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**Northern
Research Station**

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Assessing Urban Forest Effects and Values

Los Angeles' Urban Forest

Northern
RESEARCH STATION
USDA Forest Service

UFORE
Urban Forest Effects Model

Abstract

An analysis of trees in Los Angeles, CA, reveals that this area has about 6 million trees with tree and shrub canopies that cover 24.9 percent of the city. The most common tree species are Italian cypress, scrub oak, laurel sumac, Mexican fan palm, and Indian laurel, Trees in Los Angeles currently store about 1.3 million tons of carbon (4.7 million tons CO_2) valued at $26.3 million. In addition, these trees remove about 77,000 tons of carbon per year (282,000 tons CO_2/year) ($1.6 million per year) and about 1,976 tons of air pollution per year ($14.2 million per year). Los Angeles' trees are estimated to reduce annual residential energy costs by $10.2 million per year. The structural value of the trees is estimated at $12.4 billion. Information on the structure and functions of the urban forest can be used to inform urban forest management programs and to integrate urban forests within plans to improve environmental quality in Los Angeles.

The Authors

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Urban forests provide numerous benefits to society, yet relatively little is known about this important resource.

The i-Tree Eco (f.k.a. UFORE) model was used to survey and analyze Los Angeles' urban forest (2007-2008).

The calculated environmental benefits of the urban forest are significant, yet many environmental, economic, and social benefits still remain to be quantified.

Executive Summary

Trees in cities can contribute significantly to human health and environmental quality. Unfortunately, relatively little is known about the urban forest resource and what it contributes to the local and regional society and economy. To better understand the urban forest resource and its numerous values, the U.S. Forest Service, Northern Research Station, developed the Urban Forest Effects (UFORE) model, which is now known and distributed as i-Tree Eco at www.itreetools.org. Results from this model are used to advance the understanding of the urban forest resource, improve urban forest policies, planning and management, provide data to support the potential inclusion of trees within environmental regulations, and determine how trees affect the environment and consequently enhance human health and environmental quality in urban areas.

Forest structure is a measure of various physical attributes of the vegetation, including tree species composition, number of trees, tree density, tree health, leaf area, biomass, and species diversity. Forest functions, which are determined by forest structure, include a wide range of environmental and ecosystem services such as air pollution removal and cooler air temperatures. Forest values are an estimate of the economic worth of the various forest functions.

To help determine the vegetation structure, functions, and values of trees in Los Angeles, a vegetation assessment was conducted during the summer of 2007-2008. For this assessment, 0.1-acre field plots were sampled and analyzed using the UFORE model. This report summarizes results and values of:

- Forest structure
- Potential risk to forest from insects or diseases
- Air pollution removal
- Carbon storage
- Annual carbon removal (sequestration)
- Changes in building energy use

Los Angeles Urban Forest Summary (Trees)

Feature	Measure
Number of trees	6.0 million
Tree and shrub cover	24.9%
Tree cover	11.1%
Most common species	Italian cypress, scrub oak, laurel sumac, Mexican fan palm, Indian laurel
Percentage of trees < 6-inches diameter	40.0%
Pollution removal - trees	1,976 tons/year ($14.2 million/year)
Tree and shrubs*	4,500 tons/year ($32.4 million/year)
Carbon storage	1.3 million tons ($26.3 million)
Carbon sequestration	77,000 tons/year ($1.6 million/year)
Building energy reduction	$10.2 million/year
Reduced carbon emissions	$73,000/year
Structural value	$12.4 billion

*Shrub removal estimate is approximate as shrub leaf area parameters were not measured
Ton – short ton (U.S.) (2,000 lbs)

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Benefits provided by urban trees include:

- **Air pollution removal**
- **Air temperature reduction**
- **Reduced building energy use**
- **Absorption of ultraviolet radiation**
- **Improved water quality**
- **Reduced noise**
- **Improved human comfort**
- **Increased property value**
- **Improved physiological & psychological well-being**
- **Aesthetics**
- **Community cohesion**

Urban Forest Effects Model and Field Measurements

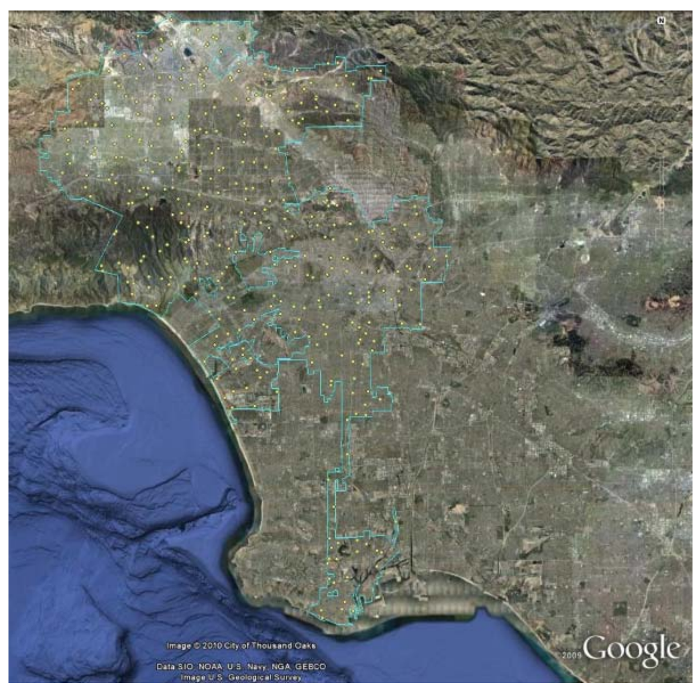
Though urban forests have many functions and values, currently only a few of these attributes can be assessed due to a limited ability to quantify all of these values through standard data analyses. To help assess the city's urban forest, data from 348 field plots located throughout the city were analyzed using the Forest Service's Urban Forest Effects (UFORE) model.[1]

UFORE is designed to use standardized field data from randomly located plots and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects, including:

- Urban forest structure (e.g., species composition, tree density, tree health, leaf area, leaf and tree biomass, species diversity, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<10 microns).
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants.
- Compensatory value of the forest, as well as the value of air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by Asian longhorned beetles, emerald ash borers, gypsy moth, or Dutch elm disease.

For more information go to http://www.ufore.org or www.itreetools.org

In the field, 0.1-acre plots were selected based on a randomized grid with an average density of approximately 1 plot for every 865 acres. The study is divided into smaller areas based on map land-use classifications provided by the city of Los Angeles. The plots were divided among the following land uses: low-density residential and rural (132 plots, 37.9 percent of area); vacant (65 plots, 20.6 percent); medium to high density residential (45 plots, 13.3 percent); commercial-industrial-extraction (43 plots, 12.3 percent); open-agriculture-recreation-institutional (35 plots, 8.7 percent); and transportation-utility (28 plots, 7.2 percent).



Field data were collected by the U.S Forest Service and the University of California Riverside; data collection took place during the leaf-on season to properly assess

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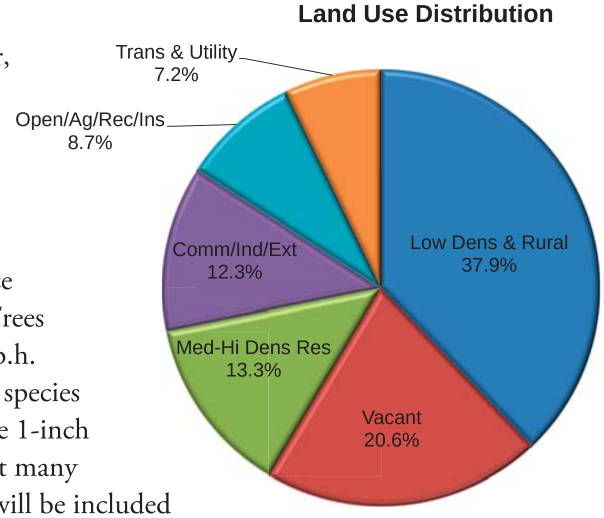
Field Survey Data

Plot Information

- Land use type
- Percent tree cover
- Percent shrub cover
- Percent plantable
- Percent ground cover types

Tree parameters

- Species
- Stem diameter
- Total height
- Height to crown base
- Crown width
- Percent foliage missing
- Percent dieback
- Crown light exposure
- Distance and direction to buildings from trees



tree canopies. Within each plot, data included land-use, ground and tree cover, shrub characteristics, and individual tree attributes of species, stem diameter at breast height (d.b.h.; measured at 4.5 ft), tree height, height to base of live crown, crown width, percentage crown canopy missing and dieback, and distance and direction to residential buildings.[2] Trees were recorded as woody plants with a d.b.h. greater than or equal to 1 inch. As many species are classified as small tree/large shrub, the 1-inch minimum d.b.h. of all species means that many species commonly considered as shrubs will be included in the species tallies when they meet the minimum d.b.h. requirement. In addition, monocot plants that reached minimum d.b.h. were also tallied in Los Angeles (e.g., palm trees, white bird of paradise).

To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations.[3] To adjust for this difference, biomass results for open-grown urban trees are multiplied by 0.8.[3] No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.[3]

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

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models.[4,5] As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature[6,7] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50-percent resuspension rate of particles back to the atmosphere.

Seasonal effects of trees on residential building energy use was calculated based on procedures described in the literature[9] using distance and direction of trees from residential structures, tree height, and tree condition data.

Compensatory values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information.[10]

To learn more about UFORE methods[11] visit:
http://nrs.fs.fed.us/tools/ufore/, www.itreetools.org, or http://www.ufore.org

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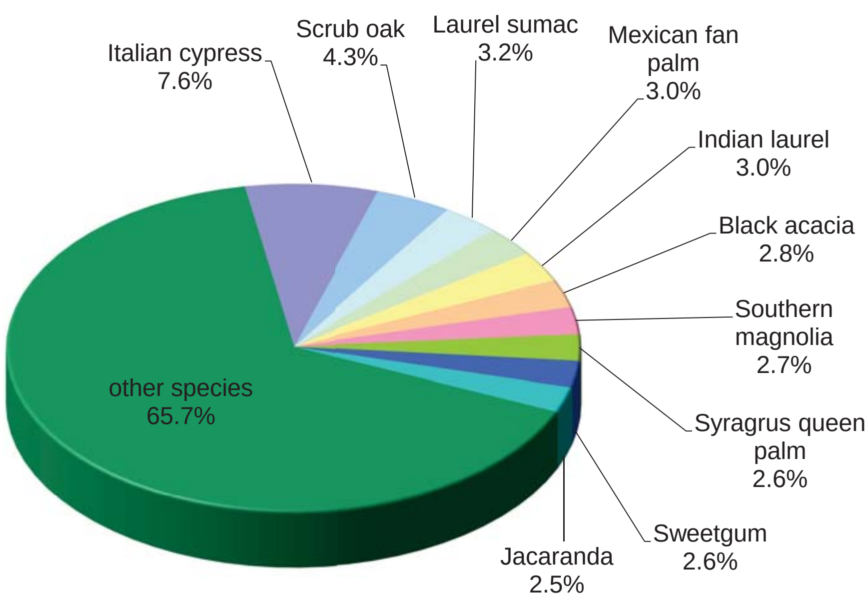
There are an estimated 6.0 million trees in Los Angeles with 24.9 percent trees and shrub cover in the area.

The 10 most common species account for 34.4 percent of the total number of trees.

Tree density is highest in low density residential and rural lands, and medium to high density residential areas.

Tree Characteristics of the Urban Forest

Los Angeles has an estimated 6.0 million trees with a standard error (SE) of 586,000. Tree and shrub cover in Los Angeles is estimated to cover 24.9 percent.[12] Based on the field data in conjunction with photo-interpretation, tree cover in Los Angeles is estimated to be 11.1 percent.[12] The five most common species in the urban forest were Italian cypress (7.6 percent), scrub oak (4.3 percent), laurel sumac (3.2 percent), Mexican fan palm (3.0 percent) and Indian laurel (3.0 percent). Some of these top five species are small tree / large shrub-like species that are often clustered in an area. These types of plants often dominant in terms of number of stems, but do not dominate in terms of leaf area. The 10 most common species account for 34.4 percent of all trees; their relative abundance is illustrated below. In total, 139 tree species were sampled in Los Angeles; these species and their relative abundance are presented in Appendix I. More information on species distribution by land use is given in Appendix II.



The highest density of trees occurs in low density residential and rural lands (29.0 trees/acre), followed by medium to high density residential (26.4 trees/acre) and vacant land (15.5 trees/acre). The overall tree density in Los Angeles is 19.9 trees/acre, which is relatively low compared to other city tree densities that range between 9.1 and 119.2 trees/acre (Appendix III). Trees that have diameters less than 6 inches account for 40.0 percent of the population. Land uses that contain the most leaf area are low density residential and rural lands (70.0 percent of total tree leaf area) and medium to high density residential (9.8 percent).

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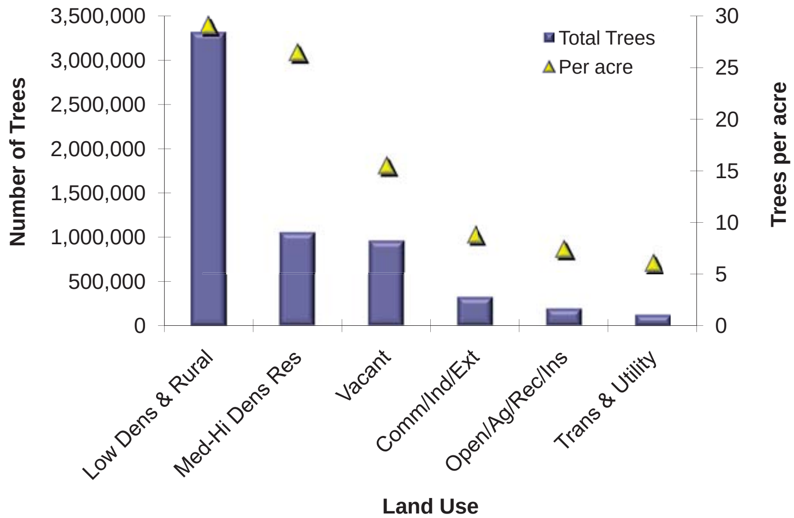
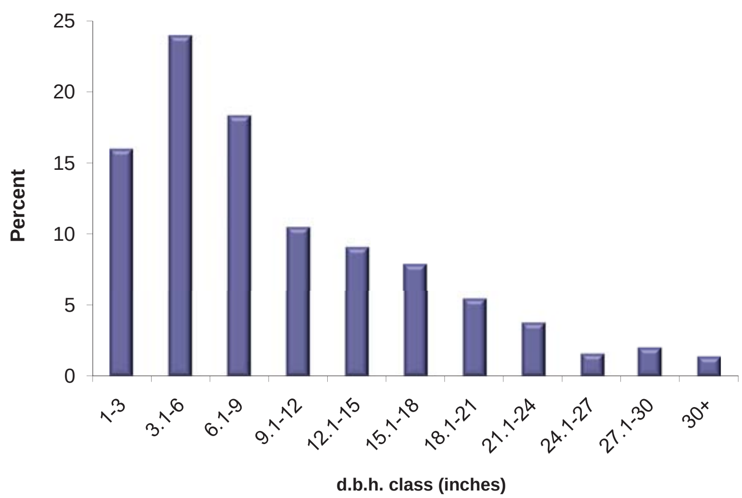
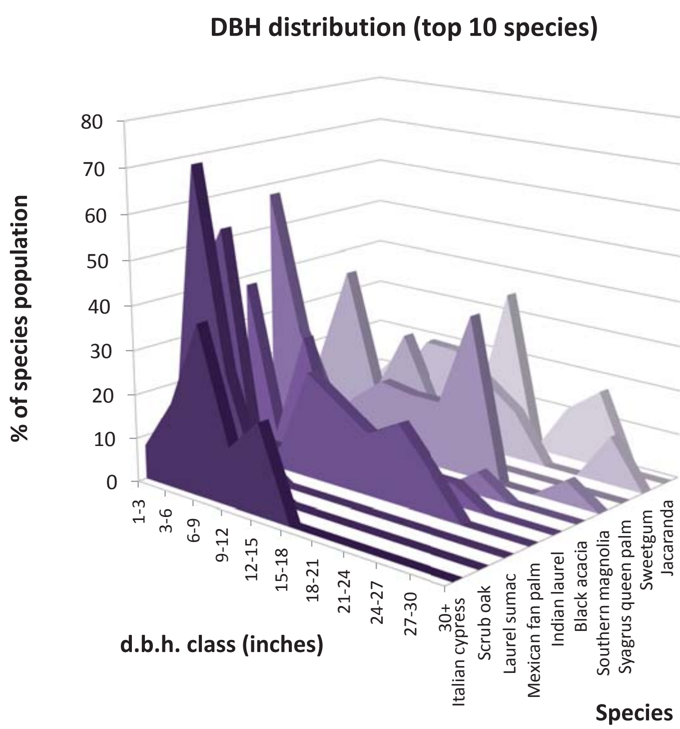


Approximately 16.1 percent of the tree species in Los Angeles are native to California.

Urban forests are a mix of native tree species that existed prior to the development of the city and exotic species that were introduced by residents or other means.





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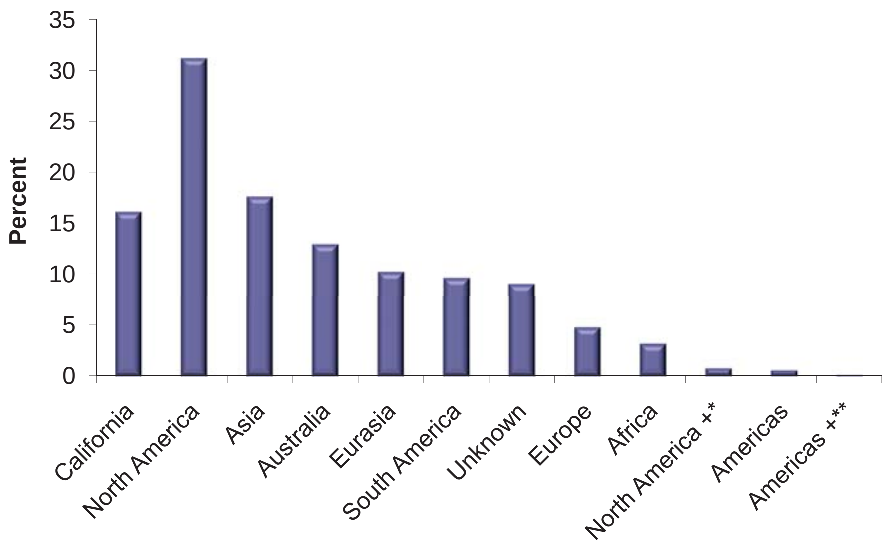
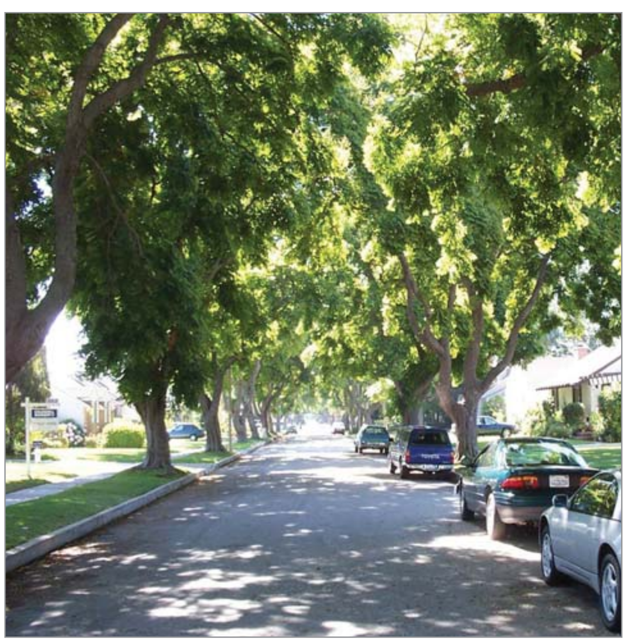
Urban forests are a mix of native tree species that existed prior to the development of the city and exotic species that were introduced by residents or other means. Thus, urban forests, particularly in areas like Los Angeles that are conducive to growing plants from around the world, often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but the increase in the number of exotic plants can also pose a risk to native plants if exotic species are invasive and out-compete and displace native species. In Los Angeles, about 16.1 percent of the trees are native to California. Trees with a native origin outside of North America are mostly from Asia (17.6 percent of the species).



* native to North America and one other continent, excluding South America
** native to North America and South America, and one other continent



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Urban Forest Cover and Leaf Area

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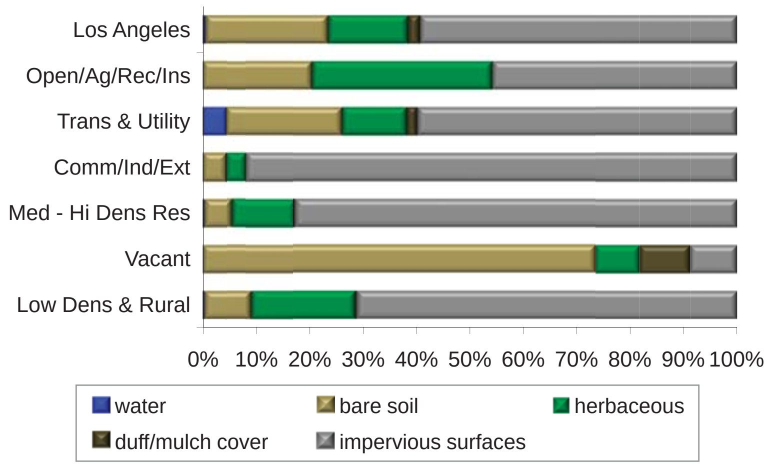
Healthy leaf area equates directly to tree benefits provided to the community.

Southern magnolia is currently the most dominant species in Los Angeles based on relative leaf area and relative population.

Tree cover in Los Angeles is about 11.1 percent, with shrub cover occupying approximately 13.8 percent. Dominant ground cover types include impervious (59.4 percent), bare soil (23.0 percent), and herbaceous (14.9 percent).



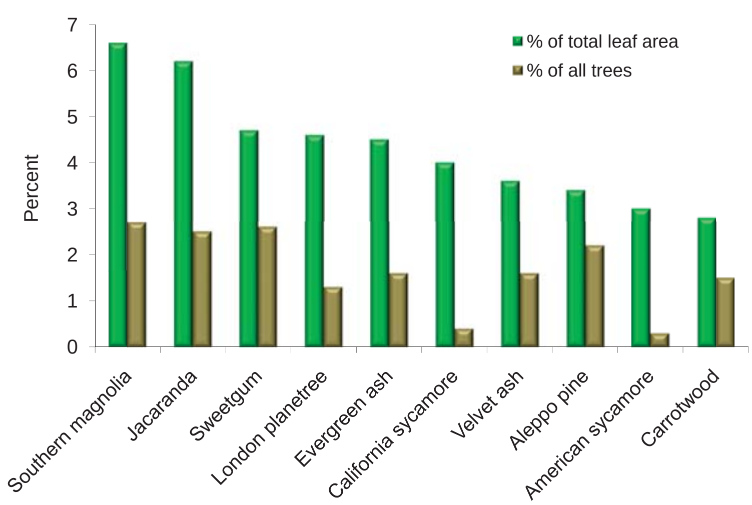
Many tree benefits are linked directly to the amount of healthy leaf surface area of the plant. In Los Angeles, trees that dominate in terms of leaf area are southern magnolia, jacaranda, and sweetgum.

Tree species with relatively large individuals contributing leaf area to the population (species with percent of leaf area much greater than percent of total population) are London planetree, evergreen ash, and Chinese elm. Smaller trees in the population are Italian cypress, laurel sumac, and lemon bottlebrush (species with percent of leaf area much less than percent of total population). The species must also have constituted at least 1 percent of the total population to be considered as relatively large or small trees in the population.

Common Name	% Pop[a]	% LA[b]	IV[c]
Southern magnolia	2.7	6.6	9.3
Jacaranda	2.5	6.2	8.7
Italian cypress	7.6	0.6	8.2
Sweetgum	2.6	4.7	7.3
Evergreen ash	1.6	4.5	6.1
London planetree	1.3	4.6	5.9
Aleppo pine	2.2	3.4	5.6
Indian laurel	3.0	2.4	5.4
Scrub oak	4.3	1.0	5.3
Velvet ash	1.6	3.6	5.2

[a] percent of population
[b] percent of leaf area
[c] Percent Pop + Percent LA

The importance values (IV) are calculated using a formula that takes into account the relative leaf area and relative abundance. The most important species in the urban forest, according to calculated IVs, are southern magnolia, jacaranda, and Italian cypress. High importance values do not mean that these trees should necessarily be used in the future, rather that these species currently dominate the urban forest structure.



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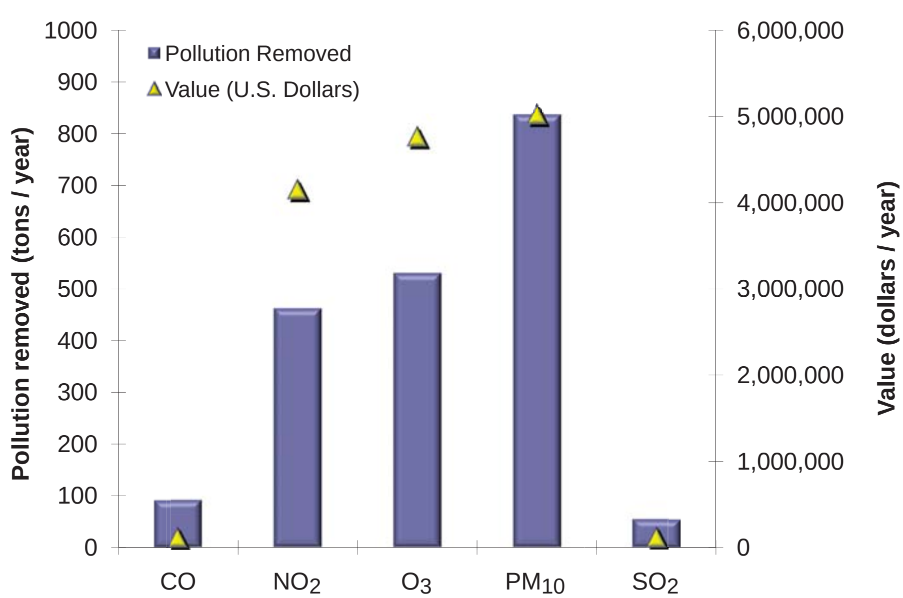
Trees in Los Angeles remove approximately 1,976 tons of pollutants each year, with a societal value of $14.2 million/year.

General urban forest management recommendations to improve air quality are given in Appendix IV.

Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to human health problems, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduce air pollutant emissions from power plants. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation.[13]

Pollution removal by trees (11.1 percent tree cover) in Los Angeles was estimated using the UFORE model in conjunction with field data and hourly pollution and weather data for the year 2000. Pollution removal was greatest for particulate matter less than 10 microns (PM_{10}), followed by ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), and sulfur dioxide (SO_2). It is estimated that trees remove 1,976 tons of air pollution (CO, NO_2, O_3, PM_{10}, SO_2) per year with an associated value of $14.2 million (based on estimated 2007 national median externality costs associated with pollutants[14]). The effects of shrub cover in Los Angeles (13.8 percent cover or 15.0 percent including shrubs beneath canopies) would remove an additional estimated 2,500 tons per year ($18.3 million/year). Thus, tree and shrub cover combined remove approximately 4,500 tons of pollution per year ($32.4 million per year). The shrub removal estimate is approximate and assumes a removal rate that is 0.95 of the tree removal rate per unit area of cover based on average shrub-tree removal ratio from 23 cities.



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Carbon storage:

Carbon currently held in tree tissue (roots, stems, and branches).

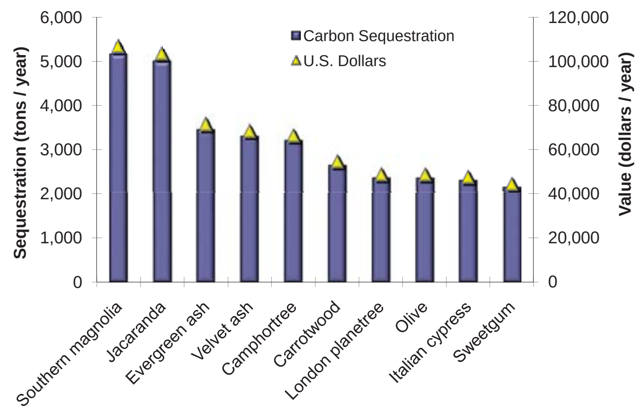
Carbon sequestration:

Estimated amount of carbon removed annually by trees. Net carbon sequestration can be negative if emission of carbon from decomposition is greater than amount sequestered by healthy trees.

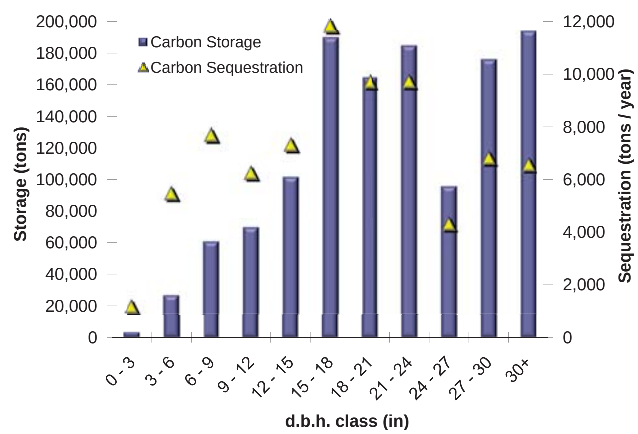
Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by reducing energy use in buildings, and consequently reducing carbon dioxide emissions from fossil-fuel based power plants.[15]

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new tissue growth every year. The amount of carbon annually sequestered is increased with healthier and larger diameter trees. Gross sequestration by Los Angeles' trees is about 77,000 tons of carbon per year (282,000 tons per year of carbon dioxide) with an associated value of $1.6 million per year. Net carbon sequestration in Los Angeles is estimated at about 57,600 tons per year (211,000 tons per year of carbon dioxide) based on estimated carbon loss due to tree mortality and decomposition.



Carbon storage by trees is another way trees can influence global climate change. As trees grow, they store more carbon by holding it in their accumulated tissue. As trees die and decay, they release much of the stored carbon back to the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions.[16] When trees die, utilizing the wood in long-term wood products or to help heat buildings or produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel-based power plants. Trees in Los Angeles are estimated to store 1.3 million tons of carbon (4.7 million tons of carbon dioxide) ($26.3 million). Of all the species sampled, evergreen ash stores the most carbon (approximately 7.4 percent of total carbon stored) and southern magnolia annually sequesters the most carbon (7.1 percent of all sequestered carbon).



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Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds.

Interactions between buildings and trees are estimated to reduce residential heating and cooling costs by $10.2 million per year.

Trees Affect Energy Use in Buildings

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. To enhance or sustain evaporative cooling from trees in Los Angeles, many trees are or may need to be irrigated. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space-conditioned residential buildings.[9]

Based on average energy costs in 2007 and 2010,[17] trees in Los Angeles are estimated to reduce energy costs from residential buildings by $10.2 million annually. Trees also provide an additional $73,000 in value per year by reducing amount of carbon released by fossil-fuel based power plants (a reduction of 3,530 tons of carbon emissions or 12,900 tons of carbon dioxide).

Annual energy savings due to trees near residential buildings

	Heating	Cooling	Total
MBTU[a]	-293,500	n/a	-293,500
MWH[b]	-16,800	96,400	79,600
Carbon avoided (t)	-6,393.34	9,920	3,527

[a]Million British Thermal Units
[b]Megawatt-hour

Annual savings[c] (U.S. $) in residential energy expenditures during heating and cooling seasons

	Heating	Cooling	Total
MBTU[a]	-3,410,000	n/a	-3,410,000
MWH[b]	-2,874,000	16,467,000	13,593,000
Carbon avoided	-132,700	205,700	73,000

[a]Million British Thermal Units
[b]Megawatt-hour
[c]Based on 2007 and 2010 energy costs from Los Angeles[17]

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Urban forests have a structural value based on the tree itself.

Urban forests also have functional values based on the functions the tree performs.

Large, healthy, long-lived trees provide the greatest structural and functional values.

A list of tree species found in the city of Los Angeles is in Appendix I.

A map of priority planting locations for the city of Los Angeles is found in Appendix VI.

Structural and Functional Values

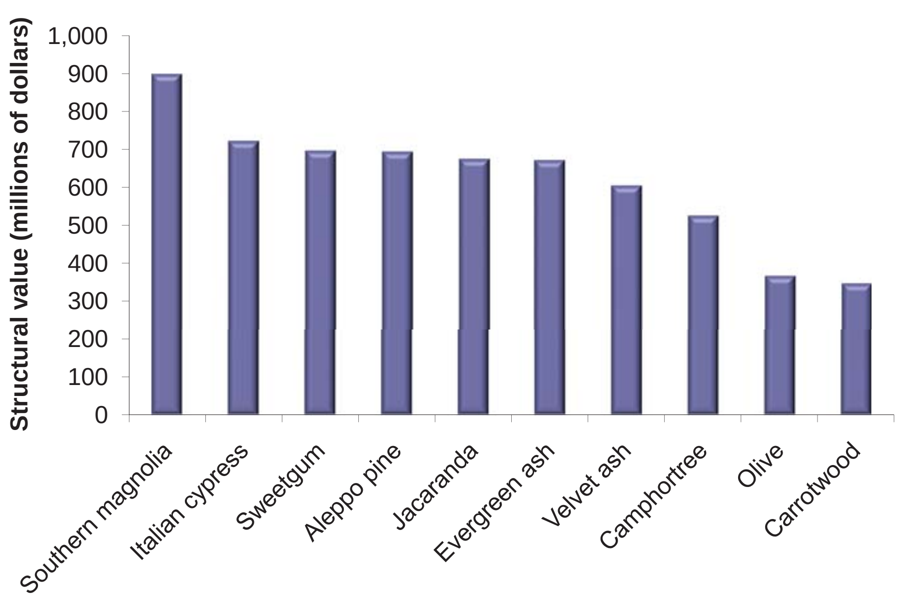
Urban forests have a structural value based on the tree itself (e.g., the cost of having to replace the tree with a similar tree). The structural value[10] of the trees and forests in Los Angeles is about $12.4 billion. The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees.

Urban forests also have functional values (either positive or negative) based on the functions the tree performs. Annual functional values also tend to increase with increased number and size of healthy trees, and are usually on the order of several million dollars per year. There are many other functional values of the urban forest, though they are not quantified here (e.g., reduction in air temperatures and ultra-violet radiation, improvements in water quality, aesthetics, wildlife habitat, etc.). Through proper management, urban forest values can be increased. However, the values and benefits also can decrease as the amount of healthy tree cover declines.

Structural values:
- Structural value: $12.4 billion
- Carbon storage: $26.3 million

Annual functional values:
- Carbon sequestration: $1.6 million
- Pollution removal: $14.2 million
- Reduced energy costs: $10.2 million

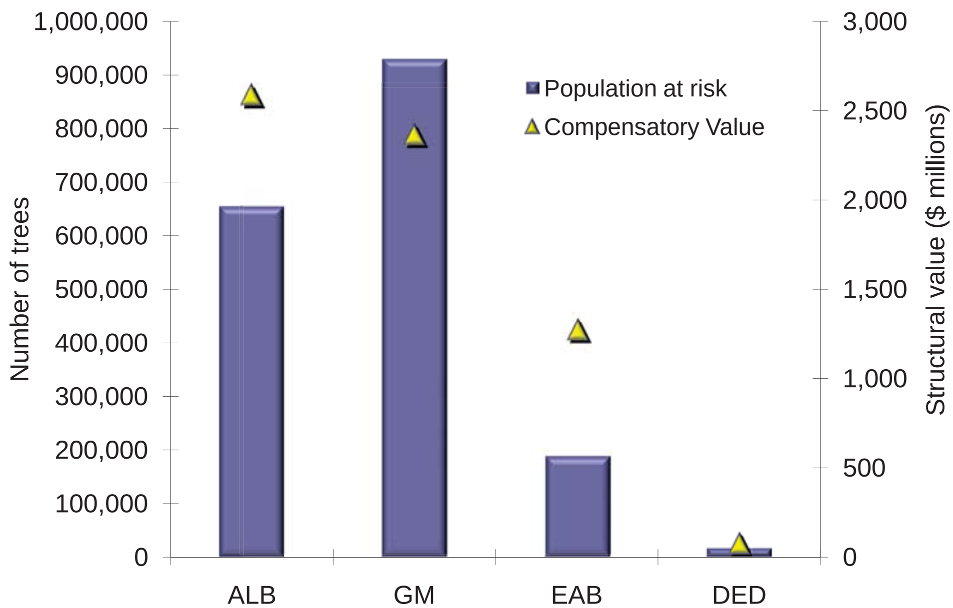
More detailed information on the trees and forests in Los Angeles can be found at http://nrs.fs.fed.us/data/urban. Additionally, information on other urban forest values can be found in Appendix III and tree statistics by diameter class can be found in Appendix V.



Potential Insect and Disease Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, value and sustainability of the urban forest. As various pests have differing tree hosts, the potential damage or risk of each pest will differ. Four exotic pests/diseases were analyzed for their potential impact: Asian longhorned beetle, gypsy moth, emerald ash borer, and Dutch elm disease. Species hosts lists used for these pests/diseases can be found at http://nrs.fs.fed.us/tools/ufore/.

The Asian longhorned beetle (ALB)[18] is an insect that bores into and kills a wide range of hardwood species. This beetle was discovered in 1996 in Brooklyn, NY and has subsequently spread to Long Island, Queens, and Manhattan. In 1998, the beetle was discovered in the suburbs of Chicago, IL. Beetles have also been found in Jersey City, NY (2002), Toronto/Vaughan, Ontario (2003) and Middlesex/Union counties, NJ (2004). In 2007, the beetle was found on Staten and Prall's Island, NY. Most recently, beetles were detected in Worcester, Massachusetts (2008). This beetle represents a potential loss to Los Angeles of $2.6 billion in structural value (11.0 percent of live tree population).



The gypsy moth (GM)[19] is a defoliator that feeds on many species causing widespread defoliation and tree death if outbreak conditions last several years. This pest could potentially result in damage to or a loss of $2.4 billion in structural value of Los Angeles' trees (15.6 percent of live tree population).

Since being discovered in Detroit in 2002, emerald ash borer (EAB)[20] has killed millions of ash trees in Illinois, Indiana, Kentucky, Maryland, Michigan, Minnesota, Missouri, New York, Ohio, Ontario, Pennsylvania, Quebec, Virginia, West Virginia, and Wisconsin. EAB has the potential to affect 3.2 percent of Los Angeles's live tree population ($1.3 billion in structural value).

Asian longhorned beetle

Kenneth R. Law
USDA APHIS PPQ
(www.invasive.org)

Gypsy moth

USDA Forest Service Archives
(www.invasive.org)

Emerald ash borer

David Cappaert
Michigan State University
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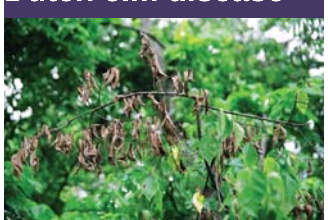
Dutch elm disease



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American elm, one of the most important street trees in the 20th century, has been devastated by the Dutch elm disease (DED). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States.[21] Although some elm species have shown varying degrees of resistance, Los Angeles possibly could lose 0.3 percent of its trees to this disease ($80 million in structural value).

Conclusion

Data from this report provide the basis for a better understanding of the urban forest resource and the ecosystem services and values provided by this resource. Managers and citizens can use these data to help develop improved long-term management plans and policies to sustain a healthy urban tree population and ecosystem services for future generations. Improved planning and management to sustain healthy tree populations can lead to improved environmental quality and quality of life for Los Angeles residents.

More information on trees in Los Angeles can be found at:
http://nrs.fs.fed.us/data/urban.

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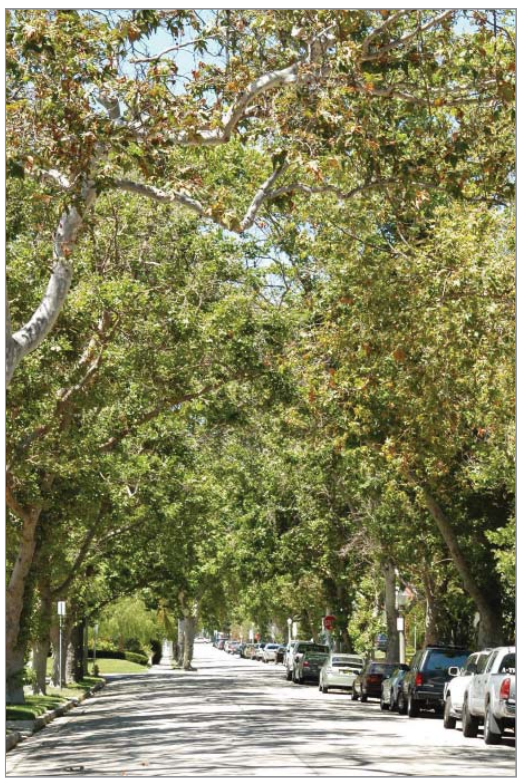

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Appendix I. List of Species Sampled in Los Angeles

Genus	Species	Common Name	Number of Trees	Population %	Leaf Area %	IV[a]	Median Dbh (in)	Average Dbh (in)	Basal Area (ft^2)	Structural Value ($ Millions)
Abies	*species*	Fir	19,100	0.3	0.0	0.3	2.5	2.5	937	0.6
Acacia	*melanoxylon*	Black acacia	165,090	2.8	1.1	3.9	2.8	4.2	41,070	118.5
Acer	*saccharum*	Sugar maple	8,640	0.1	0.0	0.1	14.5	14.5	10,604	24.3
Adenostoma	*fasciculatum*	Chamise	9,550	0.2	0.0	0.2	2.5	2.5	469	1.0
Albizia	*julibrissin*	Mimosa	15,010	0.3	0.2	0.5	6.0	6.0	3,479	24.5
Aralia	*species*	Aralia	8,640	0.1	0.1	0.2	12.5	12.5	7,965	27.6
Araucaria	*excelsa*	New caledonia pine	8,640	0.1	0.1	0.2	5.5	5.5	1,697	8.8
Araucaria	*heterophylla*	Norfolk island pine	8,640	0.1	0.0	0.1	6.5	6.5	2,309	7.8
Archontophoenix	*alexandrae*	Australian palm	44,470	0.7	0.7	1.4	7.5	7.5	16,978	23.5
Archontophoenix	*cunninghamiana*	King palm	51,700	0.9	0.9	1.8	13.0	13.5	70,951	24.6
Arecastrum	*romanozoffianum*	Queen palm	35,580	0.6	0.1	0.7	2.5	2.5	1,746	7.9
Bauhinia	*variegata*	Mountain ebony	8,890	0.1	0.1	0.2	5.5	5.5	1,746	4.1
Betula	*pendula*	European white birch	51,850	0.9	0.6	1.5	4.0	6.3	17,469	40.3
Bougainvillea	*glabra*	Paperflower	8,640	0.1	0.0	0.1	3.5	3.5	754	2.2
Brachychiton	*populneum*	Kurrajong	77,870	1.3	0.9	2.2	12.5	13.7	112,367	266.3
Broussonetia	*papyrifera*	Paper mulberry	51,850	0.9	0.6	1.5	8.0	8.2	27,807	94.6
Callistemon	*citrinus*	Lemon bottlebrush	85,910	1.4	0.2	1.6	2.6	3.7	13,307	48.3
Callistemon	*viminalis*	Weeping bottlebrush	34,560	0.6	0.3	0.9	5.7	6.3	8,907	44.7
Calycanthus	*occidentalis*	Western sweetshrub	17,790	0.3	0.0	0.3	3.0	3.0	1,213	6.6
Ceanothus	*crassifolia*	Hoaryleaf ceanothus	38,190	0.6	0.1	0.7	4.3	4.3	4,739	10.3
Ceanothus	*megacarpus*	Bigpod ceanothus	66,830	1.1	0.3	1.4	5.3	5.2	12,602	16.3
Ceanothus	*spinosus*	Green bark ceanothus	9,550	0.2	0.1	0.3	5.5	5.5	1,875	10.8
Cedrus	*deodara*	Deodar cedar	8,640	0.1	0.1	0.2	7.5	7.5	3,016	16.5
Ceratonia	*siliqua*	Carob tree	62,530	1.0	1.4	2.4	16.1	14.7	82,594	186.5
Chitalpa	*tashkentensis*	Chitalpa	8,640	0.1	0.1	0.2	6.5	6.5	2,309	13.3
Chorisia	*speciosa*	Palo borracho	17,180	0.3	0.0	0.3	6.0	12.0	18,601	0.0
Cinnamomum	*camphora*	Camphortree	59,600	1.0	1.9	2.9	19.4	21.4	201,003	525.6
Citrus	*limon*	Lemon	95,810	1.6	0.4	2.0	4.2	4.8	18,520	68.9
Citrus	*sinensis*	Orange	34,560	0.6	0.2	0.8	8.0	7.3	11,829	47.2
Citrus	*species*	Citrus	8,640	0.1	0.1	0.2	7.5	7.5	3,016	9.5
Citrus	*x paradasi*	Grapefruit	17,280	0.3	0.1	0.4	7.0	7.5	6,127	21.0
Cotoneaster	*lacteus*	Milkflower cotoneaster	8,640	0.1	0.1	0.2	3.5	3.5	754	4.0
Cupaniopsis	*anacardioides*	Carrotwood	91,600	1.5	2.8	4.3	16.7	14.4	127,764	347.6
Cupressocyparis	*xleylandii*	Leyland cypress	8,640	0.1	0.5	0.6	25.5	25.5	31,860	41.3
Cupressus	*sempervirens*	Italian cypress	457,180	7.6	0.6	8.2	6.6	7.6	192,702	721.7
Cyathea	*cooperi*	Cooper's cyathea	35,580	0.6	0.1	0.7	3.7	3.8	3,541	17.3
Cycas	*revoluta*	Sago palm	25,870	0.4	0.0	0.4	8.5	6.5	8,697	18.9
Duranta	*erecta*	Golden dewdrops	25,920	0.4	0.1	0.5	5.5	5.5	5,090	27.4
Eriobotrya	*deflexa*	Bronze loquat	8,890	0.1	0.0	0.1	1.5	1.5	194	0.6
Eriobotrya	*japonica*	Loquat tree	17,490	0.3	0.0	0.3	2.0	2.0	624	2.3
Erythrina	*caffra*	Kaffirboom coral tree	17,280	0.3	0.6	0.9	16.0	16.0	25,686	58.4
Erythrina	*crista-galli*	Arbol del coral	17,280	0.3	0.4	0.7	9.0	13.5	20,831	57.7
Eucalyptus	*camaldulensis*	Red gum eucalyptus	40,950	0.7	0.8	1.5	8.5	10.0	30,056	75.8
Eucalyptus	*cladocalyx*	Sugargum	7,700	0.1	1.3	1.4	29.0	35.5	54,414	82.7
Eucalyptus	*deglupta*	Deglupta eucalyptus	43,210	0.7	1.4	2.1	9.5	10.7	31,954	98.6
Eucalyptus	*ficifolia*	Redflower gum	8,890	0.1	0.1	0.2	11.5	11.5	6,985	3.0
Eucalyptus	*macrocarpa*	Bluebush	8,640	0.1	0.1	0.2	25.5	25.5	31,860	48.6
Eucalyptus	*nicholii*	Willow leaved gimlet	8,590	0.1	0.0	0.1	6.5	6.5	2,296	13.1
Eucalyptus	*rudis*	Desert gum eucalyptus	8,640	0.1	0.1	0.2	12.5	12.5	7,965	19.4
Eucalyptus	*sideroxylon*	Red ironbark	8,590	0.1	0.0	0.1	3.5	3.5	750	3.4

continued

Appendix I.—continued

Genus	Species	Common Name	Number of Trees	Population %	Leaf Area %	IV[a]	Median Dbh (in)	Average Dbh (in)	Basal Area (ft^2)	Structural Value ($ Millions)
Eucalyptus	*species*	Eucalyptus	28,640	0.5	1.0	1.5	16.5	19.5	69,048	35.2
Ficus	*benjamina*	Bejamin fig	69,640	1.2	2.0	3.2	11.0	13.3	104,048	260.1
Ficus	*lyrata*	Fiddle leaf fig	17,280	0.3	0.1	0.4	7.5	7.5	6,033	18.9
Ficus	*microcarpa*	Indian laurel	182,170	3.0	2.4	5.4	6.4	7.5	101,938	303.8
Fraxinus	*uhdei*	Evergreen ash	93,910	1.6	4.5	6.1	16.5	20.0	293,948	671.2
Fraxinus	*velutina*	Velvet ash	93,910	1.6	3.6	5.2	21.6	21.5	266,207	604.7
Ginkgo	*biloba*	Ginkgo	8,640	0.1	0.0	0.1	3.5	3.5	754	3.7
Heteromeles	*arbutifolia*	Christmasberry	9,550	0.2	0.1	0.3	13.5	13.5	10,206	9.5
Ilex	*aquifolium*	English holly	8,640	0.1	0.1	0.2	6.5	6.5	2,309	10.5
Jacaranda	*mimosifolia*	Jacaranda	148,530	2.5	6.2	8.7	16.1	15.6	251,561	674.6
Juglans	*californica*	Southern california walnut	114,570	1.9	2.4	4.3	6.8	7.2	43,111	107.9
Juglans	*nigra*	Black walnut	25,920	0.4	1.3	1.7	14.5	15.8	41,238	99.7
Juniperus	*chinensis*	Chinese juniper	60,490	1.0	0.2	1.2	3.5	4.1	8,106	37.4
Juniperus	*species*	Juniper	8,640	0.1	0.0	0.1	5.5	5.5	1,697	9.8
Koelreuteria	*bipinnata*	Chinese flame tree	35,030	0.6	0.3	0.9	5.0	6.6	16,402	16.4
Koelreuteria	*paniculata*	Goldenrain tree	8,590	0.1	0.3	0.4	10.5	10.5	5,670	20.8
Lagerstroemia	*indica*	Common crapemyrtle	17,280	0.3	0.1	0.4	6.5	6.5	4,619	15.1
Larix	*kaempferi*	Japanese larch	8,640	0.1	0.4	0.5	13.5	13.5	9,237	32.1
Laurus	*nobilis*	Laurel de olor	8,640	0.1	0.1	0.2	8.5	8.5	3,817	13.1
Ligustrum	*lucidum*	Chinese privet	86,410	1.4	1.8	3.2	9.0	9.6	59,714	233.2
Ligustrum	*ovalifolium*	California privet	17,280	0.3	0.7	1.0	16.0	19.0	36,997	89.1
Liquidambar	*styraciflua*	Sweetgum	156,810	2.6	4.7	7.3	13.0	14.6	231,381	696.1
Liriodendron	*tulipifera*	Tulip tree	43,210	0.7	1.5	2.2	6.5	8.5	29,927	59.7
Magnolia	*grandiflora*	Southern magnolia	161,870	2.7	6.6	9.3	16.7	16.0	258,347	897.5
Magnolia	*x soulangeana*	Chinese magnolia	8,640	0.1	0.0	0.1	4.5	4.5	1,178	9.2
Malosma	*laurina*	Laurel sumac	190,950	3.2	0.4	3.6	3.5	3.7	20,725	39.8
Malus	*species*	Crabapple	8,640	0.1	0.0	0.1	6.5	6.5	2,309	1.8
Maytenus	*boaria*	Mayten	42,070	0.7	0.2	0.9	3.5	4.4	6,779	24.6
Melaleuca	*incana*	Gray honeymyrtle	8,890	0.1	0.0	0.1	12.5	12.5	8,198	23.2
Melaleuca	*nesophila*	Pink melaleuca	8,890	0.1	0.1	0.2	7.5	7.5	3,105	15.4
Nerium	*oleander*	Oleander	35,270	0.6	0.6	1.2	5.5	10.1	39,244	106.8
Nicotiana	*glauca*	Tree tobacco	7,700	0.1	0.0	0.1	6.5	6.5	2,057	7.4
Olea	*europaea*	Olive	87,680	1.5	1.4	2.9	11.3	13.1	123,009	367.3
Other	*species*	Other species	121,730	2.0	0.6	2.6	2.7	5.2	49,291	112.9
Persea	*americana*	Avocado	17,540	0.3	0.3	0.6	5.0	11.9	20,065	42.3
Phoenix	*dactylifera*	Date palm	25,920	0.4	0.8	1.2	26.5	22.5	91,855	17.0
Phoenix	*roebelenii*	Pygmy date palm	25,920	0.4	0.0	0.4	6.5	6.5	7,022	7.9
Picea	*pungens*	Blue spruce	8,640	0.1	0.0	0.1	5.5	5.5	1,697	11.9
Pinus	*halepensis*	Aleppo pine	132,440	2.2	3.4	5.6	14.2	15.2	238,610	693.5
Pinus	*pinea*	Itailian stone pine	7,500	0.1	0.2	0.3	18.5	18.5	14,775	58.1
Pinus	*radiata*	Monterey pine	8,640	0.1	0.5	0.6	29.0	29.5	42,417	85.0
Pinus	*thunbergii*	Japanese black pine	8,640	0.1	0.1	0.2	7.5	7.5	3,016	9.7
Pittosporum	*napaliense*	Royal cheesewood	7,500	0.1	0.0	0.1	6.5	6.5	2,005	5.3
Pittosporum	*species*	Pittosporum	35,070	0.6	0.0	0.6	9.0	8.3	15,434	8.5
Pittosporum	*tobira*	Japanese pittosporum	8,640	0.1	0.0	0.1	7.5	7.5	3,016	12.8
Pittosporum	*undulatum*	Victorian box	68,990	1.2	1.7	2.9	12.1	12.1	70,208	182.0
Platanus	*acerifolia*	London planetree	78,180	1.3	4.6	5.9	13.5	15.3	127,762	317.3
Platanus	*occidentalis*	American sycamore	17,280	0.3	3.0	3.3	24.0	25.5	64,096	131.5
Platanus	*racemosa*	California sycamore	26,830	0.4	4.0	4.4	17.5	15.9	44,819	110.8
Podocarpus	*gracilior*	Fern pine	85,770	1.4	0.3	1.7	3.5	4.4	14,438	73.3

continued

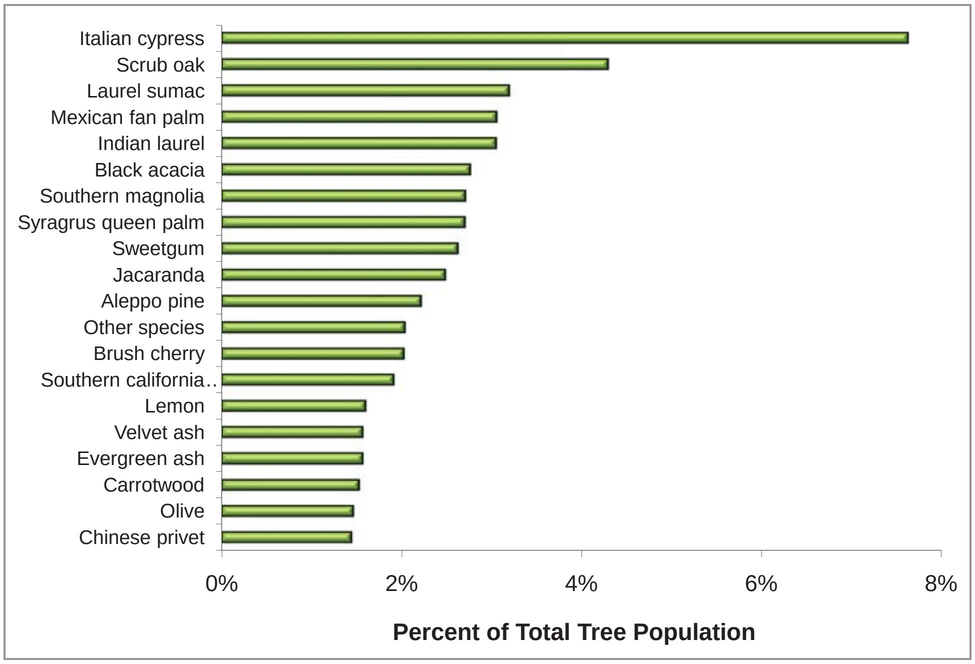
Appendix I.—continued

Genus	Species	Common Name	Number of Trees	Population %	Leaf Area %	IV[a]	Median Dbh (in)	Average Dbh (in)	Basal Area (ft^2)	Structural Value ($ Millions)
Populus	*fremontii*	Fremont cottonwood	17,790	0.3	0.1	0.4	12.5	12.5	16,396	14.8
Prunus	*armeniaca*	Apricot	8,640	0.1	0.0	0.1	6.5	6.5	2,309	8.3
Prunus	*campanulata*	Taiwan flowering cherry	8,640	0.1	0.0	0.1	1.5	1.5	189	0.3
Prunus	*cerasifera*	Cherry plum	25,870	0.4	0.1	0.5	6.3	5.8	5,790	31.4
Prunus	*persica*	Nectarine	17,540	0.3	0.1	0.4	6.0	4.5	2,801	13.1
Psidium	*guajava*	Common guava	8,590	0.1	0.1	0.2	7.5	7.5	2,999	13.2
Pyracantha	*coccinea*	Fire thorn	8,640	0.1	0.0	0.1	4.5	4.5	1,178	8.6
Pyracantha	*fortuneana*	Chinese firethorn	8,640	0.1	0.0	0.1	3.5	3.5	754	7.7
Pyracantha	*species*	Firethorn	8,640	0.1	0.1	0.2	5.5	5.5	1,697	9.4
Pyrus	*calleryana*	Callery pear	25,920	0.4	0.4	0.8	8.5	10.5	20,784	61.6
Pyrus	*kawakamii*	Evergreen pear	25,920	0.4	0.4	0.8	14.3	11.2	22,396	25.6
Quercus	*agrifolia*	Coast live oak	55,470	0.9	0.6	1.5	3.0	5.4	20,267	79.2
Quercus	*berberidifolia*	Scrub oak	257,780	4.3	1.0	5.3	5.2	5.4	52,281	85.1
Quercus	*chrysolepis*	Canyon live oak	17,230	0.3	0.8	1.1	16.0	16.0	25,607	95.1
Rhamnus	*ilicifolia*	Hollyleaf redberry	9,550	0.2	0.0	0.2	3.5	3.5	833	2.8
Rhus	*ovata*	Sugar sumac	9,550	0.2	0.1	0.3	8.5	8.5	4,218	4.8
Robinia	*pseudoacacia*	Black locust	25,920	0.4	0.9	1.3	15.5	16.5	41,521	85.2
Sambucus	*canadensis*	American elder	38,190	0.6	0.2	0.8	3.0	4.3	6,405	5.6
Schefflera	*species*	Schefflera	8,640	0.1	0.0	0.1	5.5	5.5	1,697	7.2
Schinus	*molle*	California peppertree	42,260	0.7	0.9	1.6	12.4	12.5	45,737	124.3
Schinus	*terebinthifolius*	Brazilian pepper	51,850	0.9	0.7	1.6	7.0	9.3	34,924	107.1
Senna	*didymobotrya*	African senna	8,890	0.1	0.0	0.1	4.5	4.5	1,213	10.6
Sequoia	*sempervirens*	Coast redwood	23,650	0.4	0.9	1.3	12.4	14.6	32,427	45.2
Solanum	*rantonnetii*	Blue solanum shrub	8,640	0.1	0.0	0.1	3.5	3.5	754	2.2
Strelitzia	*alba*	White bird of paradise	69,130	1.2	0.3	1.5	7.0	7.5	25,639	86.9
Syagrus	*romanzoffiana*	Syagrus queen palm	161,530	2.7	1.7	4.4	4.8	6.7	57,289	69.4
Syzygium	*paniculatum*	Brush cherry	120,980	2.0	0.5	2.5	2.8	3.7	20,156	55.2
Tabebuia	*chrysotricha*	Ipe-amarelo	8,890	0.1	0.0	0.1	2.5	2.5	437	0.2
Thevetia	*peruviana*	Lucky nut	8,640	0.1	0.0	0.1	7.5	7.5	3,016	15.2
Thuja	*orientalis*	Oriental arbor vitae	8,640	0.1	0.0	0.1	6.5	6.5	2,309	10.8
Tibouchina	*urvilleana*	Princess-flower	8,640	0.1	0.0	0.1	21.5	21.5	22,811	24.5
Tipuana	*tipu*	Tipa	31,150	0.5	1.5	2.0	9.1	11.0	26,343	87.9
Ulmus	*americana*	American elm	17,280	0.3	1.0	1.3	23.0	27.5	76,255	79.9
Ulmus	*parvifolia*	Chinese elm	63,210	1.1	2.8	3.9	18.3	17.1	138,134	319.8
Ulmus	*pumila*	Siberian elm	15,010	0.3	0.5	0.8	2.0	6.5	6,057	19.0
Washingtonia	*filifera*	California palm	17,280	0.3	0.2	0.5	19.0	19.5	37,798	7.4
Washingtonia	*robusta*	Mexican fan palm	182,550	3.0	1.7	4.7	14.2	14.1	241,711	63.8
Xylosma	*congestum*	Shiny xylosma	17,280	0.3	0.0	0.3	3.5	3.5	1,508	7.3
Yucca	*aloifolia*	Aloe yucca	26,680	0.4	0.1	0.5	7.7	9.2	14,402	6.1
Yucca	*guatemalensis*	Bluestem yucca	26,180	0.4	0.1	0.5	13.5	13.2	26,827	3.0

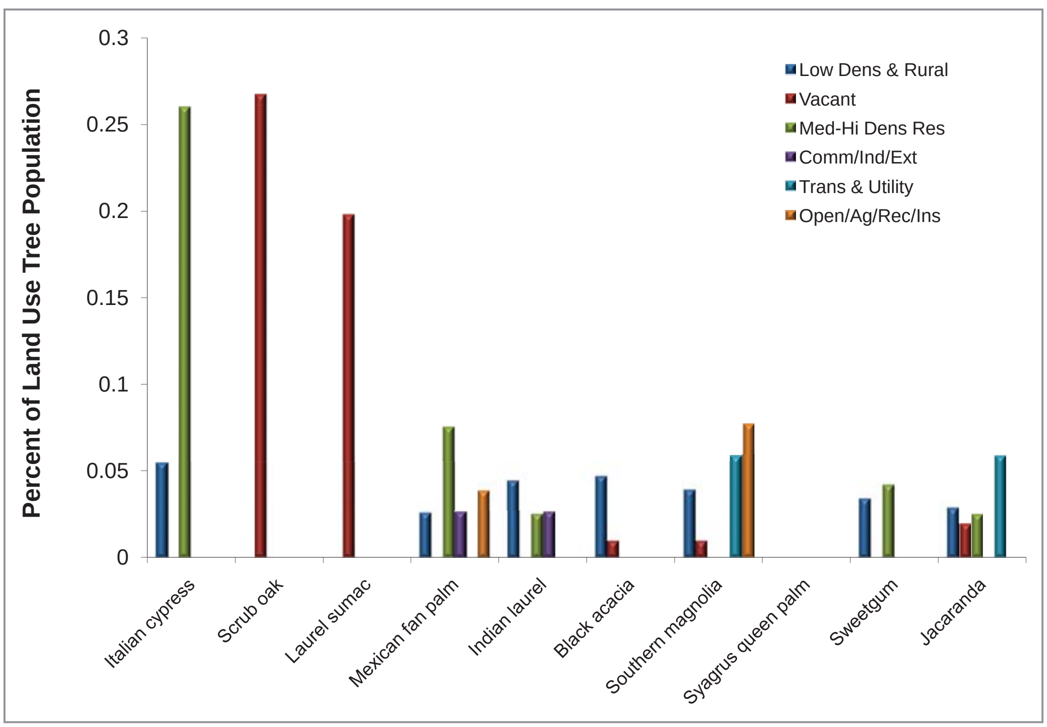
[a] IV = importance value (% population + % leaf area)

Appendix II. Tree Species Distribution

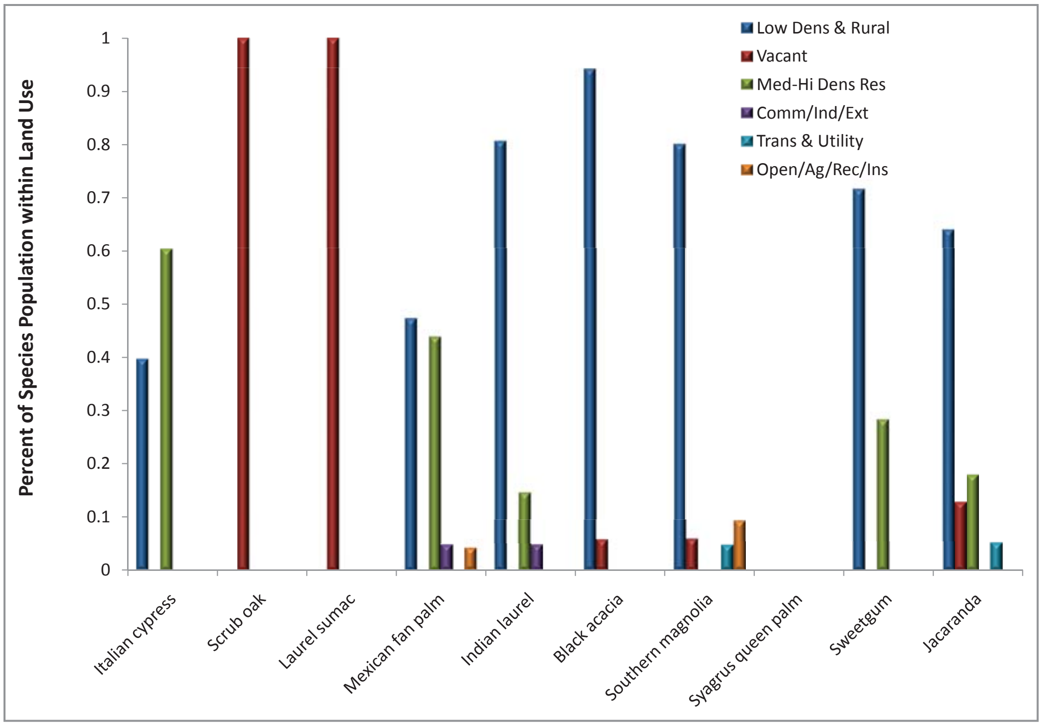
The figures in this appendix illustrate tree species distributions. The species distributions for each of six land-use types are only illustrated for up to the 20 most common species. More detailed information on species by land use can be found at: http://nrs.fs.fed.us/data/urban.



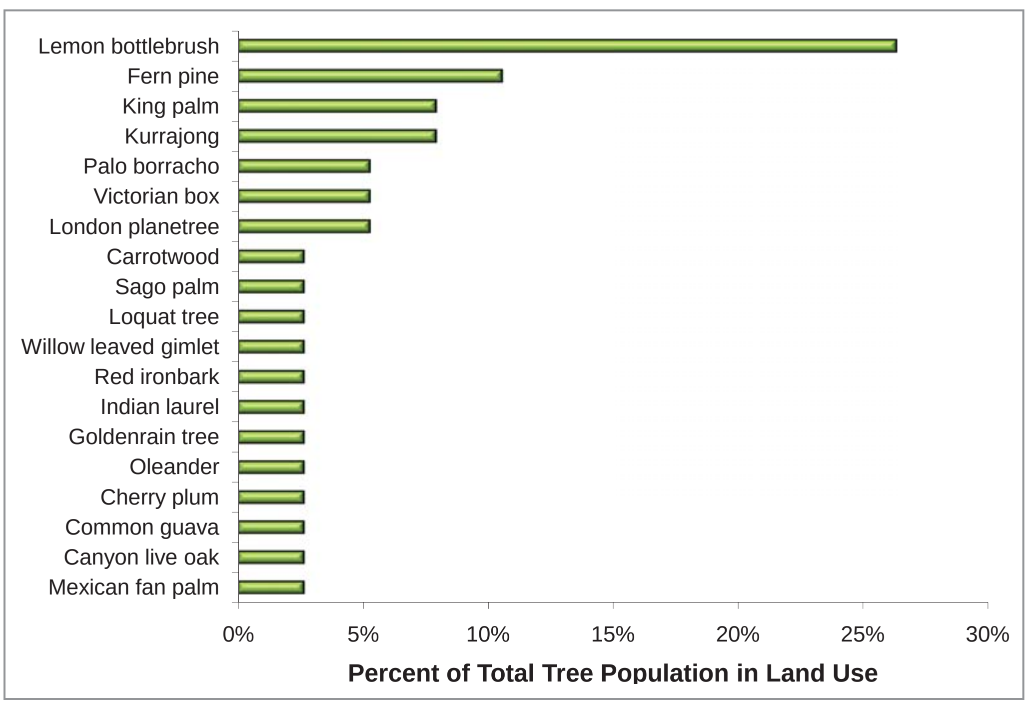
The 20 most common tree species in Los Angeles as a percent of the total tree population.



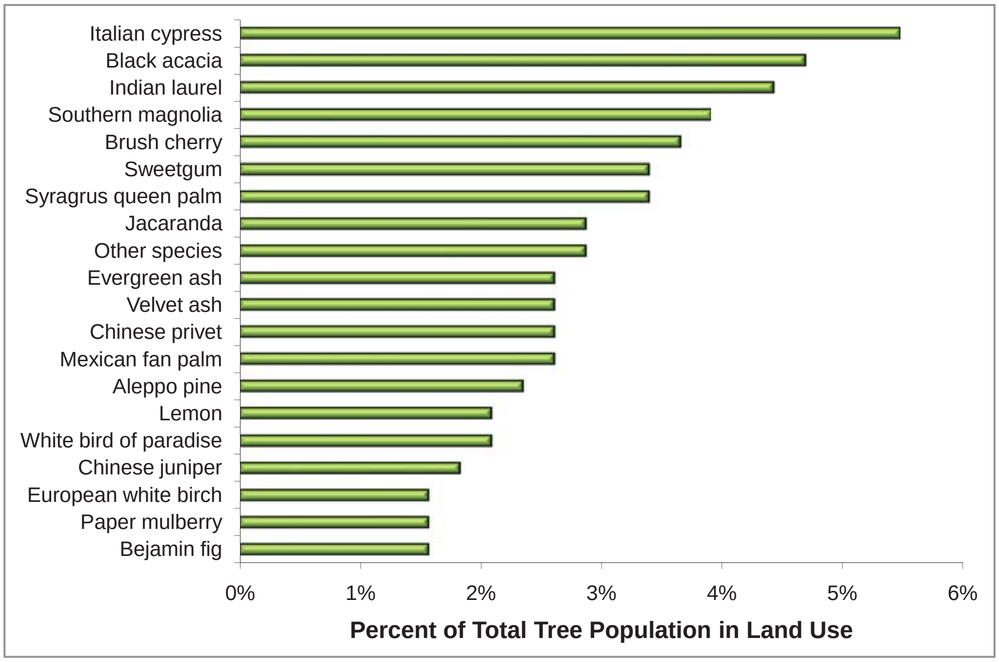
The percent of each land use population occupied by the 10 most common tree species in Los Angeles. For example, Italian cypress comprises 26 percent of the medium to high density residential tree population.



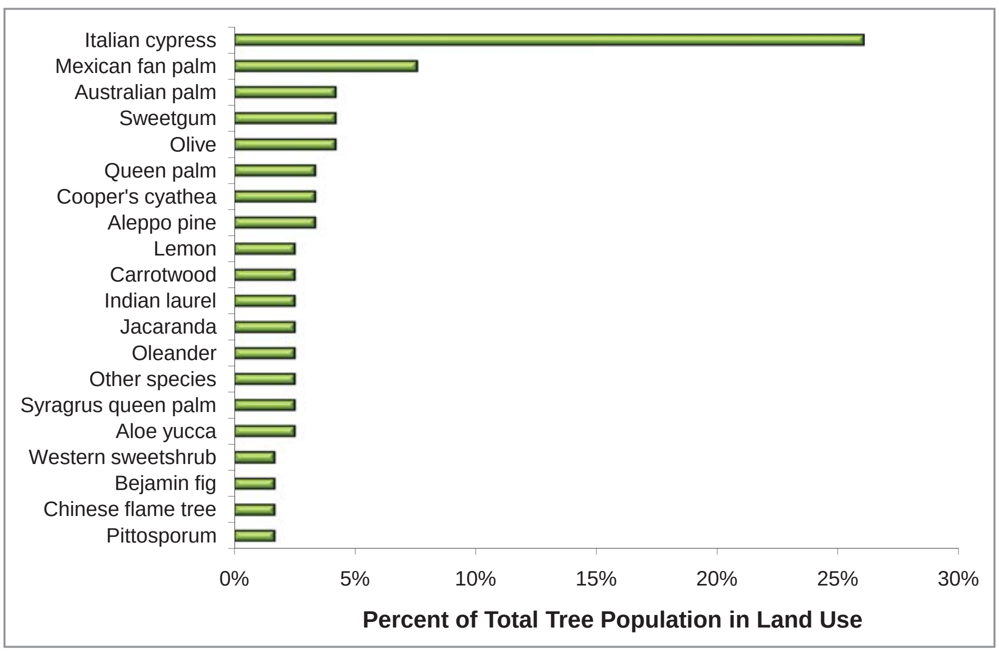
Percent of species population within each land use. For example, 60 percent of Italian cypress are found within medium to high density residential land use.



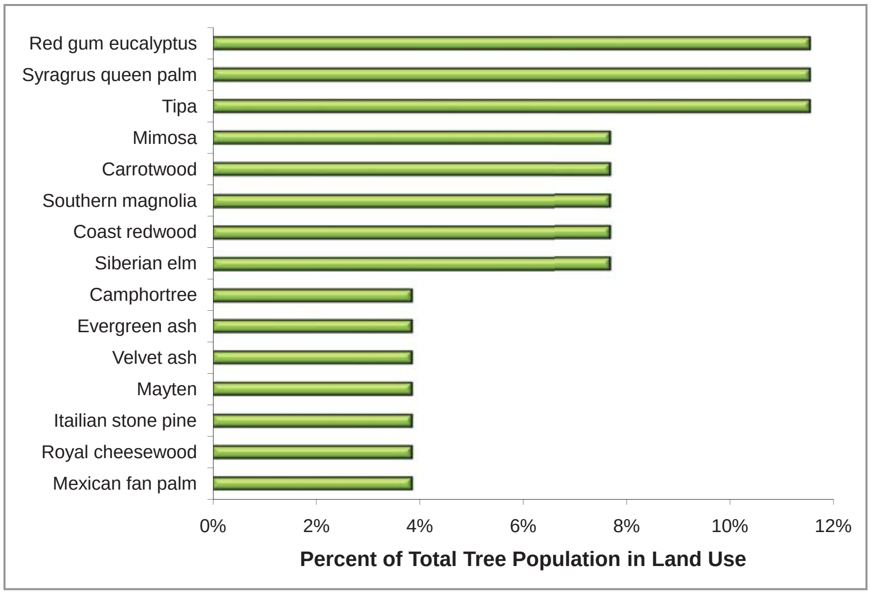
Percent of tree population in the commercial-industrial/extraction land use occupied by each tree species.



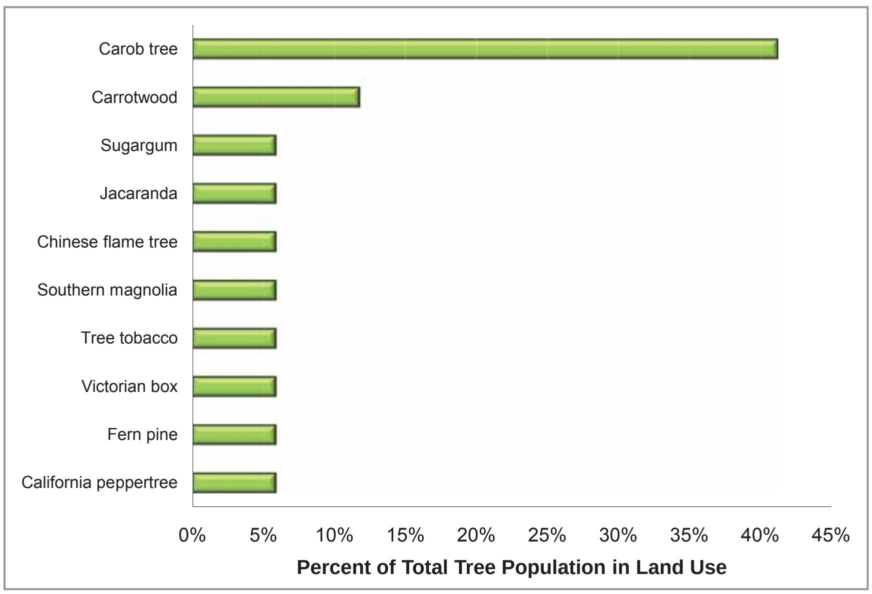
Percent of tree population in the low density residential/rural land use occupied by the 20 most common tree species.



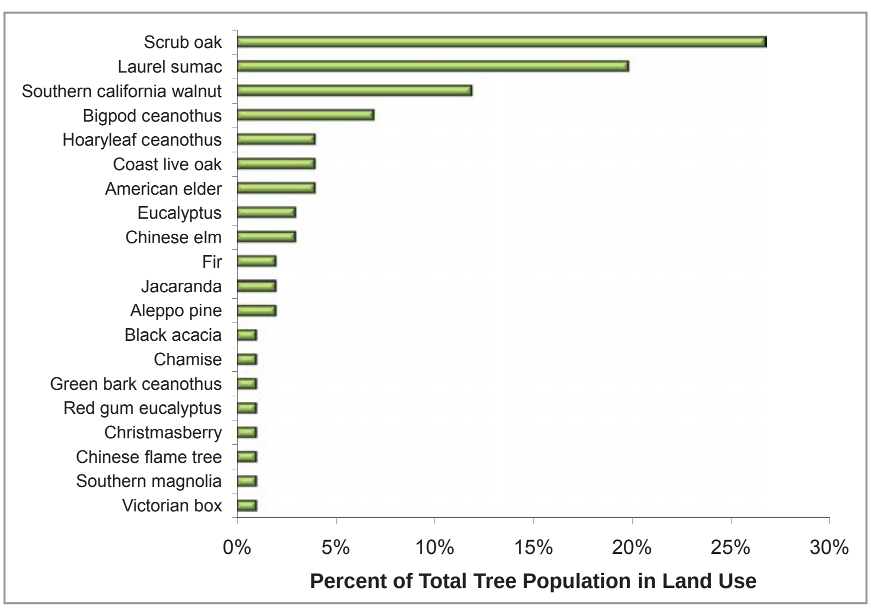
Percent of tree population in the medium and high density land use occupied by the 20 most common tree species.



Percent of tree population in the open/agriculture/recreation/institutional land use occupied by each tree species.



Percent of tree population in the transportation and utility land use occupied by each tree species.



Percent of tree population in the vacant land use occupied by the 20 most common tree species.

Appendix III. Comparison of Urban Forests

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

I. City totals, trees only

City	% Tree cover	Number of trees	Carbon storage (tons)	Carbon sequestration (tons/yr)	Pollution removal (tons/yr)[1]	Pollution removal value U.S. $[2]
Calgary, Alberta[a]	7.2	11,889,000	445,000	21,400	326	2,357,000
Toronto, Ontario[a*]	19.9	10,220,000	1,221,000	51,500	1,283	10,474,000
Atlanta, GA[b]	36.7	9,415,000	1,344,000	46,400	1,663	12,213,000
Sacramento area, CAc*	17.0	6,889,000	1,487,000	71,700	2,914	21,730,000
Los Angeles, CA[d]	11.1	5,993,000	1,269,000	77,000	1,976	14,173,000
New York, NY[b]	20.9	5,212,000	1,350,000	42,300	1,677	11,834,000
Chicago, IL[e]	17.2	3,585,000	716,000	25,200	888	6,398,000
Baltimore, MD[f]	21.0	2,627,000	597,000	16,200	430	3,123,000
Philadelphia, PA[b]	15.7	2,113,000	530,000	16,100	576	4,150,000
Washington, DC[g]	28.6	1,928,000	526,000	16,200	418	2,858,000
Oakville, Ontario[h]	29.1	1,908,000	147,000	6,600	190	1,421,000
Scranton, PA[i]	22.0	1,198,000	93,000	4,000	72	514,000
Boston, MA[b]	22.3	1,183,000	319,000	10,500	284	2,092,000
Woodbridge, NJ[j]	29.5	986,000	160,000	5,600	210	1,525,000
Minneapolis, MN[k]	26.4	979,000	250,000	8,900	306	2,242,000
Syracuse, NY[f]	23.1	876,000	173,000	5,400	109	836,000
San Francisco, CA[a]	11.9	668,000	194,000	5,100	141	1,018,000
Moorestown, NJ[j]	28.0	583,000	117,000	3,800	118	841,000
Jersey City, NJ[j]	11.5	136,000	21,000	890	41	292,000
Casper, WY[a]	8.9	123,000	37,000	1,200	37	275,000
Freehold, NJ[j]	34.4	48,000	20,000	550	22	162,000

II. Per acre values of tree effects

City	No. of trees	Carbon storage (tons)	Carbon sequestration (tons/yr)	Pollution removal (lbs/yr)	Pollution removal value U.S. $[1]
Calgary, Alberta[a]	66.7	2.5	0.12	3.7	13.2
Toronto, Ontario[a*]	64.9	7.8	0.33	16.3	66.5
Atlanta, GA[b]	111.6	15.9	0.55	39.4	144.8
Sacramento area, CA[c*]	21.3	4.6	0.22	18.0	67.3
Los Angeles, CA[d]	19.9	4.2	0.26	13.1	47.1
New York, NY[b]	26.4	6.8	0.21	17.0	59.9
Chicago, IL[e]	24.3	4.8	0.17	12.0	43.3
Baltimore, MD[f]	50.8	11.6	0.31	16.6	60.4
Philadelphia, PA[b]	25.1	6.3	0.19	13.6	49.2
Washington, DC[g]	49.0	13.4	0.41	21.2	72.7
Oakville, Ontario[h]	55.6	4.3	0.19	11.0	41.4
Scranton, PA[i]	116.4	9.1	0.39	13.9	49.9
Boston, MA[b]	33.5	9.1	0.30	16.1	59.3

Appendix III.—continued

City	No. of trees	Carbon storage (tons)	Carbon sequestration (tons/yr)	Pollution removal (lbs/yr)	Pollution removal value U.S. $[1]
Woodbridge, NJ[j]	66.5	10.8	0.38	28.4	102.9
Minneapolis, MN[k]	26.2	6.7	0.24	16.3	60.1
Syracuse, NY[f]	54.5	10.8	0.34	13.6	52.0
San Francisco, CA[a]	22.5	6.6	0.17	9.5	34.4
Moorestown, NJ[j]	62.1	12.4	0.40	25.1	89.5
Jersey City, NJ[j]	14.4	2.2	0.09	8.6	30.8
Casper, WY[a]	9.1	2.8	0.09	5.5	20.4
Freehold, NJ[j]	38.3	16.0	0.44	35.3	130.1

1 Pollution removal and values are for carbon monoxide, sulfur and nitrogen dioxide, ozone, and particulate matter less than 10 microns (PM_{10}).

2 Pollution values updated to 2007 values.

* includes shrub cover in tree cover estimate; based on photo-interpretation or satellite analyses of cover

Data collection group; notes

[a] City personnel
[b] ACRT, Inc.
[c] Sacramento Tree Foundation, urban area of Sacramento region
[d] U.S Forest Service and University of California Riverside
[e] Various Departments of the City of Chicago
[f] U.S. Forest Service
[g] Casey Trees Endowment Fund
[h] City personnel, urban boundary of city
[i] Northeast Pennsylvania Urban & Community Forestry Program staff, Keystone College interns, Penn State Extension Urban Forester, and DCNR Bureau of Forestry staff
[j] New Jersey Department of Environmental Protection
[k] Davey Resource Group

Appendix IV. 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:

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

Appendix V. Relative Tree Effects

The urban forest in Los Angeles provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate a relative value of these benefits, tree benefits were compared to estimates of average carbon emissions in the city[22], average passenger automobile emissions[23], and average household emissions.[24]

General tree information:

Average tree diameter (d.b.h.) = 9.7 in.
Median tree diameter (d.b.h.) = 7.2 in.
Number of live trees sampled = 681
Number of species sampled = 139

Average tree effects by tree diameter:

	Carbon storage			Carbon sequestration			Pollution removal	
D.b.h. Class (inch)	(lbs)	($)	(miles) [a]	(lbs/yr)	($/yr)	(miles)[a]	(lbs)	($)
1-3	7	0.07	20	2.5	0.03	9	0.06	0.21
3-6	38	0.39	140	7.6	0.08	28	0.1	0.47
6-9	111	1.14	400	14.0	0.15	51	0.4	1.27
9-12	221	2.29	810	19.9	0.21	73	0.6	2.23
12-15	375	3.87	1,370	27.0	0.28	99	0.6	2.31
15-18	803	8.31	2,940	50.0	0.52	183	1.5	5.47
18-21	1,012	10.47	3,710	59.7	0.62	219	1.5	5.49
21-24	1,650	17.06	6,040	86.7	0.90	317	2.3	8.31
24-27	2,009	20.79	7,360	90.6	0.94	332	1.9	6.72
27-30	2,886	29.86	10,570	111.6	1.15	409	2.7	9.57
30+	4,608	47.67	16,880	155.5	1.61	570	4.0	14.21

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

The trees in urban Los Angeles provide:

Carbon storage equivalent to:
Amount of carbon (C) emitted in city in 20 days or
Annual carbon emissions from 762,000 automobiles or
Annual C emissions from 382,500 single family houses

Carbon monoxide removal equivalent to:
Annual carbon monoxide emissions from 365 automobiles or
Annual carbon monoxide emissions from 1,500 family houses

Nitrogen dioxide removal equivalent to:
Annual nitrogen dioxide emissions from 29,200 automobiles or
Annual nitrogen dioxide emissions from 19,400 single family houses

Sulfur dioxide removal equivalent to:
Annual sulfur dioxide emissions from 80,200 automobiles or
Annual sulfur dioxide emissions from 1,300 single family houses

Particulate matter less than 10 micron (PM_{10}) removal equivalent to:
Annual PM_{10} emissions from 2,229,800 automobiles or
Annual PM_{10} emissions from 215,300 single family houses

Annual C sequestration equivalent to:
Amount of C emitted in city in 1.2 days or
Annual C emissions from 46,200 automobiles or
Annual C emissions from 23,200 single family homes

Appendix VI. Tree Planting Index Map

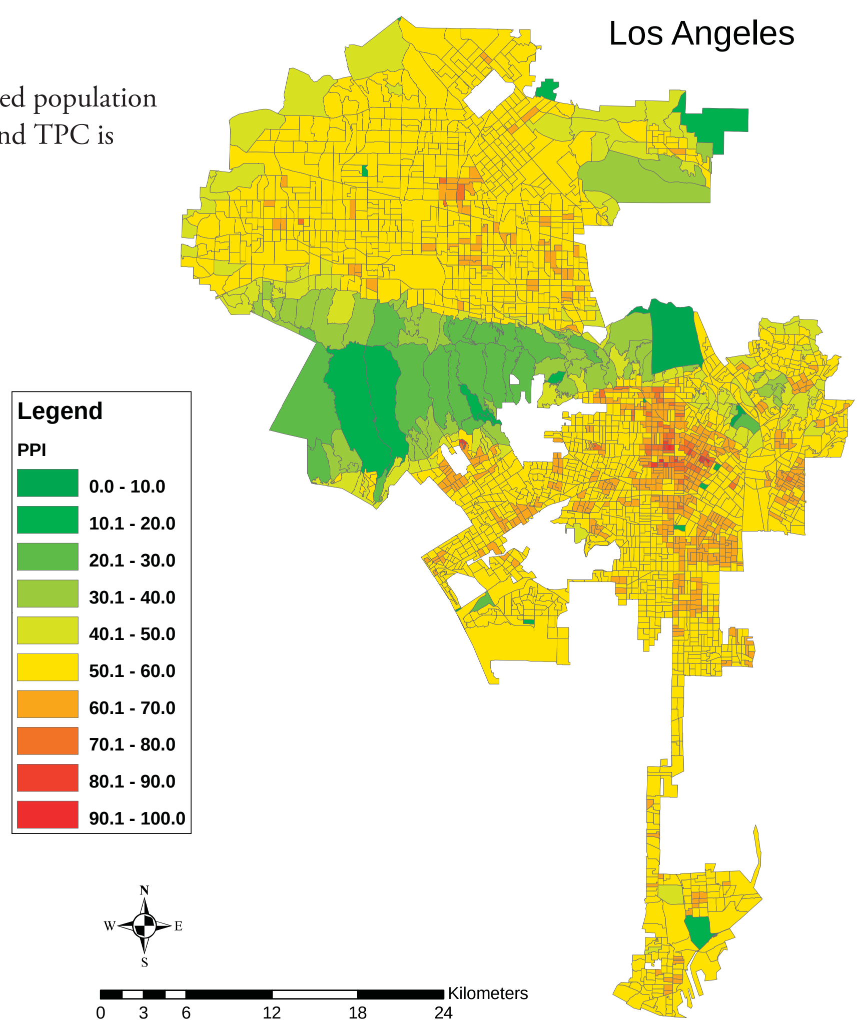
To determine the best locations to plant trees, tree canopy and impervious cover maps from National Land Cover Data[25] were used in conjunction with 2000 U.S. Census data to produce an index of priority planting areas for the City of Los Angeles. Index values were produced for each census block group; the higher the index value, the higher the priority of the area for tree planting. This index is a type of "environmental equity" index with areas with higher human population density and lower tree cover tending to get the higher index value. The criteria used to make the index were:

- Population density: the greater the population density, the greater the priority for tree planting
- Tree stocking levels: the lower the tree stocking level (the percent of available greenspace (tree, grass, and soil cover areas) that is occupied by tree canopies), the greater the priority for tree planting
- Tree cover per capita: the lower the amount of tree canopy cover per capita (m^2/capita), the greater the priority for tree planting

Each criteria was standardized[26] on a scale of 0 to 1 with 1 representing the census block group with the highest value in relation to priority of tree planting (i.e., the census block group with highest population density, lowest stocking density or lowest tree cover per capita were standardized to a rating of 1). Individual scores were combined and standardized based on the following formula to produce an overall priority planting index (PPI) value between 0 and 100:

$$PPI = (PD * 40) + (TS * 30) + (TPC * 30)$$

Where PPI = index value, PD is standardized population density, TS is standardized tree stocking, and TPC is standardized tree cover per capita.



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Explanation of Calculations of Appendix III and IV

22 Total city carbon emissions were based on 2003 U.S. per capita carbon emissions, calculated as total U.S. carbon emissions (Energy Information Administration, 2003, Emissions of Greenhouse Gases in the United States 2003. http://www.eia.doe.gov/oiaf/1605/1605aold.html) divided by 2003 total U.S. population (www.census.gov). Per capita emissions were multiplied by study population to estimate total city carbon emissions.

23 Average passenger automobile emissions per mile were based on dividing total 2002 pollutant emissions from light-duty gas vehicles (National Emission Trends http://www.epa.gov/ttn/chief/trends/index.html) by total miles driven in 2002 by passenger cars (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Average annual passenger automobile emissions per vehicle were based on dividing total 2002 pollutant emissions from light-duty gas vehicles by total number of passenger cars in 2002 (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Carbon dioxide emissions from automobiles assumed 6 pounds of carbon per gallon of gasoline with energy costs of refinement and transportation included (Graham, R.L.; Wright, L.L.; Turhollow, A.F. 1992. The potential for short-rotation woody crops to reduce U.S. CO_2 emissions. Climatic Change. 22: 223-238.)

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CO emission per kWh assumes one-third of 1 percent of C emissions is CO based on:

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PM_{10} emission per kWh from:

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CO_2, NOx, SO_2, PM_{10}, 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:

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26 Standardized value for population density was calculated as PD = (n – m)/r, where PD is the value (0-1), n is the value for the census block (population / km^2), m is the minimum value for all census blocks, and r is the range of values among all census blocks (maximum value – minimum value). Standardized value for tree stocking was calculated as TS = 1 – [t/(t+g)], where TS is the value (0-1), t is percent tree cover, and g is percent grass cover. Standardized value for tree cover per capita was calculated as TPC = 1 – [(n – m)/r], where TPC is the value (0-1), n is the value for the census block (m^2/capita), m is the minimum value for all census blocks, and r is the range of values among all census blocks (maximum value – minimum value).


Used with permission by the City of Los Angeles Urban Forestry Division

Nowak, David J.; Hoehn, Robert E. III; Crane, Daniel E.; Weller, Lorraine; Davila, Antonio. 2011. **Assessing urban forest effects and values, Los Angeles' urban forest.** Resour. Bull. NRS-47. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 30 p.

An analysis of trees in Los Angeles, CA, reveals that this area has about 6 million trees with tree and shrub canopies that cover 24.9 percent of the city. The most common tree species are Italian cypress, scrub oak, laurel sumac, Mexican fan palm, and Indian laurel, Trees in Los Angeles currently store about 1.3 million tons of carbon (4.7 million tons CO_2) valued at $26.3 million. In addition, these trees remove about 77,000 tons of carbon per year (282,000 tons CO_2/year) ($1.6 million per year) and about 1,976 tons of air pollution per year ($14.2 million per year). Los Angeles' trees are estimated to reduce annual residential energy costs by $10.2 million per year. The structural value of the trees is estimated at $12.4 billion. Information on the structure and functions of the urban forest can be used to inform urban forest management programs and to integrate urban forests within plans to improve environmental quality in Los Angeles.

KEY WORDS: urban forestry, ecosystem services, air pollution removal, carbon sequestration, tree value

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