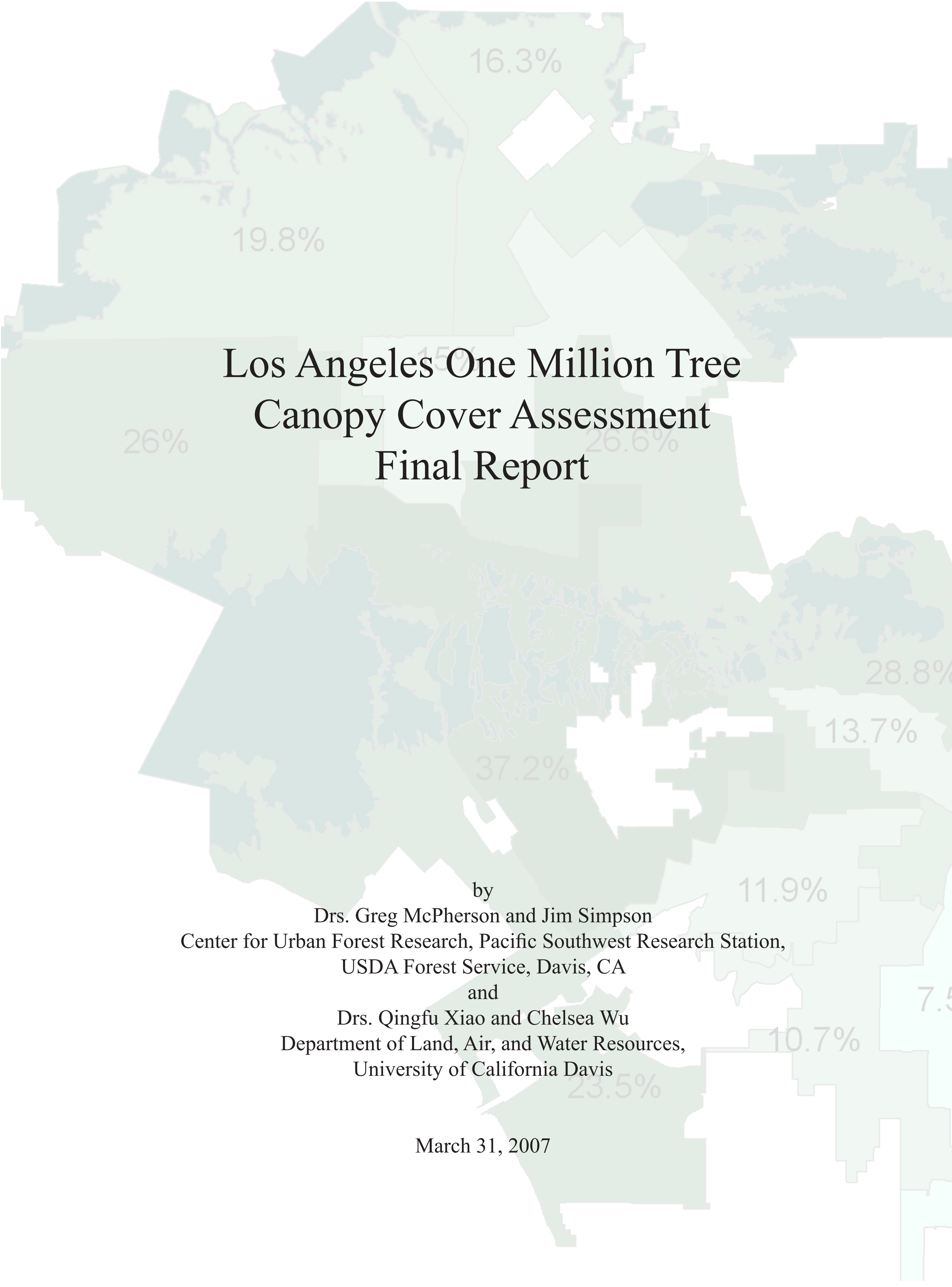

Los Angeles One Million Tree Canopy Cover Assessment Final Report

by
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Executive Summary

Mayor Antonio Villaraigosa of the City of Los Angeles, California, has charted a course for sustainable growth, and the region's community forest is a critical component of that vision. On September 30, 2006, the mayor kicked-off his plan to plant one million trees in the next several years. The Million Trees LA initiative demonstrates the relevance of community forestry to the environmental, social, and economic health of Los Angeles.

To assist the city of Los Angeles, the Center for Urban Forest Research has conducted the study presented here to (1) measure existing tree canopy cover (TCC), (2) characterize potential TCC to determine the feasibility of planting one million trees, and (3) estimate future benefits from planting one million new trees. The study area is the City of Los Angeles (473 sq. miles, population 3.7 million), excluding mountainous areas. Results are reported citywide and for the 15 council districts and 86 neighborhood councils.

High-resolution QuickBird remote sensing data, aerial photographs, geographic information systems, and image-processing software were used to classify land cover types, measure TCC, and identify potential tree planting sites. The accuracy assessment found that overall land cover classification accuracy was 88.6% based on a pixel-by-pixel comparison. The accuracy for classifying existing TCC was 74.3%.

One unique aspect of this study was "training" the computer to follow rules for locating potential planting sites, then drawing a circle for each small (15-ft crown diameter), medium (30 ft), and large (50 ft) tree site. Ground-truthing of 55 parcels led to calibration of the computer-generated estimates. Realistic TCC targets were determined for each council district with the goal of filling 50% of the available planting sites. This TCC target recognizes that each council district is unique because it has a different land use mix, as well as different existing and potential TCC that reflects historic patterns of development and tree stewardship. Each council district can do its "fair share" in helping the city meet its overall goal by filling 50% of its available tree planting sites. In so doing, council districts with the greatest number of empty planting sites will achieve the greatest relative increase in TCC, while those with higher stocking levels will obtain less enhancement.

Los Angeles's existing TCC is 21%, which compares favorably with 20% in Baltimore and 23% in New York City. This finding is surprising given Los Angeles's Mediterranean climate, which makes irrigation essential for establishment and growth of many tree species. Other plantable space, such as irrigated grass and dry grass/bare soil, accounts for 12 and 6% of the city, respectively. Impervious (e.g., paving, roofs) and other surfaces (i.e., water) comprise the remaining 61% of the city's land cover (excluding mountainous areas). Hence, one-third of Los Angeles's land cover is either existing TCC or grass/bare soil with potential to become TCC. The number of existing trees is estimated to be 10.8 million assuming an average tree crown diameter of 16.4 ft.

At the council district (CD) level, TCC varied from lows of 7 to 9% in CDs 9 and 15 (Perry and Hahn) to a high of 37% in CD 5 (Weiss). TCC was strongly related to land use. As expected, low-density residential land uses had the highest TCC citywide (31%), while industrial and commercial land uses had lowest TCC (3–6%).

Existing TCC exceeded 40% in three neighborhood councils: Bel Air-Beverly Crest (53%), Arroyo Seco (46%), and Studio City (42%). Neighborhood councils with the lowest TCC were Downtown Los Angeles (3%), Wilmington (5%), and Historic Cultural and Macarthur (6%).

There is potential to add 2.5 million additional trees or 12.4% TCC. Thus, technical potential for Los Angeles is 33.2% TCC, or about 13.3 million trees. However, it is not realistic to think that every possible tree site will be planted. Assuming a realistic target of filling about 50% of the unplanted sites results in adding 1.3 million more trees equivalent to a 6.7% increase in TCC. Hence, market potential is 27.5% TCC, or 12.1 million trees. Planting one million trees is feasible and if accomplished as indicated above, would saturate 97% of the existing market potential.

Benefits are forecast for a scenario that gradually increases the rate of the planting of one million trees between 2006 and 2010 and tracks their growth and mortality until 2040. Tree growth over the 35-year period is based on intensive measurements of predominant street tree species in Santa Monica for coastal Los Angeles, and in Claremont, for inland Los Angeles. Representative small, medium, and large species were selected for each zone to model growth, with nearly one-half of the trees small, 42% medium, and 9% large at maturity. Low- and high-mortality scenarios reflect effects of loss rates on tree numbers and associated benefits. After 35 years, the number of surviving trees is 828,924 and 444,889 for the two scenarios, respectively. In both scenarios, planted trees are distributed among land uses such that 55% are in low density residential, 17% in institutional, 14% in medium/high density residential, 9% in commercial and 5% in industrial.

Numerical models were used with geographic data and tree size information for the coastal and inland climate zones to calculate annual benefits and their monetary value. Benefits calculated on an annuall basis and summed for the 35-year period are $1.64 billion and $1.95 billion for the high- and low-mortality scenarios, respectively. These values translate into $1,639 and $1,951 per tree planted, or $49 and $60 per tree per year when divided by the 35-year period. Eighty-one percent of total benefits are aesthetic/other, 8% are stormwater runoff reduction, 6% energy savings, 4% air quality improvement, and less than 1% atmospheric carbon reduction.

The distribution of benefits among council districts is closely related to the climate zone and the number of trees planted. Benefits per tree are about 50% less ($700⁻1,000 instead of $1,300–2,400) in the coastal zone (CD 11 and 15) than the inland zone because the growth curve data indicate that the trees are smaller, air pollutant concentrations are lower, and building heating and cooling loads are less due to the milder climate.

Aesthetic and other benefits. Citywide, aesthetic and other benefits ranged from $1.1 to $1.6 billion, or $1,100 to $1,600 per tree over the 35-year period for the high and low mortality scenarios. This amount reflects the economic contribution of trees to property sales prices and retail sales, as well as other benefits such as beautification, privacy, wildlife habitat, sense of place, psychological and spiritual well-being.

Stormwater runoff reduction. By intercepting rainfall in their crowns, trees reduce stormwater runoff and protect water quality. Over the 35-year span of the project, one million trees will reduce runoff by approximately 13.5–21.3 billion gallons (18.1–28.4 million Ccf). The value of this benefit ranges from $97.4 to $153.1 million for the high- and low-mortality scenarios, respectively. The average annual interception rate per tree ranges from a low of 102 gal to a high of 1,481 gal based on tree size, rainfall amounts, and foliation period.

Energy use reduction. By shading residential buildings and lowering summertime air temperatures, the one million trees are projected to reduce electricity consumed for air conditioning by 718,671 to 1.1 million MWh or $76 to $119 million for the high- and low-mortality scenarios. However, this cooling savings is partially offset by increased heating costs from tree shade that obstructs winter sunlight. Tree shade is expected to increase natural gas required for heating by 101,000 to 154,000 MBtu, which is valued at $674,000 to $1 million. Despite this cost, a net energy savings of $75.7 to $117.4 million is projected for the high- and low-mortality scenarios.

Atmospheric carbon dioxide reduction. Over the 35-year planning horizon, the one million trees are projected to reduce atmospheric carbon dioxide (CO_2) by 764,000 to 1.27 million tons, for the high- and low-mortality scenarios. Assuming this benefit is priced at $6.68 per ton, the corresponding value is $5.1 to $8.5 million. Emission reductions at power plants associated with effects of the trees on building energy use (498,000 to 772,000 tons) are greater than biological sequestration of CO_2 by the trees themselves (389,000 to 598,000 tons). A relatively small amount of CO_2 is released during tree care and due to decomposition of dead biomass (101,000 to 123,000 tons). The CO_2 reduction benefit varies widely based on tree size. For example, in the inland zone for the low-mortality scenario, the small tree annually sequesters and reduces emissions by only 5 and 55 lb per tree on average, compared to 220 and 150 lb for the large tree.

Air quality improvement. By improving air quality, the tree planting will enhance human health and environmental quality in Los Angeles. This benefit is valued at $53 to $83 million over the 35-year planning horizon. Interception of small particulate matter (PM_{10}) and uptake of ozone (O_3) and nitrogen dioxide (NO_2) are especially valuable. The one million tree planting project is estimated to intercept and reduce power plant emissions of PM_{10} by 1,846 to 2,886 tons over the 35-year period for the high and low mortality scenarios, respectively. The value of this benefit ranges from $19 to $29 million, or 35% of total air quality benefits.

The one million trees are projected to reduce O_3 by 2,430 to 3,813 tons, with average annual deposition rates ranging from 0.25 to 0.35 lb per medium tree in the low-mortality scenario for the coastal and inland zones, respectively. Ozone uptake is valued at $17.9 to $28.1 million over the project life for the high and low mortality scenarios, or 34% of total air quality benefits.

Uptake of NO_2, an ozone precursor, is estimated to range from 1,949 to 3,039 tons, with a value of $14.6 to $22.8 million for the high and low mortality scenarios over the 35-year period. This benefit accounts for 27% of the total air quality benefit.

We found that the benefit values reported here are reasonable when compared with previously reported findings from similar analyses for the same region. However, it is important to note limitations of this study and to identify sources of error. These limitations are discussed fully in the Discussion section of this report.

We conclude this study with a series of recommendations. The GIS data and benefit values generated here are valuable assets for the city and its residents. To manage and disseminate this information we suggest:

- The City establish a central clearinghouse for GIS data related to the Million Trees LA program.
- Million Trees LA develop a one-page handout that summarizes key points from this study, particularly the future benefits to be gained from investment in tree planting and stewardship.
- To document all aspects of this research and make it readily accessible, the Center for Urban Forest Research publish a General Technical Report, peer-reviewed and available at no cost to the public through the U.S. Forest Service.
- Important aspects of this study be summarized and posted on the Million Trees LA Web site.

The Center for Urban Forest Research proposes working with Million Trees LA to develop a GIS Decision Support System (GDSS) that allows tree planting coordinators to make use of the data from this study. The GDSS will allow users without extensive GIS experience to examine different parcels, select and locate trees to provide the greatest benefits, budget for planting and maintenance costs, project the future stream of benefits, assess the ecological stability of the planting at a population level, and track future tree survival and growth. The GDSS will help Los Angeles maximize its return on investment in tree planting through application of state-of-the-art science and technology.

Approximately 20% of the target TCC for Los Angeles is paved parking lot area. Planting trees in parking lots poses technical and financial challenges. However, if done judiciously, there are opportunities for parking lot tree plantings to substantially improve air quality, reduce stormwater runoff, cool urban heat islands, and improve community attractiveness. We recommend that the Million Trees LA program establish new partnerships aimed at developing the technical specifications, financial means, and community support for a major parking lot greening effort in Los Angeles that could serve as a model for cities around the world.

CUFR proposes a collaboration with other scientists in Southern California to study the effects of trees on the social, economic, and environmental health of Los Angeles and its nearly four million residents. In particular, we need to better understand:

- Barriers to tree planting and incentives for different markets
- Effects of trees on the urban heat island and air quality
- Effects of drought stress on tree survival and ability to remove air pollutants
- Primary causes of tree mortality
- Best management practices to promote tree survival
- Citywide policy scenarios to promote urban tree canopy, neighborhood desirability, and economic development
- How to link TCC goals to other city goals: increasing community health, neighborhood quality of life, environmental literacy, and sustainability.

As the second largest city in the United States, Los Angeles manages an extensive municipal forest. Its management should set the standard for the region and the country. We recommend that CUFR and the City of Los Angeles cooperate to conduct a tree inventory and assessment that provides information on the structure, function, value, and management needs of the existing urban forest. This information will establish a sound basis for management aimed at increasing resource sustainability.

Los Angeles is a vibrant city that will continue to grow. As it grows it should also continue to invest in its tree canopy. This is no easy task, given financial constraints and trends toward higher density development that may put space for trees at a premium. The challenge ahead is to better integrate the green infrastructure with the gray infrastructure by increasing tree planting, providing adequate space for trees, and designing plantings to maximize net benefits over the long term, thereby perpetuating a resource that is both functional and sustainable. CUFR looks forward to working with the City of Los Angeles and its many professionals to meet that challenge in the years ahead.

Introduction

Urbanization creates significant changes in land use and land cover, affecting the structure, pattern and function of ecosystems. The public is increasingly concerned about how these changes influence daily life and affect the sustainability of "quality of life" for future generations. Improving air quality, alleviating water shortages, cooling urban heat islands, and reducing stormwater runoff are challenges facing Los Angeles. With a current population of nearly four million, rapid growth in Los Angeles is accelerating these problems. The problems need solutions as the region tries to protect and restore environmental quality while enhancing economic opportunity.

Tree canopy is a valuable component of Los Angeles's urban ecosystem (McBride and Jacobs 1986). Trees in urban settings are termed an urban forest, and they can play an important role by improving urban life, human health, and emotional well-being. Research suggests that human beings have an innate affiliation to natural settings – a concept described as biophilia (Kellert and Wilson 1993). Numerous studies link access to living trees, outdoor air, and natural light to increased employee and student productivity, faster hospital recoveries, less crime, and an overall reduction in stress and anxiety. Thus, expanding the urban forest is part of the solution to Los Angeles's social, environmental, and economic problems—it is integral to enhancing public health programs, increasing land values and local tax bases, providing job training and employment opportunities, reducing costs of city services, and increasing public safety, as well as improving air quality, offsetting carbon emissions, managing stormwater runoff, mitigating water shortages, and conserving energy.

Million Trees LA initiative

Mayor Antonio Villaraigosa of the City of Los Angeles, California, has charted a course for sustainable growth, and the region's community forest is a critical component of that vision. On September 30, 2006, the mayor kicked-off his plan to plant one million trees in the next several years. The Million Trees LA initiative demonstrates the relevance of community forestry to the environmental, social, and economic health of Los Angeles.

Tree canopy cover assessments

Tree canopy cover (TCC) is the percentage of a site covered by the canopies of trees. Many communities are adopting TCC goals to maintain and improve forest cover. Advances in remote sensing technology and geographic information systems (GIS) make it practical to measure TCC on a periodic basis (Price et al. 2002, Ustin and Xiao 2001, Weber and Puissant 2003, Xiao and McPherson 2005, Xiao et al. 2004). Vegetation has unique spectral reflectance characteristics with strong absorption in red wavelengths and strong reflectance in near-infrared wavelengths that allow separation of trees from other ground surface covers.

TCC has become a popular metric for several reasons. It is relatively easy to measure with remote sensing technology and less costly than field sampling. TCC is a number that is comparable across a city and among cities. The size of the area measured does not matter. TCC is a good performance measure because it can be applied to detect change across space and time. Finally, TCC is an easy-to-understand concept that is useful in communicating to the public (Poracsky and Lander 2004).

It is important to recognize the limitations associated with TCC as a metric. TCC is two dimensional, only indicating the spread of canopy across land surfaces. It does not provide information on the vertical extent of tree canopy, species composition, age diversity, or health. To describe the structure, function, and value of urban forests fully, data obtained from field sampling are required as well. For example, many functional benefits have been linked to the leaf surface area of trees, which is difficult to estimate with accuracy using only TCC. Moreover, predicting future trends in urban forest structure, function, and management needs requires a richer data set than TCC alone provides.

Accurately classifying TCC is difficult owing to the complex spatial assemblages of disparate patches of land cover types in urban settings. Urban areas are a mosaic of many different land covers, land uses, and built structures, each of which has different spectral reflectance characteristics (Gong and Howarth 1990). Unlike trees in rural forests that tend to form continuous canopies, trees in urban settings are often isolated or in small groups. The influence of background, such as soil and shadow, makes the problem of characterizing trees by remote sensing even more difficult. In such cases, high-resolution remotely sensed data is important for accurate TCC mapping (Xiao et al. 2004).

Many studies have used remote sensing data and GIS to map tree canopy cover. American Forests has used satellite imagery and CITYgreen GIS software to map historic TCC change, as well as the value of annual benefits from urban forests for cities such as Atlanta, Georgia, Washington, D.C., and Roanoke, North Carolina (American Forests 2002a, b, c). Galvin and others (2006) used IKONOS data (13-ft spatial resolution) to map TCC in Baltimore, Maryland. Goetz and others (2003) found the accuracy of tree cover estimates mapped with IKONOS imagery in the mid-Atlantic region to be comparable to manual aerial photo interpretation. Poracsky and Lackner (2004) compared Portland's tree canopy in 1972, 1991, and 2002 using TM and multi-spectral scanner data (100-ft plus resolution). High-resolution infrared photography and light detection and ranging (LIDAR) data were used to map TCC in Vancouver, Washington (Kaler and Ray 2005). Urban cover was mapped with 82% accuracy for Syracuse, New York, using high-resolution digital color-infrared imagery (Myeong et al. 2001), and similar data were used to assess New York City's TCC (Grove et al. 2006). Xiao and others (2004) used AVIRIS (Airborne Visible Infrared Imaging Spectrometer) data to map urban tree species in Modesto, California, but developing spectral signatures for each species was time consuming.

Potential TCC is the percentage of area on the ground that could be covered by tree canopy. Traditionally, potential TCC is the amount of residual pervious surface, including all grass and bare soil. It does not include tree cover that could be achieved by adding trees to impervious surfaces like paved parking lots and plazas.

We differentiate between two other terms related to TCC, technical potential and market potential (McPherson 1993). Technical potential is the total amount of planting space—existing TCC plus pervious surfaces that could have trees—while market potential subtracts the amount that is not plantable given physical or preferential barriers that preclude planting. Physical barriers include conflicts between trees and other higher priority existing or future uses, such as sports fields, vegetable gardens, and development. Another type of market barrier is personal preference to keep certain locations free of TCC. While technical potential is easily measured, market potential is a complex sociocultural phenomenon that has not been well-studied. The only study we are aware of is a survey of nonparticipants of the Sacramento Shade program (Sarkovich 2006). The two most common reasons customers chose not to accept a free shade tree were lack of space (34%), a physical constraint, and "Do Not Want Any More Trees," (25%) a personal preference. This finding applies primarily to low density residential land uses and suggests that a substantial amount of potential TCC is likely to remain tree-free due to market forces.

Communities set TCC targets as measurable goals that inform policies, ordinances, and specifications for land development, tree planting, and preservation. TCC targets should respond to the regional climate and local land use patterns. Climate is important because cities in regions where the amount of rainfall favors tree growth tend to have the most TCC. For example, mean TCC was higher in cities in naturally forested areas (31%) than in grasslands (19%) and deserts (10%) (Nowak et al. 1996). Within a city, land use is the dominant factor influencing TCC because it affects the amount of space available for vegetation. Residential land uses tend to have the greatest TCC, and commercial/industrial land uses have the least (Sanders 1984).

American Forests has developed the most widely adopted TCC targets. Their TCC targets reflect constraints posed by regional climate and land use patterns. Based on studies throughout the United States, American Forests developed generic tree canopy cover targets for temperate and arid climate cities (Kollin 2006). For arid cities such as Los Angeles, they recommend an average citywide TCC of 25%, with values of 35% for suburban zones, 18% for urban residential zones, and 9% for commercial land uses. Suggested TCC targets are substantially higher for temperate cities. Communities such as Roanoke, Virginia (Urban Forestry Task Force 2003) and Montgomery County, Maryland (Montgomery County 2000) have adopted American Forests' TCC targets.

In New York City, where existing TCC was 23% and another 43% of potential TCC was identified, the TCC target was set at 30% (Grove et al. 2006) (*Figure 1*). The 30% target corresponded to an air quality modeling scenario employed in a related study (Luley and Bond 2002), but there was no functional relationship indicating that this was an optimal TCC. In Baltimore, existing TCC was 20% and there was potential for another 53% TCC (Galvin et al. 2006). The target TCC was 46%, filling one-half of the potential TCC (*Figure 1*). This target was related to results from a remote sensing study that detected increased levels of stream health associated with greater watershed tree cover, although impervious cover was the primary predictive variable (Geotz et al. 2003). Different TCC targets were set for each land use in both New York City and Baltimore.

The cities of Portland, Oregon (Poracsky and Lackner 2004), and Vancouver, Washington (Kaler and Ray 2005), set TCC targets by land use corresponding to the 75th percentile, a value that falls mid-way in the range of the upper-half of the data (*Figure 1*). They found that TCC values were not normally distributed within land uses and, therefore, the mean value is not very representative. They selected the 75th percentile value as a target because it is both attainable—that value had been achieved or surpassed in 25% of the data set—and high enough to result in a noticeable expansion of TCC. Citywide TCC targets were set at 46% in Portland and and 28% in Vancouver.

Objectives

The objectives of this study were to (1) measure existing TCC, (2) characterize potential TCC to determine the feasibility of planting one million trees, and (3) estimate future benefits from planting one million new trees.

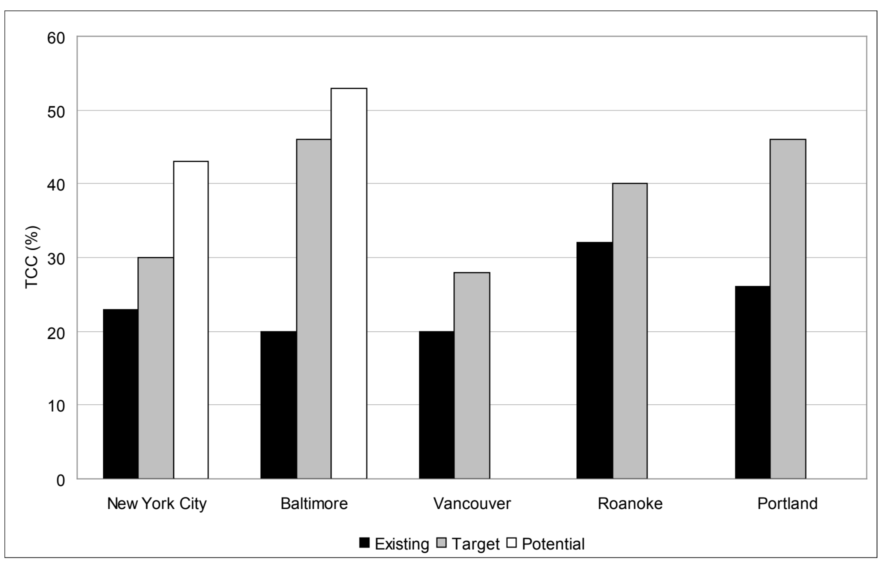

Figure 1. Existing, target, and potential tree canopy cover (TCC) for five U.S. cities

Figure 2. The study area is the city of Los Angeles

Methodology

Study site

The city of Los Angeles was founded by the Spanish in 1781 and served as a colonial capital before incorporation in 1850. City development began in the late 1800s after arrival of the railroads and the discovery of oil in the 1890s. Today, Los Angeles is one of the largest metropolitan areas in the United States and is a major shipping, manufacturing, communications, financial, and distribution center noted for its entertainment industry (*Figure 2*). Like many coastal California cities, it is undergoing a period of rapid population growth and expansion.

Los Angeles (latitude: 34°06′36″ N, longitude: 118°24′40″ W) has a land area of 473 square miles and a population of 3,694,820 (U.S. Census Bureau 2000). There are 15 council districts and 86 neighborhood councils. Topographic gradients are small in the coastal areas and inland valleys; however, within the city limits there are mountain ranges with steep slopes. Elevation changes from sea level to 5,063 ft at Mount Lukens in the northeast corner of the city.

Data sets

Remote sensing data

Very high spatial resolution remote sensing data were required to accurately map vegetation coverage and available tree planting sites at the parcel scale. QuickBird satellite imagery (DigitalGlobe, Longmont, CO) was used with pixel resolutions of 2.0 ft for panchromatic data and 7.9 ft for multispectral data.

In this study, we demonstrate an important application of urban TCC mapping by combining remote sensing and GIS (geographic information system) techniques. Coupling GIS to the analysis of remote sensing data improves the accuracy of the results. Incorporating spatial location is a standard method for registering images to base maps (Ambrosia et al. 1998, Lakshmi et al. 1998, Shao et al. 1998).

Three types of remotely sensed data and several GIS data layers were used in this study. The QuickBird data included 82 scenes that were collected from 2002 to 2005. Most of these data were collected when deciduous trees were in leaf, but several images were collected during the transition periods of late March and early November. Aerial imagery included year 2000 black and white images at 6-in resolution (City of Los Angeles, California) and 2005 natural color images at 3-ft resolution (USDA Forest Service). The image-processing system ENVI (Environment for Visualizing Images, Research Systems, Lafayette, CO) was used for image analysis.

GIS data

GIS data layers were provided by the Public Works, Bureau of Engineering of the City of Los Angeles. Data layers included the boundaries of the city, neighborhood councils, council districts, parcels, and parks, and streets and land uses. ArcGIS (Environmental Systems Research Institute) was used for mapping and other spatial analysis. All vegetation and potential tree planting sites were in ArcGIS format. Nine original land use classes were aggregated into six classes (*Table 1*).

Table 1. Nine land use classes aggregated into six

Final land use class	Original land use class
Unknown	Unknown
Low density residential	Low density housing
Medium/high density residential	Medium density housing High density housing
Industrial	Heavy industry Light industry
Commercial	Neighborhood commerce Regional commerce
Institutional	Open space/public and quasi-public lands

Measuring existing TCC

Initial data processing involved reassembling remote sensing and GIS data layers. The key elements of this step included geo-registering remote sensing data and projecting all data to the California State Plane. The multispectral QuickBird data were pan-sharpened using a PC bilinear interpolation to produce a more defined image at 60-cm spatial resolution.

General classification processes

Classification is a statistical process that groups homogeneous pixels into areas of interest based on common spectral characteristics. Two commonly used classification techniques are supervised (human-assisted) and unsupervised (clustering). Each method serves a particular purpose, and both methods were used in this study. We selected four land cover mapping types based on the objectives of this project: tree (tree and shrub), grass (green grass and ground cover), dry grass/bare soil (dry grass and bare soil), and impervious surface (include pervious pavement).

Supervised classification used spectral angle mapper (SAM) because it is a physically-based spectral classification. Pixels were classified using radiance rather than reflectance. Unsupervised classification automatically clusters pixels into classes with similar spectral signatures based on statistics, without any user-defined training classes. We used K-means, which calculates class means evenly distributed in the data space, then iteratively clusters the pixels into the nearest class using a minimum-distance technique (Tou and Gonzalez 1974).

Data set masking

Masking techniques have been widely used in urban vegetation mapping (Xiao et al. 2004) to reduce the possibility of confusion among cover classes. Three masks were used in this study. The first mask separated green vegetation. The second mask separated nonvegetation (i.e., pavements, buildings, water and bare soil) and dry vegetation (i.e., unirrigated grass). The third mask separated areas with dry vegetation, bare soil, and other pavements where spectral mixing occurs. These masks were created based on NDVI (normalized difference vegetation index), the ratio of the reflectance difference between near-infrared (NIR) and red and the sum of the reflectance at NIR and red. The NDVI's threshold values for these masks varied from image to image because the QuickBird images were from several years.

The naturally vegetated mountains (50,208 acres) were digitized and masked out from the study area. We masked mountains because their land cover, vegetation management, and topographic gradient are different from the urban areas. A small part of the study area was covered with cloud cover and masked out (8,202 acres). Color aerial images replaced the QuickBird data in these areas.

Vegetation cover mapping

Vegetation cover mapping included mapping tree cover, green grass cover, and dry grass cover. In this study, shrubs were treated as trees. NDVI was used to distinguish vegetation and nonvegetation cover. In urban settings, most trees are planted in irrigated turf grass, where trees and the background cover (e.g., turf grass) have similar NDVI values. We used supervised and nonsupervised classification methods to separate trees from irrigated grass.

Vegetation mapping accuracy assessment

The accuracy of the classification models was assessed on a land cover type basis. The confusion matrix (Kohavi and Provost 1998, Xiao and McPherson 2005) was used as the basis for comparison. We evaluate model accuracy at the parcel scale to avoid the problem commonly caused by co-registration of different data layers. The UFORE (Urban Forest Effects) random plot selection tool (Nowak et al. 2003) was used to select the sample parcels. Land cover types were digitized from the Quickbird images as a reference for comparison.

Existing TCC and tree number estimates

Existing TCC is presented at the citywide, council district, and neighborhood council levels. The number of existing trees is estimated assuming an average tree crown diameter of 16.4 ft, based on results from an intensive field study of trees throughout Sacramento, California (McPherson 1998).

Characterizing potential and target TCC

Previous studies characterized potential TCC as the amount of existing pervious surface (i.e., grass and bare soil) that is not tree cover. Instead of characterizing potential TCC as the residual pervious area, we identify potential tree planting sites for individual trees of small (15-ft crown diameter), medium (30-ft crown diameter), and large (50-ft crown diameter) mature sizes. Data on the numbers and ratios of small, medium, and large trees are used to project future benefits from the one million tree planting for trees with these mature sizes.

Decision rules for locating potential tree planting sites

Although circle-packing and bin-packing algorithms have been developed to place circles into an empty space, they are hard to implement in ArcGIS given the many irregularly shaped polygons that could contain tree sites. We therefore developed a computer program to iteratively search, test, and locate potential tree planting sites. The program begins by masking out a 2-ft buffer around impervious surfaces to avoid conflicts with tree trunks and roots that are too close to buildings and paving. In addition, restricted soil volumes in urban areas can limit tree survival and growth. The computer program therefore tests each potential planting site to insure that each tree is allotted sufficient space to grow: 16 ft^2 of pervious surface for small trees, 36 ft^2 for medium trees, and 100 ft^2 for large trees. Because large trees produce proportionately greater benefits than small trees, the program starts by filling sites with large trees (50-ft crown diameters) wherever possible, then medium (30-ft crown diameter), and small (15-ft) trees. The program "draws" a 25-ft no-planting buffer around existing TCC to avoid overlapping crowns from potential trees with 50-ft crown diameters. It then "draws" the circular crowns of appropriately scaled 50-ft trees beginning in the center of each polygon. This procedure is repeated several times for 50-ft trees, with buffers redrawn each time to eliminate overlap with crowns of previously located planting sites for new 50-ft trees. The process is then repeated for 30-ft and 15-ft trees (*Figure 3*).

Parking lot sampling

Parking lots cover a large area of Los Angeles and represent an important tree planting opportunity. However, distinguishing parking lots from other

Figure 3. Potential tree planting sites in a Los Angeles neighborhood as identified by the tree-planting algorithm

Table 2. Estimated paved parking lot area by land use and council district

CD	Council district representative	Land use (ICI)	ICI land area (acres)		Paved parking measured in sample area		Paved parking, estimated		
			Total	Sampled	(acres)	(%)	(acres)	Total (acres)	% of ICI land
1	Ed P. Reyes	Ind.	818	575	45	7.9%	65		
		Com.	854	692	101	14.5%	124		
		Instit.	1,494	719	25	3.4%	51	240	7.6%
2	Wendy Greuel	Ind.	973	251	45	18.0%	175		
		Com.	940	311	93	30.0%	282		
		Instit.	2,049	590	25	4.2%	86	544	13.7%
3	Dennis P. Zine	Ind.	731	521	104	20.1%	147		
		Com.	1,335	592	175	29.5%	394		
		Instit.	2,240	367	21	5.7%	128	669	15.5%
4	Tom LaBonge	Ind.	402	189	25	13.2%	53		
		Com.	997	515	82	15.9%	159		
		Instit.	3,496	411	23	5.6%	197	409	8.4%
5	Jack Weiss	Ind.	167	100	12	11.6%	19		
		Com.	1,077	265	33	12.6%	136		
		Instit.	2,269	223	6	2.8%	64	220	6.3%
6	Tony Cardenas	Ind.	3,362	2,526	302	12.0%	402		
		Com.	692	512	160	31.2%	216		
		Instit.	3,633	1,627	78	4.8%	174	793	10.3%
7	Alex Padilla	Ind.	983	335	105	31.2%	307		
		Com.	667	210	71	33.9%	226		
		Instit.	3,080	624	18	3.0%	91	624	13.2%
8	Bernard C. Parks	Ind.	179	83	14	16.8%	30		
		Com.	980	266	39	14.8%	145		
		Instit.	722	178	21	12.0%	87	261	13.9%
9	Jan Perry	Ind.	1,748	461	54	11.8%	207		
		Com.	1,043	648	112	17.3%	180		
		Instit.	891	521	50	9.6%	85	472	12.8%
10	Herb J. Wesson, Jr.	Ind.	328	41	2	3.9%	13		
		Com.	896	201	26	12.7%	114		
		Instit.	601	138	12	8.7%	53	179	9.8%
11	Bill Rosendahl	Ind.	952	499	77	15.4%	147		
		Com.	904	319	33	10.3%	93		
		Instit.	3,943	778	51	6.6%	260	500	8.6%
12	Greig Smith	Ind.	1,885	1,252	224	17.9%	337		
		Com.	972	198	57	28.5%	277		
		Instit.	4,428	483	49	10.1%	447	1,061	14.6%
13	Eric Garcetti	Ind.	412	213	24	11.5%	47		
		Com.	950	413	71	17.1%	163		
		Instit.	1,121	554	18	3.2%	36	246	9.9%
14	Jose Huizar	Ind.	2,113	929	58	6.2%	131		
		Com.	708	169	21	12.3%	87		
		Instit.	2,173	641	31	4.9%	107	325	6.5%
15	Janice Hahn	Ind.	6,815	1,149	264	23.0%	1,565		
		Com.	743	252	48	18.9%	140		
		Instit.	3,017	1,199	57	4.8%	145	1,850	17.5%
Total			70,784	23,742	2,962			8,393	

impervious surfaces (e.g., buildings and roads) is difficult because they are constructed from similar materials. Using remotely sensed data to identify parking lots and potential tree planting sites was not feasible given the resources at hand. Therefore, we decided to identify the amount of paved area that could be available for tree planting based on a sample of parking lots located throughout the city. We focused on large parking lots (>5,000 ft^2) in industrial, commercial, and institutional (called ICI land) land uses, as residential land uses contain relatively few lots, and these lots are usually small.

Sixteen sample boxes were randomly located across Los Angeles. The boxes were large and each contained a mix of land uses. The total area within these boxes was 70,890 acres, or approximately 28.3% of the city. ICI land in the sample boxes equaled 23,742 acres, approximately 34% of the city's total ICI land (*Table 2*).

Pan-sharpened QuickBird images were analyzed to separate asphalt surfaces from other impervious surfaces using ENVI 4.2. Classification results from ENVI were exported to ArcGIS and reclassified into three categories: vegetation cover or no data, parking lot, and nonparking impervious area.

Further processing was required to separate streets from parking areas where trees could be planted. Streets were partitioned from the imagery by overlaying land use shapefiles. Segmentation resulted in delineation of paved parking lot areas, but contained many small polygons representing motor vehicles and other objects within paved parking lot areas. These segments were cleaned up in the ArcGIS environment.

For each council district, the total area of land use type *i* (*Area_CDLU*, where *i* = 3: industrial, 4: commercial, 5: institutional), the sampled area (*spArea*) and the total area of identified parking lots (*sp_PkArea*) were calculated for each land use. The total paved parking area for land use type *i* within a council district can be estimated as:

$$CD\_pkArea_i = \frac{sp\_PkArea_i}{spArea_i} * Area\_CDLU_i$$

Then the total parking lot area for each council district can be calculated as:

$$CD\_pkArea = \sum_i \left(\frac{sp\_PkArea_i}{spArea_i} * Area\_CDLU_i\right)$$

where $i = 3, 4, 5$.

The total parking lot area in a council district is estimated based on the ratio of parking lot area to total area of same type of land use in the samples. This approach assumes that ratios of parking lot area to land use area found in each council district sample are representative of actual ratios throughout the council district.

To estimate technical potential TCC in paved parking areas, the number of potential tree planting sites was assumed to cover 50% of the paved area, based on municipal tree shade ordinances that specify 50% shade within 10 to 15 years of planting (McPherson 2001). To calculate the number of trees needed to shade 50% of the paved area we assume that all have the 30-ft crown diameter of the medium-stature tree.

Ground-truthing and calibration

The accuracy of potential planting site estimates depends on the accuracy of the initial land cover classification, as well as errors associated with the computer-based tree site selection process. A simple ground-truthing method was applied to estimate the accuracy of identifying potential tree planting sites and to calibrate our findings accordingly.

A stratified random sample of 100 parcels was located across Los Angeles using the UFORE random plot selection tool (Nowak et al. 2003). The number of sample plots was proportional to land use by area. Personnel from TreePeople visited 55 of the sites to assess the accuracy of computer-generated maps showing potential planting sites for large, medium, and small trees. Sampled parcels were distributed by land use as follows: 44% low density housing, 18% medium to high density housing, 16% industrial, 13% commercial, and 9% public/open space. Field crews had three maps for each site: aerial photograph (2000, 3-ft resolution, black and white) and two Quickbird pan-sharpened images (2-ft resolution), one showing existing tree cover, the other showing potential tree sites. After locating the property and obtaining permission to conduct the analysis, the crews crossed out potential planting sites that did not exist and drew circles locating sites not identified by the computer program. In some cases, the sizes of trees and their placement were changed in the field using the same rules that the program applied.

Computer-based estimates of potential tree sites were adjusted using ratio estimators for each tree size and land use (*Table 3*). Ratio estimators express the ratio of ground-truthed tree sites to computer-generated sites by land use. For example, the value 1.67 for medium trees in the low density residential land use indicates that the number of plantable sites found from ground truthing was 1.67 times the number generated by the computer.

The computer program generated 877 potential tree planting sites (73 large, 170 medium, and 634 small) that increased TCC by 8.6 acres for the 55 parcels. Our ground-truth results indicated potential for 599 trees (106 large, 158 medium, and 335 small) that increased TCC by 8.7 acres. Overall, the number of ground-truthed potential tree sites was 32% less than computer-generated sites, but the overall potential canopy increase was similar (difference is less than 1%). This result is explained by the fact that the ground-truthed sites contained relatively more sites for large and medium stature trees than were generated by the computer. After applying the ratio estimators to our computer-generated estimates, the total number of potential sites was reduced.

TCC target

The primary purpose behind setting a realistic TCC target for Los Angeles was to determine if the one million tree planting goal was feasible. In the event that our TCC target exceeded the one million tree goal, it would confirm feasibility of the goal and provide impetus for planting in excess of the goal. If our TCC target was less than the goal it would indicate need to reevaluate the goal.

We examined the distribution of TCC by land use polygons and found that, in most cases they were not normally distributed. However, determining the appropriate percentile targets for different land uses seemed arbitrary and nonuniform. Therefore, TCC targets for this study were designed to fill 50% of the available planting sites in each land use and council district. The exception is for large paved parking lot surfaces (>5,000 ft^2) for commercial and institutional land uses, where we assume that the TCC target is 50% of the paved area based on the fact that many municipal parking lot tree shade ordinances have adopted this 50% target. However, for industrial land uses we reduced the target to 25% TCC because a substantial amount of paved area is used by trucks, as temporary storage and for loading and unloading. The goal of filling 50% of all potential tree planting sites acknowledges that:

- Each council district is unique because it has a different land use mix, as well as different existing and potential TCC that reflects historic patterns of development and tree stewardship.
- Every council district can do its "fair share" by filling 50% of its available tree planting sites, thus contributing to a shared citywide goal.

Table 3. Ratio estimators used to correct the number of computer-generated potential tree planting site based on ground-truthing

	Tree size					
	Small		Medium		Large	
Land Use	**Ratio**	**SE**	**Ratio**	**SE**	**Ratio**	**SE**
Low density residential	0.73	0.72	1.67	1.65	1	1.54
Medium/high density residential	0.88	0.46	1	0.63	1	0
Industrial	0.28	0.48	0.5	0.8	1.04	0.23
Commercial	0.8	0.49	1.18	0.67	1.62	1.43
Institutional	0.61	0.07	1	0.24	2.2	0.15

- Council districts with the mostempty planting sites will achieve the greatest relative increase in TCC, while those with higher stocking levels will obtain less enhancement.

The one million tree planting scenario

The one million tree planting scenario was developed using the TCC targets and a reduction factor applied uniformly across all council districts and land uses. The reduction factor, 76.5%, was the ratio of program trees (1 million) to target trees (1.31 million).

We used existing data on tree benefits for coastal (McPherson et al. 2000) and inland southern California (McPherson et al. 2001) to project future annual benefits from one million new trees. Our analysis incorporated a range of mortality rates for typical small, medium, and large growing trees over a 35-year period (2006–2040). Results are reported in terms of annual value per tree planted and cumulative value for the 35-year period. This accounting approach "grows" trees in different locations and uses computer simulation to directly calculate the annual flow of benefits as trees mature and die (McPherson 1992).

Tree data

Based on discussions with program planners, we adopted the assumption that one million trees are planted during the first five years of the program at an increasing rate to allow the program to ramp-up as resources and capacity grow:

- 2006 – 50,000 trees
- 2007 – 160,000 trees
- 2008 – 230,000 trees
- 2009 – 270,000 trees
- 2010 – 290,000 trees

Low- and high-mortality rates provide realistic bounds for uncertainty regarding survival of transplants. Respective annual mortality rates for establishment (the first 5 years after planting) are 1% (low) and 5% (high), and thereafter rates are 0.5 and 2%. Over a 35-year period, these annual mortality rates translate into total low and high rates of about 17 and 56%. The average mortality rate is 36.5%.

Los Angeles has a variety of climate zones due to its proximity to the Pacific Ocean and the nearby mountain ranges. We have classified each council district as coastal zone or inland zone based on an aggregation of Sunset climate zones (Brenzel 2001). Council districts 11 (Rosendahl) and 15 (Hahn) are coastal, while the remaining 13 are inland.

To account for differences in the growth patterns and benefits of trees of different sizes, we made use of growth curves for small, medium, and large tree species in each climate zone developed from street trees in Santa Monica and Claremont (McPherson et al. 2000, 2001). For the coastal zone, growth curves for the yew (*Podocarpus macrophyllus*), jacaranda (*Jacaranda mimosifolia*), and camphor (*Cinnamomum camphora*) were used. For the inland zone, growth curves for crapemyrtle (*Lagerstroemia indica*), jacaranda (*Jacaranda mimosifolia*), and evergreen ash (*Fraxinus uhdei*) were used. The mature crown diameters of these species roughly correspond with the 15-, 30-, and 50-ft sizes used in determining potential planting sites. The selection of these species was based on data availability and is not intended to endorse their use in large numbers. In fact, the camphor has a poor form for a street tree and in certain areas crapemyrtle is overused. In addition, relying on too few species can increase the likelihood of catastrophic loss owing to pests, disease, or other threats.

Benefits

Benefits are calculated with numerical models and data for trees in each land use, using methods previously described (McPherson et al. 2000, 2001). Projected energy savings reflect differences in cooling and heating loads associated with coastal and inland zone climates. Similarly, air pollutant uptake calculations use air pollutant concentrations measured at monitoring stations in each zone. Costs of preventing or repairing damage from pollution, flooding, or other environmental risks are used to estimate society's willingness to pay for clean air and water (Wang and Santini 1995). For example, the value of storm water runoff reduction owing to rainfall interception by trees is estimated by using marginal control costs. If a community or developer is willing to pay an average of \$0.01 per gallon of treated and controlled runoff to meet minimum standards, then the stormwater runoff mitigation value of a tree that intercepts 1,000 gal of rain, eliminating the need for control, should be \$10.

Energy savings. Effects of tree shade and urban heat island mitigation on building energy use are applied to trees planted in residential areas only. Energy effects were based on computer simulations that incorporated building, climate, and shading effects (McPherson and Simpson 1999). Tree distribution with respect to residential buildings was determined by classifying 130 potential planting sites in 34 ground-truthed low-density housing parcels by azimuth and distance class from the building (*Table 4*). We lack sufficient data on nonresidential building stock and tree location effects to simulate energy savings for these buildings.

Typical meteorological year (TMY) weather data for Los Angeles International Airport (coastal) and Riverside (inland), as well as local building characteristics were used. The dollar values of electrical energy (\$0.10634/kWh) and natural gas (\$0.0067/kBtu) were based on retail residential electricity and natural gas prices obtained from LADWP.

Atmospheric carbon dioxide reductions. Sequestration, the net rate of carbon dioxide (CO_2) storage in above and belowground biomass over the course of one growing season, was calculated using Santa Monica (coastal) and Claremont (inland) tree growth data and biomass equations for urban trees (Pillsbury et al. 1998). CO_2 released through decomposition of dead woody biomass was based on annual tree removal rates. CO_2 released due to tree maintenance activities was estimated based on annual consumption of gasoline and diesel fuel as 0.635 lb/inch of diameter at breast height (d.b.h.), the average of values previously used (McPherson et al. 2000, 2001).

Reductions in building energy use result in reduced emissions of CO_2. Emission reductions were calculated as the product of energy savings and CO_2 emission factors for electricity and heating. Heating fuel was natural gas, and the fuel mix for electrical generation was 52% coal, 6% hydro, 26% natural gas, 11% nuclear, and 5% other. The value of CO_2 reductions was \$6.68/ton CO_2 (Pearce 2003).

Air quality benefits. The hourly pollutant dry deposition per tree was expressed as the product of deposition velocity $V_d = 1/(R_a+R_b+R_c)$ (where R_a, R_b and R_c are aerodynamic, boundary layer, and stomatal resistances), pollutant concentration C, canopy projection area CPA, and a time step. Hourly deposition velocities for ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulate matter of <10 micron diameter (PM_{10}) were calculated using estimates for the resistances R_a, R_b and R_c for each hour throughout a "base year" (Scott et al. 1998). Hourly meteorological data and pollutant concentrations were obtained from monitoring stations in Hawthorne (coastal) and Azusa (inland) when pollutant concentrations were near average.

Energy savings result in reduced emissions of criteria air pollutants (volatile organic hydrocarbons [VOCs], NO_2, SO_2, PM_{10}) from power plants and space-heating equipment. These avoided emissions were calculated using LADWP emission factors for electricity and heating fuels.

Emissions of biogenic volatile organic compounds (BVOCs) from trees impact ozone formation. The

Table 4. Distribution (%) of potential tree planting sites around homes based on ground-truthing

Distance Classes	N	NE	E	SE	S	SW	W	NW
Adjacent (<20 ft)	10.8	1.5	10.0	2.3	10.0	3.8	6.2	2.3
Near (21~40 ft)	7.7	2.3	12.3	4.6	6.2	3.8	3.8	1.5
Far (41~ 60 ft)	1.5	0.0	3.8	1.5	1.5	0.8	0.8	0.8

hourly emission rates of the four tree species used in this analysis are minimal (Benjamin and Winer 1998). In reality, a large-scale tree planting like this is likely to include some species with higher emission rates than reported here. While our approach may understate BVOC emissions from new trees, it also understates the air quality benefit associated with lowered summertime air temperatures and the resulting reduced hydrocarbon emissions from anthropogenic and biogenic sources.

The monetary value of tree effects on air quality should reflect the value that society places on clean air, as indicated by willingness to pay for pollutant reductions. Lacking specific data for Los Angeles, air quality benefits were monetized as damage values (*Table 5*) using regression relationships among emission values, pollutant concentrations, and population numbers (Wang and Santini 1995). This regression provides estimates of the costs of damages to human health resulting from air pollution.

Stormwater runoff reductions. A numerical interception model accounted for the amount of annual rainfall intercepted by trees, as well as throughfall and stem flow (Xiao et al. 2000). The volume of water stored in tree crowns was calculated from tree crown leaf and stem surface areas and water depth on these surfaces. Hourly meteorological and rainfall data for 1996 from California Irrigation Management Information System stations in Santa Monica and Claremont were used because total rainfall in that year was close to the average annual amount.

Stormwater runoff reduction benefits were priced by estimating costs of controlling stormwater runoff and treating sanitary waste in Los Angeles. During small rainfall events excess capacity in sanitary treatment plants can be used to treat stormwater. In the Los Angeles region, it costs approximately $1.37/Ccf ($0.0018/gal) to treat sanitary waste (Condon and Moriarty 1999). We used this price to value the water quality benefit of rainfall interception by trees because the cost of treating stormwater in central facilities is likely to be close to the cost of treating an equal amount of sanitary waste.

Table 5. Values of air pollutant reduction for coastal and inland zones ($/lb)

Pollutant	Coastal	Inland
Nitrogen dioxide	2.26	3.95
Sulfur dioxide	2.50	2.50
Small particulate matter	5.44	4.95
Volatile organic compounds	1.06	1.98
Ozone	2.26	3.95

To calculate water quality benefit, the treatment cost is multiplied by gallons of rainfall intercepted after the first 0.1 in has fallen for each event (24 h without rain) during the year. The first 0.1 inch of rainfall seldom results in runoff, and thus, interception is not a benefit until precipitation exceeds this amount. Over $50 million ($500,000/square mile) is spent annually controlling floods in the Los Angeles area (Condon and Moriarty 1999). We assume that rainfall interception by tree crowns will have minimal effect during very large storms that result in catastrophic flooding of the Los Angeles River and its tributaries (133-year design storm).

Although storm drains are designed to control 25-year events, localized flooding is a problem during smaller events. We assume that $50 million is spent per year for local problem areas and the annual value of peak flow reduction is $500,000 per square mile for each 25-year peak flow event (Jones & Stokes Associates 1998 [need citation]). A 25-year winter event deposits 6.7 in of rainfall during 67 hr. Approximately $0.0054/gal is spent annually for controlling flooding caused by such an event. Water quality and flood control benefits are summed to calculate the total hydrology benefit of $0.0072/gal. This price is multiplied by the amount of rainfall intercepted annually, after excluding events less than 0.1 inch.

Aesthetics and other benefits. Many benefits attributed to urban trees are difficult to price (e.g., beautification, privacy, wildlife habitat, sense of place, well-being). However, the value of some of these benefits can be captured in the differences in sales prices of properties with and without trees. Anderson and Cordell (1988) found that each large frontyard tree was associated with a 0.88% increase in sales price. In this analysis, aesthetic (A) benefits ($/tree/year) are expressed for a single tree as:

$A = L \times P$

where L is the annual increase in tree leaf area (LA) and P is the adjusted price ($\$/m^2$ LA) :

$P = (T \times C) / M$

where

T = Large tree contribution to home sales price = 0.88% × median sales price

C = Tree location factor (%) that depreciates the benefit for trees outside of low density residential areas

M = Large tree leaf area

The median sales price for single-family homes in Los Angeles in December 2006 was $530,000 (CAR 2006). The values for C were 100% for low density residential, 70% for medium/high density residential, and 40% for other land uses (Gonzales 2004, McPherson 2001). The values for M were 2,691 and 3,591 ft^2 for coastal and inland zones, respectively.

Results

Existing tree canopy cover

TCC in the city of Los Angeles is 21% (52,493 acres) (*Table 6*). Irrigated grass and dry grass/ bare soil account for 12% (31,206 acres) and 6% (13,790 acres) of the city, respectively (*Figure 4*). Impervious (e.g., paving, roofs) and other surfaces (i.e., water) comprise the remaining 61% (154,895 acres) of the city's land cover (excluding mountainous areas). Hence, one-third of Los Angeles's land cover is existing TCC and grass/bare soil with potential to become TCC. The number of existing trees is estimated to be 10.8 million assuming an average tree crown diameter of 16.4 ft.

By council district

At the council district (CD) level, TCC varied from lows of 7 to 9% in CDs 9 and 15 (Perry and Hahn) to a high of 37% in CD 5 (Weiss) (*Table 6*). TCC was strongly related to land use. As expected, low-density residential land uses had the highest TCC citywide (31%), while industrial and commercial land uses had lowest TCC (3–6%) (*Table 7*). TCC tended to be higher in areas near mountains compared to areas closer to downtown Los Angeles.

Relations between TCC and land use are evident in CDs 5 and 9 (Weiss and Perry). CD 5 (37% TCC)

Table 6. Land cover distribution by council district (excludes mountains)

CD	Council district representative	Land area (acres)	Tree canopy cover (acres)	Tree canopy cover (%)	Irrigated grass cover (acres)	Irrigated grass cover (%)	Dry grass / bare soil (acres)	Dry grass / bare soil (%)	Impervious/ other (acres)	Impervious/ other (%)
1	Ed P. Reyes	7,949	1,266	15.9	474	6.00	395	5.00	5,814	73.0
2	Wendy Greuel	20,295	5,395	26.6	1,987	9.80	1,310	6.50	11,603	57.0
3	Dennis P. Zine	24,359	6,345	26.0	3,443	14.10	1,458	6.00	13,114	54.0
4	Tom LaBonge	15,404	4,429	28.8	1,954	12.70	679	4.40	8,341	54.0
5	Jack Weiss	24,317	9,047	37.2	2,798	11.50	737	3.00	11,735	48.0
6	Tony Cardenas	17,047	2,550	15.0	1,808	10.60	945	5.50	11,744	69.0
7	Alex Padilla	15,789	2,572	16.3	1,513	9.60	2,334	14.80	9,371	59.0
8	Bernard C. Parks	11,174	1,192	10.7	2,175	19.50	414	3.70	7,393	66.0
9	Jan Perry	9,564	719	7.5	838	8.80	254	2.70	7,753	81.0
10	Herb J. Wesson, Jr.	8,541	1,018	11.9	812	9.50	415	4.90	6,296	74.0
11	Bill Rosendahl	25,922	6,094	23.5	4,467	17.20	642	2.50	14,719	57.0
12	Greig Smith	29,232	5,796	19.8	4,751	16.30	2,258	7.70	16,426	56.0
13	Eric Garcetti	7,845	1,072	13.7	889	11.30	323	4.10	5,560	71.0
14	Jose Huizar	13,976	3,126	22.4	673	4.80	704	5.00	9,470	68.0
15	Janice Hahn	20,976	1,871	8.9	2,625	12.50	923	4.40	15,557	74.0
	Total for city	252,384	52,493	20.8	31,206	12.40	13,790	5.50	154,895	61.0

Table 7. Land cover distribution by land use

Land use	Total area (acres)	Tree cover (acres)	Tree cover (%)	Grass cover (acres)	Grass cover (%)	Dry grass /bare soil (acres)	Dry grass /bare soil (%)
Low density residential	120,151	36,615	30.5	18,182	15.1	8,601	7.2
Medium/high density residential	43,803	6,351	14.5	4,377	10.0	1,881	4.3
Industrial	25,693	901	3.5	649	2.5	493	1.9
Commercial	20,130	1,121	5.6	622	3.1	352	1.7
Institutional	39,093	7,174	18.3	6,809	17.4	2,356	6.0
Unknown	3,514	331	9.4	569	16.2	108	3.1
Total	252,384	52,493	20.8	31,209	12.4	13,791	5.5

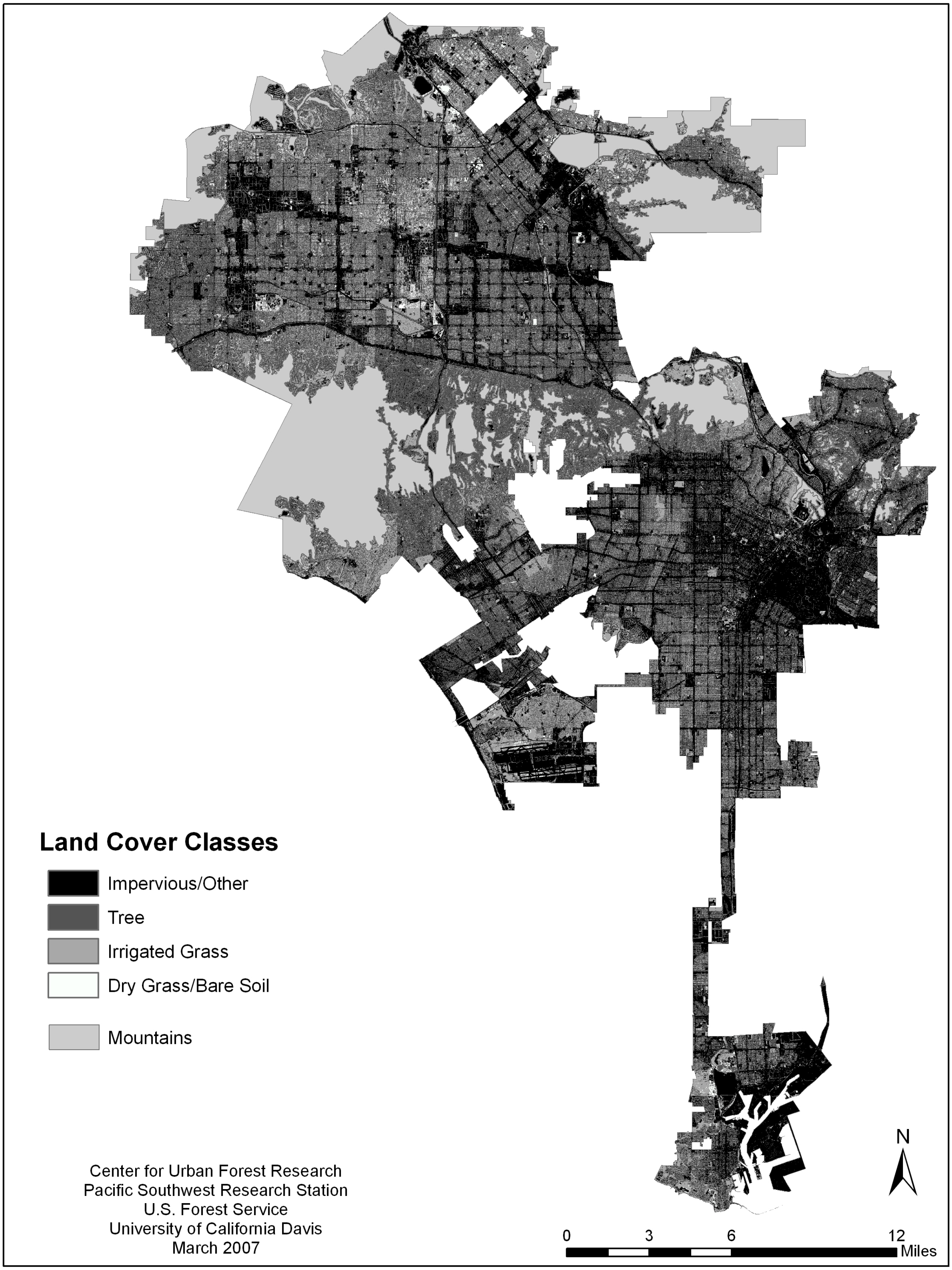

Figure 4. Spatial distribution of land cover classes

is dominated by low-density housing (59%) and has 49% tree/grass/soil cover. In contrast, low-density housing covered only 3% of CD 9 (7% TCC), while industrial and commercial land uses covered 29% of the land (*Table 8*).

There are approximately 10.8 million trees (43 trees/acre) in Los Angeles assuming an average crown diameter of 16.4 ft. Council districts estimated to have the highest tree densities are 5 (Weiss, 37%), 4 (LaBonge, 29%), 2 (Greuel, 27%), 3 (Zine, 26%) (*Figure 5*). These council districts contain approximately 77, 59, 55, and 53 trees/acre, respectively. Council districts with the lowest estimated tree densities are 9 (Perry, 8%), 15 (Hahn, 9%), 8 (Parks, 11%), and 10 (Wesson, 12%).

By neighborhood council

TCC and area are presented for each of the 86 neighborhood councils in *Appendix A*. Existing TCC exceeded 40% in three neighborhood councils: Bel Air-Beverly Crest (53%), Arroyo Seco (46%), and Studio City (42%). Neighborhood councils with the lowest TCC were Downtown Los Angeles (3%), Wilmington (5%), and Historic Cultural and Macarthur (6%). The mean TCC was 17.7% and standard deviation was 9.8%.

Accuracy assessment

Overall classification accuracy was 88.6% based on a pixel by pixel comparison (*Table 9*). The accuracy for classifying existing TCC was 74.3%. Not surprisingly, TCC was most often misclassified as irrigated grass (13%), and vice versa (17%). Factors that affected the mapping accuracy included the treatment of the shadowed area and minimum mapping units during digitizing.

Potential tree planting sites and target tree canopy cover

Potential tree planting sites

After calibrating computer-estimated potential tree sites with ground-truthed data, we estimate that there are approximately 2.47 million potential tree planting sites in Los Angeles (*Table 10*). This potential for new trees covers 31,219 acres, or 12% of the city. Hence, if all potential tree sites were filled and the canopy matured as noted above, TCC would increase to 33% from 21%. Fifty-two percent of these potential sites are for small trees (15-ft crown diameter at maturity), 38% for medium trees (30-ft at maturity), and 10% for large trees (50-ft). All potential parking lot tree sites, which are estimated to total 258,642 (10.5%), are assumed to be for medium trees, although in reality there will be a mix of tree sizes.

The distribution of potential tree sites differs by land use. Low density residential areas contain the largest number of potential sites (1.4 million, 58%), followed by institutional (377,574, 15%) and medium/high density residential (360,382, 15%). Industrial and commercial land uses each contain about 6% (about 140,000) of the total potential tree planting sites.

Six council districts (12, 3, 11, 15, 7, and 2) have potential for over 200,000 new trees, with these trees adding an additional 11 to 20% TCC when mature and assuming no mortality (*Table 10*). Five council districts (1, 13, 14, 9, and 10) have space for less than 100,000 trees, with potential to increase TCC by 7 to 12%.

Target tree canopy cover

The target TCC for Los Angeles accounts for the fact that only about 50% of the potential sites are suitable for planting owing to residents' desire for no additional trees and conflicts with higher-priority uses. Thus, it is realistic for Los Angles to strive to increase its TCC by 6.7% (16,797 ac), and this equates to 1.3 million tree sites (*Table 10*). If all target tree sites were filled and the canopy matured as noted above, TCC would increase to 28% from 21%. This finding indicates that the goal of planting one million trees is feasible.

The distribution of target tree sites among size classes and land uses is similar to the distribution of potential sites described above. Most sites are for

Table 8. Land use distribution by council district

CD	Council district representative	Total area (acres)	Land use: Low density residential (acres)	(%)	Medium/high density residential (acres)	(%)	Industrial (acres)	(%)	Commercial (acres)	(%)	Institutional (acres)	(%)	Unknown (acres)	(%)
1	Ed P. Reyes	7,949	1,117	14.1%	2,751	34.6%	1,017	12.8%	1,299	16.3%	1,763	22.2%		
2	Wendy Greuel	20,295	12,760	62.9%	2,798	13.8%	1,113	5.5%	1,323	6.5%	2,294	11.3%	8.27	0.04%
3	Dennis P. Zine	24,359	17,486	71.8%	1,736	7.1%	846	3.5%	1,754	7.2%	2,537	10.4%		
4	Tom LaBonge	15,403	6,374	41.4%	3,378	21.9%	482	3.1%	1,460	9.5%	3,709	24.1%		
5	Jack Weiss	24,317	17,094	70.3%	2,878	11.8%	215	0.9%	1,638	6.7%	2,488	10.2%	4.33	0.02%
6	Tony Cardenas	17,047	6,723	39.4%	1,616	9.5%	3,776	22.2%	934	5.5%	3,997	23.4%	1.19	0.01%
7	Alex Padilla	15,789	8,550	54.2%	1,907	12.1%	1,121	7.1%	879	5.6%	3,332	21.1%		
8	Bernard C. Parks	11,174	4,750	42.5%	3,725	33.3%	235	2.1%	1,604	14.4%	860	7.7%		
9	Jan Perry	9,564	339	3.5%	4,084	42.7%	2,389	25.0%	1,639	17.1%	1,113	11.6%		
10	Herb J. Wesson, Jr.	8,541	1,841	21.6%	4,142	48.5%	465	5.4%	1,361	15.9%	731	8.6%		
11	Bill Rosendahl	25,922	12,004	46.3%	3,502	13.5%	1,170	4.5%	1,377	5.3%	4,373	16.9%	3,496.06	13.49%
12	Greig Smith	29,232	19,595	67.0%	1,422	4.9%	2,177	7.4%	1,224	4.2%	4,813	16.5%	1.89	0.01%
13	Eric Garcetti	7,845	1,110	14.2%	3,526	44.9%	504	6.4%	1,439	18.3%	1,265	16.1%	0.46	0.01%
14	Jose Huizar	13,972	5,053	36.2%	2,711	19.4%	2,635	18.9%	1,090	7.8%	2,483	17.8%		
15	Janice Hahn	20,976	5,356	25.5%	3,627	17.3%	7,547	36.0%	1,109	5.3%	3,335	15.9%	1.57	0.01%
	Total	252,384	120,151	47.6%	43,803	17.4%	25,693	10.2%	20,130	8.0%	39,093	15.5%	3,513.76	1.39%

Table 9. Land cover classification error matrix (percentage of pixels matched) for four classes. *Rows* show the distribution of the class in the base map, *columns* show the distribution in Quickbird pixels. The overall accuracy for all classes is 89%

	Pixel					%			
Base map	**TCC**	**Irrigated grass**	**Soil**	**Impervious**	**Total**	**TCC**	**Irrigated grass**	**Bare soil**	**Impervious**
TCC	**145,335**	25,451	2,871	21,905	195,562	**74.3**	13	1.5	11.2
Irrigated grass	17,290	**65,188**	5,989	11,369	99,836	17.3	**65.3**	6	11.4
Bare soil	1,402	1,435	**2,717**	4,795	10,349	13.5	13.9	**26.3**	46.3
Impervious	41,290	17,737	21,258	**1,134,016**	1,214,301	3.4	1.5	1.8	**93.4**
Total	205,317	109,811	32,835	1,172,085	**1,520,048**	13.5	7.2	2.2	77.1

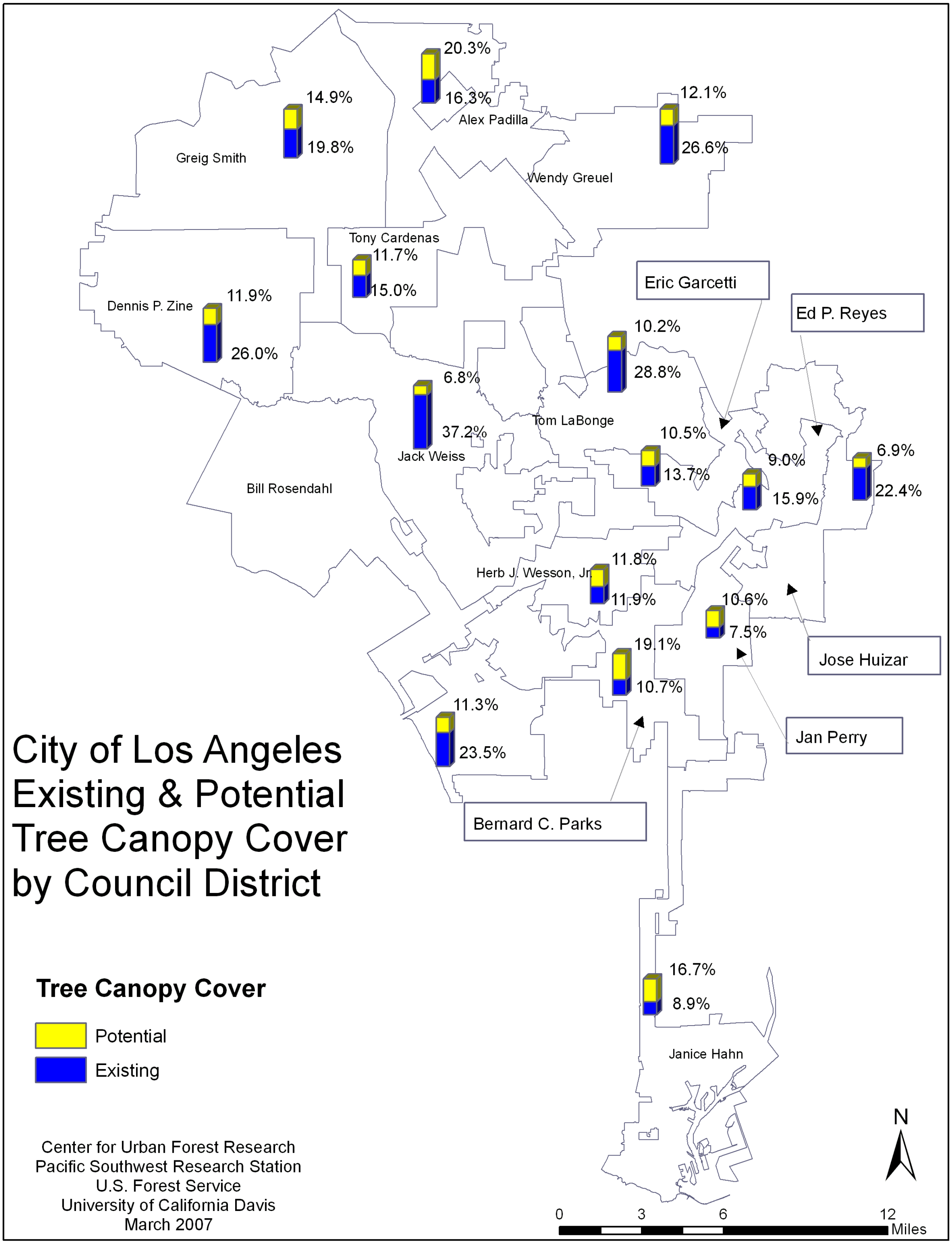

Figure 5. Existing and potential tree canopy cover by council district

Table 10. Existing, potential, and target tree numbers and canopy cover (TCC) by council district and mature tree size class

CD	Council district member	Area (acres)	Existing TCC (acres)	Existing TCC (%)	Potential trees Small	Potential trees Medium	Potential trees Large	Potential trees Total	Potential TCC (acres)	Potential TCC (%)	Target trees Small	Target trees Medium	Target trees Large	Target trees Total	Target TCC (acres)	Target TCC (%)	Existing + target TCC (%)
1	Ed P. Reyes	7,949	1,266	15.9	23,821	18,320	7,087	49,228	713	9.0	11,910	11,856	3,543	27,310	400	5.0	21.0
2	Wendy Greuel	20,295	5,395	26.6	109,200	78,161	16,590	203,950	2,459	12.1	54,600	44,750	8,295	107,645	1,322	6.5	33.1
3	Dennis P. Zine	24,359	6,345	26.0	144,751	89,421	18,905	253,078	2,890	11.9	72,376	52,755	9,453	134,583	1,576	6.5	32.5
4	Tom LaBonge	15,403	4,429	28.8	70,179	45,282	12,265	127,726	1,572	10.2	35,090	28,126	6,133	69,348	875	5.7	34.4
5	Jack Weiss	24,317	9,047	37.2	107,119	52,056	8,465	167,640	1,661	6.8	53,560	29,120	4,232	86,912	881	3.6	40.8
6	Tony Cardenas	17,047	2,550	15.0	66,538	64,545	15,175	146,258	2,001	11.7	33,269	38,289	7,587	79,145	1,098	6.4	21.4
7	Alex Padilla	15,789	2,572	16.3	116,529	86,463	29,355	232,347	3,199	20.3	58,264	48,120	14,678	121,062	1,679	10.6	26.9
8	Bernard C. Parks	11,174	1,192	10.7	84,116	61,943	17,577	163,637	2,139	19.1	42,058	34,534	8,788	85,380	1,127	10.1	20.8
9	Jan Perry	9,564	719	7.5	40,970	31,665	7,481	80,115	1,017	10.6	20,485	19,925	3,740	44,150	575	6.0	13.5
10	Herb J. Wesson, Jr.	8,541	1,018	11.9	47,971	27,641	8,037	83,649	1,005	11.8	23,986	16,389	4,018	44,393	544	6.4	18.3
11	Bill Rosendahl	25,922	6,094	23.5	132,350	84,742	22,527	239,619	2,927	11.3	66,175	47,814	11,264	125,253	1,552	6.0	29.5
12	Greig Smith	29,232	5,796	19.8	180,791	127,648	34,104	342,543	4,342	14.9	90,396	74,985	17,052	182,433	2,352	8.0	27.9
13	Eric Garcetti	7,845	1,072	13.7	37,459	24,539	6,150	68,148	827	10.5	18,730	15,331	3,075	37,135	463	5.9	19.6
14	Jose Huizar	13,972	3,126	22.4	39,821	29,272	7,244	76,337	963	6.9	19,911	17,627	3,622	41,159	530	3.8	26.2
15	Janice Hahn	20,976	1,871	8.9	90,963	116,363	27,585	234,912	3,501	16.7	45,482	62,570	13,793	121,844	1,822	8.7	17.6
	Total	252,384	52,493	20.8	1,292,578	938,062	238,546	2,469,186	31,219	12.4	646,289	542,192	119,273	1,307,754	16,797	6.7	27.5

small and medium trees (49% and 42%). Over 70% of the target tree sites are located in low density residential and institutional land uses. About 16% (202,482) of the sites are in large parking lots.

Filling the targeted tree sites in council districts with the least TCC would have the greatest impact (*Table 10*). For example, TCC would increase to 20.8% from 10.7% in CD 8 (Parks) and to 17.6% from 8.8% in CD 15 (Hahn) (*Figure 6*). Similarly, the increase would be least in CDs with the greatest TCC, for example, an increase to 40.8% from 37.2% in CD 5 (Weiss). If the targeted TCC was filled with 1.3 million trees, TCC would range from 13 to 40% across CDs, instead of the current 8 to 37%.

In summary, the existing TCC of Los Angeles is 20.8%, comprised of approximately 10.8 million trees (*Table 11*). There is potential to add 2.5 million additional trees or 12.4% TCC. Thus, technical potential for Los Angeles is 33.2% TCC, or about 13.3 million trees. However, it is not realistic to think that every possible tree site will be planted. Assuming that about 50% of the unplanted sites are feasible to plant results in adding 1.3 million more trees equivalent to a 6.7% increase in TCC. Hence, market potential is 27.5% TCC, or 12.1 million trees. Planting one million trees is feasible and if accomplished as indicated above, would saturate 97% of the existing market potential.

Benefits from one million trees

Benefits forecast from the planting of one million trees in Los Angeles depend on tree mortality, as well as climate zone, land use, and tree species (*Figure 7*). Our planting scenarios reflect effects of low (17%) and high (56%) mortality rates on tree numbers and associated benefits. After 35 years (2040), the number of surviving trees equals 828,924 and 444,889 for the low and high mortality scenarios, respectively. In both scenarios, planted trees are distributed among land uses such that 55% are in low density residential, 17% in institutional, 14% in medium/high density residential, 9% in commercial and 5% in industrial. Nearly one-half of the trees are small (49%), 42% are medium, and 9% are large at maturity.

Citywide benefits

Benefits calculated annually and totaled for the 35-year period are $1.64 and $1.95 billion for the high- and low-mortality scenarios, respectively (*Tables 12* and *13*). These values translate into $1,639 and $1,951 per tree planted, or $49 and $60 per tree per year when divided by the 35-year period.

Eighty-one percent of total benefits are aesthetic/other, 8% are stormwater runoff reduction, 6% energy savings, 4% air quality improvement, and less than 1% atmospheric carbon reduction (*Figure 8*).

Benefits by land use and council district

The distribution of benefits among council districts is closely related to the climate zone and the number of trees. Benefits per tree are about 50% less ($700-1,000 instead of $1,300-2,400) in the coastal zone (CD 11 and 15) than the inland zone because the growth curve data indicate that the trees are smaller, air pollutant concentrations are lower, and building heating and cooling loads are less due to the milder climate (*Figures 9* and *10)*.

Another factor influencing the distribution of benefits among council districts is the mix of land uses (*Figure 11*). Districts with relatively less land for housing and relatively more land for commercial, industrial, and institutional use have lower benefits per tree planted. Energy savings are less because our model did not estimate benefits for heating and cooling effects in nonresidential buildings. Our model did not incorporate effects of trees on cool-

Table 11. Summary of tree canopy cover and tree number estimates for Los Angeles

	Existing	Potential	Technical potential	Target	Market potential
Tree canopy cover (%)	20.8	12.4	33.2	6.7	27.5
Tree numbers	10,824,628	2,469,186	13,293,814	1,307,754	12,132,382

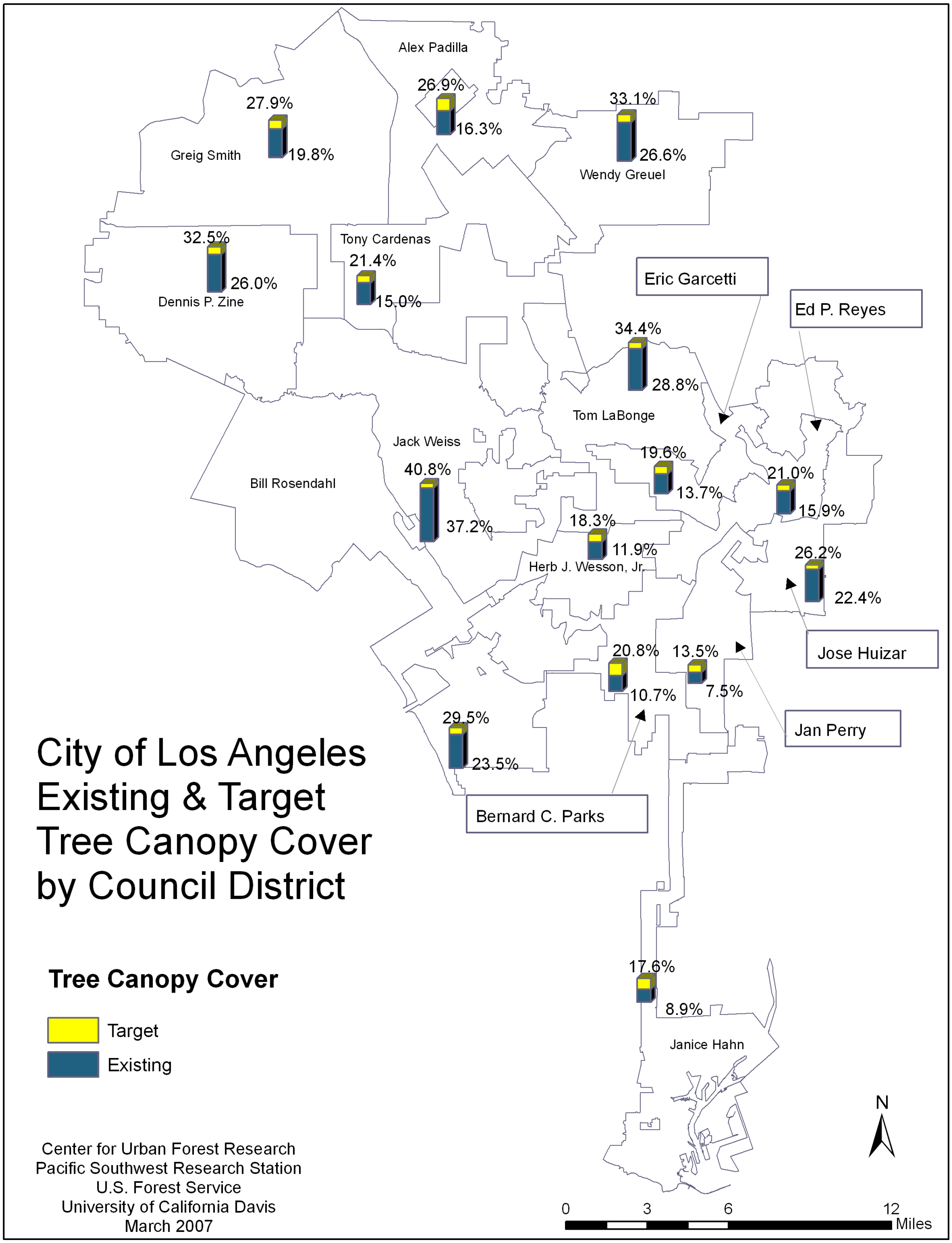

Figure 6. Existing and target tree canopy cover by council district

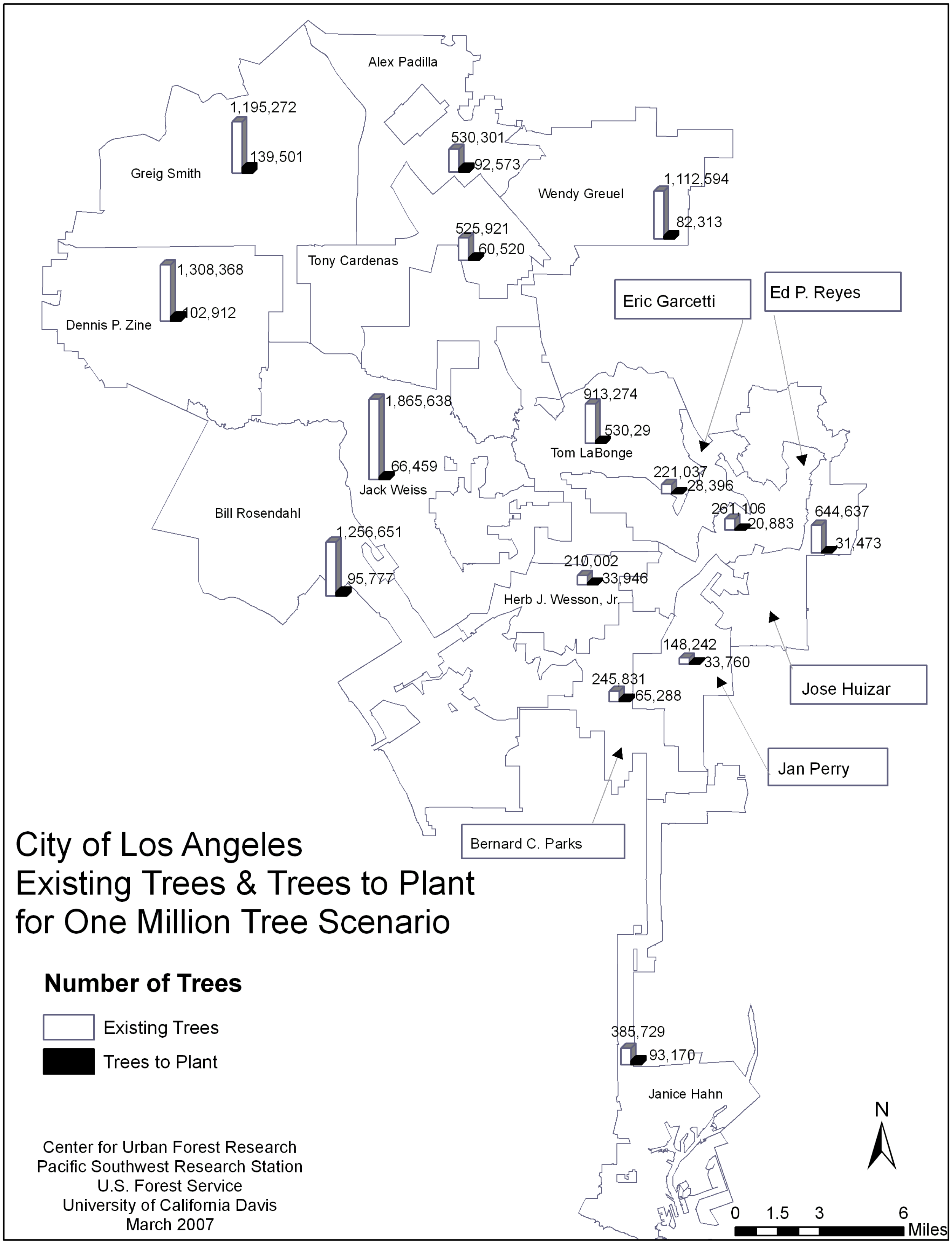

Figure 7. Number of existing trees and trees to plant (1 million total) by council district

Table 12. Cumulative benefits (2006–2040) and average benefit per tree planted by council district for the low mortality scenario

CD	Council district member	Trees planted	Trees alive in 2040	Energy		Air quality		Carbon dioxide		Stormwater runoff		Aesthetic/other		Total benefits	
				Total $	$/tree	Total $	$/tree	Total $	$/tree	Total $	$/tree	Total $	$/tree	Total $	$/tree
1	Ed P. Reyes	20,883	17,311	1,415,847	68	1,762,961	84	162,689	7.79	3,950,229	189.16	31,278,375	1,498	38,570,101	1,847
2	Wendy Greuel	82,313	68,231	12,974,614	158	7,850,324	95	859,878	10.45	14,621,169	177.63	156,354,878	1,900	192,660,864	2,341
3	Dennis P. Zine	102,912	85,306	15,351,113	149	9,400,287	91	1,013,258	9.85	17,362,590	168.71	181,878,208	1,767	225,005,456	2,186
4	Tom LaBonge	53,029	43,957	5,549,222	105	4,536,519	86	443,172	8.36	9,291,042	175.21	82,645,520	1,559	102,465,473	1,932
5	Jack Weiss	66,459	55,090	10,213,205	154	5,708,874	86	622,241	9.36	9,757,767	146.82	109,185,934	1,643	135,488,021	2,039
6	Tony Cardenas	60,520	50,167	6,845,792	113	5,679,725	94	553,869	9.15	12,293,102	203.12	105,723,228	1,747	131,095,715	2,166
7	Alex Padilla	92,573	76,736	13,470,678	146	8,848,116	96	1,007,167	10.88	16,254,404	175.59	177,691,502	1,919	217,271,868	2,347
8	Bernard C. Parks	65,288	54,119	10,358,233	159	6,331,353	97	721,359	11.05	11,505,944	176.23	131,054,146	2,007	159,971,035	2,450
9	Jan Perry	33,760	27,984	2,330,587	69	2,768,387	82	231,661	6.86	6,439,504	190.74	47,375,894	1,403	59,146,034	1,752
10	Herb J. Wesson, Jr.	33,946	28,139	4,063,135	120	2,911,931	86	303,757	8.95	5,524,913	162.76	55,755,710	1,642	68,559,446	2,020
11	Bill Rosendahl	95,777	79,392	4,494,173	47	4,561,895	48	319,986	3.34	5,135,221	53.62	77,801,510	812	92,312,785	964
12	Greig Smith	139,501	115,635	20,486,019	147	13,172,516	94	1,442,660	10.34	24,774,501	177.59	259,540,968	1,860	319,416,665	2,290
13	Eric Garcetti	28,396	23,538	2,530,265	89	2,347,087	83	214,871	7.57	5,031,419	177.19	42,054,322	1,481	52,177,964	1,837
14	Jose Huizar	31,473	26,089	3,444,288	109	2,774,938	88	271,603	8.63	5,761,254	183.05	51,541,911	1,638	63,793,994	2,027
15	Janice Hahn	93,170	77,231	3,895,333	42	4,755,920	51	309,052	3.32	5,382,414	57.77	78,262,865	840	92,605,585	994
	Total	1,000,000	828,924	117,422,505	117	83,410,834	83	8,477,224	8.48	153,085,472	153.09	1,588,144,972	1,588	1,950,541,007	1,951

Table 13. Cumulative benefits (2006–2040) and average benefit per tree planted by council district for the high mortality scenario

CD	Council district member	Trees planted	Trees alive in 2040	Energy		Air quality		Carbon dioxide		Stormwater runoff		Aesthetic/other		Total benefits	
				Total $	$/tree	Total $	$/tree	Total $	$/tree	Total $	$/tree	Total $	$/tree	Total $	$/tree
1	Ed P. Reyes	20,883	9,291	912,296	44	1,121,764	54	94,218	4.51	2,511,415	120.26	21,507,152	1,030	26,146,845	1,252
2	Wendy Greuel	82,313	36,620	8,367,563	102	5,008,384	61	522,874	6.35	9,295,655	112.93	107,544,314	1,307	130,738,789	1,588
3	Dennis P. Zine	102,912	45,784	9,900,006	96	5,996,296	58	616,283	5.99	11,037,937	107.26	124,949,646	1,214	152,500,169	1,482
4	Tom LaBonge	53,029	23,592	3,578,062	67	2,890,179	55	264,175	4.98	5,906,717	111.39	56,805,841	1,071	69,444,974	1,310
5	Jack Weiss	66,459	29,567	6,586,022	99	3,642,382	55	381,817	5.75	6,202,337	93.33	74,881,653	1,127	91,694,211	1,380
6	Tony Cardenas	60,520	26,925	4,415,479	73	3,619,609	60	329,891	5.45	7,816,601	129.16	72,874,493	1,204	89,056,074	1,472
7	Alex Padilla	92,573	41,185	8,687,081	94	5,642,314	61	605,258	6.54	10,333,083	111.62	122,123,766	1,319	147,391,503	1,592
8	Bernard C. Parks	65,288	29,046	6,678,559	102	4,038,655	62	436,477	6.69	7,314,704	112.04	90,137,473	1,381	108,605,867	1,663
9	Jan Perry	33,760	15,019	1,500,722	44	1,761,633	52	135,277	4.01	4,094,339	121.28	32,600,171	966	40,092,141	1,188
10	Herb J. Wesson, Jr.	33,946	15,102	2,618,321	77	1,855,579	55	182,259	5.37	3,512,055	103.46	38,273,115	1,127	46,441,329	1,368
11	Bill Rosendahl	95,777	42,610	2,921,106	30	2,966,367	31	190,585	1.99	3,320,115	34.67	55,843,968	583	65,242,141	681
12	Greig Smith	139,501	62,062	13,211,419	95	8,401,166	60	871,748	6.25	15,750,370	112.91	178,387,854	1,279	216,622,557	1,553
13	Eric Garcetti	28,396	12,633	1,630,553	57	1,494,522	53	127,237	4.48	3,198,768	112.65	28,920,459	1,018	35,371,539	1,246
14	Jose Huizar	31,473	14,002	2,220,566	71	1,768,095	56	162,091	5.15	3,662,890	116.38	35,447,144	1,126	43,260,785	1,375
15	Janice Hahn	93,170	41,451	2,521,639	27	3,091,410	33	181,931	1.95	3,477,891	37.33	55,895,029	600	65,167,901	699
	Total	1,000,000	444,889	75,749,392	76	53,298,356	53	5,102,121	5.10	97,434,876	97.43	1,096,192,081	1,096	1,327,776,826	1,328

ing and heating of nonresidential buildings. For example, residential land uses occupied only 35–37% of the land in CDs 1 and 9 (Reyes and Perry), and average benefits were among the lowest per tree (about $1,800 and $1,200 for low and high mortality scenarios) for all inland CDs. On the other hand, in CDs 2, 7, and 8 (Greuel, Padilla, Parks) residential land uses exceeded 52% of total land, and average benefits were the highest (greater than $2,300 per tree for the low mortality scenario).

Citywide benefits by benefit type

Aesthetic and other benefits. Citywide, aesthetic and other benefits ranged from $1.1 to $1.6 billion, or $1,100 to $1,600 per tree over the 35-year period for the high and low mortality scenarios (*Figure 12*). This amount reflects the economic contribution of trees to property sales prices and retail sales, as well as other benefits such as beautification, privacy, wildlife habitat, sense of place, psychological and spiritual well-being.

Stormwater runoff reduction. By intercepting rainfall in their crowns, trees reduce stormwater runoff and thereby protect water quality. Over the 35-year span of the project, one million trees will reduce runoff by approximately 13.5–21.3 billion gallons (18.1–28.4 million Ccf) (*Figure 12*). The value of this benefit ranges from $97.4 to $153.1 million for the high and low mortality scenarios, respectively. The average annual interception rate per tree ranges from a low of 102 gal for the crapemyrtle (representative of small trees in the inland zone) to a high of 1,481 gal for the jacaranda (representative of medium trees in the inland zone). The difference is due to tree size and foliation period. The crapemyrtle is small at maturity and is deciduous during the rainy winter season, while the jacaranda develops a broad spreading crown and is in-leaf during the rainy season.

Energy use reduction. By shading residential buildings and lowering summertime air temperatures, the

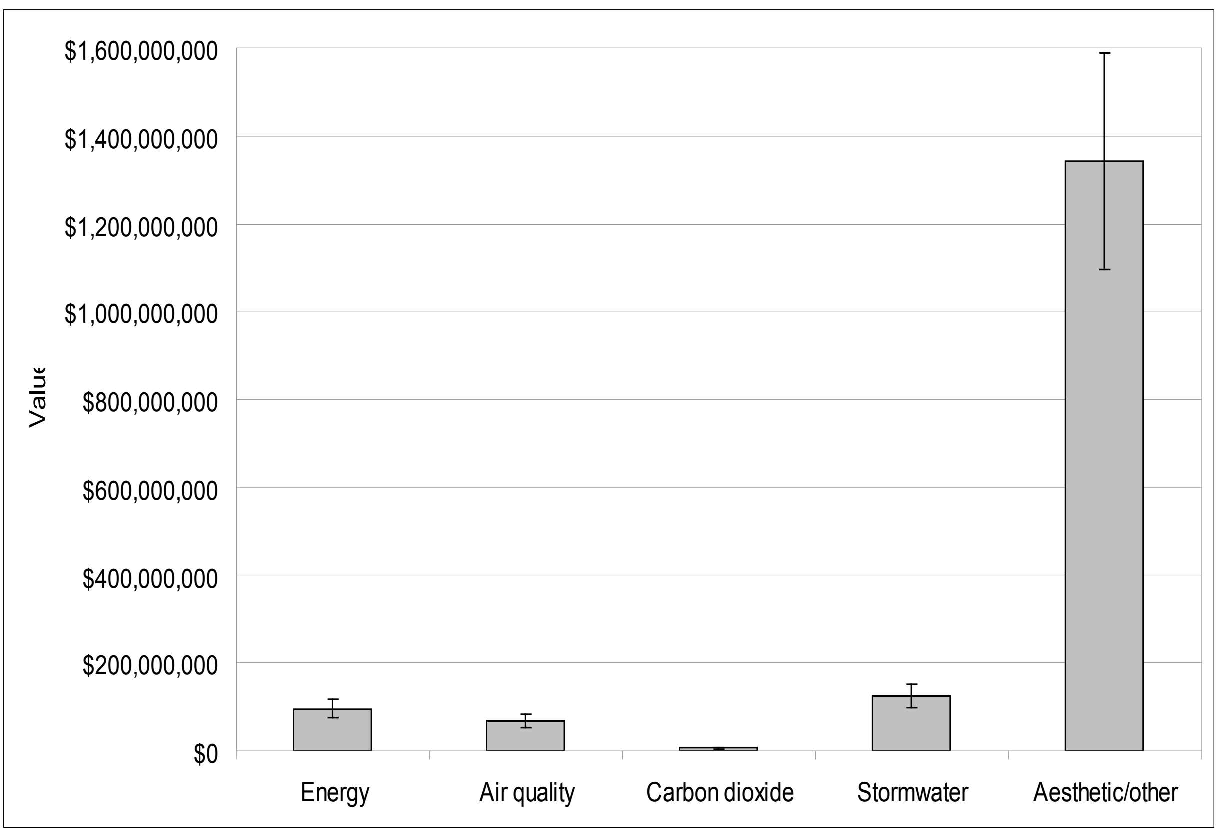

Figure 8. Total average value of benefits over the 35-year period by benefit type. Error bars show values for the low- and high-mortality scenarios

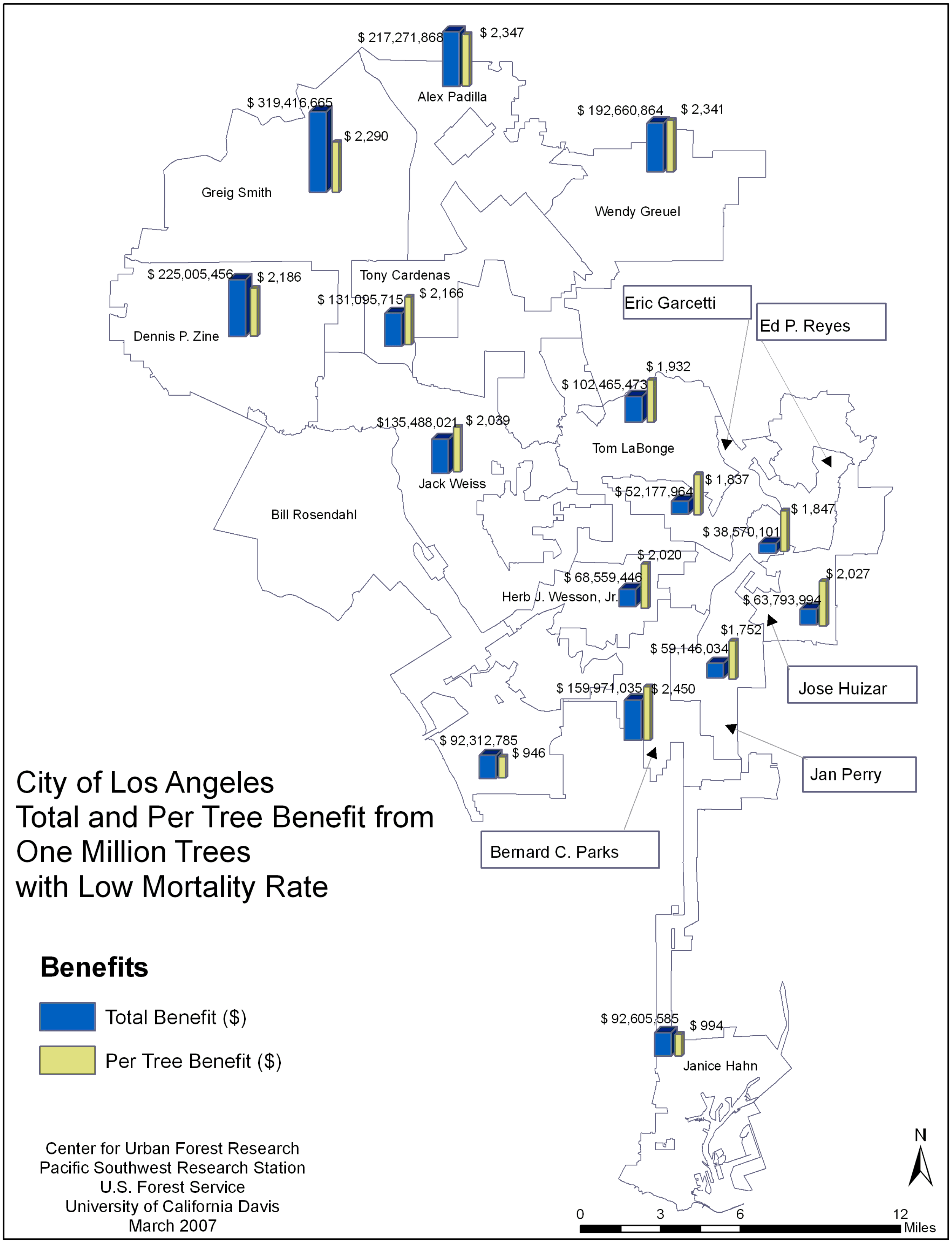

Figure 9. Total value of benefits and average benefit per tree planted over the 35-year period for the low mortality scenario

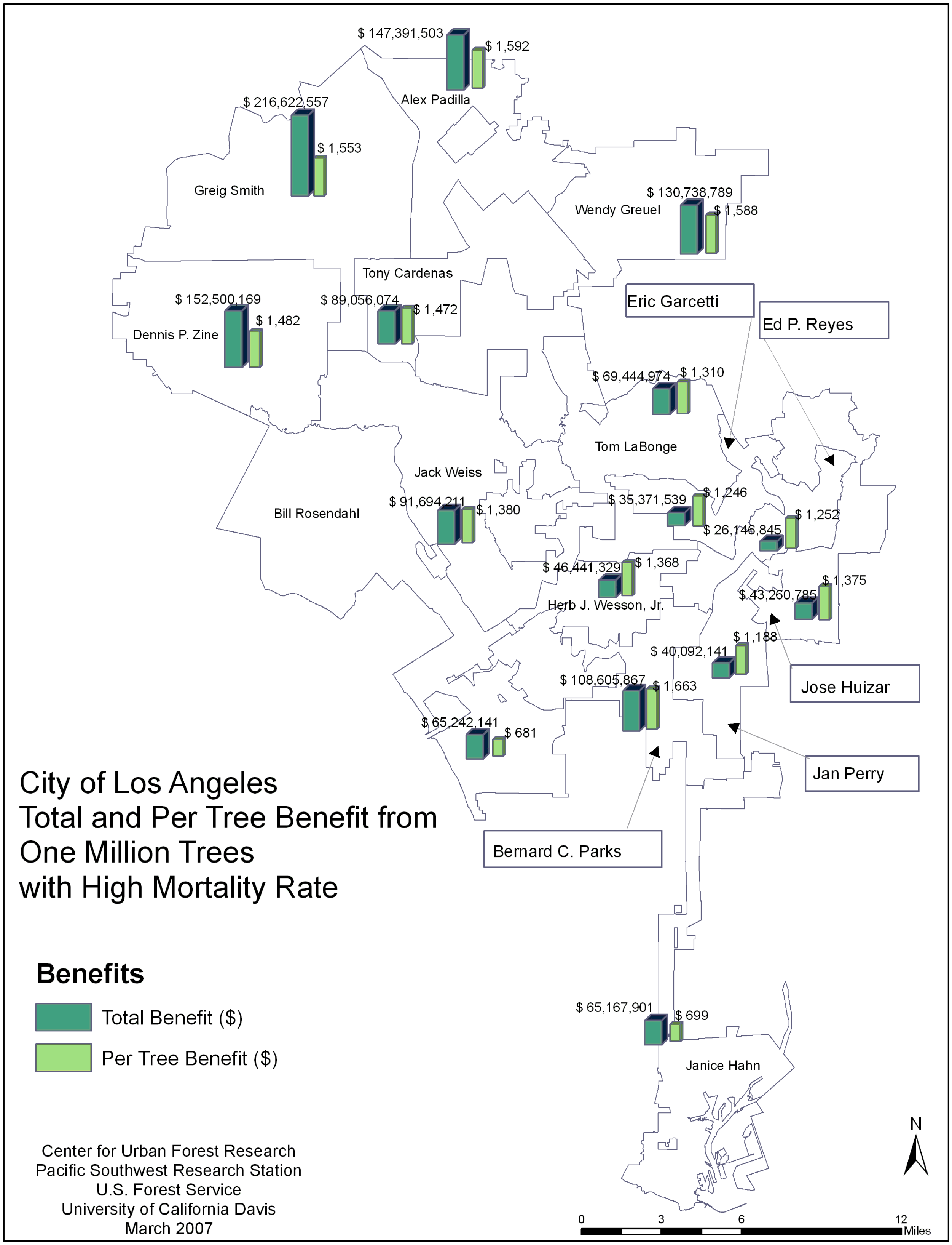

Figure 10. Total value of benefits and average benefit per tree planted over the 35-year period for the high-mortality scenario

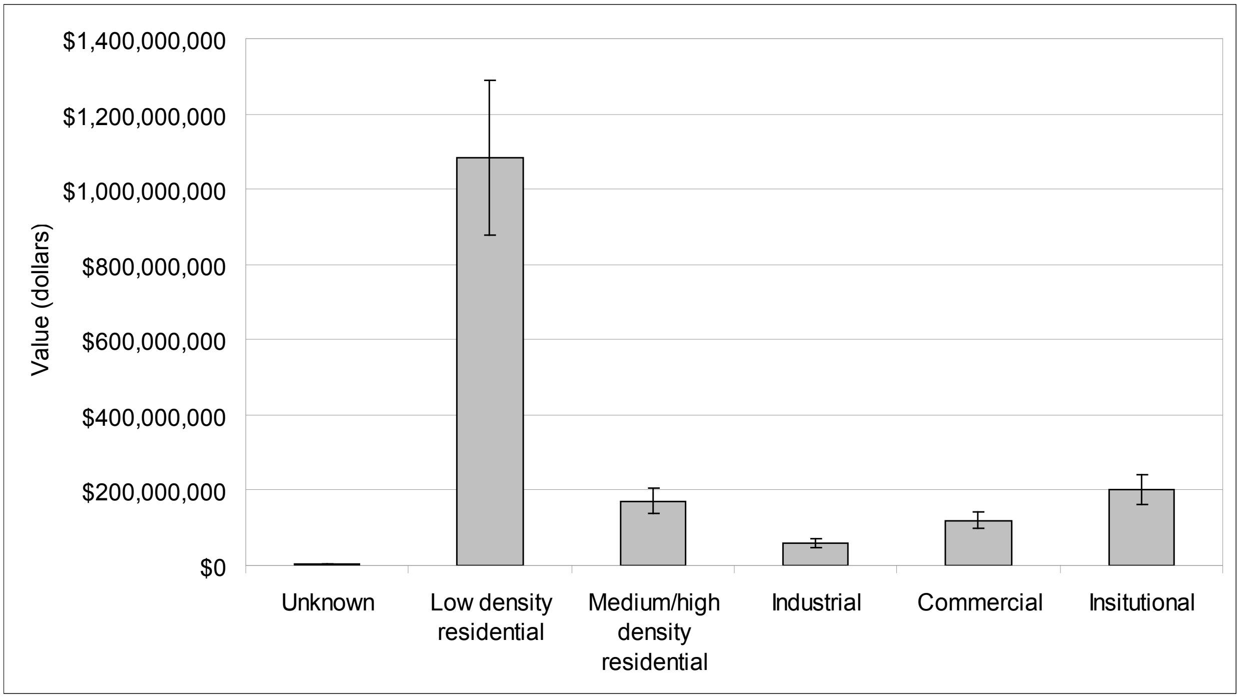

Figure 11. Total average value of benefits by land use class. Error bars show values for the low and high mortality scenarios

one million trees are projected to reduce electricity consumed for air conditioning by 718,671 to 1.1 million MWh or $76 to $119 million for the high and low mortality scenarios (*Figure 13*). However, this cooling savings is partially offset by increased heating costs from tree shade that obstructs winter sunlight. Tree shade is expected to increase natural gas required for heating by 101,000 to 154,000 MBtu, which is valued at $674,000 to $1 million. Despite this cost, a net energy savings of $75.7 to $117.4 million is projected for the high and low mortality scenarios. The adverse effects of winter tree shade can be limited by strategically locating trees and selecting solar-friendly species for locations where solar access is a concern (McPherson et al. 2000, 2001).

Atmospheric carbon dioxide reduction. Over its 35-year planning horizon, the one million tree planting is projected to reduce atmospheric CO_2 by 764,000 to 1.27 million tons, for the high and low mortality scenarios (*Figure 14*). Assuming this benefit is priced at $6.68 per ton, the corresponding

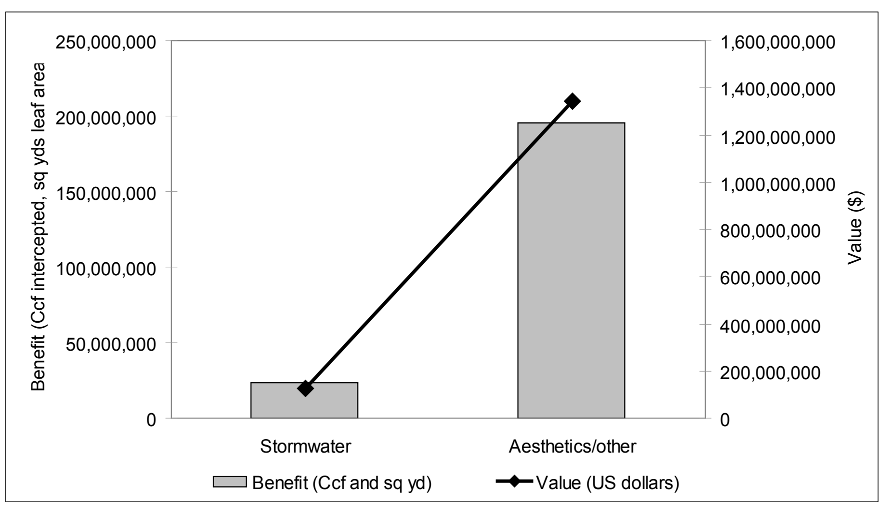

Figure 12. Total average value of aesthetic/other benefits and stormwater runoff reduction benefits for the 35-year period. The total amount of rainfall interception is shown in hundred cubic feet (Ccf). Aesthetic/other benefits are based on annual change in leaf surface area, shown in square yards

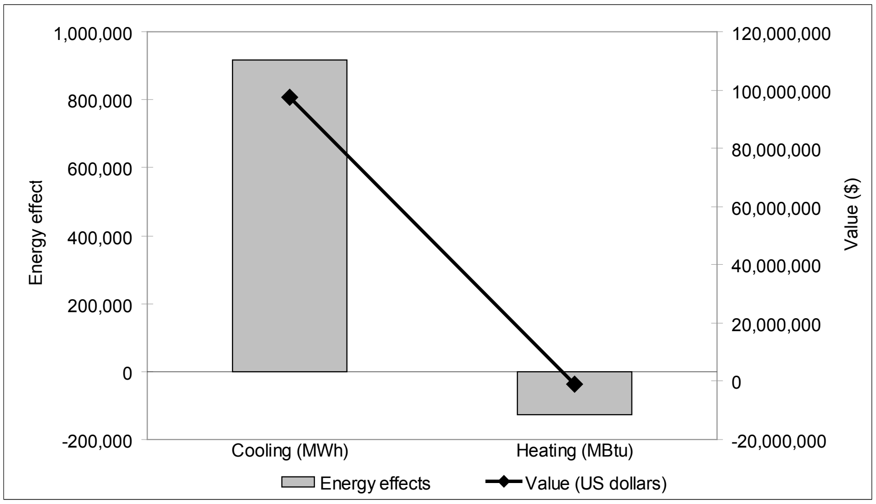

Figure 13. Total average value of tree effects on residential cooling (electricity, MWh) and heating (natural gas, MBtu) energy use for the 35-year period

benefit varies widely based on tree size. For example, in the inland zone for the low mortality scenario, the small crapemyrtle annually sequesters and reduces emissions by only 5 and 55 lb per tree on average, compared to 220 and 150 lb for the large evergreen ash. Where space permits, strategically locating large trees to reduce home cooling costs will result in substantial benefits to mitigate climate change.

value is $5.1 to $8.5 million. Emission reductions at power plants associated with effects of the trees on building energy use (498,000 to 772,000 tons) are greater than biological sequestration of CO_2 by the trees themselves (389,000 to 598,000 tons). A relatively small amount of CO_2 is released during tree care and due to decomposition of dead biomass (101,000 to 123,000 tons). The CO_2 reduction

Air quality improvement. By improving air quality, the tree planting will enhance human health and environmental quality in Los Angeles. This benefit is valued at $53 to $83 million over the 35-year planning horizon (*Figure 15*). Interception of PM_{10} and uptake of O_3 and NO_2 are especially valuable. The one million tree planting project is estimated to intercept and reduce power plant emissions of PM_{10}

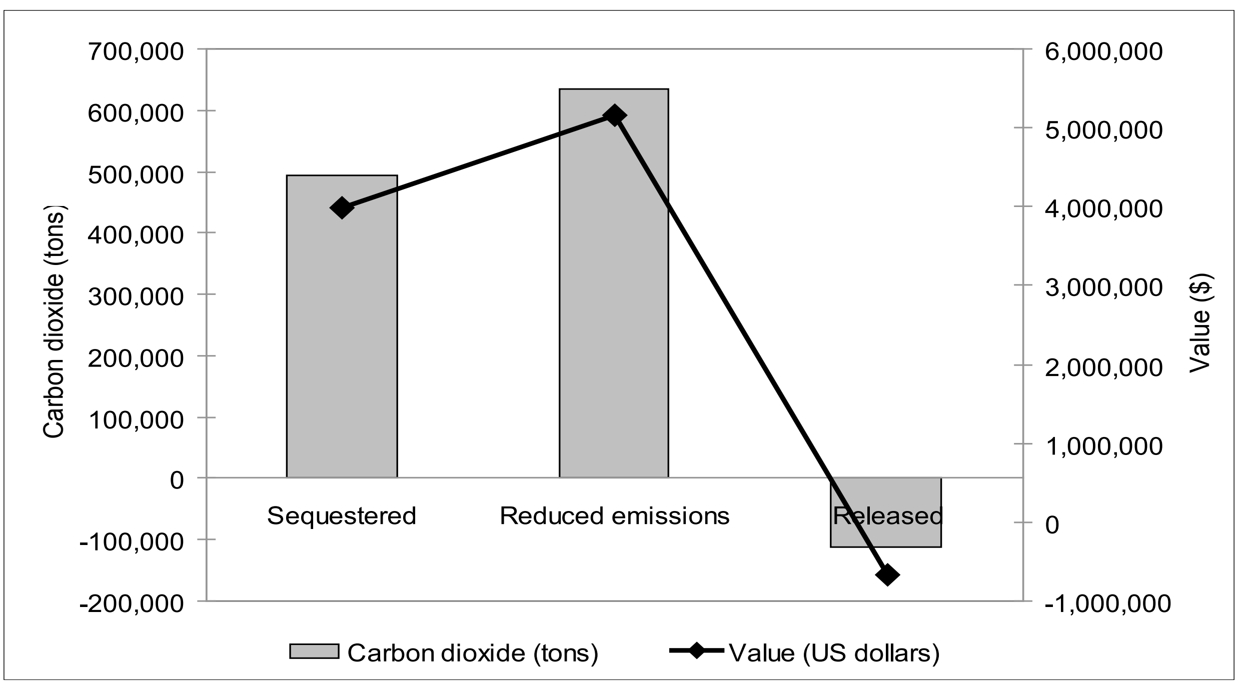

Figure 14. Total average value of carbon dioxide sequestration, emission reductions associated with energy effects, and release owing to tree care activities and decomposition of dead wood (1 short ton = 2,000 lb)

by 1,846 to 2,886 tons over the 35-year period for the high and low mortality scenarios, respectively. The value of this benefit ranges from $19 to $29 million, or 35% of total air quality benefits. For the low mortality example, annual deposition rates average 0.14 to 0.19 lb per tree for the medium tree in coastal and inland zones, while corresponding emission reductions range from 0.04 to 0.12 lb.

The one million trees are projected to reduce O_3 by 2,430 to 3,813 tons, with average annual deposition rates ranging from 0.25 to 0.35 lb per medium tree in the low mortality scenario for the coastal and inland zones, respectively. Ozone uptake is valued at $17.9 to $28.1 million over the project life for the high and low mortality scenarios, or 34% of total air quality benefits. Uptake of NO_2, an ozone precursor, is estimated to range from 1,949 to 3,039 tons, with a value of $14.6 to $22.8 million for the high and low mortality scenarios over the 35-year period. This benefit accounts for 27% of the total air quality benefit. A small amount of volatile organic compounds (VOC) emissions from power plants will be reduced because of energy savings. However, this analysis does not incorporate costs associated with biogenic VOCs, because all five species are low-emitters.

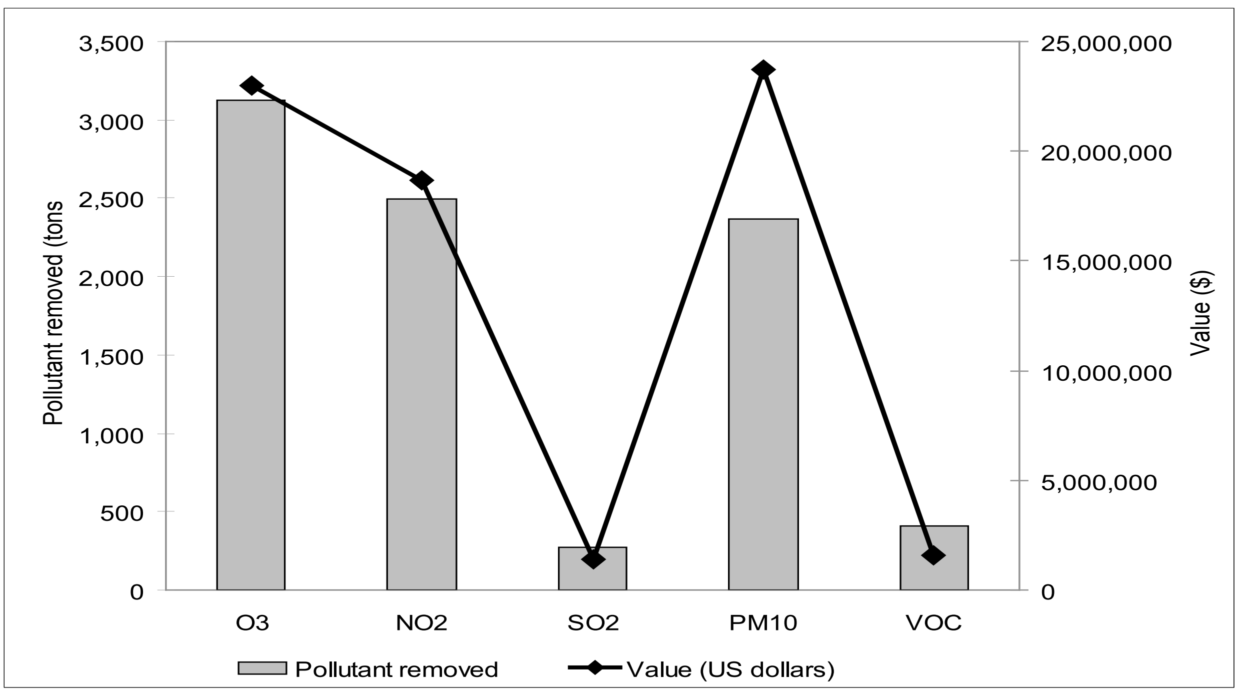

Figure 15. Total average value of tree effects on ozone (O_3), nitrogen dioxide (NO_2), sulfer dioxide (SO_2), particulate matter (PM_{10}), and volatile organic compounds (VOC). These values account for deposition to the tree canopy and emission reductions associated with energy effects

Discussion

This section provides context for study results through comparisons with data from New York City and Baltimore, the only other cities where existing, potential, and target TCC have been reported. Limitations and uncertainty of the study are described. It concludes with several recommendations related to dissemination of the data, implementation of the program, and future research.

Comparison of results

In Los Angeles, the existing TCC is 20.8%, which compares favorably with 20% in Baltimore and 23% in New York City (*Table 14*). This is surprising given Los Angeles's Mediterranean climate, which makes irrigation essential for establishment and growth of many tree species. However, the technical potential (existing TCC plus potential TCC) is much less in Los Angeles than reported for the other two cities. In Los Angeles, the technical potential (33%) represents only a 12% increase in TCC above the existing 21%. Hence, the potential TCC is 57% of existing TCC. In New York City and Baltimore the potential TCC is 187% and 265% times greater than the existing TCC. This finding suggests that there is much less available growing space for trees in Los Angeles than in the other cities. Although we don't have a definitive explanation for this result, a one reason may be the masking of mountain areas from our study site, which eliminated many potential tree planting sites.

In Los Angeles and Baltimore, the market potential, or target TCC equals the existing TCC plus about one-half the difference between existing and potential TCC. In New York City, the market potential is a much small percentage of the potential TCC. The lower target in New York City may reflect the fact that a larger proportion of potential TCC is in open spaces where new plantings would conflict with existing uses such as ball fields and prairie landscapes.

We compared results of the benefits assessment with previous benefit-cost analyses in our Tree Guides for Coastal Southern California and Inland Empire communities (McPherson et al. 2000, 2001). We expected differences in results because the simulations for this study used more recent air quality data and median home sales prices, and different benefit prices and tree mortality rates. Nevertheless, the dollar values of average annual benefits compared favorably. In the Coastal Southern California Tree Guide, average annual benefits for the representative small and medium street trees were $22 and $48, compared to $38 for this study (low-mortality scenario). In the Inland Empire Tree Guide the average annual benefit was $15 and $61 for the small and medium trees. In this study the corresponding value was $60 (assumes 50% small, 41% medium, 9% large). Hence, benefit values reported here are reasonable when compared with previously reported findings from similar analyses for the same region.

Uncertainty and limitations

There are several sources of error associated with these benefit projections. One source of error pertains to land cover classification. Inaccurate land cover classification results in inaccurate assessments of potential tree planting sites when pervious sites without trees are misclassified as having trees or as impervious, and impervious sites are misclassified as pervious and without trees. Our image classification assessment indicates that overall classification accuracy is 88.6% based on a pixel-by-pixel comparison.

Although ground-truthing of computer-based estimates of potential tree sites led to a calibration of the estimates, other errors can reduce the accuracy of estimates. For example, the computer-based

Table 14. Tree canopy cover results for three U.S. cities (%)

City	Existing	Potential	Technical potential	Market potential
Los Angeles	21	12	33	28
New York City	23	43	66	30
Baltimore	20	53	73	46

method can miss potential tree sites in large open spaces because a limited number of iterations are run for each tree size class. Potential tree planting sites in parking lots in medium/high density housing areas were not included. These types of limitations were observed during a workshop in Los Angeles when 15 sample areas were reviewed by local program participants. Computer-based tree sites were confirmed, deleted, and added based on local understanding of tree planting potential. Our informal findings were that the largest discrepancies between computer- and human-based potential tree sites were for institutional and industrial land uses, while estimates for residential land uses were in close agreement.

Modeling error influences the accuracy of benefit estimates. In this analysis we used three representative species in two climate zones, an obvious simplification of the actual tree planting program. In reality, over 100 species will be planted throughout the city, which has a myriad of microclimates. Therefore, these results are only accurate to the extent that the actual trees planted resemble the size and foliation characteristics of the species mix we have used here.

Our numerical models do not fully account for effects of BVOC emissions from trees on ozone formation, or the effects of shade from new trees on VOC emissions from parked cars and other anthropogenic sources. We also have not simulated the effects of trees on nonresidential building energy use.

Over three-quarters of total value is for aesthetic and other benefits, and our understanding of this type of benefit is least certain. To estimate this value we rely on research conducted in Georgia that may not be directly transferable to Los Angeles. Moreover, we assume that our value fully accounts for all the other benefits associated with city trees that have not been explicitly calculated.

The benefits quantified here should be considered a conservative estimate. They do not include many other benefits that are more difficult to translate into dollar terms. For example, tree shade on streets can help offset pavement management costs by protecting paving from weathering. The asphalt paving on streets contains stone aggregate in an oil binder. Tree shade lowers the street surface temperature and reduces heating and volatilization of the binder (McPherson and Muchnick 2005). As a result, the aggregate remains protected for a longer period by the oil binder. When unprotected, vehicles loosen the aggregate, and much like sandpaper, the loose aggregate grinds down the pavement. Because most weathering of asphalt-concrete pavement occurs during the first 5 to 10 years, when new street tree plantings provide little shade, this benefit mainly applies when older streets are resurfaced.

Scientific studies confirm our intuition that trees in cities provide social and psychological benefits. Views of trees and nature from homes and offices provide restorative experiences that ease mental fatigue and help people to concentrate (Kaplan and Kaplan 1989). Desk workers with a view of nature report lower rates of sickness and greater satisfaction with their jobs compared to those having no visual connection to nature (Kaplan 1992). Trees provide important settings for recreation and relaxation in and near cities. The act of planting trees can have social value, as bonds between people and local groups often result.

The presence of trees in cities provides public health benefits and improves the well-being of those who live, work, and play in cities. Physical and emotional stress has both short-term and long-term effects. Prolonged stress can compromise the human immune system. A series of studies on human stress caused by general urban conditions and city driving show that views of nature reduce the stress response of both body and mind (Parsons et al. 1998). Urban green also appears to have an "immunization effect," in that people show less stress response if they have had a recent view of trees and vegetation. Hospitalized patients with views of nature and time spent outdoors need less medication, sleep better, have a better outlook, and recover more quickly than patients without connections to nature (Ulrich 1985). Skin cancer is a particular concern in sunny Southern California. Trees reduce exposure to ultraviolet light, thereby lowering the risk of harmful effects from skin cancer and cataracts (Tretheway and Manthe 1999). Our accounting approach may not capture the full value of all benefits associated with a large-scale tree planting program in Los Angeles.

Recommendations

GIS data on existing TCC and potential tree planting sites, as well as information on the projected benefits of one million new trees are valuable assets for the city and its residents. To manage and disseminate this information we suggest the following:

- The City establish a central clearinghouse for GIS data related to the Million Trees LA program. Data from this and other studies could be accessed through the clearinghouse.
- Million Trees LA develop a 1-page handout that summarizes key points from this study, particularly the future benefits to be gained from investment in tree planting and stewardship.
- To document all aspects of this research and make it readily accessible, the Center for Urban Forest Research publish a General Technical Report, peer-reviewed and available at no cost to the public through the U.S. Forest Service.
- Important aspects of this study be summarized and posted on the Million Trees LA web-site.

Information on the benefits of this large-scale tree planting program can be helpful in developing partnerships with investors. For example, corporations may invest in the program because they can report carbon credits from trees that help offset their emissions. Similarly, if the South Coast Air Quality Management District includes trees as an air quality improvement measure in their State Implementation Plan, more funds for tree planting and management would become available. To capitalize on these opportunities, the Million Trees LA program will need a credible process for tracking tree planting and monitoring the survival, growth, and functionality of its trees. To attract serious investment, the program will have to demonstrate that the benefits from these trees will be permanent and quantifiable. To do this will entail a commitment to accountability through annual monitoring and reporting.

The Center for Urban Forest Research (CUFR) proposes working with Million Trees LA to develop a GIS Decision Support System (GDSS) that provides a user-friendly interface for making use of the data from this study for planning and implementation of neighborhood tree planting projects by tree planting coordinators such as NorthEast Trees and TreePeople. The GDSS will allow users without extensive GIS experience to examine different parcels, select and locate trees to provide the greatest benefits, budget for planting and maintenance costs, project the future stream of benefits, assess the ecological stability of the planting at a population level, and track future tree survival and growth. The GDSS will help Los Angeles maximize its return on investment in tree planting through application of state-of-the-art science and technology. The project will require one year and cost approximately $175,000.

Approximately 20% of the target TCC for Los Angeles is paved parking lot area. Planting trees in parking lots poses technical and financial challenges. However, if done judiciously, there are opportunities for parking lot tree plantings to substantially improve air quality, reduce stormwater runoff, cool urban heat islands, and improve community attractiveness. We recommend that the program establish new partnerships aimed at developing the technical specifications, financial means, and community support for a major parking lot greening effort in Los Angeles that could serve as a model for cities around the world.

CUFR proposes to collaborate with other scientists in southern California to study the effects of trees on the social, economic, and environmental health of Los Angeles and its nearly four million residents. In particular, we need to better understand:

- Barriers to tree planting and incentives for different markets
- Effects of trees on the urban heat island and air quality
- Effects of drought stress on tree survival and ability to remove air pollutants
- Primary causes of tree mortality
- Best management practices to promote tree survival
- Citywide policy scenarios to promote urban tree canopy, neighborhood desirability, and economic development
- How to link TCC goals to other city goals: increasing community health, neighborhood quality of life, environmental literacy, and sustainability.

As the second largest city in the United States, Los Angeles manages an extensive municipal forest. Its management should set the standard for the region and the country. We recommend that CUFR and the City of Los Angeles cooperate to conduct a tree inventory and assessment that provides information on the existing urban forest:

- Structure (species composition, diversity, age distribution, condition, etc.)
- Function (magnitude of environmental and esthetic benefits)
- Value (dollar value of benefits realized)
- Management needs (sustainability, maintenance, costs)
- Management recommendations aimed at increasing resource sustainability.

Los Angeles is a vibrant city that will continue to grow. As it grows it should also continue to invest in its tree canopy. This is no easy task, given financial constraints and trends toward higher density development that may put space for trees at a premium. The challenge ahead is to better integrate the green infrastructure with the gray infrastructure by increasing tree planting, providing adequate space for trees, and designing plantings to maximize net benefits over the long term, thereby perpetuating a resource that is both functional and sustainable. CUFR looks forward to working with the City of Los Angeles and its many professionals to meet that challenge in the years ahead.

Acknowledgments

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Appendix A. Land cover distributions by neighborhood council. Some neighborhood council boundaries overlap

	Area	Tree canopy cover		Irrigated grass cover		Dry grass/bare soil		Impervious/other		Mountain
Neighborhood councils	**(acres)**	**(acres)**	**(%)**	**(acres)**	**(%)**	**(acres)**	**(%)**	**(acres)**	**(%)**	**(acres)**
Northridge West	2,556	435	17.0	469	18.4	215	8.4	1,433	56.1	35
Northridge East	2,566	519	20.2	479	18.7	176	6.9	1,419	55.3	
Wilshire Center - Koreatown	1,485	111	7.5	48	3.3	35	2.3	1,284	86.5	
Harbor Gateway North	2,029	244	12.0	370	18.2	33	1.6	1,378	67.9	0
Empowerment Congress West area	2,091	279	13.3	458	21.9	78	3.7	1,276	61.0	0
West Van Nuys/Lake Balboa	5,640	614	10.9	546	9.7	118	2.1	2,416	42.8	
Woodland Hills-Warner Center	9,122	2,785	30.5	1,175	12.9	561	6.1	4,600	50.4	806
Winnetka	2,827	538	19.0	387	13.7	234	8.3	1,668	59.0	
Wilmington	6,033	303	5.0	208	3.4	219	3.6	4,496	74.5	673
West LA	1,197	133	11.1	68	5.7	33	2.7	964	80.5	0
Watts	1,294	168	13.0	226	17.4	77	5.9	824	63.7	0
Westside	2,405	606	25.2	361	15.0	110	4.6	1,328	55.2	2
West Hills	4,569	1,238	27.1	657	14.4	114	2.5	2,561	56.0	1,402
Westschester/Playa Del Rey	9,170	1,170	12.8	1,887	20.6	333	3.6	5,721	62.4	1
West Adams	1,387	168	12.1	152	10.9	75	5.4	992	71.5	0
Vernon/Main	1,346	123	9.1	134	9.9	55	4.1	1,035	76.9	
Vermont Harbor	1,396	151	10.8	176	12.6	60	4.3	1,009	72.3	
Van Nuys	3,757	695	18.5	328	8.7	154	4.1	2,580	68.7	
Nc Valley Village	1,257	346	27.6	142	11.3	51	4.1	717	57.1	
Valley Glen	2,443	608	24.9	301	12.3	129	5.3	1,405	57.5	
United neighborhoods of the Historic Arlington Heights, West Adams, and Jefferson Park Community	1,772	205	11.6	138	7.8	84	4.7	1,345	75.9	
Greater Toluca Lake	961	308	32.0	152	15.8	26	2.7	476	49.5	
Tarzana	4,282	1,290	30.1	776	18.1	285	6.7	1,932	45.1	779
Sylmar	6,957	1,185	17.0	760	10.9	1,212	17.4	3,799	54.6	963
Empowerment Congress Southwest Area	1,708	135	7.9	401	23.5	44	2.6	1,127	66.0	1
Sun Valley Area	5,260	551	10.5	251	4.8	245	4.7	4,208	80.0	314
Sunland-Tujunga	3,613	1,093	30.3	344	9.5	320	8.9	1,856	51.4	4,024
Studio City	3,403	1,420	41.7	303	8.9	82	2.4	1,580	46.4	528

Neighborhood councils	Area (acres)	Tree canopy cover (acres)	Tree canopy cover (%)	Irrigated grass cover (acres)	Irrigated grass cover (%)	Dry grass/bare soil (acres)	Dry grass/bare soil (%)	Impervious/other (acres)	Impervious/other (%)	Mountain (acres)
Southeast/Central Ave	1,662	107	6.5	98	5.9	43	2.6	1,414	85.1	0
South Robertson	1,682	332	19.7	191	11.4	74	4.4	1,086	64.5	0
Silver Lake	1,839	409	22.2	242	13.1	67	3.7	901	49.0	
Sherman Oaks	5,016	1,720	34.3	552	11.0	176	3.5	2,567	51.2	527
Empowerment Congress Southeast Area	2,725	270	9.9	481	17.7	42	1.6	1,915	70.3	
Elysian Valley Riverside	459	47	10.2	30	6.5	28	6.2	338	73.7	
Reseda	3,759	649	17.3	556	14.8	294	7.8	2,259	60.1	
Porter Ranch	2,394	276	11.5	586	24.5	216	9.0	1,316	55.0	1,294
Pico Union	1,026	103	10.0	68	6.6	24	2.3	831	81.0	
P.I.C.O.	1,155	165	14.3	132	11.4	73	6.4	785	67.9	
Park Mesa Heights	1,818	170	9.3	396	21.8	84	4.6	1,168	64.2	1
Pacoima	3,852	474	12.3	239	6.2	477	12.4	2,612	67.8	931
Olympic Park	724	97	13.4	75	10.3	41	5.7	512	70.6	
Old Northridge	857	122	14.3	103	12.0	57	6.7	574	67.0	
Northwest San Pedro	2,431	277	11.4	528	21.7	198	8.1	1,362	56.0	0
North Hollywood North East	1,930	232	12.0	141	7.3	91	4.7	1,466	76.0	
North Hills West	2,212	507	22.9	432	19.5	130	5.9	1,208	54.6	
Mid-town North Hollywood	3,030	545	18.0	265	8.7	121	4.0	2,100	69.3	
Mid City	1,113	137	12.3	102	9.2	61	5.5	813	73.0	
Mid City West	2,641	457	17.3	253	9.6	95	3.6	1,835	69.5	1
Macarthur	334	20	6.0	24	7.2	8	2.4	282	84.5	
Mar Vista	2,671	611	22.9	291	10.9	52	1.9	1,638	61.3	0
Lincoln Heights	1,893	253	13.4	47	2.5	67	3.6	1,491	78.8	93
LA-32	2,665	732	27.5	82	3.1	229	8.6	1,577	59.2	443
Hollywood United	1,468	532	36.3	93	6.3	61	4.2	694	47.3	752
Historic Cultural	1,369	81	5.9	59	4.3	38	2.8	1,148	83.8	166
Historic Highland Park	2,423	648	26.7	48	2.0	140	5.8	1,313	54.2	274
Harbor City	1,565	245	15.7	260	16.6	88	5.6	971	62.0	0
Hollywood Hills West	3,525	1,278	36.3	363	10.3	145	4.1	1,635	46.4	1,330
Greater Wilshire	2,538	682	26.9	379	14.9	108	4.2	1,370	54.0	
Grass Roots Venice	2,048	334	16.3	177	8.6	7	0.4	1,529	74.7	1

Neighborhood councils	Area (acres)	Tree canopy cover (acres)	Tree canopy cover (%)	Irrigated grass cover (acres)	Irrigated grass cover (%)	Dry grass/bare soil (acres)	Dry grass/bare soil (%)	Impervious/other (acres)	Impervious/other (%)	Mountain (acres)
Granada Hills North	4,600	1,191	25.9	644	14.0	454	9.9	2,311	50.2	2,770
Greater Griffith Park	3,528	964	27.3	664	18.8	232	6.6	1,561	44.3	2,356
Foothill Trails District	4,010	958	23.9	341	8.5	624	15.6	2,086	52.0	8,368
Encino	7,361	2,293	31.2	1,253	17.0	247	3.4	3,583	48.7	1,337
Greater Echo Park Elysian	2,324	390	16.8	413	17.8	123	5.3	1,370	59.0	370
Empowerment Congress North Area	2,455	289	11.8	281	11.5	104	4.2	1,781	72.5	
Eagle Rock	2,323	801	34.5	105	4.5	179	7.7	1,238	53.3	321
Downtown Los Angeles	3,214	95	3.0	74	2.3	27	0.8	3,017	93.9	2
Del Rey	1,942	192	9.9	259	13.3	34	1.7	1,457	75.0	0
Greater Cypress Park	787	122	15.5	38	4.8	64	8.1	563	71.5	41
Coastal San Pedro	2,287	233	10.2	515	22.5	174	7.6	1,365	59.7	2
Chatsworth	5,348	909	17.0	659	12.3	454	8.5	3,327	62.2	1,950
Central Hollywood	786	66	8.3	21	2.7	11	1.4	689	87.6	0
Empowerment Congress Central Area ndc	1,812	192	10.6	371	20.5	98	5.4	1,152	63.6	
Central San Pedro	1,386	134	9.7	91	6.6	67	4.8	1,094	79.0	0
Community and Neighbors for Ninth District Unity	1,632	126	7.7	196	12.0	34	2.1	1,276	78.2	
Canoga Park	2,361	357	15.1	208	8.8	135	5.7	1,660	70.3	
Boyle Heights	3,668	418	11.4	278	7.6	46	1.3	2,926	79.8	
Bel Air-Beverly Crest	6,964	3,715	53.3	699	10.0	194	2.8	2,356	33.8	3,997
Atwater Village	1,305	188	14.4	180	13.8	62	4.7	874	66.9	
Arroyo Seco	1,698	781	46.0	64	3.8	145	8.5	708	41.7	523
Arleta	2,089	350	16.8	217	10.4	231	11.1	1,291	61.8	
Central Alameda	861	84	9.8	86	10.0	34	4.0	616	71.5	
Mission Hills	2,302	422	18.3	286	12.4	361	15.7	1,233	53.6	
Harbor Gateway South	2,062	177	8.6	316	15.3	34	1.6	1,535	74.4	0
Palms	571	45	7.8	34	5.9	14	2.4	479	83.9	
Glassell Park	1,531	292	19.0	209	13.7	120	7.8	910	59.5	97

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