United States Department of Agriculture

Austin's Urban Forest, 2014 Appendix

APPENDIX 1—Urban FIA

Sampling Design

The FIA program maintains a systematic grid of permanent plots (FIA core plots) across the United States that is used to inventory and monitor the nation's forests (Reams et al. 2005). The urban FIA inventory uses the same sampling frame as the core FIA program and data are used to produce estimates of the quantity, health, composition, and benefits of urban trees. The urban FIA protocol follows a city-based model where urban inventory plots are located in the U.S. Census-defined urban areas and urban clusters (UAUC), within a chosen core-based statistical area (CBSA). Austin city limits are defined by the 2010 U.S. Census.

There are two zones of interest in the urban FIA sample design (Fig. 33). Urban FIA plots within the CBSA-confined UAUC boundaries are established at the same location as the FIA core plots and tree measurements are taken at all sample sites regardless of whether they are forested or not. Collocated urban plots are measured at the same intensity and on the same time line as the rest of the FIA core plots in the region.

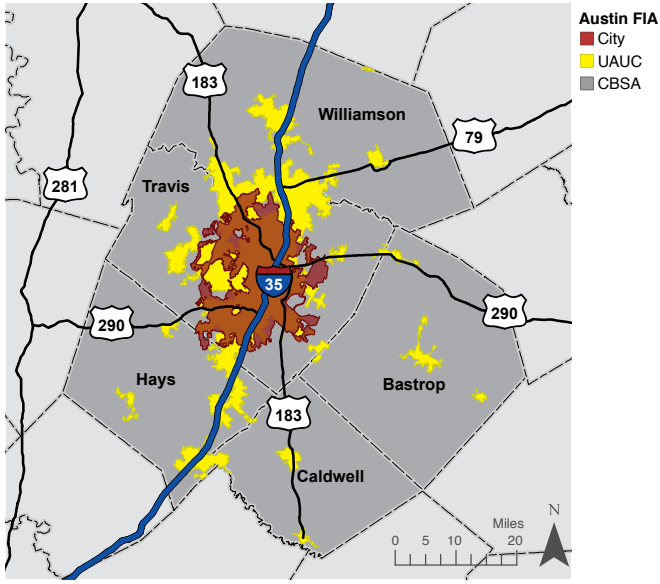

Figure 33.—Location of Austin city boundary and urban areas and urban clusters (UAUC), within the Austin core-based statistical area (CBSA).

The second zone of interest in the urban FIA sample design is the city boundary that is associated with the chosen CBSA. Urban plots within the city boundary may include some plots that are collocated with established core FIA plots, but also consist

of an intensified set of urban-design only plots. In general, sampling within the target city will be intensified to the point of reaching a total of about 200 plots.

In Austin, there were 66 established FIA core plots within the CBSA-confined UAUC boundary. Six of these plots were being sampled in the year of the study (i.e., 2014 field season), but only four were located in the Austin city boundaries. Intensification within Austin city boundaries added 219 additional urban plots, bringing the total number of urban FIA plots to 223. The estimates contained within this report are based only on that sample of 223 plots in the city boundaries of Austin.

Data Collection

With the support from state and city cooperators, data collection on the intensified plots in Austin was accelerated so all data collection took place during the 2014 field season. Ordinarily, under the standard urban FIA protocol, the intensified plots within the city limits are measured on the same timeline as core FIA plots in the state, using the FIA panel system (Ream et al. 2005). The proportion of the total sample plots measured in a given year is related to the cycle length. States with a cycle length of 10 years will have one-tenth of the total number of plots sampled each year, and remeasurement will begin in the 11th year. The Austin urban plots will be remeasured on a 10-year cycle, as are the FIA core plots in western and central Texas.

As data collection continues annually, there will be additional data collected in the CBSA-confined UAUC boundary and analysis and reporting will be expanded to include this new urban zone. Annual plot remeasurements will also begin on a portion of intensified plots within the city beginning in the 2015 field season, allowing for urban monitoring and analyses of change in future reports.

Plot Layout

Each urban forest inventory plot consisted of one circular plot 1/6 acre in size with a radius of 48 feet (See Fig. 3 in main document). Each plot contained four nested microplots; each 1/300 acre in size, with a radius of 6.8 feet and offset 12 feet horizontal in each cardinal direction from the plot center. Urban FIA and core FIA plot layouts are the same in total sampled area but differ in configuration. The single circular urban plot has the same total area as the FIA core plot consisting of a cluster of four subplots. The urban nested microplots are the equivalent of the nested microplots of an FIA core plot, with each being the same diameter. For more details on the FIA core plot layout, see Bechtold and Scott (2005).

APPENDIX 2—Species Sampled in the Austin Urban Forest

Table 20.— Scientific and common names of tree species sampled in the urban forest, with estimated metrics for species, Austin, 2014

Genus	Species	Common name	Trees		Leaf area	IV[a]	Diameter[b]		Basal area[c]	Structural value
							Median	Average		
			number	*%*	*%*		*inches*	*inches*	*ft²*	*$ millions*
Acacia	*farnesiana*	sweet acacia	5,000	0.0	0.0	0.0	5.5	5.5	1,000	1
Acer	*negundo*	boxelder	368,000	1.1	1.5	2.6	1.8	4.2	79,000	81
Albizia	*julibrissin*	mimosa*	5,000	0.0	0.1	0.1	5.5	5.5	1,000	3
Arbutus	*xalapensis*	Texas madrone	6,000	0.0	0.0	0.0	7.5	7.5	2,000	1
Betula	*nigra*	river birch	60,000	0.2	0.1	0.3	1.5	1.5	1,000	4
Broussonetia	*papyrifera*	paper mulberry*	336,000	1.0	0.9	1.9	2.7	4.7	71,000	155
Carya	*illinoinensis*	pecan	196,000	0.6	2.1	2.7	12.8	13.6	259,000	551
Celtis	*laevigata*	sugarberry	2,059,000	6.1	7.4	13.5	1.8	3.5	442,000	494
Celtis	*occidentalis*	northern hackberry	162,000	0.5	0.7	1.2	5.3	5.8	53,000	73
Cercis	*canadensis*	eastern redbud	6,000	0.0	0.0	0.0	11.5	11.5	5,000	10
Cornus	*drummondii*	roughleaf dogwood	60,000	0.2	0.0	0.2	1.5	1.5	1,000	0
Diospyros	*texana*	Texas persimmon	2,016,000	6.0	1.2	7.2	1.7	1.8	63,000	89
Eriobotrya	*japonica*	loquat tree	313,000	0.9	0.4	1.3	2.0	2.0	11,000	22
Ficus	*carica*	common fig	23,000	0.1	0.1	0.2	6.2	6.1	5,000	20
Fraxinus	*berlandieriana*	Mexican ash	185,000	0.5	0.8	1.3	1.8	4.9	53,000	107
Fraxinus	*pennsylvanica*	green ash	751,000	2.2	2.8	5.0	4.1	5.0	161,000	226
Fraxinus	*texensis*	Texas ash	438,000	1.3	0.8	2.1	1.9	3.0	45,000	94
Fraxinus	*velutina*	velvet ash	59,000	0.2	0.4	0.6	8.4	10.9	54,000	120
Ilex	*vomitoria*	yaupon	834,000	2.5	0.2	2.7	1.5	1.5	19,000	46
Juglans	*nigra*	black walnut	105,000	0.3	0.5	0.8	0.0	4.4	26,000	50
Juniperus	*ashei*	Ashe juniper	13,300,000	39.3	41.2	80.5	5.1	6.0	4,351,000	6,369
Juniperus	*virginiana*	eastern red cedar	38,000	0.1	0.1	0.2	6.3	6.3	10,000	9
Koelreuteria	*paniculata*	goldenrain tree	6,000	0.0	0.0	0.0	6.5	6.5	2,000	3
Lagerstroemia	*indica*	common crapemyrtle	175,000	0.5	0.6	1.1	5.3	6.9	67,000	156
Ligustrum	*japonicum*	Japanese privet*	17,000	0.1	0.2	0.3	9.5	10.2	13,000	34
Ligustrum	*lucidum*	glossy privet*	624,000	1.8	0.7	2.5	2.1	3.0	81,000	134
Ligustrum	*sinense*	Chinese privet*	124,000	0.4	0.5	0.9	9.2	9.7	81,000	171
Magnolia	*grandiflora*	southern magnolia	6,000	0.0	0.0	0.0	6.5	6.5	2,000	5
Melia	*azedarach*	chinaberry*	539,000	1.6	1.2	2.8	2.0	3.4	86,000	155
Morus	*alba*	white mulberry*	14,000	0.0	0.1	0.1	5.5	5.5	3,000	8
Morus	*rubra*	red mulberry	125,000	0.4	0.6	1.0	2.0	2.3	7,000	10
Parkinsonia	*aculeata*	Jerusalem thorn	10,000	0.0	0.0	0.0	5.5	5.5	2,000	4
Pistacia	*chinensis*	Chinese pistache*	17,000	0.1	0.1	0.2	8.4	9.2	9,000	20
Platanus	*occidentalis*	American sycamore	132,000	0.4	1.2	1.6	5.3	6.8	48,000	93
Populus	*deltoides*	eastern cottonwood	16,000	0.0	0.6	0.6	30.4	30.9	86,000	125
Prosopis	*glandulosa*	honey mesquite	655,000	1.9	1.4	3.3	6.0	6.4	218,000	249
Prunus	*laurocerasus*	common cherry laurel	78,000	0.2	0.1	0.3	1.5	1.5	2,000	4
Prunus	*species*	plum spp	5,000	0.0	0.0	0.0	6.5	6.5	1,000	4
Quercus	*buckleyi*	Buckley oak	419,000	1.2	2.9	4.1	7.9	8.6	210,000	539
Quercus	*fusiformis*	plateau oak	102,000	0.3	0.2	0.5	2.7	4.3	19,000	31
Quercus	*macrocarpa*	bur oak	6,000	0.0	0.0	0.0	9.5	9.5	4,000	10
Quercus	*muehlenbergii*	chinkapin oak	11,000	0.0	0.1	0.1	8.1	7.3	4,000	11
Quercus	*nigra*	water oak	5,000	0.0	0.1	0.1	14.5	14.5	6,000	14

(Table 20 continued on next page)

(Table 20 continued)

Genus	Species	Common name	Trees		Leaf area	IV[a]	Diameter[b] Median	Diameter[b] Average	Basal area[c]	Structural value
			number	*%*	*%*		*inches*	*inches*	*ft²*	*$ millions*
Quercus	*polymorpha*	netleaf white oak	85,000	0.3	0.3	0.6	4.5	4.5	12,000	27
Quercus	*shumardii*	shumard oak	43,000	0.1	0.6	0.7	14.1	14.2	60,000	164
Quercus	*sinuata*	bastard oak[d]	410,000	1.2	0.4	1.6	1.9	2.8	31,000	42
Quercus	*stellata*	post oak	86,000	0.3	0.2	0.5	1.6	4.3	42,000	95
Quercus	*texana*	Texas red oak	5,000	0.0	0.2	0.2	47.5	47.5	59,000	146
Quercus	*virginiana*	live oak	2,859,000	8.4	13.1	21.5	6.7	7.9	1,564,000	3,442
Rhus	*lanceolata*	prairie sumac	77,000	0.2	0.1	0.3	2.5	2.5	4,000	5
Sapindus	*saponaria*	wingleaf soapberry	193,000	0.6	0.3	0.9	1.8	2.5	11,000	24
Sideroxylon	*lanuginosum*	gum bully	90,000	0.3	0.2	0.5	1.8	2.9	8,000	19
Sophora	*secundiflora*	mescalbean	649000	1.9	0.4	2.3	1.7	1.8	20,000	48
Taxodium	*distichum*	baldcypress	13,000	0.0	0.2	0.2	10.0	10.0	8,000	20
Thrinax	*radiata*	Florida thatchpalm	5,000	0.0	0.0	0.0	20.5	20.5	11,000	6
Triadica	*sebifera*	tallowtree*	28,000	0.1	0.1	0.2	7.7	11.0	25,000	31
Ulmus	*alata*	winged elm	134,000	0.4	0.2	0.6	3.1	2.9	10,000	14
Ulmus	*americana*	American elm	72,000	0.2	0.4	0.6	8.8	9.4	42,000	35
Ulmus	*crassifolia*	cedar elm	4,585,000	13.5	10.9	24.4	2.3	3.5	720,000	1,528
Ulmus	*parvifolia*	Chinese elm	78,000	0.2	0.1	0.3	2.5	2.5	4,000	6
Ulmus	*rubra*	slippery elm	13,000	0.0	0.1	0.1	5.5	5.5	3,000	6
Unknown	species	unknown species	6,000	0.0	0.0	0.0	8.5	8.5	3,000	9

[a] IV = importance value (% population + % leaf area)

[b] Diameter measurements were taken at breast height (d.b.h.) or root collar (d.r.c.) for woodland species

[c] Basal area is the cross sectional area of the tree stems measured at the diameter

[d] *Quercus sinuata* includes multiple varieties that may be known by other common names, e.g., Durand oak

* invasive species

APPENDIX 3—Land Cover Category Descriptions

Land cover locations and definitions are based on the 2011 National Land Cover Database (Homer at al. 2015).

Table 21.—Land cover categories and descriptions (from Homer et al. 2015)

Land cover category	NLCD code	NLCD class	Land cover description
Water/Barren	11	Open Water	Areas of open water, generally with less than 25% cover of vegetation or soil.
	31	Barren Land	Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
	95	Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Developed—Open	21	Developed, Open Space	Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
Developed—Low	22	Developed, Low Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
Developed—Medium	23	Developed, Medium Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
Developed—High	24	Developed, High Intensity	Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
Deciduous/Mixed Forest	41	Deciduous Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
	43	Mixed Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
	90	Woody Wetlands	Areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Evergreen Forest	42	Evergreen Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
Shrub/Herbaceous	52	Shrub/Scrub	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
	71	Grassland/Herbaceous	Areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
	81	Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
	82	Cultivated Crops	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

APPENDIX 4—Tree Species Distribution

This appendix illustrates various species distributions for the Austin urban forest. During field data collection, sampled trees are identified to the most specific classification possible. Some trees have been identified to the species or genus level. The species distributions for each land cover are illustrated for the 20 most common species or all species if there are less than 20 species in the land cover category.

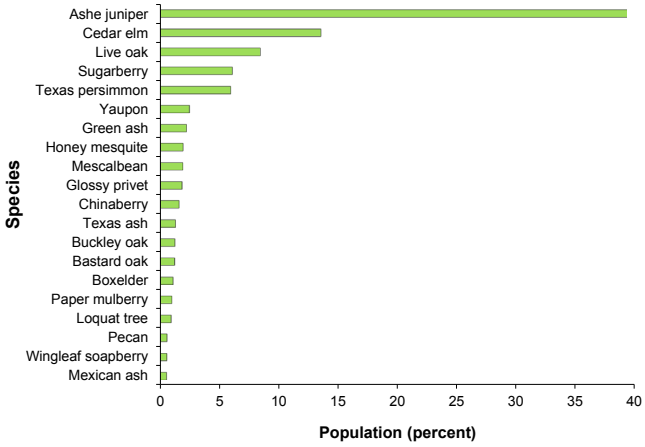

Figure 34.—The 20 most common tree species as a percent of the total urban tree population, Austin, 2014.

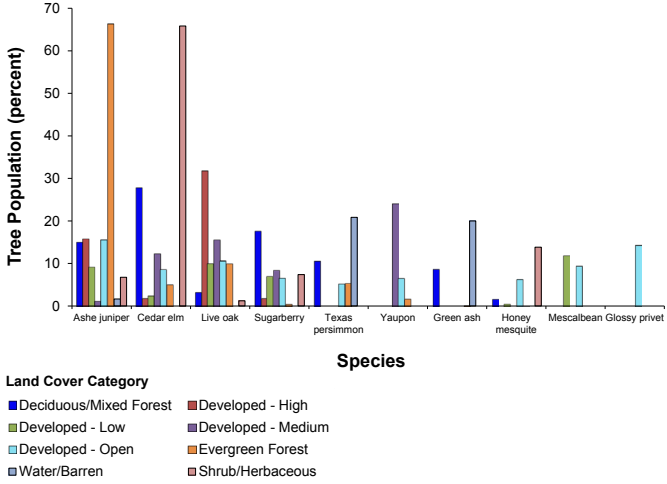

Figure 35.—Proportion of the total tree population found in each land cover category for the 10 most common species, Austin, 2014. For example, Ashe juniper comprises 66.4 percent of the tree population in the Evergreen Forest land cover.

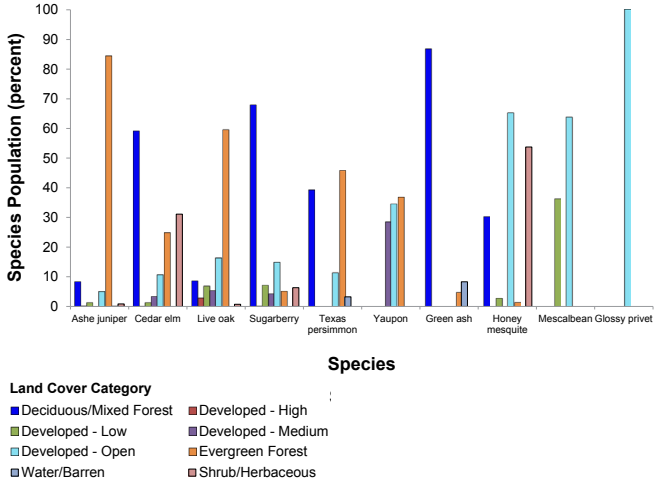

Figure 36.—Distribution of each species' total citywide population among each land cover category for the 10 most common species, Austin, 2014. For example, 84.5 percent of Ashe juniper in Austin is located in the Evergreen Forest land cover.

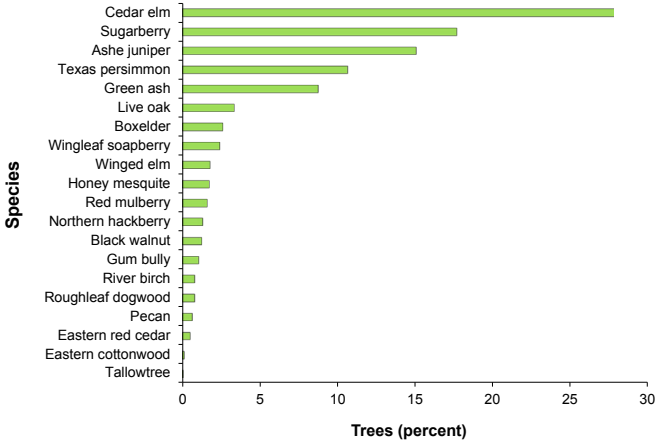

Figure 37.—Percentage of trees in Deciduous/Mixed Forest land cover category, Austin, 2014.

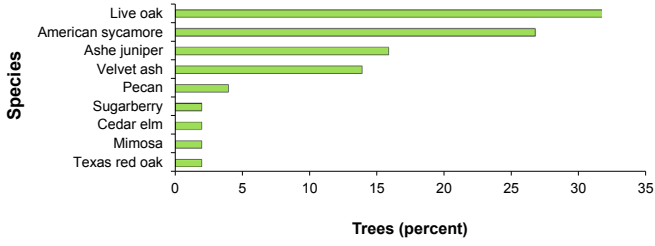

Figure 38.—Percentage of trees in Developed–High land cover category, Austin, 2014.

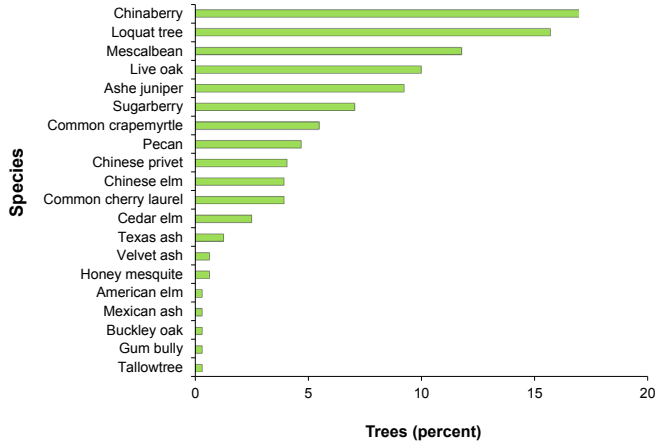

Figure 39.—Percentage of trees in Developed–Low land cover category for the 20 most common trees in that category, Austin, 2014.

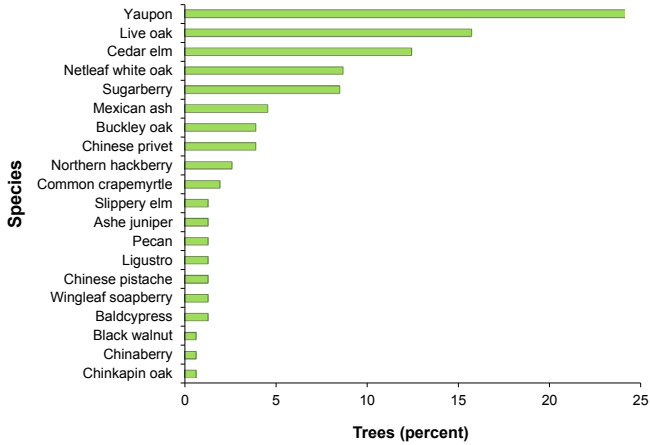

Figure 40.—Percentage of trees in Developed–Medium land cover category for the 20 most common trees in that category, Austin, 2014.

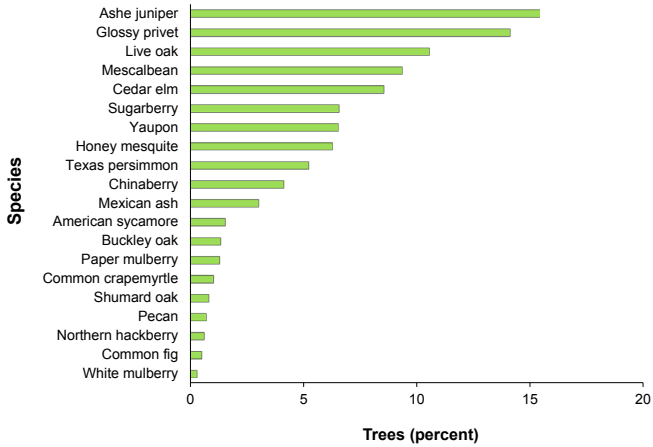

Figure 41.—Percentage of trees in Developed–Open land cover category for the 20 most common trees in that category, Austin, 2014.

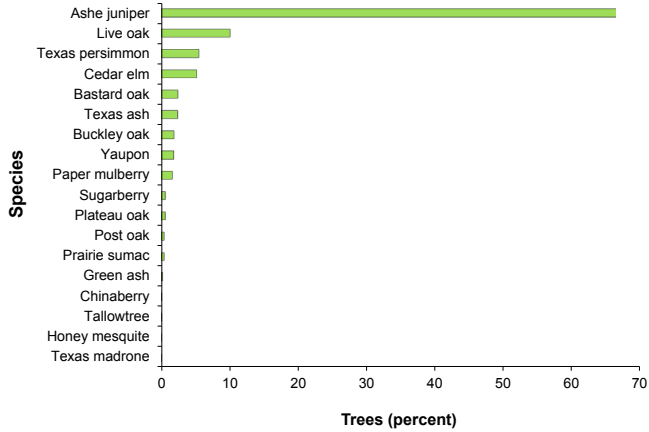

Figure 42.—Percentage of trees in Evergreen Forest land cover category, Austin, 2014.

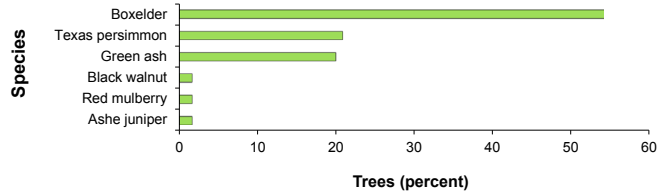

Figure 43.—Percentage of trees in Water/Barren land cover category, Austin, 2014.

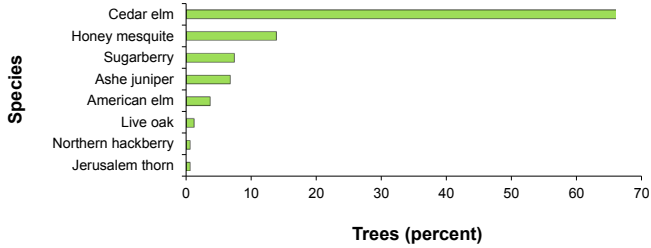

Figure 44.—Percentage of trees in Shrub/Herbaceous land cover category, Austin, 2014.

APPENDIX 5—Relative Tree Effects

The urban forest in Austin provides benefits that include carbon storage, carbon sequestration, and air pollutant removal. These benefits vary across diameter classes (Table 22). The relative value of tree benefits is calculated to show how carbon storage and sequestration, and air pollutant removal equate to municipal carbon emissions, passenger automobile emissions, and household emissions.

General tree information:
Average tree diameter = 5.0 in.
Median tree diameter = 3.3 in.
Number of live trees sampled = 2,325
Number of species sampled = 62

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (World Bank 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (grams/mile) for carbon monoxide (CO), nitrogen oxides (NOx), VOCs, particulate matter less than 10 microns (PM_{10}), SO_2 for 2010 (Heirigs et al. 2004, U.S. Bureau of Transportation Statistics 2010), and CO_2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (U.S. Federal Highway Administration 2013) to determine average emissions per vehicle.

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

CO_2, SO_2, and NOx power plant emission per KWh are from Leonardo Academy (2011). CO emission per kWh assumes one-third of 1 percent of C emissions is CO based on U.S. Energy Information Administration (1994).

CO_2, NOx, SO_2, and CO emission per Btu for natural gas, propane, and butane (average used to represent LPG), Fuel #4, and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy (2011).

CO_2 emissions per Btu of wood from U.S. Energy Information Administration (2014a).

CO, NOx, and sulfur oxides (SOx) emission per Btu based on total emissions and wood burning (tons) from British Columbia Ministry (2005), and Georgia Forestry Commission (2009).

Total annual pollution removal per pollutant was contrasted with annual emissions per city, vehicle and household to determine offset equivalents of urban forests vs. city, vehicle and household emissions.

The trees in Austin provide:

Carbon storage equivalent to:

Amount of carbon (C) emitted in the city in 152 days, or

Annual C emissions from 1,353,000 automobiles, or

Annual C emissions from 554,700 single family houses

Nitrogen dioxide removal equivalent to:

Annual nitrogen dioxide emissions from 12,300 automobiles, or

Annual nitrogen dioxide emissions from 5,500 single family houses

Sulfur dioxide removal equivalent to:

Annual sulfur dioxide emissions from 248,400 automobiles, or

Annual sulfur dioxide emissions from 700 single family houses

Annual carbon sequestration equivalent to:

Amount of C emitted in the city in 7 days, or

Annual C emissions from 64,900 automobiles, or

Annual C emissions from 26,600 single family home

Table 22.—Average tree effects by tree diameter class, Austin, 2014

Diameter [a]	Carbon storage			Carbon sequestration			Pollution removal	
inch	*lbs*	*$*	*miles*[b]	*lbs/yr*	*$/yr*	*miles*[b]	*lbs/yr*	*$/yr*
2	5	0.34	22	1.3	0.08	5	0.02	0.02
4	26	1.62	102	3.0	0.19	12	0.05	0.05
6	67	4.20	266	5.2	0.33	21	0.07	0.08
8	126	8.00	507	7.3	0.46	29	0.11	0.12
10	207	13.08	829	10.4	0.66	42	0.15	0.17
12	337	21.34	1,352	15.6	0.99	63	0.22	0.24
14	492	31.11	1,971	20.3	1.28	81	0.26	0.29
16	706	44.65	2,828	25.6	1.62	103	0.35	0.38
18	949	59.96	3,799	31.1	1.97	125	0.42	0.46
20	1,218	76.97	4,876	39.3	2.49	158	0.36	0.40
22	2,054	129.83	8,224	63.4	4.01	254	0.42	0.47
24	1,771	111.97	7,093	43.3	2.74	174	0.59	0.66
26	3,000	189.64	12,014	67.0	4.23	268	0.40	0.45
28	3,240	204.82	12,975	79.5	5.02	318	0.48	0.53
30+	6,453	407.93	25,842	67.1	4.24	269	0.58	0.65

[a] Diameter classes are designated by their midpoint (e.g. 2 is actually 1.0 to 2.9 inches).
Diameter measurements were taken at breast height (d.b.h.) or root collar (d.r.c.) for woodland species.

[b] miles = number of automobile miles driven that produces emissions equivalent to tree effect

APPENDIX 6—Tree Species Statistics

Table 23.—Tree statistics by land cover and species, Austin, 2014

Land cover and species	Trees	Basal Area	Diameter[a] avg	Diameter[a] median
	number	*ft²/ac*	*inches*	
Water/Barren				
Black walnut	5,196	0.27	6.5	6.5
Boxelder	168,996	13.21	6.6	6.4
Green ash	62,353	6.20	9.0	8.0
Red mulberry	5,196	0.54	9.5	9.5
Ashe juniper	5,196	0.27	6.5	6.5
Texas persimmon	65,074	0.61	2.5	2.5
Developed–Low				
American elm	6,229	0.27	15.5	15.5
Chinese elm	78,269	0.12	2.5	2.5
Ashe juniper	184,162	2.32	7.1	5.7
Pecan	93,435	2.77	11.8	10.8
Sugarberry	140,559	2.22	6.8	2.9
Mexican ash	6,229	0.21	13.5	13.5
Texas ash	24,916	0.39	9.0	9.0
Velvet ash	12,458	0.14	7.5	7.0
Common crapemyrtle	109,414	0.76	5.4	4.7
Chinese privet	80,977	1.87	10.1	7.5
Chinaberry	337,992	1.41	3.3	2.2
Honey mesquite	12,458	0.07	5.0	5.0
Buckley oak	6,229	0.52	21.5	21.5
Live oak	199,327	7.13	13.0	13.3
Gum bully	6,229	0.04	5.5	5.5
Mescalbean	234,807	0.16	1.5	1.5
Tallowtree	6,229	0.31	16.5	16.5
Cedar elm	49,832	1.19	10.9	11.0
Eastern redbud	6,229	0.15	11.5	11.5
Other species	6,229	0.09	8.5	8.5
Eastern cottonwood	6,229	0.90	28.5	28.5
Loquat tree	313,076	0.35	2.0	2.0
Common cherry laurel	78,269	0.05	1.5	1.5
Developed–Medium				
Black walnut	6,427	0.20	13.5	13.5
Northern hackberry	25,707	0.21	6.5	5.7
Slippery elm	12,854	0.07	5.5	5.5
Ashe juniper	12,854	0.09	6.0	6.0
Pecan	12,854	0.38	13.0	13.0
Sugarberry	83,549	1.43	9.3	8.3
Mexican ash	44,988	1.12	11.5	11.8
Common crapemyrtle	19,280	0.12	5.8	5.7
Japanese privet	12,854	0.30	10.5	6.0
Chinese privet	38,561	0.62	9.3	10.0
Chinaberry	6,427	0.23	14.5	14.5
Chinese pistache	12,854	0.15	8.0	8.0
Buckley oak	38,561	0.90	11.2	10.0
Chinkapin oak	6,427	0.08	8.5	8.5
Shumard oak	6,427	0.07	7.5	7.5
Live oak	154,243	3.56	10.6	10.0
Cedar elm	122,109	2.17	9.3	8.3
Goldenrain tree	6,427	0.05	6.5	6.5
Southern magnolia	6,427	0.05	6.5	6.5
Bur oak	6,427	0.10	9.5	9.5
Netleaf white oak	85,327	0.34	4.5	4.5
Wingleaf soapberry	12,854	0.10	6.5	6.0
Baldcypress	12,854	0.23	10.0	10.0
Yaupon	236,701	0.15	1.5	1.5
Developed–High				
American sycamore	63,544	0.38	4.6	4.5
Ashe juniper	37,646	1.10	9.9	7.0
Pecan	9,412	0.86	18.0	11.0
Sugarberry	4,706	0.09	8.5	8.5
Velvet ash	32,941	0.95	9.5	7.8
Live oak	75,293	1.76	9.2	8.7
Cedar elm	4,706	0.07	7.5	7.5
Mimosa	4,706	0.04	5.5	5.5
Texas red oak	4,706	2.49	47.5	47.5

[a] Diameter measurements were taken at breast height (d.b.h.) or root collar (d.r.c.) for woodland species

(Table 23 continued on next page)

(Table 23 continued)

Land cover and species	Trees	Basal Area	Diameter[a] avg	Diameter[a] median
	number	*ft²/ac*	*inches*	
Developed–Open				
American sycamore	68,743	1.28	8.8	7.6
American elm	4,583	0.21	15.5	15.5
Boxelder	4,583	0.05	7.5	7.5
White mulberry	13,749	0.09	5.5	5.5
Northern hackberry	27,497	0.67	9.7	9.0
Plum spp	4,583	0.04	6.5	6.5
Ashe juniper	681,549	6.79	5.9	4.8
Sweet acacia	4,583	0.03	5.5	5.5
Pecan	32,080	1.57	15.9	16.3
Sugarberry	290,910	5.95	5.0	2.5
Common fig	22,914	0.18	6.1	6.2
Mexican ash	133,998	0.26	2.2	1.6
Texas ash	9,166	0.28	12.5	12.5
Velvet ash	13,749	0.88	17.5	14.5
Common crapemyrtle	45,829	1.26	10.9	8.7
Japanese privet	4,583	0.08	9.5	9.5
Glossy privet	624,162	2.64	3.0	2.1
Chinese privet	4,583	0.03	5.5	5.5
Chinaberry	182,666	0.31	2.2	1.8
Chinese pistache	4,583	0.14	12.5	12.5
Honey mesquite	277,810	2.69	6.5	5.8
Buckley oak	59,577	1.27	9.8	8.5
Chinkapin oak	4,583	0.03	5.5	5.5
Water oak	4,583	0.18	14.5	14.5
Shumard oak	36,663	1.88	15.4	14.5
Post oak	9,166	1.33	28.0	27.0
Live oak	466,803	11.74	9.4	8.5
Gum bully	4,583	0.03	5.5	5.5
Mescalbean	413,999	0.50	2.0	1.9
Florida thatchpalm	4,583	0.36	20.5	20.5
Tallowtree	4,583	0.33	19.5	19.5
Cedar elm	377,984	5.88	6.5	2.8
Texas persimmon	231,333	0.37	2.5	2.5
Paper mulberry	57,833	0.04	1.5	1.5
Yaupon	289,166	0.23	1.6	1.5
Shrub/Herbaceous				
American elm	61,009	0.70	8.3	8.5
Northern hackberry	10,168	0.04	4.5	4.5
Ashe juniper	111,850	2.12	10.4	9.5
Sugarberry	122,019	1.71	9.1	9.0
Honey mesquite	228,819	1.65	4.9	1.9
Live oak	20,336	0.49	12.5	12.0
Cedar elm	1,088,273	1.46	2.2	1.9
Jerusalem thorn	10,168	0.05	5.5	5.5
Evergreen Forest				
Green ash	37,021	1.08	8.3	9.0
Ashe juniper	11,144,706	229.92	6.0	5.2
Sugarberry	101,829	0.80	3.7	2.7
Texas ash	404,248	1.52	2.4	1.9
Chinaberry	12,340	1.47	18.0	16.0
Honey mesquite	6,170	0.10	6.5	6.5
Buckley oak	314,678	7.77	7.8	7.4
Post oak	77,148	0.11	1.5	1.5
Live oak	1,693,893	41.18	6.4	5.7
Tallowtree	12,340	0.21	6.5	6.0
Cedar elm	873,263	10.89	3.7	1.8
Texas persimmon	925,772	1.37	1.6	1.5
Texas madrone	6,170	0.13	7.5	7.5
Paper mulberry	277,698	4.39	5.3	2.9
Plateau oak	101,829	1.22	4.3	2.7
Bastard oak	410,419	1.92	2.8	1.9
Yaupon	308,591	0.42	1.5	1.5
Prairie sumac	77,148	0.24	2.5	2.5
Deciduous/Mixed Forest				
Black walnut	93,473	1.10	3.7	0.0
Boxelder	194,151	0.55	1.9	1.5
Green ash	651,929	7.11	4.5	3.9
Northern hackberry	98,265	1.52	4.7	1.8
River birch	59,924	0.08	1.5	1.5
Red mulberry	119,848	0.27	2.0	2.0
Winged elm	134,226	0.67	2.9	3.1
Ashe juniper	1,121,673	18.17	4.8	2.8
Pecan	47,926	5.72	15.0	8.0
Sugarberry	1,315,921	3.85	1.9	1.5
Honey mesquite	129,401	4.39	8.9	8.4
Live oak	249,217	8.90	8.6	7.1
Gum bully	79,095	0.34	2.5	1.7
Tallowtree	4,793	0.11	7.5	7.5
Cedar elm	2,068,495	12.58	3.1	2.5
Eastern cottonwood	9,585	3.64	32.5	31.0
Wingleaf soapberry	179,773	0.50	2.2	1.7
Texas persimmon	793,393	1.69	1.8	1.7
Eastern red cedar	38,341	0.61	6.3	6.3
Roughleaf dogwood	59,924	0.08	1.5	1.5

[a] Diameter measurements were taken at breast height (d.b.h.) or root collar (d.r.c.) for woodland species

APPENDIX 7—General Recommendations for Air Quality Improvement

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

- **T**emperature reduction and other microclimatic effects
- **R**emoval of air pollutants
- **E**mission of volatile organic compounds (VOC) and tree maintenance emissions
- **E**nergy conservation on buildings and consequent power plant emissions

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

Urban forest management strategies to help improve air quality include:

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

APPENDIX 8—Damage Type and Maintenance or Site Issue Statistics

Table 24.—Percentage of sampled trees identified with damage or maintenance or site issues, Austin, 2014

		Damage Variable						
Species	**Sample**	**Trunk bark inclusion**	**Root/stem girdling**	**Overhead wires**	**Topping/ pruning**	**Sidewalk-root conflict**	**Excess mulch**	**Improper planting**
	n				*percent*			
American elm	4	14.2	0.0	0.0	0.0	0.0	0.0	0.0
American sycamore	17	0.0	0.0	6.9	6.9	20.8	0.0	3.5
Mexican ash	14	34.2	0.0	13.9	0.0	13.9	13.9	0.0
Ashe juniper	1,090	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Baldcypress	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bastard oak	9	18.8	0.0	0.0	0.0	0.0	0.0	0.0
Black walnut	9	4.9	0.0	0.0	0.0	0.0	0.0	0.0
Boxelder	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Buckley oak	68	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bur oak	1	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Cedar elm	205	5.5	0.0	0.3	0.1	0.0	0.1	0.0
Chinaberry	14	26.1	0.0	1.2	0.0	0.0	0.0	0.0
Chinese elm	1	0.0	100.0	0.0	0.0	0.0	0.0	0.0
Chinese pistache	3	73.7	0.0	0.0	0.0	0.0	0.0	0.0
Chinese privet	20	0.0	0.0	15.5	0.0	0.0	0.0	5.0
Chinkapin oak	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common cherry laurel	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common crapemyrtle	19	52.7	0.0	0.0	5.3	0.0	5.3	0.0
Common fig	5	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Eastern cottonwood	3	0.0	0.0	0.0	0.0	39.4	0.0	0.0
Eastern red cedar	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eastern redbud	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Florida thatchpalm	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glossy privet	20	10.7	0.0	0.7	2.2	0.0	0.0	0.0
Goldenrain tree	1	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Green ash	56	19.1	0.0	0.0	0.0	0.0	0.0	0.0
Gum bully	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Honey mesquite	72	10.0	0.0	0.0	0.0	0.0	0.0	0.0
Jerusalem thorn	1	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Japanese privet	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Live oak	345	12.7	0.2	0.0	1.8	0.2	0.2	0.6
Loquat tree	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mescalbean	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mimosa	1	100.0	100.0	0.0	0.0	100.0	0.0	0.0
Netleaf white oak	2	0.0	0.0	0.0	7.5	0.0	0.0	0.0
Northern hackberry	16	8.8	0.0	2.8	2.8	0.0	0.0	0.0
Other species	1	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Paper mulberry	22	27.6	0.0	0.0	0.0	0.0	0.0	0.0
Pecan	35	38.6	0.0	2.4	9.5	2.3	6.4	4.7
Plateau oak	5	6.1	0.0	0.0	0.0	0.0	0.0	0.0
Plum spp	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Post oak	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prairie sumac	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Red mulberry	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(Table 24 continued on next page)

(Table 24 continued)

Species	Sample	Damage Variable						
		Trunk bark inclusion	Root/stem girdling	Overhead wires	Topping/ pruning	Sidewalk-root conflict	Excess mulch	Improper planting
	n				*percent*			
River birch	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Roughleaf dogwood	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shumard oak	9	42.5	0.0	0.0	0.0	10.6	0.0	0.0
Slippery elm	2	50.0	0.0	0.0	100.0	0.0	0.0	0.0
Southern magnolia	1	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Sugarberry	88	13.1	4.1	1.6	1.0	0.7	0.0	0.0
Sweet acacia	1	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Tallowtree	4	44.2	0.0	0.0	0.0	0.0	0.0	0.0
Texas ash	14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Texas madrone	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Texas persimmon	33	7.1	0.0	0.0	0.0	0.0	0.0	0.0
Texas red oak	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Velvet ash	12	68.2	0.0	23.9	0.0	55.7	0.0	23.2
Water oak	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
White mulberry	3	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Winged elm	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wingleaf soapberry	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yaupon	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All Trees	2,325	6.1	0.5	0.5	0.4	0.4	0.2	0.1

APPENDIX 9—Potential Insect and Disease Impacts

We evaluated 31 insects and diseases, along with their tree hosts in the city, to quantify their potential impact on the urban forest. The number of trees at risk (Table 26) reflects only the known host tree species that are likely to experience mortality.

Pest range maps (U.S. Forest Service 2014b, U.S. Forest Service 2013, Worrall 2007) were used to determine the proximity of each pest to the city. For Austin, proximity was classified for insects and diseases in Hays, Travis, or Williamson Counties, within 250 miles of any of these three counties, between 250 and 750 miles of the counties, or greater than 750 miles away. Since there are no pest range maps for Dutch elm disease and chestnut blight, the ranges of these pests were based on known occurrence and the known host range, respectively (U.S. Forest Service 2014b, U.S. Forest Service 2013, Worrall 2007).

Proximity data for eight insects and diseases, along with the numbers of trees potentially affected and their compensatory values are illustrated in Fig. 45.

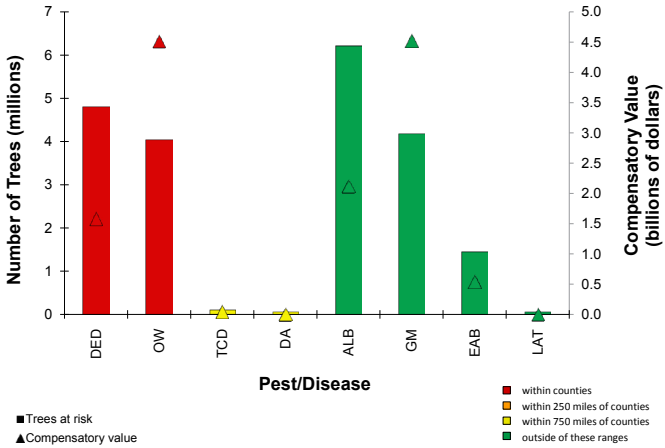

Figure 45.—Number of trees at risk of insect and disease and the associated compensatory value, Austin, 2014. This figure does not include the pests and diseases that were not a threat to any of the species sampled in the city. For a complete list of the pests and diseases assessed, see Table 25.

Based on the host tree species for each pest and the current range of the pest, it is possible to estimate the risk of attack by one of these insects or diseases for each tree species sampled in Austin. In Table 25, species risk is designated as one of the following:

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

Tree species that were sampled in Austin, but are not listed in this matrix, are not known to be hosts to any of the 31 insects and diseases evaluated. This table also excludes the pests and diseases that were not a threat to any of the species sampled in the city. For a complete list of the pests and diseases assessed, see Table 26. Tree species groups with the greatest risk to existing pest infestations in Austin are oaks and elms.

Table 25.—Potential insect and disease risk for tree species, Austin, 2014

			Pests[c]							
Spp. risk[a]	Risk weight[b]	Common name	DED	OW	TCD	DA	ALB	GM	EAB	LAT
	5	Cedar elm								
	5	Live oak								
	5	Buckley oak								
	5	Bastard oak								
	5	Winged elm								
	5	Plateau oak								
	5	Post oak								
	5	Netleaf white oak								
	5	American elm								
	5	Shumard oak								
	5	Slippery elm								
	5	Chinkapin oak								
	5	Bur oak								
	5	Texas red oak								
	5	Water oak								
	2	Black walnut								
	2	Roughleaf dogwood								
	3	River birch								
	2	Green ash								
	2	Chinese elm								
	1	Texas ash								
	1	Boxelder								
	1	Mexican ash								
	1	American sycamore								
	1	Velvet ash								
	1	Eastern cottonwood								
	1	**Mimosa**								

[a]Species risk

Red indicates that the tree species is at risk to at least one pest within Hays County, Travis County, or Williamson County
Orange indicates that the tree species has no risk to pests within Hays County, Travis County, or Williamson County, but has a risk to at least one pest within 250 miles of the county
Yellow indicates that the tree species has no risk to pests within 250 miles of Hays County, Travis County, or Williamson County, but has a risk to at least one pest that is 250 to 750 miles from the county
Green indicates that the tree species has no risk to pests within 750 miles of Hays County, Travis County, or Williamson County, but has a risk to at least one pest that is greater than 750 miles from the county

[b]Risk weight

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

[c]Pest color codes

Red indicates pest is within Hays County, Travis County, or Williamson County
Orange indicates pest is within 250 miles of Hays County, Travis County, or Williamson County
Yellow indicates pest is within 750 miles of Hays County, Travis County, or Williamson County
Green indicates pest is outside of these ranges

[d]Species in bold text indicate that species is on the state invasive species list

Table 26.—Selected insect or disease threats and the potential risk to Austin trees, 2014

Code	Scientific name	Common name	Trees at risk	Compensatory value
			number	*$ millions*
AL	*Phyllocnistis populiella*	aspen leafminer	0	0
ALB	*Anoplophora glabripennis*	Asian longhorned beetle	6,214,000	2,121
BBD	*Cryptococcus fagisuga*	beech bark disease	0	0
BC	*Sirococcus clavigignenti-juglandacearum*	butternut Canker	0	0
CB	*Cryphonectria parasitica*	chestnut blight	0	0
DA	*Discula destructive*	dogwood anthracnose	60,000	<1
DED	*Ophiostoma novo-ulmi*	Dutch elm disease	4,804,000	1,583
DFB	*Dendroctonus pseudotsugae*	douglas-fir beetle	0	0
EAB	*Agrilus planipennis*	emerald ash borer	1,434,000	546
FE	*Scotylus ventralis*	fir engraver	0	0
FR	*Cronartium fusiforme*	fusiform rust	0	0
GSOB	*Agrilus auroguttatus*	goldspotted oak borer	0	0
GM	*Lymantria dispar*	gypsy moth	4,170,000	4,530
HWA	*Adelges tsugae*	hemlock woolly adelgid	0	0
JPB	*Dendroctonus jeffreyi*	Jeffrey pine beetle	0	0
LAT	*Choristoneura conflictana*	large aspen tortrix	60,000	4
LWD	*Raffaelea lauricola*	laurel wilt	0	0
MPB	*Dendroctonus ponderosae*	mountain pine beetle	0	0
NSE	*Ips perturbatus*	northern spruce engraver	0	0
OW	*Ceratocystis fagacearum*	oak wilt	4,032,000	4,521
POCRD	*Phytophthora lateralis*	port-orford-cedar root disease	0	0
PSB	*Tomicus piniperda*	pine shoot beetle	0	0
SB	*Dendroctonus rufipennis*	spruce beetle	0	0
SBW	*Choristoneura fumiferana*	spruce budworm	0	0
SOD	*Phytophthora ramorum*	sudden oak death	0	0
SPB	*Dendroctonus frontalis*	southern pine beetle	0	0
SW	*Sirex noctilio*	Sirex woodwasp	0	0
TCD	*Pityophthorus juglandis & Geosmithia* spp.	thousand canker disease	105,000	50
WPB	*Dendroctonus brevicomis*	western pine beetle	0	0
WPBR	*Cronartium ribicola*	white pine blister rust	0	0
WSB	*Choristoneura occidentalis*	western spruce budworm	0	0

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