Puget Sound Region:
Climate Projections & Tree Species Vulnerability

Seattle from Jose Rizal Park. Source: Flickr, David Sprankle.

Rutledge, A. 2021. Puget Sound Region: Climate Projections & Tree Species Vulnerability. Summary Report from the Northern Institute of Applied Climate Science (NIACS). [**Unpublished Draft; Do Not Cite**].

Abstract

As the climate changes over the 21st century, the Puget Sound Region's urban forest will be impacted by changing temperatures and precipitation regimes, leading to implications for the people who depend on its ecosystem services. This report summarizes climate change projections for the Puget Sound Region and provides an assessment of tree species vulnerability in the region. We used projected shifts in plant hardiness and heat zones to understand how species of interest are projected to tolerate future conditions. We also assessed the adaptability of planted trees to stressors such as drought, flooding, wind damage, and air pollution, as well as environmental conditions such as shade, soils, and restricted rooting.

The region has been warming at a rate of about 0.2℉ per decade since 1960 and the average temperature is projected to increase by 5℉ to 8.6℉ by the end of the century compared to the 1971-2000 historical average. Precipitation in the region has been increasing by 0.49 inches per decade since 1960 and is projected to increase by 2.1 to 3.2 inches by the end of the century compared to the 1971-2000 historical average. By the end of the century, the Puget Sound Region is projected to shift from hardiness zones 8-9 to zone 9 completely, and from heat zone 2 to heat zones 3 (RCP4.5) or 6 (RCP8.5), depending on the climate change scenario. Of the evaluated tree species 27% received a high adaptability score, 59% received a medium adaptability score, and 14% received a low adaptability score. Considering heat zones only, the majority of tree species fell into the low-moderate (57%) vulnerability category followed by low vulnerability (26%) and moderate vulnerability (17%) under both low and high climate change scenarios. The vulnerability ratings remain the same between low and high climate change scenarios because all assessed tree species are considered suitable under the heat zone projections through the end of the century. Considering both heat and hardiness zones, the majority of tree species assessed fall into the moderate-high vulnerability category (39%), followed by low-moderate (20%), moderate (18%), low (13%), and high (9%). The vulnerability ratings are the same between low and high climate change scenarios because the projected hardiness zone is the same under both scenarios through the end of the century. Factors such as tree species diversity and allergenicity are additional considerations and are briefly included in this assessment. These projected changes in climate and their associated impacts and vulnerabilities will have important implications for urban forest management, including the planting and maintenance of street and park trees, equity and environmental justice efforts, and long-term planning from partnerships to green infrastructure.

Funds for this project were provided by the USDA Forest Service Urban and Community Forestry Program, administered through the State of Washington Department of Natural Resources Urban and Community Forestry Program.

Table of Contents

Climate Observations & Projections

Climate, the average weather over a long-term period for a particular location, can change substantially on the scale of thousands of years. Precipitation and temperature are changing at a global scale and the rate is projected to increase in the coming decades. However, these changes will impact different areas in different ways and these changes are best summarized at a local level for informed decision-making. To assist in evaluating these local changes, this section summarizes past and projected changes in precipitation and temperature in the Puget Sound region.

Observed Climate Trends

Historical climate trends were retrieved from the National Oceanic and Atmospheric Administration's (NOAA) Climate at a Glance tool (NOAA, 2020). Climate at a Glance was developed to facilitate near real-time analysis of monthly temperature and precipitation data across the contiguous U.S. and intended for the study of climate variability and change.

Precipitation Observations

Annual precipitation in Seattle has increased by 0.49 inches per decade since 1960 (Figure 1; NOAA, 2020). This trend varies by season. Precipitation has increased the greatest in March to May (+0.42 inches/decade) followed by September to November (+0.30 inches/decade). Precipitation has decreased overall from June to August (-0.15 inches/decade) as well as December to February (-0.12 inches/decade).

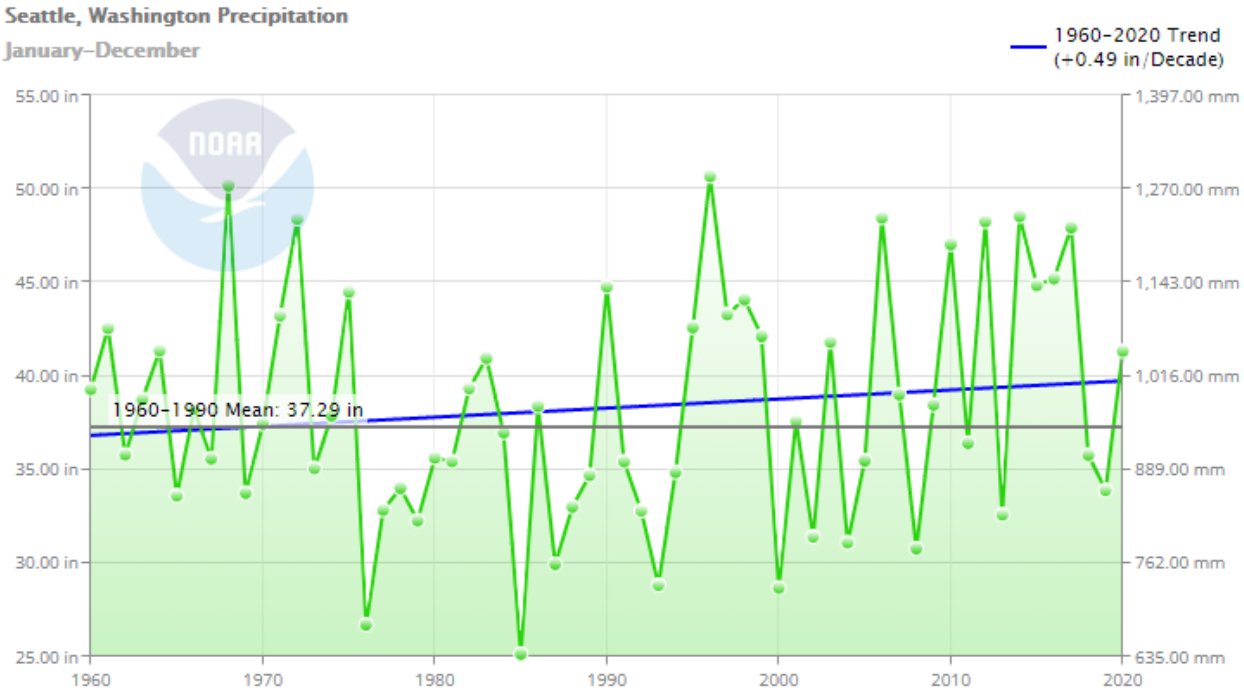
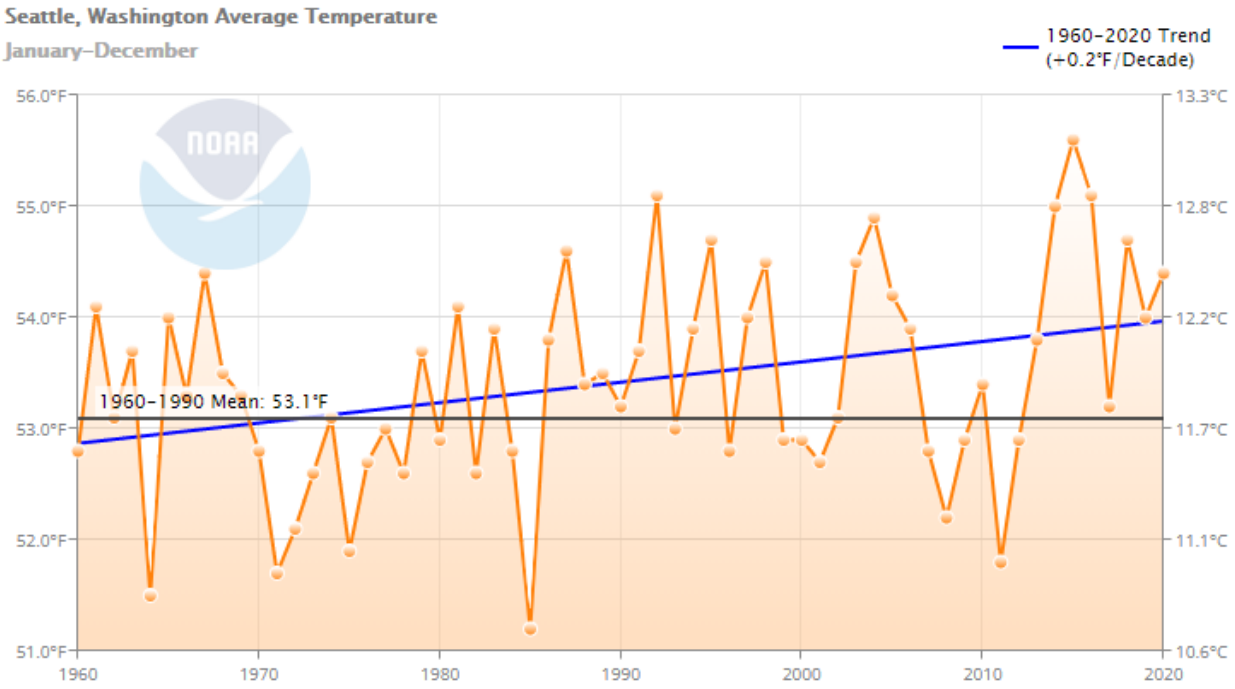


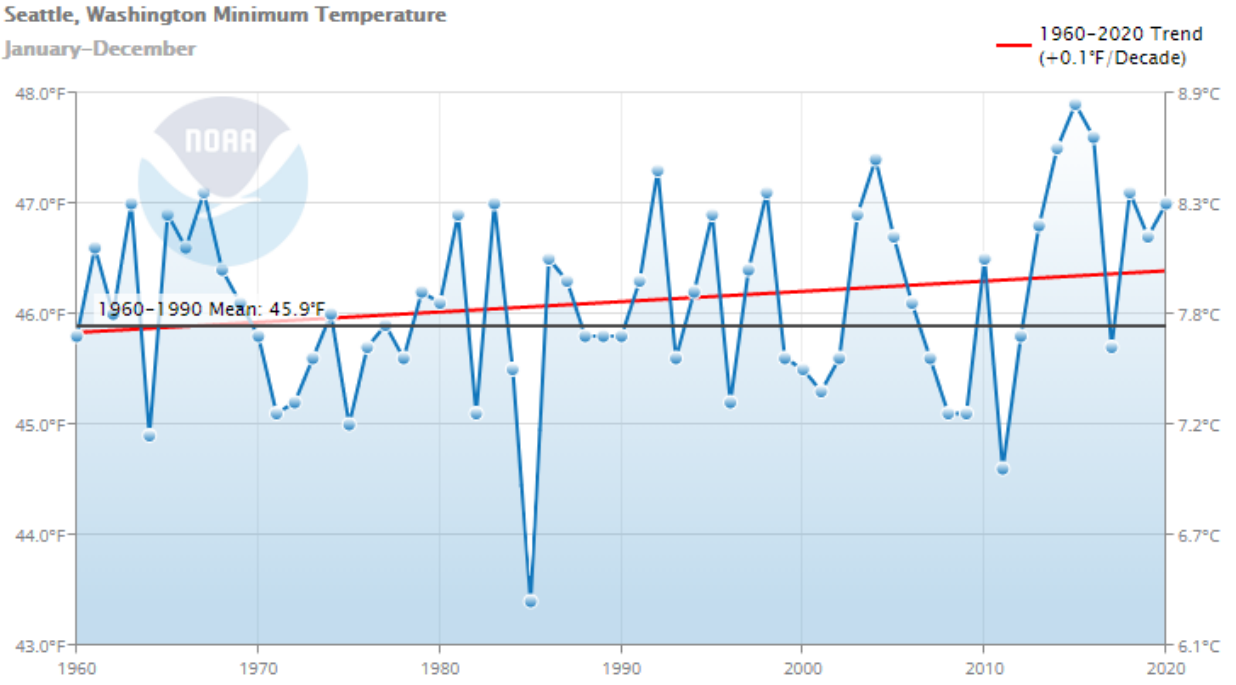
Figure 1.—Changes in Annual Precipitation Over the Observational Record from 1960 to 2020 for Seattle, Washington Including Average, Minimum, and Maximum Temperatures January - December. The gray line indicates the 1960-1990 average and the blue line shows the trend over the observational record (NOAA, 2021).

Temperature Observations

The average annual temperature in Seattle has increased by 0.2℉ per decade since 1960, and the average annual minimum (+0.1℉/decade) and maximum (+0.3℉/decade) temperatures follow a similar trend

(Figure 2; NOAA, 2020). The trend varies by season, increasing the most in March to May (+0.3℉/decade) and June to August (+0.3℉/decade). Temperature has increased by 0.1℉ per decade from September to November, and has remained stable in December to February (+0℉/decade).





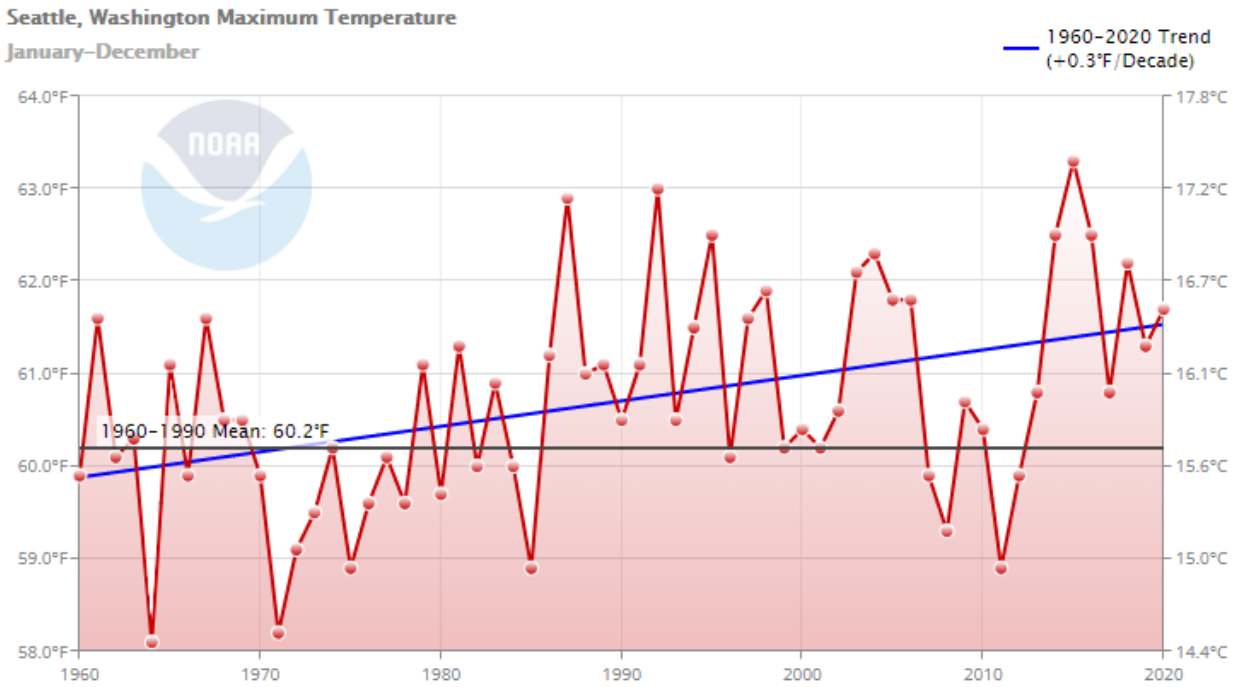


Figure 2.—Changes in Annual Temperature Over the Observational Record from 1960 to 2020 for Seattle, Washington, Including Average, Minimum, and Maximum Temperatures January - December. The gray line indicates the 1960-1990 average and the blue line shows the trend over the observational record (NOAA, 2021).

Climate Projections for the Puget Sound Region

Precipitation Projections

Precipitation is projected to increase under both low (RCP 4.5) and high (RCP 8.5) climate change scenarios through the end of the century in the winter, spring, and fall seasons, while decreasing in the summer by as much as -0.6 inches (Table 1). Annual precipitation is projected to increase by 2.1 inches by the end of the century under a *low* climate change scenario, and by as much as 3.2 inches by the end of the century under a *high* climate change scenario.

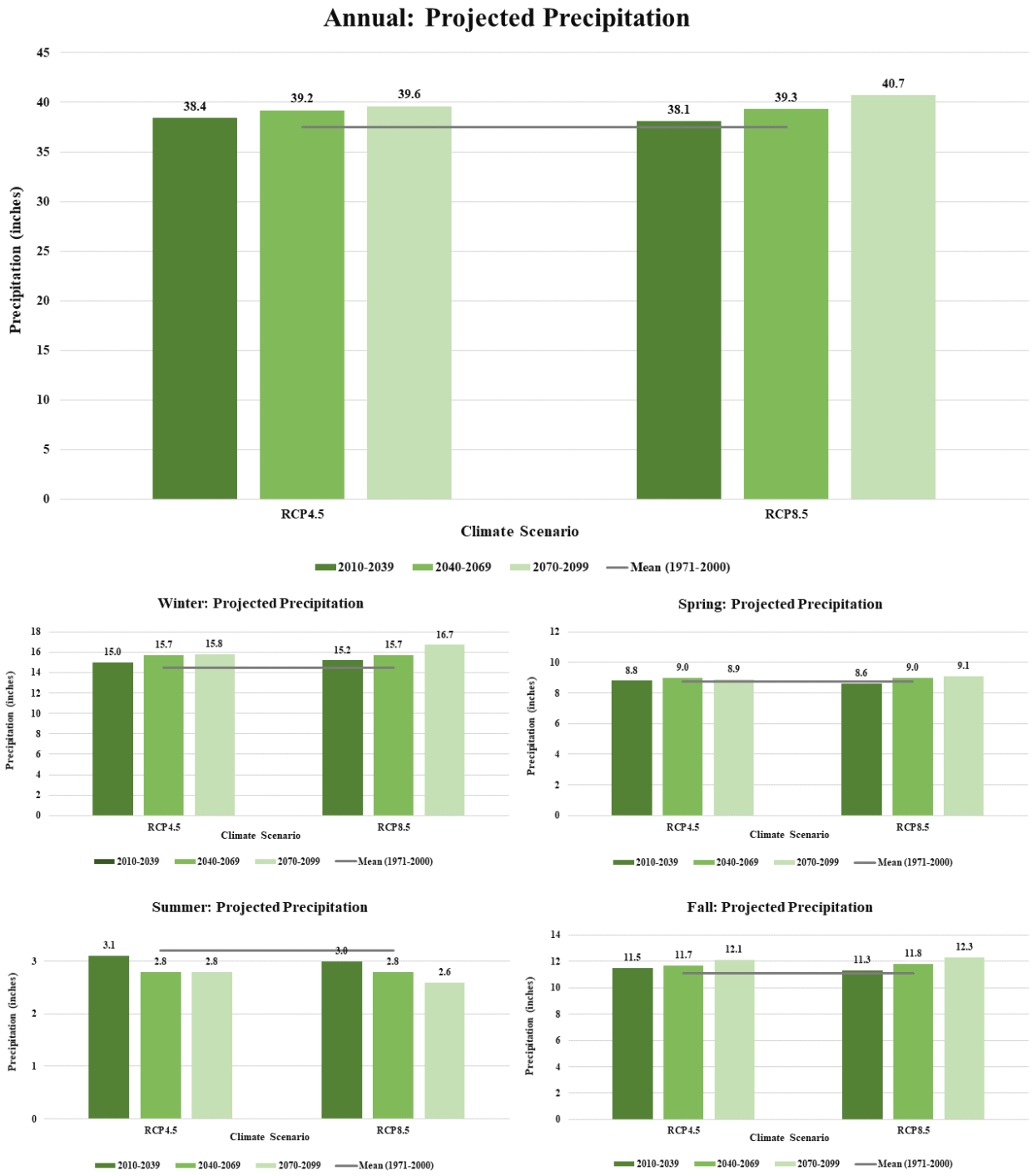


Figure 3.—Projected Precipitation in the Puget Sound Region Under RCP 4.5 and RCP 8.5 Climate Change Scenarios.

Temperature Projections for the Puget Sound Region

Mean, minimum, and maximum temperature is projected to increase under both low (RCP 4.5) and high (RCP 8.5) climate change scenarios in every season through the end of the century (Table 1). Annual

mean temperature is projected to increase by 5℉ by the end of the century under a *low* climate change scenario, and by as much as 8.6℉ by the end of the century under a *high* climate change scenario.

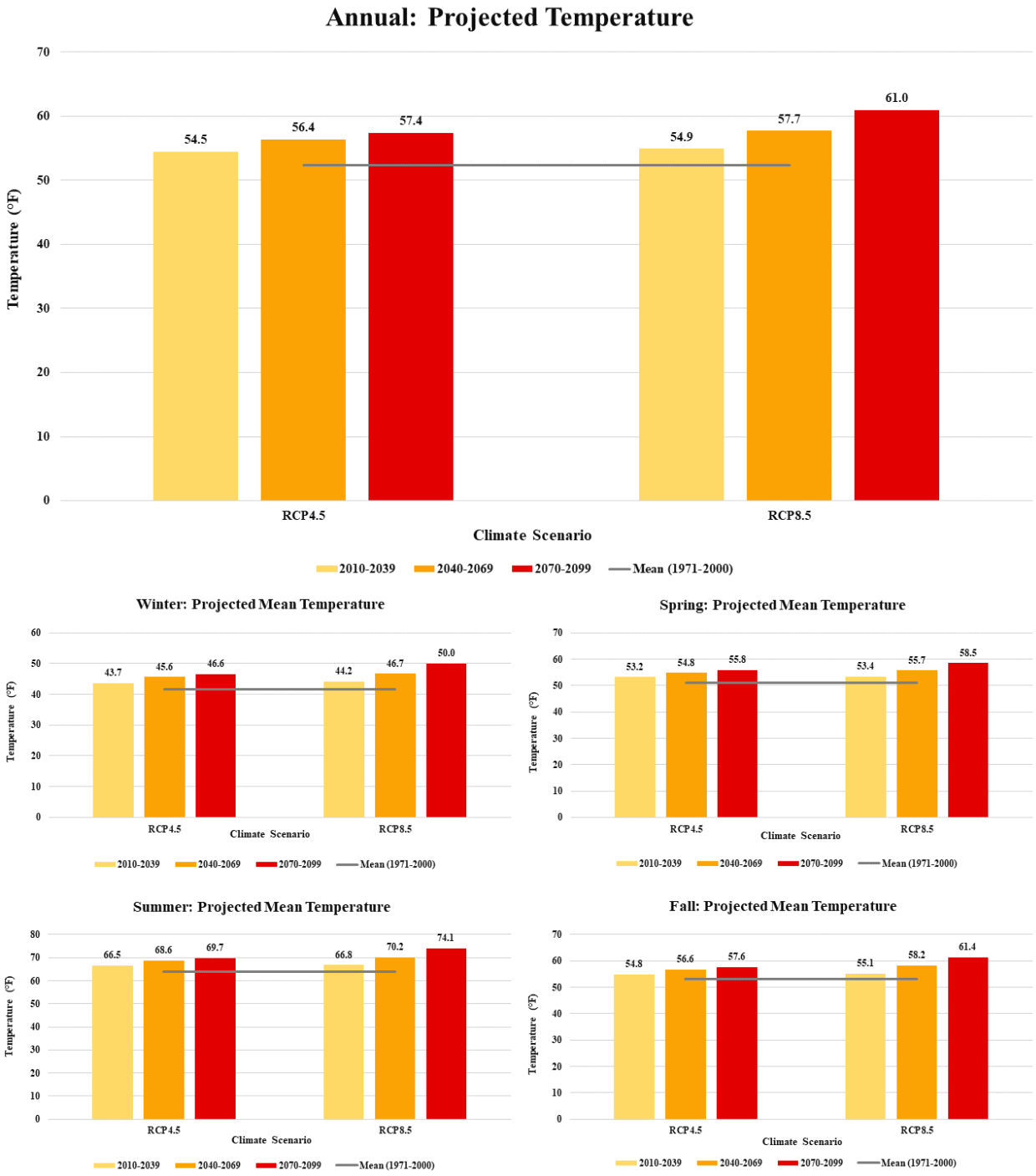


Figure 4.—Projected Temperature in the Puget Sound Region Under RCP 4.5 and RCP 8.5 Climate Change Scenarios.

Table 1.—Precipitation and Temperature Projections Under RCP 4.5 and RCP 8.5 Climate Change Scenarios. Values indicate the multi-model mean derived from 20 downscaled CMIP5 models. Data retrieved from https://climatetoolbox.org/tool/climate-mapper

	Precipitation (inches)						
	2010-2039		**2040-2069**		**2070-2099**		**Historical Average**
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**1971-2000**
Annual	38.4 in (+0.9 in)	38.1 in (+0.7 in)	39.2 in (+1.7 in)	39.3 in (+1.8 in)	39.6 in (+2.1 in)	40.7 in (+3.2 in)	37.5 in
Winter (Dec - Feb)	15 in (+0.5 in)	15.2 in (+0.7 in)	15.7 in (+1.2 in)	15.7 in (+1.2 in)	15.8 in (+1.3 in)	16.7 in (+2.2 in)	14.5 in
Spring (Mar - May)	8.8 in (+0.1 in)	8.6 in (-0.1 in)	9 in (+0.3 in)	9 in (+0.3 in)	8.9 in (+0.2 in)	9.1 in (+0.4 in)	8.7 in
Summer (June - Aug)	3.1 in (-0.1 in)	3 in (-0.2 in)	2.8 in (-0.4 in)	2.8 in (-0.4 in)	2.8 in (-0.4 in)	2.6 in (-0.6 in)	3.2 in
Fall (Sept - Nov)	11.5 in (+0.4 in)	11.3 in (+0.2 in)	11.7 in (+0.6 in)	11.8 in (+0.7 in)	12.1 in (+1 in)	12.3 in (+1.2 in)	11.1 in
	Mean Temperature (℉)						
	2010-2039		**2040-2069**		**2070-2099**		**Historical Average**
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**1971-2000**
Annual	54.5℉ (+2.1℉)	54.9℉ (+2.4℉)	56.4℉ (+4℉)	57.7℉ (+5.3℉)	57.4℉ (+5℉)	61℉ (+8.6℉)	52.4℉
Winter (Dec - Feb)	43.7℉ (+2℉)	44.2℉ (+2.5℉)	45.6℉ (+3.9℉)	46.7℉ (+5℉)	46.6℉ (+4.9℉)	50℉ (+8.3℉)	41.7℉
Spring (Mar - May)	53.2℉ (+2.1℉)	53.4℉ (+2.4℉)	54.8℉ (+3.8℉)	55.7℉ (4.7℉)	55.8℉ (+4.7℉)	58.5℉ (+7.4℉)	51℉
Summer (June - Aug)	66.5℉ (+2.5℉)	66.8℉ (+2.8℉)	68.6℉ (+4.6℉)	70.2℉ (+6.2℉)	69.7℉ (+5.7℉)	74.1℉ (+10.1℉)	64℉
Fall (Sept - Nov)	54.8℉ (+1.8℉)	55.1℉ (+2.1℉)	56.6℉ (+3.6℉)	58.2℉ (+5.2℉)	57.6℉ (+4.6℉)	61.4℉ (+8.4℉)	53℉
	Minimum Temperature (℉)						
	2010-2039		**2040-2069**		**2070-2099**		**Historical Average**
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**1971-2000**
Annual	47℉ (+2℉)	47.3℉ (2.3℉)	48.8℉ (+3.8℉)	50.1℉ (+5.1℉)	49.9℉ (+4.9℉)	53.4℉ (+8.4℉)	45℉
Winter (Dec - Feb)	38.2℉ (+2℉)	38.8℉ (+2.6℉)	40.2℉ (+4.1℉)	41.3℉ (+5.2℉)	41.2℉ (+5.1℉)	44.8℉ (+8.6℉)	36.1℉
Spring (Mar - May)	45.2℉ (+2℉)	45.4℉ (+2.2℉)	46.8℉ (+3.6℉)	47.7℉ (+4.5℉)	47.7℉ (+4.5℉)	50.5℉ (+7.3℉)	43.2℉

Summer (June - Aug)	56.9℉ (+2.2℉)	57.2℉ (+2.5℉)	58.9℉ (+4.1℉)	60.5℉ (+5.8℉)	60℉ (+5.3℉)	64.2℉ (+9.5℉)	54.7℉
Fall (Sept - Nov)	47.7℉ (+1.8℉)	47.9℉ (+2℉)	49.4℉ (+3.6℉)	51℉ (+2℉)	50.5℉ (+4.6℉)	54.3℉ (+8.4℉)	45.9℉
	Maximum Temperature (℉)						
	2010-2039		**2040-2069**		**2070-2099**		**Historical Average**
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**1971-2000**
Annual	62.1℉ (+2.2℉)	62.4℉ (+2.6℉)	64℉ (+4.1℉)	65.3℉ (+5.4℉)	65℉ (+5.1℉)	68.6℉ (+8.7℉)	59.9℉
Winter (Dec - Feb)	49.2℉ (+1.9℉)	49.6℉ (+2.4℉)	51℉ (+3.7℉)	52℉ (4.7℉)	52℉ (+4.7℉)	55.2℉ (+8℉)	47.3℉
Spring (Mar - May)	61.2℉ (+2.3℉)	61.4℉ (+2.5℉)	62.9℉ (+4℉)	63.7℉ (+4.8℉)	63.9℉ (+5℉)	66.5℉ (+7.6℉)	58.9℉
Summer (June - Aug)	76℉ (+2.8℉)	76.4℉ (+3.2℉)	78.3℉ (+5℉)	80℉ (+6.8℉)	79.4℉ (+6.2℉)	83.9℉ (+10.7℉)	73.2℉
Fall (Sept - Nov)	61.9℉ (+1.8℉)	62.3℉ (+2.2℉)	63.7℉ (+3.6℉)	65.4℉ (5.3℉)	64.8℉ (+4.7℉)	68.6℉ (8.5℉)	60.1℉
	Days with Heat Index ≥90℉						
	2010-2039		**2040-2069**		**2070-2099**		**Historical Average**
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**	**1971-2000**
Annual	2.5 days (+1.7 days)	3.2 days (+2.4 days)	6.6 days (+5.8 days)	11.6 days (+10.8 days)	9.8 days (+9 days)	31 days (+30.2 days)	0.8 days

Tree Species Vulnerability

Changes in climate have the potential to profoundly affect the Puget Sound Region's trees. Some tree species that are currently present may experience declines in habitat suitability under warmer temperatures and altered precipitation patterns. Other tree species may be less vulnerable to these conditions. Some species not currently present could potentially be planted in the area as hardiness zones shift with milder winters. Climate change can have indirect effects on the urban forests in the region by changing insect pests, pathogens, and nonnative invasive species, as well as the probability, severity, and extent of severe storms. Tree species in the area will differ in their capacity to adapt to such stressors. This document summarizes expected changes in habitat suitability and the adaptive capacity of different species in the region's developed areas.

Shifts in Heat and Hardiness Zones

Heat and hardiness zones are geographic areas that define which species or cultivars are considered suitable for planting and survival. These zones are critical for understanding tree species selection under a changing climate. Defined by the U.S. Department of Agriculture, climate hardiness zones help arborists, gardeners, farmers, and others interested in tree and plant growth compare their local climate to that where a specific tree or plant is known to grow well. Each hardiness zone is 10ºF warmer (or colder) than the adjacent zone to its north (or south). It is significant, therefore, that hardiness zones have migrated north by one-half, to one full level since 1990 (USDA Forest Service, 2020).

The Puget Sound Region is historically (1980-2009) in hardiness zones 8 (-12.2°C to -6.7°C) to 9 (-6.7°C to -1.1°C). Future hardiness and heat zones were obtained from Matthews et al. (2018). Under the RCP 4.5 scenario, which assumes a reduction in global emissions of greenhouse gases, the hardiness zone is projected to stay in zones 8-9 in the Puget Sound Region by 2039, and shift completely to zone 9 by 2040-2069 (Table 2). Under the high climate change scenario, RCP 8.5, the hardiness zone is projected to shift completely to zone 9 by 2039 and remain in zone 9 through 2099.

The American Horticultural Society has established heat zones for determining the upper temperature limits trees are able to tolerate. The average number of days greater than 86°F (30°C) determines heat zones. The Puget Sound Region is historically (1980-2009) in heat zone 2 (1 to 7 days exceeding 30°C). Under the intermediate climate change scenario, RCP 4.5, which assumes a reduction in global emissions of greenhouse gases, the heat zone is projected to stay in heat zone 2 by 2039 and shift to zone 3 (>7 to 14 days exceeding 30°C) by 2040-2069, remaining through 2099 (Table 2). Under the high climate change scenario, RCP 8.5, the heat zone is projected to shift to zone 3 by 2039, zone 4 (>14-30 days exceeding 30°C) by 2040-2069, and zone 6 (>45-60 days exceeding 30°C) by 2070-2099.

Table 2.—Hardiness and Heat Zone Shifts by Climate Scenario (RCP4.5 and RCP8.5) and Time Period (2010-2039, 2040-2069, and 2070-2099) Compared to the 1980-2010 Ranges.

Time Period	Hardiness Zone Range		Heat Zone Range	
1980-2009	Zone 8-9		Zone 2	
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
2010-2039	Zone 8-9	Zone 9	Zone 2	Zone 3
2040-2069	Zone 9	Zone 9	Zone 3	Zone 4
2070-2099	Zone 9	Zone 9	Zone 3	Zone 6

As the climate warms, the composition of forests changes. Many tree species are moving northward, resulting in more southerly varieties replacing them (Groffman et al., 2014). Following this trend, many iconic tree species are expected to lose their advantage and be replaced within the next century (Groffman et al., 2014). When significantly warmer temperatures occur over a period of time long enough to cause a change in hardiness zone classification, trees' vulnerability to mortality from insect infestations, temperature, soil moisture levels, and disease will increase. How climate change impacts the future diversity and vitality of trees in the Puget Sound Region still depends, in part, on land-use and tree planting decisions residents, businesses, and city governments make today.

Projected Suitability from Heat Zones

Model information is not available for all species and cultivars that are found in the Puget Sound Region or for some of the species being considered for future planting. These species are usually either too rare in the region to be modeled reliably, have a range that extends outside of the U.S., are not native to North America, or are cultivars. To understand how climate change may affect these species, one approach is to examine heat zone ranges of the species to see how they compare to projected future zones in the region. Note that using heat zones to estimate which species will benefit or fare worse in a changing climate does not take into account changes in precipitation, seasonal climate changes, and other habitat requirements such as soil texture. This analysis is only meant to provide a coarse estimate of potential changes in habitat suitability based on temperature extremes.

A species' hardiness and heat zone ranges are the areas in which the species is considered suitable for planting. For this particular assessment, we include both heat zone suitability alone, as well as heat and hardiness zone suitability. Suitability was determined by the current and projected heat zones for the Puget Sound Region through the end of the century. For some species, only the hardiness zone ranges were available, and heat zone suitability was not determined (marked N/A).

For heat zone suitability, a tree species was considered to be suitable under the low climate change scenario if its maximum heat zone was 3 or greater (Table 3). A tree species was considered suitable under the high climate change scenario if its maximum heat zone was 6 or greater. All species assessed for the Puget Sound Region are considered suitable under both low and high climate change scenarios through the end of the century.

For hardiness zone suitability, the species was considered to be suitable under the low climate change scenario if its minimum hardiness zone was 9 or lower, its maximum hardiness zone was 9 or greater, and its maximum heat zone was 3 or greater (Table 3). The species was considered suitable under the high climate change scenario if it had a minimum hardiness zone of 9 or lower, its maximum hardiness was 9 or greater, and its maximum heat zone was 6 or greater. These minima and maxima were determined by the current and projected heat and hardiness zones for the Puget Sound Region through the end of the century (Table 2).

Considering heat zones only, the majority of tree species fell into the low-moderate (57%) vulnerability category followed by low vulnerability (26%) and moderate vulnerability (17%) under both low and high climate change scenarios. The vulnerability ratings remain the same between low and high climate change scenarios because all assessed tree species are considered suitable under the heat zone projections through the end of the century. Considering both heat and hardiness zones, the majority of tree species assessed fall into the moderate-high vulnerability category (39%), followed by low-moderate (20%), moderate (18%), low (13%), and high (9%).

Table 3.—Heat Zone Suitability and Heat and Hardiness Zone Suitability Under Low (RCP 4.5) and High (RCP 8.5) Climate Change Scenarios for Species That Are Currently Found in the Puget Sound Region or Are Being Considered for Planting in the Area. N/A= not available.

Scientific Name	Common Name	Hardiness Zone	Heat Zone	Heat Zone Suitability - Low	Heat Zone Suitability - High	Heat and Hardiness Zone Suitability - Low	Heat and Hardiness Zone Suitability - High
Abies concolor	White Fir	3-7	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Abies grandis	Grand Fir	5-6	6 (5-6)	Suitable	Suitable	Not Suitable	Not Suitable
Abies procera	Noble Fir	5-6	6 (5-6)	Suitable	Suitable	Not Suitable	Not Suitable
Acer buergerianum	Trident Maple	5-9	9 (5-9)	Suitable	Suitable	Suitable	Suitable
Acer circinatum	Vine Maple	6-9	9 (4-9)	Suitable	Suitable	Suitable	Suitable
Acer freemanii	Freeman Maple	4-7	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Acer griseum	Paperbark Maple	5-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Acer macrophyllum	Big Leaf Maple	5-9	9 (4-9)	Suitable	Suitable	Suitable	Suitable
Acer miyabei	Miyabe's Maple	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Acer negundo	Boxelder	2-10	8 (3-8)	Suitable	Suitable	Suitable	Suitable
Acer nigrum	Black Maple	4-8	8 (3-8)	Suitable	Suitable	Not Suitable	Not Suitable
Acer palmatum	Japanese Maple	5-8	8 (2-8)	Suitable	Suitable	Not Suitable	Not Suitable
Acer platanoides	Norway Maple	4-7	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Acer pseudoplatanus	Sycamore Maple	4-7	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Acer rubrum	Red Maple	3-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Acer saccharinum	Silver Maple	3-9	8 (1-8)	Suitable	Suitable	Suitable	Suitable
Acer saccharum	Sugar Maple	3-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Acer tataricum	Tatarian Maple	3-8	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Acer triflorum	Three-Flower Maple	5-7	7 (5-7)	Suitable	Suitable	Not Suitable	Not Suitable
Acer truncatum	Shantung Maple	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Aesculus flava	Yellow Buckeye	3-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Aesculus hippocastanum	Horse Chestnut	3-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Ailanthus altissima	Tree of Heaven	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable

Albizia julibrissin	Persian Silk Tree	6-9	9 (6-9)	Suitable	Suitable	Suitable	Suitable
Alnus rubra	Red Alder	6-8	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Amelanchier arborea	Downy Serviceberry	4-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Amelanchier laevis	Allegheny Serviceberry	3-9	9 (3-9)	Suitable	Suitable	Suitable	Suitable
Arbutus menziesii	Pacific Madrone	7-9	9 (7-9)	Suitable	Suitable	Suitable	Suitable
Arbutus unedo	Strawberry Tree	8B-11	9 (6-9)	Suitable	Suitable	Suitable	Suitable
Betula alleghaniensis	Swamp Birch	3-7	8 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Betula nigra	River Birch	4-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Betula papyrifera	Paper Birch	2-6	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Betula pendula	Silver Birch	2-7	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Betula populifolia	Gray Birch	3-6	6 (1-6)	Suitable	Suitable	Not Suitable	Not Suitable
Carpinus betulus	European Hornbeam	4-9	8 (1-8)	Suitable	Suitable	Suitable	Suitable
Carpinus caroliniana	American Hornbeam	3-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Castanea mollissima	Chinese Chestnut	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Castanea sativa	Sweet Chestnut	6-7	7 (5-7)	Suitable	Suitable	Not Suitable	Not Suitable
Catalpa bignonioides	Southern Catalpa	5-9	9 (5-9)	Suitable	Suitable	Suitable	Suitable
Catalpa speciosa	Northern Catalpa	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Celtis occidentalis	Common Hackberry	2-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Cercidiphyllum japonicum	Katsura Tree	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Cercis canadensis	Eastern Redbud	4-8	9 (6-9)	Suitable	Suitable	Not Suitable	Not Suitable
Chamaecyparis lawsoniana	Lawson's Cypress	5B-7	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Chamaecyparis nootkatensis	Nootka Cypress	4-8	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Chamaecyparis obtusa	Hinoki Cypress	5-8A	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Chamaecyparis pisifera	Sawara Cypress	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable

Chionanthus retusus	Chinese Fringetree	5-9	9 (3-9)	Suitable	Suitable	Suitable	Suitable
Cladrastis kentukea	Yellowwood	4-8	9 (1-9)	Suitable	Suitable	Not Suitable	Not Suitable
Cornus florida	Flowering Dogwood	6-9	9 (3-9)	Suitable	Suitable	Suitable	Suitable
Cornus kousa	Kousa Dogwood	5-8	8 (5-8)	Suitable	Suitable	Not Suitable	Not Suitable
Cornus mas	Cornelian Cherry	4-8	8 (5-8)	Suitable	Suitable	Not Suitable	Not Suitable
Cornus nuttallii	Pacific Dogwood	7-8	8 (3-8)	Suitable	Suitable	Not Suitable	Not Suitable
Corylus avellana	Common Hazel / European Filbert	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Corylus colurna	Turkish Filbert	4-7	7 (4-7)	Suitable	Suitable	Not Suitable	Not Suitable
Cotinus coggygria	Smoke Tree	4-8	9 (3-9)	Suitable	Suitable	Not Suitable	Not Suitable
Cotinus obovatus	American Smoke Tree	5-8	9 (1-9)	Suitable	Suitable	Not Suitable	Not Suitable
Crataegus crus-galli	Cockspur Hawthorn	3-7	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Crataegus laevigata	Midland Hawthorn / English Hawthorn	4B-8	8 (3-8)	Suitable	Suitable	Not Suitable	Not Suitable
Crataegus monogyna	Common Hawthorn	5-7	7 (4-7)	Suitable	Suitable	Not Suitable	Not Suitable
Crataegus phaenopyrum	Washington Hawthorn	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Cupressus sempervirens	Mediterranean Cypress	7-11	9 (3-9)	Suitable	Suitable	Suitable	Suitable
Elaeagnus angustifolia	Russian Olive	3-7	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Eucommia ulmoides	Hardy Rubber Tree	4-7	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Fagus grandifolia	American Beech	4-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Fagus sylvatica	Green Beech	5-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Ficus carica	Common Fig	6-10 (various cultivars)	9 (6-9)	Suitable	Suitable	Suitable	Suitable
Fraxinus americana	White Ash	4-9	10 (1-10)	Suitable	Suitable	Suitable	Suitable
Fraxinus angustifolia	Narrow-leafed Ash	5-8	9 (4-9)	Suitable	Suitable	Not Suitable	Not Suitable
Fraxinus excelsior	European Ash	5-7	8 (3-8)	Suitable	Suitable	Not Suitable	Not Suitable

Fraxinus latifolia	Oregon Ash	6-8	8 (6-8)	Suitable	Suitable	Not Suitable	Not Suitable
Fraxinus pennsylvanica	Green Ash	3-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Ginkgo biloba	Ginkgo / Maidenhair	4-8	9 (3-9)	Suitable	Suitable	Not Suitable	Not Suitable
Gleditsia triacanthos	Honey Locust	4-8	9 (1-9)	Suitable	Suitable	Not Suitable	Not Suitable
Gymnocladus dioicus	Kentucky Coffeetree	4-8	9 (2-9)	Suitable	Suitable	Not Suitable	Not Suitable
Hamamelis virginiana	American Witch-hazel	3-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Hesperocyparis arizonica	Arizona Cypress	7-9	9 (2-9)	Suitable	Suitable	Suitable	Suitable
Hibiscus syriacus	Common Hibiscus	5-8	9 (1-9)	Suitable	Suitable	Not Suitable	Not Suitable
Ilex aquifolium	Common Holly	7-9	9 (7-9)	Suitable	Suitable	Suitable	Suitable
Juglans nigra	Black Walnut	4-9	9 (3-9)	Suitable	Suitable	Suitable	Suitable
Juglans regia	English Walnut	4-8	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Juniperus chinensis	Chinese Juniper	4-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Juniperus virginiana	Eastern Red Cedar	3-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Koelreuteria paniculata	Goldenrain Tree	5-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Laburnum anagyroides	Common Laburnum	5A-7B	8 (5-8)	Suitable	Suitable	Not Suitable	Not Suitable
Lagerstroemia indica	Crepe Myrtle	7-9	9 (6-9)	Suitable	Suitable	Suitable	Suitable
Larix decidua	European Larch	3-6	6 (1-6)	Suitable	Suitable	Not Suitable	Not Suitable
Ligustrum japonicum	Wax-leaf Privet / Japanese Privet	7-10	10 (7-10)	Suitable	Suitable	Suitable	Suitable
Ligustrum lucidum	Glossy Privet	8-10	8 (8-10)	Suitable	Suitable	Suitable	Suitable
Liquidambar styraciflua	Sweetgum	5-9	10 (1-10)	Suitable	Suitable	Suitable	Suitable
Liriodendron tulipifera	Tulip Tree	5-7	9 (2-9)	Suitable	Suitable	Not Suitable	Not Suitable
Maackia amurensis	Amur Maackia	3-7	7 (4-7)	Suitable	Suitable	Not Suitable	Not Suitable
Magnolia grandiflora	Southern Magnolia	7-10	11 (1-11)	Suitable	Suitable	Suitable	Suitable
Magnolia kobus	Kobus Magnolia	5-8A	not defined	N/A	N/A	Not Suitable	Not Suitable

Malus domestica	Edible Apple	3-8	9 (1-9)	Suitable	Suitable	Not Suitable	Not Suitable
Malus spp.	Crabapple	3-8	9 (1-9)	Suitable	Suitable	Not Suitable	Not Suitable
Metasequoia glyptostroboides	Dawn Redwood	4-8	10 (5-10)	Suitable	Suitable	Not Suitable	Not Suitable
Morus alba	White Mulberry	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Nyssa sylvatica	Tupelo	some zone 4/5 provenances, 6-9	9 (7-9)	Suitable	Suitable	Suitable	Suitable
Olea europaea	European Olive	8-10	10 (8-10)	Suitable	Suitable	Suitable	Suitable
Ostrya virginiana	Ironwood	3-9	9 (5-9)	Suitable	Suitable	Suitable	Suitable
Oxydendrum arboreum	Sourwood	5-9	9 (3-9)	Suitable	Suitable	Suitable	Suitable
Parrotia persica	Persian Parrotia	5-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Paulownia tomentosa	Empress Tree	5-9	8 (4-8)	Suitable	Suitable	Suitable	Suitable
Picea abies	Norway Spruce	3-7	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Picea glauca	White Spruce	2-6	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Picea omorika	Serbian Spruce	4-7	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Picea pungens	Colorado Spruce	2-7	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Pinus banksiana	Jack Pine	2-6	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Pinus halepensis	Aleppo Pine	8-11	10 (1-10)	Suitable	Suitable	Suitable	Suitable
Pinus mugo	Sweet Mountain Pine	3-7	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Pinus nigra	Austrian Pine	4-7	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Pinus parviflora	Japanese White Pine	6-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Pinus pinea	Italian Stone Pine	7-11	12 (9-12)	Suitable	Suitable	Suitable	Suitable
Pinus ponderosa	Ponderosa Pine	3-8	8 (4-8)	Suitable	Suitable	Not Suitable	Not Suitable
Pinus sabiniana	Foothill Pine	8-10	unknown	N/A	N/A	Suitable	Suitable
Pinus strobus	Eastern White Pine	3-8	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Pinus sylvestris	Scots Pine	3-7	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable

Pistacia chinensis	Chinese Pistachio	6-9	9 (6-9)	Suitable	Suitable	Suitable	Suitable
Platanus occidentalis	American Sycamore	4-9	9 (3-9)	Suitable	Suitable	Suitable	Suitable
Populus alba	White Poplar	4-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Populus nigra	Black Poplar	3-9	unknown	N/A	N/A	Suitable	Suitable
Populus tremuloides	Quaking Aspen	2-6	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Prunus armeniaca	Apricot	5-7	9 (1-9)	Suitable	Suitable	Not Suitable	Not Suitable
Prunus avium	Sweet Cherry	3-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Prunus cerasifera	Cherry Plum	4-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Prunus cerasus	Sour Cherry	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Prunus domestica	Common Plum	4-9	8 (3-8)	Suitable	Suitable	Suitable	Suitable
Prunus laurocerasus	English Laurel	6-9	10 (6-10)	Suitable	Suitable	Suitable	Suitable
Prunus pendula	Weeping Higan Cherry	5-8	8 (6-8)	Suitable	Suitable	Not Suitable	Not Suitable
Prunus persica	Peach	5-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Prunus sargentii	Sargent Cherry	5-8	9 (5-9)	Suitable	Suitable	Not Suitable	Not Suitable
Prunus serotina	Black Cherry	3-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Prunus serrula	Birch Bark Cherry	6-8	8 (6-8)	Suitable	Suitable	Not Suitable	Not Suitable
Prunus serrulata	Japanese Cherry	5-6	9 (4-9)	Suitable	Suitable	Not Suitable	Not Suitable
Prunus subhirtella	Higan Cherry	5-8	8 (6-8)	Suitable	Suitable	Not Suitable	Not Suitable
Prunus virginiana	Common Chokecherry	2-7	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Pseudotsuga menziesii	Douglas Fir	4-6	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Pyrus calleryana	Callery Pear	5-9	8 (3-8)	Suitable	Suitable	Suitable	Suitable
Pyrus communis	Common Pear	5-9	9 (5-9)	Suitable	Suitable	Suitable	Suitable
Quercus acutissima	Sawtooth Oak	5-9	8 (3-8)	Suitable	Suitable	Suitable	Suitable
Quercus agrifolia	Coast Live Oak	8-10	11 (9-11)	Suitable	Suitable	Suitable	Suitable
Quercus alba	White Oak	3-9	8 (1-8)	Suitable	Suitable	Suitable	Suitable

Quercus bicolor	Swamp White Oak	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Quercus coccinea	Scarlet Oak	4-9	9 (4-9)	Suitable	Suitable	Suitable	Suitable
Quercus garryana	Oregon Oak	7-9	8 (3-8)	Suitable	Suitable	Suitable	Suitable
Quercus imbricaria	Shingle Oak	4-8	8 (4-8)	Suitable	Suitable	Not Suitable	Not Suitable
Quercus palustris	Pin Oak	4-8	7 (3-7)	Suitable	Suitable	Not Suitable	Not Suitable
Quercus phellos	Willow Oak	6-9	9 (3-9)	Suitable	Suitable	Suitable	Suitable
Quercus robur	English Oak	3-8	8 (3-8)	Suitable	Suitable	Not Suitable	Not Suitable
Quercus rubra	Red Oak	4-8	9 (5-9)	Suitable	Suitable	Not Suitable	Not Suitable
Quercus shumardii	Shumard Oak	5-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Quercus virginiana	Live Oak	8-11	11 (6-11)	Suitable	Suitable	Suitable	Suitable
Robinia pseudoacacia	Black Locust	4-8	9 (3-9)	Suitable	Suitable	Not Suitable	Not Suitable
Salix matsudana	Corkscrew Willow	5-9	unknown	N/A	N/A	Suitable	Suitable
Sequoia sempervirens	Coast Redwood	7-10A	9 (8-9)	Suitable	Suitable	Suitable	Suitable
Sequoiadendron giganteum	Giant Sequoia	6-8	9 (4-9)	Suitable	Suitable	Not Suitable	Not Suitable
Sorbus alnifolia	Korean Mountain Ash	3-8	10 (1-10)	Suitable	Suitable	Not Suitable	Not Suitable
Sorbus aucuparia	Rowan	3-6	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Stewartia pseudocamellia	Japanese Stewartia	5B-7	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Styrax japonicus	Japanese Snowbell	5-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Syringa pekinensis	Chinese Tree Lilac / Peking Lilac	3-8 zone data from *reticulata*	8 (3-8)	Suitable	Suitable	Not Suitable	Not Suitable
Syringa reticulata	Japanese Tree Lilac	3-7	8 (3-8)	Suitable	Suitable	Not Suitable	Not Suitable
Syringa vulgaris	Common Lilac	4-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Taxodium distichum	Bald Cypress	4-11	12 (5-12)	Suitable	Suitable	Suitable	Suitable
Thuja occidentalis	Northern White Cedar	2-7	7 (1-7)	Suitable	Suitable	Not Suitable	Not Suitable
Thuja plicata	Western Red Cedar	6-8A	8 (6-8)	Suitable	Suitable	Not Suitable	Not Suitable

Tilia americana	American Basswood	3-8	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Tilia cordata	Littleleaf Linden	3-7	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Tilia platyphyllos	Large Leaf linden	2-6	6 (1-6)	Suitable	Suitable	Not Suitable	Not Suitable
Tilia tomentosa	Silver Linden	4-7	9 (1-9)	Suitable	Suitable	Not Suitable	Not Suitable
Trachycarpus fortunei	Windmill Palm	8-11	12 (8-12)	Suitable	Suitable	Suitable	Suitable
Tsuga canadensis	Eastern Hemlock	3-7	8 (1-8)	Suitable	Suitable	Not Suitable	Not Suitable
Tsuga heterophylla	Western Hemlock	6-8	8 (6-8)	Suitable	Suitable	Not Suitable	Not Suitable
Tsuga mertensiana	Mountain Hemlock	6-8	not defined	N/A	N/A	Not Suitable	Not Suitable
Ulmus americana	American Elm	3-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Ulmus parvifolia	Chinese Elm	5-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Ulmus procera	English Elm	5-8	8 (2-8)	Suitable	Suitable	Not Suitable	Not Suitable
Ulmus propinqua	Emerald Sunshine Elm	5-8	unknown	N/A	N/A	Not Suitable	Not Suitable
Ulmus pumila	Siberian Elm	4-9	9 (1-9)	Suitable	Suitable	Suitable	Suitable
Zelkova serrata	Japanese Zelkova	5-8	9 (5-9)	Suitable	Suitable	Not Suitable	Not Suitable

Adaptability Scores: Planted Environments

The results presented above provide information on potential changes in tree species habitat suitability across a range of projected extreme high and low temperatures (in the case of hardiness and heat zones), but do not account for factors such as changes in flood regime, extreme weather events, insects and disease, and nonnative invasive species. To understand the capacity of tree species and cultivars in the area to adapt to these other effects of climate change, we relied on a scoring system developed by Matthews et al. (2011) called “modification factors.” Other scoring systems have been developed (Roloff et al., 2009), but we found the system developed by Matthews et al. to be the most comprehensive for all potential climate change–related stressors.

Modification factors can include life history traits or environmental factors that make a species more or less likely to persist on the landscape (Matthews et al., 2011). Examples of modification factors include fire or drought tolerance, dispersal ability, shade tolerance, site specificity, and susceptibility to insect pests and diseases (Table 4). These factors can then be weighted by their intensity, the level of uncertainty about their impacts, and relative importance to future changes to tree mortality and survival to arrive at a numerical score (see Appendix A). Modification factors are highly related to the adaptive capacity of a species: the ability to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2014). A species with a large number of positive modification factors would have a high adaptive capacity, and a species with a large number of negative modification factors would have a low adaptive capacity.

We used the modification factors developed for the Chicago Wilderness vulnerability assessment to better capture the unique environment of urban areas (Brandt et al., 2017). We developed modification factor scores for 181 species and varieties. Scores were then converted to categories of high, medium, and low adaptive capacity. It is important to note that modification factors are meant to be used as a general summary of a species' adaptive capacity across its entire range, and not meant to capture site-specific factors that may enhance or reduce a species ability to withstand stressors.

In planted/developed conditions, 181 species were scored for adaptability. Twenty-five species (14%) were found to have low adaptability, while the majority (107 species, 59%) were found to have moderate adaptability and 49 species (27%) were found to have high adaptability. Common species in the Puget Sound Region with high adaptability scores include red maple, Norway maple, Kousa dogwood, littleleaf linden, and American hornbeam. Common species with low adaptability scores include sweetgum, paperbark maple, silver birch, and katsura tree. These species tended to receive low adaptability ratings because they were susceptible to pests or diseases, were intolerant of a variety of disturbances and conditions (e.g., floods, wind, droughts, air pollution, restricted rooting conditions, temperature gradients), and had a narrow range in terms of urban sites and soil and temperature requirements.

Table 4.—Trait Codes for Adaptability Tables. Traits are listed if they were among the main contributors to the overall adaptability score. N=applies to naturally occurring trees; P=applies to planted trees. See Appendix xx for more information.

Factor	Code	Type	Description (if positive)	Description (if negative)
Air pollution	AIP	N, P	Tolerant of air pollution	Intolerant of air pollution
Browse	BRO	N, P	Resistant to browsing	Susceptible to browsing
Competition-light	COL	N, P	Tolerant of shade or limited light conditions	Intolerant of shade or limited light conditions
Disease	DISE	N, P	Disease-resistant	Has a high number and/or severity of known pathogens that attack the species
Drought	DRO	N, P	Drought-tolerant	Susceptible to drought
Edaphic specificity	ESP	N, P	Wide range of soil tolerance	Narrow range of soil requirements
Environmental habitat specificity	EHS	N	Wide range of slopes/aspects/topographic positions	Small range of slopes/aspects/topographic positions
Flood	FLO	N, P	Flood-tolerant	Flood-intolerant
Ice	ICE	N, P	N/A	Susceptible to breakage from ice storms
Insect pests	INS	N, P	Pest-resistant	Has a high number and/or severity of insects that may attack the species
Invasive plants	INPL	N, P	N/A	Strong negative effects of invasive plants on the species, either through competition for nutrients or as a pathogen
Invasive potential	INPO	P	N/A	Species has the potential to become invasive and thus disfavored for planting
Land-use and planting site specificity	LPS	P	Can be planted on a wide variety of sites	Can only be planted in a narrow range of sites or as a specimen

Maintenance required	MAR	P	Little pruning, watering, or cleanup required	Requires considerable pruning, watering, or cleanup of debris
Nursery propagation	NUP	P	Easily propagated in nursery and widely available	Not easily propagated/not usually available
Planting establishment	PLE	P	Easily transplanted and requires little care to establish	Difficult to transplant or requires considerable care to establish
Restricted rooting conditions	RRC	P	Can tolerate restricted rooting conditions	Intolerant of restricted rooting conditions
Soil and water pollution	SWP	N, P	Tolerant of soil and/or water pollution	Intolerant of soil and/or water pollution
Temperature gradients	TEM	N, P	Wide range of temperature tolerances	Narrow range of temperature requirements
Wind	WIN	N, P	N/A	Susceptible to breakage from wind storms

Table 5.—Adaptability Scores for Trees in Planted Areas. Native trees are considered those native to North America. See Table 4 for Trait Codes.

Scientific Name	Common Name	Native to North America?	Native to Pacific Northwest?	Planted Adapt Score	Planted Adapt Class	Planted Positive Factors	Planted Negative Factors
Abies concolor	White Fir	Yes	Yes	3.87	Moderate	-	FLO AIP
Abies grandis	Grand Fir	Yes	Yes	4.14	Moderate	NUP MAR	DISE INS INPL ICE TEM AIP SWP SAL LPS
Abies procera	Noble Fir	Yes	Yes	3.76	Moderate	PLE MAR	DISE INS INPL DRO FLO TEM AIP SWP SAL RRC
Acer buergerianum	Trident Maple	No	No	4.21	Moderate	RRC	FLO LPS
Acer circinatum	Vine Maple	Yes	Yes	4.5	High	TEM ESP LPS PLE MAR	DISE INS SWP COL
Acer freemanii	Freeman Maple	No	No	4.91	High	TEM ESP LPS NUP	-
Acer griseum	Paperbark Maple	No	No	3.28	Low	-	DRO TEM AIP NUP

Acer macrophyllum	Big Leaf Maple	Yes	Yes	3.75	Moderate	WIN TEM COL ESP NUP	DISE INS BRO FLO ICE RRC
Acer miyabei	Miyabe's Maple	No	No	5.10	High	SAL	AIP
Acer negundo	Boxelder	Yes	No	4.30	Moderate	DRO FLO TEM	INS AIP INPO ICE
Acer nigrum	Black Maple	Yes	No	3.69	Moderate	TEM	INS AIP SAL NUP
Acer palmatum	Japanese Maple	No	No	3.92	Moderate	NUP	DRO AIP LPS
Acer platanoides	Norway Maple	No	No	5.10	High	DRO FLO ESP LPS RRC NUP	INS INPO
Acer pseudoplatanus	Sycamore Maple	No	No	4.25	Moderate	NUP	INS AIP INPO
Acer rubrum	Red Maple	Yes	No	4.70	High	FLO TEM NUP COL LPS	INS DRO AIP
Acer saccharinum	Silver Maple	Yes	No	3.80	Moderate	FLO TEM NUP	INS RRC MAR
Acer saccharum	Sugar Maple	Yes	No	4.40	Moderate	NUP MAR COL	INS FLO AIP RRC SAL
Acer tataricum	Tatarian Maple	No	No	3.92	Moderate	DRO	AIP INPO
Acer triflorum	Three-Flower Maple	No	No	3.56	Moderate	-	DRO AIP
Acer truncatum	Shantung Maple	No	No	5.41	High	DRO TEM LPS RRC NUP	INS
Aesculus flava	Yellow Buckeye	Yes	No	4.1	Moderate	-	DRO AIP
Aesculus hippocastanum	Horse Chestnut	No	No	4.20	Moderate	TEM	INPO

Ailanthus altissima	Tree of Heaven	No	No	4.94	High	DRO TEM AIP ESP LPS RRC	LPS NUP INPO ESP
Albizia julibrissin	Persian Silk Tree	No	No	2.88	Low	DRO FLO TEM ESP	AIP LPS INPO
Alnus rubra	Red Alder	Yes	Yes	3.46	Low	FLO SAL	DISE INS BRO DRO ICE WIN TEM SWP AIP COL ESP
Amelanchier arborea	Downy Serviceberry	Yes	No	5.00	High	TEM NUP	AIP
Amelanchier laevis	Allegheny Serviceberry	Yes	No	4.66	High	LPS	DRO AIP
Arbutus menziesii	Pacific Madrone	Yes	Yes	3.63	Moderate	BRO DRO WIN MAR	DISE INS FLO ICE TEM AIP SWP COL NUP PLE
Arbutus unedo	Strawberry Tree	Yes	No	4.57	High	TEM COL ESP LPS MAR	DISE INS BRO INPL DRO FLO ICE SAL
Betula alleghaniensis	Swamp Birch	Yes	No	4.58	High		
Betula nigra	River Birch	Yes	No	3.65	Moderate	TEM LPS NUP	DISE DRO PLE
Betula papyrifera	Paper Birch	Yes	Yes	3.65	Moderate	NUP	DISE INS DRO TEM AIP
Betula pendula	Silver Birch	No	No	3.22	Low	-	INS AIP
Betula populifolia	Gray Birch	Yes	No	3.22	Low	-	DISE INS AIP LPS
Carpinus betulus	European Hornbeam	No	No	4.42	Moderate	-	SAL

Carpinus caroliniana	American Hornbeam	Yes	No	4.75	High	FLO TEM NUP COL	DRO AIP
Castanea mollissima	Chinese Chestnut	No	No	3.59	Moderate	TEM	-
Castanea sativa	Sweet Chestnut	No	No	3.07	Low	-	DISE INS INPL FLO WIN TEM AIP SWP COL ESP LPS MAR
Catalpa bignonioides	Southern Catalpa	Yes	No	4.46	Moderate	TEM COL ESP LPS PLE	DISE INS INPL DRO FLO ICE WIN SAL INPO
Catalpa speciosa	Northern Catalpa	Yes	No	4.26	Moderate	DISE LPS INS PLE	AIP RRC
Celtis occidentalis	Common Hackberry	Yes	No	4.55	High	DRO TEM LPS NUP ESP	MAR WIN
Cercidiphyllum japonicum	Katsura Tree	No	No	3.31	Low	DISE NUP	DRO WIN AIP RRC
Cercis canadensis	Eastern Redbud	Yes	No	3.90	Moderate	FLO TEM NUP	AIP LPS
Chamaecyparis lawsoniana	Lawson's Cypress	Yes	No	4.03	Moderate	TEM ESP LPS PLE MAR	DISE BRO DRO FLO ICE WIN AIP SWP SAL COL
Chamaecyparis nootkatensis	Nootka Cypress	Yes	Yes	3.46	Low	TEM	DISE INS BRO INPL DRO FLO ICE WIN SWP SAL COL ESP LPS
Chamaecyparis obtusa	Hinoki Cypress	No	No	3.41	Low	TEM ESP	DISE INS BRO INPL DRO FLO ICE WIN AIP SWP SAL MAR
Chamaecyparis pisifera	Sawara Cypress	No	No	3.95	Moderate	TEM COL LPS MAR	DISE INS INPL DRO FLO ICE

							WIN AIP SWP SAL ESP
Chionanthus retusus	Chinese Fringetree	No	No	4.77	High	LPS RRC	-
Cladrastis kentukea	Yellowwood	Yes	No	4.33	Moderate	TEM RRC	AIP DRO
Cornus florida	Flowering Dogwood	Yes	No	3.84	Moderate	TEM NUP	DRO FLO AIP RRC LPS
Cornus kousa	Kousa Dogwood	No	No	4.63	High	NUP	DRO AIP
Cornus mas	Cornelian Cherry	No	No	4.06	Moderate	TEM	AIP
Cornus nuttallii	Pacific Dogwood	Yes	Yes	3.77	Moderate	FLO COL NUP	DISE INS BRO INPL DRO ICE WIN TEM AIP SWP MAR
Corylus avellana	Common Hazel / European Filbert	No	No	3.71	Moderate	NUP	AIP RRC
Corylus colurna	Turkish Filbert	No	No	4.27	Moderate	DRO TEM LPS RRC	SAL NUP
Cotinus coggygria	Smoke Tree	No	No	4.90	High	DRO RRC LPS NUP	FLO
Cotinus obovatus	American Smoke Tree	Yes	No	3.86	Moderate	DRO LPS RRC	AIP
Crataegus crus-galli	Cockspur Hawthorn	Yes	No	4.47	Moderate	DRO TEM LPS RRC NUP	INS AIP DISE FLO
Crataegus laevigata	Midland Hawthorn / English Hawthorn	No	No	3.81	Moderate	DRO ICE WIN TEM ESP NUP	DISE INS BRO FLO SWP SAL COL INPO
Crataegus monogyna	Common Hawthorn	No	No	4.41	Moderate	DRO WIN TEM COL ESP PLE	DISE INS ICE SWP SAL NUP INPO

Crataegus phaenopyrum	Washington Hawthorn	Yes	No	4.32	Moderate	DRO TEM RRC NUP	DISE INS
Cupressus sempervirens	Mediterranean Cypress	No	No	5.15	High	DRO TEM NUP PLE MAR	DISE INS BRO FLO ICE WIN SWP COL
Elaeagnus angustifolia	Russian Olive	No	No	4.95	High	DRO TEM NUP SAL PLE LPS ESP	INPO WIN ICE DISE
Eucommia ulmoides	Hardy Rubber Tree	No	No	4.69	High	DRO	FLO
Fagus grandifolia	American Beech	Yes	No	3.55	Moderate	TEM NUP	FLO AIP LPS RRC
Fagus sylvatica	Green Beech	No	No	3.80	Moderate	NUP	DRO RRC LPS
Ficus carica	Common Fig	No	No	2.84	Low	FLO	DRO AIP
Fraxinus americana	White Ash	Yes	No	3.22	Low	NUP	INS AIP RRC
Fraxinus angustifolia	Narrow-leafed Ash	No	No	4.20	Moderate	TEM ESP LPS RRC NUP PLE	DISE INS INPL DRO ICE SAL COL MAR INPO
Fraxinus excelsior	European Ash	No	No	3.83	Moderate	FLO	INS LPS
Fraxinus latifolia	Oregon Ash	Yes	Yes	4.15	Moderate	TEM ESP PLE MAR	DISE INS BRO INPL ICE SWP LPS
Fraxinus pennsylvanica	Green Ash	Yes	No	3.90	Moderate	FLO LPS NUP	INS MAR
Ginkgo biloba	Ginkgo / Maidenhair	No	No	5.97	High	DRO TEM LPS RRC NUP	FLO
Gleditsia triacanthos	Honey Locust	Yes	No	4.26	Moderate	DRO TEM RRC NUP	-

Gymnocladus dioicus	Kentucky Coffeetree	Yes	No	4.60	High	DRO LPS NUP	AIP
Hamamelis virginiana	American Witch-hazel	Yes	No	4.06	Moderate	TEM	INS AIP
Hesperocyparis arizonica	Arizona Cypress	Yes	No	3.75	Moderate	DRO ESP PLE	DISE INS BRO FLO ICE WIN AIP SWP SAL COL LPS
Hibiscus syriacus	Common Hibiscus	No	No	4.55	High	NUP	-
Ilex aquifolium	Common Holly	No	No	4.21	Moderate	TEM COL LPS NUP PLE	DISE INS BRO INPL DRO FLO ICE WIN RRC INPO
Juglans nigra	Black Walnut	Yes	No	2.73	Low	DRO	AIP LPS RRC DISE MAR NUR
Juglans regia	English Walnut	Yes	No	3.66	Moderate	-	-
Juniperus chinensis	Chinese Juniper	No	No	4.50	High	-	-
Juniperus virginiana	Eastern Red Cedar	Yes	No	4.71	High	DRO TEM LPS RRC	AIP
Koelreuteria paniculata	Goldenrain Tree	No	No	4.71	High	DRO TEM LPS RRC NUP	INPO
Laburnum anagyroides	Common Laburnum	No	No	3.40	Low	TEM ESP RRC	DISE INS BRO INPL FLO ICE WIN AIP SWP SAL COL NUP MAR
Lagerstroemia indica	Crepe Myrtle	No	No	4.71	High	DRO TEM LPS RRC NUP	FLO AIP
Larix decidua	European Larch	No	No	3.67	Moderate	-	DRO TEM AIP

Ligustrum japonicum	Wax-leaf Privet / Japanese Privet	No	No	4.14	Moderate	TEM NUIP	INPO
Ligustrum lucidum	Glossy Privet	No	No	4.92	High	TEM AIP SWP ESP LPS RRC NUP PLE	DISE INS BRO MAR INPO
Liquidambar styraciflua	Sweetgum	Yes	No	3.49	Low	FLO	INS DRO RRC LPS
Liriodendron tulipifera	Tulip Tree	Yes	No	3.47	Low	NUP	DRO AIP RRC
Maackia amurensis	Amur Maackia	No	No	4.85	High	DRO TEM RRC NUP	FLO
Magnolia grandiflora	Southern Magnolia	Yes	No	3.97	Moderate	NUP	RRC
Magnolia kobus	Kobus Magnolia	No	No	3.61	Moderate	TEM ESP	DISE INS INPL FLO ICE WIN AIP SWP SAL RRC
Malus domestica	Edible Apple	No	No	4.01	Moderate	TEM LPS RRC NUP	INS
Malus spp.	Crabapple	No	No	4.01	Moderate	DRO ICE TEM LPS RRC NUP	DISE INS BRO FLO WIN AIP SWP SAL COL ESP PLE MAR
Metasequoia glyptostroboides	Dawn Redwood	No	No	4.10	Moderate	TEM FLO	AIP COL
Morus alba	White Mulberry	No	No	4.06	Moderate	TEM NUP SAL	LPS INPO
Nyssa sylvatica	Tupelo	Yes	No	4.72	High	RRC	AIP
Olea europaea	European Olive	No	No	3.85	Moderate	DRO ESP LPS	DISE INS BRO ICE WIN TEM COL PLE MAR

Ostrya virginiana	Ironwood	Yes	No	5.41	High	DRO TEM LPS RRC NUP	FLO AIP
Oxydendrum arboreum	Sourwood	Yes	No	4.60	High	-	-
Parrotia persica	Persian Parrotia	No	No	5.47	High	DRO TEM LPS RRC NUP	SAL
Paulownia tomentosa	Empress Tree	No	No	5.55	High	NUP	INPO
Picea abies	Norway Spruce	No	No	3.61	Moderate	NUR	INS FLO AIP
Picea glauca	White Spruce	Yes	No	4.15	Moderate	-	INS
Picea omorika	Serbian Spruce	No	No	4.06	Moderate	NUP	INS
Picea pungens	Colorado Spruce	Yes	No	3.95	Moderate	NUP	INS FLO AIP
Pinus banksiana	Jack Pine	Yes	No	3.40	Low	-	-
Pinus halepensis	Aleppo Pine	No	No	4.4	Moderate	DRO TEM ESP LPS PLE MAR	DISE INS ICE AIP SWP COL
Pinus mugo	Sweet Mountain Pine	No	No	4.35	Moderate	WIN AIP RRC	FLO
Pinus nigra	Austrian Pine	No	No	3.91	Moderate	DRO TEM RRC	DISE INS
Pinus parviflora	Japanese White Pine	No	No	4.00	Moderate	-	LPS
Pinus pinea	Italian Stone Pine	No	No	4.01	Moderate	DRO TEM ESP	DISE INS BRO ICE WIN AIP SWP RRC
Pinus ponderosa	Ponderosa Pine	Yes	Yes	3.45	Low	DRO TEM ESP NUP PLE	DISE INS BRO FLO ICE WIN AIP

							SWP SAL COL LPS MAR
Pinus sabiniana	Foothill Pine	Endemic to California	No - California	3.35	Low	DRO ESP	DISE INS BRO FLO ICE WIN AIP SWP SAL COL LPS PLE
Pinus strobus	Eastern White Pine	Yes	No	2.90	Low	NUP	DISE INS DRO TEM AIP LPS RRC
Pinus sylvestris	Scots Pine	No	No	4.42	Moderate	TEM RRC NUP	INS
Pistacia chinensis	Chinese Pistachio	No	No	4.86	High	INS DRO ICE WIN TEM AIP SWP ESP LPS RRC NUP	DISE BRO FLO PLE MAR INPO
Platanus occidentalis	American Sycamore	Yes	No	4.11	Moderate	TEM NUP FLO SAL	DRO
Populus alba	White Poplar	No	No	3.59	Moderate	DRO TEM ESP NUP	-
Populus nigra	Black Poplar	No	No	3.56	Moderate	TEM	-
Populus tremuloides	Quaking Aspen	Yes	Yes	3.92	Moderate	TEM WIN MAR PLE	INS DRO AIP RRC INPO
Prunus armeniaca	Apricot	No	No	3.7	Moderate	ESP LPS NUP	DISE INS FLO ICE WIN AIP SWP SAL COL PLE MAR
Prunus avium	Sweet Cherry	No	No	4.01	Moderate	TEM	FLO INPO DISE
Prunus cerasifera	Cherry Plum	No	No	3.82	Moderate	NUP	AIP INS
Prunus cerasus	Sour Cherry	No	No	3.8	Moderate	TEM ESP NUP PLE	INS BRO FLO ICE WIN AIP SWP SAL COL MAR

Prunus domestica	Common Plum	No	No	4.25	Moderate	TEM ESP LPS RRC PLE MAR	DISE INS BRO INPL DRO FLO ICE WIN AIP SWP SAL COL NUP
Prunus laurocerasus	English Laurel	No	No	4.10	Moderate	TEM ESP RRC PLE MAR	DISE INS INPL FLO ICE COL NUP INPO
Prunus pendula	Weeping Higan Cherry	No	No	3.5	Moderate	TEM ESP LPS PLE MAR	DISE INS BRO INPL DRO FLO ICE WIN AIP SWP COL RRC NUP
Prunus persica	Peach	No	No	3.61	Moderate	NUP	-
Prunus sargentii	Sargent Cherry	No	No	3.80	Moderate	DRO TEM RRC LPS	WN AIP
Prunus serotina	Black Cherry	Yes	No	2.10	Low	CRO TEM	FLO AIP LPS RRC DRO
Prunus serrula	Birch Bark Cherry	No	No	3.62	Moderate	TEM ESP LPS MAR	DISE INS BRO INPL DRO FLO WIN AIP SWP SAL COL RRC INPO
Prunus serrulata	Japanese Cherry	No	No	4.31	Moderate	TEM LPS NUP	-
Prunus subhirtella	Higan Cherry	No	No	4.00	Moderate	SAL DRO	FLO AIP RRC
Prunus virginiana	Common Chokecherry	Yes	No	3.56	Moderate	NUP	DISE FLO AIP
Pseudotsuga menziesii	Douglas Fir	Yes	Yes	3.50	Moderate	NUP	FLO TEM LPS ESP SAL INS DISE
Pyrus calleryana	Callery Pear	No	No	4.20	Moderate	DRO TEM RRC NUP SAL AIP	INS INPO DISE

Pyrus communis	Common Pear	No	No	3.52	Moderate	-	AIP
Quercus acutissima	Sawtooth Oak	No	No	5.48	High	DRO FLO TEM LPS RRC NUP	INPO
Quercus agrifolia	Coast Live Oak	Yes	No	4.11	Moderate	TEM COL ESP NUP PLE	DISE INS BRO ICE AIP SWP LPS RRC
Quercus alba	White Oak	Yes	No	3.34	Low	TEM NUP SAL DRO	FLO AIP ESP LPS RRC DISE PLE
Quercus bicolor	Swamp White Oak	Yes	No	5.15	High	TEM RRC NUP SAL LPS TEM FLO	AIP
Quercus coccinea	Scarlet Oak	Yes	No	3.82	Moderate	TEM LPS	AIP ESP FLO DISE
Quercus garryana	Oregon Oak	Yes	Yes	3.85	Moderate	TEM ESP	DISE INS BRO INPL ICE AIP SWP SAL PLE
Quercus imbricaria	Shingle Oak	Yes	No	4.50	High	DRO NUP	AIP ESP DISE
Quercus palustris	Pin Oak	Yes	No	3.52	Moderate	FLO RRC NUP	AIP DRO SAL ESP DISE
Quercus phellos	Willow Oak	Yes	No	4.80	High	FLO LPS RRC NUP	-
Quercus robur	English Oak	No	No	4.22	Moderate	DRO TEM	-
Quercus rubra	Red Oak	Yes	No	4.05	Moderate	TEM LPS NUP	DISE FLO RRC ESP
Quercus shumardii	Shumard Oak	Yes	No	3.99	Moderate	DRO FLO TEM LPS RRC NUP	DISE PLE ESP

Quercus virginiana	Live Oak	Yes	No	4.54	High	DRO FIRT VEGR FIR	INPL
Robinia pseudoacacia	Black Locust	Yes	No	3.91	Moderate	DRO TEM ESP SAL PLE	INS FLO AIP LPS RRC INPO WIN
Salix matsudana	Corkscrew Willow	No	No	3.66	Moderate	FLO SAL COL ESP	DISE INS BRO ICE WIN LPS RRC PLE MAR
Sequoia sempervirens	Coast Redwood	Yes	No	3.4	Low	TEM ESP	DISE INS BRO INPL DRO FLO ICE WIN AIP SWP SAL LPS
Sequoiadendron giganteum	Giant Sequoia	Yes	No	3.5	Moderate	TEM ESP NUP MAR	DISE INS BRO INPL FLO ICE WIN AIP SWP COL LPS RRC
Sorbus alnifolia	Korean Mountain Ash	No	No	3.65	Moderate	NUP	AIP
Sorbus aucuparia	Rowan	No	No	3.72	Moderate	LPS RRC NUP	ESP DRO SAL AIP DISE INS
Stewartia pseudocamellia	Japanese Stewartia	No	No	3.20	Low	TEM COL	DISE INS INPL DRO FLO ICE WIN AIP SWP SAL ESP LPS PLE
Styrax japonicus	Japanese Snowbell	No	No	4.19	Moderate	DISE INS AIP COL LPS RRC	ICE TEM SAL ESP NUP PLE MAR
Syringa pekinensis	Chinese Tree Lilac / Peking Lilac	No	No	4.67	High	LPS NUP	FLO TEM
Syringa reticulata	Japanese Tree Lilac	No	No	4.55	High	LPS RRC NUP ESP PLE	AIP FLO INPO DISE
Syringa vulgaris	Common Lilac	No	No	3.88	Moderate	NUP	AIP

Taxodium distichum	Bald Cypress	Yes	No	4.90	High	FLO RRC NUP	AIP
Thuja occidentalis	Northern White Cedar	Yes	No	4.77	High	NUP ESP FLO	DRO AIP ICE BRO WIN
Thuja plicata	Western Red Cedar	Yes	Yes	5.00	High	FLO WIN TEM COL ESP LPS PLE MAR	BRO AIP SWP SAL
Tilia americana	American Basswood	Yes	No	4.38	Moderate	TEM NUP LPS PLE	AIP RRC INS DRO WIN SAL
Tilia cordata	Littleleaf Linden	No	No	5.18	High	LPS NUP PLE ESP AIP	INS SAL WIN
Tilia platyphyllos	Large Leaf linden	No	No	4.25	Moderate	TEM ESP LPS MAR	DISE INS BRO INPL FLO WIN AIP NUP
Tilia tomentosa	Silver Linden	No	No	4.15	Moderate	TEM NUP	AIP
Trachycarpus fortunei	Windmill Palm	No	No	4.96	High	TEM COL ESP RRC NUP PLE MAR	DISE INS INPL
Tsuga canadensis	Eastern Hemlock	Yes	No	2.68	Low	NUP	DRO AIP LPS INS MAR RRC SAL
Tsuga heterophylla	Western Hemlock	Yes	Yes	3.19	Low	COL PLE	DISE INS BRO DRO FLO WIN TEM AIP SWP SAL ESP
Tsuga mertensiana	Mountain Hemlock	Yes	Yes	3.54	Moderate	TEM MAR	DISE INS BRO INPL DRO FLO WIN AIP SWP SAL COL
Ulmus americana	American Elm	Yes	No	4.45	Moderate	TEM NUP DRO FLO LPS SAL	DISE INS MAR

Ulmus parvifolia	Chinese Elm	No	No	5.50	High	DRO TEM ESP LPS RRC NUP	INPO
Ulmus procera	English Elm	No	No	4.22	Moderate	TEM ESP LPS NUP PLE MAR	DISE INS INPL DRO FLO ICE WIN SWP RRC INPO
Ulmus propinqua	Emerald Sunshine Elm	No	No	5.2	High	TEM ESP NUP RRC	-
Ulmus pumila	Siberian Elm	No	No	3.76	Moderate	DRO TEM DISE	WIN INPO
Zelkova serrata	Japanese Zelkova	No	No	4.87	High	TEM LPS RRC NUP SAL DRO	-

Overall Vulnerability of the Puget Sound Region's Trees

Vulnerability is the susceptibility of a system to the adverse effects of climate change (IPCC, 2007). It is a function of potential climate change impacts and the adaptive capacity of the system. The overall vulnerability of trees in the Detroit region was estimated by considering the impacts on individual tree species using the zone suitability and the adaptive capacity of tree species as described in the previous section (adapt class in Table 5) together in a matrix (Table 6).

Table 6.—Vulnerability Scoring Matrix Based on Brandt et al. (2017).

Habitat or Zone Suitability-end of century	**Adapt Class**		
	Low	**Medium**	**High**
Not suitable	High Vulnerability	Moderate-high Vulnerability	Moderate Vulnerability
Suitable	Moderate Vulnerability	Low-moderate Vulnerability	Low Vulnerability

Tree species vulnerability is summarized in Table 7. Considering heat zones only, the majority of tree species fell into the low-moderate (57%) vulnerability category followed by low vulnerability (26%) and moderate vulnerability (17%) under both low and high climate change scenarios. The vulnerability ratings remain the same between low and high climate change scenarios because all assessed tree species are considered suitable under the heat zone projections through the end of the century. Considering both heat and hardiness zones, the majority of tree species assessed fall into the moderate-high vulnerability category (39%), followed by low-moderate (20%), moderate (18%), low (13%), and high (9%). The vulnerability ratings are the same between low and high climate change scenarios because the projected hardiness zone is the same under both scenarios through the end of the century.

Common species with low to low-moderate vulnerability considering heat zones only include red maple, Norway maple, crabapple, Japanese maple, cherry plum, Japanese cherry, midland hawthorn, callery pear,

red oak, Japanese snowbell, and kousa dogwood. None of the assessed tree species fall into the moderate-high or high categories when considering heat zones only.

Common species with low to low-moderate vulnerability considering heat and hardiness zones include red maple, Norway maple, cherry plum, callery pear, big leaf maple, scarlet oak, green ash, American hornbeam, and European hornbeam.Common species with moderate-high to high vulnerability considering heat and hardiness zones include crabapple, Japanese maple, Japanese cherry, paperbark maple, red oak, Japanese snowbell, silver birch, katsura tree, rowan, and common hawthorn.

Table 7.—Vulnerability Ratings for Trees in the Puget Sound Region Considering Heat Zones Only and Heat and Hardiness Zones Under Low and High Climate Change Scenarios. Note: Because all species are suitable under the projected heat zone for both low and high climate change scenarios and the projected hardiness zone is the same under low and high climate change scenarios, the vulnerability ratings were the same between both low and high climate change scenarios and are not separated in the table below.

Scientific Name	Common Name	Estimated Street Trees in Seattle	Vulnerability - Considering Heat Zones Only	Vulnerability - Considering Heat & Hardiness Zones
Abies concolor	White Fir	16	Low-moderate	Moderate-high
Abies grandis	Grand Fir	42	Low-moderate	Moderate-high
Abies procera	Noble Fir	27	Low-moderate	Moderate-high
Acer buergerianum	Trident Maple	166	Low-moderate	Low-moderate
Acer circinatum	Vine Maple	646	Low-moderate	Low-moderate
Acer freemanii	Freeman Maple	570	Low	Moderate
Acer griseum	Paperbark Maple	2043	Moderate	High
Acer macrophyllum	Big Leaf Maple	1261	Low-moderate	Low-moderate
Acer miyabei	Miyabe's Maple	89	Low	Moderate
Acer negundo	Boxelder	99	Low-moderate	Low-moderate
Acer nigrum	Black Maple	-	Low-moderate	Moderate-high
Acer palmatum	Japanese Maple	3630	Low-moderate	Moderate-high
*Acer platanoides***	Norway Maple**	3988	Low	Moderate
*Acer pseudoplatanus***	Sycamore Maple	879	Low-moderate	Moderate-high
Acer rubrum	Red Maple	5374	Low	Low
Acer saccharinum	Silver Maple	239	Low-moderate	Low-moderate
Acer saccharum	Sugar Maple	611	Low-moderate	Moderate-high
Acer tataricum	Tatarian Maple	181	Low-moderate	Moderate-high
Acer triflorum	Three-Flower Maple	-	Low-moderate	Moderate-high
Acer truncatum	Shantung Maple	7	Low	Moderate

Aesculus flava	Yellow Buckeye	7	Low-moderate	Moderate-high
*Aesculus hippocastanum***	Horse Chestnut	639	Low-moderate	Moderate-high
*Ailanthus altissima***	Tree of Heaven	52	Low	Moderate
Albizia julibrissin	Persian Silk Tree	96	Moderate	Moderate
Alnus rubra	Red Alder	428	Moderate	High
Amelanchier arborea	Downy Serviceberry	176	Low	Low
Amelanchier laevis	Allegheny Serviceberry	106	Low	Low
Arbutus menziesii	Pacific Madrone	249	Low-moderate	Low-moderate
Arbutus unedo	Strawberry Tree	214	Low	Low
Betula alleghaniensis	Swamp Birch	49	Low	Moderate
Betula nigra	River Birch	123	Low-moderate	Low-moderate
Betula papyrifera	Paper Birch	429	Low-moderate	Moderate-high
Betula pendula	Silver Birch	1617	Moderate	High
Betula populifolia	Gray Birch	16	Moderate	High
Carpinus betulus	European Hornbeam	1073	Low-moderate	Low-moderate
Carpinus caroliniana	American Hornbeam	1077	Low	Low
Castanea mollissima	Chinese Chestnut	16	Low-moderate	Moderate-high
Castanea sativa	Sweet Chestnut	44	Moderate	High
Catalpa bignonioides	Southern Catalpa	268	Low-moderate	Low-moderate
Catalpa speciosa	Northern Catalpa	97	Low-moderate	Moderate-high
Celtis occidentalis	Common Hackberry	126	Low	Low
Cercidiphyllum japonicum	Katsura Tree	1484	Moderate	High
Cercis canadensis	Eastern Redbud	832	Low-moderate	Moderate-high
Chamaecyparis lawsoniana	Lawson's Cypress	246	Low-moderate	Moderate-high
Chamaecyparis nootkatensis	Nootka Cypress	96	Moderate	High
Chamaecyparis obtusa	Hinoki Cypress	125	Moderate	High
Chamaecyparis pisifera	Sawara Cypress	94	Low-moderate	Moderate-high
Chionanthus retusus	Chinese Fringetree	7	Low	Low
Cladrastis kentukea	Yellowwood	33	Low-moderate	Moderate-high
Cornus florida	Flowering Dogwood	545	Low-moderate	Low-moderate
Cornus kousa	Kousa Dogwood	1676	Low	Moderate
Cornus mas	Cornelian Cherry	107	Low-moderate	Moderate-high

Cornus nuttallii	Pacific Dogwood	131	Low-moderate	Moderate-high
Corylus avellana	Common Hazel / European Filbert	56	Low-moderate	Moderate-high
Corylus colurna	Turkish Filbert	48	Low-moderate	Moderate-high
Cotinus coggygria	Smoke Tree	103	Low	Moderate
Cotinus obovatus	American Smoke Tree	18	Low-moderate	Moderate-high
Crataegus crus-galli	Cockspur Hawthorn	109	Low-moderate	Moderate-high
Crataegus laevigata	Midland Hawthorn / English Hawthorn	2491	Low-moderate	Moderate-high
*Crataegus monogyna***	Common Hawthorn	985	Low-moderate	Moderate-high
Crataegus phaenopyrum	Washington Hawthorn	841	Low-moderate	Moderate-high
Cupressus sempervirens	Mediterranean Cypress	97	Low	Low
*Elaeagnus angustifolia***	Russian Olive	22	Low	Moderate
Eucommia ulmoides	Hardy Rubber Tree	77	Low	Moderate
Fagus grandifolia	American Beech	26	Low-moderate	Low-moderate
Fagus sylvatica	Green Beech	639	Low-moderate	Moderate-high
Ficus carica	Common Fig	165	Moderate	Moderate
Fraxinus americana	White Ash	209	Moderate	Moderate
Fraxinus angustifolia	Narrow-leafed Ash	163	Low-moderate	Moderate-high
Fraxinus excelsior	European Ash	81	Low-moderate	Moderate-high
Fraxinus latifolia	Oregon Ash	87	Low-moderate	Moderate-high
Fraxinus pennsylvanica	Green Ash	1141	Low-moderate	Low-moderate
Ginkgo biloba	Ginkgo / Maidenhair	856	Low	Moderate
*Gleditsia triacanthos***	Honey Locust	871	Low-moderate	Moderate-high
Gymnocladus dioicus	Kentucky Coffeetree	20	Low	Moderate
Hamamelis virginiana	American Witch-hazel	23	Low-moderate	Moderate-high
Hesperocyparis arizonica	Arizona Cypress	-	Low-moderate	Low-moderate
Hibiscus syriacus	Common Hibiscus	28	Low	Moderate
*Ilex aquifolium***	Common Holly	298	Low-moderate	Low-moderate
Juglans nigra	Black Walnut	70	Moderate	Moderate
Juglans regia	English Walnut	80	Low-moderate	Moderate-high
Juniperus chinensis	Chinese Juniper	26	Low	Low
Juniperus virginiana	Eastern Red Cedar	13	Low	Low

*Koelreuteria paniculata***	Goldenrain Tree	358	Low	Low
Laburnum anagyroides	Common Laburnum	147	Moderate	High
Lagerstroemia indica	Crepe Myrtle	283	Low	Low
Larix decidua	European Larch	14	Low-moderate	Moderate-high
Ligustrum japonicum	Wax-leaf Privet / Japanese Privet	8	Low-moderate	Low-moderate
Ligustrum lucidum	Glossy Privet	23	Low	Low
Liquidambar styraciflua	Sweetgum	2742	Moderate	Moderate
Liriodendron tulipifera	Tulip Tree	477	Moderate	High
*Maackia amurensis***	Amur Maackia	86	Low	Moderate
Magnolia grandiflora	Southern Magnolia	683	Low-moderate	Low-moderate
Magnolia kobus	Kobus Magnolia	247	N/A	Moderate-high
Malus domestica	Edible Apple	928	Low-moderate	Moderate-high
Malus spp.	Crabapple	3960	Low-moderate	Moderate-high
Metasequoia glyptostroboides	Dawn Redwood	86	Low-moderate	Moderate-high
*Morus alba***	White Mulberry	31	Low-moderate	Moderate-high
Nyssa sylvatica	Tupelo	625	Low	Low
Olea europaea	European Olive	31	Low-moderate	Low-moderate
Ostrya virginiana	Ironwood	19	Low	Low
Oxydendrum arboreum	Sourwood	98	Low	Low
Parrotia persica	Persian Parrotia	788	Low	Moderate
*Paulownia tomentosa***	Empress Tree	33	Low	Low
Picea abies	Norway Spruce	145	Low-moderate	Moderate-high
Picea glauca	White Spruce	26	Low-moderate	Moderate-high
Picea omorika	Serbian Spruce	3	Low-moderate	Moderate-high
Picea pungens	Colorado Spruce	96	Low-moderate	Moderate-high
Pinus banksiana	Jack Pine	-	Moderate	High
Pinus halepensis	Aleppo Pine	5	Low-moderate	Low-moderate
Pinus mugo	Sweet Mountain Pine	35	Low-moderate	Moderate-high
Pinus nigra	Austrian Pine	155	Low-moderate	Moderate-high
Pinus parviflora	Japanese White Pine	-	Low-moderate	Low-moderate
Pinus pinea	Italian Stone Pine	9	Low-moderate	Low-moderate

Pinus ponderosa	Ponderosa Pine	61	Moderate	High
Pinus sabiniana	Foothill Pine	-	N/A	Moderate
Pinus strobus	Eastern White Pine	46	Moderate	High
Pinus sylvestris	Scots Pine	114	Low-moderate	Moderate-high
Pistacia chinensis	Chinese Pistachio	65	Low	Low
Platanus occidentalis	American Sycamore	154	Low-moderate	Low-moderate
Populus alba	White Poplar	26	Low-moderate	Low-moderate
Populus nigra	Black Poplar	59	N/A	Low-moderate
Populus tremuloides	Quaking Aspen	259	Low-moderate	Moderate-high
Prunus armeniaca	Apricot	17	Low-moderate	Moderate-high
Prunus avium	Sweet Cherry	469	Low-moderate	Moderate-high
Prunus cerasifera	Cherry Plum	3203	Low-moderate	Low-moderate
Prunus cerasus	Sour Cherry	119	Low-moderate	Moderate-high
Prunus domestica	Common Plum	302	Low-moderate	Low-moderate
*Prunus laurocerasus***	English Laurel	205	Low-moderate	Low-moderate
Prunus pendula	Weeping Higan Cherry	364	Low-moderate	Moderate-high
Prunus persica	Peach	118	Low-moderate	Low-moderate
Prunus sargentii	Sargent Cherry	232	Low-moderate	Moderate-high
Prunus serotina	Black Cherry	41	Moderate	Moderate
Prunus serrula	Birch Bark Cherry	123	Low-moderate	Moderate-high
Prunus serrulata	Japanese Cherry	2572	Low-moderate	Moderate-high
Prunus subhirtella	Higan Cherry	657	Low-moderate	Moderate-high
Prunus virginiana	Common Chokecherry	5	Low-moderate	Moderate-high
Pseudotsuga menziesii	Douglas Fir	609	Moderate	High
*Pyrus calleryana***	Callery Pear	2202	Low-moderate	Low-moderate
Pyrus communis	Common Pear	269	Low-moderate	Low-moderate
*Quercus acutissima***	Sawtooth Oak	55	Low	Low
Quercus agrifolia	Coast Live Oak	42	Low-moderate	Low-moderate
Quercus alba	White Oak	33	Moderate	Moderate
Quercus bicolor	Swamp White Oak	228	Low	Moderate
Quercus coccinea	Scarlet Oak	1199	Low-moderate	Low-moderate
Quercus garryana	Oregon Oak	83	Low-moderate	Low-moderate

Quercus imbricaria	Shingle Oak	121	Low	Moderate
Quercus palustris	Pin Oak	715	Low-moderate	Moderate-high
Quercus phellos	Willow Oak	192	Low	Low
Quercus robur	English Oak	370	Low-moderate	Moderate-high
Quercus rubra	Red Oak	1999	Low-moderate	Moderate-high
Quercus shumardii	Shumard Oak	72	Low-moderate	Low-moderate
Quercus virginiana	Live Oak	14	Low	Low
*Robinia pseudoacacia***	Black Locust	481	Low-moderate	Moderate-high
Salix matsudana	Corkscrew Willow	46	N/A	Low-moderate
Sequoia sempervirens	Coast Redwood	50	Moderate	Moderate
Sequoiadendron giganteum	Giant Sequoia	78	Moderate	High
Sorbus alnifolia	Korean Mountain Ash	-	Low-moderate	Moderate-high
Sorbus aucuparia	Rowan	1055	Low-moderate	Moderate-high
Stewartia pseudocamellia	Japanese Stewartia	341	Moderate	High
Styrax japonicus	Japanese Snowbell	1712	Low-moderate	Moderate-high
Syringa pekinensis	Chinese Tree Lilac / Peking Lilac	63	Low	Moderate
Syringa reticulata	Japanese Tree Lilac	239	Low	Moderate
Syringa vulgaris	Common Lilac	116	Low-moderate	Moderate-high
Taxodium distichum	Bald Cypress	37	Low	Low
Thuja occidentalis	Northern White Cedar	447	Low	Moderate
Thuja plicata	Western Red Cedar	935	Low	Moderate
Tilia americana	American Basswood	280	Low-moderate	Moderate-high
Tilia cordata	Littleleaf Linden	1541	Low	Moderate
Tilia platyphyllos	Large Leaf linden	298	Low-moderate	Moderate-high
Tilia tomentosa	Silver Linden	-	Low-moderate	Moderate-high
Trachycarpus fortunei	Windmill Palm	207	Low	Low
Tsuga canadensis	Eastern Hemlock	13	Moderate	High
Tsuga heterophylla	Western Hemlock	113	Low-moderate	Moderate-high
Tsuga mertensiana	Mountain Hemlock	62	N/A	Moderate-high
Ulmus americana	American Elm	302	Low-moderate	Low-moderate
Ulmus parvifolia	Chinese Elm	222	Low	Low

Ulmus procera	English Elm	70	Low-moderate	Moderate-high
Ulmus propinqua	Emerald Sunshine Elm	44	N/A	Moderate
*Ulmus pumila***	Siberian Elm	29	Low-moderate	Low-moderate
Zelkova serrata	Japanese Zelkova	854	Low	Moderate

***Invasive Species*

Additional Considerations

When assessing the vulnerability of an entire urban forest or ecosystem, it's important to keep other factors in mind. When assessing impacts, you'll want to consider how physical factors like elevation or soil type may affect your susceptibility to drought or flooding. You'll also want to consider how biological factors like a high proportion of vulnerable trees or the presence of particular pests or diseases may make your impacts more pronounced, as well as human-influence factors such as the amount of impervious surface, the influence of the urban heat island, or past management in your particular site.

When considering adaptive capacity of your urban forest, you'll want to consider biological factors such as the amount of biological or genetic diversity of urban forest, economic factors such as the amount of funding available to support urban forestry efforts, organizational factors such as policies and the number of trained staff to do the work, and social factors such as support from the community to assist with tree care and planting. Ecological adaptive capacity factors, such as species diversity, connectivity, age class diversity, and genetic diversity are also important to consider.

Tree Species Diversity

Tree species diversity is an important component of adaptive capacity. Areas with high taxonomic diversity (e.g., a small percentage of species in any one family, genus, or species) may be less vulnerable to pests and pathogens and other climate-related disturbances. Using Seattle's most recent street tree inventory, we can examine diversity by genus. Maples and trees such as plum and cherry make up a significant portion of the city's street trees, followed by a range of tree species diversity from apple to cedar (Table 8). The high proportions in the maple and rose families may reduce adaptive capacity to some extent, especially if species in these families are a preferred host to a specific pest or pathogen. Note that Table 8 does not contain an exhaustive list of all genera in the Puget Sound region; some municipalities and land cover types may have a very different species composition from this list.

Table 8.—Seattle Street Tree Diversity by Genus. Note: This table is not an exhaustive list of all street trees in the Puget Sound Region and may not be reflective of other municipalities.

Genus	Percentage of Street Trees
Acer (Maple)	21.5%
Prunus (Plum, etc)	17.0%
Malus (Apple)	5.2%
Crataegus (Hawthorn)	4.3%
Quercus (Oak)	3.5%
Pyrus (Pear)	3.2%
Fraxinus (Ash)	2.9%

Cornus (Dogwood)	2.7%
Tilia (Linden)	2.6%
Betula (Birch)	2.5%
Carpinus (Hornbeam)	2.1%
Amelanchier (Serviceberry)	2.1%
Magnolia	1.7%
Ulmus (Elm)	1.5%
Thuja (Cedar)	1.3%

Tree Species Allergenicity

Urban forests and their associated benefits have become more important for human health as more than half of the nation's population resides in cities. Urban trees provide ecosystem services, such as cooling the air, absorbing rainfall, providing oxygen, intercepting UV light, storing carbon, and reducing air pollution. However, trees can also pose human health issues due to the presence and intensity of allergens. The interaction between trees and a changing climate will have important implications for protecting human health. The allergenicity level (mild, moderate, severe, or no allergy reported) of the assessed tree species is included in Table 9 as an additional consideration.

Table 9.—Allergenicity of Puget Sound Tree Species of Interest.

Scientific Name	Common Name
Mild Allergen	
Castanea sativa	Sweet Chestnut
Ailanthus altissima	Tree of Heaven
Albizia julibrissin	Persian Silk Tree
Amelanchier arborea	Downy Serviceberry
Amelanchier laevis	Allegheny Serviceberry
Arbutus unedo	Strawberry Tree
Castanea mollissima	Chinese Chestnut
Catalpa bignonioides	Southern Catalpa
Catalpa speciosa	Northern Catalpa
Cercis canadensis	Eastern Redbud
Cornus florida	Flowering Dogwood
Cornus kousa	Kousa Dogwood

Cornus mas	Cornelian Cherry
Cornus nuttallii	Pacific Dogwood
Crataegus crus-galli	Cockspur Hawthorn
Crataegus laevigata	Midland Hawthorn / English Hawthorn
Crataegus monogyna	Common Hawthorn
Crataegus phaenopyrum	Washington Hawthorn
Elaeagnus angustifolia	Russian Olive
Fagus grandifolia	American Beech
Fagus sylvatica	Green Beech
Ginkgo biloba	Ginkgo / Maidenhair
Gleditsia triacanthos	Honey Locust
Gymnocladus dioicus	Kentucky Coffeetree
Hibiscus syriacus	Common Hibiscus
Koelreuteria paniculata	Goldenrain Tree
Laburnum anagyroides	Common Laburnum
Ligustrum lucidum	Glossy Privet
Liquidambar styraciflua	Sweetgum
Maackia amurensis	Amur Maackia
Magnolia grandiflora	Southern Magnolia
Magnolia kobus	Kobus Magnolia
Malus domestica	Edible Apple
Malus spp.	Crabapple
Morus alba	White Mulberry
Ostrya virginiana	Ironwood
Populus tremuloides	Quaking Aspen
Prunus armeniaca	Apricot
Prunus avium	Sweet Cherry

Prunus cerasifera	Cherry Plum
Prunus cerasus	Sour Cherry
Prunus domestica	Common Plum
Prunus laurocerasus	English Laurel
Prunus pendula	Weeping Higan Cherry
Prunus persica	Peach
Prunus sargentii	Sargent Cherry
Prunus serotina	Black Cherry
Prunus serrula	Birch Bark Cherry
Prunus serrulata	Japanese Cherry
Prunus subhirtella	Higan Cherry
Pseudotsuga menziesii	Douglas Fir
Pyrus calleryana	Callery Pear
Pyrus communis	Common Pear
Robinia pseudoacacia	Black Locust
Sorbus alnifolia	Korean Mountain Ash
Sorbus aucuparia	Rowan
Stewartia pseudocamellia	Japanese Stewartia
Styrax japonicus	Japanese Snowbell
Trachycarpus fortunei	Windmill Palm
Moderate Allergen	
Acer buergerianum	Trident Maple
Acer circinatum	Vine Maple
Acer freemanii	Freeman Maple
Acer griseum	Paperbark Maple
Acer macrophyllum	Big Leaf Maple
Acer miyabei	Miyabe's Maple
Acer nigrum	Black Maple

Acer palmatum	Japanese Maple
Acer platanoides	Norway Maple
Acer pseudoplatanus	Sycamore Maple
Acer rubrum	Red Maple
Acer saccharinum	Silver Maple
Acer saccharum	Sugar Maple
Acer tataricum	Tatarian Maple
Acer triflorum	Three-Flower Maple
Acer truncatum	Shantung Maple
Alnus rubra	Red Alder
Betula alleghaniensis	Swamp Birch
Betula nigra	River Birch
Betula papyrifera	Paper Birch
Betula pendula	Silver Birch
Betula populifolia	Gray Birch
Carpinus betulus	European Hornbeam
Carpinus caroliniana	American Hornbeam
Celtis occidentalis	Common Hackberry
Chamaecyparis lawsoniana	Lawson's Cypress
Chamaecyparis nootkatensis	Nootka Cypress
Chamaecyparis obtusa	Hinoki Cypress
Chamaecyparis pisifera	Sawara Cypress
Corylus avellana	Common Hazel / European Filbert
Corylus colurna	Turkish Filbert
Olea europaea	European Olive
Pistacia chinensis	Chinese Pistachio
Platanus occidentalis	American Sycamore

Populus alba	White Poplar
Populus nigra	Black Poplar
Sequoiadendron giganteum	Giant Sequoia
Thuja occidentalis	Northern White Cedar
Thuja plicata	Western Red Cedar
Tilia americana	American Basswood
Tilia cordata	Littleleaf Linden
Tilia platyphyllos	Large Leaf linden
Tilia tomentosa	Silver Linden
Ulmus americana	American Elm
Ulmus parvifolia	Chinese Elm
Ulmus procera	English Elm
Ulmus propinqua	Emerald Sunshine Elm
Ulmus pumila	Siberian Elm
Zelkova serrata	Japanese Zelkova
Severe Allergen	
Acer negundo	Boxelder
Fraxinus americana	White Ash
Fraxinus excelsior	European Ash
Fraxinus latifolia	Oregon Ash
Fraxinus pennsylvanica	Green Ash
Ilex aquifolium	Common Holly
Juglans nigra	Black Walnut
Juglans regia	English Walnut
Juniperus chinensis	Chinese Juniper
Larix decidua	European Larch
Ligustrum japonicum	Wax-leaf Privet / Japanese Privet
Metasequoia glyptostroboides	Dawn Redwood

Nyssa sylvatica	Tupelo
Quercus acutissima	Sawtooth Oak
Quercus agrifolia	Coast Live Oak
Quercus alba	White Oak
Quercus bicolor	Swamp White Oak
Quercus coccinea	Scarlet Oak
Quercus garryana	Oregon Oak
Quercus imbricaria	Shingle Oak
Quercus palustris	Pin Oak
Quercus phellos	Willow Oak
Quercus robur	English Oak
Quercus rubra	Red Oak
Quercus shumardii	Shumard Oak
Quercus virginiana	Live Oak
Salix matsudana	Corkscrew Willow
Cercidiphyllum japonicum	Katsura Tree
Chionanthus retusus	Chinese Fringetree
No Allergy Reported	
Abies concolor	White Fir
Abies grandis	Grand Fir
Abies procera	Noble Fir
Aesculus flava	Yellow Buckeye
Aesculus hippocastanum	Horse Chestnut
Arbutus menziesii	Pacific Madrone
Cladrastis kentukea	Yellowwood
Cotinus coggygria	Smoke Tree
Cotinus obovatus	American Smoke Tree

Cupressus sempervirens	Mediterranean Cypress
Eucommia ulmoides	Hardy Rubber Tree
Ficus carica	Common Fig
Fraxinus angustifolia	Narrow-leafed Ash
Hamamelis virginiana	American Witch-hazel
Hesperocyparis arizonica	Arizona Cypress
Juniperus virginiana	Eastern Red Cedar
Lagerstroemia indica	Crepe Myrtle
Liriodendron tulipifera	Tulip Tree
Oxydendrum arboreum	Sourwood
Parrotia persica	Persian Parrotia
Paulownia tomentosa	Empress Tree
Picea abies	Norway Spruce
Picea glauca	White Spruce
Picea omorika	Serbian Spruce
Picea pungens	Colorado Spruce
Pinus banksiana	Jack Pine
Pinus halepensis	Aleppo Pine
Pinus mugo	Sweet Mountain Pine
Pinus nigra	Austrian Pine
Pinus parviflora	Japanese White Pine
Pinus pinea	Italian Stone Pine
Pinus ponderosa	Ponderosa Pine
Pinus sabiniana	Foothill Pine
Pinus strobus	Eastern White Pine
Pinus sylvestris	Scots Pine

Prunus virginiana	Common Chokecherry
Sequoia sempervirens	Coast Redwood
Syringa pekinensis	Chinese Tree Lilac / Peking Lilac
Syringa reticulata	Japanese Tree Lilac
Syringa vulgaris	Common Lilac
Taxodium distichum	Bald Cypress
Tsuga canadensis	Eastern Hemlock
Tsuga heterophylla	Western Hemlock
Tsuga mertensiana	Mountain Hemlock

Source: http://www.pollenlibrary.com/

Appendices

Appendix A. Factors for Planted Trees in Developed Areas

We created separate scores for trees planted in developed areas. Factors, scores, and weighting were modified from naturally occurring trees to account for the different environments experienced by trees in more developed areas. Many biological factors were also altered to account for the fact that dispersal and natural reproduction are not typically factors for planted trees. Most information for native species was derived from Burns and Honkala (1990) with supplementary material relevant to cultivated environments from Gilman and Watson (1993). Most information for cultivars and nonnatives was taken from Gilman and Watson (1993). Additional information for wind and ice storm susceptibility were taken from Hauer et al. (2006) and Duryea et al. (2007).

Factors that received a weighted score of less than -4.5 or greater than 4.5 were listed as contributing negatively or positively to the species' overall adaptability score in tables. Weighted scores between these two values were not listed.

Disturbance Factors:

Disease - Accounts for the number and severity of known pathogens that attack a species. If a species is resistant to many pathogens, it is assumed that it will continue to be so in the future. If the mortality rate is low, it is assumed that the species is not greatly affected by diseases. Thus, those species would receive positive scores. Defaults for all species: -1 Score, 0.75 Uncert, and 2 FutureRelevance.

Insect Pests - Accounts for the number and severity of insects that may attack the species. If a species is resistant to attacks from known insect pests now or is adapted to cope with them, then it is assumed to be at least partially resistant in the future. This factor, although highly uncertain in overall effects, is likely to be very important over the next 50 years. Defaults for all species: -1 Score, 0.5 Uncert, and 4 FutureRelevance.

Browse - The extent to which browsing (by deer or other herbivores) has an effect on the species, either positive by promoting growth or by effective strategies for herbivory avoidance, or negative by over-browsing. Defaults for all species: -1 Score (+1 if promoted by browsing), 0.75 Uncert, and 1 FutureRelevance.

Invasive Plants - The effects of invasive plants on the species, either through competition for nutrients or as a pathogen. This factor is not yet well researched as to effects on individual tree species but could be very important in the future as invasives are usually more readily adapted to changing environments and can form monotypic stands that restrict regeneration. Defaults for all species: 0 Score, 0.5 Uncert, and 4 FutureRelevance.

Drought - Extended periods without sufficient access to water. Certain species are better adapted to drier conditions, allowing them to survive more frequent or prolonged droughts. Defaults for all species: -1 Score, 0.75 Uncert, and 3 FutureRelevance.

Flood - Frequent or prolonged periods of standing water. Species adapted to sustained flooding will be positively affected while species vulnerable to flooding will be negatively affected by the assumed greater flooding exposures under climate change. Defaults for all species: -1 Score, 0.75 Uncert, and 4 FutureRelevance.

Ice - The damaging effects of ice storms and potential for ice heaving on a species. Defaults for all species: -1 Score, 0.5 Uncert, and 2 FutureRelevance.

Wind - The damaging effects of windstorms and uprooting potential (and top breakage) of a species: -1 Score, 0.75 Uncert, and 2 FutureRelevance. If a species is susceptible to windthrow, the standard default is -2 (Score); if resistant to windthrow, Score is +1.

Temperature Gradients - The effects of variations in the temperature gradient associated with a species. Species that currently occupy regions with a diverse range of temperatures are assumed to be better adapted to warmer and highly variable climates than species occupying regions with a small range of temperatures. Defaults for all species: 1 Score, 0.75 Uncert, and 3 FutureRelevance.

Air Pollution - Airborne pollutants that affect, mostly negatively, a species' growth, health, and distribution. Includes acid rain, ozone. Defaults for all species: -3 Score, 0.75 Uncert, and 3 FutureRelevance.

Soil/Water Pollution - Pollutants in the soil and water that affect, mostly negatively, a species' growth, health, and distribution. Defaults for all species: -2 Score, 0.5 Uncert, and 1 FutureRelevance.

Biological Factors:
Competition-Light - The tolerance of a species toward light. Does the species grow better in shade, partial shade, or full sun? Default values depend on species tolerance level, and all with FutureRelevance of 3. Species intolerant to shade receive -3 (Score) 0.75 (Uncert), Intermediate either -1, 0, 1 (Score) 0.5 (Uncert). Intermediate default is 0, with flexibility to go +1 or -1. Tolerant species have scores of +3 (Score) 0.75 (Uncert).

Edaphic Specificity - The specific soil requirements (e.g., pH, texture, organic content, horizon thickness, permeability) for a species to survive in a suitable habitat. Includes long-term soil moisture capacities of the soil. Species with general requirements have positive scores, and species with specific requirements have negative defaults. Unsuitable soils north of the current range of a species can be a barrier to migration. Defaults for all species: 0 Score, 0.75 Uncert, and 2 FutureRelevance.

Land-Use/Planting Site Specificity - The ability for the species to be planted in a variety of site types (street, residential, park, campus). Also considers the range of non-edaphic environmental characteristics (e.g., slope, aspect, topographic position, climatic modulation, specific associates) that the species requires. Defaults for all species: 0 Score, 0.75 Uncert, and 3 FutureRelevance.

Restricted Rooting Conditions and Soil Compaction - The ability of a species to grow and survive in narrow boulevards and other constrained spaces. Defaults for all species: -1 Score, 0.75 Uncert, and 3 FutureRelevance.

Nursery Propagation - The ease and/or cost of producing the species in a nursery. Also relates to how widely available it is. Future Relevance is high for this factor because it will largely determine the extent to which the species is widely propagated and planted. For all species: 0.75 Uncert, and 4 FutureRelevance. If stock is widely available, Score is +2. If not currently available, Score is -2.

Planting Establishment - The ease with which the species establishes itself after planting. Also relates to the amount of care required to establish. Defaults for all species: 1 Score, 0.75 Uncert, and 2 FutureRelevance. -1 Score if not easily established.

Maintenance Required - The degree to which pruning or other maintenance is needed after establishment. Negative score indicates that maintenance is required. Defaults for all species: -1 Score, 0.75 Uncert, and 2 FutureRelevance. 1 Score if minimal maintenance required.

Invasive Potential - Likelihood the species could become invasive if planted. Applies to both native and nonnative species. Negative score indicates that a species is known to be or has the potential to be invasive. Defaults for all species: 0 Score, 0.75 Uncert, and 3 FutureRelevance. -3 Score if species is known to be invasive.

Literature Cited

1. Brandt, L. A., Lewis, A. D., Scott, L., Darling, L., Fahey, R. T., Iverson, L., et al. (2017). Chicago Wilderness region urban forest vulnerability assessment and synthesis: a report from the Urban Forestry Climate Change Response Framework Chicago Wilderness pilot project. Gen. Tech. Rep. NRS-168.
2. Groffman, P. M., P. Kareiva, S. Carter, N. B. Grimm, J. Lawler, M. Mack, V. Matzek, and H. Tallis. (2014). Ch. 8: Ecosystems, Biodiversity, and Ecosystem Services. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 195-219. doi:10.7930/J0TD9V7H.
3. Intergovernmental Panel on Climate Change [IPCC]. (2007). Climate change 2007: synthesis report. Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [Core Writing Team; Pachauri, R.K. and Reisinger, A., eds.]. Geneva, Switzerland: Intergovernmental Panel on Climate Change. 104 p. Available at http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm
4. Intergovernmental Panel on Climate Change [IPCC]. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
5. Iverson, L. R., Prasad, A. M, Matthews, S. N., & Peters, M. (2008). Estimating potential habitat for 134 eastern U.S. tree species under six climate scenarios. Forest Ecology and Management, 254(3), 390-406. doi:10.1016/j.foreco.2007.07.023
6. Iverson, L. R., Peters, M. P., Prasad, A. M., & Matthews, S. N. (2019). Analysis of climate change impacts on tree species of the eastern U.S.: Results of DISTRIB-II modeling. Forests 10(4), 302. doi:10.3390/f10040302
7. Matthews, S. N., Iverson, L. R., Prasad, A. M., Peters, M. P., & Rodewald, P. G. (2011). Modifying climate change habitat models using tree species-specific assessments of model uncertainty and life history factors. Forest Ecology and Management, 262, 1460-1472.
8. Matthews, S. N., Iverson, L. R., Peters, M. P., & Prasad, A. M. (2018). 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. RMAP-NRS-9. Newtown Square, PA: US Department of Agriculture, Forest Service, Northern Research Station. 31 p., 9, 1-31.
9. NOAA. (2021). Climate at a Glance. Retrieved from https://www.ncdc.noaa.gov/cag/
10. Parry, M. L., Canziani, O., Palutikof, J., Van der Linden, P., & Hanson, C. (2007). Climate change 2007: Impacts, adaptation, and vulnerability: Working group II contribution to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.
11. Peters, M. P., Iverson, L. R., Prasad, A. M., & Matthews, S. N. (2019). Utilizing the density of inventory samples to define a hybrid lattice for species distribution models: DISTRIB-II for 135 eastern US trees. Ecology and Evolution, 9, 8876-8899. doi:10.1002/ece3.5445
12. Peters, M.P., Prasad, A.M., Matthews, S.N., & Iverson, L.R. (2014). Climate change tree atlas, Version 4. USDA Forest Service, Northern Research Station and Northern Institute of Applied Climate Science, Delaware, OH. https://www.nrs.fs.fed.us/atlas.

13. Roloff, A., Korn, S., & Gillner, S. (2009). The climate species-matrix to select tree species for urban habitats considering climate change. Urban Forestry & Urban Greening, 8, 295-308.
14. USDA Forest Service. (2020). Plant Hardiness. Retrieved from https://planthardiness.ars.usda.gov/PHZMWeb/AboutWhatsNew.aspx
15. Wiens, J. A., Stralberg, D., Jongsomjit, D., Howell, C. A., & Snyder, M. A. (2009). Niches, models, and climate change: Assessing the assumptions and uncertainties. Proceedings of the National Academy of Sciences, 106(2), 19729-19736. doi:10.1073/ pnas.0901639106