VULNERABILITY ASSESSMENT OF AUSTIN'S URBAN FOREST AND NATURAL AREAS

A report from the Urban Forestry Climate Change Response Framework

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CHAPTER 3

VULNERABILITY OF AUSTIN'S TREES

Changes in climate have the potential to profoundly affect Austin's trees in both developed and natural areas. Many tree species that are currently present may experience declines in habitat suitability under warmer temperatures and altered precipitation patterns. Other species may experience improved habitat suitability under these conditions. Some species not currently present could potentially be planted in the area. In addition, climate change can have indirect effects on the urban forests in the region by changing insect pests, pathogens, and non-native invasive species, as well as the probability, severity, and extent of severe storms. Tree species will differ in their capacity to adapt to stressors. This chapter summarizes expected changes in habitat suitability and the adaptive capacity of different species in Austin's developed and natural areas.

Modeled Projections of Habitat Suitability

Climate change has the potential to alter habitat suitability for tree species. Scientists can project future habitat suitability using species distribution models (SDMs). SDMs establish a statistical relationship between the current distribution of a species or ecosystem and key attributes of its habitat. This relationship is used to make projections about how the range of the species will shift as climate change affects those attributes. SDMs are much less computationally expensive than process models, which model ecosystem and tree species dynamics based on interactive mathematical representations of physical and biological processes. Because of their relative computational ease, SDMs can typically provide projections for the suitable habitat of many species over a larger area. Users should be aware of some caveats, however (Wiens, Stralberg, Jongsomjit, Howell, & Snyder, 2009). SDMs use a species' realized niche instead of its fundamental niche. The realized niche is the actual habitat a species occupies given predation, disease, and competition with other species. A species' fundamental niche, in contrast, is the habitat it could potentially occupy in the absence of competitors, diseases, or predators. Given that a species' fundamental niche may be greater than its realized niche, SDMs may underestimate current niche size and future suitable habitat. In addition, species distributions in the future might be constrained by competition, disease, and predation in ways that do not currently occur. If so, SDMs could overestimate the amount of suitable habitat in the future. If some constraints are removed due to future change, the opposite could also occur. Furthermore, fragmentation or other physical barriers to migration may create obstacles for species otherwise poised to occupy new habitat. With these caveats in mind, SDMs can still be a useful tool for projecting changes in habitat suitability across species.

Modeling Native Trees

Suitable habitats for tree species native to the eastern United States were modeled in the Austin region using the DISTRIB-II model, an SDM that is an updated version of the Tree Atlas toolset (Iverson, Peters, Prasad, & Matthews, 2019; Iverson, Prasad, Matthews, & Peters, 2008; Peters, Iverson, Prasad, & Matthews, 2019; Prasad, Iverson, Matthews, & Peters, 2014). DISTRIB-II measures relative abundance, referred to as importance values, for 134 eastern tree species (note that only 31 of these were of interest to the Austin region because they are currently present or expected to gain habitat in the area). Inputs include tree species distribution data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and environmental variables (pertaining to climate, soil properties, elevation, land use, and fragmentation), which are used to statistically model current species abundance with respect to current habitat distributions. DISTRIB-II then projects future importance values and suitable habitat for individual tree species using projections of future climate conditions on a 12-by-12-mile grid (Peters et al., 2019). For this assessment, the DISTRIB-II model uses an average of three downscaled climate models (CCSM4, Hadley, and GFDL) and two representative concentration pathways (4.5 and 8.5). Note that this model does not account for projected changes in human population, land use, or the urban heat island effect.

Table 3.1 shows the projected change in potential suitable habitat for 31 species within a 1-by-1-degree latitude/longitude area (30 to 31 °N and 97 to 98 °W, approximately 69 miles north-south and 60 miles east-west) that includes the city of Austin. The table includes species that are either currently present in the region or expected to gain suitable habitat in the region for the years 2070 to 2099 compared to present values. Species were categorized based upon whether the results from the two climate-RCP scenarios projected an increase, decrease, or no change in suitable habitat compared to current conditions, or if the model results were mixed. Further, some tree species that are currently not present in the assessment area were identified as having potential suitable habitat in the future under one or both scenarios.

When examining these results, it is important to keep in mind that model reliability was generally higher for more common species than for rare species (see Appendix 3).

Of the 31 species examined for the Austin region, suitable habitat for 14 of them was projected to decline under both high and low scenarios. Species expected to decline that are currently found in Austin based on urban FIA data include American sycamore, black walnut, bur oak, eastern red cedar, post oak, and mulberry.

For three of the species examined, model results were slightly unclear of the direction of change. There was a small projected increase for cedar elm under a low-emissions scenario, a large increase under the high-emissions scenario for chittamwood/gum bumelia, and a large decrease for honey locust under the low-emissions scenario. For each of the species, the alternate scenario suggested no change in habitat suitability.

Suitable habitat for 10 species was projected to remain relatively stable under both scenarios. Common species in Austin that fell under this category include American elm, Ashe juniper, boxelder, green ash, northern hackberry, southern live oak (Q. virginiana), and winged elm. Four species were projected to experience a gain in suitable habitat. These were blackjack oak, pecan, sugarberry, and water oak.

Note that these projections are only available for native species and are based on data collected from phase II plots every 6,000 acres in natural areas through the U.S. Forest Service FIA program. Thus, these projections are not directly applicable to native species planted in highly developed cultivated settings that may have very different soils, microclimates, and management. For more discussion on modeling methods, see Iverson et al. (2019) Peters et al. (2019).

Projected Changes from Heat and Hardiness Zone Shifts and Species Ranges

Model information is not available for all species and cultivars that are found in the Austin region or for many 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 hardiness and heat zone ranges of the species to see how they compare to projected future zones in the region. Species that are currently present in the area based on urban FIA (Nowak et al., 2016) or expert knowledge were evaluated (Table 3.2). Species that are only hardy to zone 8 or higher may experience benefits from milder winters. Species that can only tolerate a heat zone of 10 or lower may experience negative effects from hotter summers. See Chapter 2 for projections of heat and hardiness zones in the area. Note that using heat and hardiness zones to estimate which species will benefit or fare worse in a changing climate is not as informative as the species distribution models described above because SDMs 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.

We also examined species' current ranges by county using the Biota of North America Program North American Plant Atlas (Kartesz, 2015). Based on climate projections, the climate of Austin is projected to be more similar to areas that are currently located south and west of the city over the coming decades. Thus, we assumed species commonly found in areas south and west of Austin may be better suited to future climate conditions than those common north and east of Austin. If a species is currently at the northern and/or eastern extent of its range in Travis County (more common to the southwest), it was considered to likely be positively affected by climate change. If a species is at the southern and/or western extent of its range (more common to the northeast), it was considered likely to be negatively affected.

Based on this method, 23 species may benefit from milder winters (indicated by a shift in hardiness zone) over the next century (Table 3.2). The most common species expected to benefit is southern live oak (Q. virginiana), followed by Texas mountain laurel. Other species that were commonly found in the urban FIA assessment that may experience positive effects include loquat, Mexican (Berlandier) ash, Jerusalem thorn (retama), Mexican white oak, and sweet acacia (huisache).

Sixty species had either hardiness zone, heat zone, or range limits (or a combination thereof) that may suggest a negative impact from an increase in temperature. Many of Austin's most common species are included in this category, including Ashe juniper, cedar elm, sugarberry/hackberry, yaupon, green ash, Texas red oak (Q. buckleyi), boxelder, bastard/white shin oak (Q. sinuata), pecan, western soapberry, crapemyrtle, winged elm, American sycamore, and Texas live oak (Q. fusiformis).

Twenty-one of the species evaluated did not have a strongly anticipated effect of temperature. Species included in this category were Texas persimmon, honey

Table 3.1
Projected Changes in Habitat Suitability for Trees Native to the 1-by-1-degree Latitude/Longitude Area around the Austin Region based on the DISTRIB-II Model

Species with lower model reliability are associated with less confidence in the direction of change. This list is limited to only species represented in the DISTRIB-II model. Note that some of the species listed may be native to part of the 1-by-1-degree latitude/longitude area, but outside of Austin. See Appendix 3 for more information.

Common Name	Scientific Name	Model Reliability	Change Class-Low Emissions (RCP 4.5)	Change Class-High Emissions (RCP 8.5)
DECREASE UNDER BOTH SCENARIOS				
American sycamore	*Platanus occidentalis*	Low	Small decrease	Small decrease
bitternut hickory	*Carya cordiformis*	Low	Large decrease	Large decrease
Black cherry	*Prunus serotina*	Medium	Small decrease	Small decrease
black oak	*Quercus velutina*	High	Small decrease	Small decrease
black walnut	*Juglans nigra*	Low	Small decrease	Small decrease
bur oak	*Quercus macrocarpa*	Medium	Small decrease	Large decrease
eastern redcedar	*Juniperus virginiana*	Medium	Small decrease	Small decrease
flowering dogwood	*Cornus florida*	Medium	Large decrease	Large decrease
loblolly pine	*Pinus taeda*	High	Small decrease	Small decrease
post oak	*Quercus stellata*	High	Small decrease	Small decrease
red mulberry	*Morus rubra*	Low	Small decrease	Small decrease
Shumard oak	*Quercus shumardii*	Low	Small decrease	Small decrease
slippery elm	*Ulmus rubra*	Low	Small decrease	Small decrease
white ash	*Fraxinus americana*	Medium	Small decrease	Small decrease
MIXED RESULTS				
cedar elm	*Ulmus crassifolia*	Medium	Small increase	No change
chittamwood/gum bumelia	*Sideroxylon lanuginosum ssp. lanuginosum*	Low	No change	Large increase
honeylocust	*Gleditsia triacanthos*	Low	Large decrease	No change
NO CHANGE				
American elm	*Ulmus americana*	Medium	No change	No change
Ashe juniper	*Juniperus ashei*	High	No change	No change
black hickory	*Carya texana*	High	No change	No change
boxelder	*Acer negundo*	Low	No change	No change
green ash	*Fraxinus pennsylvanica*	Low	No change	No change
northern hackberry	*Celtis occidentalis*	Medium	No change	No change
southern live oak	*Quercus virginiana*	High	No change	No change
Osage-orange	*Maclura pomifera*	Medium	No change	No change
winged elm	*Ulmus alata*	Medium	No change	No change
INCREASE				
blackjack oak	*Quercus marilandica*	Medium	Small increase	Small increase
pecan	*Carya illinoinensis*	Low	Small increase	Large increase
sugarberry	*Celtis laevigata*	Medium	Large increase	Large increase
water oak	*Quercus nigra*	High	Small increase	Small increase

Table 3.2
Potential Effects of Hardiness and Heat Zone (Where Available) Changes and Range Position for Species That Are Currently Found in the Austin Region or Are Being Considered for Planting in the Area

Estimated number of trees is based on 2014 Urban FIA sample (Nowak et al. 2016). Species hardiness/heat zone range is the range of zones in which the species is considered suitable for planting. Climate change was considered to have a positive effect on habitat suitability if the lowest zone for which the species was hardy was 8 or higher and/or it was at the northern and/or eastern extent of its range. Climate change was considered to have a negative effect on habitat suitability if the highest heat zone the species can tolerate was 10 or lower and/or it was at the southern and/or western extent of its range. See Chapter 2 for projected changes in heat and hardiness zones. [i] = non-native invasive species; n/a= not available

Common Name	Scientific Name	Native?	Estimated Trees in Austin	Hardiness Zone	Heat Zone	Position in Range	Climate Change Effect
American elm	*Ulmus americana*	Yes	72,039	3 to 9	9 to 1	West	Negative
American smoketree	*Cotinus obovatus*	Yes		4 to 8	N/A	South	Negative
American sycamore	*Platanus occidentalis*	Yes	132,468	5 to 9	9 to 3	Southwest	Negative
anacacho orchid tree	*Bauhinia lunarioides*	No		9 to 11	N/A	North (rare)	Positive
Arizona walnut	*Juglans major*	Yes		N/A	N/A	East	Negative
Arroyo sweetwood	*Myrospermum sousanum*	No		8 to 10	N/A	N/A	Positive
Ashe juniper	*Juniperus ashei*	Yes	13,315,759	6 to 9	10 to 7	South	Negative
Asian persimmon	*Diospyros kaki*	No		7 to 10	N/A	Center	No effect
baldcypress	*Taxodium distichum*	Yes	12,725	5 to 11	12 to 5	West	Negative
bastard/white shin oak (scalybark oak)	*Quercus sinuata*	Yes	243,656	7 to 9	N/A	South	Negative
black hickory	*Carya texana*	Yes		5 to 9	N/A	Southwest	Negative
black walnut	*Juglans nigra*	Yes	105,106	4 to 9	9 to 3	South	Negative
black willow	*Salix nigra*	Yes		4 to 9	N/A	Southwest	Negative
blackjack oak	*Quercus marilandica*	Yes		6 to 9	N/A	Southwest	Negative
boxelder	*Acer negundo*	Yes	367,930	2 to 8	8 to 3	South	Negative
Brazilian bluewood	*Condalia hookeri var. hookeri*	Yes		8 to 11	N/A	North or range	Positive
bur oak	*Quercus macrocarpa*	Yes	6,363	3 to 8	9 to 1	South	Negative
Carolina basswood	*Tilia americana var. caroliniana*	Yes		6 to 9	N/A	West	Negative
Carolina buckthorn	*Frangula caroliniana*	Yes		5 to 9	N/A	Southwest	Negative
catclaw	*Senegalia roemeriana (acacia roemeriana)*	Yes		7 to 11	N/A	Northeast	Positive
catclaw mimosa (fragrant mimosa)	*Mimosa aculeaticarpa var. biuncifera*	Yes		3 to 10	N/A	East	No effect
cedar elm	*Ulmus crassifolia*	Yes	4,583,201	7 to 9	9 to 6	South/central	Negative
cherry laurel[i]	*Prunus caroliniana*	Yes	78,107	6 to 9	9 to 6	West	Negative
Chinaberry[i]	*Melia azedarach*	No	538,729	8 to 15	12 to 7	Center	Positive
Chinese elm (lacebark elm)[i]	*Ulmus parvifolia*	No	78,107	5 to 9	9 to 1	South	Negative
Chinese pistache[i]	*Pistacia chinensis*	No	17,322	6 to 9	9 to 6	North	Negative
Chinese privet[i]	*Ligustrum sinense*	No	123,994	7 to 9	9 to 6	South	Negative
Chinese tallow tree[i]	*Triadica sebifera*	No	28,029	8 to 10	10 to 8	Center	No effect

Common Name	Scientific Name	Native?	Estimated Trees in Austin	Hardiness Zone	Heat Zone	Position in Range	Climate Change Effect
chinkapin oak	*Quercus muehlenbergii*	Yes	10,959	4 to 8	8 to 2	South	Negative
chittamwood (gum bumelia)	*Sideroxylon lanuginosum*	Yes	89,955	6 to 10	N/A	South	Negative
common hoptree (wafer ash)	*Ptelea trifoliata*	Yes		4 to 9	N/A	South	Negative
crapemyrtle	*Lagerstroemia indica*	No	174,401	7 to 9	9 to 6	N/A	Negative
desert willow	*Chilopsis linearis*	No		7 to 11	N/A	East of range	Positive
Eastern cottonwood	*Populus deltoides*	Yes	15,862	3 to 9	9 to 1	South	Negative
Eastern red cedar	*Juniperus virginiana*	Yes	38,457	3 to 9	9 to 1	South	Negative
Eastern redbud	*Cercis canadensis*	Yes	6,248	3 to 9	9 to 6	South	Negative
edible fig	*Ficus carica*	No	22,984	6 to 10	10 to 6	Center	No effect
escarpment black cherry	*Prunus serotina var. eximia*	Yes		7 to 9	N/A	South	Negative
Eve's necklace	*Styphnolobium affine*	Yes		7 to 9	N/A	Center	No effect
evergreen sumac	*Rhus virens*	Yes		8 to 11	N/A	East	Positive
fragrant sumac (skunkbush sumac)	*Rhus aromatic*	Yes		N/A	N/A	South-central	No effect
glossy privet[i]	*Ligustrum lucidum*	No	623,890	7 to 9	9 to 6	South	Negative
goldenrain tree[i]	*Koelreuteria paniculata*	No	6,363	5 to 9	9 to 1	N/A	Negative
green ash	*Fraxinus pensylvanica*	Yes	751,788	3 to 9	9 to 1	South	Negative
honey mesquite	*Prosopis glandulosa*	Yes	655,950	6 to 9	12 to 1	East-center	No effect
Japanese privet[i]	*Ligustrum japonicum*	No	17,322	7 to 10	10 to 7	Center	No effect
Jerusalem thorn (retama)	*Parkinsonia aculeata*	Yes	10,199	9 to 12	12 to 10	North	Positive
Lacey oak	*Quercus laceyi*	Yes		7 to 9	N/A	East	No effect
Lindheimer's silktassel	*Garrya ovata var. lindheimeri*	Yes		8 to 11	N/A	East	Positive
little walnut	*Juglans microcarpa*	Yes		6 to 8	N/A	East	Negative
littleleaf/goldenball leadtree	*Leucaena retusa*	No		7 to 9	N/A	East	No effect
loquat	*Eriobotrya japonica*	No	312,427	8 to 11	12 to 8	North	Positive
lotebush	*Ziziphus obtusifolia*	Yes		8 to 11	N/A	East	Positive
Mexican ash (Berlandier ash)	*Fraxinus berlandieriana*	Yes	184,758	7 to 8	N/A	North	Positive
Mexican buckeye	*Ungnadia speciosa*	Yes		7 to 9	N/A	Center	No effect
Mexican olive	*Cordia boissieri*	No		9 to 11	N/A	North or range	Positive
Mexican plum	*Prunus mexicana*	Yes		6 to 8	N/A	Southwest	Negative
Mexican redbud	*Cercis canadensis var. mexicana*	No		6 to 8	N/A	Northeast of range	Positive
Mexican sycamore	*Platanus mexicana*	No		5 to 9	N/A	North of range	Positive
Mexican white oak	*Quercus polymorpha*	No	84,966	7 to 10	12 to 8	North	Positive
Meyer lemon	*Citrus meyeri*	No		9 to 11	N/A	n/a	Positive
mimosa silktree[i]	*Albizia julibrissin*	No	4,720	6 to 9	9 to 6	Center	Negative

Common Name	Scientific Name	Native?	Estimated Trees in Austin	Hardiness Zone	Heat Zone	Position in Range	Climate Change Effect
mockernut hickory	*Carya tomentosa*	No		4 to 9	N/A	Southwest	Negative
Montezuma cypress	*Taxodium mucronatum*	No		8 to 11	N/A	North of range	Positive
netleaf hackberry	*Celtis laevigata var. reticulata*	Yes		3 to 9	N/A	East	Negative
northern hackberry	*Celtis occidentalis*	Yes	161,569	2 to 9	9 to 1	South	Negative
Osage orange	*Maclura pomifera*	Yes		4 to 9	N/A	South	Negative
paper mulberry[i]	*Broussonetia papyrifera*	No	335,755	6 to 11	N/A	Center	No effect
pecan	*Carya illinoinensis*	Yes	196,132	5 to 9	9 to 1	South	Negative
pomegranate	*Punica granatum*	No		8 to 11	12 to 4	n/a	Positive
possumhaw (deciduous holly)	*Ilex decidua*	Yes		5 to 9	N/A	Southwest	Negative
post oak	*Quercus stellata*	Yes	86,286	5 to 9	9 to 4	South	Negative
prairie sumac (flameleaf sumac)	*Rhus lanceolata*	Yes	77,093	5 to 8	N/A	Center	No effect
red bay	*Persea borbonia*	Yes		7 to 11	12 to 8	West	Negative
red buckeye	*Aesculus pavia var. pavia*	Yes		6 to 9	N/A	Southwest	Negative
red mulberry	*Morus rubra*	Yes	124,975	5 to 9	9 to 4	Southwest	Negative
roughleaf dogwood	*Cornus drummondii*	Yes	59,882	4 to 9	N/A	South	Negative
rusty blackhaw	*Viburnum rufidulum*	Yes		5 to 9	8 to 1	Southwest	Negative
Shumard oak	*Quercus shumardii*	Yes	43,137	5 to 10	9 to 1	South	Negative
slippery elm	*Ulmus rubra*	Yes	12,725	3 to 10	10 to 1	Southwest	Negative
Southern live oak (coast live oak)	*Quercus virginiana*	Yes	2,862,523	8 to 11	11 to 6	Center	Positive
Southern magnolia	*Magnolia grandiflora*	No	6,363	7 to 10	11 to 1	West	Negative
sugarberry	*Celtis laevigata*	Yes	2,058,386	5 to 10	N/A	South	Negative
sweet acacia (huisache)	*Vachellia farnesiana (acacia farnesiana)*	Yes	4,597	8 to 10	12 to 10	North	Positive
sweetgum	*Liquidambar styraciflua*	No		6 to 9	N/A	Southwest	Negative
Texas ash	*Fraxinus albicans*	Yes	438,216	3 to 9	9 to 4	Center	No effect
Texas crab apple	*Malus ioensis var. texana*	No		N/A	N/A	N/A	Unknown
Texas Hercules' club (prickly-ash, tickle-tongue)	*Zanthoxylum hirsutum*	Yes		4 to 8	N/A	Center	No effect
Texas kidneywood	*Eysenhardtia texana*	Yes		8 to 11	N/A	Northeast	Positive
Texas live oak (escarpment live oak, plateau live oak)	*Quercus fusiformis*	Yes	101,848	6 to 10	10 to 6	Center	No effect
Texas madrone	*Arbutus xalapensis*	Yes	6,189	7 to 11	12 to 3	North	No effect
Texas mountain laurel	*Dermatophyllum secundiflorum*	Yes	648,060	8 to 15	12 to 10	Northeast	Positive
Texas mulberry	*Morus microphylla*	Yes		5 to 9	N/A	East	No effect
Texas persimmon	*Diospyros texana*	Yes	2,014,199	7 to 9	N/A	North	No effect
Texas pistache	*Pistacia mexicana*	No		7 to 9	N/A	North	No effect
Texas red oak	*Quercus buckleyi*	Yes	419,812	7 to 10	10 to 1	South	Negative

Common Name	Scientific Name	Native?	Estimated Trees in Austin	Hardiness Zone	Heat Zone	Position in Range	Climate Change Effect
Texas redbud	*Cercis canadensis var. texensis*	Yes		5 to 9	N/A	Center	No effect
velvet ash	*Fraxinus velutina*	Yes	59,326	6 to 9	9 to 6	East	Negative
water oak	*Quercus nigra*	Yes	4,597	6 to 9	9 to 7	Southwest	Negative
Western soapberry	*Sapindus saponaria var. drummondii*	Yes	192,371	6 to 9	N/A	Southeast	Negative
white mulberry[i]	*Morus alba*	No	13,790	4 to 8	8 to 1	Center	Negative
winged elm	*Ulmus alata*	No	134,185	6 to 9	N/A	South	Negative
yaupon	*Ilex vomitoria*	Yes	833,143	7 to 11	12 to 7	Southwest	Negative

mesquite, and Texas ash. However, these species could be affected by other climate-related changes, such as shifts in precipitation or insect or disease outbreaks.

Adaptive Capacity of Urban Trees

The results presented above provide information on potential changes in tree species habitat suitability across a range of projected future temperature and precipitation regimes (in the case of DISTRIB-II) or 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 non-native 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, Iverson, Prasad, Peters, and Rodewald (2011) called "modification factors." Other scoring systems have been developed (Roloff, Korn, & Gillner, 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 3.3). 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 4). 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). As in the Chicago assessment, we created separate scores for developed and natural areas. For the most part, we used the same categories and weights as in Chicago but eliminated the road salt category as road salt is not used in Austin. We also put extra weight on both flooding and drought in natural areas because Austin is more susceptible to these effects than Chicago. We developed modification factor scores for 104 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.

For planted/developed conditions, 29 species received a high adaptability score, 18 received a low adaptability score, and the remaining 57 received a medium adaptability score (Table 3.4). Common native species with high adaptability scores in planted environments include cedar elm, Texas mountain laurel, yaupon, possumhaw, hoptree/wafer ash, chittamwood/gum bumelia, and Eve's necklace. Factors that tended to enhance adaptive capacity included tolerance to a wide range of disturbances, ability to be planted on a wide range of sites, and ease of propagation in a nursery. Common species that received low adaptability ratings were pecan, black walnut, and several oak species. These species tended to receive low adaptability ratings because they were susceptible to pests or diseases and were intolerant of a variety of urban sites and/or pollution.

For natural areas (both native and naturalized), 43 species received a high adaptability score, 13 received a low adaptability score, and 48 received a medium adaptability score (Table 3.5). Not surprisingly, many of the most adaptable species are non-native invasive species, such as Chinese tallowtree, Japanese and Chinese privet, Chinese elm, glossy privet, chinaberry, paper and white mulberry, mimosa/silktree, Chinese pistache, and goldenrain tree.

Table 3.3
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 4 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
Dispersal	DISP	N	High ability to effectively produce and distribute seeds	Low ability to effectively produce and distribute seeds
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
Fire regeneration	FRG	N	Regenerates well after fire	N/A
Fire topkill	FTK	N	Resistant to fire topkill	Susceptible to fire topkill
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 non-native 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
Seedling establishment	SES	N	High ability to regenerate with seeds to maintain future populations	Low ability to regenerate with seeds to maintain future populations
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
Vegetative reproduction	VRE	N	Capable of vegetative reproduction through stump sprouts or cloning	Not capable of vegetative reproduction
Wind	Win	N, P	N/A	Susceptible to breakage from windstorms

Table 3.4
Adaptability Scores for Trees in Developed Areas

See Table 3.3 for trait codes. See Appendix 4 for descriptions of Disturb, Bio and, Adapt scoring system. A negative disturb score indicates a species is highly susceptible to one or more disturbances such as drought, flooding, or pests and vice versa. A negative bio score indicates a species has a very limited range of soil, light, and other environmental requirements and vice versa. Adapt scores are all positive. A score below 3.5 is low, above 4.5 is high, and between 3.5 and 4.5 is a medium adapt class. [i] =non-native invasive species

Common Name	Scientific Name	Planted Disturb Score	Planted Bio Score	Planted Adapt Score	Planted Adapt Class	Planted Positive Factors	Planted Negative Factors
American elm	*Ulmus americana*	-2.2	1	3.83	Medium	TEM NUP	DISE DRO
American smoketree	*Cotinus obovatus*	-0.75	1	3.86	Medium	DRO LPS RRC	AIP
American sycamore	*Platanus occidentalis*	-0.75	0.56	3.85	Medium	FLO TEM NUP	DRO
Anacacho orchid tree	*Bauhinia lunarioides*	-0.34	-1	3.62	Medium		FLO AIP
Arizona walnut	*Juglans major*	-0.77	-0.66	3.53	Medium	FLO	DRO AIP
Arroyo sweetwood	*Myrospernum sousanum*	-0.57	-0.94	3.57	Medium	DRO	FLO AIP INPO
Ashe juniper	*Juniperus ashei*	0.66	0.09	4.46	Medium	AIP ESP RRC DRO	FLO ICE WIN
Asian persimmon	*Diospyros kaki*	-1.86	0	3.3	Low		FLO AIP LUP
bald cypress	*Taxodium distichum*	0.2	2	5	High	FLO RRC NUP	AIP
Bastard/white shin oak (scalybark oak)	*Quercus sinuata*	-0.3	-1	3.4	Low	DRO	AIP
Berlandier ash	*Fraxinus berlandieriana*	-2.43	1	3.94	Medium		INS DRO AIP INPO
bigtooth maple	*Acer grandidentatum*	0.82	0.22	4.64	High	TEM	
Black hickory	*Carya texana*	-1.45	-2	2.92	Low		FLO AIP NUP
black walnut	*Juglans nigra*	-1.18	-1.78	2.88	Low		DISE AIP COL LPS RRC
black willow	*Salix nigra*	-1.55	-0.38	3.3	Low	FLO	SRO AIP RRC
Blackjack oak	*Quercus marilandica*	-1.16	-2	2.87	Low	DRO TEM	DISE FLO AIP LPS RRC NUP
boxelder	*Acer negundo*	0.02	0	4.34	Medium	DRO FLO TEM	INS INPO
Brazilian bluewood	*Condalia hookeri var. hookeri*	-0.75	-0.28	3.53	Medium	DRO	FLO AIP
bur oak	*Quercus macrocarpa*	0.55	0.84	4.49	High	DRO TEM AIP LPS NUP	FLO
Carolina basswood	*Tilia americana var. caroliniana*	-1.23	0.19	3.86	Medium	COL	AIP
Carolina buckthorn	*Frangula caroliniana*	-1	1	4.17	Medium		DRO TEM
catclaw	*Acacia roemeriana*	-0.89	0	3.63	Medium	DRO	FLO COL AIP
Catclaw mimosa	*Mimosa biuncifera*	0.45	-1	3.68	Medium	DRO	AIP INPO

Common Name	Scientific Name	Planted Disturb Score	Planted Bio Score	Planted Adapt Score	Planted Adapt Class	Planted Positive Factors	Planted Negative Factors
cedar elm	*Ulmus crassifolia*	0.98	3.63	5.82	High	FLO AIP EPS LPS RRC NUP DRO	
cherry laurel[i]	*Prunus caroliniana*	-0.2	0.47	4.55	High	NUP	FLO RRC INPO
Chinaberry	*Melia azedarach*	1.11	-1.41	4.12	Medium	DRO FLO RRC PES	LPS NUP INPO
Chinese elm[i]	*Ulmus parvifolia*	1.39	2	5.5	High	DRO TEM EDS LPS RRC NUP	INPO
Chinese pistache	*Pistacia chinensis*	1.23	0.56	4.86	High	DRO LPS RRC	FLO MAIN INPO
Chinese privet[i]	*Ligustrum sinense*	-1.5	0.69	4.14	Medium	TEM NUP	INPO
Chinese tallowtree[i]	*Triadica sebifera*	0.2	2	5	High	DRO FLO WIN LPS RRC NUP	DISE AIP INPO
chinkapin oak	*Quercus muehlenbergii*	-0.27	1	4.48	Medium	DRO TEM	AIP
chittamwood (gum bumelia)	*Sideroxylon lanuginosum*	-0.36	1.75	4.53	High	DRO TEM	AIP
Common hoptree (wafer ash)	*Ptelea trifoliata*	-0.66	1.22	4.48	Medium	TEM RRC NUP	AIP
crape myrtle	*Lagerstroemia indica*	-0.95	3	4.71	High	DRO TEM LPS RRC NUP	FLO AIP
Desert willow	*Chilopsis linearis*	0.34	-0.66	3.76	Medium	DRO FLO	AIP
Eastern cottonwood	*Populus deltoides*	-1.43	-0.38	3.15	Low	TEM NUP	DIS INS AIP LPS RRC
Eastern red cedar	*Juniperus virginiana*	0	2	4.65	High	DRO TEM LPS RRC	AIP
Eastern redbud	*Cercis canadensis*	0	2	4.65	High	FLO TEM LPS RRC	AIP
edible fig	*Ficus carica*	-2.05	-1	2.84	Low		FLO AIP
escarpment black cherry	*Prunus serotina var. eximia*	-1.18	-3	2.73	Low	TEM	WIN AIP ESP LPS NUP
Eve's necklace	*Styphnolobium affine*	-0.16	2	4.89	High	DRO LPS NUP	FLO AIP
evergreen sumac	*Rhus virens*	-0.84	1	4.23	Medium	DRO	FLO AIP DISE
Fragrant sumac	*Rhus aromatica*	0.3	2	4.9	High	DRO TEM ESP LPS NUP	
glossy privet[i]	*Ligustrum lucidum*	0.48	2	4.92	High	TEM LPS RRC NUP	INPO
goldenrain tree[i]	*Koelreuteria paniculatan*	0.48	1	4.55	High	DRO TEM LPS RRC NUP	INPO
green ash	*Fraxinus pennsylvanica*	-1.2	0.81	3.86	Medium	FLO LPS NUP	INS MAIN
Honey mesquite	*Prosopis glandulosa*	0.57	-2	3.63	Medium	DRO	AIP INPO
Japanese privet[i]	*Ligustrum japonicum*	-1.5	1	4.14	Medium	TEM NUP	INPO
Jerusalem thorn (retama)	*Parkinsonia aculeata*	0.59	1.69	4.98	High	DRO LPS RRC NUP	INPO
Lacey oak	*Quercus laceyi*	-0.07	-0.16	3.94	Medium	DRO	FLO SIP

Common Name	Scientific Name	Planted Disturb Score	Planted Bio Score	Planted Adapt Score	Planted Adapt Class	Planted Positive Factors	Planted Negative Factors
Lindheimer's silktassel	*Garrya ovata var. lindheimeri*	-0.3	0	3.96	Medium		FLO AIP
little walnut	*Juglans microcarpa*	-0.98	-0.66	3.47	Low	FLO	DRO AIP
littleleaf (goldenball leadtree)	*Leucaena retusa*	-0.2	-1	3.57	Medium	DRO	WIN AIP INPO
loquat	*Eriobotrya japonica*	-1.45	0	3.76	Medium		AIP INPO
Lotebush	*Ziziphus obtusifolia*	0.25	0.47	4.36	Medium	DRO	AIP INP
Mexican buckeye	*Ungnadia speciosa*	-0.16	2	4.95	High	DRO TEM RRC NUP	AIP
Mexican olive	*Cordia boissieri*	-1.68	0.28	3.45	Low	DRO	FLO AIP
Mexican plum	*Prunus mexicana*	-0.09	1	4.59	High	DRO LPS	AIP
Mexican redbud	*Cercis canadensis L. var. mexicana*	-1.32	-0.09	3.66	Medium	DRO	FLO AIP
Mexican sycamore	*Platanus mexicana*	0.93	-1.41	4.26	Medium	FLO AIP	LPS RRC
Mexican white oak	*Quercus polymorpha*	0.14	2	4.59	High	DRO LPS NUP	AIP
Meyer lemon	*Citrus meyeri*	-1.18	0.94	3.81	Medium	NUP	FLO
mimosa (silktree)[i]	*Albizia julibrissin*	-0.77	-2.28	2.88	Low	DRO FLO TEM EDS	DISE AIP INPO LPS RRC INPO
Mockernut hickory	*Carya tomentosa*	-0.46	-0.59	3.68	Medium		AIP
Montezuma cypress	*Taxodium mucronatum*	0.86	-1	4.05	Medium	DRO FLO	AIP
Netleaf hackberry	*Celtis laevigata var. reticulata*	-0.64	-0.59	3.66	Medium	DRO FLO TEM AIP	WIN
Northern hackberry	*Celtis occidentalis*	0.25	1.66	4.64	High	DRO TEM LPS NUP	
Osage orange	*Maclura pomifera*	0.61	2.66	5.26	High	INS DRO TEM RRC NUP	AIP
paper mulberry[i]	*Broussonetia papyrifera*	0.3	-0.63	4.12	Medium	FLO TEM	INPO
pecan	*Carya illinoinensis*	-1.85	0	3.15	Low		AIP LPS RRC
Pomegranate	*Punica granatum*	-0.93	0.94	3.82	Medium	DRO RRC NUP	FLO
Possumhaw	*Ilex decidua*	1.14	1	4.95	High	FLO TEM	AIP
post oak	*Quercus stellata*	-1.39	-2	2.92	Low	TEM	DISE FLO AIP LPS NUP
prairie flameleaf sumac	*Rhus lanceolata*	1.14	-0.38	4.12	Medium	DRO TEM	AIP
prickly-ash (tickle-tongue)	*Zanthoxylum hirsutum*	-0.36	-1	3.57	Medium		AIP LPS INPO
Red bay	*Persea borbonia*	-0.5	2	4.74	High	TEM NUP	AIP
Red buckeye	*Aesculus pavia var. pavia*	-1.18	0.09	3.81	Medium		AIP

Common Name	Scientific Name	Planted Disturb Score	Planted Bio Score	Planted Adapt Score	Planted Adapt Class	Planted Positive Factors	Planted Negative Factors
red mulberry	*Morus rubra*	-1.05	0.38	4.02	Medium	TEM NUP	AIP
roughleaf dogwood	*Cornus drummondii*	0.61	0	4.31	Medium	TEM FLO	AIP RRC
rusty blackhaw	*Viburnum rufidulum*	-0.11	1	4.39	Medium	DRO TEM LPS	FLO RRC
Shumard oak	*Quercus shumardii*	-0.3	2	4.22	Medium	FLO LPS RRC NUP	DISE
slippery elm	*Ulmus rubra*	-1.36	0	3.92	Medium	TEM	DISE AIP INPO
Southern live oak	*Quercus virginiana*	-0.75	2	4.54	High	TEM LPS RRC NUP	DISE AIP
Southern magnolia	*Magnolia grandiflora*	-1.43	-0.72	3.57	Medium	NUP	DRO LPS RRC
sugarberry	*Celtis laevigata*	-0.02	0	4.03	Medium	DRO FLO TEM	WIN
sweet acacia (huisache)	*Vachellia farnesiana*	-0.89	-1	3.13	Low	DRO	FLO INPO
sweetgum	*Liquidambar styraciflua*	-0.48	-0.28	3.72	Medium	FLO	INS DRO RRC
Texas (escarpment, plateau) live oak	*Quercus fusiformis*	-1.75	-2	2.76	Low		DISE INS FLO AIP LPS RRC
Texas ash	*Fraxinus albicans*	-0.82	2.16	4.69	High	TEM LPS RRS NUP	INS FLO
Texas crab apple	*Malus ioensis var. texana*	-1.86	0	3.51	Medium		FLO AIP
Texas kidneywood	*Eysenhardtia texana*	-0.48	0	3.84	Medium	DRO	FLO AIP
Texas madrone	*Arbutus xalapensis*	-1.3	1.09	4.25	Medium	DRO RRC	FLO AIP PLE
Texas mountain laurel	*Dermatophyllum secundiflorum*	0.2	3	5.15	High	DRO LPS RRC NUP	AIP
Texas mulberry	*Morus microphylla*	-1.45455	-1.13	3.4	Low		AIP
Texas persimmon	*Diospyros texana*	-0.52	1	4.43	Medium	RRC	AIP
Texas pistache	*Pistacia mexicana*	-0.43	0	3.69	Medium	DRO	DIS AIP
Texas red (Buckley) oak	*Quercus buckleyi*	-0.43	1	4.18	Medium	TEM	DISE FLO
Texas redbud	*Cercis canadensis var. texensis*	-1.36	1	4.03	Medium	RRC LPS DRO	AIP FLO
velvet ash	*Fraxinus velutina*	-0.14	2	4.44	Medium	DRO AIP LPS RRS NUP	INS WIN MAIN
water oak	*Quercus nigra*	-1.02	0.34	3.55	Medium	FLO TEM NUP	DISE AIP
Western soapberry	*Sapindus saponaria var. drummondii*	2.09	-1.88	4.69	High	DRO FLO TEMP AIP	NUP
white mulberry[i]	*Morus alba*	0.36	-0.22	3.41	Low	NUP	LPS INPO
winged elm	*Ulmus alata*	-1.77	1.44	4.17	Medium	FLO LPS RRC	DISE AIP INPO
yaupon	*Ilex vomitoria*	0.32	3	5.46	High	ESP LPS RRC NUP	High

Table 3.5
Adaptability Scores for Trees in Natural Areas

See Table 3.3 for trait codes. See Appendix 4 for descriptions of Disturb, Bio and, Adapt scoring system. See Appendix 4 for descriptions of Disturb, Bio and, Adapt scoring system. A negative disturb score indicates a species is highly susceptible to one or more disturbances such as drought, flooding, or pests and vice versa. A negative bio score indicates a species has a very limited range of soil, light, and other environmental requirements and vice versa. Adapt scores are all positive. A score below 3.5 is low, above 4.5 is high, and between 3.5 and 4.5 s a medium adapt class. [i] = non-native invasive species

Common Name	Scientific Name	Natural Disturb Score	Natural Bio Score	Natural Adapt Score	Natural Adapt Class	Natural Positive Factors	Natural Negative Factors
American elm	*Ulmus americana*	-2.19	2	4.64	High	EHS	DISE INSP DRO AIP
American smoketree	*Cotinus obovatus*	-0.85	-1	3.35	Low	DRO	AIP EHS
American sycamore	*Platanus occidentalis*	-1.46	-0.21	3.49	Medium	FLO	DRO EHS
Anacacho orchid tree	*Bauhinia lunarioides*	-0.56	-1.5	3.38	Low	DRO	FLO COL EHS
Arizona walnut	*Juglans major*	-0.87	0	3.61	Medium	FLO	DRO AIP EHS
Arroyo sweetwood	*Myrospernum sousanum*	-0.63	0	3.61	Medium	DRO SES	FLO AIP EHS
Ashe juniper	*Juniperus ashei*	-0.79	3	5.12	High	DRO ESP EHS DISP SES	FLO FTK
Asian persimmon	*Diospyros kaki*	-2.19	-0.11	3.36	Low		FLO AIP DISP
bald cypress	*Taxodium distichum*	-1.31	0	3.81	medium	FLO	DRO AIP EHS
Bastard/white shin oak (scalybark oak)	*Quercus sinuata*	-0.44	0	4.02	Medium	DRO VRE FRG	AIP COL DISP
Berlandier ash	*Fraxinus berlandieriana*	-3.13	2.36	4.23	Medium	FTK AIP VRE	INS DRO DISP SES
bigtooth maple	*Acer grandidentatum*	0.15	2	4.87	High	COL EHS	
black hickory	*Carya texana*	-1.9	0	3.52	Medium	SES	FLO AIP COL
black walnut	*Juglans nigra*	-1.25	0	3.85	Medium	SES	DISE COL
black willow	*Salix nigra*	-1.79	-1.29	3.26	Low	FLO	DRO FTK AIP COL
Blackjack oak	*Quercus marilandica*	-1.37	2	4.67	High	DRO SES VRE	DISE FLO AIP COL
boxelder	*Acer negundo*	-0.13	4.61	5.64	High	DRO FLO TEM COL DISP SES	AIP
Brazilian bluewood	*Condalia hookeri var. hookeri*	-0.96	0.32	4.02	Medium	DRO	FLO AIP COL
bur oak	*Quercus macrocarpa*	0.23	1	4.73	High	DRO AIP	FLO
Carolina basswood	*Tilia americana var. caroliniana*	-1.54	-1	3.49	Low	COL	AIP EHS SES
Carolina buckthorn	*Frangula caroliniana*	-1.12	1	4.18	Medium	COL SES	DRO AIP
catclaw	*Acacia roemeriana*	-1.19	0	3.93	Medium	DRO	FLO COL AIP
Catclaw mimosa	*Mimosa biuncifera*	0.63	0	4.24	Medium	DRO EHS VRE	AIP COL

Common Name	Scientific Name	Natural Disturb Score	Natural Bio Score	Natural Adapt Score	Natural Adapt Class	Natural Positive Factors	Natural Negative Factors
cedar elm	*Ulmus crassifolia*	0.12	4	5.61	High	DRO FLO AIP ESP EHS DISP SES FRE	
cherry laurel[i]	*Prunus caroliniana*	-0.92	2.46	4.74	High	COL DISP SES	FLO VRE
Chinaberry	*Melia azedarach*	0.81	2	5.19	High	DRO FLO DISP SES VRE	COL
Chinese elm[i]	*Ulmus parvifolia*	0.67	3	5.44	High	DRO ESP EHS SES	
Chinese pistache	*Pistacia chinensis*	0.83	1	4.87	High	DRO WIN AIP EHS	FLO VRE
Chinese privet[i]	*Ligustrum sinense*	-1.52	5	5.81	High	COL EHS DISP SES VRE	AIP
Chinese tallowtree[i]	*Triadica sebifera*	0.6	4.71	6	High	DRO FLO WIN COL EHS DISP SES VRE	DISE AIP
chinkapin oak	*Quercus muehlenbergii*	-0.58	1.07	4.5	Medium	DRO TEM	
chittamwood (gum bumelia)	*Sideroxylon lanuginosum*	-0.69	0.54	4.22	Medium	DRO TEM	AIP COL
Common hoptree (wafer ash)	*Ptelea trifoliata*	-1.58	1	4.29	Medium	TEM COL DISP	FTK AIP VRE
Crape myrtle	*Lagerstroemia indica*	-0.75	3	5.16	High	DRO EHS DISP SES VRE	FLO COL
desert willow	*Chilopsis linearis*	0.42	0.75	4.46	Medium	DRO FLO SES	AIP COL
Eastern cottonwood	*Populus deltoides*	-1.52	1	3.93	Medium	TEM	DIS INS AIP
Eastern red cedar	*Juniperus virginiana*	-0.38	0	4.03	Medium	DRO	FTK COL
Eastern redbud	*Cercis canadensis*	-0.5	2.36	4.98	High	FLO	AIP
edible fig	*Ficus carica*	-2.35	-1.39	2.62	Low		FLO AIP VRE
escarpment black cherry	*Prunus serotina var. eximia*	-1.5	0.32	3.61	Medium	DISP SES	WIN AIP ESP EHS
Eve's necklace	*Styphnolobium affine*	-0.17	0	3.78	Medium	DRO COL	FLO AIP DISP
evergreen sumac	*Rhus virens*	-0.73	3	5.34	High	DRO DISP SES VRE FRG	FLO AIP DISE
Fragrant sumac	*Rhus aromatica*	0.33	3.86	5.72	High	DRO TEM ESP EHS DISP SES VRE	AIP
glossy privet[i]	*Ligustrum lucidum*	-0.4	3	5.22	High	TEM EHS DISP SES	
goldenrain tree[i]	*Koelreuteria paniculatan*	-0.21	2	4.7	High	DRO DISP SES	COL
green ash	*Fraxinus pennsylvanica*	-1.37	1.18	4.46	Medium	FLO	INS COL
honey mesquite	*Prosopis glandulosa*	0.13	1.39	4.68	High	DRO SES FRE	AIP COL
Japanese privet[i]	*Ligustrum japonicum*	-1.52	4.71	5.81	High	COL EHS DISP SES VRE	AIP
Jerusalem thorn (retama)	*Parkinsonia aculeata*	0.12	-0.75	3.74	Medium	DRO SES	COL VRE
Lacey oak	*Quercus laceyi*	-0.33	-1.07	3.38	Low	DRO SES	FLO AIP EHS DISP

Common Name	Scientific Name	Natural Disturb Score	Natural Bio Score	Natural Adapt Score	Natural Adapt Class	Natural Positive Factors	Natural Negative Factors
Lindheimer's silktassel	*Garrya ovata var. lindheimeri*	-0.75	0.21	4.04	Medium		FLO AIP
little walnut	*Juglans microcarpa*	-1.67	-1	2.73	Low	FLO SES	DRO FTK AIP EHS DISP VRE
littleleaf (goldenball leadtree)	*Leucaena retusa*	-0.71	2	4.33	Medium	DRO DISP SES	FLO WIN AIP VRE
loquat	*Eriobotrya japonica*	-1.62	2	4.34	Medium		AIP
Lotebush	*Ziziphus obtusifolia*	0.4	4	5.67	High	DRO EHS DSIP SES VRE	AIP
Mexican buckeye	*Ungnadia speciosa*	-0.46	-0.11	4.03	Medium	COL	AIP EHS SES
Mexican olive	*Cordia boissieri*	-1.46	0	3.61	Medium	DRO	FLO AIP COL
Mexican plum	*Prunus mexicana*	-0.73	1.07	4.13	Medium	DRO COL EHS	VRE
Mexican redbud	*Cercis canadensis L. var. mexicana*	-1.27	2	4.67	High	DRO SES	FLO AIP
Mexican sycamore	*Platanus mexicana*	0.27	3.54	5.59	High	FLO AIP EHS DISP SES	
Mexican white oak	*Quercus polymorpha*	0.02	0	3.87	Medium	DRO SES	AIP DISP
Meyer lemon	*Citrus meyeri*	-1.75	-0.32	3.53	Medium		FLO COL
mimosa (silktree)[i]	*Albizia julibrissin*	-0.88	2.89	4.99	High	DRO FLO EDS EHS SES	DISE AIP COL
mockernut hickory	*Carya tomentosa*	-0.81	1	4.46	Medium		FTK COL
Montezuma cypress	*Taxodium mucronatum*	0.98	-2.79	3.39	Low	DRO FLO	AIP COL EHS DISP
netleaf hackberry	*Celtis laevigata var. reticulata*	-0.92	5	5.74	High	COL ESP EHS DISP SES	AIP
northern hackberry	*Celtis occidentalis*	-0.44	2.36	4.9	High	DRO	FTK
Osage orange	*Maclura pomifera*	-0.21	2.04	4.94	High	DRO EDS EHS	
paper mulberry[i]	*Broussonetia papyrifera*	-0.42	3	5.1	High	FLO COL SES	
pecan	*Carya illinoinensis*	-2.46	-1	3.12	Low		FTK COL
Pomegranate	*Punica granatum*	-1.21	-0.21	3.2	low	DRO EHS SES	FLO COL DISP VRE
possumhaw	*Ilex decidua*	0.69	2.25	4.89	High	FLO COL EHS SES	AIP DISP
post oak	*Quercus stellata*	-1.42	1	4.17	Medium	TEM	DISE FLO AIP COL
prairie flameleaf sumac	*Rhus lanceolata*	0.98	3	5.48	High	DRO TEM EHS DISP SES VRE FRG	AIP COL
prickly-ash (tickle-tongue)	*Zanthoxylum hirsutum*	-0.69	2.68	5.07	High	EHS VRE	
red bay	*Persea borbonia*	-0.98	1.39	4.46	Medium		AIP
Red buckeye	*Aesculus pavia var. pavia*	-0.79	2	4.83	High	COL FLO	AIP

Common Name	Scientific Name	Natural Disturb Score	Natural Bio Score	Natural Adapt Score	Natural Adapt Class	Natural Positive Factors	Natural Negative Factors
red mulberry	*Morus rubra*	-1.71	1.93	4.44	Medium	COL	FTK AIP
roughleaf dogwood	*Cornus drummondii*	0.15	2	4.9	High	FLO COL	AIP
rusty blackhaw	*Viburnum rufidulum*	-0.38	1.07	4.36	Medium	DRO COL	FLO VRE
Shumard oak	*Quercus shumardii*	-1.19	0	3.81	Medium	FLO	DISE FTK COL
slippery elm	*Ulmus rubra*	-1.83	2	4.5	High	COL	DISE FTK AIP
Southern live oak	*Quercus virginiana*	-0.79	2	5.07	High	FTK VRE FRG	DISE AIP
Southern magnolia	*Magnolia grandiflora*	-1.56	1	4.29	Medium	COL SES	DRO FLO EHS
sugarberry	*Celtis laevigata*	-0.92	4.5	5.74	High	COL ESP EHS DISP SES	AIP
sweet acacia (huisache)	*Vachellia farnesiana*	-1.21	-1.82	2.99	Low	DRO	FLO COL
sweetgum	*Liquidambar styraciflua*	-1.46	1.82	4.63	High	FLO EHS VRE	INS DRO FTK AIP COL
Texas ash	*Fraxinus albicans*	-1.69	1	4.17	Medium	SES	INS FLO
Texas crab apple	*Malus ioensis var. texana*	-2.19	-2.14	2.56	Low		FLO AIP COL EHS
Texas kidneywood	*Eysenhardtia texana*	-1.02	0.75	4.09	Medium	DRO EHS	FLO AIP COL
Texas live oak	*Quercus fusiformis*	-1.87	3	4.86	High	FTK SES VRE FRG	DISE INS FLO AIP
Texas madrone	*Arbutus xalapensis*	-1.02	1.29	4.54	High	DRO	FLO AIP SES
Texas mountain laurel	*Dermatophyllum secundiflorum*	-0.1	1.29	4.43	Medium	DRO EHS DISP	AIP
Texas mulberry	*Morus microphylla*	-1.73	1	3.93	Medium	COL	AIP
Texas persimmon	*Diospyros texana*	-1.1	3.54	5.31	High	COL EHS DISP	AIP
Texas pistache	*Pistacia mexicana*	-0.52	0.86	4.13	Medium	DRO	DISE AIP
Texas red (Buckley) oak	*Quercus buckleyi*	-1.48	1	4.13	Medium	TEM VRE SES FRG	DISE FLO FTK DISP
Texas redbud	*Cercis canadensis var. texensis*	-1.42	1	3.97	Medium	DRO	FLO AIP
velvet ash	*Fraxinus velutina*	-0.25	0	3.93	Medium	DRO AIP SES	INS WIN COL VRE
water oak	*Quercus nigra*	-1.6	0.75	3.93	Medium	FLO	DISE FTK AIP COL
Western soapberry	*Sapindus saponaria var. drummondii*	1.56	-1	4.49	Medium	DRO FLO AIP DISP VRE	FTK EHS SES
white mulberry[i]	*Morus alba*	0.13	2.46	4.98	High	DISP SES	
winged elm	*Ulmus alata*	0	0	0	Medium	FLO COL	DISE AIP
yaupon	*Ilex vomitoria*	-0.5	4	5.68	High	COL ESP EHS DISP SES	AIP

Native species with high adaptability scores include sugarberry, sumac species, boxelder, possumhaw, roughleaf dogwood, southern live oak, yaupon, cedar elm, and hoptree/wafer ash.

Overall Vulnerability of the Austin Region's Trees

Vulnerability is the susceptibility of a system to the adverse effects of climate change (Parry, Canziani, Palutikof, Van der Linden, & Hanson, 2007). Vulnerability is a function of potential climate change impacts and the adaptive capacity of the system. Overall vulnerability of trees in the Austin region was estimated by considering the impacts on individual tree species using changes in heat and hardiness zone and species range limits (climate change effect column in table 3.2), together with the adaptive capacity of tree species as described in the previous section (adapt class in Tables 3.4 and 3.5) in a matrix (Table 3.6).

One hundred two species and cultivars were evaluated for their vulnerability, of which 58 were recorded as being present in the 2014 urban FIA data collection (Nowak et al., 2016). This overall approach is meant to give a coarse picture of vulnerability, and readers should consider the relative confidence in vulnerability estimates based on the level of information available.

Each species was given a separate vulnerability rating for natural areas versus planted/developed sites (Table 3.7). For natural areas, the most vulnerable species were American smoketree, bastard oak, black willow, and Texas red oak. These species make up a small proportion (less than 2 percent) of the total trees in Austin based on the recent urban FIA assessment. The least vulnerable species, making up about 11 percent of the total trees in Austin, included Texas persimmon, Texas Hercules' club (prickly-ash, tickle-tongue), lotebush, and several sumac species. Also rated as having low vulnerability were several non-native invasive species (chinaberry, paper mulberry, privet species) and species native to areas farther south (Mexican redbud, Mexican sycamore). The majority of the trees present in Austin fell into the moderately vulnerable category, in large part because Ashe juniper and cedar elm are in that category.

Many of the species rated as having high vulnerability in natural areas were also vulnerable in planted and developed sites. However, species less adapted to urban sites also were listed as highly vulnerable (e.g., post oak, black walnut, black hickory, and eastern cottonwood). In developed sites, native species considered to have low vulnerability included Texas mountain laurel, Mexican white oak, Jerusalem thorn (retama), red bay, Eve's necklace, Mexican buckeye,

Table 3.6
Vulnerability scoring matrix based on Brandt et al. (2017)

Climate Change Effect	**Adapt Class**		
	Low	Medium	High
Negative	High Vulnerability	Moderate-high Vulnerability	Moderate Vulnerability
No Effect	Moderate-high Vulnerability	Moderate Vulnerability	Low-moderate Vulnerability
Positive	Moderate Vulnerability	Low-moderate Vulnerability	Low Vulnerability

Table 3.7
Vulnerability Ratings for Natural and Developed Areas for Trees in the Austin Region. Estimated number of trees is based on 2014 Urban FIA sample (Nowak et al., 2016)

Common Name	**Scientific Name**	**Estimated Trees Present in Austin**	**Vulnerability in Natural Areas**	**Vulnerability in Developed Areas**
American elm	*Ulmus americana*	72,039	Moderate	Moderate-High
American smoketree	*Cotinus obovatus*		High	High
American sycamore	*Platanus occidentalis*	132,468	Moderate-High	Moderate-High
Anacacho orchid tree	*Bauhinia lunarioides*		Moderate	Low-Moderate
Arizona walnut	*Juglans major*		Moderate-High	Moderate-High
Arroyo sweetwood	*Myrospermum sousanum*		Low-Moderate	Low-Moderate
Ashe juniper	*Juniperus ashei*	13,315,759	Moderate	Moderate-High

Common Name	Scientific Name	Estimated Trees Present in Austin	Vulnerability in Natural Areas	Vulnerability in Developed Areas
Asian persimmon	*Diospyros kaki*		Moderate-High	Moderate-High
bald cypress	*Taxodium distichum*	12,725	Moderate-High	Moderate
bastard oak	*Quercus sinuata var. sinuata*	166,563	High	High
black hickory	*Carya texana*		Moderate-High	High
black walnut	*Juglans nigra*	105,106	Moderate-High	High
black willow	*Salix nigra*		High	High
blackjack oak	*Quercus marilandica*		Moderate	Moderate-High
boxelder	*Acer negundo*	367,930	Moderate	Moderate-High
Brazilian bluewood	*Condalia hookeri var. hookeri*		Low-Moderate	Low-Moderate
bur oak	*Quercus macrocarpa*	6,363	Moderate	Moderate
Carolina basswood	*Tilia americana var. caroliniana*		High	Moderate-High
Carolina buckthorn	*Frangula caroliniana*		Moderate-High	Moderate-High
catclaw	*Senegalia roemeriana (acacia roemeriana)*		Low-Moderate	Low-Moderate
catclaw mimosa (fragrant mimosa)	*Mimosa aculeaticarpa var. biuncifera*		Low-Moderate	Low-Moderate
cedar elm	*Ulmus crassifolia*	4,583,201	Moderate	Moderate
cherry laurel	*Prunus caroliniana*	78,107	Moderate	Moderate
Chinaberry	*Melia azedarach*	538,729	Low	Low-Moderate
Chinese elm (lacebark elm)	*Ulmus parvifolia*	78,107	Moderate	Moderate
Chinese pistache	*Pistacia chinensis*	17,322	Moderate	Moderate
Chinese privet	*Ligustrum sinense*	123,994	Low	Moderate-High
Chinese tallowtree	*Triadica sebifera*	28,029	Moderate	Moderate
chinkapin oak	*Quercus muehlenbergii*	10,959	Moderate-High	Moderate-High
chittamwood (gum bumelia)	*Sideroxylon lanuginosum*	89,955	Moderate-High	Moderate
common hoptree (wafer ash)	*Ptelea trifoliata*		Moderate-High	Moderate-High
crape myrtle	*Lagerstroemia indica*	174,401	Moderate	Moderate
desert willow	*Chilopsis linearis*		Low-Moderate	Low-Moderate
Eastern cottonwood	*Populus deltoides*	15,862	Moderate-High	High
Eastern red cedar	*Juniperus virginiana*	38,457	Moderate-High	Moderate
Eastern redbud	*Cercis canadensis*	6,248	Moderate	Moderate
edible fig	*Ficus carica*	22,984	Moderate-High	Moderate-High

Common Name	Scientific Name	Estimated Trees Present in Austin	Vulnerability in Natural Areas	Vulnerability in Developed Areas
escarpment black cherry	*Prunus serotina var. eximia*		Moderate	High
Eve's necklace	*Styphnolobium affine*		Low-Moderate	Low
evergreen sumac	*Rhus virens*		Low	Low-Moderate
fragrant sumac (skunkbush sumac)	*Rhus aromatica*		Low	Low
glossy privet	*Ligustrum lucidum*	623,890	Moderate	Moderate
goldenrain tree	*Koelreuteria paniculata*	6,363	N/A	N/A
green ash	*Fraxinus pensylvanica*	751,788	Moderate-High	Moderate-High
honey mesquite	*Prosopis glandulosa*	655,950	Low	Low-Moderate
Japanese privet	*Ligustrum japonicum*	17,322	Low	Low-Moderate
Jerusalem thorn (retama)	*Parkinsonia aculeata*	10,199	Low-Moderate	Low
lacey oak	*Quercus laceyi*		Moderate-High	Moderate
Lindheimer's silktassel	*Garrya ovata var. lindheimeri*		Low-Moderate	Low-Moderate
little walnut	*Juglans microcarpa*		Moderate-High	Moderate-High
littleleaf (goldenball leadtree)	*Leucaena retusa*		Moderate-High	Moderate-High
loquat	*Eriobotrya japonica*	312,427	Moderate	Moderate
lotebush	*Ziziphus obtusifolia*		Low	Low-Moderate
Mexican ash (berlandier ash)	*Fraxinus berlandieriana*	184,758	Low-Moderate	Low-Moderate
Mexican buckeye	*Ungnadia speciosa*		Moderate	Low
Mexican olive	*Cordia boissieri*		Low-Moderate	Moderate
Mexican plum	*Prunus mexicana*		Moderate-High	Moderate
Mexican redbud	*Cercis canadensis L. var. mexicana*		Low	Low-Moderate
Mexican sycamore	*Platanus mexicana*		Low	Low-Moderate
Mexican white oak	*Quercus polymorpha*	84,966	Low-Moderate	Low
Meyer lemon	*Citrus meyeri*		Low-Moderate	Low-Moderate
mimosa (silktree)	*Albizia julibrissin*	4,720	Moderate	High
mockernut hickory	*Carya tomentosa*		Moderate-High	Moderate-High
Montezuma cypress	*Taxodium mucronatum*		Moderate	Low-Moderate
northern hackberry	*Celtis occidentalis*	161,569	Moderate	Moderate
Osage orange	*Maclura pomifera*		Moderate	Moderate
paper mulberry	*Broussonetia papyrifera*	335,755	Low	Low-Moderate

Common Name	Scientific Name	Estimated Trees Present in Austin	Vulnerability in Natural Areas	Vulnerability in Developed Areas
pecan	*Carya illinoinensis*	196,132	Moderate-High	Moderate-High
pomegranate	*Punica granatum*		Moderate-High	Moderate
possumhaw (deciduous holly)	*Ilex decidua*		Moderate	Moderate
post oak	*Quercus stellata*	86,286	Moderate-High	High
prairie sumac (flameleaf sumac)	*Rhus lanceolata*	77,093	Low	Low
red bay	*Persea borbonia*		Low-Moderate	Low
red buckeye	*Aesculus pavia var. pavia*		Moderate	Moderate-High
red mulberry	*Morus rubra*	124,975	Moderate-High	Moderate-High
roughleaf dogwood	*Cornus drummondii*	59,882	Moderate	Moderate
rusty blackhaw	*Viburnum rufidulum*		Moderate-High	Moderate-High
Shumard oak	*Quercus shumardii*	43,137	Moderate-High	Moderate-High
slippery elm	*Ulmus rubra*	12,725	Moderate	Moderate-High
Southern live oak (coast live oak)	*Quercus virginiana*	2,862,523	Low-Moderate	Low-Moderate
Southern magnolia	*Magnolia grandiflora*	6,363	Moderate	Moderate-High
sugarberry	*Celtis laevigata*	2,058,386	Moderate	Moderate-High
sweet acacia (huisache)	*Vachellia farnesiana (acacia farnesiana)*	4,597	Moderate	Moderate
sweetgum	*Liquidambar styraciflua*		Moderate	Moderate-High
Texas ash	*Fraxinus albicans*	438,216	Moderate-High	Moderate
Texas crab apple	*Malus ioensis var. texana*		Moderate-High	Moderate
Texas Hercules' club (prickly-ash, tickle-tongue)	*Zanthoxylum hirsutum*		Low	Low-Moderate
Texas kidneywood	*Eysenhardtia texana*		Low-Moderate	Low-Moderate
Texas live oak (escarpment live oak, plateau live oak)	*Quercus fusiformis*	101,848	Moderate	Moderate-High
Texas madrone	*Arbutus xalapensis*	6,189	Moderate-High	Low-Moderate
Texas mountain laurel	*Dermatophyllum secundiflorum*	648,060	Low-Moderate	Low
Texas mulberry	*Morus microphylla*		Low-Moderate	Moderate
Texas persimmon	*Diospyros texana*	2,014,199	Low	Low-Moderate
Texas pistache	*Pistacia mexicana*		Low-Moderate	Low-Moderate
Texas red oak	*Quercus buckleyi*	419,812	High	Moderate-High
Texas redbud	*Cercis canadensis var. texensis*		Low-Moderate	Low-Moderate

Common Name	Scientific Name	Estimated Trees Present in Austin	Vulnerability in Natural Areas	Vulnerability in Developed Areas
velvet ash	*Fraxinus velutina*	59,326	Moderate-High	Moderate-High
water oak	*Quercus nigra*	4,597	Moderate	Moderate
Western soapberry	*Sapindus saponaria var. drummondii*	192,371	Moderate-High	Moderate
white mulberry	*Morus alba*	13,790	Moderate	High
white shin oak (scalybark oak)	*Quercus sinuata var. breviloba*	243,656	High	High
winged elm	*Ulmus alata*	134,185	Moderate-High	Moderate-High
yaupon	*Ilex vomitoria*	833,143	Moderate	Moderate

and Texas persimmon. Only 3% of the trees estimated to be present in Austin based on the most recent Urban FIA estimate were considered to have low vulnerability in developed areas.

Summary

Results from species distribution modeling suggest that habitat suitability for many tree species found in the Austin area may shift across the region, leading to declines in some species and increases in others. Species at the southern and western extent of their range are generally projected to decline in suitable habitat. Species at the northern and eastern extent of their range or currently native to areas south could experience an increase in suitable habitat, especially in areas where there is an urban heat island effect. Factors not included in the models, such as changes in extreme events, insects, and diseases, may also affect the survival of particular trees and make them more or less adaptable to climate change–induced pressures than the species

Key Points

- Modeling Native Trees: Species distribution modeling of native species suggests that suitable habitat may decrease for 14 of 31 primarily northern species and remain stable for 10 species. Suitable habitat was expected to increase for four species.
- Projected Changes from Heat and Hardiness Zone Shifts and Species Ranges: For species for which no model information is available (rare, non-native, or cultivars), shifts in heat and hardiness zones could have a positive effect on 23 species, while 60 species had either hardiness zone, heat zone, or range limits (or a combination thereof) that may suggest a negative effect.
- Adaptive Capacity of Urban Trees: Adaptive capacity of 104 species was evaluated using scoring systems for planted and natural environments, with many non-native invasive species among those with the highest capacity to adapt to a range of stressors. For planted/developed conditions, 29 species received a high adaptability score, 18 received a low adaptability score, and the remaining 57 received a medium adaptability score. For natural areas (both native and naturalized), 43 species received a high adaptability score, 13 received a low adaptability score, and 48 received a medium adaptability score.
- Overall Vulnerability of the Austin Region's Trees: An analysis of vulnerability that combines model projections, shifts in heat and hardiness zones, and adaptive capacity showed that in planted and developed sites many of the same species rated as having high vulnerability in natural areas were also vulnerable in urban areas. Species that were less adapted to urban sites were also listed as vulnerable, indicating that a greater proportion of trees were considered vulnerable in developed sites.

distribution models otherwise suggest. Going forward, the vulnerability of trees and the surrounding urban forest will need to be gauged based on the complex interaction of multiple stressors and benefits.

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