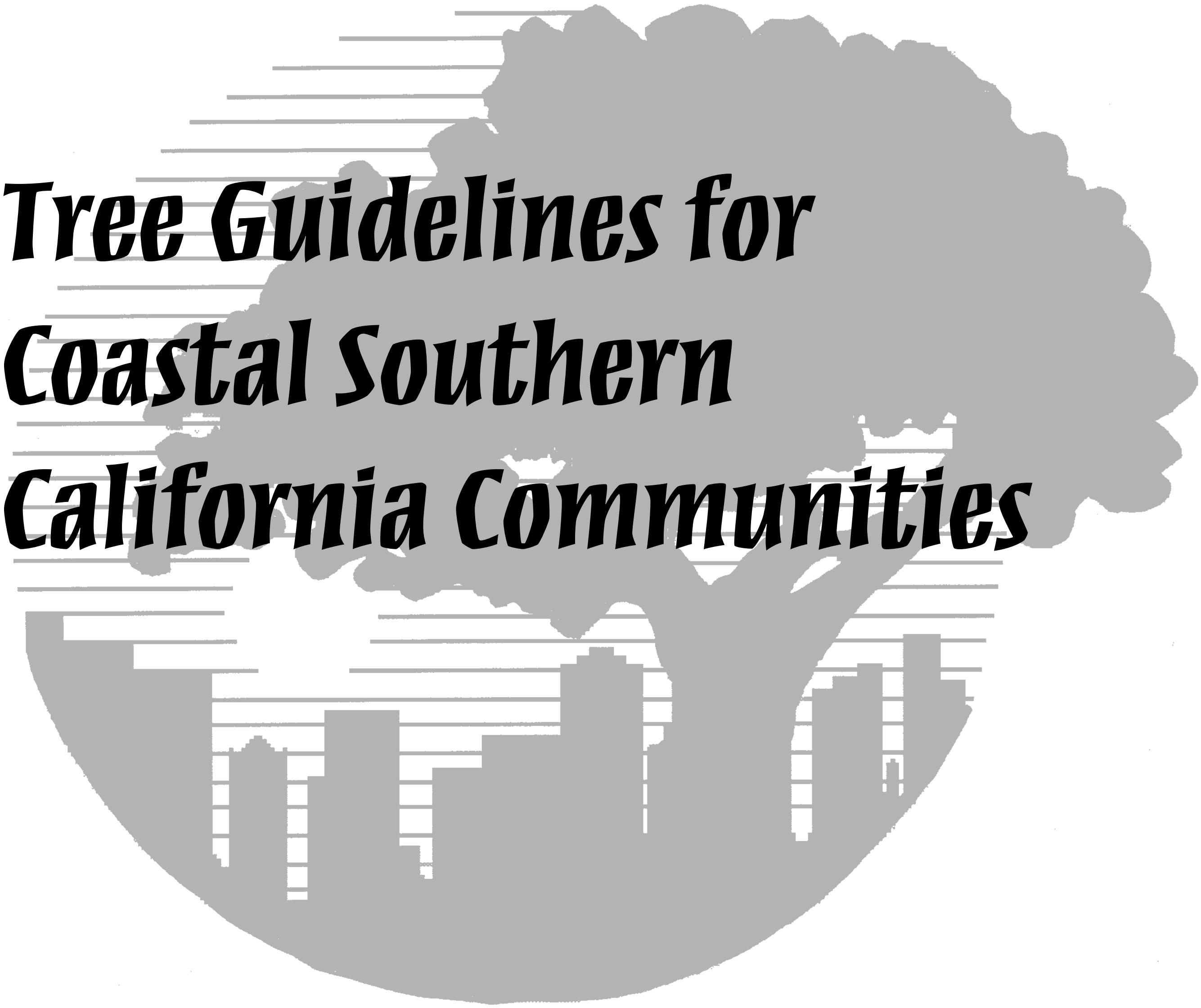
Tree Guidelines for Coastal Southern California Communities



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Tree Guidelines for Coastal Southern California Communities

Executive Summary

Communities in the Coastal Southern California region contain over 9 million people, or about 25% of the state's population. The region's climate is influenced by the ocean 85% or more of the time and extends from Santa Barbara south to the border with Mexico and from the coast to inland cities such as Camarillo, Hollywood, Anaheim and El Cajon. The role of urban forests – trees in parks, yards, public spaces, and along streets – to improve environmental quality, increase the economic, physical and social health of communities, and foster civic pride will be important to quality of life as these communities continue to grow in the next decade. Urban and community forestry has been recognized as a cost effective means to address a variety of important community and national issues from improving air quality to combating global warming.

This guidebook analyzes the multitude of benefits that trees can provide to communities and residents. By determining the community and home owner savings from planting trees and subtracting the cost, this study found that trees more than pay for themselves. Over a 40-year period, after subtracting costs, every large tree produces savings of approximately $2,600. This amount decreases with the tree's size with medium trees saving about $1,000 and small trees breaking even.

Trees can have far reaching affects on the quality of air and water in our communities, on the amount of money we spend to cool and heat our houses, on the value of our property, and on the attractiveness of our neighborhoods and public spaces. They affect our moods and our health, as well as the health of our children.

Who Should Read This Guide

Local Elected Officials
Public Works Employees
City and County Planners
Developers and Builders
Architects and Landscape Architects
Energy Professionals
Air & Water Quality Professionals
Healthcare Advocates
Homeowners
Neighborhood Activists and Organizers
Arborists
Environment Advocates
Community Foresters
Tree Advocacy Organizations
Concerned Citizens

This guidebook addresses the benefits of urban and community forests and how you can reap these benefits for your community, your neighborhood, and your family including:

- Improving environmental quality by planting trees.
- Planting trees to reduce energy consumption and save money.
- Choosing tree species that reduce conflicts with power lines, sidewalks and buildings.
- Developing and promoting tree planting and maintenance programs in your community.
- Finding sources of funding and technical assistance for planting trees in your community.

Coastal Southern California communities can promote energy efficiency through tree planting and stewardship programs that strategically locate trees to shade buildings, cool urban heat islands, and minimize conflicts with power lines and other aspects of the urban infrastructure. Also, these same trees can provide additional benefits by reducing atmospheric carbon dioxide (CO_2), improving air quality, reducing stormwater runoff, increasing property values, enhancing community attractiveness, and promoting human health and well-being. The simple act of planting trees provides opportunities to connect residents with nature and with each other. Neighborhood tree plantings and stewardship projects stimulate investment by local citizens, business, and government in the betterment of their communities.

Energy Impacts

Rapid urbanization of cities during the past 50 years has been associated with a steady increase in downtown temperatures of about 1° F per decade. As temperature increases, energy demand for cooling increases as do carbon dioxide emissions from fossil fuel power plants, municipal water demand, unhealthy ozone levels, and human discomfort and disease.

Urban forests improve climate and conserve building energy use by:

- Shading, which reduces the amount of radiant energy absorbed and stored by built surfaces,
- Evapotranspiration, which converts liquid water in leaves to vapor, thereby cooling the air, and
- Wind speed reduction, which reduces the infiltration of outside air into interior spaces.

Trees and other greenspace may lower air temperatures 5-10° F. Because of Coastal Southern California's relatively mild summer weather, potential cooling savings from trees are less than for desert and inland valley regions. Computer simulations for an energy-efficient home in El Toro indicate that shade from two 25-foot tall trees on the west side and one on the east side are estimated to save $46 each year or about one-third of the home's cooling cost. Evapotranspirational cooling from these three trees is estimated to double these savings provided that a large enough number of trees were planted to reduce summertime temperatures in the neighborhood. Simulated savings for the same residence in San Diego were about 50% of this amount due to cooler summer temperatures.

Air Quality Impacts

Urban forests can reduce atmospheric carbon dioxide (CO_2) in two ways. Trees directly store CO_2 as woody and leafy biomass while they grow. Trees around buildings can also reduce the demand for heating and air conditioning, thereby reducing emissions associated with electric power production.

Urban trees provide direct air quality benefits by:

- Absorbing gaseous pollutants (ozone, nitrogen oxides) through leaf surfaces,
- Intercepting particulate matter (e.g., dust, ash, pollen, smoke),
- Releasing oxygen through photosynthesis, and

- Transpiring water and shading surfaces, which lowers local air temperatures, thereby reducing ozone levels.

Most trees emit various biogenic volatile organic compounds that can contribute to ozone formation. The ozone forming potential of different tree species varies considerably and can be found in the tree selection chapter.

Trees that shade asphalt surfaces and parked vehicles reduce emission of hydrocarbons that come from leaky fuel tanks and worn hoses as gasoline evaporates. These evaporative emissions are a principal component of smog and parked vehicles are a primary source.

Water Quality Impacts

Urban stormwater runoff is a major source of pollution. Trees improve water quality by:

- Intercepting and storing rainfall on leaves and branch surfaces, thereby reducing runoff volumes and delaying the onset of peak flows,
- Increasing the capacity of soils to infiltrate rainfall and reduce overland flow, and
- Reducing soil erosion by diminishing the impact of raindrops on barren surfaces.

Urban forests can provide other water benefits. Irrigated tree plantations can be a safe and productive means of wastewater disposal. Reused wastewater can recharge aquifers, reduce stormwater treatment loads, and create income through sales of wood products.

Social Impacts from Trees

- Abate noise, by absorbing high frequency noise which are most distressing to people,
- Create wildlife habitat, by providing homes for many types of wildlife,
- Reduce exposure to ultraviolet light, thereby lowering the risk of harmful health effects from skin cancer and cataracts,
- Provide pleasure, whether it be feelings of relaxation, or connection to nature,
- Provide important settings for recreation,
- Improve individual health by creating spaces that encourage walking,
- Create new bonds between people involved in tree planting activities,
- Provide jobs for both skilled and unskilled labor for planting and maintaining community trees,
- Provide educational opportunities for residents who want to learn about nature through first-hand experience, and
- Increase residential property values (studies indicate people are willing to pay 3-7% more for a house in a well-treed neighborhood versus in an area with few or no trees).

Urban Forest Costs

Costs for planting and maintaining trees vary depending on the nature of tree programs and their participants. Generally, the single largest expenditure is for tree trimming, followed by tree removal/disposal, and tree planting. An initial analysis of data for Sacramento and other cities suggests that households typically spend about $5-10 annually per tree for pruning, removal, pest/disease control, irrigation, and other tree care costs.

Other costs associated with urban trees include:

- Pavement damage caused by roots,
- Flooding caused by leaf litter clogging storm sewers,
- Green waste disposal and recycling (can be offset by avoiding dumping fees and purchases of mulch), and
- Irrigation costs.

Cost effective strategies to retain benefits from large street trees while reducing costs associated with root-sidewalk conflicts are needed. The tree selection list in Chapter 6 contains information on the rooting characteristics of recommended trees.

General Tree Planting Recommendations include:

- Trees on the west and northwest sides of homes provide the greatest energy benefit; trees on the east side of homes provide the next greatest benefit,
- Plant only deciduous trees on the south side of homes to allow winter sunlight and heat,
- Plant evergreen trees as windbreaks,
- Shade trees can make paved driveways and patios cooler and more comfortable spaces,
- Shading your air conditioner can reduce its energy use, but do not plant vegetation so close that it will obstruct air flow around the unit,
- Keep trees away from overhead power lines and do not plant directly above underground water and sewer lines.

Residential Tree Selection and Location for Solar Control

The ideal shade tree has a fairly dense, round crown with limbs broad enough to partially shade the roof. Given the same placement, a large tree will provide more building shade than a small tree. Deciduous trees allow sun to shine through leafless branches in winter.

When selecting trees, match the tree's water requirements with those of surrounding plants. Also, match the tree's maintenance requirements with the amount of care different areas in the landscape receive.

Evergreens are preferred over deciduous trees for windbreaks because they provide better wind protection. The ideal windbreak tree is fast growing, visually dense, and has stiff branches that do not self-prune. Incense cedar, cajeput tree, New Zealand Christmas tree, and Canary Island and Torrey pines are among the best windbreak trees for Coastal Southern California communities.

The right tree in the right spot saves energy. In midsummer, the sun shines on the northeast and east sides of buildings in the morning, passes over the roof near midday, then shines on the west and northwest sides in the afternoon. Air conditioners work hardest during the afternoon when temperatures are highest and incoming sunshine is greatest.

Therefore, a home's west and northwest sides are the most important sides to shade. The east side is the second most important side to shade.

Trees located to shade south walls can block winter sunshine and increase heating costs, because during winter the sun is lower in the sky and shines on the south side of homes. The warmth the sun provides is an asset, so do not plant evergreen trees that will block southern exposures and solar collectors.

Tree Location and Selection in Public Places

Locate trees in common areas, along streets, in parking lots, and commercial areas to maximize shade on paving and parked vehicles. By cooling streets and parking areas, trees reduce emissions from parked cars that are involved in smog formation. Large trees can shade more area than smaller trees, but should be used only where space permits. Remember that a tree needs space for both branches and roots.

CO_2 reductions from trees in common areas are primarily due to sequestration (storage in biomass). Fast-growing trees sequester more CO_2 initially than slow-growing trees, but this advantage can be lost if the fast-growing trees die at younger ages. Large growing trees have the capacity to store more CO_2 than do smaller growing trees. To maximize CO_2 sequestration, select tree species that are well-suited to the site where they will be planted.

Contact your local utility company before planting to locate underground water, sewer, gas, and telecommunication lines. Note the location of power lines, streetlights, and traffic signs, and select tree species that will not conflict with them. Keep trees at least 30 feet away from street intersections to ensure visibility. Avoid locating trees where they will block illumination from street lights or views of street signs in parking lots, commercial areas, and along streets. Avoid planting shallow rooting species near sidewalks, curbs, and paving.

The ideal public tree is not susceptible to wind damage and branch drop, does not require frequent pruning, produces little litter, is deep-rooted, has few serious pest and disease problems, and tolerates a wide range of soil conditions, irrigation regimes, and air pollutants. Because relatively few trees have all these traits, it is important to match the tree species to planting site by determining what issues are most important on a case-by-case basis.

Program Design

A successful shade tree program is likely to be community-wide and collaborative. Fortunately, lessons learned from urban and community programs throughout the country can be applied to avoid pitfalls and promote success.

Tree planting is a simple act, but planning, training, selecting species, and mobilizing resources to provide ongoing care require considerable fore-

A Checklist for Designing Your Tree Program

- Establish the Organizing Group
- Draw a Road Map
- Send Roots into the Community
- Provide Timely, Hands-on Training and Assistance
- Nurture Your Volunteers
- Obtain High-Quality Nursery Stock
- Develop a List of Recommended Trees
- Commit to Stewardship
- Use Self-Evaluation to Improve
- Educate the Public

thought. Successful shade tree programs will address all these issues before a single tree is planted.

What Can Local Governments Do?

Local government has a long history of preserving and expanding the urban forest. Below are some recommended steps for further local government involvement. Appendices B and C provide more background materials, contact information and a list of funding resources.

Require Shade Trees in New Development

Trees can help to reduce energy costs, improve air and water quality, and provide urban residents with a connection to nature.

Trees reduce cooling needs during hot summers by shading buildings and cooling the air through evapotranspiration. Computer simulations show that an energy-efficient home in El Toro could save $46 in annual energy costs if two 25-foot tall trees were placed on the west side of the home and an additional tree was planted on the east side. Properly placed trees can also act as wind barriers, keeping outside air from entering interior spaces, potentially reducing both heating and cooling needs.

Tree selection and placement is critical to optimizing the potential benefits of trees. See Chapter 3, "General Guidelines for Siting and Selecting Trees," for more information. **The City of Redding** requires one new tree to be planted for every 500 sq. ft. of closed space for residential, one per 1000 sq. ft. for commercial, and one per 2,000 sq ft. for industrial. Credits are given for the preservation of existing trees.

The City of Escalon is requiring street trees in its new Farinelli Ranch subdivision to shade street pavement, lower ambient temperatures and reduce the cooling needs of neighboring homes. Narrowing streets increased shade cover while lowering development costs. These combined actions are projected to reduce annual energy use for cooling by 18% per home.

Require Shade Trees in Parking Lots

Emissions from parked cars are a significant contributor to smog. By shading asphalt surfaces and parked vehicles, trees reduce the emission of hydrocarbons that occur when gasoline evaporates from leaky fuel tanks and worn hoses.

The City of Davis requires that 50 percent of paved parking lot surfaces be shaded with tree canopies within 15 years of the building permit being issued. **The City of Redding** requires one tree per four parking spaces.

Proper planting procedures, including an adequate planting area and effective irrigation techniques, along with ongoing monitoring and maintenance are essential to the survival and vitality of parking lot trees. The City of Davis is currently considering using a community tree group, Tree Davis, to assist in annual inspections of parking lot trees.

Davis is also pursuing innovative construction methods that would provide parking lot trees with a larger rooting area without compromising the structural integrity of the paved surfaces. Soils underneath parking lots are usually very compact, offering parking lot trees limited root space. This can compromise the ability of parking lot trees to survive and thrive.

As part of a parking lot renovation and plaza construction project in downtown Davis, the City plans to install a structural soil mix around the parking lot and plaza trees as an alternative to standard aggregate base. The structural soil mix, developed by Cornell University, provides the compaction needed below parking lot paving surfaces while providing an accessible rooting environment for the parking lot trees.

Adopt a Tree Preservation Ordinance

This ordinance can be used to protect and enhance your community's urban forest. Many cities and counties require a permit to remove a tree or build, excavate or construct within a given distance from a tree. At least one tree should be planted for every tree that is removed.

Hire or Appoint a City Forester/Arborist

The California Energy Commission's ***Energy Aware Planning Guide*** recommends that a single person should be responsible for urban tree programs, including "planting and maintenance of public trees, tree planting requirements for new development, tree protection, street tree inventories and long-range planning." A number of cities maintain full-time arborists who are employed through the Public Works or Parks and Recreation Departments.

Conduct a Street Tree Inventory and Establish a Maintenance Program

A healthy urban forest requires regular maintenance. A street tree inventory identifies maintenance needs. A management plan prioritizes spending for pruning, planting, removal and protection of trees in the community.

Adopt a Landscaping Ordinance to Encourage Energy Efficiency and Resource Conservation

Trees placed in proper locations can provide cooling relief and reduce summer air-conditioning needs. Shrubs, vines and ground covers can also be used to lower solar heat gain and reduce cooling needs. Given the long, dry and hot summers of the San Joaquin Valley, choosing inappropriate species for the local climate can result in a large demand for water and chemical insecticides and herbicides.

The City of Irvine's Sustainability in Landscaping Ordinance outlines guidelines for developing and maintaining landscapes that conserve water and energy, optimize carbon dioxide sequestration, increase the production of oxygen, and lower air conditioning demands. The ordinance encourages the City to develop and promote programs and activities that educate residents about the benefits of sustainable landscaping. The ordinance also discourages the use of inorganic fertilizers, pesticides and herbicides.

Use Tree Planting to Strengthen Communities and Increase Resident Involvement

Research shows that residents who have participated in tree planting events are more satisfied with trees and their neighborhood than are residents where trees have been planted by the city, a developer, or volunteer groups without resident involvement.

Through the **City of Long Beach**'s Neighborhood Improvement Tree Project, city staff worked with neighborhood groups, the Conservation Corps of Long Beach, and local businesses to plant trees in physically distressed neighborhoods during the spring of 1998. Five hundred volunteers helped to plant over 800 trees. City staff report that the event provided local residents with a sense of empowerment and helped to strengthen community ties.

Utilize Funding Opportunities to Plant Trees and Maintain the Urban Forest

California ReLeaf, the urban forestry division of the Trust for Public Land, maintains an extensive list of funding resources for urban forestry and education projects. See Chapter 4 and Appendix B for more information.

The Energy Aware Planning Guide proposes including street tree planting in the capital budget for road building which may help to secure funding.

Cities with municipal utilities may want to use their public benefit funds towards street and shade tree projects. With the assistance of the Sacramento Tree Foundation, the **Sacramento Municipal Utility District**'s (SMUD) Sacramento Shade program has planted over 250,000 trees in the Sacramento region. SMUD began its program in 1990 and hopes to plant 10,000 trees in 1999. SMUD's overall goal is to plant 500,000 trees.

Since October 1992, **City of Anaheim** Public Utilities' TreePower Program has provided free shade trees to residents, businesses and schools. The City's Neighborhood Services, Code Enforcement and Community Policing Departments help to expand the reach of the program into individual neighborhoods. Through TreePower, the City of Anaheim has planted over 10,000 trees.

Local Government Contacts

Shade Trees in New Development

City of Redding, Planning Division
Phil Carr, Associate Planner
760 Parkview Avenue
Redding, CA 96049-6071
(530) 225-4020

City of Escalon
J.D. Hightower, City Planner
P.O. Box 248
Escalon, CA 95320
☎(209) 838-4110

Shade Trees in Parking Lots

City of Davis, Planning and Building Department
Ken Hiatt, Associate Planner
23 Russell Blvd.
Davis, CA 95616
☎(530) 757-5610
e-mail: KHiatt@mail.city.davis.ca.us

(see also City of Redding)

Landscaping Ordinance to Encourage Resource Efficiency

City of Irvine
Steve Burke, Landscape Superintendent
P.O. Box 19575
Irvine, CA 92623-9575
☎(949) 724-7609

Collaboration with Local Community Groups and Tree Organizations

City of Long Beach, Community Development Dept.
Craig Beck, Community Development Analyst
333 West Ocean Blvd., 3rd Floor
Long Beach, CA 90802
☎(562) 570-6866

California ReLeaf
c/o Trust for Public Land
Stephanie Alting-Mees, Program Manager
116 New Montgomery, 3rd floor
San Francisco, CA 94105
e-mail: Stephanie_Alting_Mees_at_tpl-sf@mail.tpl.org

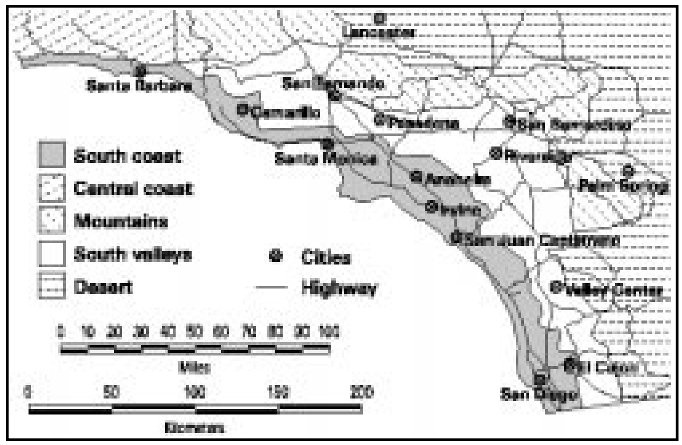
City of Anaheim Public Utilities
TreePower
P.O. Box 3222
Anaheim, CA 92803
☎(714) 491-8733

Sacramento Municipal Utility District (SMUD)
Energy Services Department
☎(916) 455-2020
web: www.smud.org

The green infrastructure is a significant component of coastal Southern California cities.

Introduction

Communities in the Coastal Southern California region contain over 9 million people comprising about 25% of the state's total population. The region's inhabitants derive great benefit from an incredibly diverse assemblage of tree species made possible by the moderating climatic influence of the nearby Pacific Ocean. The Coastal Southern California region's climate is influenced by the ocean 85% or more of the time and extends from Santa Barbara south to the border with Mexico and from the coast to inland cities such as Camarillo, Hollywood, Anaheim, Mission Viejo, Fallbrook, and El Cajon (Figure 1). The region's boundaries correspond with Sunset climate zones 22, 23, and 24 (Brenzel 1997). Occasionally, winter temperatures will drop to the low 20s° F (-4 to -7° C) in the cold-winter portions of this region (Sunset zone 22).



1. The Coastal Southern California Region extends from Santa Barbara south to the Mexican border.

Sustaining healthy community forests will be important to quality of life as many Coastal Southern California communities continue to grow during the next decade. The role of urban forests to enhance the environment, increase community attractiveness, and foster civic pride will take on greater significance as communities strive to balance economic growth with environmental quality and social well-being.

Coastal Southern California communities can promote energy efficiency through tree planting and stewardship programs that strategically locate trees to shade buildings, cool urban heat islands, and minimize conflicts with power lines and other aspects of the urban infrastructure. Also, these same trees can provide additional benefits by reducing atmospheric carbon dioxide (CO_2), improving air quality, reducing stormwater runoff, increasing property values, enhancing community attractiveness, and promoting human health and well-being. The simple act of planting trees provides opportunities to connect residents with nature and with each other. Neighborhood tree plantings and stewardship projects stimulate investment by local citizens, business, and government in the betterment of their communities (Figure 2).

This report addresses a number of questions about the energy conservation potential and other benefits of urban and community forests in Coastal Southern California:

- What is their potential to improve environmental quality and conserve energy?
- Where should residential and public trees be placed to maximize their cost-effectiveness?
- Which tree species will minimize conflicts with power lines, sidewalks, and buildings?

- What are important features of successful shade tree programs?
- What sources of funding and technical assistance are available?

Answers to these questions should assist policy makers, utility personnel, urban forest managers, non-profit organizations, design and planning professionals, and concerned citizens who are planting and managing trees to improve their local environments and build better communities.

2. Tree planting and stewardship programs provide opportunities for local residents to work together to build better communities.

What's in the Guidebook

- **Chapter 1.** Provides background information on the energy conservation potential of trees in Coastal Southern California, and describes other benefits and costs associated with trees.
- **Chapter 2.** Quantifies annual benefits and costs of maintaining a typical large, medium, and small shade tree for a period of 40 years after planting in a residential yard and a public site (street, park, or common open space).
- **Chapter 3.** Presents guidelines for selecting and siting of trees in residential yards and public open space.
- **Chapter 4.** Describes key components of shade tree programs and tips to increase their cost-effectiveness, and contains information on sources of technical assistance.
- **Chapter 5.** Contains a tree selection list with information on tree species recommended for shading and atmospheric CO_2 reduction in Coastal Southern California communities.
- **Chapter 6.** Lists references cited in the guide.
- **Chapter 7.** Provides definitions for technical terms used in the guide.
- **Appendix A.** Contains tables that list annual benefits and costs at five-year intervals for 40 years after planting. A case study illustrates how these data can be adjusted for local projects and applied to quantify costs and benefits.
- **Appendix B.** Presents funding opportunities for California communities.
- **Appendix C.** Contains resources such as sample ordinances, brochures, and information on innovative programs in Southern California.

1. Identifying Benefits and Costs of Urban and Community Forests

Benefits

Energy Conservation Potential

Buildings and paving increase the ambient temperatures within a city. Rapid growth of California cities during the past 50 years is associated with a steady increase in downtown temperatures of about 0.7° F (0.4 ° C) per decade. Because electric demand of cities increases about 1 to 2% per °F (3-4% per °C) increase in temperature, approximately 3-8% of current electric demand for cooling is used to compensate for this urban heat island effect (Akbari et al. 1992). Warmer temperatures in cities compared to surrounding rural areas has other implications, such as increases in carbon dioxide emissions from fossil fuel power plants, municipal water demand, unhealthy ozone levels, and human discomfort and disease. These problems are accentuated by global climate change, which may double the rate of urban warming.

In Coastal Southern California, there is ample opportunity to "retrofit" communities with more energy efficient landscapes through strategic tree planting and stewardship of existing trees. Accelerating urbanization hastens the need for more energy-efficient landscapes in new development.

Urban forests modify climate and conserve building energy use through:

❶ Shading, which reduces the amount of radiant energy absorbed and stored by built surfaces,

❷ Evapotranspiration, which converts liquid water in plants to vapor, thereby cooling the air, and

❸ Wind speed reduction, which reduces the infiltration of outside air into interior spaces (Simpson 1998).

Trees and other greenspace within individual building sites may lower air temperatures 5° F (3° C) compared to outside the greenspace. At the larger scale of urban climate (6 miles or 10 km square), temperature differences of more than 9° F (5° C) have been observed between city centers and more vegetated suburban areas.

The relative importance of these effects depends on the size and configuration of vegetation and other landscape elements (McPherson 1993). Generally, large greenspaces affect climate at farther distances (300 to 1,500 ft, or 100 to 500 m distance) than do smaller greenspaces. Tree spacing, crown spread, and vertical distribution of leaf area influence the transport of cool air and pollutants along streets, and out of urban canyons. For individual buildings, solar angles and infiltration are important. Because the summer sun is low in the east and west for several hours each day, shade to protect east and especially west walls helps keep buildings cool. Rates at which outside air infiltrates into a building can increase substantially with wind speed. In cold windy weather the entire volume of air in a poorly sealed home may change two to three times per hour. Even in newer or tightly sealed homes, the entire volume of air may change every two to three hours.

Because the summer and winter weather of Coastal Southern California communities is relatively mild, potential energy savings from trees are less than for desert and inland valley regions. Computer simulation of annual cooling savings for an energy efficient home in El Toro indicated that the typical household spends about $136 each year for air conditioning (1,047 kWh, 2.5 kW peak). Shade from two 25-ft tall (7.5 m) trees on the west and one on the east was estimated to save $46 each year, a 34% reduction (355 kWh) (Simpson and McPherson 1996). Evapotranspirational cooling from these three trees was estimated to double these savings provided that a large enough number of trees were planted to reduce summertime temperatures in the neighborhood. Simulated savings for the same residence in San Diego were about 50% of this amount because of cooler summer temperatures.

Atmospheric Carbon Dioxide Reductions

Urban forests can reduce atmospheric CO_2 in two ways: ❶ trees directly sequester CO_2 as woody and foliar biomass while they grow, and ❷ trees near buildings can reduce the demand for heating and air conditioning, thereby reducing emissions associated with electric power production.

On the other hand, CO_2 is released by vehicles, chain saws, chippers, and other equipment during the process of planting and maintaining trees. Eventually, all trees die and most of the CO_2 that has accumulated in their woody biomass is released into the atmosphere through decomposition.

Regional variations in climate and the mix of fuels that produce energy to heat and cool buildings influence potential CO_2 emission reductions. Southern California Edison, Los Angeles Department of Water and Power, and San Diego Gas and Electric provide electricity to Coastal Southern California communities. Carbon dioxide emissions from plants operated by these utilities varies depending on the mix of fuels used to generate the power. The CO_2 emissions factor for Coastal Southern California is approximately 0.84 lb CO_2 / kWh – 11% greater than the California state average.

To provide a complete picture of atmospheric CO_2 reductions from tree planting it is important to consider CO_2 released into the atmosphere through tree planting and care activities, as well as decomposition of wood from pruned or dead trees. The combustion of gasoline and diesel fuels by vehicle fleets, and equipment such as chainsaws, chippers, stump removers, and leaf blowers is a relatively minor source of CO_2. Typically, CO_2 released due to tree planting, maintenance, and other program related activities is about 2-8% of annual CO_2 reductions obtained through sequestration and avoided power plant emissions (McPherson and Simpson 1999).

One of the most comprehensive studies of atmospheric CO_2 reductions by an urban forest found that Sacramento's six million trees remove approximately 304,000 t (1.2 t/ha) of atmospheric CO_2 every year, with an implied value of $3.3 million (McPherson 1998). Avoided power plant emissions (75,600 t) accounted for 32% of the amount sequestered (238,000 t). The amount of CO_2 reduction by Sacramento's urban forest offsets 1.8% of total CO_2 emitted annually as a byproduct of human consumption. This savings could be substantially increased through strategic planting and long term stewardship that maximizes future energy savings from new tree plantings, as with the Cities for Climate Protection program (McPherson 1994, ICLEI 1997).

The City of Chula Vista joined the Cities for Climate Protection program and adopted urban forestry as one means to reduce CO_2 emissions to a level below the 1990 base. Using computer simulations we estimated that annual CO_2 reductions 15 years after planting would range from 411 to 536 lb depending on location for a 24-ft tall tree (McPherson and Simpson 1998). Given this emission reduction rate, 29-39 trees will be required to offset average annual emissions on a per capita basis in Chula Vista (15,811 lb/capita). Although summer temperatures along the I-15 corridor north of San Diego can get hot, Chula Vista's relatively mild summers will result in lower avoided power plant emissions associated with reduced air conditioning load than in hotter locations with higher cooling loads. Therefore, the majority of CO_2 reductions in Chula Vista will be due to sequestration.

Improving Air Quality

Urban trees provide air quality benefits by ❶ absorbing pollutants such as ozone and nitrogen oxides through leaf surfaces, ❷ intercepting particulate matter (e.g., dust, ash, pollen, smoke), ❸ releasing oxygen through photosynthesis, and ❹ transpiring water and shading surfaces, which lowers local air temperatures, thereby reducing ozone levels. In the absence of the cooling effects of trees, higher air temperatures contribute to ozone formation. Most trees emit various biogenic volatile organic compounds (BVOCs) such as isoprenes and monoterpenes that can contribute to ozone formation. The ozone forming potential of different tree species varies considerably and is listed in Chapter 5. A computer simulation study for the Los Angeles basin found that increased tree planting of low BVOC emitting tree species would reduce ozone concentrations and exposure to ozone (Taha 1996). However, planting of medium- and high-emitters would increase overall ozone concentrations.

Although air quality in Southern California has been improving in recent years, the region continues to experience the worst air quality in the nation, requiring continued progress to meet mandated air quality standards (South Coast Air Quality Management District, 1997). The extent to which urban trees reduce pollutants from the air in Coastal Southern California communities has not been well-documented. However, examination of new, potentially cost-effective approaches to improving air quality, such as urban tree planting, are receiving increased attention. One study for the entire Los Angeles region found that 20 years after planting, 11 million trees would save $93 million in air conditioning costs and $180 million due to ozone reductions (Rosenfeld et al. 1998). The total annual savings of $273 million averages about $25 per tree, assuming no trees die after planting. Air pollution benefits focused on NOx reductions because this pollutant is involved in ozone formation. Reduced air conditioning demand was estimated to reduce NOx emissions at power plants by 3.5 tons/day, while citywide cooling by trees was estimated to lower ozone levels equivalent to removing 175 tons/day of NOx emissions. Thus, air temperature reductions due to evapotranspiration by trees was estimated to produce substantial air quality benefits through ozone reduction in Los Angeles.

Other studies in Sacramento, the San Joaquin Valley and Davis, California, highlight recent research aimed at quantifying air quality benefits of urban trees. In Sacramento the total value of annual air pollutant uptake produced by Sacramento County's six million trees was $28.7 million, nearly $5/tree on average (Scott et al. 1998). The urban forest removed approximately 1,606 short tons (1,457 metric tons) of air pollutant annually. Trees were most effective at removing ozone and particulate matter (PM_{10}). Daily uptake of NO_2 and PM_{10} represented 1 to 2% of emission inventories for the county. Pollutant uptake rates were highest for residential and institutional land uses.

We estimated that the annual value of pollutant uptake by a typical medium-sized tree in the San Joaquin Valley was about $12 (McPherson et al 1999a). The $12/tree value is more than twice the $5 amount reported for Sacramento due to larger tree sizes and higher pollutant concentrations in the San Joaquin Valley study.

Recently, trees in a Davis, CA, parking lot were found to benefit air quality by reducing air temperatures 1-3° F (0.5-1.5° C) (Scott et al. 1999). By shading asphalt surfaces and parked vehicles the trees reduce hydrocarbon emissions from gasoline that evaporates out of leaky fuel tanks and worn hoses. These evaporative emissions are a principal component of smog, and parked vehicles are a primary source. Initial calculations indicate that planting trees in parking lots throughout the region could reduce hydrocarbon emissions comparable to the levels achieved through the local air quality district's currently funded programs (e.g., graphic arts, waste burning, vehicle scrappage).

Reducing Stormwater Runoff

Urban stormwater runoff is a major source of pollution entering the Pacific Ocean and its tributaries. After large storm events certain beaches are temporarily closed to swimming due to unhealthy levels of pollutants (Condon and Moriarty 1999). Finding the source of these pollutants is difficult because the region is so large and "hot spots" appear and disappear quickly. A healthy urban forest can reduce the amount of runoff and pollutant loading in receiving waters. Trees intercept and store rainfall on leaves and branch surfaces, thereby reducing runoff volumes and delaying the onset of peak flows. Root growth and decomposition increase the capacity and rate of soil infiltration by rainfall and reduce overland flow. Urban forest canopy cover reduces soil erosion by diminishing the impact of raindrops on barren surfaces.

Trees are less effective for flood control than water quality protection because canopy storage is exceeded well before peak flows occur. Trees can delay the time of peak runoff because it often takes 10-20 minutes for the tree crown to become saturated and flow to begin from stems and trunk to the ground. By reducing runoff from small storms, which are responsible for most annual pollutant washoff, trees can protect water quality.

Studies that have simulated urban forest impacts on stormwater report annual runoff reductions of 2-7%. Annual interception of rainfall by Sacramento's urban forest for the urbanized area was only about 2% due to the winter rainfall pattern and predominance of non-evergreen species (Xiao et al. 1998). However, average interception loss for the land with tree canopy cover ranged from 6-13% (150 gal per tree on average), close to values reported for rural forests. In Modesto each street and park tree is estimated to reduce stormwater runoff by 845 gal (3.2 m^3) annually, and the value of this benefit is $6.76 (McPherson et al. 1999b). Broadleaf evergreens and conifers intercept more rainfall than deciduous species because of our winter rainfall pattern.

Urban forests can provide other hydrologic benefits. For example, irrigated tree plantations or nurseries can be a safe and productive means of wastewater disposal. Reused wastewater can recharge aquifers, reduce stormwater treatment loads, and create income through sales of nursery or wood products. Recycling urban wastewater into greenspace areas can be an economical means of treatment and disposal, while at the same time providing other environmental benefits.

Trees consume irrigation through the process of evapotranspiration (ET). Annual water use for mid-sized and moderately drought-tolerant trees will seldom exceed 1,000 gal (3,785 l) in Coastal Southern California. Assuming a price of $1.86/Ccf (100 cubic feet = 748 gal), the annual cost is about $2.50. Shade from trees cast on nearby turf may reduce water use by turf, although this process has not been well-studied.

Aesthetics and Other Benefits

Trees provide a host of aesthetic, social, economic, and health benefits that should be included in any benefit-cost analysis. One of the most frequently cited reasons that people plant trees is for beautification. Trees add color, texture, line, and form to the landscape. They soften the hard geometry that dominates built environments. Well-maintained trees increase the "curb appeal" of properties. Research comparing sales prices of residential properties with different tree resources suggests that people are willing to pay 3-7% more for properties with ample tree resources versus few or no trees.

One of the most comprehensive studies of the influence of trees on residential property values was based on actual sales prices for 844 single family homes in Athens, Georgia (Anderson and Cordell 1988). Using regression analysis, each large front-yard tree was found to be associated with about a 1% increase in sales price ($336 in 1985 dollars). This increase in property value resulted in an estimated increase of $100,000 (1978 dollars) in the city's property tax revenues. A much greater value of 9% ($15,000) was determined in a U.S. Tax Court case for the loss of a large black oak on a property valued at $164,500 (Neely 1988).

The social and psychological benefits provided by urban forests improve human well-being. Research indicates that views of vegetation and nature bring relaxation and sharpen concentration. Hospitalized patients with views of nature and time spent outdoors needed less medication, slept better, and were happier than patients without these connections to nature (Ulrich et al.1985). Trees reduce exposure to ultraviolet light, thereby lowering the risk of harmful health effects from skin cancer and cataracts. Other research shows that humans derive substantial pleasure from trees, whether it be feelings of relaxation, connection to nature, or religious joy (Dwyer et al. 1992). Trees provide important settings for recreation in and near cities. Research on the aesthetic quality of residential streets has shown that street trees are the single strongest positive influence on scenic quality. Just the act of planting trees has social value in that new bonds between people often result.

Certain environmental benefits from trees are more difficult to quantify than those previously described, but can be just as important. Noise can reach unhealthy levels in cities. Trucks, trains, and planes can produce noise that exceeds 100 decibels, twice the level at which noise becomes a health risk. Thick strips of vegetation in conjunction with land forms or solid barriers can reduce highway noise by 6-15 decibels. Plants absorb more high frequency noise than low frequency, which is advantageous to humans since higher frequencies are most distressing to people (Miller 1997).

Although urban forests contain less biological diversity than rural woodlands, numerous types of wildlife inhabit cities and are generally highly valued by residents. For example, older parks, cemeteries, and botanical gardens often contain a rich assemblage of wildlife. Remnant woodlands and riparian habitats within cities can connect a city to its surrounding bioregion. Wetlands, greenways (linear parks), and other greenspace resources can provide habitats that conserve biodiversity (Platt et al. 1994).

Urban forestry can provide jobs for both skilled and unskilled labor. AmeriCorps and other programs are providing horticultural training to youth planting and maintaining trees in community forests across California. Also, urban and community forestry provides educational opportunities for residents who want to learn about nature through first-hand experience (McPherson and Mathis 1999).

Costs

Costs of Planting and Maintaining Trees

The previous section described a host of environmental, social, economic, and aesthetic benefits that trees can provide. A 1992 survey of municipal tree programs in California found that the greatest benefits from their programs were ❶ increased public safety, ❷ increased attractiveness and commercial activity, and ❸ improved civic pride (Bernhardt and Swiecki 1993). These benefits are not cost-free.

3. Although large trees can increase clean-up costs and repair costs to sidewalks compared to small trees, their shade can extend the life of street surfaces and defer costs for re-paving.

In 1992, California cities and counties spent on average $4.36 and $0.32 per resident on tree programs, respectively ($18.32 and $13.59 per tree) (Bernhardt and Swiecki 1993). These expenditures represent declines of 25% and 13% from amounts reported in 1988 (corrected for inflation). Generally, the single largest expenditure is for tree trimming, followed by tree removal/disposal, and tree planting. Most trees in new residential subdivisions are planted by developers, while cities/counties and volunteer groups plant most trees on existing streets and park lands. The report found that street tree planting has not kept pace with increases in population since 1988, with the average number of street trees per person declining by 6% (Bernhardt and Swiecki 1993).

Annual expenditures for tree management on private property have not been well-documented. Costs vary considerably, ranging from some commercial/residential properties that receive regular professional landscape service to others that are virtually "wild" and without maintenance. An initial analysis of data for Sacramento and other cities suggests that households typically spend about $5-10 annually per tree for pruning, removal, pest and disease control, irrigation, and other costs (McPherson et al. 1993, McPherson 1996).

Conflicts with Urban Infrastructure

Californians are spending millions of dollars each year to manage conflicts between trees and power lines, sidewalks, sewers, and other elements of the urban infrastructure. In San Jose alone, the backlogged repair cost for all damaged sidewalks is $21 million. Statewide, cities are spending a fraction of the total amount needed to repair all damaged sidewalks and curbs. In 1998 all California cities spent $62 million per year ($2.36 per capita) on sidewalk, curb and gutter repair, tree removal and replacement, prevention methods, and legal/liability costs (Burger et al. 1998).

Some cities spent as little as $0.75 per capita, while others spent $6.98 per resident. These figures are for street trees only and do not include repair costs for damaged sewer lines, building foundations, parking lots, and various other hardscape elements. When these additional expenditures are included, the total cost of root-sidewalk conflicts in California is well over $100 million per year.

Dwindling budgets are forcing an increasing number of cities to shift the costs of sidewalk repair to residents. This shift especially impacts residents in older areas, where large trees have outgrown small sites and infrastructure has deteriorated.

According to the State of Urban Forestry in California report (Bernhardt and Swiecki 1993), the consequences of efforts to control these costs are having alarming effects on California's urban forests:

- Cities are continuing to "downsize" their urban forests by planting far more small-statured than large-statured trees. Although small trees are appropriate under power lines and in small planting sites, they are less effective at providing shade, absorbing air pollutants, and intercepting rainfall than large trees.
- 18% of the responding cities are removing more trees than they are planting.
- Sidewalk damage is the second most common reason that street and park trees are removed. We lose thousands of healthy urban trees and forgo their benefits each year because of this problem.

Collectively, this is a lose-lose situation. Cost effective strategies to retain benefits from large street trees while reducing costs associated with infrastructure conflicts are needed. Matching the growth characteristics of trees to conditions at the planting site is one strategy. The tree selection list in Chapter 5 contains information on the rooting and crown size characteristics of recommended trees.

Tree roots can damage old sewer lines that are cracked or otherwise susceptible to invasion. Sewer repair companies estimate that sewer damage is minor until trees and sewers are over 30 years old, and roots from trees in yards are usually more of a problem than roots from trees in planter strips along streets. The latter assertion may be due to the fact that sewers become closer to the root zone as they enter houses than at the street. Repair costs typically range from $100 for rodding to $1,000 or more for excavation and replacement.

Most communities sweep their streets weekly to reduce non-point source pollution from surface runoff to streams and the ocean. Street trees drop leaves, flowers, fruit, and branches year round that constitute a significant portion of debris collected from city streets. During November through December when leaves fall and winter rains begin, leaf litter from trees can clog sewers, dry wells, and other elements of flood control systems. Costs include additional labor needed to remove leaves and property damage caused by localized flooding. Clean-up costs also occur after wind storms. Although these natural crises are infrequent, they can result in large expenditures.

Tree shade over streets can offset some of these costs by protecting the street paving from weathering. The asphalt paving on streets contains stone aggregate in an oil binder. Without tree shade, the oil heats up and volatilizes, leaving the aggregate unprotected. Vehicles then loosen the aggregate and much like sandpaper, the loose aggregate grinds down the pavement. Streets should be overlaid or slurry sealed about every 10 years over a 30-40 year period, after which reconstruction is required. A slurry seal costs approximately $0.27 per ft^2 or $50,000 per linear mile. Because the oil does not dry out as fast on a shaded street as it does on a street with no shade trees, this street maintenance can be deferred (Figure 3). It is estimated that the slurry seal can be deferred from every 10 years to every 20-25 years for older streets with extensive tree canopy cover in Modesto (personal communication, John Brusca, Streets Superintendent, City of Modesto, November 17, 1998).

Waste Disposal and Irrigation

Nearly all California cities are recycling a portion of their green waste. In 1992 the state's tree programs recycled 66% of their wood waste as mulch or compost (Bernhardt and Swiecki 1993). The amount of waste wood disposed of as firewood is relatively low and few programs burn their waste wood. In most cases, the net costs of waste wood disposal are about 1% of total tree care costs as cities and contractors strive to break-even (hauling and recycling costs are nearly offset by revenues from purchases of mulch, milled lumber, and wood products) (personal communication, Pat

Mahoney, President, West Coast Arborists, Inc., October 29, 1999). Hauling waste wood is the primary cost in Southern California, where virtually all waste wood is now recycled. Portable mills are increasingly used to produce lumber that is sold or worked to create park benches, picnic tables, and other wood products.

Despite Coastal Southern California's balmy climate, newly planted trees require irrigation for about three years. Installation of drip or bubbler irrigation can increase planting costs by $100 or more per tree. Once planted, 15-gal trees typically require 100-200 gal per year during the establishment period. Assuming the City of Santa Monica's water price of $1.86/Ccf, annual irrigation water costs are initially less than $1/tree. However, as trees mature their water use can increase with a concomitant increase in annual costs. Trees planted in areas with existing irrigation may require supplemental irrigation.

Power plants consume water in the process of producing electricity. For example, coal-fired plants use about 0.6 gal/kWh of electricity provided. Trees that reduce the demand for electricity can also reduce water consumed at the power plant (McPherson et al. 1993).

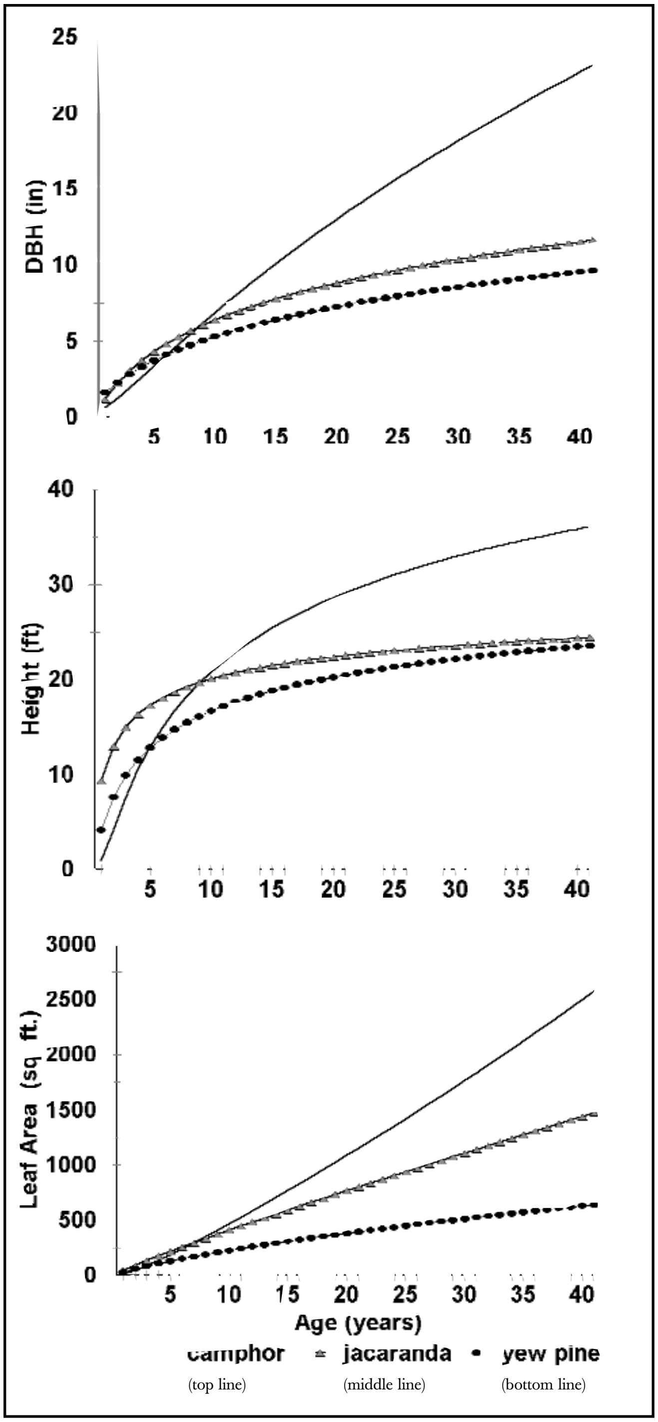
2. Quantifying Benefits and Costs of Tree Planting and Stewardship in Coastal Southern California

In this chapter, we present estimated benefits and costs for trees planted in typical residential and public sites. Because benefits and costs vary with tree size we report results for large (camphor), medium (jacaranda), and small (yew pine) statured trees. Tree growth rates and dimensions are based on street tree data obtained in Santa Monica. To make our calculations realistic we assume that 22.5% of the trees planted die over the 40-year period.

Our estimates of benefits and costs are initial approximations. Some benefits and costs are intangible or difficult to quantify (e.g., impacts on psychological health, crime, and violence). Our limited knowledge about the physical processes at work and their interactions make estimates very imprecise (e.g., fate of air pollutants trapped by trees and then washed to the ground by rainfall). Tree growth and mortality rates are highly variable and benefits and costs depend on the specific conditions at a site (e.g., tree species, growing conditions, maintenance practices). These estimates provide only a general understanding of the magnitude of benefits and costs for typical private and public tree planting programs given the underlying assumptions. The next section describes many of these assumptions and procedures used to quantify benefits and costs.

Procedures and Assumptions

In this study, annual benefits and costs are estimated for newly planted trees in three residential yard locations (east, south, and west of the dwelling unit) and a public streetside/park location for a 40-year planning horizon. Prices are assigned to each cost (e.g., planting, pruning, removal, irrigation, infrastructure repair, liability) and benefit (e.g., heating/cooling energy savings, air pollution absorption, stormwater runoff reduction) through direct estimation and implied valuation of benefits as environmental externalities. This accounting approach makes it possible to estimate the net benefits of plantings in “typical” locations and with “typical” tree species. To account for differences in the mature size and growth rates of different tree species we report results for large (Cinnamomum camphora, camphor), medium, (Jacaranda mimosifolia, jacaranda), and small (Podocarpus macrophyllus, yew pine) trees. Mature tree height is frequently used to distinguish between large, medium, and small species because matching tree height to available overhead space is an important design consideration. However, we use leaf surface area as the primary indicator of differences in mature tree size because many functional benefits of trees are related to leaf-atmosphere processes (e.g., interception, transpiration, photosynthesis), and therefore benefits increase as leaf surface area increases. Tree growth rates, dimensions, and leaf area estimates are based on measurements taken for 28-33 street trees of each



4. Tree dimensions used to estimate the 40-year stream of benefits and costs are based on data collected from street trees in Santa Monica. Data for the "typical" large, medium, and small trees are from camphor, jacaranda, and yew pine, respectively.

species in Santa Monica (Figure 4). Although the small yew pine and medium jacaranda reach the same height 40 years after planting, the jacaranda has more leaf surface area.

We report results in terms of annual values per tree planted, but our calculations assume that 22.5% of the trees die and are removed during the 40-year period (annual mortality rates of 1% for the first 5 years and 0.5% for the remaining 35 years). This mortality rate is based on rates reported by contact persons and found in other studies (Miller and Miller 1991, Nowak et al. 1990, Richards 1979). Hence, the accounting approach "grows" trees in different locations and directly calculates the annual flow of benefits and costs as trees mature and die (McPherson 1992).

Our approach directly connects benefits and costs with tree size variables such as trunk diameter at breast height (dbh) and leaf surface area. For instance, pruning and removal costs usually increase with tree size expressed as dbh inches (cm). For some parameters, such as sidewalk repair, costs are negligible for young trees but increase relatively rapidly as tree roots grow large enough to heave pavement. For other parameters, such as air pollutant uptake and rainfall interception, benefits are related to tree canopy cover and leaf area.

Most benefits occur on an annual basis, but some costs are periodic. For instance, street trees are pruned on cycles and removed in a less regular fashion, when they pose a hazard or soon after they die. We report most costs and benefits for the year that they occur. However, periodic costs such as for pruning, pest and disease control, and infrastructure repair are presented on an average annual basis. Although spreading one-time costs over each year of a maintenance cycle does not alter the 40-year nominal expenditure, it can lead to inaccuracies if future costs are discounted to the present.

In this study, both direct estimation and implied valuation are used to ascribe dollar values to benefits and costs. Much of the tree management cost data were directly estimated based on surveys with municipal foresters in Santa Monica and Beverly Hills, and four Southern California arborists. Lacking local data, we relied on survey results from Sacramento residents to estimate the frequency of contracted tree care activities for trees in yards (McPherson et al. 1993, Summit and McPherson 1998). Findings from computer simulations are used in this study to directly estimate energy savings. Implied valuation is used to price society's willingness to pay for the air quality and stormwater runoff benefits trees produce. For example, air quality benefits are estimated using transaction costs, which reflect the average market value of pollutant emission reduction credits in 1998 for the South Coast Air Quality Management District (California EPA 1999). If a corporation is willing to pay $1 per pound for a credit that will allow it to increase future emissions, then the air pollution mitigation value of a tree that absorbs or intercepts 1 pound of air pollution should be $1.

Benefits

Air Conditioning and Heating Energy Savings

We assume that residential yard trees are within 60 ft (18 m) of homes so as to directly shade walls and windows. Shading effects of these trees on building energy use are simulated for large, medium, and small trees at 3 tree-building distances, following methods outlined by McPherson and Simpson (1999). Large (camphor) and small (yew pine) trees are evergreen, with visual densities of 80% all year. The medium tree (jacaranda) is deciduous, with a visual density of 80% from April to January, and 20% in February and March. Results for each tree are averaged over distance and weighted by occurrence of trees within each of three distance classes: 28% 10-20 ft (3-6 m), 68% 20-40 ft (6-12 m), and 4% 40-60 ft (12-18 m) (McPherson and Simpson 1999). Results are reported for trees shading east-, south-, and west-facing surfaces. Our results for public trees are conservative in that we assume that they do not provide shading benefits. In Modesto, 15% of total annual dollar energy savings from street trees were due to shade and 85% due to climate effects (McPherson et al. 1999).

In addition to localized shade effects, which are assumed to accrue only to residential yard trees, lowered air temperatures and wind speeds from increased neighborhood tree cover (referred to as climate effects) produce a net decrease in demand for summer cooling (reduced wind speeds by themselves may increase or decrease cooling demand, depending on the circumstances) and winter heating.

Climate effects on energy use, air temperature and wind speed reductions as a function of neighborhood canopy cover are estimated from published values following McPherson and Simpson (1999). Existing canopy cover (trees + buildings) was estimated to be 40%. Canopy cover is calculated to increase by 3, 8 and 15% for mature small, medium, and large trees, respectively, based on an effective lot size (actual lot size plus a portion of adjacent streets and other rights-of-way) of 8,000 ft^2 (743 m^2), and assuming one tree per lot on average. Climate effects are estimated as described previously for shading by simulating effects of wind and air temperature reductions on energy use. Climate effects accrue to both public (Figure 5) and private trees.

The prototype building used as a basis for the simulations is typical of post-1980 construction practices, and represents 20-40% of the total single family residential housing stock in coastal communities. This house is of two story, stucco, slab-on-grade construction with a conditioned floor area of 2,070 ft^2 (192 m^2), window area (double-glazing) of 325 ft^2 (30 m^2), and wall and ceiling insulation of R11 and R25, respectively. The central cooling system has a seasonal energy efficiency ratio (SEER) of 10, and the natural gas furnace an annual fuel utilization efficiency (AFUE) of 78%. Building footprints are square, reflective of average impacts for a large building population (McPherson and Simpson 1999). Buildings are simulated with 1.5-ft (0.45-m) overhangs. Blinds have visual density of 37%, and are assumed closed when the air conditioner is operating. Summer thermostat settings are 78° F (25° C); winter settings are 68° F (20° C) during the day and 60° F (16° C) at night. Because the prototype building is more energy efficient than most other construction types our projected energy savings are relatively conservative. The energy simulations rely on typical year climate data from Los Angeles International Airport.

5. Although park trees seldom provide energy benefits from direct shading of buildings, they provide settings for recreation and relaxation as well as modify climate, sequester carbon dioxide, reduce stormwater runoff, and improve air quality.

Dollar value of energy savings are based on average residential electricity and natural gas prices of $0.12 per kWh (California Energy Commission, 1996) and $0.60 per therm (California Energy Commission, 1998), respectively. The former is the average of prices for Los Angeles, Orange, San Diego, Santa Barbara and Ventura counties; the latter, the average of Southern California Gas and San Diego Gas & Electric residential prices forecast for the year 2000. Homes are assumed to have central air conditioning and natural gas heating. Results are reported at five-year intervals.

Atmospheric Carbon Dioxide Reduction

Reductions in building energy use result in reduced emissions of CO_2. Emissions are calculated as the product of energy use for cooling and heating and the respective CO_2 emission factors for electricity and natural gas. Emissions factors for electricity are weighted by the approximate average fuel mix for utilities serving Coastal Southern California: Southern California Edison, Los Angeles Department of Water and Power, and San Diego Gas and Electric. This value is 49% natural gas, 17% coal, and 34% other, the latter assumed to have no emissions (California Energy Commission 1994). The price of CO_2 reductions are based on the implied value of external costs associated with increased global warming (California Energy Commission 1994). (Table 1)

Sequestration, the net rate of CO_2 storage in above- and below-ground biomass over the course of one growing season, is calculated using tree height and dbh data with biomass equations for camphor, jacaranda, and lacking data for yew pine, Monterey pine (Pinus radiata) (Pillsbury et al. 1998).

Volume estimates are converted to green and dry weight estimates (Markwardt 1930) and divided by 78% to incorporate root biomass. Dry weight biomass is converted to carbon (50%) and these values are converted to CO_2. The amount of CO_2 sequestered each year is calculated as the difference between the total amount stored for two successive years.

A national survey of 13 municipal forestry programs determined that the use of vehicles, chain saws, chippers, and other equipment powered by gasoline or diesel results in the average annual release of 0.78 lb of CO_2/inch dbh (0.14 kg CO_2/cm dbh) (McPherson and Simpson 1999). We use this value for private and public trees, recognizing that it may overestimate CO_2 release associated with less intensively maintained residential yard trees.

To calculate CO_2 released through decomposition of dead woody biomass we conservatively estimate that dead trees are removed and mulched in the year that death occurs, and that 80% of their stored carbon is released to the atmosphere as CO_2 in the same year.

Table 1. Emissions factors and implied values for CO_2 and criteria air pollutants.

	– Emission Factor –		Implied
	Electricity lbs/MWh	Natural gas lbs/MBtu	Value $/lb
CO_2	840†	116†	0.015‡
NO_2	1.78†	0.1020†	12.49¶
SO_2	1.06†	0.0006†	4.62¶
PM_{10}	0.124†	0.0075†	6.20¶
VOCs	0.054†	0.0054†	1.92¶

† U.S. Environmental Protection Agency 1995.
‡ California Energy Commission 1994 ($30/ton)
¶ Cantor Fitzgerald Environmental Brokerage Services, 1999.

Air Quality Improvement

Reductions in building energy use also result in reduced emissions of criteria air pollutants from power plants and space heating equipment. Volatile organic hydrocarbons (VOCs) and nitrogen dioxide (NO_2), both precursors of ozone (O_3) formation, as well as sulfur dioxide (SO_2) and particulate matter of <10 micron diameter (PM_{10}) are considered. Changes in average annual emissions and their offset values are calculated in the same way as for CO_2, again using utility-specific emission factors for electricity and heating fuels (California EPA 1999), with the value of emissions savings (Table 1) based on the price of emission reduction credits for the South Coast Air Quality Management District (Cantor Fitzgerald Environmental Brokerage Services, 1999).

Trees also remove pollutants from the atmosphere. The hourly pollutant dry deposition per tree is expressed as the product of a deposition velocity Vd =1/(Ra+Rb+Rc), a pollutant concentration C, a canopy projection area CP, and a time step. Hourly deposition velocities for each pollutant are calculated using estimates for the resistances Ra, Rb, and Rc estimated for each hour throughout a “base year” (1991) using formulations described by Scott et al. (1998). Hourly concentrations for NO_2, SO_2, and O_3 (ppm), daily total PM_{10} (mg C_3, approximately every sixth day), as well as hourly meteorological data (e.g., air temperature, wind speed) for 1991 were obtained from the South Coast Air Quality Management District via the California Air Resources Board (personal communication, Klaus Scott, California Air Resources Board, November 11, 1999) for the Hawthorne monitoring station. This station monitors for air pollutant concentrations representative of areas of high population density, at spatial scales of up to 3 miles, and is located approximately 4 miles ESE of Los Angeles International Airport. See Scott et al. (1998) for details. We use implied values from Table 1 to value emissions reductions; and the implied value of NO_2 for ozone. Hourly solar radiation data for 1991 was obtained from a California Department of Water Resources monitoring site located in Long Beach.

Annual emissions of biogenic volatile organic compounds (BVOC) were estimated for the three tree species (camphor, jacaranda, yew pine) using the algorithms of Guenther et al. (1991, 1993). Annual emissions were simulated over 40 years. The emission of carbon as isoprene is expressed as a product of a base emission rate adjusted for sunlight and temperature (mg-C g-1 dry foliar biomass hr-1) and the amount of (dry) foliar biomass present in the tree. Monoterpene emissions are estimated using a base emission rate adjusted for temperature. The base emission rates for the three species were based upon values reported in the literature (Benjamin et al. 1996). All three species are defined as "low emitters" because they emit little (<0.01 mg-C g-1 dry foliar biomass hr-1) or no BVOCs. We, however, assigned a total base emission rate of 0.1 mg-C g-1 dry foliar biomass hr-1 (i.e., 0.04 each for isoprene and monoterpene and 0.02 for other VOCs) to all three species. This total base emission rate is approximately mid-range for the "low emitter" category (Benjamin et al. 1996). Hourly emissions were summed to get monthly and annual emissions.

Annual dry foliar biomass was derived from field data collected in Santa Monica during the summer of 1999. The amount of foliar biomass present for each year of the simulated tree's life was unique for each species. We assumed a year-round growing season because the trees are broadleaf evergreen species and because the Southern California coastal climate is mild. We used 1991 hourly air temperature and solar radiation data from nearby sites (Hawthorne and Long Beach, CA) as model input. This model year was chosen because it most closely approximated long-term climate records for the area of interest.

The calculations do not take into account the ozone reduction benefit from lowering summertime air temperatures, thereby reducing hydrocarbon emissions from anthropogenic and biogenic sources. Simulation results from Los Angeles indicate that ozone reduction benefits of tree planting with "low-emitting" species exceed costs associated with their BVOC emissions (Taha 1996).

Stormwater Runoff Reduction

A numerical simulation model is used to estimate annual rainfall interception (Xiao et al. 1998). The interception model accounts for water intercepted by the tree, as well as throughfall and stem flow. Intercepted water is stored temporarily on canopy leaf and bark surfaces. Once the leaf is saturated, it drips from the leaf surface and flows down the stem surface to the ground or evaporates. Tree canopy parameters include species, leaf area, shade coefficient (visual density of the crown), and tree height. Tree height data are used to estimate wind speed at different heights above the ground and resulting rates of evaporation. The volume of water stored in the tree crown is calculated from crown projection area (area under tree dripline), leaf area indices (LAI, the ratio of leaf surface area to crown projection area), and water depth on the canopy surface. Species-specific shade coefficients (0.8) and tree surface saturation (0.04 inch or 1 mm for all 3 trees) values influence the amount of projected throughfall. Hourly meteorological and rainfall data for 1996 from the Santa Monica California Irrigation Management Information System (CIMIS) are used for this simulation. Annual precipitation during 1996 was 22.4 inches (570 mm), somewhat greater than the mean annual precipitation amount of 17.8 inches (451 mm) for the region (U.S. Dept. of Commerce 1968). A more complete description of the interception model can be found in Xiao et al. (1998).

To estimate the implied value of rainfall intercepted we consider current expenditures for flood control and urban stormwater quality programs. 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 ($0.00183/gal) to treat sanitary waste (Condon and Moriarty 1999). We use this value to price stormwater quality benefits 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. The treatment cost is multiplied by gallons of rainfall intercepted each year to calculate water quality benefit.

As part of the TreePeople's program called T.R.E.E.S. (Trans-agency Resources for Environmental and Economic Sustainability) it was determined that over $50 million ($500,000/sq mile) is spent annually controlling floods in the Los Angeles area (Condon and Moriarty 1999). We assume that the impact of rainfall interception by tree crowns will be minimal 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 these smaller events. Following the economic approach used in the T.R.E.E.S. cost-benefit analysis, 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 percent decrease in 25-year peak flow (Jones & Stokes Associates, Inc. 1998). A 25-year winter event deposits 5.3 inches (134 mm) of rainfall during 57 hours. Approximately $0.0054/gal ($1.44/m^3) is spent annually for controlling flooding caused by such an event. This price is multiplied by the amount of rainfall intercepted during a single 25-year event to estimate the annual flood control benefit. Water quality and flood control benefits are summed to calculate the total hydrology benefit.

Aesthetics and Other Benefits

Many benefits attributed to urban trees are difficult to translate into economic terms. Beautification, privacy, wildlife habitat, shade that increases human comfort, sense of place and well-being are products that are difficult to price. However, the value of some of these benefits may be captured in the property values for the land on which trees stand. To estimate the value of these "other" benefits we apply results of research that compares differences in sales prices of houses to statistically quantify the amount of difference associated with trees. The amount of difference in sales price should reflect the willingness of buyers to pay for the benefits and costs associated with the trees. This approach has the virtue of capturing what buyers perceive to be as both the benefits and costs of trees in the sales price.

Some limitations to using this approach for the present study include the difficulty associated with ❶ determining the value of individual trees on a property, ❷ the need to extrapolate results from studies done years ago in the east and south to California, and ❸ the need to extrapolate results from front yard trees on residential properties to trees in other locations (e.g., back yards, streets, parks, and non-residential land uses).

Anderson and Cordell (1988) surveyed 844 single family residences and found that each large front-yard tree was associated with a $336 increase in sales price or nearly 1% of the average sales price of $38,100 (in 1978 dollars). We use this 1% of sales price as an indicator of the additional value a Coastal Southern California resident would gain from sale of residential property with a large tree. The sales price of residential properties varies widely by location within the region. For example, 1999 median home prices ranged from $97,000 in Paramount to $780,000 in Pacific Palisades (California Association of Realtors 1999). In September 1999 the average home price for 70 communities in the Coastal Southern California region was $253,431 (California Association of Realtors 1999). The value of a large tree that adds 0.9% to the sales price of such a home is $2,235. Based on growth data for a 40-year old camphor tree, such a tree is 36-ft (14.2m) tall, 40-ft (12.3m) crown diameter, with a 23-in (59cm) trunk diameter, and 2,675 ft^2 (250 m^2) of leaf surface area.

To calculate the base value for a large street tree we treat street trees similar to front yard trees, but recognize that they may be located adjacent to land with little value or resale potential. An analysis of street trees in Modesto sampled from aerial photographs (8% of population) found that 15% were located adjacent to non-residential or commercial land uses (McPherson et al. 1999). We assume that 33% of these trees, or 5% of the entire street tree population, produce no benefits associated with property value increases. Although the impact of parks on real estate values has been reported (Hammer et al. 1974; Schroeder 1982; Tyrvainen 1999), to our knowledge the on-site and external benefits of park trees alone have not been isolated (More et al. 1988). After reviewing the literature and recognizing an absence of data, we assume that park trees have the same impact on property sales prices as street trees. Given these assumptions, the typical large street and park trees are estimated to increase property values by \$0.79 and \$0.83/ft^2 of leaf surface area, respectively (\$8.49 and \$8.94/m^2). Assuming that 85% of all public trees are on streets and 15% are in parks, we calculate a weighted average benefit of \$0.80/ft^2 of leaf surface area (\$8.56/m^2). To estimate annual benefits this value is multiplied by the amount of leaf surface area added to the tree during one year of growth.

To calculate the base value for a large tree on private residential property we assume that a 40-year old camphor tree (2,675 ft^2 of leaf surface area) in the front yard will increase the property's sales price by \$2,235. Approximately 75% of all yard trees are in backyards (Richards et al. 1986). Lacking specific research findings, we arbitrarily assume that backyard trees have 75% of the impact on "curb appeal" and sale price compared to front yard trees. The average annual aesthetic benefit for a tree on private property is \$0.67/ft^2 of leaf area (\$7.26/m^2).

Costs

Planting Costs

Planting costs are two-fold, the cost for purchasing the tree and the cost for planting, staking, and mulching the tree. Based on our survey of Southern California arborists and data from the Cities of Santa Monica and Beverly Hills, we assume that the total cost for purchasing, planting, staking, and mulching a 15-gal (57 l) container public tree is \$95. The total cost is \$106 for a residential yard tree.

Trimming Costs

After studying data from municipal forestry programs and their contractors we assume that during the first 3 years after planting, young public trees are trimmed once a year at a cost of \$10.25/tree. Thereafter, small public trees are trimmed on a 3 year cycle at \$20.25/tree until their height exceeds 18 ft (5.5 m) and more expensive equipment is required. Medium-sized trees (taller than 18 ft [5.5 m] and less than 46 ft [14 m]) are trimmed on a six-year cycle at a cost of \$66/tree. The cost increases to \$228.50/tree for large trees (taller than 46 ft). After factoring in trimming frequency, annual costs are \$10.25, \$6.68, \$11, and \$38 for public young, small, medium, and large trees, respectively.

Our survey of Sacramento residents indicated that 15% of households with trees never prune their residential yard trees. Moreover, the percentage of households that contract for tree trimming increases as tree height increases: 0% for young trees (< 3 years), 6% for small trees (< 20-ft tall), to 60% for medium trees (20-40-ft tall), and 100% for large trees (>40-ft tall). Similarly, the frequency of pruning decreases with tree height from once every 2 years for small trees, to every 10 years for medium trees, and every 20 years for large trees. Based on these findings and pruning prices charged by Southern California arborists ($59, $257, and $585 for small, medium, and large trees, respectively), we calculate that the average annual cost for trimming a residential yard tree is $1.50, $13.09, and $24.86 for small, medium, and large trees. These prices factor in pruning frequency and include costs for waste wood recycling.

Tree and Stump Removal and Disposal

The costs for removing public and private trees are $12 per inch dbh. Stump removal and wood waste disposal costs are $6 per inch dbh for public and private trees. The total cost for both tree sites is $18 per inch dbh.

Large tree example – camphor

Pest and Disease Control

Public trees receive treatments to control pests and disease on an as needed basis. In Coastal Southern California this expenditure is small, averaging about $0.17 per tree per year, or $0.01 per inch dbh.

We assume that approximately 85% of households with trees do not treat their trees to control pests or disease. The percentage of households that contract for pest and disease control increases as tree height increases, from 6% for small trees (< 20-ft tall), to 60% for medium trees (20-40-ft tall), and 100% for large trees (>40-ft tall). The frequency of treatment decreases with tree height from once every 2 years for small trees, to every 10 years for medium trees, and every 20 years for large trees. Based on these findings and treatment prices charged by arborists ($130, $85, and $40 for large, medium, and small trees), we calculate that the average annual cost for pest and disease control ranges from $0.18-$1.00 per residential yard tree, and averages $0.07 per inch dbh.

Irrigation

In most landscape situations trees require relatively little supplemental irrigation after establishment because they are planted in irrigated areas and can use existing sources of water. The cost for irrigating a public street or park tree is $15 per year for the first three years after planting. This price is for labor and equipment to irrigate young trees with a municipal water truck. The cost for irrigation water over the 40-year period is calculated as described below.

Irrigation costs for residential yard trees assume that the irrigation system is in-place, and supplemental water is applied at a maximum rate of 800 gal/year (3,028 l) for a mature tree. Assuming that water is purchased at a price of $1.86 Ccf (personal communication, Jean Higbee, City of Santa

Monica, November 11, 1999) and the mature tree has 2,675 ft^2 (250 m^2) of leaf area, the annual price is $0.00074/$ft^2$ of leaf area. Hence, annual irrigation water cost is assumed to increase with tree leaf area.

Other Costs for Public and Private Trees

Other costs associated with the management of trees include expenditures for infrastructure repair, root pruning, litter clean-up, litigation, liability, inspection, and administration. Tree roots can cause damage to sidewalks, curbs, paving, and sewer lines. Trees can be responsible for costly legal actions due to trip and fall claims, broken branches that damage property, or foliage that blocks visibility and impairs safety. Municipal tree programs have administrative costs for salaries of supervisors and clerical staff, operating costs, and overhead. Data from Santa Monica and Beverly Hills indicate that the average annual cost for inspection and administration associated with street and park tree management is $3.46/tree ($0.22/inch dbh).

The average annual per tree cost for litter clean-up (i.e., street sweeping) is $3.63 ($0.23/inch dbh). This value is based on a poorly documented assumption that 10% of total street sweeping costs are attributed to tree litter clean-up. Because most residential yard trees are not littering the street with leaves we assume that clean-up costs for private trees are 25% of those for public trees.

Our analysis of survey data on sidewalk repair and mitigation expenditures from nine Southern California communities found an average annual cost of $4.18/tree (Burger et al 1998). Annual payments for trip and fall claims and legal staff salaries for tree-related cases averaged $1.81/tree.

Table 2. Average annual costs per public tree for infrastructure repair, root pruning, litigation, and liability.

Trunk size (dbh, inches)	Percentage of Damage	Infrastructure Cost	Liability Payments
0-6	3.7	1.10	0.48
7-12	25.3	4.31	1.87
13-18	29.6	5.05	2.19
19-24	26.3	6.47	2.80
25-30	9.5	4.96	2.15
>30	5.6	3.34	1.45

Percentage of Damage: Based on 1997 street tree inventory of 28,392 trees, sidewalk damage (greater than 0.5 inch displacement) was observed at 7,026 sites (25% of all sites), attributed to tree roots, and distributed among tree trunk size classes as shown.

Infrastructure Costs: The average annual regional cost of $4.18/tree was distributed among tree size classes proportionate to the ratio of repairs to trees, assuming a uniform cost for all repairs (City of Santa Monica tree inventory data).

Liability Payments: The average annual regional cost of $1.81/tree was distributed in the same manner as expenditures for sidewalk repair and root pruning (personal correspondence, Walter Warriner, City Forester, City of Santa Monica, November 10, 1999).

Data from the City of Santa Monica's street tree survey indicate that sidewalk damage was present at 25% of all tree sites and the incidence of sidewalk damage varied with tree trunk size (see Table 2). We assume that the same relationships occur for litigation/liability costs. Because street trees are in closer proximity to sidewalks and sewer lines than most trees on private property we assume that repair and legal costs are 25% of those for public trees (McPherson et al. 1993).

Results

Calculating Net Benefits

Trees produce both on-site and off-site benefits. For example, property owners with on-site trees not only benefit from increased property values, but they may also benefit directly from improved human health (i.e., reduced exposure to cancer-causing UV radiation) and greater psychological well-being through visual and direct contact with plants. On the cost side, increased health care may be incurred because of nearby trees, as with allergies and respiratory ailments related to pollen. We assume that these intangible benefits and costs are reflected in what we term "aesthetics and other benefits." The property owner can obtain additional economic benefits from on-site trees depending on their location and condition. For example, judiciously located on-site trees can provide air conditioning savings by shading windows and walls and cooling building microclimate. This "consumer surplus" can extend to the neighborhood because trees provide off-site benefits. For example, adjacent neighbors can benefit from shade and air temperature reductions that lower their cooling costs. Neighborhood attractiveness and property values can be influenced by the extent of tree canopy cover on individual properties.

Medium tree example – jacaranda

The community can benefit from cleaner air and water, as well as social, educational, and employment and job training benefits that can reduce costs for health care, welfare, crime prevention, and other social service programs. Reductions in atmospheric CO_2 concentrations due to trees can have global benefits. To capture the value of all annual benefits B we sum each type of benefit as follows:

$$B = E + AQ + CO2 + H + PV$$

where

E = price of net annual energy savings (cooling and heating)

AQ = price of annual air quality improvement (pollutant uptake and avoided power plant emissions)

CO_2 = price of annual carbon dioxide reductions

H = price of annual stormwater runoff reductions

PV = price of annual property value and other benefits

Similarly, tangible tree planting and care costs accrue to the property owner (irrigation, pruning, and removal) and the community (pollen and other health care costs). Annual costs for residential yard trees (CY) and public trees (CP) are summed:

$$CY = P + T + R + D + I$$

$$CP = P + T + R + D + I + S + C + L + A$$

where

P = price of tree and planting

T = average annual price of Class 2 pruning

R = price of tree and stump removal and disposal

D = average annual price of pest and disease control

I = annual price of irrigation

S = average annual price of repair/mitigation of infrastructure damage

C = average annual price of litter/storm clean-up

L = average annual price of litigation and settlements due to tree-related claims

A = Average annual price of program administration, inspection, and other costs.

Net benefits are calculated by subtracting total costs from total benefits (B–C).

Net Benefits

Average annual net benefits per tree (40-year total / 40 years) increase with mature tree size:

- $1 to $7 for a small tree
- $25 to $28 for a medium tree
- $60 to $68 for a large tree (see Appendix A for detailed results).

Small tree example – yew pine

This finding suggests that average annual net benefits from large-growing trees such as the camphor can be substantially greater than from small trees like yew pine. Average annual net benefits for the small, medium, and large street/park trees are $1, $25, and $65, respectively. The residential yard tree opposite a west facing wall produces average annual net benefits for the small, medium, and large trees of $7, $28, and $68, respectively. Residential yard trees produce net benefits that are slightly greater than public trees primarily because of lower maintenance costs.

Costs exceed benefits during the first five years because of initial expenditures for planting and irrigation (figures 6 and 7). However, by year 10 and thereafter the small, medium, and large trees provide net benefits. The large residential tree opposite a west wall produces a net annual benefit of $68 at year 40 and $2,720 in total net benefits over 40 years. Forty years after planting the large camphor in a public site produces an annual net benefit of $95. Over the entire 40-year period it produces a stream of net benefits that totals to $2,600. Benefits from small trees are largely offset by their costs throughout the 40-year period.

Table 3. Estimated value of net annual benefits from a small-, medium- and large-sized residential yard tree opposite the west-facing wall 20 years after planting for Southern California coastal communities.

BENEFIT CATEGORY	SMALL TREE 23 ft tall, 28 ft spread LSA = 628 sq. ft.		MEDIUM TREE 24 ft tall, 28 ft spread LSA = 1,438 sq. ft.		LARGE TREE 36 ft tall, 39 ft spread LSA = 2,496 sq. ft.	
Electricity savings ($0.12/kWh)	31 kWh	$3.68	38 kWh	$4.57	74 kWh	$8.83
Natural gas ($0.60/therm)	-443 kBtu	-$2.64	-190 kBtu	-$1.13	-381 kBtu	-$2.27
Carbon dioxide ($0.015/lb)	-28 lb	-$0.42	13 lb	$0.19	98 lb	$1.47
Ozone ($12.49/lb)	0.21 lb	$2.65	0.51 lb	$6.36	0.95 lb	$11.84
NO_2 ($12.49/lb)	0.05 lb	$0.65	0.13 lb	$1.57	0.46 lb	$5.71
SO_2 ($4.62/lb)	0.13 lb	$0.58	0.21 lb	$0.96	0.41 lb	$1.92
PM_{10} ($6.20/lb)	0.37 lb	$2.29	0.89 lb	$5.50	1.67 lb	$10.33
VOCs ($1.92/lb)	-$0.004 lb	-$0.008	$0.003 lb	$0.006	$0.002 lb	$0.004
BVOCs ($1.92/lb)	-$0.003 lb	-$0.006	-$0.003 lb	-$0.007	-$0.005 lb	-$0.011
Rainfall Interception ($0.002/gal)	1,525 gal	$3.16	1,302 gal	$2.62	1,799 gal	$3.61
ENVIRONMENTAL SUBTOTAL		**$9.95**		**$20.64**		**$41.43**
Other Benefits		$9.54		$23.46		$43.70
Total Benefits		$19.49		$44.10		$85.13
Total Costs		$14.47		$15.07		$16.61
NET BENEFITS		**$5.02**		**$29.02**		**$68.53**

This analysis assumes that the tree is strategically located to shade the west side of a typical building. Other benefits include benefits and costs not accounted for such as increased sales price of property, scenic beauty, impacts on human health and well-being, wildlife habitat, and recreation opportunities.

LSA=leaf surface area

Twenty years after planting annual net benefits for a residential yard tree located west of a home are estimated to be $69 for a large tree, $29 for a medium tree, and $5 for a small tree (see Table 3). The total value of environmental benefits alone ($41) are two times greater than annual costs ($17) for the large camphor at this time. For the medium jacaranda, environmental benefits total to $21 and tree care costs are $15.

The average annual net benefit for a population of trees can be estimated using data presented here and in Appendix A. For example, the City of Santa Monica's street and park tree inventory indicates that there are about 28,000 trees and 679 are camphor (2%), 671 are jacaranda (2%), and 1,392 are yew pine (5%). Table 4 shows the distribution of these trees among age classes and the estimated annual net benefits assuming costs and benefits described in this report. The total annual net benefits produced by the camphors, jacarandas, and yew pines are $40,604, $13,876, $-442, respectively. Together trees belonging to these three species account for 10% of Santa Monica's tree population and produce benefits in excess of costs valued at approximately $54,038. Appendix A contains another example wherein benefit and cost data are adjusted to better match the situation in a community.

Table 4. Tree numbers by age class and estimated annual net benefits for three street tree species in Santa Monica.

	< 10 yrs	10-19 yrs	20-29 yrs	30-39 yrs	40+ yrs	Total
camphor (#)	140	234	129	94	82	679
$/tree	13	54	76	91	95	–
Total $	1,820	12,636	9,804	8,554	7,790	40,604
jacaranda (#)	126	359	170	16	0	671
$/tree	4	22	29	34	–	–
Total $	504	7,898	4,930	544	0	13,876
yew pine (#)	426	920	46	0	0	1,392
$/tree	-10	4	3	–	–	–
Total $	-4,260	3,680	138	0	0	-442

Average Annual Costs

Average annual costs for tree planting and care increase with mature tree size:

- $13-21 for a small tree
- $16-23 for a medium tree
- $17-28 for a large tree (see Appendix A for detailed results).

Given our assumptions and the dimensions of these trees, it is slightly more expensive to maintain a large tree than a small tree. Average annual maintenance costs for private and public trees are estimated to range from $13-$17 and $21-$28 per tree, respectively. Tree trimming is the single greatest cost for private and public trees ($7-$10). For private trees, annualized expenditures for tree planting are the second most important cost. For public trees, annual litter clean-up costs average from $3-$5 per tree, while sidewalk repair/root pruning costs range from $2-$4 per tree. Strategies are needed to reduce these costs so that municipalities can use their limited funds to plant and care for more trees rather than remediate the problems caused by trees. Planting and irrigation costs are other important costs for public street/park trees.

Average Annual Benefits

Average annual benefits (40-year total / 40 years) also increase with mature tree size:

- ➢ \$17-22 for a small tree
- ➢ \$42-48 for a medium tree
- ➢ \$78-93 for a large tree (see Appendix A for detailed results).

Mature tree size matters when considering net energy benefits. A large tree produces 2 to 4 times more savings than a small tree due to greater extent of building shade and increased evapotranspirational cooling. Also, energy savings increase as trees mature and their leaf surface area increases, regardless of their mature size (Figures 6 and 7).

Average annual net energy benefits for residential trees are estimated to be greatest for a tree located west of a building because the heating penalty associated with winter shade is minimized (\$7). A yard tree located south of a building produces the least net energy benefit, while a tree located east of a building provides intermediate net benefits. Winter shade from the small yew pine opposite south and east facing walls increases heating costs more than shading and climate benefits reduce cooling savings. Thus, this small tree is a net energy cost at these locations. The medium-sized jacaranda provides net energy benefits at all locations due in part to its leafless condition during winter months. The large camphor provides a net energy benefit at all locations. These results indicate that energy savings are relatively small in the mild Coastal Southern California climate. The strategic placement of solar friendly tree species can provide small additional savings.

Aesthetic benefits and air quality improvement are the two largest benefit categories. Average annual aesthetic benefits account for over 50% of total benefits for the small (\$10-\$12/year), medium (\$24-\$28), and large tree (\$44-\$52). These values reflect the region's relatively high residential real estate sales prices and the beneficial impact of urban forests on property values and the municipal tax base.

Aesthetic and other benefits are slightly greater for the public street/park tree than the residential yard tree because of the assumption that most yard trees are in the backyard where they have less impact on the sales prices of residential property than front yard trees. This assumption has not been tested so there is a high level of uncertainty associated with this result.

Air quality benefits are defined as the sum of pollutant uptake by trees and avoided power plant emissions due to energy savings, minus BVOCs released by trees. Air quality benefits provide about 33% of the total average annual benefits for the small (\$6), medium (\$13) and large tree (\$28). Benefit values are greatest for O_3 and PM_{10} removal, each averaging as high as \$9-\$1/year for the large tree. The average implied value of NO_2 and SO_2 removal is \$6 and \$2, respectively for the camphor. On average, the large tree removes 3.3 lb (1.5 kg) of pollutants from the air each year. The cost of BVOCs released by these low-emitting tree species is negligible and similar to the benefit from avoided VOCs emissions due to energy savings. The total value of pollutant uptake far exceeds the total value of avoided pollutant emissions because small energy savings result in small emission reductions.

Benefits associated with atmospheric CO_2 reduction are minimal except for the large, public tree (140 lb/year on average, $2). The release of CO_2 associated with tree care activities nearly offsets CO_2 sequestration by the small and medium trees, and avoided power plant emissions are small because energy savings are small.

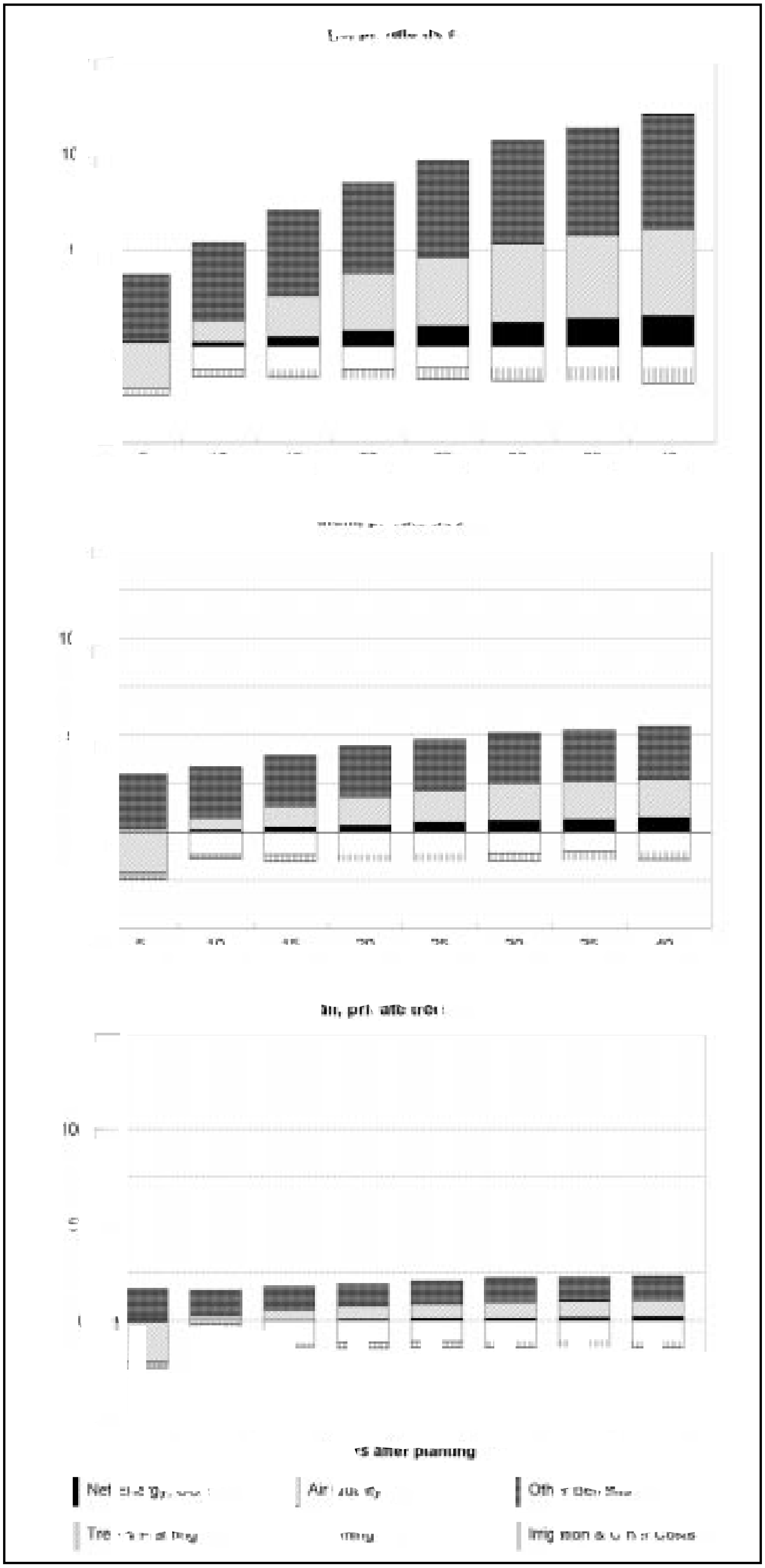
Average annual hydrologic benefits ($3) are more important than energy ($2) for the small tree (yew pine). Its evergreen foliage intercepts more rainfall (1,583 gal/year) on average than the briefly deciduous jacaranda (1,396 gal). The camphor intercepts 2,120 gal/year (8,024 l) on average with an implied value of $4.

When totaled and averaged over the 40-year period, annual environmental benefits for large and medium public trees are $41 and $20, respectively. For the large camphor, the value of environmental benefits alone exceeds average annual costs ($28). The average annual value of environmental benefits for the medium-sized jacaranda is slightly less than average annual costs ($23). Adding the value of aesthetics and other benefits ($52 and $28) to these environmental benefits results in substantial net benefits.

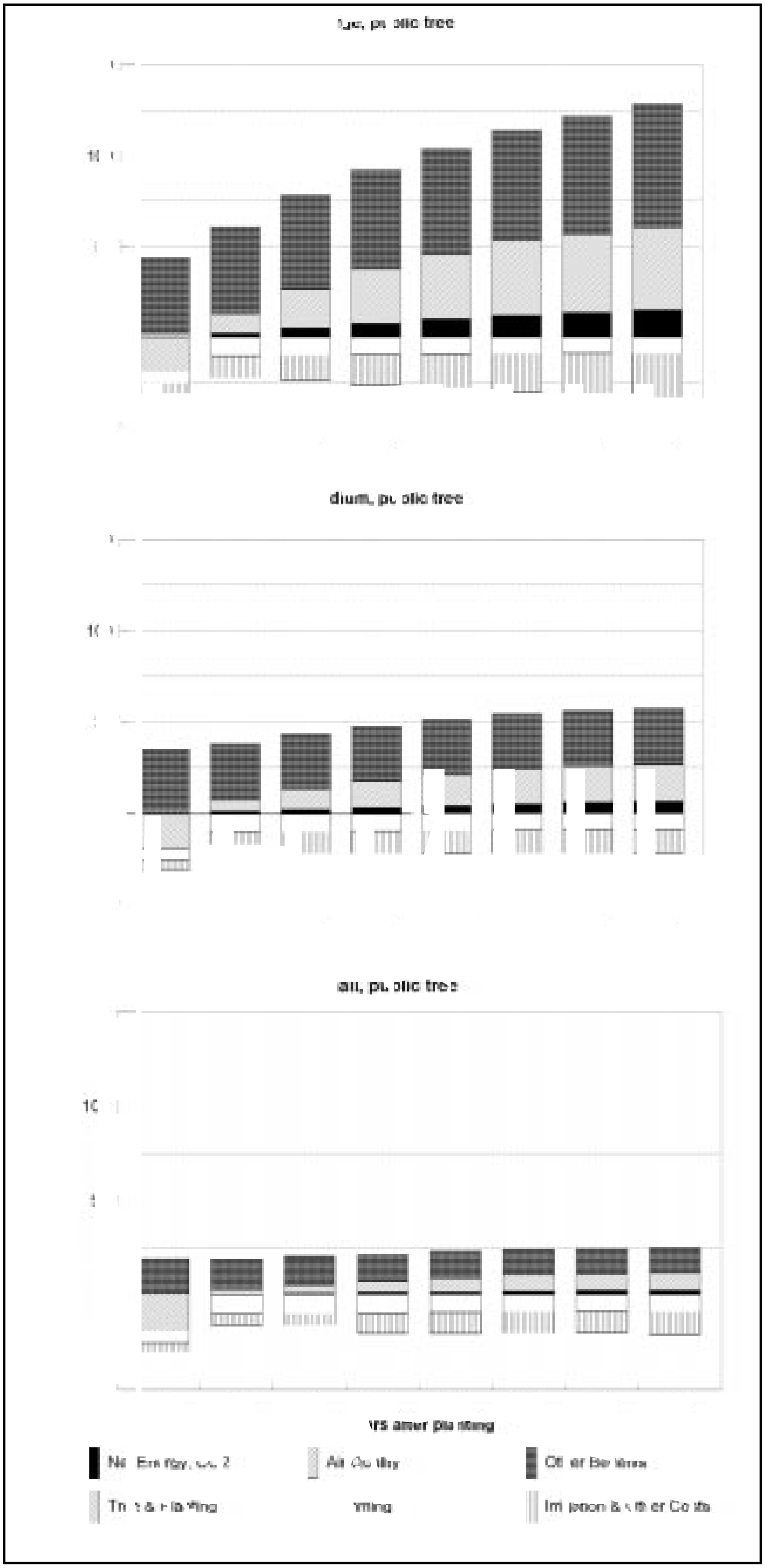
Limitations of Cost/Benefit Analysis

This analysis does not account for the wide variety of trees planted in Coastal Southern California communities or their diverse placement. It does not incorporate the full range of climatic differences within the region that influence potential energy, air quality, and hydrology benefits. There is much uncertainty associated with estimates of aesthetics and other benefits and the true value of hydrology benefits because science in these areas is not well developed. We consider only two cost scenarios, but realize that the costs associated with planting and managing trees can vary widely depending on program characteristics. As the examples in Appendix A describe, local cost data can be substituted for the data in this report to evaluate the benefits and costs of alternative programs. Because of the many simplifying assumptions, extrapolations, and general lack of research concerning urban trees and their impacts on urban environments, these results are preliminary in nature.

In this analysis, results are presented in terms of future values of benefits and costs, not present values. Thus, our findings do not incorporate the time value of money or inflation. We assume that the user intends to invest in community forests and our objective is to identify the relative magnitudes of future costs and benefits. If the user is interested in comparing an investment in urban forestry with other investment opportunities it is important to discount all future benefits and costs to the beginning of the investment period.



6. Residential trees. Estimated annual benefits and costs for a large (camphor), medium (jacaranda), and small (yew pine) residential yard tree located west of the building. Costs are greatest during the initial establishment period while benefits increase with tree size.



7. Public street/park trees. Estimated annual benefits and costs for a large (camphor), medium (jacaranda), and small (yew pine) public street/park tree.

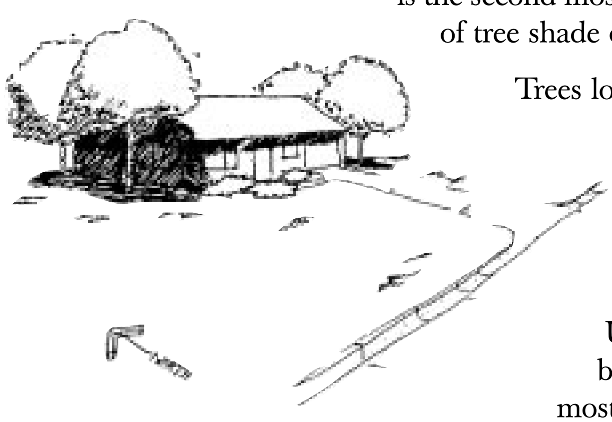
3. General Guidelines for Siting and Selecting Trees

Residential Yard Trees

Maximizing Energy Savings from Shading

The right tree in the right spot saves energy. In midsummer, the sun shines on the northeast and east sides of buildings in the morning, passes over the roof near midday, then shines on the west and northwest sides in the afternoon. Air conditioners work hardest during the afternoon when temperatures are highest and incoming sunshine is greatest. Therefore, the west and northwest sides of a home are the most important sides to shade. Sun shining through windows heats the home quickly.

Locate trees to shade windows so that they block incoming solar radiation, but do not block views. In Coastal Southern California, high fog in the morning sometimes limits sunshine that can warm the home early in the day. Despite this occasional attenuation of morning sunshine by fog, the east side is the second most important side to shade when considering the net impact of tree shade on cooling and heating costs (Figure 8).



8. Locate trees to shade west and east windows (from Sand, 1993).

Trees located to shade south walls can block winter sunshine and increase heating costs, because during winter the sun is lower in the sky and shines on the south side of homes. The warmth the sun provides is an asset, so do not plant evergreen trees that will block southern exposures and solar collectors.

Use solar friendly trees (listed in Chapter 5) to the south because the bare branches of these deciduous trees allow most sunlight to strike the building (some solar unfriendly deciduous trees can reduce sunlight striking the south side of buildings by 50%). To maximize summer shade and minimize winter shade, locate trees about 10-20 ft (3-6 m) south of the home. As trees grow taller, prune lower branches to allow more sun to reach the building if this will not weaken the tree's structure (Figure 9).

Although the closer a tree is to the home the more shade it provides, the roots of trees that are too close can damage the foundation. Branches that impinge on the building can make it difficult to maintain exterior walls and windows. Keep trees at least 5-10 ft (1.5-3 m) from the home to avoid these conflicts but within 30-50 ft (9-15 m) to effectively shade windows and walls.

Paved patios and driveways can become heat sinks that warm the home during the day. Shade trees can make them cooler and more comfortable spaces.

Shading your air conditioner can reduce its energy use, but do not plant vegetation so close that it will obstruct the flow of air around the unit.

Keep trees away from overhead power lines and do not plant directly above underground water and sewer lines. Contact your local utility company before planting to determine where underground lines are located and which tree species will not grow into power lines.

Locating Windbreaks for Heating Savings

The winter heating season is short in Coastal Southern California, but windbreaks can reduce impacts of winter storms and accompanying salt spray. Because of their size and porosity, trees are ideal wind filters. In situations where lot sizes are large enough to plant windbreaks, additional savings can be obtained.

Locate rows of trees perpendicular to the primary wind (Figure 10). Design the windbreak row to be longer than the building being sheltered because the wind speed increases at the edge of the windbreak. Ideally, the windbreak is planted upwind about 25-50 ft (7-15 m) from the building and consists of dense evergreens that will grow to twice the height of the building they shelter (Heisler 1986, Sand 1991).

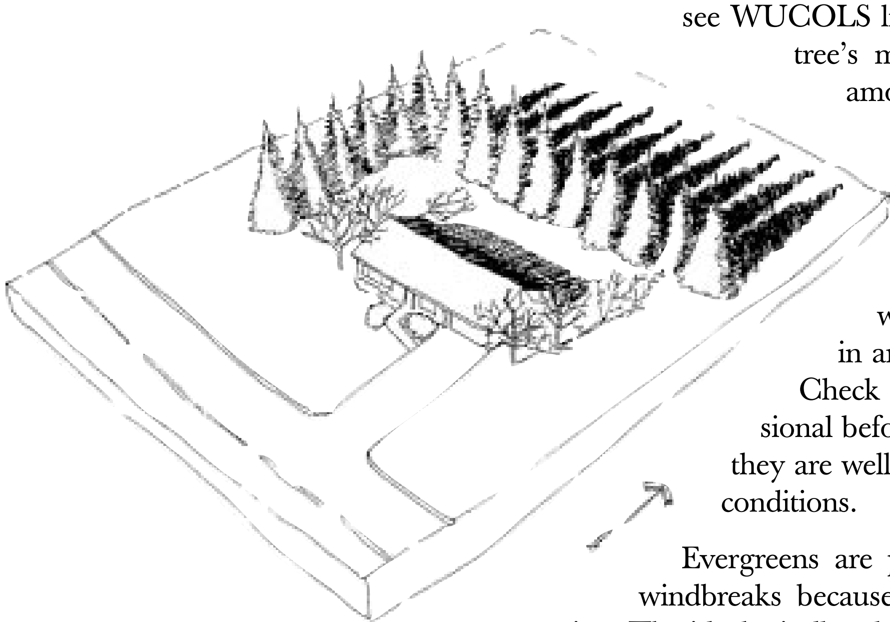
Avoid locating windbreaks that will block sunlight to south and east walls (Figure 11). Trees should be spaced close enough to form a dense screen, but not so close that they will block sunlight to each other, causing lower branches to self-prune. Most conifers can be spaced about 6 ft (2 m) on center. If there is room for two or more rows, then space rows 10-12 ft (3-4 m) apart.

Selecting Yard Trees to Maximize Benefits

The ideal shade tree has a fairly dense, round crown with limbs broad enough to partially shade the roof. Given the same placement, a large tree will provide more building shade than a small tree. Deciduous trees allow sun to shine through leafless branches in winter. Plant small trees where nearby buildings or power lines limit aboveground space. Columnar or upright trees are appropriate in narrow side yards. Because the best location for shade trees is relatively close to the west and east sides of buildings, the most suitable trees will be strong, resisting storm damage, disease, and pests (Sand 1994). Examples of trees not to select for placement near buildings include cottonwood (Populus fremontii) because of their invasive roots, weak wood, and large size, and ginkgo (Ginkgo biloba) because of their narrow form, sparse shade, and slow growth.

9. Tree south of home before and after pruning. Lower branches were pruned up to increase heat gain from winter sun (from Sand 1993).

When selecting trees, match the tree's water requirements with those of surrounding plants. For instance, select low water-use species for planting in areas that receive little irrigation (Costello and Jones 1999, see WUCOLS list and Chapter 5). Also, match the tree's maintenance requirements with the amount of care different areas in the landscape receive. Tree species that drop leaves and fruit may be more easily maintained in areas where litter disappears in coarse groundcovers or in a lawn where it can be easily raked up than in areas that are more difficult to clean. Check with your local landscape professional before selecting trees, to make sure that they are well suited to the site's soil and climatic conditions.



10. Mid-winter shadows from a well-located windbreak and shade trees do not block solar radiation on the south-facing wall (from Sand 1993).

Evergreens are preferred over deciduous trees for windbreaks because they provide better wind protection. The ideal windbreak tree is fast growing, visually dense, has strong branch attachments, and has stiff branches that do not self-prune. Species that tolerate salt spray should be selected for coastal sites. Trees that are among the best windbreak trees for Coastal Southern California communities include Incense cedar (Calocedrus decurrens), cajeput tree (Melaleuca quinquenervia), New Zealand Christmas tree (Metrosideros excelsus) and Canary Island and Torrey pines (Pinus canariensis, P. torreyana).

Trees in Public Places

Locating and Selecting Trees to Maximize Climate Benefits

Locate trees in common areas, along streets, in parking lots, and commercial areas to maximize shade on paving and parked vehicles. Shade trees reduce heat that is stored or reflected by paved surfaces. By cooling streets and parking areas, they reduce emissions of evaporative hydrocarbons from parked cars that are involved in smog formation (Scott et al. 1998). Large trees can shade more area than smaller trees, but should be used only where space permits. Remember that a tree needs space for both branches and roots.

Because trees in common areas and other public places may not shelter buildings from sun and wind, CO_2 reductions are primarily due to sequestration. Fast-growing trees sequester more CO_2 initially than slow-growing trees, but this advantage can be lost if the fast-growing trees die at younger ages. Large growing trees have the capacity to store more CO_2 than do smaller growing trees. To maximize CO_2 sequestration, select tree species that are well-suited to the site where they will be planted. Use information in the Tree Selection List (see Chapter 5), and consult with your local landscape professional to select the right tree for your site. Trees that are not well-adapted will grow slowly, show symptoms of stress, or die at an early age. Unhealthy trees do little to reduce atmospheric CO_2, and can be unsightly liabilities in the landscape.

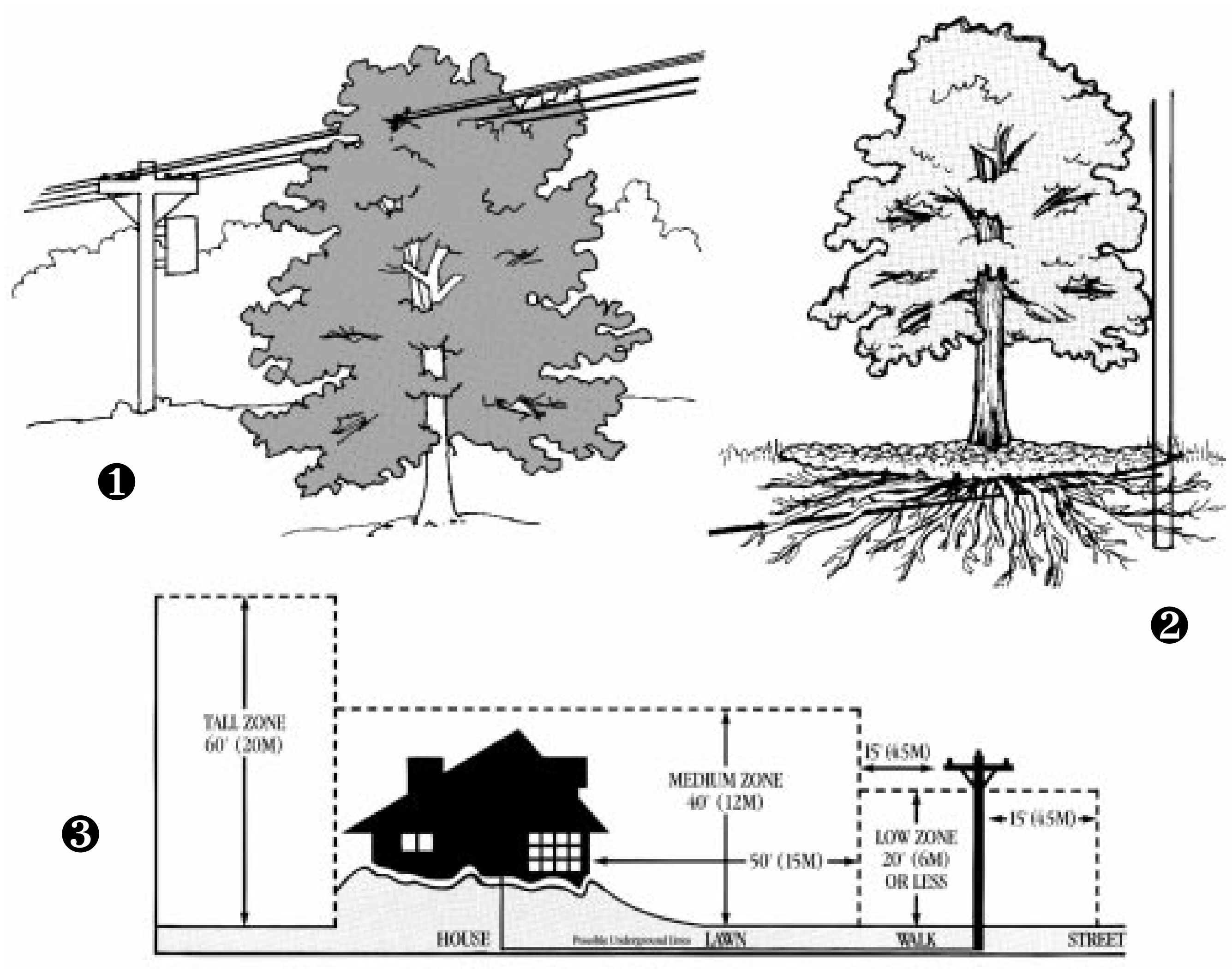
Contact your local utility company before planting to locate underground water, sewer, gas, and telecommunication lines. Note the location of power lines, streetlights, and traffic signs, and select tree species that will not conflict with these aspects of the city's infrastructure. Keep trees at least 30 ft (10 m) away from street intersections to ensure visibility. Avoid planting shallow rooting species near sidewalks, curbs, and paving. Tree roots can heave pavement if planted too close to sidewalks and patios. Generally, avoid planting within 3 ft (1 m) of pavement, and remember that trunk flare at the base of large trees can displace soil and paving for a considerable distance. Select only small-growing trees (<25 ft tall [8 m]) for locations under overhead power lines, and do not plant directly above underground water and sewer lines (Figure 12). Avoid locating trees where they will block illumination from street lights or views of street signs in parking lots, commercial areas, and along streets.

11. Evergreens guide wind over the building (from Sand, 1993).

Maintenance requirements and public safety issues influence the type of trees selected for public places. The ideal public tree is not susceptible to wind damage and branch drop, does not require frequent pruning, produces little litter, is deep-rooted, has few serious pest and disease problems, and tolerates a wide range of soil conditions, irrigation regimes, and air pollutants. Because relatively few trees have all these traits, it is important to match the tree species to planting site by determining what issues are most important on a case-by-case basis. For example, parking lot trees should be tolerant of hot, dry conditions, have strong branch attachments, and be resistant to attacks by pests that leave vehicles covered with sticky exudate. Consult the Tree Selection List in Chapter 5 and your local landscape professional for horticultural information on tree traits.

Parks and other public landscapes serve multiple purposes. Some of the following guidelines may help you maximize their ability to serve as CO_2 sinks:

- ➢ Provide as much pervious surface as possible because soil and woody plants store CO_2.
- ➢ Maximize use of woody plants, especially trees, as they store more CO_2 than do herbaceous plants and grass.
- ➢ Increase tree stocking levels where feasible, and immediately replace dead trees to compensate for CO_2 lost through tree and stump removal.
- ➢ Create a diverse assemblage of habitats, with trees of different ages and species, to promote a continuous canopy cover.



12. (❶, ❷) Know where power lines and other utility lines are before planting. ❸ Under power lines use only small-growing trees ("Low Zone"), and avoid planting directly above underground utilities. Larger trees may be planted where space permits ("Medium" and "Tall" zones) (from ISA 1992)

- ➢ Select species that are adapted to local climate, soils, and other growing conditions. Adapted plants should thrive in the long run and consume relatively little CO_2 through maintenance.
- ➢ Group species with similar landscape maintenance requirements together and consider how irrigation, pruning, fertilization, weed, pest, and disease control can be minimized.
- ➢ Compost litter fall, and apply it as mulch to reduce CO_2 release associated with irrigation and fertilization.
- ➢ Where feasible, reduce CO_2 released through landscape management by using push mowers (not gas or electric), hand saws (not chain saws), pruners (not gas/electric shears), rakes (not leaf blowers), and employing local landscape professionals who do not have to travel far to your site.
- ➢ Consider the project's life span when making species selection. Fast-growing species will sequester more CO_2 initially than slow-growing species, but may not live as long.

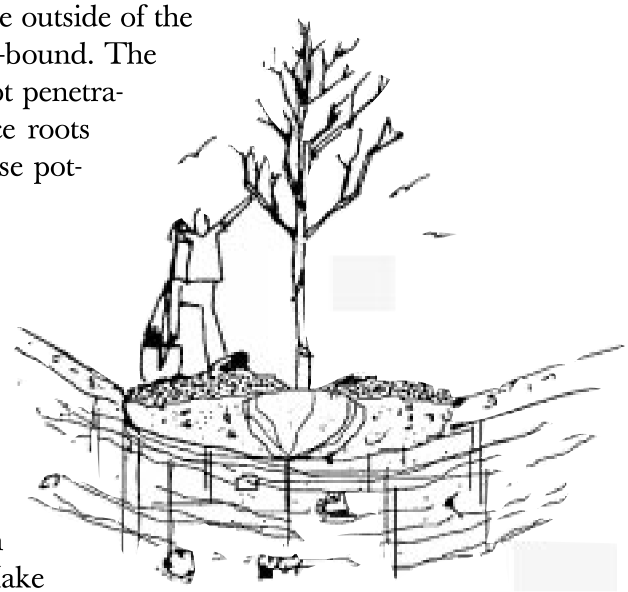
➢ Provide a suitable soil environment for the trees in plazas, parking lots, and other difficult sites to maximize initial CO_2 sequestration and longevity.

General Guidelines For Establishing Healthy Trees For Long-Term Benefits

Inspect your tree at the nursery or garden center before buying it to make sure that it is healthy and well formed. The health of the tree's root ball is critical to its ultimate survival. If the tree is in a container, check for matted roots by sliding off the container. Roots should penetrate to the edge of the root ball, but not densely circle the inside of the container or grow through drain holes. If the tree has many roots circling around the outside of the root ball or the root ball is very hard it is said to be pot-bound. The mass of circling roots can act as a physical barrier to root penetration into the landscape soil after planting. Dense surface roots that circle the trunk may girdle the tree. Do not purchase pot-bound trees.

Another way to evaluate the quality of the tree is to gently move the trunk back and forth in the container. A good tree trunk bends and does not move in the soil, while a poor quality trunk bends little and pivots at or below the soil line. If it pivots and the soil loosens, it may not be very well anchored to the container soil.

Dig the planting hole the same depth as the root ball so that the tree will not settle after it is watered in. The crown of the root ball should be slightly above ground level. Make the hole two to three times as wide as the container. Backfill with the native soil unless it is very sandy, in which case you may want to add composted organic matter such as peat moss or shredded bark (Figure 13).



13. Prepare a broad planting area and top it off with mulch and a berm to hold water (from Sand 1993).

Use the extra backfill to build a berm outside the root ball that is 6 inches (15 cm) high and 3 ft (1 m) in diameter. Soak the tree, and gently rock it to settle it in. Cover the basin with a 4-inch (10 cm) thick layer of mulch, but avoid placing mulch against the tree trunk. Water the new tree twice a week for the first month and weekly thereafter for the next couple growing seasons.

Inspect your tree several times a year, and contact a local landscape professional if problems develop. If your tree needed staking to keep it upright, remove the stake and ties as soon as the tree can hold itself up. Reapply mulch and irrigate the tree as needed. Prune the young tree to maintain a central leader and equally spaced scaffold branches. As the tree matures, have it pruned on a regular basis by a certified arborist. By keeping your tree healthy, you maximize its ability to reduce atmospheric CO_2 and provide other benefits. For additional information on tree planting, establishment, and care see *Principles and Practice of Planting Trees and Shrubs* (Watson and Himelick 1997) and *Arboriculture* (Harris et al. 1999).

4. Program Design and Implementation Guidelines

Your urban forest can become an important means for conserving energy and reducing atmospheric CO_2 through strategic tree planting and stewardship that increases canopy cover and cools urban heat islands. This section provides information about developing and implementing community forestry programs aimed at maximizing energy savings and CO_2 reductions. Such programs are often called "shade tree programs." Although shade tree plantings can be designed to provide benefits beyond energy and CO_2 savings, further research is needed before specific guidelines can be developed for benefits in the areas of air quality, hydrology, and human health.

Program Design And Delivery

A shade tree program directed towards reducing atmospheric CO_2 is likely to be community-wide and collaborative. Fortunately, lessons learned from urban and community programs throughout the country can be applied to avoid pitfalls and promote success (McPherson et al. 1992). In this section we provide a checklist to consider when initiating a shade tree program. For further information, short descriptions of successful shade tree programs are contained in the article "Utilities Grow Energy Savings" (Anderson 1995). Contact California ReLeaf for additional assistance.

Establish the Organizing Group

Most successful programs have a core group of people who provide the leadership needed to organize and plan specific planting and stewardship projects. Build this coalition with an eye toward forging important partnerships with local businesses, utility or energy organizations, politicians, service organizations, schools, individual volunteers, and agencies, and include individuals with expertise in the fields of planning, forestry, horticulture, design, and community organizing. A broad-based constituency and an inclusive process that involves people in decision-making are essential characteristics of a successful organizing group (Sand 1993).

Draw a Road Map

A road map provides a clear picture of where the program is headed and just as importantly, where it is not headed. Begin by establishing program goals and objectives. Some examples of program objectives include:

- Achieve a certain number of tree plantings per year.
- Achieve a certain percentage of future tree canopy cover based on current planting targets.
- Strategically locate trees to achieve a designated level of energy savings or CO_2 reductions per tree planted.

- ➢ Achieve a designated survival rate each year through an active stewardship program.
- ➢ Implement an outreach program to inform the public, local decision makers, and forestry and landscape professionals about energy savings and CO_2 reductions.
- ➢ Coordinate plantings on adjoining public and private properties to maximize mutual benefits and minimize conflicts with utilities, sidewalks, and other aspects of the infrastructure.
- ➢ Work with local decision makers and developers to implement tree guidelines, ordinances, and incentives that reduce the number of trees removed or damaged during construction.
- ➢ For rural areas, coordinate with existing state and federal programs by piggybacking new funds with existing cost-share programs.
- ➢ Support research to quantify and validate CO_2 reductions and other benefits and costs from tree plantings.

Once general goals and objectives are determined, set priorities for planting projects. Identify where genuine need exists and where there is a legitimate chance for success. For example, identify areas where the opportunities for shade tree planting are greatest and the interest is highest. Target these sites for planting. Concentrate on doing a few projects well to start. Take on additional campaigns after some successful projects have been established.

14. Direct participation in tree planting fosters increased satisfaction and a healthier urban forest.

Send Roots into the Community

The social environment around a tree can be as important to its survival and well-being as the physical environment. Research shows that direct participation in tree planting is associated with greater satisfaction with tree and neighborhood than when trees are planted by city, developer, or volunteer groups without resident involvement (Sommer et al. 1994). Foster active participation in tree planting and stewardship by residents (Figure 14).

Provide Timely, Hands-on Training and Assistance

Whether your program relies on volunteers or paid staff, selecting, placing, planting, and establishing trees properly requires specialized knowledge and resources. Taking the time to provide hands-on experience pays off in the long run. Planting a tree is a far more effective educational tool than reading a brochure or listening to a lecture about how to plant a tree.

Nurture Your Volunteers

Most successful tree programs depend on volunteers as the cornerstones of their efforts. Have a clear picture of how the volunteers' talents and enthusiasm can best be put to use. Pay people to do the routine work. Have volunteers do the inspirational work. Honor and reward your best volunteers.

Obtain High-Quality Nursery Stock

Don't put yourself in a hole by planting substandard trees. Identify the best sources of nursery stock, and work with them to get the best quality available. If you are planting large numbers of trees and have time to order stock in advance of planting, contract for the trees to be grown to your specifications. For more information see the *American Standard for Nursery Stock* (American Association of Nurserymen 1997).

Develop a List of Recommended Trees

Choosing trees for specific sites can be overwhelming unless the list is narrowed down to a limited number of species that will perform best. Enlist landscape professionals to identify species that thrive in local soils and climates. Tree lists may be subdivided by mature tree size (e.g., large, small), life form (e.g., deciduous, conifer), and type of site (e.g., under power lines, parking lots, narrow side yards).

15. The local media and corporate sponsors can be a real asset when you need to inform the public about your program.

Commit to Stewardship

Commitment is the key to a healthy urban forest (Lipkis and Lipkis 1990). After the tree-planting fervor subsides, community members need to be dedicated to the ongoing care of those trees and all that follow. Send out information on tree care to prompt program participants to water, mulch, prune, and inspect their trees. Establish a Shade Tree Hotline to dispense stewardship information. Select a sample of trees to track. Monitor their survival and growth, and use the findings to fine-tune your program. For example, the Sacramento Shade program discontinued planting species that were found to have the lowest survival and growth rates.

Use Self-Evaluation to Improve

After every project ask staff and volunteers to fill out an evaluation form by noting what worked well, what didn't work, and what can be done to achieve better results. Use these evaluations to fine-tune your program on a continuous basis.

Educate the Public

Work with the local media to inform and involve the public in your program. Stimulate new linkages with the community by publicizing the program's goals and accomplishments. Share the big picture, and show people what a force for change they can be by working together (Figure 15).

Tree planting is a simple act, but planning, training, selecting species, and mobilizing resources to provide ongoing care require considerable forethought. Successful shade tree programs will address all these issues before a single tree is planted

Increasing Program Cost Effectiveness

What if the program you have designed is promising in terms of energy savings, volunteer participation, and ancillary benefits, but the cost per unit energy saved is too high? This section describes some steps to consider that may increase benefits and reduce costs, thereby increasing cost effectiveness.

Increasing Energy Savings and Other Benefits

Active stewardship that increases the health and survival of recently planted trees is one strategy for increasing cost effectiveness. An evaluation of the Sacramento Shade program found that assumed tree survival rates had a substantial impact on projected benefits (Hildebrandt et al. 1996). Higher survival rates increase energy savings and reduce tree removal costs.

You can further increase energy benefits by targeting a higher percentage of trees for locations that produce the greatest energy savings, such as opposite west-facing walls and close to buildings. By customizing tree locations to increase numbers in high-yield sites, cooling savings can be boosted.

Reducing Program Costs

Cost effectiveness is influenced by program costs and benefits (Cost Effectiveness = Total Net Benefit / Total Program Cost). Cutting these costs is one strategy to increase cost effectiveness. A substantial percentage of total program costs occur during the first five years and are associated with tree planting (McPherson 1993).

Some strategies to reduce these costs include the use of trained volunteers, smaller tree sizes, and follow-up care to increase tree survival and reduce replacement costs. Where growing conditions are likely to be favorable, such as yard or garden settings, it may be cost effective to use smaller, less expensive stock or bare root trees that reduce planting costs. However, in highly urbanized settings and sites subject to vandalism, large trees may survive the initial establishment period better than small trees.

Investing in the resources needed to promote tree establishment during the first five years after planting is usually worthwhile because, once trees are established, they have a high probability of continued survival (Richards 1979).

If your program has targeted trees on private property, then encourage residents to attend tree care workshops. Develop standards of “establishment success” for different types of tree species. Perform periodic inspections to alert residents to tree health problems, and reward those whose trees meet your program’s establishment standards. Replace dead trees as soon as possible, and identify ways to improve survivability.

A cadre of trained volunteers can easily maintain trees until they reach a height of about 20 ft (6 m) and limbs are too high to prune from the ground with pole pruners. By the time trees reach this size they are well-established. Pruning during this establishment period should result in a desirable branching structure that will require less frequent thinning and shaping. Although organizing and training these volunteers requires labor and resources, it is usually less costly than contracting the work. As trees grow larger, contracted pruning costs may increase on a per-tree basis. The frequency of pruning will influence these costs, since it takes longer to prune a tree that has not been pruned in 10 years than one that was pruned a few years ago. Although pruning frequency varies by species and location, a return frequency of about five years is usually sufficient (Miller 1997).

When evaluating the bottom line and whether trees pay, do not forget to consider benefits other than the energy savings, atmospheric CO_2 reductions, and other tangible benefits described in this report. The magnitude of benefits related to employment opportunities, job training, community-building, and enhanced human health and well-being can be substantial. Moreover, these benefits extend beyond the site where trees are planted, furthering collaborative efforts to build better communities.

Sources of Technical Assistance

Alliance for Community Trees
2121 San Jacinto St., Suite 810
Dallas, TX 75201
(214) 953-1187 fax (214) 953-1986
http://willow.ncfes.umn.edu/coop_stk/act.htm

American Forests
P.O. Box 2000
Washington, D.C. 20013
(202) 955-4500
http://www.amfor.org

American Nursery and Landscape Association
1250 I St. NW, Suite 500
Washington, D.C. 20005
(202) 789-2900 fax (202) 789-1893
http://www.anla.org

American Public Power Association
2301 M St. NW
Washington, D.C. 20037
(202) 467-2900 fax (202) 467-2910
http://www.appanet.org

American Society of Consulting Arborists
15245 Shady Grove Rd., Suite 130
Rockville, MD 20850
(301) 947-0483 fax (301) 990-9771

American Society of Landscape Architects
1733 Connecticut Ave.
Washington, D.C. 20009
(202) 898-2444 fax (202) 898-1185
http://www.asla.org

California Association of Nurserymen
3947 Lennane Dr., Suite 150
Sacramento, CA 95834
(916) 928-3500 fax (916) 567-0505
http://www.can-online.org

California Landscape Contractors Association
2021 N St., Suite 300
Sacramento, CA 95814
(916) 448-CLCA fax (916) 446-7692
http://www.clca.org

California Department of Forestry and Fire Protection
Urban and Community Forestry
2524 Mulberry St.
Riverside, CA 92501
(909) 782-4140 fax (909) 782-4248
http://www.fire.ca.gov/urban_forestry.html

California Releaf
The Trust for Public Land
Western Regional Office
116 New Montgomery St., 3rd Floor
San Francisco, CA 94105
(415) 495-5660
http://www.tpl.org/cal

Global Releaf for New Communities
American Forests
P.O. Box 2000
Washington, D.C. 20013
(202) 955-4500 fax (202) 955-4588
http://www.amfor.org/garden/global_releaf/gr_su

International Council for Local Environmental Initiatives
15 Shattuck Sq., Suite 215
Berkeley, CA 94704
(510) 540-8843 fax (510) 540-4787
http://www.ICLEI_USA@iclei.org

International Society of Arboriculture, Western Chapter
P.O. Box 255155
Sacramento, CA 95865
(916) 641-2990 fax (916) 649-8487
http://www.wcisa.net

League of California Cities
1400 K St., 4th Floor
Sacramento, CA 95814
(916) 658-8200 fax (916) 658-8240
http://www.cacities.org

Local Government Commission
1414 K St., Suite 250
Sacramento, CA 95814-3966
(916) 448-1198 fax (916) 448-8246
http://www.lgc.org

National Arbor Day Foundation
100 Arbor Ave.
Nebraska City, NE 68410
(402) 474-0820 fax (402) 474-0820
http://www.arborday.org

National Arborists Association
P.O. Box 1094
Amherst, NH 03031
(603) 673-3311 fax (603) 672-2613
http://www.natlarb.com

National Association of State Foresters
444 N. Capitol St. NW, Suite 540
Washington, D.C. 20001
(504) 925-4500
http://www.stateforesters.org

National Association of Towns and Townships
National Center for Small Communities
444 North Capital St. NW, Suite 208
Washington, D.C. 20001
(202) 624-3550 fax (202) 624-3554
http://www.natat.org/natat

National Tree Trust
1120 G St. NW, Suite 770
Washington, D.C. 20005
(202) 628-8733 or (800) 846-8733 fax (202) 628-8735
http://www.nationaltreetrust.org

National Urban and Community Forestry Advisory Council
c/o Suzanne DelVillar
20628 Diane Dr.
Sonora, CA 95370
(209) 536-9201 fax (209) 536-9089
http://treelink.org/connect/orgs/nucfac/index.htm

National Wildlife Federation
8925 Leesburg Pike
Vienna, VA 22184
(800) 822-9919 or (703) 790-4000 fax (703) 790-4040
http://www.nwf.org/nwf

Phytosphere Research
Ted Swiecki
1027 Davis St.
Vacaville, CA 95687
(707) 452-8735
http://phytosphere.com/treeord/Ordintro.htm

Society of American Foresters
5400 Grosvenor Ln.
Bethesda, MD 20814-2198
(301) 897-8720 fax (301) 897-3690
http://www.safnet.org

Society of Municipal Arborists
7000 Olive Blvd.
University City, MO 63130-2300
(314) 862-1711
http://www.urban-forestry.com

Street Tree Seminar, Inc.
P.O. Box 6415
Anaheim, CA 92816-6415
(714) 991-1900 fax (714) 956-3745
guidebook: *Street Trees Recommended for Southern California*

Tree Link Homepage
http://www.treelink.org

TreePeople
Andy Lipkis
12601 Mulholland Dr.
Beverly Hills, CA 90210
(818) 753-4600 fax (818) 753-4625
http://www.treepeople.org

Urban Forest Ecosystems Institute
California Polytechnic State University
San Luis Obispo, CA 93407
(805) 756-5171 fax (805) 756-1402
http://www.ufei.calpoly.edu

USDA Forest Service
Urban and Community Forestry
1323 Cub Dr.
Vallejo, CA 94591
(707) 562-8737

USDA Forest Service
GreenLink, Rudy Retamoza
4600 Oak Grove Dr.
La Canada Flintridge, CA 91011
(818) 952-4935 fax (818) 790-5392
email: rretamoz/r5_angeles@fs.fe.us

Western Center for Urban Forest Research and Education
USDA Forest Service, PSW
c/o Dept of Environmental Horticulture, University of California
Davis, CA 95616-8587
(530) 752-7636 fax (530) 752-6634
http://wcufre.ucdavis.edu

5. Trees for Coastal Southern California

The matrix in this chapter presents information to assist tree selection with an emphasis on obtaining conservation benefits. For example, no palms are on the list. Tree species recommended in general for coastal Southern California communities are listed alphabetically by mature tree height class – large (>50 ft [15 m]), medium (30-50 ft [9-15 m]), and small (<30 ft [9 m]). Future publications in this series will describe trees for inland valley and desert regions. The climate in Coastal Southern California (see map and region description on page 11) is influenced by the ocean 85% or more of the time.

Information is presented here on characteristics influencing selection for energy and water conservation (i.e., solar friendly, deciduous/ evergreen, irrigation requirement, growth rate), air quality improvement (ozone-forming potential), and reducing infrastructure conflicts (surface rooting, tidiness, pruning requirement). Information was unavailable for certain characteristics, in which case we use the notation NDA (no data available). A general assessment of each tree's suitability for street, yard, and park locations is also presented.

It is important to note that a tree's size, life span, growth, and rooting pattern is highly variable depending on conditions at the site where it grows and the care it receives. Therefore, the tree's actual performance can be very different than described here. Use this information as a general guide and obtain more specific information from landscape professionals with knowledge of your local situation.

Tree selection is a compromise. There is no perfect tree that matches all the criteria required by specific sites: beautiful flowers and form, deep rooting, drought tolerance, pest/disease resistance, rapid growth, strong branch attachments, low BVOC emissions, and so on. Finding the best tree takes time and study. Collecting information on conditions at the site is the first step. Consider the amount of below- and above-ground space, soil type and irrigation, microclimate, and the type of activities occurring around the tree that will influence its growth and management (e.g., mowing, parking, partying). In most cases, it is too expensive to alter site conditions by making them more suitable for a specific tree species. Instead, it is more practical to identify trees with characteristics that best match the existing site conditions, particularly those conditions that will be most limiting to growth.

We received helpful reviews of this information from Michael Mahoney, Ken Greby, Bob Chavez, and Walter Warriner. References used to develop the tree selection matrix include *Street Trees Recommended for Southern California* (Mahoney et al. 1995), *Sunset Western Garden Book* (Brenzel 1997), *SelecTree* (Reimer 1996), and *Southern Trees* (Gilman el al. 1996). These and other references are listed in Chapter 6.

Key to the Matrix

A: Mature tree height (ft.) Note that actual height depends on soils, irrigation, and other factors.

B: Mature tree crown spread (ft.) Note that actual height depends on soils, irrigation, and other factors.

C: Tree Type: D=deciduous, E=evergreen, S=semi-evergreen

D: Solar friendly trees provide winter solar access as well as summer shade; trees numerically ranked based on crown density, time of leaf drop, time of leaf out, crown area and growth rate. Y=Yes; N=No; NDA=no data available (Ames 1987).

E: Growth Rate: F=Fast; M=Moderate; S=Slow (Gilman et al. 1996). Note that actual growth rates depend on soils, irrigation, and other factors.

F: Longevity: L=Long (>50 years); M=Medium (25-50 years); S=Short (<25 years) (Gilman et al. 1996). Note that actual life span is highly site specific and depends on soils, irrigation, and other factors.

G: Availability of cultivars (an asset when trees with specific traits are needed to match site conditions, such as upright form, pest resistance, fruitless): Y=Yes; N=No.

H: Susceptibility to pests and disease: H=pest/disease sensitive; M=resistant; L=free from pests/disease (Gilman et al. 1996).

I: Problems with surface roots: Y=can form large surface roots; O=occasional problem; N=not a problem (Reimer 1996). Note that actual problems are highly site specific.

J: Contribute to ozone formation (data only available for Los Angeles): H=>10; M=1-10; L=<1 g ozone per day, NDA=no data available (Benjamin and Winer 1998).

K: Irrigation requirement: H=high; M=moderate; L=low (Costello and Jones 1999).

L: Locations where genereally suitable to plant: S- Street=difficult growing conditions, in heavily used areas: median, streetside, commercial plaza, and retail. Y- Yard=less difficult growing conditions, less public, sometimes restricted space: residential yard, common areas in residential developments, commercial office. P- Park=less restricted space, public use: parks, schools, cemeteries, commercial campus/industrial park.

M: Other factors that may influence tree selection such as tidiness, soil tolerance, flowers, fruit, and pruning requirement (Gilman et al. 1996, Reimer 1996).

Tree Species Common Name	A Mature Height (ft.)	B Mature Spread (ft.)	C Type	D Solar Friendly	E Growth Rate	F Longevity	G Cultivars Available	H Pest/ Disease Occurrence	I Surface Roots	J Ozone Forming Potential	K Irrigation Needs	L Suitability S=Street Y=Yard P=Park	M Comments
Large Trees >50 ft. Height													
Acrocarpus fraxinifolius pink cedar	50-60	30-40	S	N	F	M	N	L	O	NDA	NDA	S/Y/P	diff. to obtain
Chorisia speciosa 'Los Angeles beautiful' Los Angeles beautiful floss silk tree	40-55	35-50	S	NDA	F	M	Y	L	Y	NDA	L	S/Y/P	very showy
Cinnamomum camphora camphor tree	40-60	50-70	E	N	M	L	N	M	Y	L	M	S/Y/P	shallow roots
Eucalyptus sideroxylon red ironbark	50-60	20-40	E	N	F	M	Y	M	Y	H	L	S/Y/P	flower/seed litter
Ficus micropcarpa nitida Indian laurel fig	50-60	40-60	E	N	F	M	Y	H	Y	H	L	Y/P	thrips
Fraxinus uhdei Mexican ash	70-80	40-60	E	N	F	L	Y	M	Y	NDA	M	Y/P	needs pruning
Jacaranda mimosifolia jacaranda	30-60	30-45	D	NDA	F	M	Y	M	O	L	M	S/Y/P	showy flowers
Liquidambar styraciflua sweetgum	60-75	35-50	D	N	M	L	Y	M	Y	H	M	S/Y/P	fruits, fall color
Magnolia grandiflora Southern magnolia	50-70	30-40	E	N	M	L	Y	M	Y	M	M	S/Y/P	flowers
Paulownia tomentosa princess tree	40-50	40-50	D	Y	F	M	N	L	O	NDA	M	Y/P	diff. to obtain
Pinus canariensis Canary island pine	60-90	30-40	E	N	F	L	N	L	O	L	L	S/Y/P	litter
Pinus pinea stone pine, umbrella pine	35-80	35-60	E	N	M	L	N	L	Y	L	L	S/P	limb drop common

Key to the Matrix
A: Mature tree height (ft). Note that actual height depends on soils, irrigation, and other factors.
B: Mature tree crown spread (ft). Note that actual height depends on soils, irrigation, and other factors.
C: Tree Type: D- Deciduous, E-Evergreen, S-Semi-Evergreen, P-Palm.
D: Solar friendly trees provide winter solar access as well as summer shade; trees numerically ranked based on crown density, time of leaf drop, time of leaf out, crown area and growth rate; NDA, No data available (Ames 1987).
E: Growth Rate: F, Fast; M, Moderate; S, Slow (Gilman et al. 1996). Note that actual growth rates depend on soils, irrigation, and other factors.
F: Longevity: L, Long (>50 years); M, Medium (25-50 years); S, Short (<25 years) (Gilman et al. 1996). Note that actual life span is highly site specific and depends on soils, irrigation, and other factors.
G: Availability of cultivars (an asset when trees with specific traits are needed to match site conditions, such as upright form, pest resistance, fruitless): Y=yes; N=no.
H: Susceptibility to pests and disease: H = pest/disease sensitive, M = resistant, L = free from pests/disease (Gilman et al. 1996).
I: Problems with surface roots: Y = can form large surface roots, O = occasional problem, N = not a problem (Reimer 1996). Note that actual problems are highly site specific.
J. Contribute to ozone formation (data only available for Los Angeles): H = > 10, M = 1-10, L < 1 g ozone per day, NDA, No data available (Benjamin and Winer 1998).
K: Irrigation requirement: H = High, M = Moderate, L = Low (Costello and Jones 1999),
L: Locations where generally suitable to plant: S= Street= difficult growing conditions in heavily used areas: median, streetside, commercial plaza and retail. Y= Yard= less difficult growing conditions, less public, sometimes restricted space: residential yard, common areas in residential developments, commercial office. P= Park= less restricted space, public use: parks, schools, cemeteries, commercial campus/industrial park.
M: Other factors that may influence tree selection such as tidiness, soil tolerance, flowers, fruit, and pruning requirement (Gilman et al. 1996, Reimer 1996).

Tree Species Common Name	A Mature Height (ft.)	B Mature Spread (ft.)	C Type	D Solar Friendly	E Growth Rate	F Longevity	G Cultivars Available	H Pest/ Disease Occurrence	I Surface Roots	J Ozone Forming Potential	K Irrigation Needs	L Suitability S=Street Y=Yard P=Park	M Comments
Large Trees >50 ft. Height													
Pinus torreyana Torrey pine	40-60	40-50	E	N	F	L	N	M	O	M	L	S/P	native
Platanus acerifolia 'Yarwood' or 'Bloodgood' London plane tree	50-70	50-70	D	N	F	L	Y	H	O	H	M	S/P	litter
Platanus x *hispanica* 'Columbia' Columbia London plane tree	40-60	40-60	D	N	F	L	Y	M	O	H	NDA	S/P	litter
Podocarpus gracilior fern pine	50-60	50-60	E	N	S	L	Y	M	N	L	M	S/Y/P	low main-tenance
Quercus agrifolia coastal live oak	50-60	50-60	E	N	M	L	N	H	Y	H	L	Y/P	native
Tristania conferta Brisbane box	50-60	30-50	E	N	F	M	Y	H	O	H	M	S/Y	
Ulmus parvifolia 'Athena' or 'Allee' Chinese elm	50-70	35-45	D	N	M	L	Y	M	N	L	M	S/Y/P	frequent pruning
Umbellularia californica California laurel	40-60	40-60	E	N	S	L	N	L	O	M	M	S/Y/P	native
Zelkova serrata sawleaf zelkova	50-65	50-65	D	NDA	M	M	Y	M	O	L	M	S/Y/P	Dutch elm resistant

Key to the Matrix

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C: Tree Type: D = Deciduous; E = Evergreen; S = Semi-evergreen.
D: Solar friendly trees provide winter solar access as well as summer shade; trees numerically ranked based on crown density, time of leaf drop, time of leaf out, crown area and growth rate; N = No; Y = Yes; NDA = No data available (Ames 1987).
E: Growth Rate: F = Fast; M = Moderate; S = Slow (Gilman et al. 1996). Note that actual growth rates depend on soils, irrigation, and other factors.
F: Longevity: L = Long (>50 years); M = Medium (25-50 years); S = Short (<25 years) (Gilman et al. 1996). Note that actual life span is highly site specific and depends on soils, irrigation, and other factors.
G: Availability of cultivars (an asset when trees with specific traits are needed to match site conditions, such as upright form, pest resistance, fruitless): Y=yes; N=no.
H: Susceptibility to pests and disease: H = pest/disease sensitive, M = resistant, L = free from pests/disease (Gilman et al. 1996).
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M: Other factors that may influence tree selection such as tidiness, soil tolerance, flowers, fruit, and pruning requirement (Gilman et al. 1996, Reimer 1996).

Tree Species Common Name	A Mature Height (ft.)	B Mature Spread (ft.)	C Type	D Solar Friendly	E Growth Rate	F Longevity	G Cultivars Available	H Pest/ Disease Occurrence	I Surface Roots	J Ozone Forming Potential	K Irrigation Needs	L Suitability S=Street Y=Yard P=Park	M Comments
Medium Trees 30-50 ft. Height													
Alnus cordata Italian alder	30-40	20-25	D	NDA	F	M	N	H	Y	NDA	M	Y/P	borers, litter
Bauhinia blakeana Hong Kong orchid tree	20-30	20-25	E	N	F	M	N	L	N	NDA	M	S/Y/P	winter flowers showy
Bauhinia variegata purple orchid tree	30-35	30-35	D	NDA	F	M	N	L	N	M	M	S/Y/P	spring flowers
Bischofia javanica toogtree	30-50	25-35	E	N	M	M	N	H	Y	NDA	M	S/Y/P	
Brachychiton populneus bottle tree	35-50	25-40	E	N	M	L	N	L	Y	NDA	M	S/Y/P	fruit litter
Callistemon viminalis weeping bottlebrush	25-40	15-25	E	N	M	M	Y	M	N	H	M	S/Y/P	flowers
Calodendrum capense cape chestnut	25-40	25-40	S	N	S	N	N	L	N	L	M	Y	showy flowers
Cassia excelsa golden-shower	20-30	20-30	S	NDA	F	M	N	L	N	NDA	M	S/Y/P	litter
Cassia leptophylla golden medallion tree	20-30	20-30	S	NDA	F	M	N	M	N	NDA	M	S/Y/P	flowers
Cupaniopsis anacardiopsis carrotwood	25-35	25-35	E	N	M	M	N	L	Y	H	M	Y/P	fruit litter

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C: Tree Type: D = Deciduous; E = Evergreen; S = Semi-evergreen.
D: Solar friendly trees provide winter solar access as well as summer shade; trees numerically ranked based on crown density, time of leaf drop, time of leaf out, crown area and growth rate; N = No; Y = Yes; NDA = No data available (Ames 1987).
E: Growth Rate: F = Fast; M = Moderate; S = Slow (Gilman et al. 1996). Note that actual growth rates depend on soils, irrigation, and other factors.
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Tree Species Common Name	A Mature Height (ft.)	B Mature Spread (ft.)	C Type	D Solar Friendly	E Growth Rate	F Longevity	G Cultivars Available	H Pest/ Disease Occurrence	I Surface Roots	J Ozone Forming Potential	K Irrigation Needs	L Suitability S=Street Y=Yard P=Park	M Comments
Medium Trees 30-50 ft. Height													
Ficus elastica rubber tree	30-45	25-30	E	N	F	L	Y	M	Y	M	M	Y/P	litter
Ficus elastica 'variegata' variegata rubber tree	30-45	25-30	E	N	F	L	Y	M	Y	M	M	Y/P	litter
Ficus lyrata fiddleleaf fig	25-40	25-35	E	N	M	M	N	M	Y	H	NDA	S/Y/P	fruit litter
Fraxinus oxycarpa 'Raywood' Raywood or flame ash	30-40	25-35	D	Y	M	M	Y	H	N	NDA	M	S/Y/P	seedless, fall color
Geijera parviflora Australian willow	30-35	20-25	E	N	F	M	N	L	N	L	L	S/Y/P	low maintenance
Koelreuteria bipinnata Chinese flame tree	30-40	20-40	D	Y	M	M	N	M	N	H	M	S/Y/P	litter, attractive flowers/ fruit
Koelreuteria paniculata goldenrain tree	25-30	15-30	D	Y	M	M	N	L	N	H	M	S/Y/P	litter, attractive flowers/ fruit
Melaleuca quinquenervia cajeput tree	30-40	15-20	E	N	M	M	N	L	O	H	M	S/Y/P	tolerates saline soils

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Medium Trees 30-50 ft. Height													
Pistacia chinensis 'Keith Davey' Chinese pistache	30-40	30-40	D	Y	M	M	Y	L	O	L	M	S/Y/P	fall color, use male clone
Podocarpus macrophyllus yew pine	35-40	10-15	E	N	S	L	Y	M	N	L	M	S/Y/P	low maintenance
Pyrus kawakamii evergreen pear	25-35	15-20	E	N	F	M	N	H	N	L	M	S/Y/P	needs maintenance
Quercus ilex holly oak	40-50	40-50	E	N	M	M	N	M	O	H	M	Y/P	acorns
Robinia ambigua 'Purple Robe' purple robe locust	40-50	30-50	D	NDA	M	M	N	H	Y	NDA	L	S/Y/P	flowers, brittle
Stenocarpus sinuatus firewheel tree	25-35	15	E	N	S	M	N	L	N	NDA	M	S/Y/P	flowers showy
Tabebuia avellanedae pink trumpet tree	25-35	25-35	S	N	F	M	N	L	O	NDA	NDA	Y/P	winter flowers
Tipuana tipu tipu tree	35-50	35-55	S	N	F	M	N	L	O	M	M	S/Y/P	flower litter

Key to the Matrix
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D: Solar friendly trees provide winter solar access as well as summer shade; trees numerically ranked based on crown density, time of leaf drop, time of leaf out, crown area and growth rate; N = No; Y = Yes; NDA = No data available (Ames 1987).
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H: Susceptibility to pests and disease: H = pest/disease sensitive, M = resistant, L = free from pests/disease (Gilman et al. 1996).
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Tree Species Common Name	A Mature Height (ft.)	B Mature Spread (ft.)	C Type	D Solar Friendly	E Growth Rate	F Longevity	G Cultivars Available	H Pest/ Disease Occurrence	I Surface Roots	J Ozone Forming Potential	K Irrigation Needs	L Suitability S=Street Y=Yard P=Park	M Comments
Small Trees <30 ft. Height													
Arbutus unedo strawberry tree	10-30	10-30	E	N	S	M	Y	L	N	NDA	L	S/Y/P	needs pruning
Acacia subporosa river wattle	20-30	20-30	E	N	F	S	N	L	O	L	L	S/Y	weeping
Acer oblongum evergreen maple	20-25	20-25	E	N	M	M	N	L	N	NDA	M	S/Y/P	attractive spring growth
Agonis flexuosa peppermint tree	25-30	25-30	E	N	F	M	N	L	O	NDA	L	S/Y/P	leaves smell like peppermint
Callistemon citrinus lemon bottlebrush	10-15	10-15	E	N	M	S	Y	M	N	H	L	Y	flowers
Cercis occidentalis Western redbud	15-25	15-25	D	Y	M	M	N	M	N	L	L	S/Y/P	flowers, fall color
Chitalpa tashkentensis chitalpa	20-30	20-25	D	NDA	M	M	Y	M	N	NDA	M	S/Y/P	litter
Chionanthus retusus Chinese fringe tree	15-20	10-15	D	NDA	M	M	N	L	N	NDA	M	S/Y/P	showy flowers
Erythrina caffra kaffirboom coral tree	25-30	25-40	D	NDA	F	M	N	H	Y	M	L	S/Y/P	showy flowers
Lagerstroemia indica x *L. faurei* crape myrtle	15-25	10-20	D	Y	M	M	Y	M	N	L	M	S/Y/P	needs training, flowers

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Tree Species Common Name	A Mature Height (ft.)	B Mature Spread (ft.)	C Type	D Solar Friendly	E Growth Rate	F Longevity	G Cultivars Available	H Pest/ Disease Occurrence	I Surface Roots	J Ozone Forming Potential	K Irrigation Needs	L Suitability S=Street Y=Yard P=Park	M Comments
Small Trees <30 ft. Height													
Plumeria rubra frangipani	20-25	20-25	D	NDA	S	M	Y	M	N	NDA	L	S/Y/P	very showy
Prunus cerasifera 'Krauter Vesuvius' or 'Thundercloud' purple leaf or thundercloud	15-25	15-25	D	Y	M	S	Y	H	N	L	M	S/Y/P	fruit attracts animals
Psidium littorale strawberry guava	15-25	12-20	E	N	M	M	Y	M	N	NDA	M	Y	edible fruit
Tabebuia chrysotricha golden trumpet tree	20-25	25-35	S	N	F	M	N	L	N	M	M	S/Y/P	difficult to obtain
Tristania laurina water gum	20-25	15-20	E	N	S	M	Y	L	N	NDA	M	S/Y/P	tolerates moist sites
Vitex agnus-castus chaste tree	10-15	15-20	D	NDA	F	M	Y	M	N	NDA	L	Y/P	diff. to obtain

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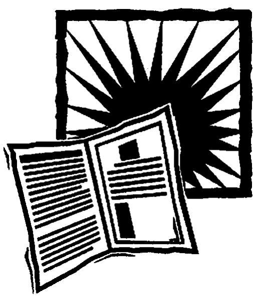
D: Solar friendly trees provide winter solar access as well as summer shade; trees numerically ranked based on crown density, time of leaf drop, time of leaf out, crown area and growth rate; N = No; Y = Yes; NDA = No data available (Ames 1987).
E: Growth Rate: F = Fast; M = Moderate; S = Slow (Gilman et al. 1996). Note that actual growth rates depend on soils, irrigation, and other factors.
F: Longevity: L = Long (>50 years); M = Medium (25-50 years); S = Short (<25 years) (Gilman et al. 1996). Note that actual life span is highly site specific and depends on soils, irrigation, and other factors.
G: Availability of cultivars (an asset when trees with specific traits are needed to match site conditions, such as upright form, pest resistance, fruitless): Y=yes; N=no.
H: Susceptibility to pests and disease: H = pest/disease sensitive, M = resistant, L = free from pests/disease (Gilman et al. 1996).
I: Problems with surface roots: Y = Can form large surface roots; O = Occasional problem; N = Not a problem (Reimer 1996). Note that actual problems are highly site specific.
J. Contribute to ozone formation (data only available for Los Angeles): H = > 10; M = 1-10; L = < 1 g ozone per day; NDA = No data available (Benjamin and Winer 1998).
K: Irrigation requirement: H = High; M = Moderate; L = Low (Costello and Jones 1999).
L: Locations where generally suitable to plant: S = Street = difficult growing conditions in heavily used areas: median, streetside, commercial plaza and retail. Y = Yard = less difficult growing conditions, less public, sometimes restricted space: residential yard, common areas in residential developments, commercial office. P = Park = less restricted space, public use: parks, schools, cemeteries, commercial campus/industrial park.
M: Other factors that may influence tree selection such as tidiness, soil tolerance, flowers, fruit, and pruning requirement (Gilman et al. 1996, Reimer 1996).

6. References



Akbari, H.; Davis, S.; Dorsano, S.; Huang, J.; Winnett, S., eds. 1992. **Cooling Our Communities: A Guidebook on Tree Planting and Light-Colored Surfacing.** Washington, DC: U.S. Environmental Protection Agency.; 26 p.

Ames, M.J. 1987. **Solar Friendly Trees Report.** Portland, Oregon: City of Portland Energy Office.

American Association of Nurserymen. 1997. **American standard for nursery stock.** Z60.1-1996. Washington, DC: American Association of Nurserymen; 57 p.

Anderson, A. 1995. **Utilities grow energy savings.** Home Energy 12(2): 14-15.

Anderson, L.M.; Cordell, H.K. 1988. **Residential property values improve by landscaping with trees.** Southern Journal of Applied Forestry 9: 162-166.

Benjamin, M.T.; Winer, A.M. 1998. **Estimating the ozone-forming potential of urban trees and shrubs.** Atmospheric Environment 32(1): 53-68.

Bernhardt, E.; Swiecki, T.J. 1993. **The State of Urban Forestry in California: Results of the 1992 California Urban Forest Survey.** Sacramento: California Department of Forestry and Fire Protection.; 51 p.

Brenzel, K.N. (Ed.) 1997. **Sunset Western Garden Book.** 5th ed. Menlo Park, CA: Sunset Books Inc.

Burger, D.; Costello, L.; McPherson, G.; Peper, P. 1998. **Funding sought to reduce tree-sidewalk damage in California cities.** Western Arborist 25: 36-37.

California Association of Realtors. 1999. **September Median Prices.** http://www.car.org/economics/archives/.

California Energy Commission. 1994. **Electricity Report,** State of California, Energy Commission, Sacramento, CA.

California Energy Commission. 1996. **California Electricity Accounts by County in 1996,** http://www.energy.gov/electricity_by_county.html, State of California, Energy Commission, Sacramento, CA.

California Energy Commission. 1998. **Natural Gas Market Outlook Staff Report, Pub. P300-98-006**, State of California, Energy Commission, Sacramento, CA.

Cantor Fitzgerald Environmental Brokerage Services, 1999. **South Coast Air Quality Management District Market Price Index for Emission**

Reduction Credits, October 31, 1999, http://www.cantor.com/ebs/marketp.htm.

Condon, P.; Moriarty, S. (eds.) 1999. **Second Nature: Adapting LA's Landscape for Sustainable Living.** Los Angeles: TreePeople. 116 p.

Costello, L.R.; Jones, K.S. 1992. **WUCOLS Project – Water Use Classification of Landscape Species.** University of California Cooperative Extension Services, Oakland, CA.

Dwyer, J.F.; McPherson, E.G.; Schroeder, H.W.; Rowntree, R.A. 1992. **Assessing the benefits and costs of the urban forest.** Journal of Arboriculture 18(5): 227-234.

Gilman, E.F.; Beck, H.; Watson, D.; Fowler, P.; Weigle, D.; Morgan, N. 1996. **Southern Trees.** 2nd ed. Gainesville, FL: University of Florida.

Guenther, A.B.; Monson, R.K.; Fall, R. 1991. **Isoprene and monterpene emission rate variability: observations with eucalyptus and emission rate algorithm development.** Journal of Geophysical Research. 96: 10799-10808.

Guenther, A.B.; Zimmerman, P.R.; Harley, P.C.; Monson, R.K.; Fall, R. 1993. **Isoprene and monterpene emission rate variability: model evaluations and sensitivity analysis.** Journal of Geophysical Research. 98: 12609-12617.

Hammer, T. T.; Coughlin, R.; Horn, E. 1974. **The effect of a large urban park on real estate value.** Journal of the American Institute of Planning. July: 274-275.

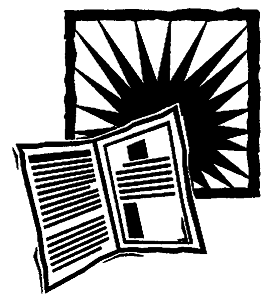
Harris, R.W.; Clark, J.R.; Matheny, N.P. 1999. **Arboriculture.** 3rd. ed. Englewood Cliffs, NJ: Regents/Prentice Hall; 674 p.

Heisler, G.M. 1986. **Energy savings with trees.** Journal of Arboriculture 12(5): 113-125.

Hildebrandt, E.W.; Kallett, R.; Sarkovich, M.; Sequest, R. 1996. **Maximizing the energy benefits of urban forestation.** In: Proceedings of the ACEEE 1996 summer study on energy efficiency in buildings, volume 9; Washington DC: American Council for an Energy Efficient Economy; 121-131.

ICLEI. 1997. **U.S. Communities Acting to Protect the Climate. A Report on the Achievements of ICLEI's Cities for Climate Protection – U.S.** Berkeley, CA: International Council for Local Environmental Initiatives; 35 p.

ISA. 1992. **Avoiding tree and utility conflicts.** Savoy, IL: International Society of Arboriculture; 4 p.



Jones & Stokes Associates, Inc. 1998. **Cost-Benefit Analysis for the T.R.E.E.S. Project.** Sacramento: Jones & Stokes Associates, Inc.

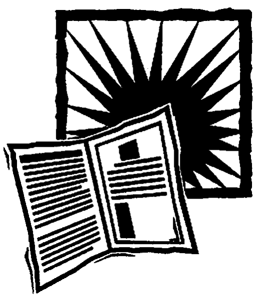
Lipkis, A.; Lipkis, K. 1990. **The Simple Act of Planting a Tree, Healing Your Neighborhood, Your City, and Your World.** Los Angeles, CA: Jeremy P. Tarcher, Inc.; 236 p.

Mahony, M.; Remyn, A.; Trotter, M.; Trotter, W.; Kelly, A.; Epperson, A.; Chamness, M. (Eds.) 1994. **Street Trees Recommended for Southern California.** Anaheim, CA: Street Tree Seminar Inc.

Markwardt, L.J. 1930. **Comparative Strength Properties of Woods Grown in the United States.** Tech. Bull. No. 158. Washington, DC; U.S. Department of Agriculture.

McPherson, E.G. 1992. **Accounting for benefits and costs of urban greenspace.** Landscape and Urban Planning 22: 41-51.

McPherson, E.G.; Ratliffe, J.D.; Sampson, N. 1992. **Lessons learned from successful tree programs.** In: Akbari, H.; Davis, S.; Dorsano, S.; Huang, J.; Winnett, S., eds. Cooling our communities: a guidebook on tree planting and light-colored surfacing. Washington, DC: U.S. Environmental Protection Agency; 63-92. Available from U.S. Government Printing Office. Washington, DC; #055-000-00371-8.



McPherson, E.G. 1992. **Evaluating the cost effectiveness of shade trees for demand-side management.** The Electricity Journal. 6(9): 57-65.

McPherson, E.G.; Sacamano, P.L.; Wensman, S. 1993. **Modeling Benefits and Costs of Community Tree Plantings.** Davis, CA: USDA Forest Service, Pacific Southwest Research Station.; 170 p.

McPherson, E.G. 1994. **Using urban forests for energy efficiency and carbon storage.** Journal of Forestry 92(10): 36-41.

McPherson, E.G. 1996. **Urban forest landscapes, how greenery saves greenbacks.** In: Wagner, C., ed. 1996 Annual Meeting Proceedings, American Society of Landscape Architects. Washington, DC: ASLA; 27-29.

McPherson, E.G. 1998. **Atmospheric carbon dioxide reduction by Sacramento's urban forest.** Journal of Arboriculture 24(4): 215-223.

McPherson, E.G.; Simpson, J.R. 1998. **Guidelines for Tree Planting to Reduce Atmospheric Carbon Dioxide in Chula Vista, CA.** Unpublished Technical Report, USDA Forest Service, Western Center for Urban Forest Research and Education: Davis, CA. 14 p.

McPherson, E.G.; Mathis, S. (eds.) 1999. **Proceedings of the Best of the West Summit.** Western Chapter, International Society of Arboriculture: Sacramento, CA. 93 p.

McPherson, E.G.; Simpson, J.R. 1999. **Guidelines for Calculating Carbon Dioxide Reductions Through Urban Forestry Programs.** USDA Forest Service, PSW General Technical Report No. 171, Albany, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Xiao, Q. 199a. **Tree Guidelines for San Joaquin Valley Communities.** Local Government Commission: Sacramento, CA. 63 p.

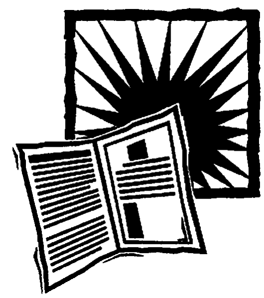
Miller, R.W. 1997. **Urban forestry: planning and managing urban greenspaces.** 2nd. ed. Upper Saddle River: Prentice-Hall; 502 p.

Miller, R.H.; Miller, R.W. 1991. **Planting survival of selected street tree taxa.** Journal of Arboriculture 17(7): 185-191.

Neely, D., ed. 1988. **Valuation of Landscape Trees, Shrubs, and Other Plants.** 7th. ed. Urbana, IL: International Society of Arboriculture.; 50 p.

Nowak, D.J.; McBride, J.; Beatty, R.A. 1990. **Newly planted street tree growth and mortality.** Journal of Arboriculture 16(5): 124-129.

Pillsbury, N.H.; Reimer, J.L.; Thompson, R.P. 1998. **Tree Volume Equations for Fifteen Urban Species in California.** Tech. Rpt. 7. Urban Forest Ecosystems Intitute, California Polytechnic State University; San Luis Obispo, CA. 56 p.



Platt, R.H.; Rowntree, R.A.; Muick, P.C., eds. 1994. **The Ecological City.** Boston, MA: University of Massachusetts.; 292 p.

Reimer, J. 1996. **SelecTree: A Tree Selection System.** San Luis Obispo, CA: University of California.

Richards, N.A.; Mallette, J.R.; Simpson, R.J.; Macie, E.A. 1984. **Residential greenspace and vegetation in a mature city: Syracuse, New York.** Urban Ecology 8: 99-125.

Rosenfeld, A.H.; Akbari, H.; Romm, J.J.; Pomerantz, M. 1998. **Cool communities: strategies for heat island mitigation and smog reduction.** Energy and Buildings. 28: 51-62.

Sand, M. 1991. **Planting for energy conservation in the north.** Minneapolis: Department of Natural Resources: State of Minnesota; 19 p.

Sand, M. 1993. **Energy conservation through community forestry.** St. Paul: University of Minnesota; 40 p.

Sand, M. 1994. **Design and species selection to reduce urban heat island and conserve energy.** In: Proceedings from the sixth national urban forest conference: growing greener communities. Minneapolis, Minnesota: Sept. 14-18, 1993. Washington DC: American Forests; 282.

Schroeder, T. 1982. **The relationship of local park and recreation services to residential property values.** Journal of Leisure Research. 14: 223-234.

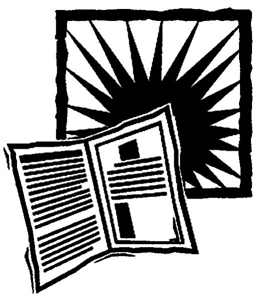
Scott, K.I.; McPherson, E.G.; Simpson, J.R. 1998. **Air pollutant uptake by Sacramento's urban forest.** Journal of Arboriculture 24(4): 224-234.

Scott, K.I.; Simpson, J.R.; McPherson, E.G. 1999. **Effects of tree cover on parking lot microclimate and vehicle emissions.** Journal of Arboriculture 25(3): 129-142.

Simpson, J.R.; McPherson, E.G. 1996. **Potential of tree shade for reducing residential energy use in California.** Journal of Arboriculture 22(1): 10-18.

Simpson, J.R. 1998. **Urban forest impacts on regional space conditioning energy use: Sacramento County case study.** Journal of Arboriculture 24(4): 201-214.

Sommer, R.; Leary, F.; Summit, J.; Tirrell, M. 1994. **Social benefits of resident involvement in tree planting.** Journal of Arboriculture 20(6): 323-328.



South Coast Air Quality Management District, 1997. **Air Quality Management Plan.** South Coast Air Quality Management District, Diamond Bar, CA.

Summit, J.; McPherson, E.G. 1998. **Residential tree planting and care: A study of attitudes and behavior in Sacramento, CA.** Journal of Arboriculture 24(2): 89-97.

Taha, H. 1996. **Modeling impacts of increased urban vegetation on ozone air quality in the South Coast Air Basin.** Atmospheric Environment 30: 3423-3430.

Tryvainen, L. 1999. **Monetary Valuation of Urban Forest Amenities in Finland.** Vantaa, Finland: Finnish Forest Research Institute, Research paper 739. 129 p.

Ulrich, Roger S. 1985. **Human responses to vegetation and landscapes.** Landscape and Urban Planning 13: 29-44.

U.S. Department of Commerce. 1968. **Climatic Atlas of the United States.** Asheville, NC: National Oceanic and Atmospheric Administration. 80 p.

U.S. Environmental Protection Agency. 1995. **Ap-42 Compilation of Air Pollutant Emission Factors** (5th edition). Vol. I. Research Triangle Park, NC.

Watson, G.W.; Himelick, E.B. 1997. **Principles and practice of planting trees and shrubs.** Savoy, IL: International Society of Arboriculture; 199 p.

Xiao, Q.; McPherson, E.G.; Simpson, J.R.; Ustin, S.L. 1998. **Rainfall interception by Sacramento's urban forest.** Journal of Arboriculture 24(4): 235-244.

7. Glossary of Terms

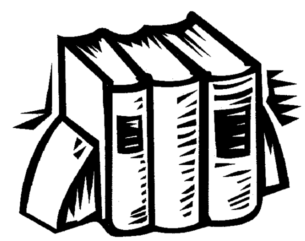
AFUE (Annual Fuel Utilization Efficiency): A measure of space heating equipment efficiency defined as the fraction of energy output/energy input.

Anthropogenic: Produced by humans.

Avoided Power Plant Emissions: Reduced emissions of CO_2 or other pollutants that result from reductions in building energy use due to the moderating effect of trees on climate. Reduced energy use for heating and cooling result in reduced demand for electrical energy, which translates into fewer emissions by power plants.

Biodiversity: The variety of life forms in a given area. Diversity can be categorized in terms of the number of species, the variety in the area's plant and animal communities, the genetic variability of the animals, or a combination of these elements.

Biogenic: Produced by living organisms.



BVOCs (Biogenic Volatile Organic Compounds): Hydrocarbon compounds from vegetation (e.g. isoprene, monoterpene) that exist in the ambient air and contribute to the formation of smog and/or may themselves be toxic.

Canopy: A layer or multiple layers of branches and foliage at the top or crown of a forest's trees.

Climate: The average weather (usually taken over a 30-year time period) for a particular region and time period. Climate is not the same as weather, but rather, it is the average pattern of weather for a particular region. Weather describes the short-term state of the atmosphere. Climatic elements include precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms, and other measures of the weather.

Climate Change (also referred to as "global climate change"): "Climate change" is sometimes used to refer to all forms of climatic inconsistency, but because the earth's climate is never static, the term is more properly used to imply a significant change from one climatic condition to another. In some cases, "climate change" has been used synonymously with the term, "global warming"; scientists however, tend to use the term in the wider sense to also include natural changes in the climate.

Climate Effects: Impact on residential space heating and cooling (kg CO_2/tree/year) from trees located greater than approximately 15 m (50 ft) from a building due to associated reductions in wind speeds and summer air temperatures.

Crown: The branches and foliage at the top of a tree.

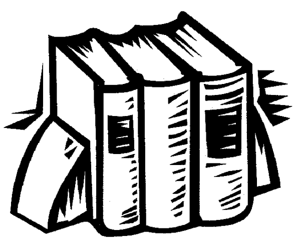
Cultivar (derived from "cultivated variety"): Denotes certain cultivated plants that are clearly distinguishable from others by any characteristic and that when reproduced (sexually or asexually) retain their distinguishing characters. In the United States, variety is often considered synonymous with cultivar.

Deciduous: Trees or shrubs that lose their leaves every fall.

Diameter at Breast Height (dbh): Tree dbh is outside bark diameter at breast height. Breast height is defined as 4.5 feet (1.37m) above ground-line on the uphill side (where applicable) of the tree.

Emission Factor: A rate of CO_2 output resulting from the consumption of electricity, natural gas or any other fuel source.

Evapotranspiration (ET): The total loss of water by evaporation from the soil surface and by transpiration from plants, from a given area, and during a specified period of time.



Evergreen: Trees or shrubs that are never entirely leafless. Evergreen trees may be broadleaved or coniferous (cone-bearing with needle-like leaves).

Fossil Fuel: A general term for combustible geologic deposits of carbon in reduced (organic) form and of biological origin, including coal, oil, natural gas, oil shales, and tar sands. A major concern is that they emit carbon dioxide into the atmosphere when burned, thus significantly contributing to the enhanced greenhouse effect.

Global Warming: An increase in the near surface temperature of the Earth. Global warming has occurred in the distant past as a result of natural influences, but the term is most often used to refer to the warming predicted to occur as a result of increased emissions of greenhouse gases.

Greenspace: Urban trees, forests, and associated vegetation in and around human settlements, ranging from small communities in rural settings to metropolitan regions.

Heat Sinks: Paving, buildings, and other built surfaces that store heat energy from the sun.

Hourly Pollutant Dry Deposition: Removal of gases from the atmosphere by direct transfer to and absorption of gases and particles by natural surfaces such as vegetation, soil, water or snow.

Interception: Amount of rainfall held on tree leaves and stem surfaces.

kBtu: A unit of work or energy, measured as 1,000 British thermal units. One kBtu is equivalent to 0.293 kWh.

kWh (Kilowatt-hour): A unit of work or energy, measured as one kilowatt (1,000 watts) of power expended for one hour. One kWh is equivalent to 3.412 kBtu.

Leaf Surface Area (LSA): Measurement of area of one side of leaf or leaves.

Leaf Area Index (LAI): Total leaf area per unit crown projection area.

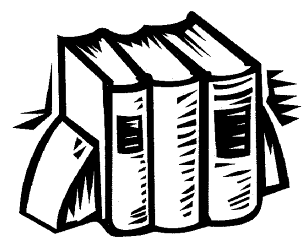
Mature Tree: A tree that has reached a desired size or age for its intended use. Size, age, or economic maturity varies depending on the species, location, growing conditions, and intended use.

Mature Tree Size: The approximate tree size 40 years after planting.

MBtu: A unit of work or energy, measured as 1,000,000 British thermal units. One MBtu is equivalent to 0.293 MWh.

Metric Tonne: A measure of weight (abbreviate "t") equal to 1,000,000 grams (1,000 kilograms) or 2,205 pounds.

MJ: A unit of work or energy, measured as 1,000,000 Joules.



Municipal Forester: A person who manages public street and/or park trees (municipal forestry programs) for the benefit of the community.

MWh (Megawatt-hour): A unit of work or energy, measured as one Megawatt (1,000,000 watts) of power expended for one hour. One MWh is equivalent to 3.412 Mbtu.

Nitrogen Oxides (Oxides of Nitrogen, NOx): A general term pertaining to compounds of nitric acid (NO), nitrogen dioxide (NO_2), and other oxides of nitrogen. Nitrogen oxides are typically created during combustion processes, and are major contributors to smog formation and acid deposition. NO_2 may result in numerous adverse health effects.

Ozone: A strong-smelling, pale blue, reactive toxic chemical gas consisting of three oxygen atoms. It is a product of the photochemical process involving the sun's energy. Ozone exists in the upper atmosphere ozone layer as well as at the earth's surface. Ozone at the earth's surface can cause numerous adverse health effects. It is a major component of smog.

Peak Cooling Demand: The single greatest amount of electricity required at any one time during the course of a year to meet space cooling requirements.

Peak Flow (or Peak Runoff): The maximum rate of runoff at a given point or from a given area, during a specific period.

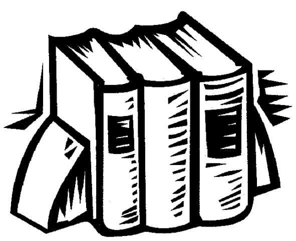
Photosynthesis: The process in green plants of converting water and carbon dioxide into sugar with light energy; accompanied by the production of oxygen.

PM_{10} (Particulate Matter): Major class of air pollutants consisting of tiny solid or liquid particles of soot, dust, smoke, fumes, and mists. The size of the particles (10 microns or smaller, about 0.0004 inches or less) allows them to enter the air sacs (gas exchange region) deep in the lungs where they may get deposited and result in adverse health effects. PM_{10} also causes visibility reduction.

Riparian Habitats: Narrow strips of land bordering creeks, rivers, lakes, or other bodies of water.

SEER (Seasonal Energy Efficiency Ratio): Ratio of cooling output to power consumption; kBtuh output/kWh input as a fraction. It is the Btu of cooling output during its normal annual usage divided by the total electric energy input in watt-hours during the same period.

Sequestration: Annual net rate that a tree removes CO_2 from the atmosphere through the processes of photosynthesis and respiration (kg CO_2/tree/year).



Shade Coefficient: The percentage of light striking a tree crown that is transmitted through gaps in the crown.

Shade Effects: Impact on residential space heating and cooling (kg CO_2/tree/year) from trees located within approximately 15 m (50 ft) of a building (Near Trees) so as to directly shade the building.

Shade Tree Program: An organization that engages in activities such as tree planting and stewardship with the express intent of achieving energy savings and net atmospheric CO_2 reductions.

SO_2 (Sulfur Dioxide): A strong smelling, colorless gas that is formed by the combustion of fossil fuels. Power plants, which may use coal or oil high in sulfur content, can be major sources of SO_2. SO_2 and other sulfur oxides contribute to the problem of acid deposition.

Solar Friendly Trees: Trees that have characteristics that reduce blocking of winter sunlight. According to one numerical ranking system, these traits include open crowns during the winter heating season, early to drop leaves and late to leaf out, relatively small size, and a slow growth rate (Ames 1987).

Stem Flow: Amount of rainfall that travels down the tree trunk and onto the ground.

Throughfall: Amount of rainfall that falls directly to the surface below the tree crown or drips onto the surface from branches and leaves.

Transpiration: The loss of water vapor through the stomata of leaves.

Tree or Canopy Cover: The percent of a fixed area covered by the crown of an individual tree or delimited by the vertical projection of its outermost perimeter; small openings in the crown are included. Used to express the relative importance of individual species within a vegetation community or to express the canopy cover of woody species.

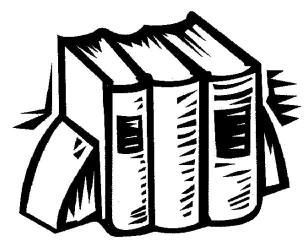
Tree Litter: Fruit, leaves, twigs, and other debris shed by trees.

Tree-Related Emissions: Carbon dioxide releases that result from activities involved with growing, planting, and caring for program trees.

Tree Height: Total height of tree from base (at groundline) to tree top.

Tree Surface Saturation Storage (or Tree Surface Detention Storage): The volume of water required to fill the tree surface to its overflow level. This part of rainfall stored on the canopy surface does not contribute to surface runoff during and after a rainfall event.

Urban Heat Island: An "urban heat island" is an area in a city where summertime air temperatures are 3 to 8° F warmer than temperatures in the surrounding countryside. Urban areas are warmer for two reasons: ❶ they use dark construction materials which absorb solar energy, ❷ they have few trees, shrubs or other vegetation to provide shade and cool the air.



VOCs (Volatile Organic Compounds): Hydrocarbon compounds which exist in the ambient air. VOCs contribute to the formation of smog and/or may themselves be toxic. VOCs often have an odor. Some examples of VOCs are gasoline, alcohol, and the solvents used in paints.

Appendix A.

Estimated Benefits and Costs for a Large, Medium, and Small Tree for 40 Years after Planting

Data Tables

Information in this Appendix can be used to estimate benefits and costs associated with proposed or existing tree programs. The first three tables contain data for the large (camphor, Table A1), medium (jacaranda, Table A2), and small (yew pine, Table A3) tree. Data are presented as annual values for each five-year interval. There are two columns for each five-year interval. In the first column values describe resource units: the amount of air conditioning energy saved in kW/hyr/tree, air pollutant uptake in pounds/yr/tree, rainfall intercepted in gallons/yr/tree. These values reflect the assumption that 22.5% of all trees planted will die over 40 years. Energy and CO_2 benefits for residential yard trees (Private) are broken out by tree location to show how shading impacts vary among trees opposite west, south, and east facing building walls. In the Aesthetics and Other Benefits row, the dollar value for Private trees replaces values in resource units since there is no resource unit for this type of benefit. For the remaining rows, the first column contains dollar values for Private trees.

The second column for each five-year interval contains dollar values obtained by multiplying resource units by local prices (kWh saved x $/kWh). In the Aesthetics and Other Benefits row and all subsequent rows, the dollar values are for a Public tree (street/park).

Costs for the Private and Public tree do not vary by location. Although Tree and Planting costs are assumed to occur initially at Year 1, we divided this value by five years to derive an average annual cost for the first five-year period. All other costs, as well as benefits, are the estimated values for each year and not values averaged over five years.

Total Net Benefits are calculated by subtracting Total Costs from Total Benefits. Data are presented for a Private tree opposite west, south, and east facing walls, as well as the Public tree.

The last two columns in each table present 40-year average values. These numbers were calculated by dividing the total stream of annual costs and benefits (not shown in Tables A1-A3 due to lack of space) by 40 years.

Table A1. Data table for small tree (yew pine)

SMALL TREE	Year 5		Year 10		Year 15		Year 20		Year 25		Year 30		Year 35		Year 40		40 year average	
Benefits	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$
Cooling (kWh)																		
Private: West	4	0.52	13	1.61	23	2.74	31	3.68	38	4.56	43	5.16	48	5.69	52	6.22	31	$3.77
Private: South	4	0.42	11	1.32	19	2.28	26	3.09	32	3.85	37	4.38	40	4.84	44	5.29	27	$3.18
Private: East	3	0.35	9	1.12	16	1.94	22	2.66	28	3.33	32	3.80	35	4.22	38	4.61	23	$2.75
Public	0	0.05	2	0.25	5	0.55	7	0.87	10	1.16	12	1.41	14	1.62	15	1.78	8	$0.96
Heating (kBtu)																		
Private: West	-137	-0.81	-259	-1.54	-370	-2.20	-443	-2.64	-511	-3.05	-551	-3.28	-589	-3.51	-631	-3.76	-436	-$2.60
Private: South	-215	-1.28	-411	-2.45	-592	-3.53	-715	-4.26	-829	-4.94	-898	-5.35	-963	-5.74	-1,033	-6.15	-707	-$4.21
Private: East	-149	-0.89	-283	-1.68	-404	-2.41	-485	-2.89	-561	-3.34	-605	-3.61	-648	-3.86	-694	-4.13	-479	-$2.85
Public	2	0.01	11	0.07	25	0.15	39	0.23	52	0.31	63	0.38	73	0.43	80	0.48	43	$0.26
Net Energy (kBtu)																		
Private: West	-93	-0.29	-125	0.06	-141	0.54	-136	1.04	-131	1.51	-121	1.88	-114	2.18	-112	2.46	-122	$1.17
Private: South	-180	-0.86	-301	-1.13	-402	-1.25	-457	-1.17	-508	-1.09	-533	-0.97	-559	-0.90	-591	-0.86	-441	-$1.03
Private: East	-120	-0.54	-190	-0.57	-242	-0.46	-263	-0.23	-283	-0.01	-288	0.20	-296	0.36	-309	0.48	-249	-$0.10
Public	6	0.06	32	0.32	70	0.69	111	1.10	149	1.47	181	1.79	208	2.05	229	2.26	123	$1.22
Net CO_2 (lb)																		
Private: West	-12	-0.18	-17	-0.26	-24	-0.36	-28	-0.42	-31	-0.47	-33	-0.50	-35	-0.53	-38	-0.57	-27	-$0.41
Private: South	-23	-0.35	-40	-0.60	-57	-0.86	-69	-1.03	-80	-1.19	-86	-1.29	-92	-1.38	-99	-1.48	-68	-$1.02
Private: East	-15	-0.22	-24	-0.37	-35	-0.52	-42	-0.62	-48	-0.72	-52	-0.77	-55	-0.83	-59	-0.89	-41	-$0.62
Public	3	0.04	8	0.12	11	0.16	14	0.21	16	0.24	18	0.28	20	0.30	21	0.32	14	$0.21
Air Pollution (lb)																		
O_3 uptake	0.016	0.21	0.074	0.92	0.150	1.88	0.212	2.65	0.252	3.15	0.288	3.59	0.299	3.74	0.311	3.88	0.20	$2.50
NO2 uptake+avoided	0.004	0.05	0.018	0.23	0.037	0.46	0.052	0.65	0.062	0.77	0.071	0.88	0.073	0.92	0.076	0.95	0.05	$0.61
SO_2 uptake+avoided	0.014	0.07	0.050	0.23	0.090	0.42	0.125	0.58	0.154	0.71	0.177	0.82	0.193	0.89	0.208	0.96	0.13	$0.58
PM_{10} uptake+avoided	0.050	0.31	0.164	1.02	0.287	1.78	0.370	2.29	0.410	2.54	0.448	2.78	0.449	2.79	0.456	2.83	0.33	$2.04
VOC's avoided	-0.002	-0.00	-0.003	-0.01	-0.004	-0.01	-0.004	-0.01	-0.004	-0.01	-0.004	-0.01	-0.004	-0.01	-0.004	-0.01	-0.00	-$0.01
BVOC's released	-0.001	-0.00	-0.002	-0.00	-0.002	-0.00	-0.003	-0.01	-0.004	-0.01	-0.004	-0.01	-0.004	-0.01	-0.005	-0.01	-0.00	-$0.01
Avoided + net uptake	0.082	0.63	0.301	2.39	0.559	4.53	0.752	6.16	0.871	7.16	0.975	8.05	1.006	8.31	1.042	8.60	0.70	$5.73
Hydrology (gal)																		
Rainfall interception	531	1.09	929	1.91	1,265	2.60	1,525	3.16	1,786	3.72	2,033	4.25	2,206	4.64	2,392	5.06	1,583	$3.30
Aesthetics and	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public
Other Benefits	$15.17	$17.88	$12.07	$14.22	$10.52	$12.39	$9.54	$11.25	$8.86	$10.44	$8.34	$9.83	$7.94	$9.35	$7.60	$8.96	$10.01	$11.79
Total Benefits	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public
Private: West	$16.41		$16.17		$17.82		$19.49		$20.78		$22.02		$22.54		$23.15		$19.80	
Private: South	$15.68		$14.64		$15.54		$16.67		$17.45		$18.38		$18.62		$18.92		$16.99	
Private: East	$16.13		$15.43		$16.66		$18.01		$19.01		$20.07		$20.43		$20.85		$18.32	
Public		$19.70		$18.96		$20.38		$21.87		$23.04		$24.20		$24.66		$25.19		$22.25
SMALL TREE	Year 5		Year 10		Year 15		Year 20		Year 25		Year 30		Year 35		Year 40		40 year average	
Costs ($/yr/tree)	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public
Tree & Planting	21.2	19.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	$2.65	$2.38
Trimming	1.43	6.35	1.39	10.18	11.78	9.90	11.45	9.63	11.13	9.35	10.80	9.08	10.47	8.80	10.80	9.08	$7.53	$9.37
Remove & Dispose	0.67	0.67	0.48	0.48	0.58	0.58	0.65	0.65	0.72	0.72	0.77	0.77	0.82	0.82	0.86	0.86	$0.64	$0.64
Pest & Disease	0.21	0.04	0.29	0.05	0.34	0.06	0.38	0.07	0.40	0.07	0.42	0.08	0.43	0.08	0.47	0.09	$0.35	$0.06
Infrastructure	0.26	1.05	0.26	1.02	0.25	0.99	0.94	3.78	0.92	3.67	0.89	3.56	0.86	3.45	0.89	3.56	$0.61	$2.43
Irrigation	0.10	0.10	0.16	0.16	0.21	0.21	0.25	0.25	0.29	0.29	0.32	0.32	0.34	0.34	0.39	0.39	$0.24	$1.34
Clean-Up	0.21	1.61	0.30	2.23	0.35	2.62	0.38	2.88	0.41	3.07	0.43	3.21	0.44	3.30	0.48	3.57	$0.35	$2.66
Liability & Legal	0.11	0.45	0.11	0.44	0.11	0.43	0.41	1.63	0.40	1.59	0.39	1.54	0.37	1.49	0.39	1.54	$0.26	$1.05
Admin & Other	0.00	0.77	0.00	1.06	0.00	1.25	0.00	1.37	0.00	1.46	0.00	1.53	0.00	1.57	0.00	1.70	$0.00	$1.27
Total Costs	$24.20	$30.04	$2.99	$15.62	$13.62	$16.04	$14.47	$20.27	$14.26	$20.22	$14.01	$20.07	$13.74	$19.85	$14.26	$20.79	$12.63	$21.19
Total Net Benefits																		
Private: West	-$8		$13		$4		$5		$7		$8		$9		$9		$7	
Private: South	-$9		$12		$2		$2		$3		$4		$5		$5		$4	
Private: East	-$8		$12		$3		$4		$5		$6		$7		$7		$6	
Public		-$10		$3		$4		$2		$3		$4		$5		$4		$1

Table A2. Data table for medium tree (jacaranda)

MEDIUM TREE	Year 5		Year 10		Year 15		Year 20		Year 25		Year 30		Year 35		Year 40		40 year average	
Benefits	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$
Cooling (kWh)																		
Private: West	4	0.52	15	1.78	27	3.24	38	4.57	49	5.81	56	6.75	63	7.55	69	8.27	40	$4.81
Private: South	4	0.42	13	1.50	23	2.78	33	3.99	43	5.11	50	5.98	56	6.71	61	7.35	35	$4.23
Prvate: East	3	0.31	10	1.19	19	2.28	28	3.35	36	4.33	43	5.12	48	5.78	53	6.34	30	$3.59
Public	1	0.12	5	0.64	12	1.40	18	2.21	25	2.96	30	3.61	35	4.14	38	4.55	20	$2.45
Heating (kBtu)																		
Private: West	-78	-0.46	-133	-0.79	-174	-1.03	-190	-1.13	-205	-1.22	-207	-1.23	-212	-1.26	-223	-1.33	-177	-$1.06
Private: South	-145	-0.86	-264	-1.57	-365	-2.17	-423	-2.52	-478	-2.85	-505	-3.01	-533	-3.17	-567	-3.38	-410	-$2.44
Prvate: East	-50	-0.30	-79	-0.47	-94	-0.56	-92	-0.55	-91	-0.54	-83	-0.49	-78	-0.46	-79	-0.47	-81	-$0.48
Public	6	0.03	29	0.17	63	0.37	99	0.59	133	0.79	162	0.96	185	1.10	204	1.21	110	$0.66
Net Energy (kBtu)																		
Private: West	-34	0.06	15	0.99	97	2.20	192	3.44	280	4.59	357	5.52	419	6.29	468	6.94	224	$3.75
Private: South	-110	-0.44	-139	-0.07	-132	0.61	-90	1.47	-52	2.26	-6	2.97	28	3.54	46	3.97	-57	$1.79
Prvate: East	-23	0.02	21	0.72	97	1.72	187	2.80	271	3.79	345	4.63	405	5.32	450	5.87	219	$3.11
Public	16	0.16	82	0.81	180	1.77	284	2.80	380	3.75	463	4.57	530	5.24	583	5.76	315	$3.11
Net CO_2 (lb)																		
Private: West	0	0.00	5	0.07	8	0.11	13	0.19	17	0.26	22	0.33	25	0.38	28	0.42	15	$0.22
Private: South	-9	-0.14	-15	-0.22	-22	-0.32	-23	-0.35	-25	-0.37	-24	-0.36	-24	-0.36	-26	-0.39	-21	-$0.32
Prvate: East	2	0.04	7	0.11	11	0.16	16	0.24	21	0.31	25	0.38	29	0.43	31	0.47	18	$0.27
Public	8	0.12	17	0.26	24	0.37	32	0.48	39	0.59	46	0.68	51	0.76	55	0.82	34	$0.51
Air Pollution (lb)																		
O_3 uptake	0.039	0.49	0.177	2.21	0.361	4.51	0.509	6.36	0.604	7.55	0.690	8.62	0.718	8.96	0.745	9.31	0.48	$6.00
NO2 uptake+avoided	0.010	0.12	0.044	0.55	0.089	1.11	0.125	1.57	0.148	1.85	0.169	2.12	0.176	2.20	0.183	2.28	0.12	$1.47
SO_2 uptake+avoided	0.019	0.09	0.074	0.34	0.145	0.67	0.209	0.96	0.261	1.20	0.303	1.40	0.332	1.53	0.357	1.65	0.21	$0.98
PM_{10} uptake+avoided	0.121	0.75	0.393	2.44	0.689	4.27	0.887	5.50	0.984	6.10	1.075	6.66	1.078	6.68	1.093	6.78	0.79	$4.90
VOC's avoided	-0.001	-0.00	-0.000	-0.00	0.001	0.00	0.003	0.01	0.005	0.01	0.006	0.01	0.007	0.01	0.008	0.02	0.00	$0.01
BVOC's released	-0.001	-0.00	-0.002	-0.00	-0.003	-0.01	-0.003	-0.01	-0.004	-0.01	-0.005	-0.01	-0.006	-0.01	-0.007	-0.01	-0.00	-$0.01
Avoided + net uptake	0.187	1.45	0.687	5.54	1.282	10.56	1.730	14.39	1.997	16.71	2.238	18.80	2.305	19.38	2.380	20.02	1.60	$13.36
Hydrology (gal)																		
Rainfall Interception	419	0.83	774	1.54	1,049	2.11	1,302	2.62	1,528	3.07	1,815	3.71	2,020	4.19	2,264	4.72	1,396	$2.85
Aesthetics and	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public
Other Benefits	$27.63	$32.56	$25.25	$29.76	$24.13	$28.43	$23.46	$27.65	$23.02	$27.13	$22.71	$26.76	$22.48	$26.49	$22.30	$26.28	$23.87	$28.13
Total Benefits	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public
Private: West	$29.96		$33.39		$39.11		$44.10		$47.64		$51.07		$52.72		$54.41		$44.05	
Private: South	$29.32		$32.03		$37.09		$41.59		$44.68		$47.83		$49.22		$50.64		$41.55	
Prvate: East	$29.96		$33.16		$38.68		$43.50		$46.89		$50.23		$51.80		$53.39		$43.45	
Public		$35.11		$37.91		$43.24		$47.94		$51.24		$54.53		$56.06		$57.61		$47.96
MEDIUM TREE	Year 5		Year 10		Year 15		Year 20		Year 25		Year 30		Year 35		Year 40		40 year average	
Costs ($/yr/tree)	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public
Tree & Planting	21.2	19.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	$2.65	$2.38
Trimming	1.43	6.35	11.87	10.18	11.78	9.90	11.45	9.63	11.13	9.35	10.80	9.08	10.47	8.80	10.14	8.53	$9.65	$9.25
Remove & Dispose	0.87	0.87	0.59	0.60	0.72	0.72	0.81	0.81	0.88	0.88	0.95	0.95	1.00	1.00	1.05	1.05	$0.79	$0.79
Pest & Disease	0.27	0.05	0.36	0.07	0.43	0.08	0.47	0.09	0.49	0.09	0.51	0.09	0.53	0.10	0.53	0.10	$0.43	$0.08
Infrastructure	0.26	1.05	0.26	1.02	0.97	3.88	0.94	3.78	0.92	3.67	0.89	3.56	0.86	3.45	0.84	3.34	$0.43	$2.93
Irrigation	0.18	0.18	0.30	0.30	0.41	0.41	0.51	0.51	0.61	0.61	0.69	0.69	0.77	0.77	0.84	0.84	$0.73	$1.60
Clean-Up	0.28	2.07	0.37	2.81	0.44	3.27	0.48	3.57	0.50	3.79	0.52	3.93	0.54	4.03	0.55	4.09	$0.50	$3.29
Liability & Legal	0.11	0.45	0.11	0.44	0.42	1.68	0.41	1.63	0.40	1.59	0.39	1.54	0.37	1.49	0.36	1.45	$0.44	$1.27
Admin & Other	0.00	0.99	0.00	1.34	0.00	1.56	0.00	1.70	0.00	1.80	0.00	1.87	0.00	1.92	0.00	1.95	$0.32	$1.57
Total Costs	$24.60	$31.01	$13.86	$16.76	$15.17	$21.50	$15.07	$21.72	$14.93	$21.78	$14.75	$21.72	$14.54	$21.56	$14.31	$21.34	$15.93	$23.15
Total Net Benefits																		
Private: West	$5		$20		$24		$29		$33		$36		$38		$40		$28	
Private: South	$5		$18		$22		$27		$30		$33		$35		$36		$26	
Prvate: East	$5		$19		$24		$28		$32		$35		$37		$39		$28	
Public		$4		$21		$22		$26		$29		$33		$34		$36		$25

Table A3. Data table for large tree (camphor)

LARGE TREE	Year 5		Year 10		Year 15		Year 20		Year 25		Year 30		Year 35		Year 40		40 year average	
Benefits/tree	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$	Res units	$
Cooling (kWh)																		
Private: West	8	0.99	28	3.41	52	6.23	74	8.83	94	11.25	109	13.09	122	14.65	134	16.04	78	$9.31
Private: South	8	0.99	28	3.41	52	6.23	74	8.83	94	11.24	109	13.08	122	14.64	134	16.04	78	$9.31
Prvate: East	6	0.72	22	2.65	42	5.00	60	7.24	78	9.33	92	10.97	103	12.35	113	13.54	64	$7.73
Public	2	0.25	11	1.28	23	2.79	37	4.41	49	5.91	60	7.19	69	8.24	76	9.07	41	$4.89
Heating (kBtu)																		
Private: West	-156	-0.93	-267	-1.59	-349	-2.08	-381	-2.27	-412	-2.46	-417	-2.48	-426	-2.54	-449	-2.67	-357	-$2.13
Private: South	-433	-2.58	-806	-4.80	-1,135	-6.76	-1,342	-7.99	-1,536	-9.15	-1,643	-9.79	-1,747	-10.40	-1,868	-11.12	-1,314	-$7.83
Prvate: East	-201	-1.20	-356	-2.12	-478	-2.84	-539	-3.21	-597	-3.55	-618	-3.68	-643	-3.83	-681	-4.06	-514	-$3.06
Public	11	0.07	57	0.34	125	0.75	198	1.18	265	1.58	322	1.92	369	2.20	406	2.42	219	$1.31
Net Energy (kBtu)																		
Private: West	-73	0.06	17	1.82	172	4.16	355	6.56	526	8.79	676	10.61	796	12.11	890	13.37	420	$7.18
Private: South	-351	-1.59	-522	-1.39	-615	-0.53	-605	0.83	-598	2.09	-551	3.30	-525	4.24	-529	4.92	-537	$1.48
Prvate: East	-141	-0.48	-135	0.53	-60	2.15	66	4.03	182	5.78	298	7.29	388	8.52	449	9.48	131	$4.66
Public	32	0.31	164	1.62	358	3.54	565	5.58	758	7.48	923	9.11	1,058	10.44	1,163	11.49	628	$6.20
Net CO_2 (lb)																		
Private: West	-10	-0.14	20	0.30	60	0.90	98	1.47	127	1.91	150	2.26	166	2.49	176	2.64	99	$1.48
Private: South	-47	-0.70	-52	-0.78	-45	-0.67	-30	-0.46	-23	-0.34	-13	-0.20	-10	-0.15	-13	-0.20	-29	-$0.44
Prvate: East	-18	-0.27	2	0.03	33	0.50	64	0.96	87	1.31	107	1.60	119	1.78	125	1.87	65	$0.97
Public	7	0.10	46	0.69	96	1.43	139	2.09	175	2.62	201	3.02	221	3.31	234	3.51	140	$2.10
Air Pollution (lb)																		
O_3 uptake	0.073	0.92	0.330	4.12	0.672	8.39	0.948	11.84	1.124	14.05	1.284	16.04	1.336	16.69	1.387	17.33	0.89	$11.17
NO2 uptake+avoided	-0.018	-0.22	0.101	1.26	0.279	3.48	0.457	5.71	0.603	7.54	0.733	9.15	0.818	10.22	0.887	11.08	0.48	$6.03
SO_2 uptake+avoided	0.038	0.17	0.149	0.69	0.289	1.34	0.415	1.92	0.518	2.39	0.603	2.79	0.660	3.05	0.711	3.29	0.42	$1.95
PM_{10} uptake+avoided	0.223	1.38	0.733	4.55	1.290	8.00	1.666	10.33	1.854	11.49	2.029	12.58	2.040	12.65	2.073	12.85	1.49	$9.23
VOC's avoided	-0.003	-0.01	-0.003	-0.00	-0.001	-0.00	0.002	0.00	0.005	0.00	0.007	0.01	0.009	0.02	0.011	0.02	0.00	$0.01
BVOC's released	-0.001	-0.00	-0.002	-0.00	-0.004	-0.01	-0.005	-0.01	-0.007	-0.01	-0.009	-0.02	-0.011	-0.02	-0.013	-0.02	-0.01	-$0.01
Avoided + net uptake	0.312	2.24	1.308	10.60	2.525	21.20	3.483	29.80	4.097	35.46	4.647	40.56	4.852	42.60	5.056	44.54	3.28	$28.38
Hydrology (gal)																		
Rainfall Interception	209	0.45	740	1.54	1,270	2.59	1,799	3.61	2,354	4.73	2,910	5.84	3,519	7.19	4,159	8.51	2,120	$4.31
Aesthetics and	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public
Other Benefits	$34.47	$40.63	$39.51	$46.56	$41.80	$49.26	$43.70	$51.50	$45.54	$53.67	$47.41	$55.88	$49.33	$58.13	$51.28	$60.43	$44.13	$52.01
Total Benefits	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public
Private: West	$37.09		$53.78		$70.65		$85.13		$96.43		$106.68		$113.72		$120.35		$85.48	
Private: South	$34.88		$49.49		$64.39		$77.49		$87.49		$96.92		$103.21		$109.05		$77.87	
Prvate: East	$36.43		$52.22		$68.24		$82.10		$92.82		$102.71		$109.42		$115.69		$82.45	
Public		$43.74		$61.03		$78.03		$92.58		$103.97		$114.41		$121.68		$128.48		$92.99

LARGE TREE	Year 5		Year 10		Year 15		Year 20		Year 25		Year 30		Year 35		Year 40		40 year average	
Costs ($/yr/tree)	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public
Tree & Planting	21.20	19.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	$2.65	$2.38
Trimming	1.43	6.35	12.11	10.18	11.78	9.90	11.45	9.63	11.13	9.35	10.80	9.08	10.47	8.80	10.80	9.08	$9.94	$9.37
Remove & Dispose	0.86	0.86	0.74	0.74	1.01	1.01	1.27	1.27	1.50	1.50	1.72	1.72	1.92	1.92	2.12	2.12	$1.26	$1.26
Pest & Disease	0.27	0.05	0.45	0.08	0.60	0.11	0.73	0.13	0.84	0.15	0.93	0.17	1.01	0.18	1.15	0.21	$0.69	$0.13
Infrastructure	0.26	1.05	1.00	3.99	0.97	3.88	1.10	4.42	1.07	4.29	1.33	5.34	1.29	5.17	1.33	5.34	$0.96	$3.82
Irrigation	0.24	0.24	0.44	0.44	0.63	0.63	0.82	0.82	1.01	1.01	1.20	1.20	1.38	1.38	1.65	1.65	$0.84	$1.94
Clean-Up	0.27	2.06	0.46	3.43	0.61	4.61	0.75	5.60	0.86	6.45	0.95	7.16	1.04	7.77	1.17	8.81	$0.71	$5.31
Liability & Legal	0.11	0.45	0.43	1.73	0.42	1.68	0.48	1.91	0.46	1.86	0.58	2.31	0.56	2.24	0.58	2.31	$0.41	$1.66
Admin & Other	0.00	0.98	0.00	1.64	0.00	2.19	0.00	2.67	0.00	3.07	0.00	3.41	0.00	3.70	0.00	4.19	$0.00	$2.53
Total Costs	$24.65	$31.05	$15.62	$22.22	$16.03	$24.02	$16.61	$26.45	$16.88	$27.69	$17.52	$30.39	$17.68	$31.17	$18.80	$33.70	$17.46	$28.39
Total Net Benefits																		
Private: West	$12		$38		$55		$69		$80		$89		$96		$102		$68	
Private: South	$10		$34		$48		$61		$71		$79		$86		$90		$60	
Prvate: East	$12		$37		$52		$65		$76		$85		$92		$97		$65	
Public		$13		$39		$54		$66		$76		$84		$91		$95		$65

Tree Planting Example: The City of Buena Vista

To illustrate how information in this Appendix can be adjusted to apply to a specific project, consider this example. As a municipal cost-cutting measure, the City of Buena Vista is planning to no longer require street tree planting with new development. Instead, developers will be required to plant yard trees. These yard trees will not receive care from municipal arborists, thereby reducing costs to the city. The community forester and local non-profit believe that although this policy will result in lower costs for tree care, the benefits "forgone" will exceed cost savings. The absence of street trees in new development will mean that benefits are not captured because street trees can enhance neighborhood aesthetics, property values, air quality, water quality, and other aspects of the environment.

As a first step in the analysis, the forester and local non-profit group decide to quantify the total cumulative benefits and costs over 40 years for a typical street tree planting of 100 trees in Buena Vista. Based on planting records this would include 50 large trees, 30 medium trees, and 20 small trees. Three aspects of the Buena Vista planting program are different than assumed in Appendix A: ❶ the price of electricity is $0.14/kWh, not the $0.12/kWh assumed in the Appendix, ❷ no funds are spent on pest and disease control, and ❸ planting costs are higher than the assumed value of $95/tree for 15-gal trees because, although the non-profit plants 15-gal trees and these account for 50% of the street trees planted in Buena Vista, all large trees are planted by the City in 24-inch boxes at a cost of $215 each.

To calculate the dollar value of total benefits and costs for the 40-year period, the last column in Appendix A (40-Year Average) is multiplied by 40 years. Since this value is for one tree it must be multiplied by the total number of trees planted in the respective large, medium, or small tree size classes. To adjust for higher electricity prices we multiply electricity saved for a Large Public tree in the resource unit column by the Buena Vista price (41 kWh x $0.14 = $5.74). This value is multiplied by 40 years and 50 trees ($5.74 x 40 x 50 = $11,480) to obtain cumulative air conditioning savings for the project (Table A4). The same steps are followed for medium and small trees.

To adjust the cost figures, we eliminate a row for pest and disease control costs in Table 2. We multiply 50 Large trees by the unit planting cost ($215) to obtain the adjusted cost for Buena Vista (50 x $215 = $10,750). The average annual 40-year costs for other items are multiplied by 40 years and the appropriate number of trees to compute total costs. These 40-year cost values are entered into Table A4.

Net benefits are calculated by subtracting total costs from total benefits for the large ($142,370), medium ($35,796), and small ($2,960) trees. The total net benefit for the 40-year period is $181,126 (total benefits - total costs). This result indicates that by not investing in street tree planting and stewardship the City saves $996/tree ($99,582/100 trees) on average, and forgoes $2,807/tree in benefits, for a net loss of potential benefits in the amount of $1,811/tree. The analysis assumes 22.5% of the planted trees die. It does not account for the time value of money from a municipal capital investment perspective, but this could be done using the municipal discount rate. Also, for a more complete analysis it is important to consider the extent to which benefits from increased yard tree plantings may offset the loss of street tree benefits.

Table A4. Estimated 40-year total benefits and costs for the City of Buena Vista street tree planting (100 trees).

	50 Large Trees		**30 Medium Trees**		**20 Small Trees**		**100 Trees**	**Total**
Benefits	Res units	$	Res units	$	Res units	$	Res units	$
Electricity (kWh)	82,000	11,480	24,000	3,360	6,400	896	112,400	15,736
Natural Gas (kBtu)	438,000	2,620	132,000	792	34,400	208	604,400	3,620
Net Energy (kBtu)	1,256,000	12,400	378,000	3,732	98,400	976	1,732,400	17,108
Net CO_2 (lb)	280,000	4,200	40,800	612	11,200	168	332,000	4,980
Air Pollution (lb)	6,000	56,760	2,400	16,032	800	4,584	9,200	77,376
Hydrology (gal)	4,240,000	8,620	1,675,200	3,420	1,266,400	2,640	7,181,600	14,680
Aesthetics/Other Benefits		104,020		33,756		9,432		147,208
Total Benefits		**$200,100**		**$61,704**		**$18,904**		**$280,708**
Costs		Public		Public		Public		Public
Tree & Planting		10,750		2,856		1,904		15,510
Pruning		18,740		11,100		7,496		37,336
Remove & Dispose		2,520		948		512		3,980
Infrastructure		260		96		48		404
Irrigation		7,640		3,516		1,944		13,100
Clean-Up		3,880		1,920		1,072		6,872
Liability & Legal		10,620		3,948		2,128		16,696
Admin & Other		3,320		1,524		840		5,684
Total Costs		**$57,730**		**$25,908**		**$15,944**		**$99,582**
Total Net Benefits		**$142,370**		**$35,796**		**$2,960**		**$181,126**

Appendix B.

Funding Opportunities for Urban Forestry in California

Compiled December 1999
by California ReLeaf
The Trust for Public Land
116 New Montgomery St., Suite 300
San Francisco, CA 94105
(415) 495-5660
www.tpl.org/cal

SECTION 1. GRANT PROGRAMS DESIGNATED IN WHOLE OR IN PART FOR URBAN FORESTRY PROJECTS

American Forests/Global ReLeaf Forest Cost-Share Grants

Funds available: Not specified

Application deadline: January 1, 2000; July 1, 2000

Notification: March 1, 2000; September 1, 2000

Grant period: One year (multi-year projects are accepted)

Min/max award: No minimum/maximum
(previous grants range from $300 - $30,000)

Eligible applicants: Groups interested in tree-planting and forestry or riparian restoration programs

Description: Tree planting or environmental improvement projects that involve an organization and other public or private sector partners who are willing to partner with American Forests. The projects can be on public land or certain public-assisted private lands meeting special criteria. The planting area must be 20 acres or more and have been damaged by wildfire, hurricane, tornado, insects, disease, or misguided treatment by humans. Only projects where funding from regular programs or sources is not available qualify.

Contacts: American Forests (Attn: Bill Tikkala)
P.O. Box 2000
Washington, DC 20013
(202) 955-4500 x204
amfor.org

International Society of Arboriculture Hyland R. Johns Grant Program

Funds available: $55,000

Application deadline: May 1, 2000

Grant period: One to two years

Notification: September 30, 2000

Min/max award: Minimum $5,000; maximum $20,000

Eligible applicants: Individuals privately or publicly employed in various fields, including arboriculture, urban forestry, horticulture, plant pathology, entomology,and soil science.

Description: Research projects of interest and benefit to the arboricultural industry that fall within one or more of the following research priority areas: ecological benefits of the urban forest; economic benefits of the urban forest; innovative tree-care techniques and practices; urban tree genetics; impact of the urban forest on energy consumption; and basic tree biology.

Contact: ISA Research Trust Grant Program
P.O. Box 3129
Champaign, IL 61826
(217) 355-9411
isa–arbor.com

National Tree Trust Community Tree-Planting Grant Program

Funds available: Grants of one-year-old seedlings, 2-gallon containers, and cash subsidies for soil ($10 per cubic yard)

Application deadline: May 31, 2000 (Part 1: Seedling Order Forms, available in January 2000);

July (Part 2: Project Information Forms mailed by National Tree Trust)

October 1, 2000 (Part 2: Project Information Forms)

Notification: Late-Autumn/Winter 2000 (approval of grant)

Grant period: Seedlings delivered in Spring 2001

Min/max award: Maximum 1,000 seedlings and containers for first-time recipients. Seedlings must be requested in increments of 100.

Eligible applicants: Nonprofit organizations, schools, municipalities, counties, state and federal agencies

Description: Projects that plant seedlings on public property or that establish a growing center for raising seedlings; to an appropriate size for planting and projects that plant seedlings along streets or highways, or on any land under the jurisdiction of a transportation authority. A list of species available is provided with Part 1 of the application.

Contact: National Tree Trust
1120 G Street, NW, Suite 770
Washington, DC 20005
☎(800) 846-8733
www.nationaltreetrust.org

SECTION 2. ENVIRONMENTAL EDUCATION GRANT PROGRAMS THAT OFFER POSSIBILITIES FOR URBAN FORESTRY PROJECTS

Environmental Quality Incentives Program

Funds available: Not specified

Application deadline: January 7, 2000

Notification: March 15, 2000

Grant period: Project are to be completed between May 1,2000 and September 30, 2001

Min/max award: Two grant categories: grants up to $10,000; grants from $10,001 to $30,000

Eligible applicants: Nonprofit conservation, agricultural, commodity, and environmental organizations

Description: Educate farmers and ranchers to use sound conservation practices. Grants are to provide nonprofit organizations the opportunity to conduct educational activities and create support materials to encourage farmers and ranchers to install natural resource enhancements. Educational activities and materials should address resource concerns that have been identified at the local level and provide cost-effective and technically sound ways to conserve and improve soil, water, air, and related natural resources. Educational activities and materials can include workshops, field days, seminars, tours, news releases, demonstrations, brochures, and fact sheets.

Contact: USDA, Natural Resources Conservation Service
430 G St., #4164
Davis, CA 95616-4164
(530) 792-5646
www.ca.nrcs.usda.gov/eqip/index.html

Toyota Tapestry Grants for Teachers

Funds available: $500,000

Application deadline: January 20, 2000

Notification: March 1, 2000

Grant period: Projects must begin by June 1, 2000, and funds must be spent by May 31, 2001

Min/max award: Maximum $10,000

Eligible applicants: Middle- and high-school science teachers(defined as those that spend at least 50% of their classroom time teaching science); elementary school teachers who teach science in a self-contained classroom setting or as teaching specialists. All applicants must have at least three years' science teaching experience.

Description: Two categories of grants: (1) Environmental education: projects that emphasize the efficient use of natural resources and protection of the environment; students participating in these projects should gain an increased awareness of the terrestrial, aquatic, and/or atmospheric environment and an understanding of their own interdependence on the natural world. (2) Physical science applications: projects that relate the laws, principles, and concepts of physics and chemistry to phenomena and events relevant to students' lives and that involve students' own experiences and interests.

Contact: Toyota Tapestry
c/o National Science Teachers Association
1840 Wilson Boulevard
Arlington, VA 22201-3000
(800) 807-9852
www.nsta.org/programs/toyota.htm

SECTION 3. OTHER GRANT AND SUPPORT PROGRAMS THAT OFFER POSSIBILITIES FOR URBAN FORESTRY PROJECTS

The Conservation Technology Support Program

Funds available: Grants of hardware, software, and technical support for Geographic Information Systems (GIS) only (no monetary grants are awarded)

Application deadline: January 7, 2000

Grant period: One year (includes one year of technical support)

Notification: Late-April 2000

Eligible applicants: Non-profit organizations that focus on conservation, restoration, or enhancement of natural resources; have 501(c)3 status or a formal relationship with a 501(c)3 fiscal agent, or expect to have 501(c)3 status by April, 2000, and have annual budgets of less than $2 million (focus is on organizations with annual budgets of less than $100,000). Applicants that receive a grant must also attend a three-day training program.

Description: Formed to aid non-profit conservation organizations that use GIS in carrying out their mission. Two grant levels: Basic(computer/printer/software) and Special (particular to items you request).NOTE: applicants are strongly encouraged to review the website [www.ctsp.org] and/or use e-mail rather than calling for details on applying for a grant.

Contact: Conservation Technology Support Program
Amy Karon, CTSP Coordinator
201 Mission St., 4th Floor
San Francisco, CA 94105
(415) 979-0474
ctsp@ctsp.org(preferred)
www.ctsp.org

Do Something Brick Award for Community Leadership

Funds available: Up to $190,000

Application deadline: May 10, 2000

Notification: July 2000

Grant period: Not specified

Min/max award: Up to nine $10,000 grants; one $100,000 grand prize grant

Eligible applicants: Individuals under the age of 30 as of May10, 2000

Description: Individuals are recognized for solving problems and improving their communities; a long-term commitment to and vision for a healthier and stronger community; a proven ability to bring people together for a larger goal; and a wide range of skills and talents in community-building action. Qualifying activities must be within a geographic area no larger than city-wide. Grants must be used to continue the winners' work by furthering the goals of an existing community program or establishing a new one.

Contact: Do Something BRICK Award
Attn: Lara Galinsky
423 West 55th St., 8th Floor
New York, NY 10019
(212) 523-1175
brick@dosomething.org

Earth Island Institute Brower Legacy Leaders Program

Funding available: Paid internship program

Application deadlines: March 20, 2000 (internship starts May 1); July 17, 2000 (internship starts August 28)

Notification: Not specified

Internship period: Three months

Min/max award: Up to $1,000 per month

Eligible applicants: Applicants must commit a minimum of 20 hours per week to the training and work program, have a high school diploma or GED, and have an interest in environmental issues.

Description: Internships are designed to enhance environmental career development by giving interns a chance to earn money while gaining experience in the field. Interns may be trained in a variety of areas including research methods, campaign development, and coalition strategies.

Contact: Earth Island Institute / Internship Coordinator
300 Broadway, Suite 28
San Francisco, CA 94133
(415) 788-3666

Environmental Support Center Environmental Loan Fund

Funds available: Not specified

Application deadlines: January 15, March 15, June 15, September 15, 2000

Notification: Not specified

Loan period: Repayment schedule is designed to meet individual circumstances

Min/max loan: Minimum $10,000/Maximum $50,000

Eligible applicants: Local-, regional-, or state-level nonprofit organizations that devote a portion of their resources to environmental issues; have 501(c)(3) status; have been in existence for at least three years; and have at least one paid full-time staff person or the equivalent.

Description: The loan fund provides low-interest loans to help grassroots environmental organizations diversify and increase their funding sources. Projects funded include membership development, workplace giving, start-up money needed to sell mission-related products or services, donor development, special events, and other long-term, income-producing projects.

Contact: The Environmental Support Center
4420 Connecticut Ave., Suite 2
Washington, DC 20008-2301
✆(202) 966-9834
www.envsc.org
loanfund@envsc.org

Environmental Support Center Training and Organizational Assistance Program

Funds available: Not specified (amount varies)

Application deadline: Applications accepted monthly

Notification: Within one month

Grant period: One year or less

Min/max award: Maximum $2,000 for Individual Assistance; maximum $3,500 for Coalition Building; none specified for Group Training, although typically no greater than $350 per group involved.

Eligible applicants: Local, regional, or state-level nonprofit organizations (incorporated or unincorporated) that devote a portion of their resources to environmental issues.

Description: Three categories of assistance: Individual Assistance (one organization); Group Training (a number of organizations); Coalition Building (a number of organizations). In each, the project focus must be on improving capabilities and effectiveness in areas such as planning, organizing, board development, computer skills, fundraising, communications, financial management, leadership development, and collaborative strategies. Funds can be used to subsidize the costs of consultants, trainers, workshops, and networking activities.

Contact: Environmental Support Center
4420 Connecticut Ave. NW, Suite 2
Washington, DC 20008-2301
✆(202) 966-9834
www.envsc.org

Horticultural Research Institute Grant Program

Funds available: Approximately $425,000

Application deadline: May 1, 2000

Notification: Late-December 2000

Grant period: Usually one year

Min/max award: Minimum $500; maximum $50,000

Eligible applicants: Scientist and collegiate level researchers

Description: Projects that help the landscape/nursery trade to be more efficient and more profitable, and advance trade knowledge and progress.

Projects that address issues identified in "The Nursery Industry's National Research Needs" are encouraged.

Contacts: Research Coordinator
Horticultural Research Institute
1250 I Street, NW, Suite 500
Washington, DC 20005
(202) 789-5980 x3014
www.anla.org/research/

Kodak American Greenways Awards Program

Funds available: Amount varies each year

Application deadline: June 2000; (applications available March 1, 2000)

Notification: September 2000

Grant period: Varies with project

Min/max award: Maximum $2,500; most grants range from $500 to $1,000

Eligible applicants: Individuals, nonprofit organizations, public agencies (community organizations receive preference)

Description: Action-oriented projects that further the planning and development of greenways, including recreational trails, wildlife corridors, and waterways.

Contact: American Greenways Program
The Conservation Fund
1800 North Kent St., Suite 1120
Arlington, VA 22209
(703) 525-6300
www.conservationfund.org

SECTION 4. REGIONAL GRANT PROGRAMS THAT OFFER POSSIBILITIES FOR URBAN FORESTRY PROJECTS

Great Valley Center LEGACI Grant Program

Funds available: Not specified

Application deadline: January 30, 2000

Notification: April 2000

Grant period: Not specified

Min/max award: No minimum/maximum specified (average grants in 1998 were $11,400)

Eligible applicants: Community groups, nonprofit organizations, and local government agencies in the Central Valley.

Description: Projects that encourage and facilitate extensive, wide-ranging, and balanced participation in the development of sound public policy;

enhance the appreciation and conservation of natural resources; and support programs in the areas of land use, economic development, growth, agriculture, and conservation and investment. Programs that create a healthy, sustainable Central Valley and provide support for its residents, economy, and natural resources.

Contacts: Great Valley Center/LEGACI Grant
911 13th St.
Modesto, CA 95354
✆(209) 522-5103
www.greatvalley.org

Los Angeles Urban Resources Partnership Grants

Funds available: $265,000

Application deadline: Spring 2000 - pre-proposal (last year: April 30);
Summer 2000 - full proposal (last year: mid-July)

Notification: Early-Summer - finalists notified (last year: mid-June)
Late-Summer - awardees notified (last year: late-Aug)

Grant period: October 1, 2000 to September 30, 2001

Min/max award: Minimum $1,000; maximum $50,000

Eligible applicants: Applicants, or sponsors of applicants, must be public agencies, educational institutions, or nonprofit organizations

Description: Projects that address a natural resource issue or opportunity integrating one or more of the following themes: anti-littering and beautification; community environmental monitoring and stewardship; environmental education; erosion and sediment control; greenway development; municipal tree recycling; natural habitat creation and enhancement; open space enhancement; public trails creation and restoration; urban community gardens; roadbank stabilization; streambank restoration; urban agroforesty; urban forestry; urban wood recycling; water quality; wetland restoration.

Projects must be located within Los Angeles or benefit its residents; benefit underserved neighborhoods and communities; and demonstrate community involvement and the likelihood of long-term community support.

Contact: Urban Resources Partnership
201 North Figueroa Street
Suite 200, Mail Stop 177
Los Angeles, CA 90012
✆(213) 580-1055
ccochran@ead.ci.la.ca.us

San Francisco Urban Resources Partnership Grants

Funds available: $270,000 (approximate)

Application deadline: Late May (last year: May 28 for letterof intent)
July (last year: July 9 for full proposals)

Notification: Late-August (last year: August 23)

Grant period: Late-August 2000 to September 2001 (tentative)

Min/max award: Minimum $2,500; maximum $25,000 (average grants range from $5,000 -$25,000) and must be matched one-to-one with non-federal funds, in-kind services, resource donations, or volunteer labor and professional services.

Eligible applicants: Local government agencies, educational institutions, non-profit organizations, and community groups working with a non-profit as a project sponsor.

Description: Projects that are collaborative in nature and can demonstrate community involvement that will result in urban natural resource conservation. Examples include: urban and community forestry; creek, shoreline, or wetland restoration or protection; open space development and restoration; community beautification; urban natural resources education, awareness, and events that have a hands-on or on-the-ground component; public housing greening projects; environmental job training and career guidance for youth; and soil erosion and sediment control.

Projects must be located within southeast San Francisco or benefit its residents and demonstrate community involvement and the likelihood of long-term community support.

Contact: San Francisco Urban Resources Partnership
c/o San Francisco League of Urban Gardeners
2088 Oakdale Avenue
San Francisco, CA 94124
✆(415) 285-7584

SECTION 5. OTHER FUTURE GRANT PROGRAMS FOR FUNDING URBAN FORESTRY PROJECTS

The following funding programs will be accepting applications later in the year. Please contact these programs directly to obtain program descriptions, grant criteria and application deadlines.

National Fish and Wildlife Foundation Challenge Grants	(202) 857-0166
California Horticultural Society Grants Program	(800) 624-6633
National Fish and Wildlife Foundation Challenge Grants	(202) 857-0166
California Native Plant Society Educational Grants Program	(916) 447-2677
National Tree Trust Partnership Enhancement Monetary Grant Program	(800) 846-8733
National Tree Trust Tree-Planting Grant Program, Part 2	(800) 846-8733
Project Learning Tree Green Works! Grant Program	(202) 463-2472
California ReLeaf/Capacity-Building Grant Program	(949) 642-0127
ISA John Z. Duling Grant Program	(217) 355-9411
NUCFAC Challenge Cost-Share Grant Program	(209) 536-9201
Constitutional Rights Foundation's Robinson Mini-Grant Program	(213) 487-5590 x 108
Environmental Enhancement and Mitigation Program	(916) 653-5656
Environmental Protection Agency Environmental Education Grants	(415) 744-1161

Appendix C.
Local Government Programs and Ordinances

Requiring Shade Trees in New Developments:
Tree Preservation Ordinance, City of Redding

Requiring Shade Trees in Parking Lots:
Parking Lot Shading Guidelines and Master Parking Lot Tree List, City of Davis

Adopting a Tree Preservation Ordinance:
Trees and Construction: A Guide to Preservation, City of Redding

Adopting a Landscaping Ordinance to Encourage Energy Efficiency and Resource Conservation:
Sustainability in Landscaping Ordinance, City of Irvine

Using Tree Planting to Strengthen Communities and Increase Resident Involvement:
"Neighborhood Tree Project," City of Long Beach
"Cool Schools," LADWP and Los Angeles Unified School District

Municipal Utility Shade Tree Programs:
TreePower Brochure, Anaheim Public Utilities

Fruits and Vegetables Aren't the Only Things Growing in the San Joaquin Valley!

They have trees, too.

The Local Government Commission and the Western Center for Urban Forest Research and Education, USDA Forest Service, Pacific Southwest Research Station, have also teamed up to produce a version of the *Tree Guidelines* for the San Joaquin Valley.

And look for an Inland Empire guidebook later in 2000!

Who We Are: The Local Government Commission

The Local Government Commission is a non-profit, non-partisan membership organization of forward-thinking leaders that includes mayors, city councilmembers, and county supervisors, along with associate members drawn from local government staff and community leaders.

With almost 1,000 members, the LGC provides a diverse forum for exchanging ideas and inspiring local leaders to action. We provide practical, tested ideas and programs, technical assistance, networking, workshops, policy development, publications, and peer support that help foster a sustainable environment, strong economy, and social equity, as well as meaningful civic involvement.

The LGC serves cities and counties and is directed toward promoting cooperative efforts among all levels of government through such programs as land use planning for resource-efficient communities, energy efficiency and renewable energy, and waste and pollution prevention.

For more information about the LGC and its other publications:

(916) 448-1198 www.lgc.org

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