Mission Statement for the KSU Arboretum

The KSU Arboretum aims to be a leading source of information on woody plants in Kansas and beyond. It aims to inspire and empower visitors, students, researchers, and partners to appreciate, conserve, and adapt to the challenges of a changing environment.

3. CREATE A COLLECTIONS POLICY

Recommendations for K-State:

Define the Purpose and Scope of the Policy

Explain the goal and rationale of the collection policy and how it supports the Arboretum's mission and vision. Specify the types and categories of plants that will be included in the collection and the criteria for selecting them.

Describe the Acquisitions Process and Sources

Outline the procedures and standards for acquiring new plants for the collection, such as collecting, purchasing, exchanging, or receiving donations. Identify the sources and methods of obtaining plants, such as nurseries, botanical gardens, research institutions, or field expeditions. Address any legal, ethical, or environmental issues related to acquiring plants.

Establish a Record-Keeping and Documentation System

To maintain and enhance the quality and accessibility of its plant collection, it is important for the arboretum to invest in collections software that can store, organize, and analyze various types of data. Iris BG and BG-BASE are examples of such software that can help the arboretum to record and manage information such as plant names, origins, locations, phenology, health status, propagation history and conservation status (Gratzfeld 2016, President and Fellows of Harvard College 2022, Rakow and Lee 2011). This software can also be integrated with geographic information systems software such as ArcGIS or BG-MAP to create accurate and interactive maps of the plant inventory. Furthermore, these software can allow the arboretum to link photographs to the database records, enhancing the visual appeal and documentation of the collection (Rakow and Lee 2011). By investing in collections software, the KSU arboretum can improve its efficiency, accuracy, and outreach in managing its plant collection.

A consistent recordkeeping system is essential for evaluating collections over time. Each plant has core information that should be tracked in accordance with the ArbNet standards, which are adapted from the Public Garden Management Book. Record keeping for each accession in the KSU arboretum should include:

- Name, scientific and common
- Plant family
- Source type
- Source
- Type of material received
- Number of materials received
- Date received
- Accession number
- Accession condition with date
- Accession location with date
- Deaccession reason
- Deaccession date

(Rakow and Lee 2011).

Develop the Maintenance and Care Guidelines

Specify the practices and operations that will be performed to ensure the health and quality of the plants in the collection, such as watering, pruning, fertilizing, pest control, etc. Indicate the frequency and responsibility of these tasks, and any special requirements or precautions for different types of plants.

Determine the Deaccessioning and Disposal Criteria

Explain the reasons and circumstances that may lead to removing plants from the collection, such as death and disease. Describe the procedures and standards for deaccessioning and disposing of plants, such as updating records, notifying donors or stakeholders, and transferring or destroying plants.

Regulate the Access and Use of the Collection

Encourage and facilitate the educational and research use of the collection by various groups, such as staff, students, visitors, researchers, etc. Provide guidelines and rules for accessing and using the collection, such as hours of operation, permissions or restrictions, and safety measures.

4. COLLECTION RECOMMENDATIONS

Organizing the existing trees into collections can be significantly beneficial for KSU. Therefore, it is recommended that the trees be separated into two distinct categories - Historical Collections and Taxonomic Collections. By doing this, the University can align itself with established collections and gain recognition from the Arbnet program.

Historical Collection

It is recommended that a display collection of historical trees be created, specifically, those initially planted for shelterbelt purposes, those gifted by the esteemed Arnold Arboretum, and those holding significant historical value as determined by the Arboretum committee.

- Conduct a thorough review of the Hale Library and other relevant historical archives to identify trees of significant historical value that still exist on campus.
- Consult with knowledgeable tree experts at KSU who are well-versed in the campus landscape and its tree history.
- Locate and recognize the remaining trees on the campus gifted from the Arnold Arboretum back in 1878.
- Locate and recognize the remaining trees on the campus planted for shelterbelt research.
- The arboretum committee ought to establish criteria to determine which trees on campus have historical significance. For example, trees planted before 1920 on campus should be classified as historical trees.

Subsequently, these trees can be organized and grouped together to form a comprehensive historical collection.

Taxonomic Collections

Following the completion of a comprehensive tree inventory on the campus, it is strongly recommended that the identified trees be organized into distinct taxonomic collections. Taxonomic collections can promote awareness of the existing diverse tree species on university grounds.

- The arboretum committee should establish criteria to determine how trees should be grouped into taxonomic collections.
- A first great step would be to gather the trees into collections by genus. The identified ash trees on campus in accordance with KSU's Emerald Ash Borer Response Plan can be grouped into the Fraxinus collection.

THE K-STATE CLIMATE-READY COLLECTION FOR KANSAS

This Climate-Ready Tree Collection is curated for Kansas, considering the state's current climate and projected future conditions. The collection includes tree species thriving in South Central Kansas known for their inherent drought and heat tolerance traits and species of trees grown in Texas with the same notable traits. These species are projected to acclimate to the anticipated shifts in hardiness and heat zones, increased frequency of droughts, and a rise in growing degree days, implying more hot days annually. This collection of trees was thoughtfully assigned to the five landscape typologies at KSU, with careful consideration given to tree placement and attributes.

Palettes for the KSU Landscape Typologies

NOTE: Trees with an asterisk are native to Kansas. Refer to Appendices for tree profiles.

Surface Parking

- Acer buergerianum
- Acer saccharum Oregon Trail*
- Acer truncatum
- Carpinus betulus
- Carya illinoensis
- Celtis occidentalis*
- Cercis canadensis var. texensis
- Cercis canadensis var. texensis
- Cercis canadensis*
- Chionanthus retusus
- Cotinus obovatus
- Crataegus viridis 'Winter King'
- Eucommia ulmoides
- Ginkgo biloba
- Gleditsia triacanthos var. inermis*
- Hesperocyparis arizonica (syn. Cupressus arizonica)*tx tree trial info
- Juniperus chinensis
- Pinus cembroides

- Quercus graciliformis (Quercus canbyi)
- Sapindus drummondii
- Syringa reticulata
- Taxodium distichum
- Ulmus parvifolia

Quadrangles

- Acer buergerianum
- Acer campestre
- Acer grandidentatum
- Acer miyabei
- Acer saccharum ‘John Pair’*
- Acer saccharum ‘Legacy’*
- Acer saccharum Oregon Trail*
- Acer truncatum
- Calocedrus decurrens
- Carpinus betulus
- Carya illinoensis
- Cercis canadensis var. texensis
- Cercis canadensis var. texensis
- Cercis canadensis*
- Chionanthus retusus
- Cotinus obovatus
- Crataegus viridis ‘Winter King’
- Eucommia ulmoides
- Ginkgo biloba
- Heptacodium miconioides
- Hesperocyparis arizonica (syn. Cupressus arizonica)*tx tree trial info
- Juniperus chinensis
- Koelreuteria paniculata
- Maackia amurensis
- Pinus cembroides
- Pinus cembroides
- Pinus ponderosa
- Pinus ponderosa var. scopulorum
- Quercus buckleyi
- Quercus graciliformis (Quercus canbyi)
- Quercus imbricaria*
- Quercus macrocarpa*
- Quercus muehlenbergii*
- Quercus phellos
- Quercus robur

- Quercus rubra*
- Quercus shumardii*
- Sapindus drummondii
- Syringa reticulata
- Taxodium distichum
- Ulmus americana*
- Ulmus parvifolia
- x Chitalpa tashkentensis
- Zelkova serrata

Plazas

- Acer buergerianum
- Acer campestre
- Acer grandidentatum
- Acer miyabei
- Acer saccharum ‘John Pair’*
- Acer saccharum ‘Legacy’*
- Acer saccharum Oregon Trail*
- Acer truncatum
- Calocedrus decurrens
- Carpinus betulus
- Carya illinoensis
- Cercis canadensis var. texensis
- Cercis canadensis var. texensis
- Cercis canadensis*
- Chionanthus retusus
- Cotinus obovatus
- Crataegus viridis ‘Winter King’
- Eucommia ulmoides
- Ginkgo biloba
- Heptacodium miconioides
- Hesperocyparis arizonica
- Juniperus chinensis
- Pinus cembroides
- Pinus cembroides
- Sapindus drummondii
- Syringa reticulata
- Taxodium distichum
- Ulmus parvifolia
- x Chitalpa tashkentensis
- Zelkova serrata

Campus Green

- Acer buergerianum
- Acer campestre
- Acer grandidentatum
- Acer miyabei
- Acer saccharum ‘John Pair’*
- Acer saccharum ‘Legacy’*
- Acer saccharum Oregon Trail*
- Acer truncatum
- Arbutus xalapensis
- Bauhinia lunarioides
- Calocedrus decurrens
- Carpinus betulus
- Carya illinoensis
- Carya illinoensis*
- Catalpa bignonioides
- Catalpa speciosa*
- Cedrus atlantica
- Celtis lindheimeri
- Celtis occidentalis*
- Cercis canadensis var. texensis
- Cercis canadensis var. texensis
- Cercis canadensis*
- Chionanthus retusus
- Cotinus coggygria
- Cotinus obovatus
- Crataegus viridis ‘Winter King’
- Cupressus arizonica
- Diospyros texana
- Eucommia ulmoides
- Euonymus bungeanus
- Ginkgo biloba
- Gleditsia triacanthos var. inermis*
- Gymnocladus dioica*
- Heptacodium miconioides
- Hesperocyparis arizonica (syn. Cupressus arizonica)*tx tree trial info
- Juniperus chinensis
- Juniperus deppeana
- Koeleria paniculata
- Liquidambar styraciflua
- Maackia amurensis
- Magnolia grandiflora

- Pinus bungeana
- Pinus cembroides
- Pinus cembroides
- Pinus flexilis
- Pinus ponderosa
- Pinus ponderosa var. scopulorum
- Pinus strobiformis
- Pistacia chinensis
- Platanus x acerifolia
- Platycladus orientalis
- Quercus arizonica
- Quercus bicolor*
- Quercus buckleyi
- Quercus graciliformis (Quercus canbyi)
- Quercus imbricaria*
- Quercus macrocarpa*
- Quercus muehlenbergii*
- Quercus nuttallii
- Quercus oblongifolia
- Quercus phellos
- Quercus robur
- Quercus rubra*
- Quercus shumardii*
- Quercus stellata
- Sapindus drummondii
- Senegalia wrightii
- Syringa reticulata
- Taxodium distichum
- Taxodium distichum
- Tilia americana var. caroliniana
- Ulmus americana*
- Ulmus crassifolia
- Ulmus davidiana var. japonica
- Ulmus parvifolia
- x Chitalpa tashkentensis
- Zelkova serrata

Campus Corridor

- Acer buergerianum
- Acer campestre
- Acer grandidentatum
- Acer miyabei
- Acer saccharum ‘John Pair’*
- Acer saccharum ‘Legacy’*
- Acer saccharum Oregon Trail*
- Acer truncatum
- Arbutus xalapensis
- Bauhinia lunarioides
- Calocedrus decurrens
- Carpinus betulus
- Carya illinoensis
- Carya illinoensis*
- Catalpa bignonioides
- Catalpa speciosa*
- Cedrus atlantica
- Celtis laevigata
- Celtis lindheimeri
- Celtis occidentalis*
- Cercis canadensis var. texensis
- Cercis canadensis var. texensis
- Cercis canadensis*
- Chionanthus retusus
- Cotinus coggygria
- Cotinus obovatus
- Crataegus ambigua
- Crataegus viridis ‘Winter King’
- Cupressus arizonica
- Dermatophyllum secundiflorum (Sophora secundiflora)
- Diospyros texana
- Diospyros virginiana*
- Eucommia ulmoides
- Euonymus bungeanus
- Ginkgo biloba
- Gleditsia triacanthos var. inermis*
- Gymnocladus dioicus*
- Heptacodium miconioides
- Hesperocyparis arizonica (syn. Cupressus arizonica)*tx tree trial info
- Juglans major
- Juglans microcarpa

- Juniperus chinensis
- Juniperus deppeana
- Koelreuteria paniculata
- Leucaena retusa
- Liquidambar styraciflua
- Maackia amurensis
- Maclura pomifera*
- Magnolia grandiflora
- Morus microphylla
- Pinus bungeana
- Pinus cembroides
- Pinus cembroides
- Pinus flexilis
- Pinus ponderosa
- Pinus ponderosa var. scopulorum
- Pinus remota
- Pinus strobiformis
- Pistacia chinensis
- Pistacia mexicana
- Platanus x acerifolia
- Platycladus orientalis
- Prunus mexicana
- Prunus serotina var. eximia
- Prunus serotina var. virens
- Quercus arizonica
- Quercus bicolor*
- Quercus buckleyi
- Quercus graciliformis (Quercus canbyi)
- Quercus gravesii
- Quercus grisea
- Quercus imbricaria*
- Quercus laceyi
- Quercus macrocarpa*
- Quercus mohriana
- Quercus muehlenbergii*
- Quercus nigra
- Quercus nuttallii
- Quercus oblongifolia

- Quercus phellos
- Quercus robur
- Quercus rubra*
- Quercus shumardii*
- Quercus stellata
- Quercus vaseyana
- Sapindus drummondii
- Sapindus drummondii*
- Senegalia wrightii
- Styphnolobium affine
- Styphnolobium japonicum
- Syringa reticulata
- Taxodium distichum
- Taxodium distichum
- Tilia americana var. caroliniana
- Ulmus americana*
- Ulmus crassifolia
- Ulmus davidiana var. japonica
- Ulmus parvifolia
- Ungnadia speciosa
- x Chitalpa tashkentensis
- Zelkova serrata

MAPPED CAMPUS LANDSCAPE TYPOLOGIES

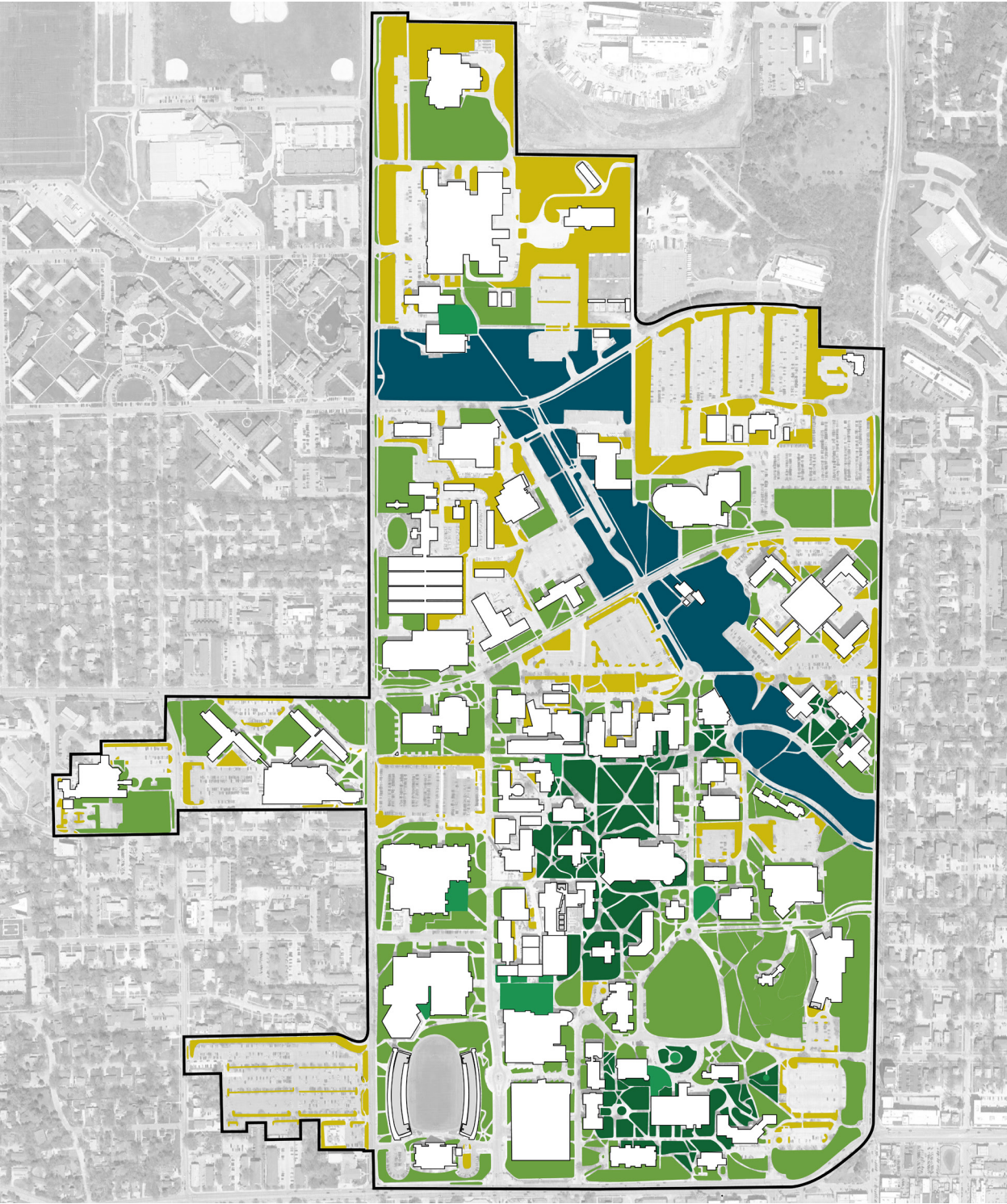


Figure 5.3 Kansas State University Main Campus Landscape Typologies (by author using satellite imagery from Google Earth 2022).

LEGEND

- | | | |
|--------------|-------------|-----------------|
| Campus Green | Quadrangles | Campus Corridor |
| Buildings | Plazas | Surface Parking |

Plan not to scale ⓘ

5. DEVELOP WOODY PLANT CARE AND MANAGEMENT PRACTICES

CREATE AN ARBORETUM CAMPUS TREE-CARE PLAN

Establish Tree Planting and Maintenance Best Practices

Kansas State University Tree Management employees and tree care companies contracted to do work on the KSU campus should be supervised by a certified arborist on campus. It is recommended that tree care operations adhere to American National Standards Institute (ANSI) A300 Standards. Best Management Practices for Tree Care Operations on the KSU campus are defined in the following publications from the International Society of Arboriculture. These publications can be accessed online at isa-arbor.com.

- ANSI A300 Best Management Practices – Tree Pruning
- ANSI A300 Best Management Practices – Utility Pruning of Trees
- ANSI A300 Best Management Practices – Tree Planting
- ANSI A300 Best Management Practices – Integrated Pest Management
- ANSI A300 Best Management Practices – Managing Trees during Construction
- ANSI A300 Best Management Practices – Tree and Shrub Fertilization

Set Landscaping Standards

Provide technical specifications and drawings for tree planting and protection on the campus. This is to help ensure that trees are planted in appropriate locations and protected from damage.

Tree Removal Policy

The arboretum advisory committee must create a tree removal policy. In this document, a detailed description of the process for removing, transplanting, or protecting the plant should be provided. For example, it is advised that if a tree is diagnosed with a disease or poses a safety risk to the campus community, it should undergo a risk assessment by the Campus Arborist and Campus Landscape Architect. If a tree requires removal, it should be communicated to the advisory committee.

Prohibited Species

Prohibitive species that should not be planted on the campus due to their potential to become invasive or cause other problems should be identified.

Plan for Managing Catastrophic Events

Outline how the campus manages catastrophic events such as snowstorms or strong winds, prioritizing the campus community's safety and the trees' health. This will help ensure that trees are protected during extreme weather events.

Establish Protection and Preservation Policies

To safeguard trees that may be at risk of damage due to development activities, it is important to establish policies that include conducting a thorough tree inventory, creating a mitigation plan, implementing a protection plan, and enforcing a replacement policy. This comprehensive approach will help ensure that trees are protected and preserved during construction activities.

Define a Tree Damage Assessment Process

Establish a process for assessing trees damaged during construction activities and compensating for their loss based on industry-recognized methods. This will help ensure that trees are properly valued and compensated for when damaged.

Prohibit Harmful Practices

Prohibit practices that are not consistent with best management practices or that may harm or damage campus trees, such as locking bikes to trees and graffiti. This will help protect trees from unnecessary damage.

INVENTORIES

KSU should immediately inventory its campus trees. It has been over 20 years since K-State's main campus trees were inventoried. An inventory provides a fundamental baseline of information about campus tree types, locations, and conditions. It can show changes over time if updated regularly, documenting tree loss and planting (Rakow and Lee 2011). Arboretum staff also use inventories to determine whether the accession is still present and in the same condition as when it was last recorded. This keeps records and grounds in sync. It is advised that routine inventories are conducted every three, five, or seven years, depending on the collection type (Rakow and Lee 2011). Also, in the event of a severe storm, an inventory serves as a record of what existed before the event.

Develop a Plant Inventory Operations Manual

A plant inventory operations manual describes the procedures and standards for inventorying living plant collections. Below are recommendations KSU needs to consider when developing its Plant Inventory Manual.

- Define the purpose and scope of the plant inventory operations manual and its intended users.
- Outline the procedures and standards for conducting field inventory checks, such as the steps and tasks involved in verifying the location and conditions of the plants.
- Provide guidelines on what information needs to be gathered, such as plant health and how to record information during field checks.
- Include appendices with resources such as operationally defined plant conditions, inventory timelines and regions, label standards, post-disaster procedures, and data management tutorials.

Refer to the Plant Inventory Operations Manual by The Arnold Arboretum in developing this manual.

6. DEVELOP RESEARCH PURSUITS ON WOODY PLANTS

Recommendations for K-State Based on the Texas Tree Trail Research by UC Davis Arboretum

- Consider trees native to hot and arid climates, such as Texas, that could potentially thrive despite the increasing temperatures and extending drought conditions of the Sacramento Valley region.
- Visit the field trial sites in the UC Davis Arboretum, where researchers and students have planted test trees from Texas to monitor their progress and gather data on their drought and heat tolerance, potential issues or hazards, and notable characteristics.
- Learn from the experiences of other horticulturists, arborists, researchers, and tree lovers who have planted or observed these trees in different conditions.

Recommendations for K-State Based on the Climate Ready Tree Study – Selecting Tree Fit for the Future by UC Davis Arboretum

- Choose tree species adapted to the state's projected climate conditions, such as higher temperatures, lower rainfall, and more extreme weather events.
- Experiment with a diversity of tree species that are rarely grown in Kansas communities.
- Monitor the performance of the planted trees over time and evaluate their growth, health, water use, and aesthetic value.
- Share the results and lessons learned from the tree trial with arboretums and communities interested in creating climate-ready urban forests.

FOR A LIST OF CLIMATE-READY TREES SUITABLE FOR THE KSU CAMPUS, PLEASE REFERENCE RECOMMENDATION #4, UNDER PALETTES FOR THE KSU LANDSCAPE TYPOLOGIES

7. COMMENCE EDUCATION AND PUBLIC OUTREACH INITIATIVES

- Organize and market tours, workshops, lectures, or events that educate and engage the campus community and visitors about the arboretum.
- Offer opportunities for virtual engagement with the arboretum, such as recorded tours and educational presentations.
- Establish partnerships with campus departments to create innovative internship programs on improving the longevity and resilience of the campus tree canopy.
- Create a program for arboretum stewardship that allows students and interns to gain knowledge about tree management.
- Foster an arboretum program where students plan and coordinate outreach activities and education events for K- 12 students on the importance and benefits of trees.
- Engage with the network of Kansas State Foresters to create tree management courses for Kansans.
- Develop specialized campus arboretum areas that are tailored to the needs of specific instructors or courses.
- Design outreach programs for the public on woody plants that perform best in their region.
- Promote the arboretum by creating a map, brochure, website, or app showcasing the tree collections' features and benefits.

Interactive Website

- Develop a comprehensive website dedicated to the arboretum.
- Showcase tree species with detailed profiles, including botanical names, common names, and significance.
- Provide virtual tours, interactive maps, and educational resources.
- Highlight upcoming events, workshops, and volunteer opportunities.

Arboretum App

Create a user-friendly mobile app for iOS and Android platforms. Include features like:

- Tree Identification: Users can identify trees by uploading photos or using a search function.
- Seasonal Highlights: Share what’s in bloom or changing colors throughout the year.
- Walking Trails: Map out different trails within the arboretum.
- Educational Content: Offer articles, videos, and quizzes about trees.
- Event Calendar: Keep users informed about workshops, guided tours, and special events.

KSU Arboretum Virtual Tours

Recorded tours of the arboretum are an excellent addition to outreach opportunities. These tours can allow participants to access the arboretum from the comfort of their own screens. Here are some suggestions on outreach activities that could be planned:

Virtual Guided Tours

- Create professionally recorded video tours led by knowledgeable guides.
- Highlight significant trees, collections, and interesting features.
- Include historical context, insights, and fun facts.
- Share these videos on the arboretum's website or social media channels.

Self-Guided Audio Tours

- Develop audio recordings visitors can listen to while virtually exploring the arboretum.
- Provide detailed descriptions of key points of interest.
- Encourage participants to follow along on a virtual map or use images to enhance the experience.

Interactive Virtual Maps

- Combine recorded audio with an interactive map.
- Participants can click on specific locations to hear relevant information.
- Include images, videos, and links to additional resources.

Live Virtual Tours

- Host live streaming sessions where guides walk through the arboretum in real-time.
- Participants can ask questions and interact with the guide.
- Promote these events in advance to attract a larger audience.

Make tours engaging, informative, and visually appealing to connect people with the arboretum.

Adopting the Learning by Leading™ program at KSU

The Learning by Leading™ program at the UC Davis Arboretum and Public Garden is an innovative initiative that empowers students to learn through leadership. The following are key details of this distinguished program that Kansas State University Arboretum could adopt to enhance educational and outreach opportunities.

Program Overview

- Learning by Leading™ offers quarter-long and school year-long internships.
- Students gain leadership experience by addressing various environmental sustainability and restoration issues.
- They work in teams to solve real-world problems within the UC Davis Arboretum and Public Garden.

Internship Opportunities

- SmartLandscape: This program focuses on reducing water and fertilizer use in urban landscaping while maintaining aesthetic and ecological value.
- Nursery Management Internship: Students engage in hands-on plant-related activities at the Teaching Nursery. It's a great opportunity to work closely with peers and mentors.
- Arboretum Ambassadors: This organization empowers youth leaders to advocate for the environment through public outreach, environmental education, and networking.
- Ecological Land Management: Interns gain experience in managing, stewarding, and restoring natural lands on the UC Davis Putah Creek Riparian Reserve and other campus natural areas.

Benefits for Students

- Transferable Skills: Students develop leadership and team-building professional skills.
- Expert Mentorship: They build strong relationships with staff experts and receive recommendations for future endeavors.
- Hands-On Experience: Students engage in gardening, landscape restoration, and plant cultivation.
- Community Impact: They organize events that engage volunteers, visitors, and other community members.

Schedule

- Internships correspond with the UC Davis academic calendar (fall, winter, and spring semesters).
- Summer internships are offered individually and coordinated with staff mentors.

For more information, visit the UC Davis Arboretum and Public Garden website.

Educational Partnerships with Manhattan Public Schools

The KSU arboretum can engage in various partnership activities with a K-12 program to enhance education, such as:

- Outdoor Learning: Facilitate field studies in the arboretum to teach students about the value of trees.
- Curriculum Development: Collaborate with teachers to develop science curricula incorporating hands-on learning experiences in the arboretum.
- Teacher Training: Offer workshops or courses for teachers on effectively using outdoor spaces for teaching various subjects.
- Community Science Projects: Involve students in ongoing research projects at the arboretum, allowing them to contribute to real-world science and conservation efforts.

These activities can help foster a connection between students and the natural world, enrich their educational experience, and support teachers in delivering engaging science education.

Arboretum Poetry

The University of Arizona Campus Arboretum hosts various events that intertwine the arboretum's beauty and nature with the art of poetry. Here are some key aspects.

Poetry and Nature: The Arboretum organizes events like "Poetry Nature Walk" and "Poetry Tree Tour," which combine the exploration of the arboretum and nature with the appreciation of poetry.

Educational Outreach: They offer educational programs such as "Poetry and Science" to engage the community in the scientific aspects of the natural world through poetic expression.

Cultural Integration: The Arboretum collaborates with the Poetry Center to host readings and workshops, fostering a connection between the literary community and the Arboretum.

For more information, visit the University of Arizona Campus Arboretum website.

K-State Climate-ready Trees Outreach Initiatives

Tree Planting Workshops

Organize workshops or webinars to educate the community about the importance of planting diverse tree species. Highlight climate-ready species options that can thrive in changing conditions. Encourage participants to plant these trees in their own yards or public spaces.

Tree Adoption Program

Create a program where community members can "adopt" a tree. Provide information on tree care, maintenance, and the benefits of planting climate species. This fosters a sense of ownership and environmental stewardship.

Collaborate with Local Schools

Partner with local schools to teach students about climate change, tree biology, and the role of trees in mitigating its effects.

Tree Giveaways

Host tree giveaway events where community members can receive free climate-ready trees. Provide planting instructions and resources to ensure successful establishment.

Collaborate with Landscape Architects and Urban Planners

Engage professionals in designing climate-resilient landscapes. Advocate for incorporating climate-ready trees in urban development projects, streetscapes, and public spaces.

Educational Materials

Develop brochures, pamphlets, or online resources highlighting climate-ready tree species suitable for the region. Include planting tips, maintenance guidelines, and success stories.

Community Tree Planting Events

Organize community tree-planting days. Involve volunteers, students, and local organizations to plant climate-ready trees in parks, school campuses, and other public areas.

Collaborate with Local Businesses

Partner with nurseries, garden centers, and landscaping companies to promote climate-ready trees. Offer discounts or incentives for purchasing and planting these species.

Effective outreach involves collaboration, education, and community engagement. By spreading awareness and empowering individuals, the KSU arboretum can contribute to a more climate-resilient urban forest.

COLLABORATION RECOMMENDATIONS

One of the ways that the KSU Arboretum can enhance its impact and relevance is by collaborating with other arboreta and relevant organizations with different areas of expertise and interest. By doing so, KSU can reach a wider and more diverse audience and benefit from exchanging knowledge and experience in arboretum management and development. Some of the possible collaborative endeavors that the KSU Arboretum can pursue are the evaluation of woody plants, tree trials, research projects, conservation efforts, educational programs, exhibits, public events, tours, collection expeditions, plant exchanges, professional meetings, and co-authoring of research papers.

By engaging in these collaborative endeavors, KSU can increase its visibility, credibility, and influence in arboreta. It can also enrich its knowledge base and resources, as well as those of its partners. Moreover, it can foster community and camaraderie among arboreta staff and supporters who share a common passion and vision for woody plants.

Collaboration Between Existing K-State Departments

- Landscape Architecture & Regional Community Planning Department
- Horticulture & Arboriculture
- Entomology
- Agricultural Education
- K-State Garden

**Recommended Partnerships for K-State:
Kansas Forest Service & K-State Research Extensions**

- Kansas Forest Service has seven district offices across the state.
- K-State John C. Pair Horticulture Center
Location: Wichita, Kansas
- K-State Research & Extension Center Olathe
Location: Olathe, Kansas
- K-State Tuttle Forestry Research Center
Location: Manhattan, Kansas

Accredited State Arboreta

- Kansas Forest Service Demonstration Arboretum and Honor Grove
Location: Manhattan, Kansas
Accreditation Level: Level II
- Lawrence Rotary Arboretum
Location: Lawrence, Kansas
Accreditation Level: Level I
- Douglas County Fairgrounds Arboretum
Location: Lawrence, Kansas
Accreditation Level: Level I
- SouthPark Arboretum
Location: Lawrence, Kansas
Accreditation Level: Level I

Nonaccredited Kansas Arboreta

- Sedgwick County Extension Arboretum
Location: Wichita, Kansas
- Dyck Arboretum of the Plains
Location: Hesston, Kansas
- Bartlett Arboretum
Location: Belle Plaine, Kansas
- Kansas Landscape Arboretum
Location: Wakefield, Kansas
- Overland Park Arboretum and Public Garden
Location: Overland Park, Kansas
- Parsons Arboretum
Location: Parsons, Kansas

CHAPTER 6
CONCLUSION



CONCLUSION

This project addressed an opportunity and a need for the KSU campus to become an accredited arboretum with a climate-ready tree collection dedicated to researching and demonstrating species suitable for Kansas’s changing climate.

By the end of the 21st century, climatic predictions for Kansas (under the high-emissions scenario model) indicate that its Plant Hardiness Zone will change from zones 5-6 to 7-8, its Heat Zones will change from an average of 61-120 days per year with a maximum temperature of at least 86°F, to have 151-180 days per year with temperatures above 86°F with a small area in south-central Kansas projected to have 181-210 days per year with temperatures above 86°F. Growing Degrees Days will change from 3,000-3,999 GDD, with the southern part of the state having 4,000-4,999 GDD to a predominantly uniform range of growing degree days between 5,000 and 5,999 with the northwest region of the state between 4,000 and 4,999 GDD. Additionally, KS will likely see more severe storms and the emergence of new tree pests and diseases. Thus, tree species that currently thrive in KS may not be able to survive under these changed conditions. Thus, it is essential to begin planting and studying tree species from regions with conditions similar to those predicted for KS.

To answer the research question: *How can KSU develop an accredited arboretum with a dedicated “climate-ready” tree collection to demonstrate the viability of species most suitable for Kansas’s changing climate?* This project included surveys of subject matter experts, precedent studies of notable university arboreta, a climate evaluation of Kansas’s current and future conditions, a site inventory of K-State campus landscape typologies, the development of a “climate-ready” tree species list, planting considerations per campus landscape typology, and recommendations for how the campus can become an accredited arboretum.

Establishing such an arboretum would support KSU’s land-grant mission and exemplify the university’s dedication to research, education, and outreach. Achieving ArbNet accreditation would demonstrate KSU’s commitment to trees and elevate its recognition and value to the broader scientific and academic communities and the public.

BROADER IMPACT

A climate-ready tree collection will further the KSU campus as a dynamic living laboratory, offering a wealth of research and outreach potential. Studying the collection will allow researchers to see how various tree species adapt to changing climatic conditions. Data on long-term tree health, growth, and resilience to storms, drought, and pests can benefit municipalities and residents, enabling them to make informed decisions about what to plant and where to plant it. Furthermore, the arboretum will provide a local demonstration site for faculty, staff, students, and visitors to directly engage with and observe trees over time.

The campus arboretum will enhance the campus’s visual appeal, help support biodiversity, and contribute to urban cooling, which benefits surrounding communities. Climate-ready trees are expected to withstand higher temperatures and prolonged droughts and survive heat waves. Knowledge of climate-ready trees will be especially beneficial for local plant nurseries, which purchase, propagate, and sell trees. They can use the information to align their inventory with customer demand for trees that will survive the changing climate. Such data will also benefit landscape architects, arborists, urban foresters, and policymakers, who influence what gets planted within the public realm. Data on growth rates, resilience, and the ability to withstand extreme events can guide them in selecting the most suitable species for specific locations.

Drawing together these points, the KSU arboretum, with a specialized climate-ready tree collection, emerges as an indispensable asset for the campus and the greater public. The arboretum will aid in preserving biodiversity, thereby ensuring the survival of various species for future generations and providing actionable insights for a diverse group of stakeholders. The knowledge gained from the arboretum can guide effective climate adaptation strategies, contributing to the sustainability of our planet for generations to come.

LIMITATIONS

Precedent Studies

Precedent studies did not include site visits or direct observations of the arboreta, which limited the understanding of their physical and spatial characteristics.

Surveys

Surveys were conducted via email; while very insightful, the response rate for the survey was 36%, which may impact the representativeness and generalizability of the results. Additionally, the open-ended nature of the survey questions may have introduced subjectivity and inconsistency in the responses, making it challenging to analyze and compare them. Furthermore, since the survey targeted only one group of experts (community and rural foresters), there may be limitations in the diversity and comprehensiveness of the perspectives and opinions on trees in Kansas.

Site Inventory

This report examined a specific section of the main Kansas State University campus to ensure a more focused approach. This approach facilitated a more thorough and detailed analysis, particularly about considerations for new tree plantings. However, it's important to note that this study did not encompass the entire KSU main campus. This selective focus, while beneficial for detailed analysis, may present a limitation as it does not account for the diverse conditions and needs that might exist in other parts of the campus.

Climate Evaluation

The climate evaluation method only analyzed three key metrics related to plant growth. However, it is essential to consider other vital metrics, such as precipitation and drought, which also significantly impact plant growth. Additionally, the projections were only considered for the high emissions climate scenario, while the low emissions scenario was not considered. The high emissions scenario was chosen due to the dramatic projections for fossil fuel consumption in the world's developing economies and the unlikelihood of policy mechanisms controlling greenhouse gas emissions (Matthews et al. 2018). This choice, while based on current trends, may limit the applicability of the findings to scenarios with lower emissions. Furthermore, the climate report and app used to create the maps in the report only reflect recent conditions from 1980 through 2009 and do not show the existing conditions in 2024. These limitations should be considered when interpreting the project's results.

Tree Species Selection

The tree species selection for this project was limited to two lists. These two lists were selected because they were both notable in each of their states. The comprehensive SelecTree database lacked data on branch strength, salt tolerance, and root damage potential for all species, posing a challenge when integrating them into KSU's landscape typology palettes. However, this focus on Texas trees may have overlooked suitable species from other regions that could thrive under different conditions. For instance, precipitation and humidity, which were not factored into our criteria, can significantly influence species selection and survival. Furthermore, the data and species selection might have varied if a different emissions scenario had been chosen. These limitations should be considered when interpreting the project's results. It's also important to note that other data, such as utilities and sight lines, are needed for exact tree placement. These factors can significantly impact the optimal placement and survival of the trees.

FUTURE RESEARCH

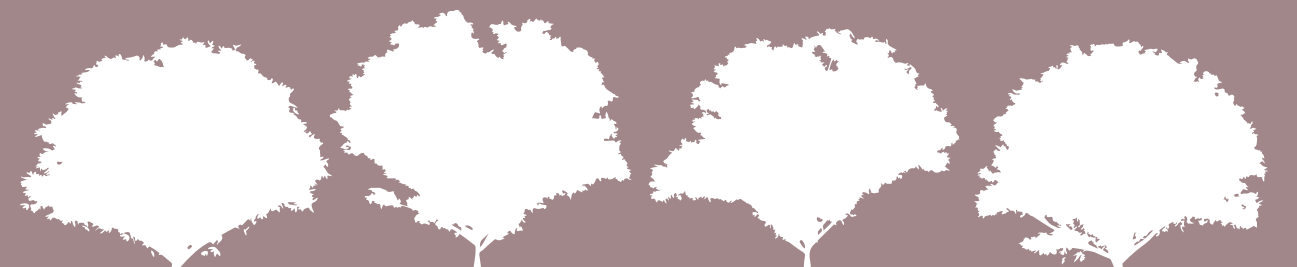
Two key areas emerge as crucial for future research: species selection and evaluation and climate modeling and projections.

In terms of species selection and evaluation, understanding the long-term performance of climate-ready tree species is essential. This involves monitoring their growth, survival rates, and resilience over extended periods. In this context, "evaluation" refers to the process of assessing the suitability of these tree species for the specific climatic and environmental conditions of Kansas. Research should investigate how these species adapt to changing environmental conditions over decades, assess their ability to withstand extreme events such as heatwaves, prolonged droughts, and storms, and understand the trade-offs between growth rates and resilience. The outcome of this research will provide robust data on long-term performance, guiding botanical gardens, arboreta, landscape architects, arborists, communities, and policymakers in selecting the most suitable species for specific locations.

Regarding climate modeling and projections, refining existing climate models is vital for accurate climate projections, which are essential for species selection and management. Research should aim to continuously improve climate models by incorporating finer spatial resolutions and more localized data, validating models against observed climate data to reduce biases, and enhancing the representation of microclimates.

In summary, future research should emphasize long-term species performance monitoring and continuous refinement of climate models. These efforts will enhance the ability to create climate-ready tree communities that are better positioned to withstand climate challenges and benefit both people and the environment.

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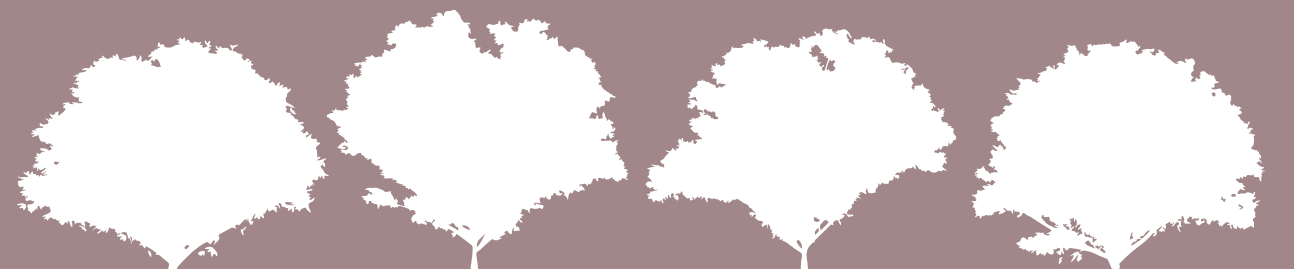
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APPENDICES



IRB EXEMPTION



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

Proposal Number: IRB-10971

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

DATE: 12/21/2021

RE: Proposal Entitled, “Climate Positive Campus Landscape Design at Kansas State University.”

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.

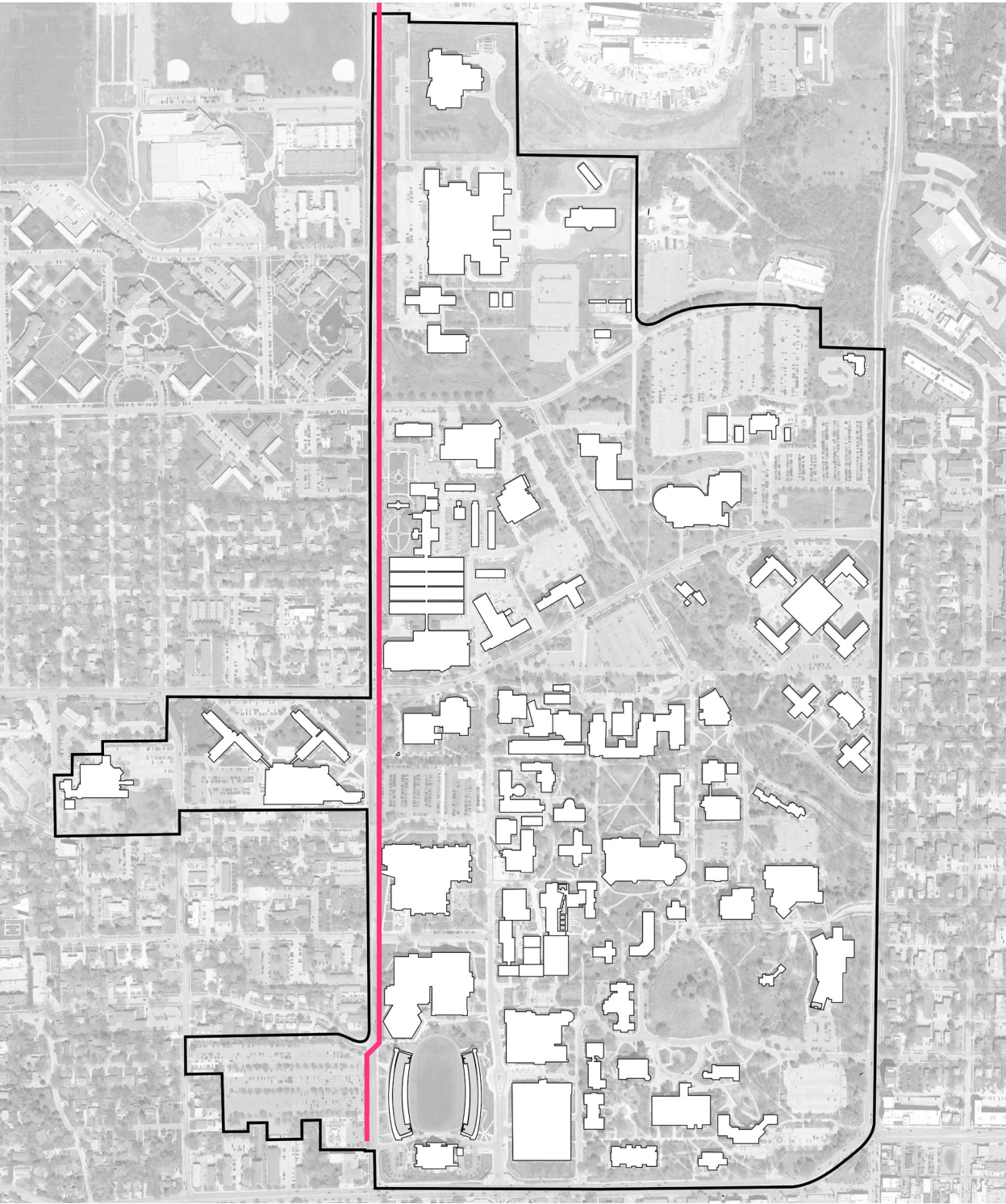
Based upon information provided to the IRB, this activity is exempt under the criteria set forth in the Federal Policy for the Protection of Human Subjects, **45 CFR §104(d), category:Exempt Category 2 Subsection ii.**

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 12/21/2021 6:50 PM ET

OVERHEAD UTILITIES

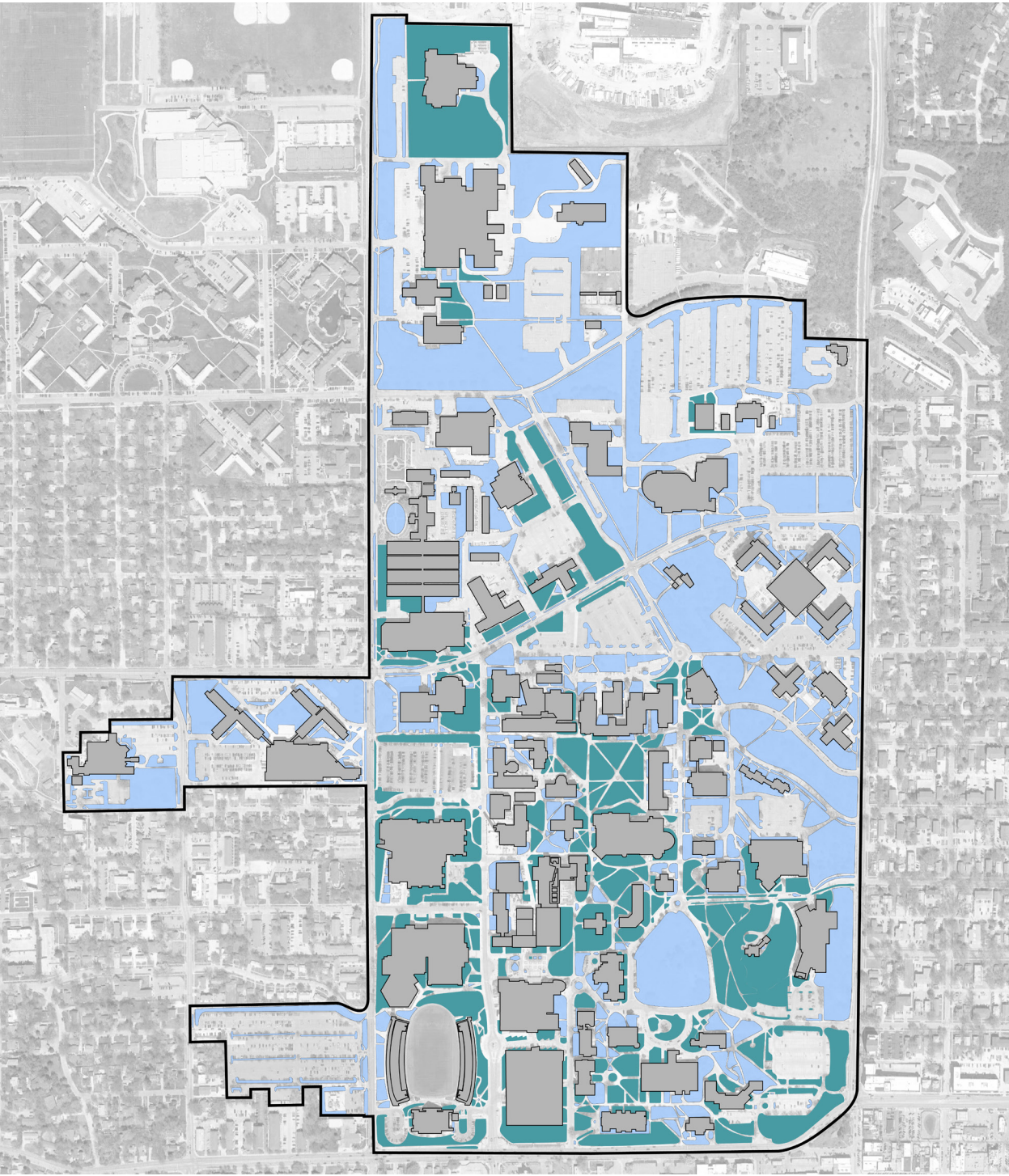


Kansas State University Main Campus Overhead Utilities (by author using satellite imagery from Google Earth 2022).

- LEGEND
- Buildings
 - Overhead Utilities

Plan not to scale ⓘ

ACTIVE TURF IRRIGATED ZONES



Kansas State University Main Campus Existing Irrigation Zones (by author using satellite imagery from Google Earth 2022).

- LEGEND
- Irrigated Zones
 - Non- irrigated Zones
 - Buildings

Plan not to scale ⓘ

TREE PROFILES

(* indicates KS native)

Scientific Name: Acer miyabei

Common Name: Miyabe Maple

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 30-40'

Spread at Maturity: 30-40'

Hardiness Zone: 4 to 8

Sun Exposure: full sun to partial shade

Potential Issues: No serious insect or disease problems.

Suggested Use(s) and or Planting Site: Excellent small tree for small properties. Good specimen tree for lawns or street. Accent or shade tree. Appropriate as an understory tree in a woodland garden or as a specimen in many locations around the home

Aesthetic Characteristics: Flower: Insignificant Leaf: Good Fall Bloom Description: Greenish yellow Leaf stalks contain a milky sap.

Scientific Name: Acer saccharum 'Legacy'*

Common Name: 'Legacy' Sugar Maple*

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 40-80'

Spread at Maturity: 30-60'

Hardiness Zone: 3 to 8

Sun Exposure: Full sun to part shade

Potential Issues: Susceptible to verticillium wilt, anthracnose, cankers, leaf spot and tar spot. Also susceptible to aphids, borers and scale. Leaf scorch may be a problem in drought conditions. Has been frequently used as a street tree, but is generally intolerant of road salt, soil compaction and pollution.

Suggested Use(s) and or Planting Site: Excellent specimen tree for the lawn or parks with beautiful fall color. May be used as a street tree as long as it can be located on a street and in a location where road salt, soil compaction and pollution will not be significant problems.

Suggested Use: Shade Tree

Aesthetic Characteristics: Bloom Description: Greenish; Flower: Insignificant; Leaf: Good Fall turn yellow-orange in autumn, sometimes with considerable color variations.

Scientific Name: Acer saccharum Oregon Trail*

Common Name: Oregon Trail Sugar Maple*

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 45'

Spread at Maturity: 40'

Hardiness Zone: 4 to 6

Sun Exposure: Full Sun

Potential Issues: No serious insect or disease problems.

Suggested Use(s) and or Planting Site: Notably, this cultivar is heat-resistant, making it an excellent choice for landscapes in regions with warm climates. Its strong branch structure ensures longevity and provides ample shade.

Aesthetic Characteristics: (no data available)

Scientific Name: Acer saccharum 'John Pair'*

Common Name: 'John Pair' & 'Autumn Splendor' Sugar Maple*

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 25'-30'

Spread at Maturity: 25'-30'

Hardiness Zone: 4 to 8

Sun Exposure: full sun to partial shade

Potential Issues: No serious insect or disease problems.

Suggested Use(s) and or Planting Site: Shade Tree

Aesthetic Characteristics: Leaf: Glossy, dark-green, deeply-lobed leaves with pointed tips. Fruit: Samaras.
Flower: Not significant

Scientific Name: Carya illinoensis*

Common Name: Pecan*

Salt Spray Tolerance: Low

Branch Strength: Medium Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 75-100’

Spread at Maturity: 40-70’

Hardiness Zone: 5 to 9

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. Scab can infect both nuts and foliage, although scab resistant cultivars are available. Aphids, pecan weevils, twig girdlers and fall webworms can also do damage.

Suggested Use(s) and or Planting Site: A tall ornamental shade tree for large properties. May also be grown for nut production. Suggested Use: Shade Tree

Aesthetic Characteristics: Bloom Description: Greenish-yellow Flower: Insignificant Fruit: Showy, Edible

Scientific Name: Catalpa speciosa*

Common Name: Northern Catalpa*

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 40-70’

Spread at Maturity: 20-50’

Hardiness Zone: 4 to 8

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems. Susceptible to verticillium wilt, leaf spots, mildew and twig blight. The larvae (caterpillars) of the catalpa sphinx moth may do considerable damage when feeding on the leaves.

Suggested Use(s) and or Planting Site: Shade Tree, Rain Garden; This tree is ideal for shade and rain gardens, despite its brittle branches and non-classic form. Its large leaves may deteriorate throughout the season due to various factors. It’s widely used in urban areas as a street and lawn tree, and it’s suitable for challenging landscapes, including moist low spots or areas with poor soils.

Aesthetic Characteristics: Bloom Description: White with purple and yellow interior spotting Flower: Showy Fruit: Showy

Scientific Name: Celtis occidentalis*

Common Name: Common Hackberry*

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 40-60'

Spread at Maturity: 40-60'

Hardiness Zone: 2 to 9

Sun Exposure: Full sun to part shade

Potential Issues: Hackberry nipple gall, Powdery mildew, leaf spot and root rot may occur. Watch for lacebugs and scale.

Suggested Use(s) and or Planting Site: This is a tough shade tree that grows in a wide range of soils. This tree may be used as a lawn tree or street tree. Seeds can pose clean up problems if trees are sited near sidewalks or patios, however. Suggested Use: Shade Tree, Street Tree, Rain Garden

Aesthetic Characteristics: Bloom Description: Green Flower: Insignificant Attracts: Birds, Butterflies Fruit: Edible

Scientific Name: Ginkgo biloba

Common Name: Ginkgo

Salt Spray Tolerance: Moderate

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 50-80'

Spread at Maturity: 30-40'

Hardiness Zone: 3 to 8

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. Usually slow growing, with initial growth being somewhat sparse.

Suggested Use(s) and or Planting Site: Excellent selection for a variety of uses, including lawn tree, street tree or shade tree. Also effective in city parks or near commercial buildings. Suggested Use: Street Tree

Aesthetic Characteristics: Bloom Description: Green Flower: Insignificant Leaf: Good Fall

Scientific Name: Gleditsia triacanthos var. inermis*

Common Name: Thornless Honeylocust*

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 35-45'

Spread at Maturity: 25-35'

Hardiness Zone: 3 to 8

Sun Exposure: Full sun

Potential Issues: Honey locust is susceptible to diseases and insects such as leaf spot, canker, rust, borers, and webworms and spider mites.

Suggested Use(s) and or Planting Site: A thornless and nearly seedless form that is recommended for lawns and streets. Shade Tree, Street Tree

Aesthetic Characteristics: Bloom Description: Greenish-white Flower: Showy The leaves turn bright yellow in the fall.

Scientific Name: Gymnocladus dioicus*

Common Name: Kentucky Coffeetree*

Salt Spray Tolerance: Low

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 60-80'

Spread at Maturity: 40-55'

Hardiness Zone: 3 to 8

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. Leaves and seedpods can create litter problems.

Suggested Use(s) and or Planting Site: Good landscape tree for large lawns and parks. Male trees are generally considered more desirable because of the lack of seedpods. Shade Tree, Rain Garden

Aesthetic Characteristics: Bloom Description: Greenish-white Flower: Showy, Fragrant Fruit: Showy

Scientific Name: Liquidambar styraciflua

Common Name: Sweetgum

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: High

Foliage Type: Deciduous

Height at Maturity: 60-80'

Spread at Maturity: 40-60'

Hardiness Zone: 5 to 9

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. Webworms, caterpillars, borers and scale may cause problems in some areas. Leaf spots, wood rot and bleeding necrosis may occur. Chlorosis may occur in alkaline soils.

Suggested Use(s) and or Planting Site: Excellent shade, lawn or park tree. Must be planted in large area with room to grow. Fruit can cause litter problems that detract from using this tree as a street tree. Shade Tree

Aesthetic Characteristics: Bloom Description: Yellow-green Flower: Insignificant Leaf: Fragrant, Good Fall

Scientific Name: Platanus x acerifolia

Common Name: London Planetree

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 75-100'

Spread at Maturity: 60-75'

Hardiness Zone: 4 to 8

Sun Exposure: Full sun

Potential Issues: disease problem of concern is cankerstain which can be fatal. Canker, leaf spot and powdery mildew may also occur. Insect visitors include borers, scale, Japanese beetles, caterpillars and mites. When grown as a lawn tree, litter from twigs, large leaves, bark and fruiting balls can pose significant clean-up problems.

Suggested Use(s) and or Planting Site: A large tree for a large space. Generally considered too large and too messy for street tree use. Shade Tree, Rain Garden

Aesthetic Characteristics: Bloom Description: Yellow (male) and red (female) Flower: Insignificant
Fruit: Showy

Scientific Name: Quercus bicolor*

Common Name: Swamp White Oak*

Salt Spray Tolerance: Low

Branch Strength: Medium Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 50-60'

Spread at Maturity: 50-60'

Hardiness Zone: 3 to 8

Sun Exposure: Full sun

Potential Issues: anthracnose, canker, leaf spot, rust, blight, galls, caterpillars, borers, leaf miners, oak lace bug and oak mite. Chlorosis often occurs when soils are not properly acidic. Can be difficult to transplant and establish.

Suggested Use(s) and or Planting Site: Shade Tree, Street Tree, Rain Garden Specimen, street tree, lawn tree. A good tree for wet ground and low spots.

Aesthetic Characteristics: Bloom Description: Yellowish-green Flower: Insignificant Leaf: Good Fall

Scientific Name: Quercus buckleyi

Common Name: Texas Red Oak

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 30-75'

Spread at Maturity: 40-60'

Hardiness Zone: 6 to 8

Sun Exposure: Full sun

Potential Issues: Oak Wilt, Aphids, Oak Leafroller, Gypsy Moth, Powdery Mildew.

Suggested Use(s) and or Planting Site: Highly regarded as an ornamental and shade tree. Its autumn foliage adds vibrant colors to landscapes. Drought and heat tolerant.

Aesthetic Characteristics: Fruit Characteristics: acorns, reddish-brown

Scientific Name: Quercus imbricaria*

Common Name: Shingle Oak*

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: Strong

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 40-60'

Spread at Maturity: 40-60'

Hardiness Zone: 5 to 8

Sun Exposure: Full sun

Potential Issues: Shingle oak is a low-maintenance tree with good pest resistance. However, like other oaks, it can be susceptible to various diseases and pests, including oak wilt, chestnut blight, root rot, anthracnose, leaf blister, cankers, leaf spots, powdery mildew, and insects such as scale, skeletonizer, leaf miner, galls, lace bugs, borers, caterpillars, and nut weevils.

Suggested Use(s) and or Planting Site: A medium shade tree for large lawns or parks. Street tree. May be pruned for use as a screen or hedge. Shade Tree

Aesthetic Characteristics: Bloom Description: Yellowish-green Flower: Insignificant Leaf: Good Fall Fruit: Showy Fruits are rounded acorns

Scientific Name: Quercus macrocarpa*

Common Name: Bur Oak*

Salt Spray Tolerance: Moderate

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 60-80'

Spread at Maturity: 60-80'

Hardiness Zone: 3 to 8

Sun Exposure: Full sun

Potential Issues: Oaks are susceptible to a large number of diseases, including oak wilt, chestnut blight, shoestring root rot, anthracnose, oak leaf blister, cankers, leaf spots and powdery mildew. Potential insect pests include scale, oak skeletonizer, leaf miner, galls, oak lace bugs, borers, caterpillars and nut weevils. Bur oak is generally considered to be a low-maintenance, long-lived tree.

Suggested Use(s) and or Planting Site: large shade tree for very large lawns or parks. Shade Tree, Rain Garden

Aesthetic Characteristics: Bloom Description: Yellowish-green Flower: Insignificant Fruit: Showy Fruits are oval acorns

Scientific Name: Quercus nigra

Common Name: Water Oak

Salt Spray Tolerance: Low

Branch Strength: Weak

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 50-80'

Spread at Maturity: 40-60'

Hardiness Zone: 6 to 9

Sun Exposure: Full sun

Potential Issues: Water oak is a weak-wooded tree prone to trunk cankers, rots, and limb breakage due to wind or snow. Like other oaks, it can be affected by diseases such as oak wilt, chestnut blight, root rot, anthracnose, leaf blister, cankers, leaf spots, powdery mildew, and pests like scale, skeletonizer, leaf miner, galls, lace bugs, borers, caterpillars, and nut weevils.

Suggested Use(s) and or Planting Site: A medium oak for moist areas or lowspots. Has been used as a street tree and shade tree, particularly in southern towns and cities. Shade Tree, Street Tree

Aesthetic Characteristics: Flower: Insignificant Fruit: Showy

Scientific Name: Quercus nuttallii

Common Name: Nuttall Oak

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 50'-80'

Spread at Maturity: 50-60'

Hardiness Zone: 6 to 8

Sun Exposure: Full sun

Potential Issues: (no data available)

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: (no data available)

Scientific Name: Quercus phellos

Common Name: Willow Oak

Salt Spray Tolerance: Low

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 40-75'

Spread at Maturity: 25-50'

Hardiness Zone: 5 to 9

Sun Exposure: Full sun

Potential Issues: Oaks are susceptible to a large number of diseases, including oak wilt, chestnut blight, shoestring root rot, anthracnose, oak leaf blister, cankers, leaf spots and powdery mildew. Potential insect pests include scale, oak skeletonizer, leaf miner, galls, oak lace bugs, borers, caterpillars and nut weevils. Notwithstanding the aforementioned, willow oak is generally considered to have good resistance to pests and to be a low-maintenance, long-lived tree.

Suggested Use(s) and or Planting Site: A medium to large shade tree for large lawns, along streets or in parks. Also effective along ponds or water gardens. Suggested Use: Shade Tree, Street Tree, Rain Garden

Aesthetic Characteristics: Bloom Description: Yellow-green Flower: Insignificant

Scientific Name: Quercus robur

Common Name: English Oak

Salt Spray Tolerance: Moderate

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 40-70'

Spread at Maturity: 40-70'

Hardiness Zone: 5 to 8

Sun Exposure: Full sun

Potential Issues: English oak is considered to be a low-maintenance tree with few problems. Oaks in general are susceptible to a large number of diseases, including oak wilt, chestnut blight, shoestring root rot, anthracnose, oak leaf blister, cankers, leaf spots and powdery mildew. Potential insect pests include scale, oak skeletonizer, leaf miner, galls, oak lace bugs, borers, caterpillars and nut weevils.

Suggested Use(s) and or Planting Site: A large shade tree for very large lawns or parks. Shade Tree

Aesthetic Characteristics: Bloom Description: Yellowish-green Flower: Insignificant Fruit: Showy Fruits are oval acorns

Scientific Name: Quercus rubra*

Common Name: Northern Red Oak*

Salt Spray Tolerance: Moderate

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 50-75'

Spread at Maturity: 50-75'

Hardiness Zone: 4 to 8

Sun Exposure: Full sun

Potential Issues: Generally a durable and long-lived tree. Susceptible to oak wilt which is a systemic fungal disease that has no cure. Chlorosis often occurs when soils are not sufficiently acidic.

Suggested Use(s) and or Planting Site: Specimen, street tree, lawn tree. Shade Tree, Street Tree

Aesthetic Characteristics: Bloom Description: Yellowish-green Flower: Insignificant
Leaf: Good Fall Fruits are acorns

Scientific Name: Quercus shumardii*

Common Name: Shumard Oak*

Salt Spray Tolerance: Moderate

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 40-60'

Spread at Maturity: 30-40'

Hardiness Zone: 5 to 9

Sun Exposure: Full sun

Potential Issues: Generally a durable and long-lived tree, but is susceptible to a large number of potential diseases and insect pests, including anthracnose, canker, leaf spot, rust, blight, galls, caterpillars, borers, leaf miners, oak lace bug and oak mite. Chlorosis often occurs when soils are not properly acidic.

Suggested Use(s) and or Planting Site: Shade tree, street tree, lawn tree. Does well in wide range of soils from dry locations to wet ground and low spots. Shade Tree, Street Tree, Rain Garden

Aesthetic Characteristics: Bloom Description: Greenish Flower: Insignificant Leaf: Good Fall
Fruits are acorns which are usually not produced until the tree has reached the age of 25 years.

Scientific Name: Styphnolobium japonicum

Common Name: Japanese Pagodatree

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 50-75'

Spread at Maturity: 50-75'

Hardiness Zone: 4 to 8

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems. Twig blight, verticillium wilt, canker, powdery mildew and rust may occur. Watch for leaf hoppers.

Suggested Use(s) and or Planting Site: Lawn or street tree. Shade Tree, Street Tree

Aesthetic Characteristics: Bloom Description: Creamy white Flower: Showy
Fruit: Showy Flowers give way to slender, 1- to 6-seeded, knobby, bean-like pods

Scientific Name: Taxodium distichum

Common Name: Bald Cypress

Salt Spray Tolerance: Moderate

Branch Strength: Medium Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 50-70'

Spread at Maturity: 20-45'

Hardiness Zone: 4 to 9

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. Chlorosis often occurs in alkaline soils. Bagworms, gall mites and spider mites are occasional insect pests and twig blight is an occasional disease pest.

Suggested Use(s) and or Planting Site: A large ornamental tree for parks or large lawns. Good selection for growing in wet soils either in low spots or near water. Rain Garden

Aesthetic Characteristics: Bloom Description: Brown Leaf: Good Fall Attracts: Birds Fruit: Showy

Scientific Name: Ulmus americana*

Common Name: American Elm*

Salt Spray Tolerance: Moderate

Branch Strength: Medium Weak

Root Damage Potential: High

Foliage Type: Deciduous

Height at Maturity: 60-80'

Spread at Maturity: 40-70'

Hardiness Zone: 2 to 9

Sun Exposure: Full sun

Potential Issues: Dutch elm disease and Phloem necrosis. Various wilts, rots, cankers and leaf spots may also occur. Insect visitors include borers, leaf miner, beetles, mealy bugs, caterpillars and scale.

Suggested Use(s) and or Planting Site: May be used as a lawn, shade or street tree. Shade Tree, Street Tree, Rain Garden

Aesthetic Characteristics: Bloom Description: Reddish-green Flower: Insignificant Flowers give way to single-seeded wafer-like samaras

Scientific Name: Ulmus parvifolia

Common Name: Lacebark Elm

Salt Spray Tolerance: Moderate

Branch Strength: Medium Weak to Medium

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 40-50'

Spread at Maturity: 25-40'

Hardiness Zone: 4 to 9

Sun Exposure: Full sun

Potential Issues: Chinese elm has good resistance to Dutch elm disease, a fatal fungal disease spread by airborne bark beetles. It also has good resistance to Japanese beetle and elm leaf beetle. Occasional disease problems include wilts, rots, cankers and leaf spots. Branches tend to break when stressed with snow, ice or wind.

Suggested Use(s) and or Planting Site: Shade or specimen tree for the landscape. Shade Tree, Street Tree

Aesthetic Characteristics: Bloom Description: Reddish-green Flower: Insignificant Flowers give way to single-seeded wafer-like samaras

Scientific Name: Zelkova serrata

Common Name: Japanese Zelkova

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 50-80'

Spread at Maturity: 50-80'

Hardiness Zone: 5 to 8

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. Highly resistant to Dutch elm disease. Phloem necrosis, wilts and cankers may occur. Insect visitors include leaf miner, beetles and scale. Spider mites can be a problem in hot, dry summers.

Suggested Use(s) and or Planting Site: May be used as a lawn, shade or street tree. Shade Tree, Street Tree

Aesthetic Characteristics: Bloom Description: Green Flower: Insignificant Leaf: Good Fall

Scientific Name: Acer buergerianum

Common Name: Trident Maple

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 20-30'

Spread at Maturity: 20-30'

Hardiness Zone: 5 to 9

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems. Limbs may be damaged in winter by snow and/or ice.

Suggested Use(s) and or Planting Site: Attractive small tree for streets, patios and around the home. Bonsai. Shade Tree, Street Tree

Aesthetic Characteristics: Bloom Description: Greenish-yellow Flower: Insignificant Leaf: Good Fall

Scientific Name: Acer campestre

Common Name: Hedge Maple

Salt Spray Tolerance: Low

Branch Strength: Medium

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 25-35'

Spread at Maturity: 25-35'

Hardiness Zone: 5 to 8

Sun Exposure: Full sun to part shade

Potential Issues: Leaf spots, tar spot, verticillium wilt, canker and root rots may occur. Potential insect pests include aphids, scale, borers and caterpillars. Mites may appear.

Suggested Use(s) and or Planting Site: This is an attractive tree or shrub for lawns or along streets. May be sheared to form a high hedge. Hedge, Shade Tree, Street Tree

Aesthetic Characteristics: Bloom Description: Yellowish-green Flower: Insignificant

Scientific Name: Acer truncatum

Common Name: Shantung Maple

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 20-25'

Spread at Maturity: 15-20'

Hardiness Zone: 4 to 8

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems.

Suggested Use(s) and or Planting Site: Excellent small landscape tree or street tree. Specimen around the home for patios and small areas. Suggested Use: Street Tree

Aesthetic Characteristics: Bloom Description: Greenish yellow Flower: insignificant
Leaf: Good Fall Leaf stems exude a milky sap when cut. Fruit is a samara.

Scientific Name: Carpinus betulus

Common Name: European Hornbeam

Salt Spray Tolerance: Moderate

Branch Strength: Strong

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 40-60'

Spread at Maturity: 30-40'

Hardiness Zone: 4 to 8

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems.

Suggested Use(s) and or Planting Site: Shade tree for lawns. Street tree. Prune as a hedge.
Suggested Use: Shade Tree, Street Tree

Aesthetic Characteristics: Bloom Description: Yellow (male) and green (female) Flower: Insignificant
Fruits are small nutlets in 3-lobed bracts that appear in drooping 5" long clusters in summer

Scientific Name: Catalpa bignonioides

Common Name: Southern Catalpa

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 30-60'

Spread at Maturity: 20-40

Hardiness Zone: 5 to 9

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems. Susceptible to verticillium wilt, leaf spots, mildew, dieback, anthracnose and twig blight. The larvae (caterpillars) of the catalpa sphinx moth may do considerable damage when feeding on the leaves. Watch for mealybugs, aphids, scale and whiteflies.

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: Bloom Description: White with purple and yellow markings Flower: Showy
Fruit: Showy After flowering, seeds appear in long narrow pods.

Scientific Name: Diospyros virginiana*

Common Name: Persimmon*

Salt Spray Tolerance: Low

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 35-60'

Spread at Maturity: 25-35'

Hardiness Zone: 4 to 9

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems. Leaf spot may occur.

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: Bloom Description: White to greenish yellow Flower: Insignificant
Attracts: Birds. Fruit: Showy, Edible

Scientific Name: Eucommia ulmoides

Common Name: Hardy Rubber Tree

Salt Spray Tolerance: Moderate

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: (no data available)

Height at Maturity: 40-60'

Spread at Maturity: 30-50'

Hardiness Zone: 4 to 7

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems.

Suggested Use(s) and or Planting Site: Shade tree for lawns or parks. Street tree. Suggested Use: Shade Tree, Street Tree

Aesthetic Characteristics: Bloom Description: Greenish-brown Flower: Insignificant
Tear a leaf, break a twig or peel off some bark and a stringy latex-like sap appears.

Scientific Name: Koelreuteria paniculata

Common Name: Goldenrain Tree

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 30-40'

Spread at Maturity: 30-40'

Hardiness Zone: 5 to 9

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. Some susceptibility to root rot, leaf spot and canker.

Suggested Use(s) and or Planting Site: Small shade tree, street tree, lawns or terraces.

Aesthetic Characteristics: Bloom Description: Yellow Flower: Showy
Leaf: Good Fall

Scientific Name: Maackia amurensis

Common Name: Amur Maackia

Salt Spray Tolerance: Low

Branch Strength: Medium

Root Damage Potential: Moderate
Foliage Type: Deciduous

Height at Maturity: 20-30'

Spread at Maturity: 20-30'

Hardiness Zone: 3 to 7

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems.

Suggested Use(s) and or Planting Site: Small shade tree or street tree. Suggested Use: Shade Tree, Street Tree, Flowering Tree
Aesthetic Characteristics: Bloom Description: Dull White Flower: Showy, Fragrant
Flowers are followed by flat seed pods

Scientific Name: Maclura pomifera*

Common Name: Osage Orange*

Salt Spray Tolerance: Moderate

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 35-60'

Spread at Maturity: 35-60'

Hardiness Zone: 4 to 9

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems. Fruits and flowers produced by female trees pose a considerable litter problem. Flowers from male trees also create a litter problem, and if not promptly cleaned up, can produce an unpleasant odor as they rot on the ground.

Suggested Use(s) and or Planting Site: Windbreaks. Particularly effective for areas with poor soils where other woody plants may struggle. Male trees can be effective shade trees in corners of the landscape. Female trees are generally not recommended for landscape use because the fruits pose a considerable litter problem.

Suggested Use: Hedge, Shade Tree

Aesthetic Characteristics: Bloom Description: Green Flower: Insignificant
Fruit: Showy. Other: Thorns

Scientific Name: Pistacia chinensis

Common Name: Chinese Pistache

Salt Spray Tolerance: Low

Branch Strength: Strong

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 30-35'

Spread at Maturity: 20-30'

Hardiness Zone: 6 to 9

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. Susceptible to verticillium wilt.

Suggested Use(s) and or Planting Site: Street tree. Shade tree. Small landscape specimen for patio or garden.

Aesthetic Characteristics: Flower: Insignificant. Leaf: Good Fall. Fruit: Showy

Scientific Name: Quercus muehlenbergii*

Common Name: Chinkapin Oak*

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: Strong

Root Damage Potential: Low

Foliage Type: Deciduous
Height at Maturity: 40-60'

Spread at Maturity: 50-70'

Hardiness Zone: 5 to 7

Sun Exposure: Full sun

Potential Issues: Oaks are susceptible to a large number of diseases, including oak wilt, chestnut blight, shoestring root rot, anthracnose, oak leaf blister, cankers, leaf spots and powdery mildew. Potential insect pests include scale, oak skeletonizer, leaf miner, galls, oak lace bugs, borers, caterpillars and nut weevils.

Suggested Use(s) and or Planting Site: A shade tree for large lawns or parks. Uncommonly cultivated. Suggested Use: Shade Tree

Aesthetic Characteristics: Bloom Description: Yellowish-green Flower: Insignificant
Fruit: Showy

Scientific Name: Sapindus drummondii*

Common Name: Western Soapberry*

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Low

Foliage Type: Deciduous
Height at Maturity: 20-50'

Spread at Maturity: 20-50'

Hardiness Zone: 6 to 9

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems. Powdery mildew, leaf blight and leaf spot may appear in some areas.

Suggested Use(s) and or Planting Site: Suggested Use: Shade Tree, Lawn specimen, small shade tree, patio tree or screen where winter hardy.

Aesthetic Characteristics: Bloom Description: Yellowish-white Fruit: Showy. Flower: Showy

Scientific Name: Ulmus davidiana var. japonica

Common Name: Japanese Elm

Salt Spray Tolerance: Moderate

Branch Strength: Medium Weak

Root Damage Potential: High

Foliage Type: Deciduous

Height at Maturity: 40'-50'

Spread at Maturity: 20'-25'

Hardiness Zone: 5 to 10

Sun Exposure: Full sun to part shade

Potential Issues: exhibits excellent resistance to Dutch elm disease

Suggested Use(s) and or Planting Site: Planting Site: City parkway, Residential and parks, Restricted sites, Wide median

Aesthetic Characteristics: (no data available)

Scientific Name: Cercis canadensis*

Common Name: Eastern Redbud*

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 20-30'

Spread at Maturity: 25-35'

Hardiness Zone: 4 to 8

Sun Exposure: Full sun to part shade

Potential Issues: Canker can be a significant disease problem. Verticillium wilt, dieback, leaf spots, mildew and blights may also occur. Insect pests include Japanese beetles, tree hoppers, leaf hoppers, caterpillars, borers, webworms and scale.

Suggested Use(s) and or Planting Site: Specimen or small groups. Lawns, shrub borders, woodland margins, or along patios. Street tree or lawn tree. Attractive in naturalized settings. Good cut flower for forcing indoors. Suggested Use: Street Tree, Flowering Tree, Naturalize

Aesthetic Characteristics: Bloom Description: Pink Flower: Showy, Good Cut Leaf: Good Fall. Attracts: Birds, Hummingbirds, Butterflies

Scientific Name: Cercis canadensis var. texensis

Common Name: Texas Redbud

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 12-18'

Spread at Maturity: 15-24'

Hardiness Zone: 6 to 9

Sun Exposure: Full sun to part shade

Potential Issues: Canker can be a significant disease problem. Verticillium wilt, dieback, leaf spots, mildew and blights may also occur. Insect pests include Japanese beetles, tree hoppers, leaf hoppers, caterpillars, borers, webworms and scale.

Suggested Use(s) and or Planting Site: Specimen or small groups. Lawns, shrub borders, woodland margins, or along patios. Street tree or lawn tree. Attractive in naturalized settings.
Suggested Use: Street Tree, Flowering Tree

Aesthetic Characteristics: Bloom Description: Wine-red Flower: Showy, Good Cut
Leaf: Good Fall Attracts: Birds, Hummingbirds, Butterflies

Scientific Name: Chionanthus retusus

Common Name: Chinese Fringetree

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 10-20'

Spread at Maturity: 10-20'

Hardiness Zone: 5 to 9

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems. Some susceptibility to mites, scale and borers. Watch for leaf spots, canker and powdery mildew. Plants sold in commerce may not be identified as either male or female.

Suggested Use(s) and or Planting Site: Grow in groups or as specimens in lawns or in shrub or woodland borders. Also may be sited near streams or ponds. Can be spectacular in full bloom.
Suggested Use: Flowering Tree, Rain Garden. Planting SiteL Residential and parks, under utility lines

Aesthetic Characteristics: Bloom Description: White Flower: Showy, Fragrant
Leaf: Good Fall Attracts: Birds. Fruit: Showy

Scientific Name: Cotinus obovatus

Common Name: American Smoketree

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 20-30'

Spread at Maturity: 20-30'

Hardiness Zone: 4 to 8

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. Some susceptibility to leaf spots, rust and wilt.

Suggested Use(s) and or Planting Site: Best when massed or grouped in the shrub border. Long-lasting, summer "smoke" display makes this a striking accent plant. Planting site: Residential and parks, Under utility line

Aesthetic Characteristics: Bloom Description: Yellowish-green Flower: Insignificant
Leaf: Good Fall

Scientific Name: Cotinus coggygia

Common Name: Smoketree

Salt Spray Tolerance: Moderate

Branch Strength: Medium Weak

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 10-15'

Spread at Maturity: 10-15'

Hardiness Zone: 5 to 8

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. Some susceptibility to leaf spot, rust and verticillium wilt.

Suggested Use(s) and or Planting Site: Single specimen, group or mass in shrub borders or sunny areas around the home. Long-lasting summer smoke display makes this a striking accent plant. Also, may be used as an informal hedge or screen (a smoke screen as it were). Suggested Use: Hedge

Aesthetic Characteristics: Bloom Description: Yellow Flower: Insignificant
Leaf: Colorful, Good Fall

Scientific Name: Crataegus ambigua

Common Name: Russian Hawthorn

Salt Spray Tolerance: Moderate

Branch Strength: Strong

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 25'

Spread at Maturity: 15-25'

Hardiness Zone: 4 to 6

Sun Exposure: Full Sun

Potential Issues: Fire Blight, Armillaria, Powdery Mildew, Root Rot and Aphids, Beetle Borers, Scales, Spider Mites

Suggested Use(s) and or Planting Site: Horticultural use: Screen

Aesthetic Characteristics: Leaf color: Green. Flowers: Showy. Flower color: White

Scientific Name: Crataegus viridis ‘Winter King’

Common Name: Green Hawthorn ‘Winter King’

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 25-35'

Spread at Maturity: 25-35'

Hardiness Zone: 4 to 7

Sun Exposure: Full sun

Potential Issues: This hawthorn is disease-resistant, but can still be affected by rust, fireblight, leaf spots, powdery mildew, cankers, apple scab, borers, caterpillars, lacebugs, leafminers, and scale.

Suggested Use(s) and or Planting Site: Excellent spring flowering tree for lawns and streets. Good fall color and persistent fruit help provide year-round interest. Pollution tolerance makes it a good candidate for urban plantings. Suggested Use: Flowering Tree

Aesthetic Characteristics: Bloom Description: White Flower: Showy. Leaf: Good Fall Attracts: Birds, Butterflies. Fruit: Showy

Scientific Name: Euonymus bungeanus

Common Name: Winterberry Euonymus

Salt Spray Tolerance: Low

Branch Strength: Medium Strong

Root Damage Potential: Low

Foliage Type: semi-evergreen to deciduous

Height at Maturity: 15-24'

Spread at Maturity: 10-15'

Hardiness Zone: 4 to 8

Sun Exposure: Full sun to part shade

Potential Issues: Euonymus scale can be a significant problem and should be treated if it appears. Anthracnose, crown gall, leaf spot, mildew and aphids can also be problems.

Suggested Use(s) and or Planting Site: Group or mass. Shrub borders, informal hedge/screen. Foundations. Suggested Use: Hedge

Aesthetic Characteristics: Bloom Description: Yellowish-green Flower: Insignificant
Leaf: Good Fall. Fruit: Showy

Scientific Name: Heptacodium miconioides

Common Name: Seven-son flower

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 15-20'

Spread at Maturity: 8-10'

Hardiness Zone: 5 to

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems.

Suggested Use(s) and or Planting Site: A somewhat rare and unique plant with year-round interest. Shrub border or woodland garden. Excellent as a lawn specimen or accent around the home. Suggested Use: Flowering Tree

Aesthetic Characteristics: Bloom Description: White with pink calyx Flower: Showy, Fragrant
Attracts: Hummingbirds, Butterflies. Fruit: Showy

Scientific Name: Syringa reticulata

Common Name: Japanese Tree Lilac

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 20-30'

Spread at Maturity: 15-20'

Hardiness Zone: 3 to 7

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. It reportedly has good resistance to some of the major pests of lilacs, such as powdery mildew, scale and borers. It has some susceptibility to additional diseases including blights, leaf spots, wilt and ring spot virus. Additional insect pests of note include caterpillars and leaf miner.

Suggested Use(s) and or Planting Site: Effective as a specimen in the landscape. Tree forms are effective along streets, in lawns, near decks/patios or in foundations. Shrub forms are effective in borders or small groups. May be used as a screen along property lines. Suggested Use: Hedge, Street Tree, Flowering Tree

Aesthetic Characteristics: Bloom Description: Creamy white Flower: Showy, Fragrant
Attracts: Hummingbirds, Butterflies

Scientific Name: x Chitalpa tashkentensis

Common Name: Chitalpa

Salt Spray Tolerance: Moderate

Branch Strength: Medium Weak

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 20-35'

Spread at Maturity: 20-35'

Hardiness Zone: 6 to 9

Sun Exposure: Full sun to part shade

Potential Issues: Powdery mildew can be a significant problem in growing conditions where trees are planted in too much shade. Additional disease problems include verticillium wilt, root rot and leaf spots. Watch for aphids, mealybugs, scale and whiteflies.

Suggested Use(s) and or Planting Site: Interesting medium-sized landscape or street tree with a long summer flowering period. Suggested Use: Shade Tree

Aesthetic Characteristics: Bloom Description: Pink to white Flower: Showy

Scientific Name: Calocedrus decurrens

Common Name: Incense Cedar

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Moderate

Foliage Type: Evergreen

Height at Maturity: 30-50'

Spread at Maturity: 8-10'

Hardiness Zone: 5 to 8

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems. Heart rot and rust may occur in some areas.

Suggested Use(s) and or Planting Site: Large specimen tree. Screen, windbreak or hedge.
Suggested Use: Hedge

Aesthetic Characteristics: Bloom Description: Non-flowering Leaf: Fragrant, Evergreen

Scientific Name: Cedrus atlantica

Common Name: Atlas Cedar

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Moderate

Foliage Type: Evergreen

Height at Maturity: 40-60'

Spread at Maturity: 30-40'

Hardiness Zone: 6 to 9

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. Tip blight may occur. Heavy snow in winter can break branches.

Suggested Use(s) and or Planting Site: Specimen plant.

Aesthetic Characteristics: Bloom Description: Non-flowering Leaf: Colorful, Evergreen

Scientific Name: Cupressus arizonica

Common Name: Arizona Cypress

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: Low

Foliage Type: Evergreen

Height at Maturity: 40'

Spread at Maturity: 25'

Hardiness Zone: 6 to 9

Sun Exposure: Full sun

Potential Issues: Leaf Blight

Suggested Use(s) and or Planting Site: Horticultural use: Specimen or Screen

Aesthetic Characteristics: Bark: Reddish Brown, Rough. Fruit: Medium Brown Cone

Scientific Name: Juniperus chinensis

Common Name: Chinese Juniper

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Low

Foliage Type: Evergreen

Height at Maturity: 40-50'

Spread at Maturity: 15-20'

Hardiness Zone: 4 to 9

Sun Exposure: Full sun

Potential Issues: Junipers are generally susceptible to tip and needle blights. Cedar-apple rust and related rust diseases spend part of their life cycle on junipers. Root rot may occur, particularly in wet, poorly drained soils. Canker may attack bark or main stems. Occasional insect pests include aphids, bagworms, webworms and scale.

Suggested Use(s) and or Planting Site: Evergreen conifer with a large variety of cultivars. Landscape use depends on form and size of cultivar.

Aesthetic Characteristics: Bloom Description: Non-flowering Leaf: Evergreen.
Planting site: Residential and parks are quite salt-tolerant; they can be used near roads, driveways, and sidewalks.

Scientific Name: Magnolia grandiflora

Common Name: Southern Magnolia

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: High

Foliage Type: Evergreen

Height at Maturity: 60-80'

Spread at Maturity: 30-50'

Hardiness Zone: 7 to 9

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems.

Suggested Use(s) and or Planting Site: Specimen or accent for lawns or other open areas where its ultimate size can be accommodated. Can be grouped to form an evergreen screen. Suggested Use: Flowering Tree

Aesthetic Characteristics: Bloom Description: White Flower: Showy, Fragrant

Leaf: Evergreen. Fruit: Showy

Scientific Name: Pinus bungeana

Common Name: Lacebark Pine

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Moderate

Foliage Type: Evergreen

Height at Maturity: 30-50'

Spread at Maturity: 20-35'

Hardiness Zone: 4 to 8

Sun Exposure: Full sun

Potential Issues: No serious insect or disease problems. Branches are brittle and susceptible to damage from heavy snow and ice, particularly in multi-trunked form.

Suggested Use(s) and or Planting Site: White barked mature trees are excellent specimens for the landscape.

Aesthetic Characteristics: Bloom Description: Non-flowering Leaf: Evergreen

Fruit: Showy

Scientific Name: Pinus cembroides

Common Name: Pinyon Pine

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Low

Foliage Type: Evergreen

Height at Maturity: 70'

Spread at Maturity: 50'

Hardiness Zone: 6 to 9

Sun Exposure: Full sun

Potential Issues: Like many pine species, pinyon pines can be susceptible to bark beetles

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: Drought resistant. pine cones are globose and compact. When closed, they are green, and as they mature, they turn a warm yellow-brown

Scientific Name: Pinus flexilis

Common Name: Limber Pine

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: Moderate

Foliage Type: Evergreen

Height at Maturity: 40-60'

Spread at Maturity: 25-40'

Hardiness Zone: 4 to 7

Sun Exposure: Full sun

Potential Issues: It is susceptible to certain rots and blights, but its most dangerous enemy is white pine blister rust which is a bark disease that is usually fatal.

Suggested Use(s) and or Planting Site: Medium-size pine for the landscape. Residential and Parks

Aesthetic Characteristics: Bloom Description: Non-flowering Leaf: Evergreen

Scientific Name: Pinus ponderosa

Common Name: Ponderosa Pine

Salt Spray Tolerance: Low

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Evergreen

Height at Maturity: 60-125'

Spread at Maturity: 25-30'

Hardiness Zone: 3 to 7

Sun Exposure: Full sun

Potential Issues: Root rots, needle blight and blister rust may occur. Bark beetle can cause significant damage.

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: Bloom Description: Non-flowering Leaf: Fragrant, Evergreen

Scientific Name: Pinus strobiformis

Common Name: Southwestern White Pine

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Evergreen

Height at Maturity: 80'-100'

Spread at Maturity: 20'-40'

Hardiness Zone: 4 to 9

Sun Exposure: Full sun

Potential Issues: (no data available)

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: (no data available)

Scientific Name: *Platycladus orientalis*

Common Name: Oriental Arborvitae

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: Medium

Root Damage Potential: Moderate

Foliage Type: Evergreen

Height at Maturity: 18-25'

Spread at Maturity: 10-15'

Hardiness Zone: 6 to 9

Sun Exposure: Full sun to part shade

Potential Issues: Watch for bagworms and spider mites. Scales, aphids, caterpillars, borers and mealybugs may appear. Branches may be broken from snow weight in winter.

Suggested Use(s) and or Planting Site: Specimen. Hedge. Foundations.

Aesthetic Characteristics: Bloom Description: Non-flowering Leaf: Evergreen

Scientific Name: *Juniperus deppeana*

Common Name: Alligator Juniper

Salt Spray Tolerance: Moderate

Branch Strength: Medium Strong

Root Damage Potential: Low

Foliage Type: Evergreen

Height at Maturity: 70'

Spread at Maturity: 20-25'

Hardiness Zone: 7 to 8

Sun Exposure: Full Sun

Potential Issues: Disease and pest susceptibility: Armillaria, Root Rot, Rust and Aphids, Beetle Borers, Spider Mites

Suggested Use(s) and or Planting Site: Horticultural use: Screen

Aesthetic Characteristics: Bark: Striking, Light Green, Light Gray or Red Brown, Blocky, Rough, Scaly
Texas Tree Trial Database Comments: *Juniperus deppeana*, alligator juniper, is a medium-sized evergreen tree with blue-green foliage and striking bark that resembles alligator scales. It is sometimes multistemmed and grows at a fast rate. It is highly adaptable and tolerant of dry, sunny, hot locations.

Scientific Name: Bauhinia lunarioides

Common Name: Anacacho Orchid Tree

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 10-20'

Spread at Maturity: 5-10'

Hardiness Zone: 8 to 11

Sun Exposure: Part Shade

Potential Issues: Susceptible to strong winds.

Suggested Use(s) and or Planting Site: Best placed on South side of a building.

Aesthetic Characteristics: Flower Color: white or pink Fruit Characteristics: legume
Texas Tree Trial Database Comments: (no data available)

Scientific Name: Juglans major

Common Name: Arizona Walnut

Salt Spray Tolerance: Low

Branch Strength: Medium Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 30-60'

Spread at Maturity: 30-50'

Hardiness Zone: 6 to 7

Sun Exposure: Sun to Part Shade

Potential Issues: Sooty Mold and Aphids

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: Fruit: Large Brown or Mostly Green Nut Leaf color: Green

Texas Tree Trial Database Comments: Juglans major, Arizona walnut, is a medium to large deciduous tree. It has a spreading crown of pinnate foliage and produces edible nuts.

Scientific Name: Quercus arizonica

Common Name: Arizona White Oak

Salt Spray Tolerance: Lo

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Semi-Evergreen

Height at Maturity: 30-60'

Spread at Maturity: 40-50'

Hardiness Zone: 6 to 7

Sun Exposure: Sun to Part Shade

Potential Issues: Allergy health hazard. No signs of pests or diseases found.

Suggested Use(s) and or Planting Site: Excellent potential utility as an urban tree based on evaluation of 3 trees, healthy crown, 100% survival, very fast growth rate.

Aesthetic Characteristics: Fruit: Small to Medium Brown Acorn Bark: dark gray, light gray, Fissured

Texas Tree Trial Database Comments: Quercus arizonica, Arizona white oak is a small to medium, semi-evergreen tree. It has attractive bluish foliage has spreading branches growing at right angles to the trunk. It's highly drought and heat tolerant and gets to maximum heights in moister areas.

Scientific Name: Tilia americana var. caroliniana

Common Name: Carolina Basswood

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 30-60'

Spread at Maturity: 20-30'

Hardiness Zone: 3 to 8

Sun Exposure: Sun, Part-Shade

Potential Issues: Easily damaged by fire, butt rot.

Suggested Use(s) and or Planting Site: Planting site: City parkway, residential and parks, wide medians.note that is highly susceptible to ice damage.

Aesthetic Characteristics: the bark gray and furrowed with flat ridges. Flowers yellowish-white,, fragrant and nectar-bearing.

Texas Tree Trial Database Comments: Tilia americana var. caroliniana, Carolina basswood, is a medium-sized, deciduous tree with medium water requirements. Carolina basswood has fragrant, yellow to white drooping flowers stalks. It is the southern most basswood.

Scientific Name: Acer grandidentatum

Common Name: Bigtooth Maple

Salt Spray Tolerance: Low

Branch Strength: Strong

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 20-30'

Spread at Maturity: 20-30'

Hardiness Zone: 5 to 8

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems. Potential disease problems include verticillium wilt, anthracnose, root rot and cankers. Potential insect problems include aphids and borers. Watch for mites.

Suggested Use(s) and or Planting Site: Small landscape tree

Aesthetic Characteristics: Bloom Description: Yellow-green Flower: Insignificant Leaf: Good Fall

Texas Tree Trial Database Comments: Acer grandidentatum, bigtooth maple, is a fast-growing small deciduous tree. It is relatively drought tolerant and has medium or low water needs. It has a spreading, rounded canopy with colorful fall foliage color.

Scientific Name: Ulmus crassifolia

Common Name: Cedar Elm

Salt Spray Tolerance: Moderate

Branch Strength: Weak

Root Damage Potential: High

Foliage Type: Semi-Evergreen

Height at Maturity: 50-70'

Spread at Maturity: 40-50'

Hardiness Zone: 6 to 9

Sun Exposure: Sun, Part-Shade

Potential Issues: Susceptible to Dutch Elm disease. Potential allergen. Seeds germinate readily, monitor for invasiveness.

Suggested Use(s) and or Planting Site: Horticultural use: Buffer Strip or Shade Tree or Street Tree

Aesthetic Characteristics: Leaf arrangement and form: Alternate, Simple; Leaf/leaflet shape: Elliptic; Leaf color: Green; Flowers: Inconspicuous; Flower color: green; Flower type: Has male and female reproductive parts in each flower (perfect); Flowering time: Fall; Fruit: Green Samara; Fruiting time: Winter; Bark: Dark Gray, Rough

Texas Tree Trial Database Comments: Ulmus crassifolia, cedar elm, is a large semi-evergreen tree with luscious green foliage that changes to yellow in the fall. It is drought-tolerant and prefers partly shaded or sunny areas with dry soil. Tree should be monitored for invasiveness as its seeds germinate rapidly.

Scientific Name: Quercus graciliformis (Quercus canbyi)

Common Name: Chisos Oak

Salt Spray Tolerance: High

Branch Strength: Strong

Root Damage Potential: Low

Foliage Type: Semi-Evergreen

Height at Maturity: 20-30'

Spread at Maturity: 20-30'

Hardiness Zone: 7 to 9

Sun Exposure: Sun, Part-Shade

Potential Issues: Allergy health hazard

Suggested Use(s) and or Planting Site: Horticultural use: Park Tree or Street Tree or Shade Tree or Hedged

Aesthetic Characteristics: Leaf arrangement and form: Alternate, Simple; Leaf/leaflet shape: Spear-shaped; Leaf color: Dark Green; Flowers: Inconspicuous; Flower color: Brown or Yellow; Flower type: Has separate male and female reproductive parts on the same tree (monoecious); Flowering time: Winter or Spring; Fruit: Small Brown, Yellow Acorn; Fruiting time: Winter or Summer; Fruit value: Wildlife use it; Bark: Brown, Green, Dark Drey, Fissured; Litter: Dry Fruit, Leaves

Texas Tree Trial Database Comments: Quercus graciliformis, Chisos oak, is a small to medium sized semi-evergreen tree with slender branches and narrow, glossy leaves. Found at elevation, it is heat and drought tolerant.

Scientific Name: Quercus grisea

Common Name: Gray Oak

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Semi-Evergreen; Deciduous

Height at Maturity: 20-30'

Spread at Maturity: 20-30'

Hardiness Zone: 7

Sun Exposure: Sun, Part-Shade

Potential Issues: Allergy health hazard

Suggested Use(s) and or Planting Site: large shrub small tree

Aesthetic Characteristics: Flower Color: catkins Blooming Period: spring Fruit Characteristics: acorn 1/2 inch long

Texas Tree Trial Database Comments: Quercus grisea, gray oak, is a small tree with blue-green leathery leaves that are semi-deciduous. Its growth habit can be shrubby but is upright and sturdy.

Scientific Name: Quercus gravesii

Common Name: Chisos Red Oak

Salt Spray Tolerance: Moderate

Branch Strength: Strong

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 30–40'

Spread at Maturity: 30–40'

Hardiness Zone: 7 to 10

Sun Exposure: Part-Shade

Potential Issues: Allergy health hazard; susceptible to anthracnose

Suggested Use(s) and or Planting Site: uncommon in cultivation. Its bright red fall color is highly dependent on its planting location, with lower elevations producing a less noticeable fall color. Prefers wet soils.

Aesthetic Characteristics: Leaf arrangement and form: Alternate, Simple; Leaf/leaflet shape: Elliptic; Leaf color: Green; Flowers: Inconspicuous; Flower color: Yellow or Brown; Flower type: Has separate male and female reproductive parts on the same tree (monoecious); Flowering time: Spring; Fruit: Small Brown Acorn; Fruiting time: Summer; Fruit value: Wildlife use it Bark: Black, Furrowed; Litter: Dry Fruit, Leaves

Texas Tree Trial Database Comments: Quercus gravesii, Graves Oak, is a deciduous tree that reaches between 30 to 40 feet at maturity. Its foliage forms a round crown of dark-green leaves decorated with small brown acorns, and has a vibrant red fall color. Nuts and foliage attract local wildlife.

Scientific Name: Prunus serotina var. eximia

Common Name: Escarpment Black Cherry

Salt Spray Tolerance: Low

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 40-50'

Spread at Maturity: 30–40'

Hardiness Zone: 3 to 9

Sun Exposure: Full sun to part shade

Potential Issues: native Missouri tree, black cherry is adapted to the Missouri climate and has good resistance to most pests. Potential diseases include leaf spot, die back, leaf curl, powdery mildew, root rot and fireblight. Potential insects include aphids, scale, borers, leafhoppers, caterpillars, tent caterpillars and Japanese beetles.

Suggested Use(s) and or Planting Site: Medium to large flowering shade tree.Suggested Use: Shade Tree, Flowering Tree

Aesthetic Characteristics: Bloom Description: White Flower: Showy, Fragrant; Leaf: Good Fall; Attracts: Birds Bark, roots and leaves contain concentrations of toxic cyanogenic compounds, hence the noticeable bitter almond aroma of the inner bark; Fruit: Showy

Texas Tree Trial Database Comments: Prunus serotina var. eximia, escarpment black cherry is a medium sized deciduous tree. It has attractive bark, showy white blooms, and yellow fall foliage. Fruits are attractive to wildlife. Prefers medium water use.

Scientific Name: Styphnolobium affine

Common Name: Eve’s Necklace

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 20–30’

Spread at Maturity: 15–20’

Hardiness Zone: 7 to 9

Sun Exposure: Part-Shade

Potential Issues: Flowers and seeds are poisonous. Suckering roots.

Suggested Use(s) and or Planting Site: Horticultural use: Specimen or Buffer Strip or Container or Street Tree

Aesthetic Characteristics: Leaf arrangement and form: Alternate, Pinnately Compound; Leaf/leaflet shape: Ovate; Leaf color: Green; Flowers: Showy; Flower color: Pink or White; Flowering time: Summer; Fruit: Very Large Black Legume; Fruiting time: Fall or Summer; Bark: Brown, Scaly

Texas Tree Trial Database Comments: Styphnolobium affine, Eve’s necklace, is a small deciduous tree with showy, aromatic pink white cascading flowers and ornamental seed pods. It prefers dry, well drained soils and can take full sun or part shade. Spring flowers attract pollinators and foliage has a fine and delicate form.

Scientific Name: Leucaena retusa

Common Name: Golden Ball Lead Tree

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 10–20’

Spread at Maturity: 15–20’

Hardiness Zone: 7 to 9

Sun Exposure: Sun, Part-Shade

Potential Issues: Branches susceptible to breakage.

Suggested Use(s) and or Planting Site: Specimen or Buffer Strip

Aesthetic Characteristics: Leaf arrangement and form: Alternate, Bipinnately Compound; Leaf/leaflet shape: Oval; Leaf color: Green; Flowers: Showy; Flower color: Yellow; Flowering time: Fall or Summer; Fruit: Large to Very Large Brown Legume; Fruiting time: Fall or Winter; Litter: Dry Fruit, Leaves, Twigs

Texas Tree Trial Database Comments: Leucaena retusa, golden ball lead tree, is a small deciduous tree with bold yellow flowers, brown legume fruits, and an overall vase shape. It is known to have weaker wood that leaves the branches vulnerable to snapping. The tree grows well in rocky, well-drained soil and requires low water.

Scientific Name: Pinus ponderosa var. scopulorum

Common Name: Interior Ponderosa Pine (Rocky Mountain Ponderosa Pine)

Salt Spray Tolerance: Low

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Evergreen, Conifer

Height at Maturity: 70'+

Spread at Maturity: 20-30'

Hardiness Zone: 5 to 9

Sun Exposure: Sun

Potential Issues: Susceptible to Aphids, California Five Spined Engraver Beetle, IPS, Red Turpentine Beetle, Western Pine Beetle, Western Pine Shoot Borer and Beetle Borers, Pitch Canker, Red Ring Rot, Pitted Sap Rot, Armillaria, Mistletoe, Western Gall Rust, Mountain Pine Beetle and Black Stain. Allergy health hazard.

Suggested Use(s) and or Planting Site: Uses: Beautification: This is a handsome tree for purposes of beautification but due to its height should not be grown within road rights-of-way.

Aesthetic Characteristics: Leaf arrangement and form: Alternate, Simple; Leaf/leaflet shape: Needle; Leaf color: Dark Green; Flowers: Fragrant; Flowering time: Spring; Fruit: Medium Brown Cone; Fruiting time: Fall, Winter or Summer; Bark: Black, Orange or Red Brown, Furrowed, Scaly Litter: Dry Fruit

Texas Tree Trial Database Comments: Pinus ponderosa var. scopulorum, interior ponderosa pine, is a large evergreen conifer that thrives in high elevations, full sun, and low water environments.

Scientific Name: Quercus laceyi

Common Name: Lacey Oak

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 30-60'

Spread at Maturity: 20-30'

Hardiness Zone: 7 to 10

Sun Exposure: Sun, Part-Shade

Potential Issues: Allergy health hazard

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: Leaf arrangement and form: Alternate, Simple; Leaf/leaflet shape: Oblong; Leaf color: Pink or Peach; Flowers: Inconspicuous; Flower color: Brown or Yellow-Green; Flower type: Has either male or female reproductive parts (dioecious); Flowering time: Spring; Bark: Brown, Fissured, Furrowed; Litter: Dry Fruit, Leaves

Texas Tree Trial Database Comments: Quercus laceyi, Lacey oak, is a medium to large, multi-stemmed deciduous tree with graceful foliage with spreading branches. It has low water needs and is highly drought tolerant. It has blue- or grey-tinted foliage that turns peach colored in spring and fall.

Scientific Name: Celtis lindheimeri

Common Name: Lindeimer’s Hackberry

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 30–60’

Spread at Maturity: 30–40’

Hardiness Zone: 5

Sun Exposure: Sun

Potential Issues: May be susceptible to beetle leaves and scales, mistletoe, armillaria and root damage potential.

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: Flower Color: greenish, inconspicuous Fruit Characteristics: small, reddish-brown drupe

Texas Tree Trial Database Comments: Celtis lindheimeri, Lindeimer’s hackberry, is a medium to large deciduous tree with a spreading crown. It has a low to medium water usage, high heat tolerance and is very fast growing.

Scientific Name: Juglans microcarpa

Common Name: Little Walnut

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 20–30’

Spread at Maturity: 15–20’

Hardiness Zone: 6 to 7

Sun Exposure: Sun, Part-Shade

Potential Issues: May be sensitive to thousand cankers disease, low CaCO3 tolerance, may be susceptible to mistletoe.

Suggested Use(s) and or Planting Site: Along creeks and rivers

Aesthetic Characteristics: dark, attractive wood, distinctive for its fine, graceful leaves

Texas Tree Trial Database Comments: Juglans microcarpa, little walnut, is a small round-crowned tree with edible nuts. It is found in dry, hot regions in both part shade and sun. The nuts are the smallest of any walnut species and mostly provide food for wildlife in the area

Scientific Name: Quercus oblongifolia

Common Name: Mexican Blue Oak

Salt Spray Tolerance: Moderate

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Evergreen

Height at Maturity: 20–30'

Spread at Maturity: 20–30'

Hardiness Zone: 7 to 10

Sun Exposure: Sun

Potential Issues: Potential root damage moderate. Allergy and poison hazard.

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: Leaf arrangement and form: Alternate, SimpleLeaf/leaflet shape: OblongLeaf color: GreenFlowers: InconspicuousFlower color: Brown or YellowFlower type: Has separate male and female reproductive parts on the same tree (monoecious)Flowering time: SpringFruit: Brown AcornFruiting time: FallFruit value: Wildlife use itBark: Light Gray, Furrowed, Ridged, ScalyLitter: Dry Fruit, Leaves

Texas Tree Trial Database Comments: Quercus oblongifolia, Mexican blue oak, is a small evergreen tree with a unique blue foliage color. It thrives in harsh environments with full sun and dry soil. Additionally, it is resistant to fires as well as various pests and diseases like aphids or sudden oak death.

Scientific Name: Ungnadia speciosa

Common Name: Mexican Buckeye

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 10–30'

Spread at Maturity: 15–20'

Hardiness Zone: 7 to 9

Sun Exposure: Sun, Part-Shade

Potential Issues: Poisonous health hazard.

Suggested Use(s) and or Planting Site: Specimen or Buffer Strip or Container

Aesthetic Characteristics: Leaf arrangement and form: Alternate, Pinnately Compound; Leaf/leaflet shape: Spear-shaped; Leaf color: Green; Flowers: Showy, Fragrant; Flower color: Pink; Flower type: Has male and female reproductive parts in each flower (perfect); Flowering time: Fall or Spring; Fruit: Large Brow Capsule; Fruiting time: Fall or Winter; Bark: Gray, Smooth

Texas Tree Trial Database Comments: Ungnadia speciosa, Mexican buckeye, is a small, multi-stemmed tree with dense branching that does well in dry soil with partial to full sun. Fragrant purple and pink flowers bloom in spring, fruit is ornamental in the summer and foliage becomes light yellow in fall.

Scientific Name: Pistacia mexicana

Common Name: Mexican Pistachio

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Evergreen, Semi-Evergreen

Height at Maturity: 10–30'

Spread at Maturity: 20–30'

Hardiness Zone: (no data available)

Sun Exposure: Sun

Potential Issues: (no data available)

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: evergreen foliage, attractive red berries and a multi-trunked form

Texas Tree Trial Database Comments: Pistacia mexicana, Mexican pistachio, is a small tree with fine evergreen foliage, attractive red berries and a multi-trunked form. It is drought, heat, and salt tolerant and can grow quickly.

Scientific Name: Prunus mexicana

Common Name: Mexican Plum

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 20–30'

Spread at Maturity: 20–30'

Hardiness Zone: 6 to 8

Sun Exposure: Full sun to part shade

Potential Issues: No serious insect or disease problems. In the event harvest of fruit for human consumption is a goal, some chemical spraying may be necessary in order to insure a good fruit harvest.

Suggested Use(s) and or Planting Site: Interesting landscape tree. It is best sited in areas where fruit drop in fall, which can be messy, will occur in areas where foot traffic does not frequently occur (e.g., away from patios, decks or sidewalks). Plums may be eaten fresh off the tree or made into tasty preserves and jellies. Flowering Tree Horticultural use: Specimen or Buffer Strip or Container

Aesthetic Characteristics: Bloom Description: WhiteFlower: Showy; Attracts: Birds; Fruit: Showy, Edible Leaf arrangement and form: Alternate, Simple; Leaf/leaflet shape: Elliptic; Leaf color: Green; Flowers: Showy, Fragrant; Flower color: White; Flower type: Has male and female reproductive parts in each flower (perfect) Flowering time: Spring Fruit: Large Red or Purple Drupe Fruiting time: Spring or Summer Fruit value: Edible Litter: Leaves, Fruit

Texas Tree Trial Database Comments: Prunus mexicana, Mexican plum, is a small, rounded deciduous tree. It has red and orange fall foliage, and produces white flowers and edible red plums. It is cold and drought tolerant.

Scientific Name: Quercus mohriana

Common Name: Mohr Oak

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Evergreen, Semi-Evergreen

Height at Maturity: 10–20'

Spread at Maturity: 15–20'

Hardiness Zone: 7

Sun Exposure: Sun, Part-Shade

Potential Issues: Allergy health hazard, does not like to be over watered

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: (no data available)

Texas Tree Trial Database Comments: Quercus mohriana, Mohr oak is a small semi-evergreen tree or large shrub. It does well in full sun to part shade and has low water requirements. Mohr oak has dark blue-gray leaves that are shiny and have gray hairs on the underside.

Scientific Name: Pinus remota

Common Name: Papershell Pinyon

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Evergreen Conifer

Height at Maturity: 10–30'

Spread at Maturity: 20–30'

Hardiness Zone: (no data available)

Sun Exposure: Sun, Part-Shade

Potential Issues: Allergy health hazard.

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: (no data available)

Texas Tree Trial Database Comments: Pinus remota, papershell pinyon, is a small, slow-growing evergreen tree with a pyramidal form. It has blue-green needles and edible nuts. It is the most drought-resistant and heat-resistant species of pinyon.

Scientific Name: Quercus stellata

Common Name: Post Oak

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: Strong

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 35-50'

Spread at Maturity: 35-50'

Hardiness Zone: 5 to 9

Sun Exposure: Full Sun

Potential Issues: oak wilt, chestnut blight, shoestring root rot, anthracnose, oak leaf blister, cankers, leaf spots and powdery mildew. Potential insect pests include scale, oak skeletonizer, leaf miner, galls, oak lace bugs, borers, caterpillars and nut weevils.

Suggested Use(s) and or Planting Site: Shade tree, street tree or lawn tree. Infrequently cultivated.

Suggested Use: Shade Tree Horticultural use: Specimen or Buffer Strip or Shade Tree

Aesthetic Characteristics: Bloom Description: Yellowish-green Flower: Insignificant; Leaf: Good Fall; Fruit: Showy Leaf arrangement and form: Alternate, Simple; Leaf/leaflet shape: Ovate; Leaf color: Green; Flowers: Inconspicuous; Flower color: Green; Flower type: Has either male or female reproductive parts (dioecious); Flowering time: Spring; Fruit: Medium Brown Acorn; Fruiting time: Fall; Fruit value: Wildlife use it; Bark: Gray Brown, Blocky, Scaly; Litter: Leaves

Texas Tree Trial Database Comments: Quercus stellata, post oak, is a medium-sized deciduous tree. It is found in dry sandy soils and has a slow growth rate.

Scientific Name: Prunus serotina var. virens

Common Name: Southwestern Black Cherry

Salt Spray Tolerance: Low

Branch Strength: Strong

Root Damage Potential: Moderate

Foliage Type: Deciduous

Height at Maturity: 20-30'

Spread at Maturity: 15-20'

Hardiness Zone: 4 to 8

Sun Exposure: Sun

Potential Issues: (no data available)

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: Flower Color: white racemes 4 to 6 in. long Blooming Period: spring Fruit Characteristics: small clusters of pea-sized purple-black to red-black cherries Texas Tree Trial Database Comments: Prunus serotina var. virens, Southwestern black cherry, is a small multi-trunked tree or large shrub. It has an attractive fall color, fragrant white flowers bloom in spring, and produces fruit with a red to black color.

Scientific Name: *Arbutus xalapensis*

Common Name: Texas Madrone

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: Strong

Root Damage Potential: Low

Foliage Type: Evergreen

Height at Maturity: 20–30'

Spread at Maturity: 15–20'

Hardiness Zone: 7 to 8

Sun Exposure: Sun, Part-Shade

Potential Issues: (no data available)

Suggested Use(s) and or Planting Site: Specimen or Container or Shade Tree or Buffer Strip

Aesthetic Characteristics: Leaf arrangement and form: Alternate, Simple; Leaf/leaflet shape: Elliptic; Leaf color: Green; Flowers: Showy, Fragrant; Flower color: White; Flower type: Has male and female reproductive parts in each flower (perfect); Flowering time: Spring; Fruit: Small Orange or Red Berry; Fruiting time: Fall or Summer; Bark: Striking Red Brown, Exfoliating, Scaly, Smooth Litter: Bark, Wet Fruit

Texas Tree Trial Database Comments: *Arbutus xalapensis*, Texas madrone, is a small multi-stemmed evergreen tree. It has ornamental flowers and fruit and striking exfoliating bark. This tree prefers full sun to part-shade and has a low to medium water requirement.

Scientific Name: *Dermatophyllum secundiflorum* (*Sophora secundiflora*)

Common Name: Texas Mountain Laurel (Mescal Bean)

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: Medium

Root Damage Potential: Low

Foliage Type: Evergreen

Height at Maturity: 10–20'

Spread at Maturity: 5–10'

Hardiness Zone: 7 to 10

Sun Exposure: Sun, Part-Shade

Potential Issues: Pest: Genista moth larvae.
May develop chlorosis in response to overwatering or poorly drained soils.

Suggested Use(s) and or Planting Site: Screen or Espalier

Aesthetic Characteristics: Leaf arrangement and form: Alternate, Pinnately Compound; Leaf/leaflet shape: Oblanceolate; Leaf color: Dark Green; Flowers: Showy, Fragrant; Flower color: Blue or Lavender or White; Flowering time: Winter or Spring; Fruit: Very Large Gray Legume; Fruiting time: Summer; Bark: Dark Brown or Light Green, Furrowed, Scaly; Litter: Dry Fruit

Texas Tree Trial Database Comments: *Dermatophyllum secundiflorum* (syn. *Sophora secundiflora*), Texas mountain laurel, is a small, often multi-stemmed evergreen tree, large shrub. It bears dramatic clusters of pungent lavender flowers and fruit pods with poisonous seeds. The tree has a high heat tolerance and is quite slow growing.

Scientific Name: Morus microphylla

Common Name: Texas Mulberry

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Deciduous

Height at Maturity: 20–30'

Spread at Maturity: 20–30'

Hardiness Zone: 5

Sun Exposure: Sun, Part-Shade

Potential Issues: May be susceptible to Beetle Borers, Caterpillars, Spider Mites and White Fly, Chlorosis, Crown Rot, Fusarium, Armillaria, Leaf Blight, Phytophthora and Root Rot. Possible allergy health hazard

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: (no data available)

Texas Tree Trial Database Comments: Morus microphylla, Texas mulberry, is a small, multi-stemmed deciduous tree. It grows in dry, well drained soils, and produces edible red fruits.

Scientific Name: Diospyros texana

Common Name: Texas Persimmon

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 10–20'

Spread at Maturity: 15–20'

Hardiness Zone: 7 to 10

Sun Exposure: Sun

Potential Issues: Root damage potential rated as low.

Suggested Use(s) and or Planting Site: Specimen or Buffer Strip or Container or Street Tree or Bonsai

Aesthetic Characteristics: Leaf arrangement and form: Alternate, Simple; Leaf/leaflet shape: Ovate; Leaf color: Green; Flowers: Inconspicuous, Fragrant; Flower color: White; Flower type: Has either male or female reproductive parts (dioecious); Flowering time: Spring; Fruit: Medium Black or Green Berry; Fruiting time: Summer; Fruit value: Edible, Wildlife use it; Bark: Gray to White, Smooth

Texas Tree Trial Database Comments: Diospyros texana, Texas persimmon, is a small vase-shaped, multi-stemmed tree with fragrant white flowers. Female plants bear edible fruits that attract wildlife. Its has ornamental peeling white or grey bark and is drought tolerant. Glossy, dark green rounded leaves are typically evergreen but can be deciduous in coler climates.

Scientific Name: Cercis canadensis var. texensis

Common Name: Texas Redbud

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: Low

Foliage Type: Deciduous

Height at Maturity: 12-18'

Spread at Maturity: 15-24'

Hardiness Zone: 6 to 9

Sun Exposure: Full sun to part shade

Potential Issues: Canker can be a significant disease problem. Verticillium wilt, dieback, leaf spots, mildew and blights may also occur. Insect pests include Japanese beetles, tree hoppers, leaf hoppers, caterpillars, borers, webworms and scale. Keeping the tree vigorous by regular watering and fertilization and by pruning out dead branches as needed will help keep the tree healthy.

Suggested Use(s) and or Planting Site: Specimen or small groups. Lawns, shrub borders, woodland margins, or along patios. Street tree or lawn tree. Attractive in naturalized settings. Suggested Use: Street Tree, Flowering Tree Horticultural use: Specimen or Container or Shade Tree or Buffer Strip or Screen

Aesthetic Characteristics: Bloom Description: Wine-red Flower: Showy, Good Cut; Leaf: Good Fall; Attracts: Birds, Hummingbirds, Butterflies Leaf arrangement and form: Alternate, Simple; Leaf/ leaflet shape: Heart-shaped; Leaf color: Green or Bluish Green or Silver or Gray Green; Flowers: Showy; Flower color: Pink or Rose or White; Flowering time: Spring; Fruit: Large Purple Legume; Fruiting time: Summer or Spring; Bark: Dark Brown or Red Brown, Rough, Smooth; Litter: Dry Fruit

Texas Tree Trial Database Comments: Cercis canadensis var. texensis, Texas redbud, is a small vase shaped, multi-branched tree with showy pink flowers in spring and deciduous heart-shaped foliage. It is found in arid, hot climates and is fast growing.

Scientific Name: Celtis laevigata

Common Name: Texas Sugarberry

Salt Spray Tolerance: Moderate

Branch Strength: Medium

Root Damage Potential: High

Foliage Type: Deciduous

Height at Maturity: 60-80'

Spread at Maturity: 60-80'

Hardiness Zone: 6 to 9

Sun Exposure: Full sun to part shade

Potential Issues: Powdery mildew and leaf spot may occur. Watch for lacebugs and scale.

Suggested Use(s) and or Planting Site: This is a tough shade tree that grows in a wide range of soils. This tree may be used as a lawn tree or street tree. Seeds can pose clean up problems if trees are sited near sidewalks or patios, however. Suggested Use: Shade Tree, Street Tree, Rain Garden

Aesthetic Characteristics: Flower: Insignificant Attracts: Birds; Fruit: Edible Bloom Description: Green

Texas Tree Trial Database Comments: Celtis laevigata, Texas sugarberry, is a large deciduous tree with a high, spreading canopy. It grows quickly, and produces edible fruit that attracts wildlife. It is highly drought tolerant and heat tolerant

Scientific Name: Quercus vaseyana

Common Name: Vasey Oak

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Semi-Evergreen

Height at Maturity: 20–40'

Spread at Maturity: 30–40'

Hardiness Zone: (no data available)

Sun Exposure: Sun, Part-Shade

Potential Issues: Allergy health hazard

Suggested Use(s) and or Planting Site: (no data available)

Aesthetic Characteristics: (no data available)

Texas Tree Trial Database Comments: Quercus vaseyana, Vasey oak, is a small, semi-evergreen tree. It is multi-trunked, and has glossy leaves and shingled bark. It is extremely drought tolerant.

Scientific Name: Senegalia wrightii

Common Name: Wright Acacia

Salt Spray Tolerance: (no SelecTree data)

Branch Strength: (no SelecTree data)

Root Damage Potential: (no SelecTree data)

Foliage Type: Evergreen, Semi-Evergreen

Height at Maturity: 20–30'

Spread at Maturity: 20–30'

Hardiness Zone: 7 to 10

Sun Exposure: Sun

Potential Issues: Stems armed with hooked prickles, susceptible to invasive shot hole borer.

Suggested Use(s) and or Planting Site: Container or planter; deck or patio

Aesthetic Characteristics: Leaf color: green Leaf type: even-pinnately compound

Texas Tree Trial Database Comments: Senegalia wrightii (syn. Acacia wrightii), Wright acacia, is a small semi-evergreen tree characterized by fragrant white flowers, fine pinnate foliage, prickles, and green legumes. It is mostly found in dry soils and thrives in full sun and low water environments. The tree is highly drought tolerant and multi-stemmed in form.