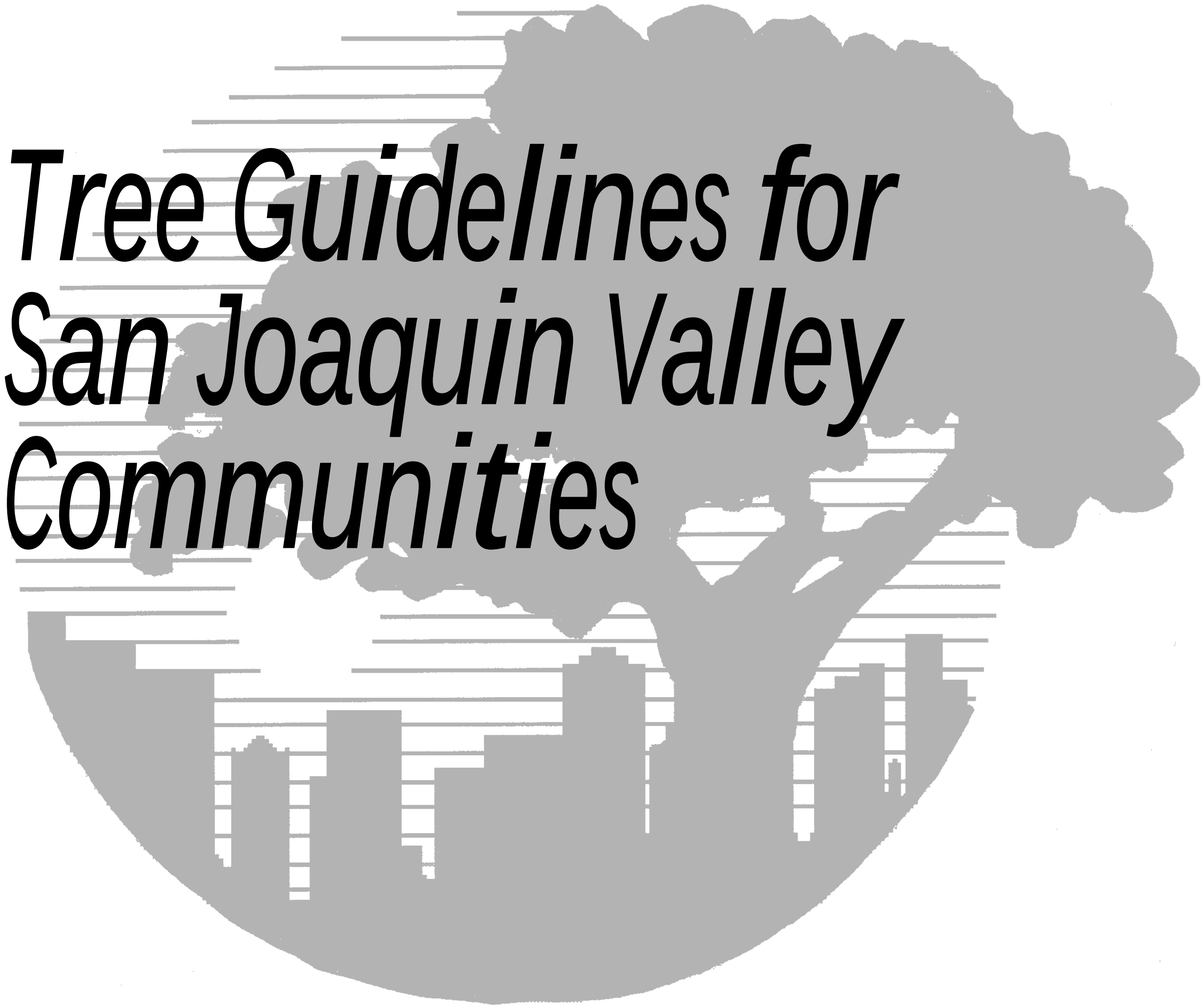
Tree Guidelines for San Joaquin Valley Communities



by

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March *1999*

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Executive Summary

San Joaquin Valley Communities will be among the fastest growing communities in the state during the next decade. 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 take on greater significance as communities strive to preserve and improve their quality of life in the face of this growth. 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 $2,000. This amount decreases with the tree's size with medium trees saving $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.

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:

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

- 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.

San Joaquin Valley 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 the San Joaquin Valley's hot, dry summer weather, potential cooling savings from trees are among the highest in the nation. Computer simulations for an energy-efficient home in Fresno indicate that shade from two 25-foot tall trees on the west side and one on the east side are estimated to save $75 each year. Evapotranspirational cooling from these three trees is estimated to increase savings by another $28.

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.

Trees can 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.

By shading asphalt surfaces and parked vehicles trees 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 entering San Joaquin Valley rivers and lakes. 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 leaflitter 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.

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.

Conifers 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. Pines, cypress, and oak are among the best windbreak trees for San Joaquin Valley 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. In San Joaquin Valley communities, 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.

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.

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, they 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 forethought. 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. Appendix B provides more background materials, contact information and a list of funding resources.

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

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 Fresno could save $103 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
Phil Carr, Associate Planner
Planning Division
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
Ken Hiatt, Associate Planner
Planning and Building Department
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

Collaboratation with Local Community Groups and Tree Organizations

City of Long Beach
Craig Beck, Community Development Analyst
Community Development Dept.
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

Introduction

San Joaquin Valley communities will be among the fastest growing in the state 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 Valley communities strive to preserve and improve their quality of life. Urban and community forestry has been recognized as a cost effective means to cool urban heat islands, improve air quality, and combat global warming.

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

San Joaquin Valley 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 infrastructure elements. Also, these same trees can also reduce atmospheric carbon dioxide (CO_2), improve air quality, reduce stormwater runoff, increase property values, enhance community attractiveness, and promote public health. Neighborhood tree plantings and stewardship projects stimulate investment by local citizens, business, and government to improve their communities. The simple act of planting trees also provides opportunities to connect residents with nature and with each other.

This report addresses a number of questions about the energy conservation potential and other benefits of urban and community forests in the San Joaquin Valley. 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.

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 temperature 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. Accelerating urbanization, especially in the San Joaquin Valley, hastens the need for energy-efficient landscapes.

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 (300-1,500 feet, or 100-500 m) 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 of the San Joaquin Valley's hot, dry summer weather, potential cooling savings from trees are among the highest in the U.S. Computer simulation of annual cooling savings for an energy-efficient home in Fresno indicated that the typical household spends about $325 each year for air conditioning (3,000 kWh, 3.4 kW peak). Shade from two 25-foot tall (7.5 m) trees on the west and one on the east was estimated to save $75 (628 kWh, 0.75 kW) each year (Simpson and McPherson 1996). Evapotranspirational cooling from these three trees was estimated to increase savings by another $28 (250 kWh) provided that a large enough number of trees were planted to reduce summertime temperatures in the neighborhood.

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. The San Joaquin Valley climate is marked by hot, dry summers with substantial cooling loads, and temperate, wet winters. Energy consumed to heat and cool buildings is relatively large compared to coastal California locations. Pacific Gas and Electric's CO_2 emissions factor for the San Joaquin Valley is approximately 0.99 lb CO_2/kWh – 24% 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 motorized 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.

Sacramento's urban forest, for example, removes approximately 304,000 tons (1.2 t/ha) of atmospheric CO_2 every year, with an implied value of $3.3 million (McPherson 1998). Avoided power plant emissions accounted for 32% of the amount sequestered (75,600 of 238,000 tons). The amount of CO_2 reduction by Sacramento's urban forest offsets 1.8% of total CO_2 emitted annually as a by-product 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 (ICLEI 1997, McPherson 1994). Although these values for Sacramento do not directly apply to San Joaquin Valley communities, they provide a good indication of the magnitude of urban forest impacts on atmospheric CO_2.

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 reduces ozone levels by lowering local air temperatures. 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 (see Chapter 5).

The total value of annual air pollutant uptake produced by Sacramento County's six million trees was $28.7 million – nearly $5 per 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.

Recently, trees in a Davis, California, 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. Planting trees in parking lots throughout the region could reduce hydrocarbon emissions comparable to the levels achieved through the local air quality district's existing programs (e.g., graphic arts, waste burning, vehicle scrappage).

Reducing Stormwater Runoff

Urban stormwater runoff is a major source of pollution entering San Joaquin Valley rivers and lakes. A healthy urban forest can reduce the amount of runoff and pollutants that enter these 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 runoff as well as soil erosion by diminishing the impact of raindrops on barren surfaces.

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, for example, 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 to 13% (averaging 150 gallons per tree), close to values reported for rural forests.

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.

Urban forests can provide other hydrologic benefits. For example, 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. Recycling urban wastewater into greenspace areas can be an economical means of treatment and disposal. During the summer, trees can also transpire large amounts of water. If trees are plentiful, they can lower ground water levels – which helps San Joaquin Valley areas where ground water tables are high.

Other Benefits and Property Values

Trees provide a host of social, economic, and health benefits that should be included in any benefit-cost analysis. 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). Additional environmental benefits from trees include noise abatement and wildlife habitat.

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 – an advantage since higher frequencies are most distressing to people (Miller 1997).

Although urban forests are less biologically diverse than rural woodlands, numerous types of wildlife inhabit cities and are generally highly valued by residents. For example, older parks, cemeteries, and botanical gardens are often filled with a rich mix 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).

The social, physical and psychological benefits provided by urban forests improve human well-being. Views of vegetation and nature can 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. Humans can 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. They also encourage people to walk, improving overall physical fitness. Research on the aesthetic quality of residential streets has shown that street trees are the single strongest positive influence on scenic quality. The simple act of planting trees can often bring people together.

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

Research suggests that people are willing to pay 3-7% more for residential 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). Each large front-yard tree there was found to be associated with a nearly 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).

Costs

Costs of Planting and Maintaining Trees

These benefits are not cost-free. In 1992, California cities spent an average of $4.36 per resident ($18.32 per tree) on tree programs, while counties spent an average of $0.32 per resident ($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. Street 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 and 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 cost of repairing all damaged sidewalks is $21 million. Statewide, cities are spending $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 spend as little as $0.75 per capita, while others spend $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 $62 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 than large trees at providing shade, absorbing air pollutants, and intercepting rainfall.
- 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 – perhaps because sewers get closer to the root zone as they enter houses from the street. Repair costs typically range from $100 for rodding to $1,000 or more for excavation and replacement.

Leaf litter from trees can clog sewers, dry wells, and other elements of flood control systems during October through December when leaves fall and winter rains begin. 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.

2. 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.

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 every 7-10 years over a 30-40 year period, after which reconstruction is required. A slurry seal costs approximately $0.27 per sq. ft. 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 (see Figure 2). 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 not substantial as cities and contractors strive to break-even (recycling costs are offset by avoiding dumping fees and purchases of mulch). The disposal costs of wood waste from tree removals can be significant for residents who do not have access to chippers. Landfill tipping fees are usually $10-20 per truckload (about $20/ton) – and a large tree may require several truckloads.

San Joaquin Valley trees require irrigation because of the region's arid climate. Installation of drip or bubbler irrigation can increase planting costs by $100 or more per tree. Once planted, 15-gallon trees will typically require 100-200 gallons per year during the establishment period. Assuming Bakersfield's commercial water price of $0.43 per hundred cubic feet (CCF or 748 gallons), annual irrigation water costs are initially less than $1 per tree. However, as trees mature their water use can increase to 1,000 gal or more, with a concomitant increase in annual costs. Trees planted in areas with existing irrigation may require supplemental irrigation, such as deep-watering of trees in turf areas.

Power plants consume water in the process of producing electricity. For example, coal-fired plants use about 0.6 gallons per 1 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 San Joaquin Communities

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 a large (London plane), medium (Chinese pistache), and small (crape myrtle) statured tree. Tree growth rates and dimensions are based on street tree data obtained in Modesto. To keep our calculations realistic, we assume that 22.5% of the trees planted die over the 40-year period.

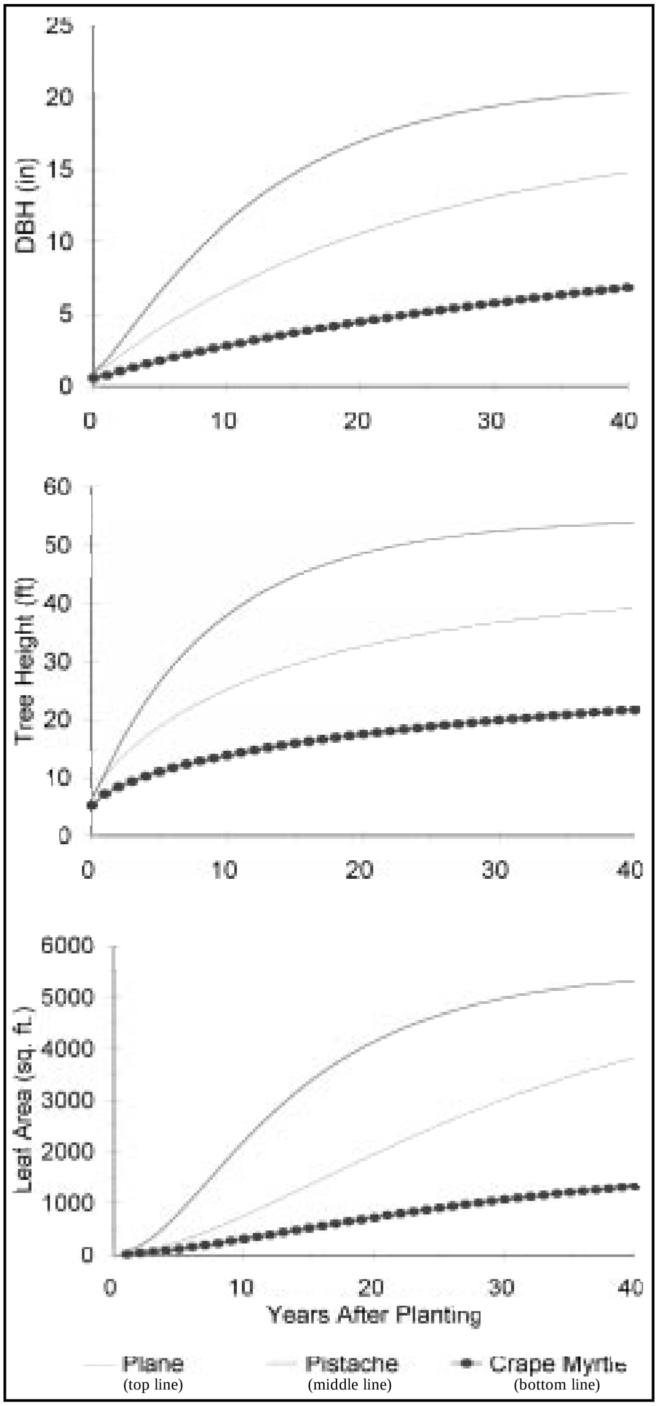
Our estimates of benefits and costs are initial approximations. Some benefits and costs are intangible or difficult to quantify (e.g., impacts on psychological health, crime and violence). Our limited knowledge about the physical processes at work and their interactions make estimates very imprecise (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.

Procedures and Assumptions

We estimate annual benefits and costs for newly planted trees over a 40-year period in three residential yard locations – the east, south, and west sides of the dwelling unit – and one public streetside/park location. 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 for "typical" locations and "typical" tree species. To account for differences in the mature size and growth rates of different tree species, we include results for large (Platanus acerifolia, London plane tree), medium (Pistacia chinensis, Chinese pistache), and small (Lagerstroemia indica, crape myrtle) trees. Tree growth rates, dimensions, and leaf area estimates are based on measurements taken for 28 to 30 street trees of each species in Modesto.

Although we report results in terms of annual values per tree planted, 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 five 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 dif-



3. Tree dimensions used to estimate the 40-year stream of benefits and costs are based on data collected from street trees in Modesto. Data for the "typical" large, medium, and small trees are from London plane tree, Chinese pistache, and crape myrtle, respectively.

ferent locations and directly calculates the annual flow of benefits and costs as trees mature and die (McPherson 1992) (see Figure 3).

Our approach directly connects benefits and costs with tree size variables such as trunk diameter at breast height (dbh) and leaf surface area. Many functional benefits of trees are related to leaf-atmosphere processes (e.g., interception, transpiration, photosynthesis). Therefore, benefits increase as tree canopy cover and leaf surface area increase. Similarly, pruning and removal costs usually increase with tree size. 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, benefits are directly proportional 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.

Much of the tree management cost data were directly estimated based on surveys with municipal foresters in Fresno and Modesto, Sacramento residents, and arborists and nursery managers in the Sacramento area (McPherson et al. 1993, Summit 1998). Findings from computer simulations are used in this study to directly estimate energy savings (McPherson and Simpson 1999). 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 credits from 1994-97 for the San Joaquin Unified Air Pollution Control District. 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 one pound of air pollution should be $1.

Benefits

Air Conditioning and Heating Energy Savings

We assume that residential yard trees are within 60 feet (18 m) of homes so as to directly shade walls and windows. Shading effects of these trees on building energy use were simulated for large, medium, and small trees at three tree-building distances (following methods outlined by McPherson and Simpson 1999). All trees are deciduous, with a visual density of 80% from April to November, and 20% from December to March. Results are averaged over distance weighted by occurrence of trees within each of three distance classes, 10-20 feet (3-6 m), 20-40 feet (6-12 m), and 40-60 feet (12-18 m), based on results from Sacramento (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 assumed that they do not provide shading benefits. In some situations, street trees do shade adjacent buildings (see Figure 4).

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

To estimate 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 2%, 4%, and 9% 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 20,000 square feet (1,858 sq. m), 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. Public and private trees both benefit from climate effects.

The prototype home 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 Valley communities. The energy simulations rely on climate data from Fresno. This house is two-story, stucco, slab-on-grade construction with a conditioned floor area of 1,660 sq. ft. (154 sq. m), window area (double-glazing) of 179 sq. ft. (16.6 sq. m), and insulation values of R13 for walls and R29 for ceilings. The central cooling system has a SEER of 10, and the natural gas furnace an 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-foot (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 house is more energy-efficient than most other construction types, our projected energy savings are relatively conservative.

Dollar value of energy savings obtained from Pacific Gas and Electric (personal communication, PG&E Residential Services Department, November 13, 1998) are based on marginal prices of $0.12 per kWh for electricity and $0.81 per therm for natural gas. Cooling and heating effects are reduced based on the saturation of air conditioning and heating equipment, which is 81% for central air conditioning and 14% for window/wall-mounted units (energy use is approximately 25% of that for a central system): 71% of homes used natural gas heating, 20% electric resistance and 9% heat pumps (McPherson and Simpson 1999). Changes in energy use due to shade are increased by 15% to account for shading of adjacent structures (McPherson and Simpson 1999). Results are reported at five-year intervals for private residential yard trees shading east-, south-, and west-facing surfaces and include both shade and climate effects, and for public street/park trees which provide climate effects only.

4. 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, reduce stormwater runoff, and improve air quality.

Atmospheric Carbon Dioxide Reduction

Reductions in building energy use result in reduced CO_2 emissions. Emissions are calculated as the product of energy use and CO_2 emission factors for electricity and heating. In the San Joaquin Valley, heating fuel is almost exclusively natural gas and electricity (natural gas was assumed for electric generation). Average annual changes in emissions due to trees (lbs/tree) are weighted by the appropriate fuel mix. Value of CO_2 reductions are based on control costs recommended by the California Energy Commission (California Energy Commission 1994). (See Table 1)

Air Quality Improvement

Reductions in building energy use also result in reduced emissions of criteria air pollutants from power plants and space heating equipment. We consider volatile organic hydrocarbons (VOC's) and nitrogen dioxide (NO_2), both precursors of ozone (O_3) formation, as well as particulate matter of <10 micron diameter (PM_{10}). 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, with the value of emissions savings (see Table 1) based on control costs specific to the San Joaquin Valley Unified Air Quality Management District (California EPA 1998).

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 meteorological data for wind speed, solar radiation and precipitation from California Department of Water Resources monitoring sites located in Modesto and Manteca are used as input data. Hourly concentrations for NO_2, O_3 and PM_{10} are obtained from the USEPA AIRS data base for 1991 for a monitoring station located in Modesto. The station monitors for air pollutant concentrations representative of areas of high population density, at spatial scales of up to 4 km. (See Scott et al. 1998 for details.) We use control costs from Table 1 to value emissions reductions and NO_2 control costs for ozone since ozone production is primarily NO_x limited in the San Joaquin Valley.

We do not account for the costs associated with increased ozone formation due to BVOCs emissions from trees or the benefit from lowering summertime air temperatures, thereby reducing hydrocarbon emissions from anthropogenic and biogenic sources.

Preliminary review of simulation results from Los Angeles and Sacramento indicate that ozone reduction benefits of tree planting with “low-emitting” species exceed costs associated with their BVOC emissions (McPherson et al. 1998, Taha 1996).

Table 1. Emissions factors and control costs for CO_2 and criteria air pollutants.

	– Emission Factor –		Control
	Electricity	**Natural gas**	**Costs**
	lbs/MWh	**lbs/MBtu**	**$/lb**
CO_2	990†	116†	0.015‡
NO_2	1.46†	0.1756†	5.00¶
PM_{10}	0.074†	0.0108†	3.17¶
VOCs	0.54†	0.0078†	2.78¶

† U.S. Environmental Protection Agency 1995.
‡ California Energy Commission 1994 ($30/ton)
¶ California EPA, 1998.

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 indexes (LAI, the ratio of leaf surface area to crown projection area), and water depth on the canopy surface. Species-specific shade coefficients influence the amount of projected throughfall. Hourly meteorological and rainfall data for 1995 from the Modesto California Irrigation Management Information System are used. Annual precipitation during 1995 was 12.3 inches (315 mm), close to the average annual precipitation amount from 1988-1997 of 12.1 inches (310 mm). (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. In

Fresno, the average annual cost for constructing and maintaining a typical detention/retention basin is $0.0074 per gallon of runoff stored (personal communication, Alan Hofmann, Fresno Metropolitan Flood Control District, Nov. 25, 1998). This amount assumes a development cost of $128,000 per acre, an annual maintenance cost of $800 per acre for 20 years. There is a 50% probability that the 6-foot deep basin will fill in any given year (designed to fill from 6 inches of rain falling at 0.5 inch/hour intensity [two-year return frequency]). Because trees function similar to retention/detention basins by reducing overland flow and delaying the time of peak flow, we price interception at the same price as retention/detention.

In 1997, the City of Modesto spent approximately $350,000 for its storm-water quality management program (personal communication, John Rivera, Industrial Waste Supervisor, City of Modesto, Nov. 17, 1998). The staff conduct water quality sampling, report findings, and develop and implement educational programs. This price is assumed to reflect resident's willingness to pay for cleaner stormwater runoff. Assuming that, during a typical year, 12 inches of rain falls on the city's 15,000 acres of urbanized land and 40% of that becomes stormwater runoff, total annual runoff is about 6,000 acre feet. Hence, about $0.0002 per gallon of runoff is spent annually to improve water quality. We use this price to estimate the water quality benefit produced by interception. The total hydrologic benefit is thus about $0.008 per gallon due to flood control and water quality protection.

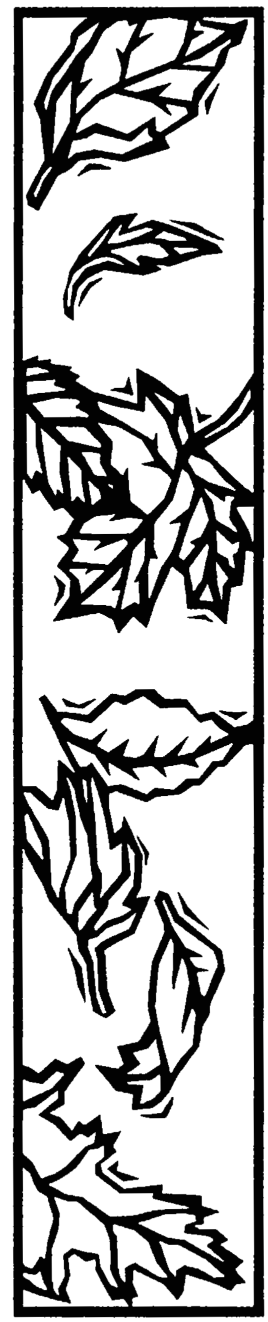
Property Value and Other Benefits

Many benefits attributed to urban trees are difficult to translate into economic terms. Beautification, privacy, shade that enhances human comfort, wildlife habitat, sense of place and well-being are products that are difficult to put a price on. 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 can compare differences in home sales prices. The difference in sales price should reflect the willingness of buyers to pay for the benefits and costs associated with the trees by capturing what buyers perceive to be their benefits and costs in the sales price.

Some limitations to using this approach here 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 Eastern and Southern United States 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) found that each large front-yard tree was associated with a $336 increase in sales price ($508 in 1998 dollars when adjusted with the Consumer Price Index). We use this $508 as an indicator of the additional value that a San Joaquin Valley resident would gain from selling a home with a large front yard tree. If the tree was 20 years old when the property sold, the average annual benefit is estimated to be $25 ($508/20). We assume the large tree is approximately 40-feet tall (12.2 m), with a 13-inch (33 cm) trunk diameter and 2,700 sq. ft. (250 sq. m) of leaf surface area.

To calculate the base value for a large tree on private residential property we assume that 75% of all yard trees are in backyards (Richards et al. 1986) and backyard trees have 75% of the impact on "curb appeal" and sale price compared to front yard trees. We assume that 85% of all public trees are on streets and 15% are in parks. 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. Thus, we assume that 5% of the street-tree population produces no benefits associated with property value increases. Park trees are assumed to have 50% of the impact on property sales prices as street trees. (There is little research for this last assumption.)



Given these assumptions, the typical large private residential yard tree increases property values by $0.153 per square foot of leaf surface area and by $0.166 for a public street/park tree. To estimate annual benefits, these values are multiplied by the amount of leaf surface area added to the tree each year. Thus, at 20 years after planting the annual value of this benefit for the London plane, pistache, and crape myrtle in private yards is $20, $18, and $6, respectively, while the value for each tree on public land is $22, $20, and $7.

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 Sacramento garden centers and data from the City of Modesto, we assume that the tree is in a 15-gallon container and costs $60 retail and $25 to grow in a municipal tree nursery. In our Sacramento resident survey, we found that 50 of the 52 residents who planted trees planted at least one of those trees themselves – instead of using professional landscape contractors (Summit and McPherson 1998). We assume that the yard tree is planted by the resident at no additional cost. The cost to plant, stake, and mulch a public tree is $25.

Pruning Costs

After studying data from municipal forestry programs in Modesto and Fresno, we assume that during the first three years after planting, public trees are pruned once a year at a cost of $2.36 per inch trunk diameter (dbh). Thereafter, all public trees are pruned on a six-year cycle at $0.67 per inch dbh, an average annual cost of $6-9 per tree.

Our survey of Sacramento residents indicated that 15% of households with trees never prune their trees. Moreover, the percentage of households that contract for tree trimming increases as tree height increases, from 6% for small trees (< 20-feet tall), to 60% for medium trees (20-40-feet tall), and 100% for large trees (>40-feet tall). Similarly, the frequency of pruning decreases with tree height from once every two years for small trees, to every ten years for medium trees, and every 20 years for large trees. Based on these findings and pruning prices charged by arborists ($245 for a large tree, $145 for a medium tree, and $46 for a small tree), the average annual cost for pruning a residential yard tree ranges from $4-9, with an average of $0.54 per inch dbh. Prices include costs for waste wood recycling and disposal.

Tree and Stump Removal and Disposal

The costs for removing public and private trees are $9 and $8 per inch dbh, respectively. Stump removal and wood waste disposal costs are $3 and $4 per inch dbh for public and private trees. The total cost for both tree sites is $12 per inch dbh.

Pest and Disease Control

A limited number of public trees receive treatments to control pests and disease on an annual basis. This expenditure averages to about $0.15 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-feet tall), to 60% for medium trees (20-40-feet tall), and 100% for large trees (>40-feet tall). The frequency of treatment decreases with tree height from once every two years for small trees, to every ten 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 $38 per year for the first five years after planting. This price is for labor, equipment, and water to irrigate young trees with a municipal water truck.

Irrigation costs for residential yard trees assumes that the irrigation system is in-place, and supplemental water is applied during the first five years of establishment. Water is purchased at a price of $0.43 CCF (Bakersfield Municipal Water District). The formula used to calculate annual irrigation water consumption (WC in gallons) is

$$WC = CP \times PF \times (ETo - P) \times 0.623$$

where CP is the tree crown projection (area under the dripline in sq. ft. and ranges from 10-340 sq. ft.), PF is the plant factor (assumed to be 0.5), and ETo – P is the difference between the reference evapotranspiration rate and rainfall (25 inches for the San Joaquin Valley). Given these assumptions, irrigation costs are relatively low for trees ($1.50 at five years after planting for the large tree).

Other Costs for Public Trees

Other costs associated with the municipal management of street and park trees include expenditures for infrastructure repair, litter/storm clean-up, litigation/liability, and inspection/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. Also, administrative costs are incurred for salaries, operating costs, and overhead not previously accounted for. Data from municipal forestry programs in Fresno and Modesto indicate that average annual per tree costs are: $4.26 for infrastructure repair ($0.27 per inch dbh, assuming average dbh of 14 inches), $1.27 for litter/storm clean-up ($0.09 per inch dbh), $0.27 for litigation/liability ($0.02 per inch dbh), and $0.19 for inspection/administration ($0.01 per inch dbh). Infrastructure repair and litigation/liability costs are assumed to be negligible until trees reach 12 inch dbh.

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 pollen-related allergies and respiratory ailments. These intangible benefits and costs are reflected in what we term “property value 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 property values can be influenced by the extent of tree canopy cover on individual properties.

The community can benefit from cleaner air and water, as well as social, educational, and employment/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 for the 40-year period increased with mature tree size:

- $1-8 for a small tree
- $26-37 for a medium tree
- $48-63 for a large tree (see Appendix A for detailed results).

Average annual net benefits from large-growing trees such as the London plane can be as much as 8 times greater than from small trees like crape myrtle. Average annual net benefits for the small, medium, and large street/park trees were $1, $26, and $48, respectively.

Residential yard trees produced slightly higher net benefits than public trees due primarily to lower planting and maintenance costs. Average annual net benefits for residential trees were greatest for a tree located west of a building due to large cooling savings. A yard tree located south of a building produced the least net benefit, while a tree located east of a building provided intermediate net benefits. Twenty years after planting annual net benefits for a residential yard tree located west of a home were estimated to be $65 for a large tree, or over 6 times the value of net benefits for a small tree ($10), and nearly twice the value of net benefits for a medium tree ($39) (see Table 2). The total value of environmental benefits alone were 2-5 times greater than annual costs at this time.

During the first five-year time period estimated costs were greater than benefits for all three tree sizes, primarily due to expenditures for planting (see Figures 5 and 6). Estimated benefits were greater than costs during the remaining five-year time periods. Average annual costs and benefits increased gradually as trees matured.

Average Annual Costs

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

- ➢ $4-9 for a small tree
- ➢ $7-15 for a medium tree
- ➢ $11-21 for a large tree (see Appendix A).

Given our assumptions, it is approximately 2-3 times more expensive to maintain a large tree than a small tree. Expenditures for pruning and planting were the largest cost categories for residential yard trees. Irrigation costs were the most important single cost for small public street/park trees (40-year average of $4.61/year). Pruning ($3-6/year), planting ($1.25/year), and infrastructure repair costs ($1-3/year) were the largest expense categories for medium and large statured public trees. Tree and stump removal and disposal costs for the large tree were about $1 per year on average, but costs would be higher if mortality rates were greater than assumed here.

Average Annual Benefits

The single largest benefit category was for air quality improvement, defined as the sum of pollutant uptake by trees and avoided power plant emissions due to energy savings (average of $28/year per large tree). In most cases, air quality benefits accounted for more than 50% of total environmental benefits. The total value of pollutant uptake far exceeded the total value of avoided pollutant emissions. However, avoided NO_2 emissions accounted for about

Table 2. 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 in the San Joaquin Valley.

BENEFIT CATEGORY	SMALL TREE 13 ft tall, 12 ft spread LSA = 210 sq. ft.		MEDIUM TREE 32 ft tall, 31 ft spread LSA = 1,840 sq. ft.		LARGE TREE 48 ft tall, 40 ft spread LSA = 4,010 sq. ft.	
Electricity ($0.12/kWh)	35 kWh	$4.16	76 kWh	$9.15	131 kWh	$15.73
Natural gas ($0.81/therm)	–49 kBtu	–$0.40	–52 kBtu	–$0.42	–45 kBtu	–$0.37
Carbon dioxide ($0.015/lb)	44 lb	$0.67	164 lb	$2.46	320 lb	$4.81
Ozone ($5.00/lb)	0.14 lb	$0.70	1.21 lb	$6.06	2.83 lb	$14.17
NO_2 ($5.00/lb)	0.14 lb	$0.72	0.69 lb	$3.43	1.55 lb	$7.75
PM_{10} ($3.17/lb)	0.12 lb	$0.38	1.02 lb	$3.22	2.38 lb	$7.52
VOC's ($2.78/lb)	0.003 lb	$0.01	0.009 lb	$0.02	0.019 lb	$0.05
Rainfall Interception ($0.008/gal)	47gal	$0.38	357 gal	$2.85	612 gal	$4.90
		====		=====		=====
ENVIRONMENTAL SUBTOTAL		**$6.62**		**$26.77**		**$54.56**
Property Value & Other Benefits		$6.03		$18.08		$20.24
Total Benefits		$12.65		$44.86		$74.80
Total Costs		$2.61		$6.22		$9.82
NET BENEFITS		**$10.04**		**$38.64**		**$64.98**

This analysis assumes that the tree is strategically located to shade the west side of a typical building. Property value and 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

35% of total atmospheric NO_2 reduction benefits. Pollutant uptake values were greatest for O_3 removal, followed by PM_{10} and NO_2.

Net energy savings were the second largest environmental benefit category, ranging from $1-4 per year for a small tree, to $3-9 for a medium tree, and $8-16 for a large tree. These values are conservative because they assume that 15% of the trees are shading residential buildings that do not have air conditioning, and all residences are relatively energy efficient (post-1980 construction). Savings for public street and park trees assumed no shading of buildings. Estimated savings for private yard trees assumed to shade buildings varied with tree location.

A tree to the west produced the greatest net energy savings, followed by a tree to the east and south. A west tree provided the greatest cooling savings ($4-17/year on average), while increasing heating costs only slightly. An east tree had a negligible impact on heating costs, but produced less summer cooling than a west tree.

A large or medium tree shading a south-facing wall increased winter heating costs the most ($1/year on average), while reducing air conditioning costs the least ($4-9). After 20 years, a large yard tree located west of a residence is estimated to produce net annual energy savings valued at $15, while the same tree in a street or park will produce approximately $9 worth of annual net energy benefit.

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 (see Figures 5 and 6).

Hydrologic and atmospheric CO_2 reduction benefits were on the same order of magnitude, averaging $3-5 per year for a large tree. Approximately 45-65% of the estimated total CO_2 reduction is due to avoided power plant emissions, while the remaining amount is a result of sequestration minus CO_2 release from decomposition and tree care related activities.

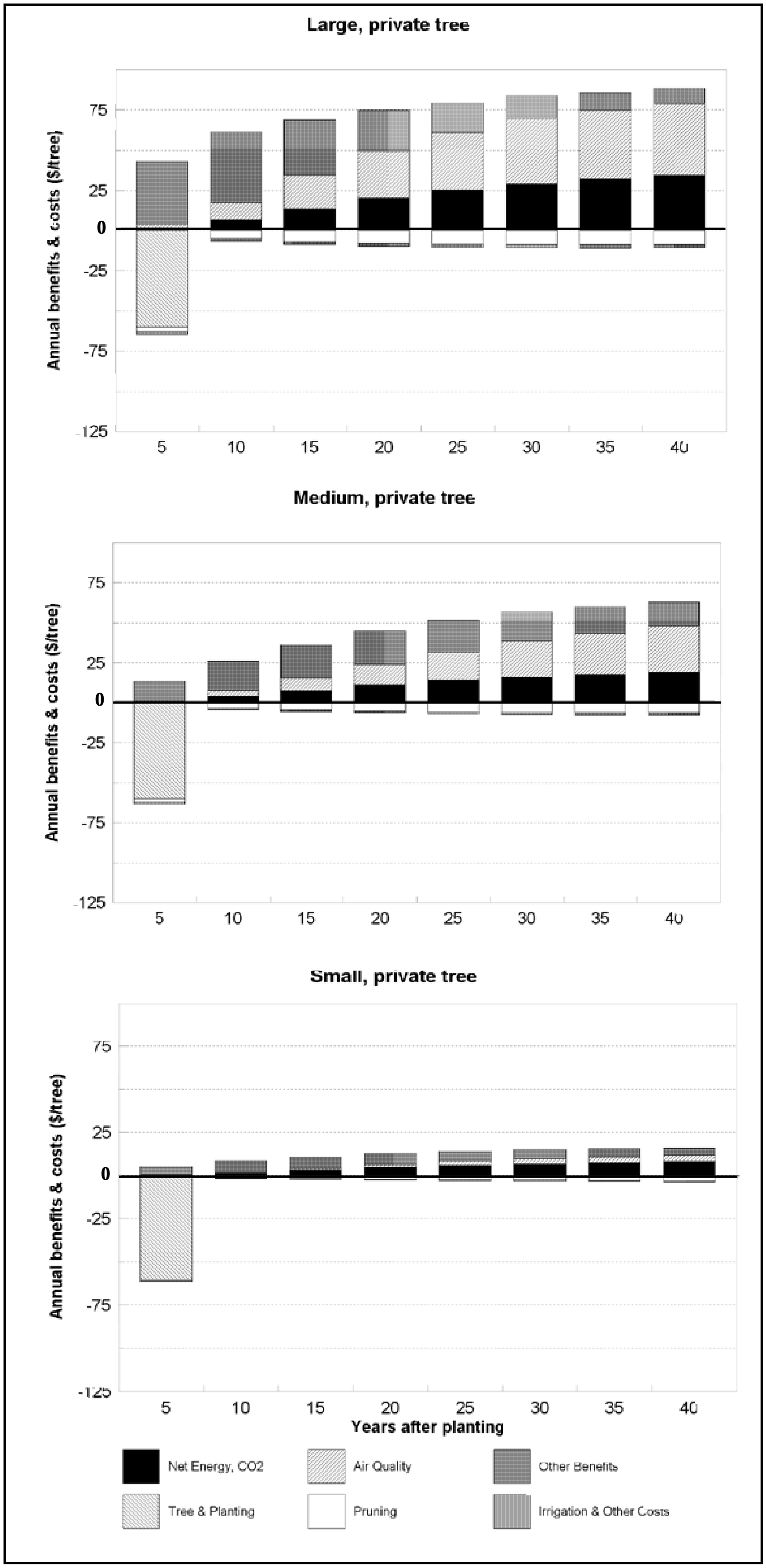
When totaled and averaged over the 40-year period, annual environmental benefits ranged from $22-29 for medium trees to $43-53 for large trees. For medium and large trees, the value of environmental benefits alone exceeded average annual costs and totaled to about twice the estimated value of property value and other benefits. Average annual environmental benefits for small trees ($4-7) were similar to the value of other benefits ($5-6).

Property value and other benefits accounted for 30-50% of total benefits. Average annual amounts ranged from $5-6 for a small tree, to $15-16 for a medium tree, and $20-22 for a large tree (see Appendix A). Property value and other benefits were slightly greater for a public street/park tree than for a residential yard tree.

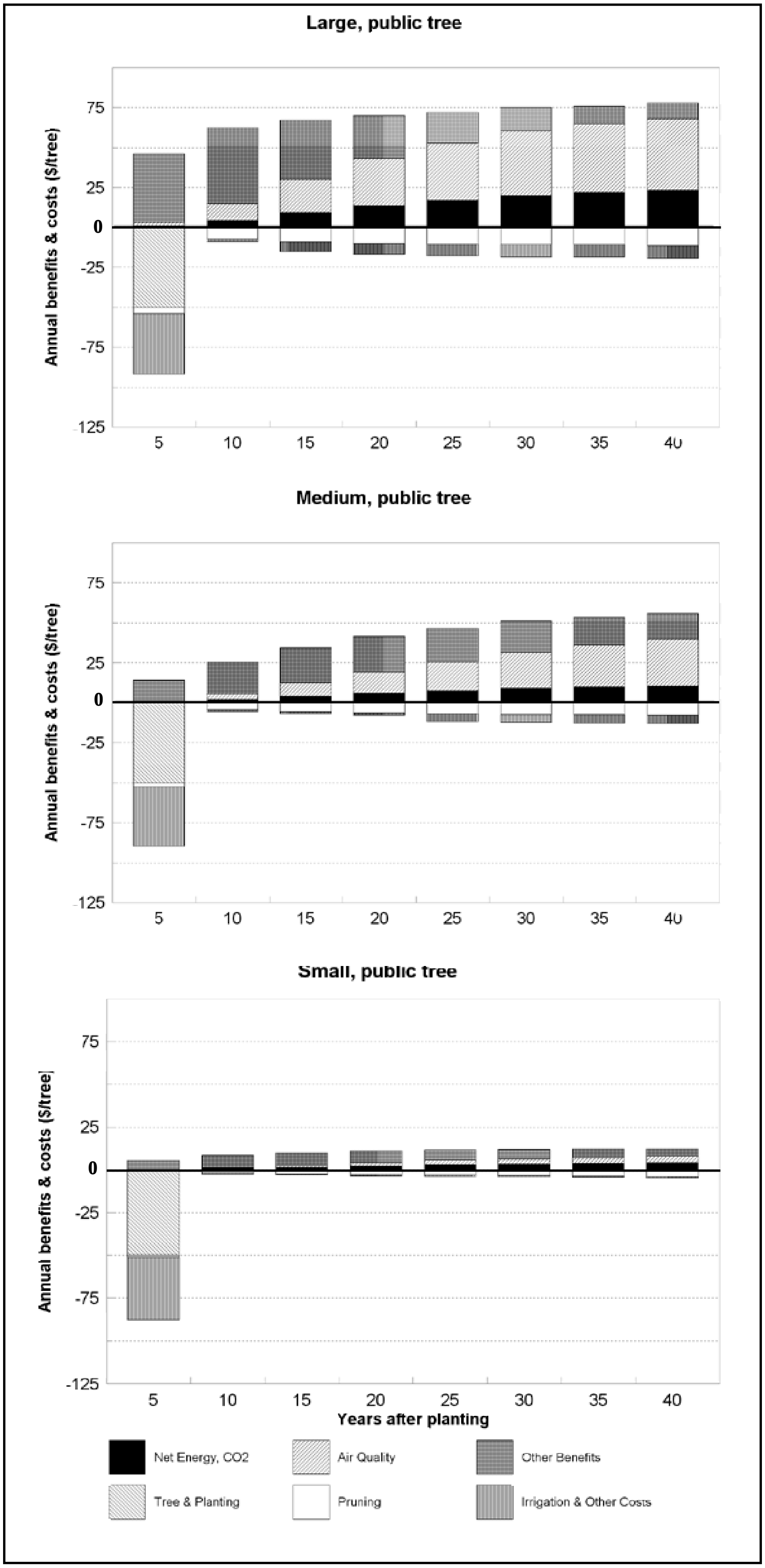
Limitations of Cost/Benefit Analysis

This analysis does not account for the wide variety of trees planted in San Joaquin Valley communities or their diverse placement. It does not incorporate the wide range of climatic differences within the Valley that influence potential energy, air quality, and hydrologic benefits. There is much uncertainty associated with estimates of property value/other benefits and the true value of hydrologic benefits because science in these areas is not well developed. We consider only two cost scenarios, but know that the costs associated with planting and managing trees can vary widely depending on program characteristics. 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.

Results are presented here 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.



5. Estimated annual benefits and costs for a large (London plane), medium (Chinese pistache), and small (crape myrtle) residential yard tree located west of the building. Costs are greatest during the initial establishment period while benefits increase with tree size.



6. Estimated annual benefits and costs for a large (London plane), medium (Chinese pistache), and small (crape myrtle) public street/park tree.

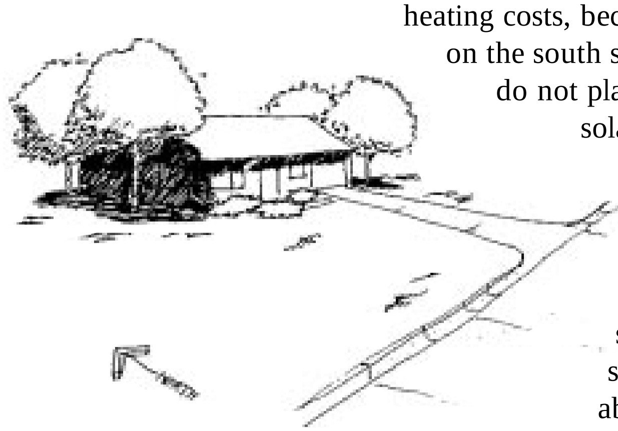
3. General Guidelines for Siting and Selecting Trees

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 San Joaquin Valley communities, the east side is the second most important side to shade (see Figure 7).

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.



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

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 feet (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 (see Figure 8).

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 feet (1.5-3 m) from the home to avoid these conflicts but within 30-50 feet (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 not too long in the San Joaquin Valley, but heating costs can still be several hundred dollars per year. Because of their size and porosity, trees are ideal wind filters. Even leafless trees in the city can reduce wind speeds and heating costs. 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 direction – usually along the north and west sides of the property in the San Joaquin Valley (see Figure 9). 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 feet (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. 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 feet (2 m) on center. If there is room for two or more rows, then space rows 10-12 feet (3-4 m) apart.

BEFORE

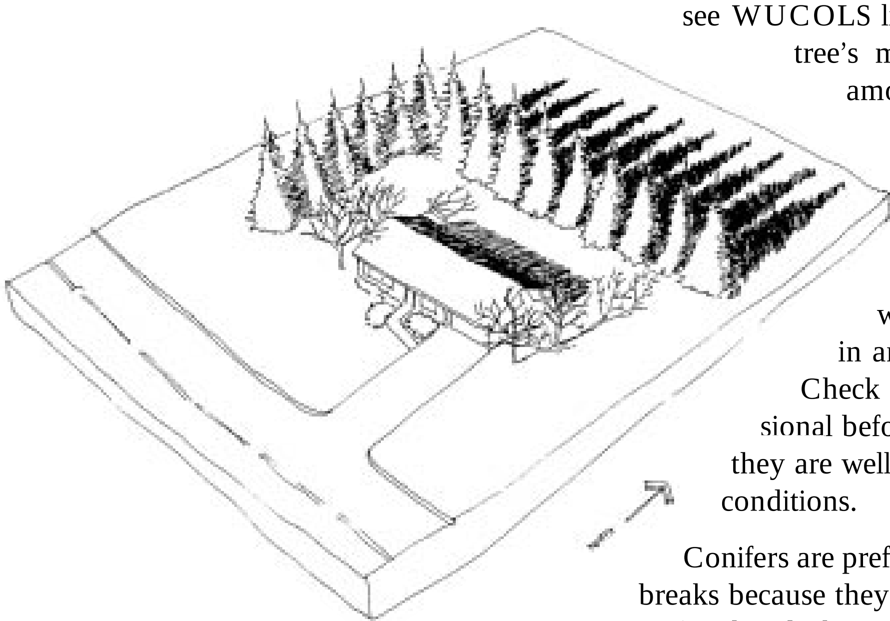
AFTER

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

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, ginkgo (Ginkgo biloba) because of their narrow form, sparse shade, and slow growth, and pine trees (Pinus spp.) because of their evergreen foliage.

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 1992, 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.



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

Conifers are preferred over deciduous trees for windbreaks because they provide better wind protection (see Figure 10). The ideal windbreak tree is fast growing, visually dense, and has stiff branches that do not self-prune. Species in the pine (Pinus spp.), cypress (Cupressus spp.) genera, and evergreen oak species (Quercus spp.) are among the best windbreak trees for San Joaquin Valley communities.

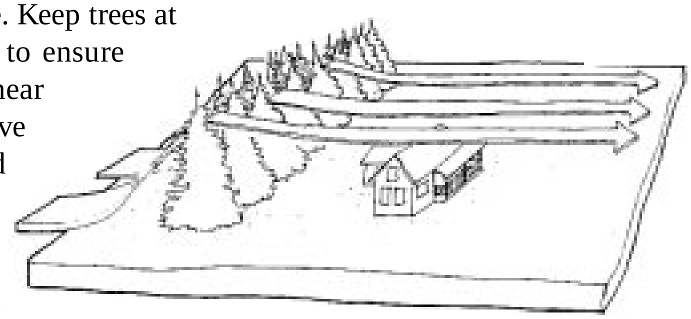
Trees in Public Places

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 feet (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 feet (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 feet tall) for locations under overhead power lines, and do not plant directly above underground water and sewer lines (see Figure 11). Avoid locating trees where they will block illumination from street lights or views of street signs in parking lots, commercial areas, and along streets.

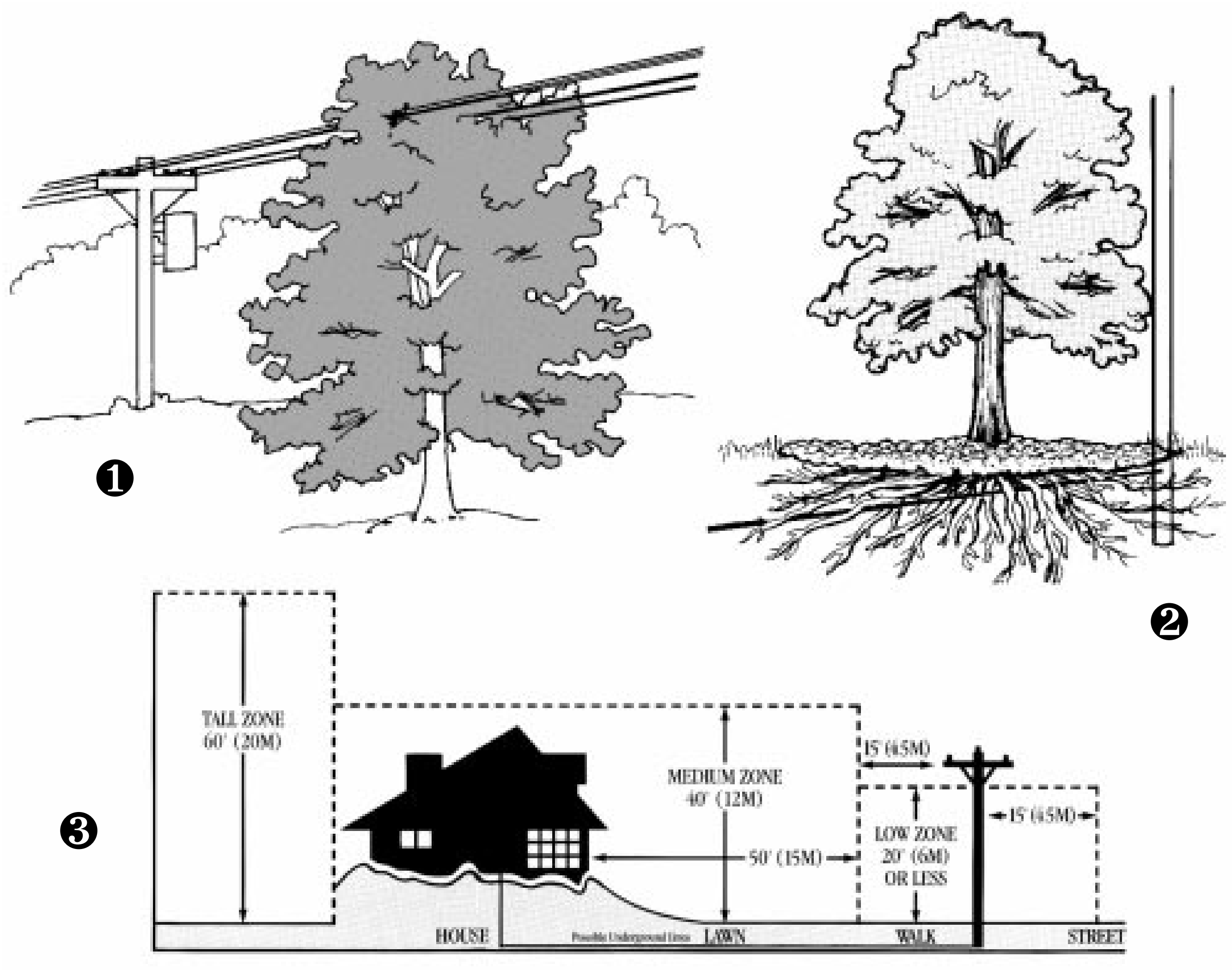


10. Conifers guide wind over the building (from Sand, 1993).

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.
- ➢ 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.



11. (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)

- ➢ 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. If the tree is in a container, check for matted roots by sliding off the container or feeling down the side of it. Roots should penetrate to the edge of the root ball, but not densely circle the inside of the container or grow through drain holes. Avoid trees with dense surface roots that circle the trunk and may girdle the tree. Gently move the trunk back and forth in the container. If it wiggles 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 tree 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 (see Figure 12).

Use the extra backfill to build a berm outside the root ball that is 6 inches (15 cm) high and 3 feet (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 of growing seasons.

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

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 more 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 – often called “shade tree programs” – aimed at maximizing energy savings and CO_2 reductions. 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 public 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). This section provides a checklist to consider when initiating a shade tree program. For more information, short descriptions of successful shade tree programs are contained in “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.

13. 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 residents are more satisfied with the tree and their neighborhood when they participate directly in the tree planting than when trees are planted by the city, a developer, or volunteer groups without resident involvement (Sommer et al. 1994). Foster active participation in tree planting and stewardship by residents (see Figure 13).

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).

14. 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 about 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 (see Figure 14).

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 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. Cooling savings can be boosted by customizing tree locations to increase numbers in high-yield sites.

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 feet (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 ten 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 energy savings and atmospheric CO_2 reductions. The magnitude of benefits related to storm water runoff reductions, increased property values, employment opportunities, job training, air quality improvements, and enhanced human health and well-being can be substantial. Moreover, these benefits extend beyond the site where trees are planted, and promote collaborative efforts to build better communities.

Sources of Technical Assistance

Alliance for Community Trees
201 Lathrop Way, Suite F
Sacramento, CA 95815
✎(800) ACT-8886 fax (916) 924-3803
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

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

California Association of Nurserymen
4620 Northgate Blvd., Suite 155
Sacramento, CA 95834
(916) 567-0200 fax (916) 567-0505

California Landscape Contractors Association
2021 N St., Suite 300
Sacramento, CA 95814
(916) 448-CLCA fax (916) 446-7692

California Department of Forestry and Fire Protection
Urban and Community Forestry
2524 Mulberry St.
Riverside, CA 92501
(909) 782-4140 fax (909) 782-4248

California Releaf
The Trust for Public Land
3001 Redhill Ave., Bldg. 4, Suite 224
Costa Mesa, CA 92626
(714) 557-2575
http://www.capweb.com/tpl

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

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
1414K St., Suite 250
Sacramento, CA 95814-3929
(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@ssl.org

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://home.earthlink.net/~appleseedz/NTT.html

National Urban and Community Forestry Advisory Council
c/o Suzanne DelVillar
20628 Diane Dr.
Sonora, CA 95370
(209) 536-9201

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

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
City of Great Falls
P.O. Box 5021
Great Falls, MT 59403-5021
(406) 771-1265 fax (406) 761-4055

Tree Link Homepage
http://www.treelink.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
630 Sansome St.
San Francisco, Ca 94111
(415) 705-1274 fax (415) 705-1140

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://www.pswfs.gov/units/urban.html

Grant Programs in Urban and Community Forestry

American Forests/Global ReLeaf Forest Cost/Share Grants, July
Contact: American Forests
P.O. Box 2000
Washington, DC 20013
✎(202) 955-4500

California Releaf / CDF Tree-Planting Grant Program, Early August
California Releaf / National Urban Forestry Grant Program, Mid-October
Contact: California Releaf / The Trust for Public Land
3001 Redhill Ave., Bldg. 4, Suite 224
Costa Mesa, CA 92626
✎(714) 557-2575

Environmental Enhancement and Mitigation Program, Fall
Contact: EEMP Coordinator, State of California Resources Agency
1416 Ninth St., Suite 1311
Sacramento, CA 95814
✎(916) 653-5656

ISA Hyland R. Johns Grant Program, Early April
and ISA John Z. Duling Grant Program, Early November
Contact: ISA Research Trust Grant Program
P.O. Box 3129
Champaign, IL 61826
✎(217) 335-9411

For information on environmental education and other grant programs that offer possibilities for urban forestry, please contact California ReLeaf.

Los Angeles Urban Resources Partnership Grants, Mid-April
Contact: Urban Resources Partnership
201 N. Figueroa St., Suite 200, MS-177
Los Angeles, CA 90012
✎(213) 580-1055

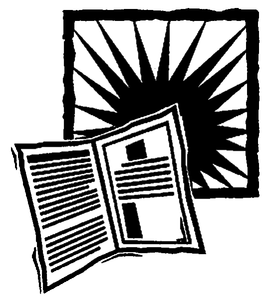
National Tree Trust
Partnership Enhancement Monetary Grant Program, Early October
Tree-Planting Grant Programs (Part 1), Late May
Tree-Planting Grant Programs (Part 2), Early October
Contact: National Tree Trust
1120 G St. NW, Suite 770
Washington, DC 20005
✎(800) 846-8733

NUCFAC Challenge Cost Share Program, Early January
Contact: Suzanne M. del Villar, Executive Assistant to NUCFAC
20628 Diane Dr.
Sonora, CA 95370
✎(209) 536-9201

5. Trees for San Joaquin Valley Communities

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.

The matrix in this chapter presents information to assist tree selection. Tree species recommended in general for San Joaquin Valley communities are listed alphabetically by mature tree size category – large, medium, and small. Information is presented 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). A general assessment of each tree's suitability for street, yard, and park locations is also presented.



We received helpful reviews of this information from Alan Lagarbo (City of Modesto), Keith Warren (J. Frank Schmidt & Son Co.), and Janet Rademacher (Mountain States Nursery).

References used to develop the tree selection matrix are listed in Chapter 6.

Key to the Matrix

A: Mature tree height (ft.)
B: Mature tree crown spread (ft.)
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; 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).
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: Resistance to pests and disease: S=pest/disease sensitive; R=resistant; F=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).
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: Other important features that influence tree selection such as irrigation requirement (from Costello and Jones 1992), soil tolerance, tidiness, and pruning requirement (Gilman et al. 1996, Reimer 1996).
L: 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.

Tree Name	A Mature Height ft.	B Mature Spread ft.	C Type	D Solar Friendly	E Growth Rate	F Long-evity	G Cultivars Avail.	H Pest/ Disease Resistance	I Sur-face Roots	J Ozone Forming Potential	K Comments (soil, drought, tidiness, pruning)	L Suitability S=Street Y=Yard P=Park
Large Trees >50 ft. Height												
Celtis australis, occidentalis European/common hackberry	40-70	40-50	D	Y	M	L	N	R	O	L	fruit, mod. irr., avoid clay soil	S/Y/P
Eucalyptus papuana, sideroxylon, ghost gum, red ironbark eucalyptus	40-80	30-80	E	N	F	M	Y	R	Y	H	litter, little irr., limb breakage	P
Fraxinus americana 'Autumn Purple,' 'Chicago Regal' - white ash	40-60	35-50	D	Y	F	L	Y	S	O	L	mod. irr., fall color	S/Y/P
Fraxinus pennsylvanica 'Patmore' 'Leprechaun,' 'Centerpoint,' green ash	60-70	45-50	D	Y	F	L	Y	S	O	L	mod. irr., fall color	S/Y/P
Gymnocladus dioica Kentucky coffee tree	40-60	40-60	D	Y	M	L	N	R	N	NDA	mod. irr., tough conditions, fruit	S/Y/P
Liquidambar styraciflua sweetgum	60-75	35-50	D	N	M	L	Y	R	O	H	fruits, mod. irr., fall color	S/Y/P
Magnolia grandiflora Southern magnolia	60-80	30-40	E	N	M	L	Y	R	Y	M	litter, high irr., flowers	S/Y/P
Pinus canariensis Canary Island pine	60-90	30-40	E	N	F	L	N	S	O	L	low irr., litter	Y/P
Pinus pinea Italian stone pine	35-80	35-60	E	N	M	L	N	S	N	L	low irr., limb breakage	P
Pinus torreyana torrey pine	40-60	40-50	L	N	F	L	N	F	O	M	native, low irr.	P
Platanus acerifolia 'Yarwood' or 'Bloodgood' London plane	50-70	50-70	D	N	F	L	Y	S	O	H	litter, low irr.	S/P

Large Trees
>50 ft. height

Large Trees

>50 ft. height

Tree Name	A Mature Height ft.	B Mature Spread ft.	C Type	D Solar Friendly	E Growth Rate	F Long-evity	G Cultivars Avail.	H Pest/ Disease Resistance	I Sur-face Roots	J Ozone Forming Potential	K Comments (soil, drought, tidiness, pruning)	L Suitability S=Street Y=Yard P=Park
Platanus x hispanica 'Columbia' London plane	40-60	40-60	D	N	F	L	Y	R	O	H	litter, low irr.	S/P
Quercus frainetto 'Forest Green,' Forest Green oak	40-50	30-40	D	N	F	L	Y	S	O	H	low. irr., acorns	Y/P
Quercus ilex holly oak	40-50	40-50	E	N	M	M	N	R	O	H	mod. irr., acorns	Y/P
Quercus suber cork oak	60-70	40-50	E	N	M	L	N	R	O	H	low irr., acorns	P
Quercus virginiana, fusiformis Southern, escarpment live oak	50-80	50-80	E	N	M	L	Y	R	O	H	mod. irr., acorns	P
Taxodium distichum bald cypress	50-60	25-30	D	Y	F	L	N	R	N	M	mod. irr., rusty fall color	S/Y/P
Umbellularia californica California laurel	40-60	40-60	E	N	S	L	N	F	O	M	native, mod. irr.	S/Y/P

Medium Trees

30-50 ft. height

Tree Name	A Mature Height ft.	B Mature Spread ft.	C Type	D Solar Friendly	E Growth Rate	F Long-evity	G Cultivars Avail.	H Pest/ Disease Resistance	I Sur-face Roots	J Ozone Forming Potential	K Comments (soil, drought, tidiness, pruning)	L Suitability S=Street Y=Yard P=Park
Medium Trees 30-50 ft. Height												
Acacia stenophylla shoestring acacia	30-40	20-30	E	N	R	L	N	R	N	L	very low irr., thornless	S/Y/P
Acer freemanii 'Autumn Blaze,' Autumn Blaze maple	40-50	30-40	D	Y	M	M	Y	R	O	L	mod. irr., fall color	S/Y/P
Brachychiton populneus bottle tree	35-50	25-40	E	N	M	L	N	F	Y	NDA	fruit litter, mod. irr.	S/Y/P
Cercidium x 'Desert Museum,' palo verde	25-35	25-35	S	N	F	M	Y	F	N	L	thornless, low irr.	S/Y/P
Cinnamomum camphora camphor tree	40-60	50-70	E	N	M	L	N	R	Y	L	mod. irr., shallow roots	S/Y/P
Dalbergia sisoo, rosewood	30-50	30-50	S	N	R	M	N	R	O	NDA	low irr., low maint	S/Y/P
Diospyros virginiana (male clones), persimmon	30-50	20-40	D	Y	M	L	Y	S	N	NDA	mod. irr., litter, fall color	Y/P
Eucalyptus microtheca, coolibah	40-50	40-50	E	N	F	L	N	F	O	H	low irr., soil tolerant	S/Y/P
Geijera parviflora Australian willow	30-35	20-25	E	N	F	M	N	F	N	L	low maint., mod. irr.	S/Y/P
Koelreuteria paniculata, bipinnata, elegans goldenrain, Chinese flame, and Formosan flame tree	30-40	20-40	D	Y	M	M	N	R	N	H	litter, mod. irr., attractive flowers/fruit	S/Y/P
Metasequoia glyptostroboides dawn redwood	40-50	15-25	D	Y	F	L	N	R	N	M	high irr.	S/Y/P

Medium Trees 30-50 ft. height

Tree Name	A Mature Height ft.	B Mature Spread ft.	C Type	D Solar Friendly	E Growth Rate	F Long-evity	G Cultivars Avail.	H Pest/ Disease Resistance	I Sur-face Roots	J Ozone Forming Potential	K Comments (soil, drought, tidiness, pruning)	L Suitability S=Street Y=Yard P=Park
Paulownia tomentosa princess-tree	40-50	40-50	D	Y	F	M	N	F	O	NDA	litter, mod. irr.	S/Y/P
Pistacia chinensis 'Keith Davey', Chinese pistache	40-50	30-40	D	Y	M	M	Y	F	O	L	low irr, fall color, use male clone	S/Y/P
Prosopis alba 'Thornless' thornless Mesquite	25-35	25-35	S	N	F	M	Y	R	O	L	thornless, low irr.	S/Y/P
Pyrus calleryana 'Trinity,' 'Chanticleer,' flowering pear	25-35	15-20	D	N	M	M	Y	R	N	L	mod. irr., fruit litter, fall color	S/Y/P
Sapium sebiferum Chinese tallow tree	25-40	25-35	D	Y	F	S	N	F	O	NDA	low irr., fall color, poison seeds	Y
Tilia americana 'Redmond' Redmond linden	30-50	30-45	D	Y	M	L	Y	R	N	NDA	mod. irr., fall color	S/Y/P
Ulmus 'Frontier,' 'Prospector' Frontier and Prospector elm	35-50	25-45	D	Y	F	M	Y	R	O	L	mod. irr., disease resist.	S/Y/P
Ulmus parvifolia 'Athena', 'Allee,' Chinese/lacebark elm	40-50	25-35	D	N	F	S	Y	R	N	L	freq. pruning, mod. irr.	S/Y/P
Zelkova serrata 'Green Vase' Green Vase zelkova	40-60	40-60	D	Y	M	L	Y	R	N	L	low irr., orange fall color	S/Y/P

Small
Trees
<30 ft. height

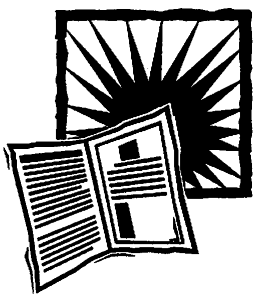
Tree Name	A Mature Height ft.	B Mature Spread ft.	C Type	D Solar Friendly	E Growth Rate	F Long-evity	G Cultivars Avail.	H Pest/ Disease Resistance	I Sur-face Roots	J Ozone Forming Potential	K Comments (soil, drought, tidiness, pruning)	L Suitability S=Street Y=Yard P=Park
Small Tree < 30 ft. Height												
Acer bergerianum and *truncatum*, trident and 'Norwegian Sunset' maple	20-30	20-30	D	Y	S	M	Y	R	N	L	mod. irr., attractive fall color	S/Y/P
Amelanchier 'Autumn Brilliance', serviceberry	15-25	10-20	D	Y	S	M	Y	S	N	NDA	white flws, fall color	S/Y/P
Arbutus unedo strawberry tree	10-30	10-30	E	N	S	M	Y	F	N	NDA	low irr., needs pruning	S/Y/P
Cercis canadensis, occidentalis, Eastern and Western redbud	15-25	15-25	D	Y	M	M	N	R	N	L	low-mod. irr., flowers/fall color	S/Y/P
Chilopsis linearis desert willow	15-30	15-25	D	NDA	M	M	N	F	N	H	very low irr., needs pruning,	S/Y/P
Chitalpa tashkentensis chitalpa	20-30	20-25	D	NDA	M	M	Y	R	N	NDA	litter, mod. irr., flowers	S/Y/P
Lagerstroemia indica x *L. faurei* clones, crape myrtle (Catawba, Cherokee, Pecos etc.)	15-25	10-20	D	Y	M	M	Y	R	N	L	low irr., needs training, flowers	S/Y/P
Malus 'Snowdrift' and 'Golden Raindrops,' crabapple	15-25	15-25	D	N	M	M	N	R	N	L	mod. irr., litter, attractive flws.	Y/P
Prunus 'Cascade Snow' Cascade Snow cherry	20-25	15-20	D	Y	M	S	Y	R	N	L	high irr., white flowers	S/Y/P
Prunus cerasifera 'Krauter Vesuvius' 'Thundercloud,' purple leaf plum	20-30	20-30	D	Y	M	S	Y	S	N	L	mod. irr., fruit litter, pink flowers	Y/P

Small Trees

<30 ft. height

Tree Name	A Mature Height ft.	B Mature Spread ft.	C Type	D Solar Friendly	E Growth Rate	F Long-evity	G Cultivars Avail.	H Pest/ Disease Resistance	I Sur-face Roots	J Ozone Forming Potential	K Comments (soil, drought, tidiness, pruning)	L Suitability S=Street Y=Yard P=Park
Syringa reticulata 'Ivory Silk' Ivory Silk Japanese tree lilac	20-30	15-20	D	Y	M	M	Y	R	N	NDA	mod. irr., white flowers	S/Y/P
Quercus buckleyi 'Redrock' redrock oak	20-30	20-25	D	NDA	M	L	Y	R	N	H	low irr., red fall color	S/Y/P
Vitex agnus-castus chaste tree	10-15	15-20	D	NDA	F	M	Y	R	N	NDA	low irr., flowers	S/Y/P
Xylosma congestum shiny xylosma	15-30	15-30	E	N	M	M	N	R	N	NDA	low irr., needs training	S /Y/P

6. References



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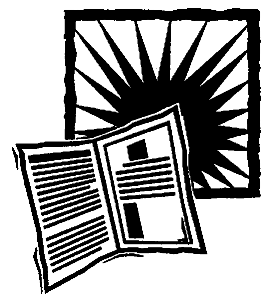

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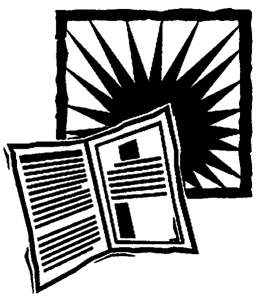

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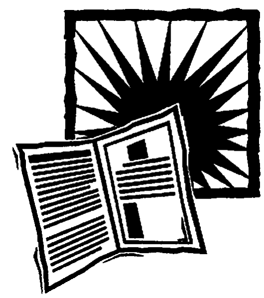

Appendix A.

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

LARGE TREE Benefits/tree	Year 5 Res units	$	Year 10 Res units	$	Year 15 Res units	$	Year 20 Res units	$	Year 25 Res units	$	Year 30 Res units	$	Year 35 Res units	$	Year 40 Res units	$	40 year average Res units	$
Electricity (kWh)																		
Private: West	10	1.25	46	5.54	89	10.63	131	15.73	171	20.49	199	23.93	224	26.84	244	29.23	139.21	$16.71
Private: South	0	0.06	17	2.01	41	4.88	67	8.07	92	11.02	113	13.54	130	15.61	144	17.23	75.43	$9.05
Prvate: East	6	0.69	29	3.49	60	7.18	92	11.01	122	14.58	145	17.41	165	19.76	180	21.64	99.76	$11.97
Public	4	0.48	21	2.47	45	5.39	71	8.50	95	11.40	116	13.88	133	15.91	146	17.50	78.68	$9.44
Natural Gas (kBtu)																		
Private: West	-33	-0.27	-60	-0.49	-60	-0.49	-45	-0.37	-31	-0.25	-12	-0.10	3	0.03	14	0.11	-27.94	-$0.23
Private: South	-62	-0.50	-128	-1.04	-155	-1.26	-157	-1.27	-158	-1.29	-147	-1.19	-139	-1.13	-134	-1.09	-134.79	-$1.10
Prvate: East	-20	-0.16	-28	-0.22	-15	-0.12	8	0.06	29	0.23	52	0.42	70	0.57	83	0.68	22.32	$0.18
Public	4	0.03	29	0.24	63	0.52	100	0.81	134	1.09	164	1.33	187	1.52	206	1.68	111.01	$0.90
Net Energy (kBtu)																		
Private: West	71	0.99	402	5.06	826	10.14	1,266	15.37	1,676	20.24	1,982	23.83	2,239	26.86	2,450	29.34	1,364.18	$16.48
Private: South	-57	-0.45	39	0.97	252	3.62	516	6.79	760	9.74	982	12.35	1,162	14.48	1,302	16.14	619.53	$7.96
Prvate: East	38	0.53	264	3.27	583	7.05	925	11.08	1,244	14.82	1,503	17.83	1,716	20.33	1,887	22.32	1,019.95	$12.15
Public	44	0.51	235	2.71	512	5.90	809	9.32	1,084	12.49	1,321	15.21	1,513	17.43	1,664	19.17	897.81	$10.34
Net CO2 (lb)																		
Private: West	25	0.37	131	1.96	243	3.64	320	4.81	357	5.35	361	5.41	350	5.25	335	5.03	265.20	$3.98
Private: South	10	0.15	91	1.36	180	2.71	240	3.60	259	3.89	254	3.82	236	3.54	214	3.21	185.66	$2.78
Prvate: East	22	0.34	120	1.79	222	3.33	291	4.37	319	4.79	319	4.78	304	4.56	286	4.29	235.41	$3.53
Public	25	0.37	121	1.81	221	3.31	286	4.29	311	4.67	309	4.63	293	4.39	273	4.09	229.79	$3.45
Avoided pollutants (lb)																		
NO2	0.011	0.05	0.132	0.66	0.313	1.57	0.512	2.56	0.697	3.49	0.849	4.25	0.974	4.88	1.074	5.37	0.57	$2.85
PM10	0.000	0.00	0.006	0.02	0.016	0.05	0.026	0.08	0.035	0.11	0.043	0.14	0.050	0.16	0.055	0.17	0.03	$0.09
VOC's	0.000	0.00	0.005	0.01	0.011	0.03	0.019	0.05	0.026	0.05	0.031	0.09	0.036	0.10	0.040	0.11	0.02	$0.05
Pollutant uptake (lb)																		
O3	0.205	1.03	0.951	4.76	1.978	9.90	2.832	14.17	3.399	17.01	3.914	19.59	4.103	20.53	4.282	21.43	2.71	$13.55
NO2	0.076	0.38	0.350	1.75	0.725	3.63	1.036	5.18	1.241	6.21	1.427	7.14	1.494	7.48	1.558	7.80	0.99	$4.95
PM10	0.248	0.78	0.934	2.96	1.751	5.54	2.349	7.44	2.687	8.51	2.995	9.48	3.054	9.67	3.132	9.92	2.14	$6.79
O2																		
Total avoided and uptake	0.540	2.25	2.378	10.16	4.794	20.72	6.773	29.49	8.083	35.37	9.260	40.68	9.712	42.81	10.140	44.80	6.46	$28.28
Hydrology (gal)																		
Rain Intercept	123.31	0.99	338.27	2.71	506.33	4.05	612.36	4.90	672.00	5.38	701.13	5.61	709.62	5.68	751.84	6.01	551.86	$4.41
Environ. Subtotal																		
Private: West		$4.59		$19.89		$38.55		$54.56		$66.33		$75.54		$80.60		$85.19		$53.16
Private: South		$2.94		$15.20		$31.10		$44.78		$54.37		$62.46		$66.51		$70.16		$43.44
Prvate: East		$4.10		$17.93		$35.15		$49.83		$60.35		$68.91		$73.38		$77.42		$48.38
Public		$4.11		$17.39		$33.98		$48.00		$57.90		$66.14		$70.32		$74.08		$46.49

LARGE TREE Costs ($/yr/tree)	Year 5 Private	Public	Year 10 Private	Public	Year 15 Private	Public	Year 20 Private	Public	Year 25 Private	Public	Year 30 Private	Public	Year 35 Private	Public	Year 40 Private	Public	40 year average Private	Public
Tree & Planting	60	50.00															$1.50	$1.25
Pruning	2.80	4.19	5.26	7.08	6.89	8.93	7.86	10.01	8.37	10.57	8.59	10.79	8.62	10.79	8.53	11.34	$6.91	$9.06
Remove & Dispose	0.65	0.79	0.63	0.68	0.85	0.88	1.00	1.02	1.09	1.11	1.15	1.16	1.19	1.20	1.22	1.22	$0.94	$0.94
Pest & Disease	0.34	0.07	0.64	0.11	0.84	0.14	0.96	0.16	1.02	0.17	1.05	0.17	1.06	0.17	1.04	0.18	$0.85	$0.14
Infrastructure		0.00		0.00		3.53		3.96		4.18		4.27		4.27		4.49		$3.00
Irrigation	1.10	36.10	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	$0.10	$4.61
Clean-Up		0.57		0.96		1.21		1.35		1.43		1.46		1.46		1.53		$1.17
Liability & Legal		0.00		0.00		0.23		0.25		0.27		0.27		0.27		0.29		$0.19
Admin & Other		0.08		0.14		0.18		0.20		0.21		0.22		0.22		0.23		$0.17
Total Costs	64.89	91.80	6.53	8.97	8.58	15.11	9.82	16.96	10.49	17.93	10.80	18.34	10.87	18.37	10.79	19.28	$10.29	$20.52
Property Values and Other Benefits	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public
	$38.61	$41.93	$41.37	$44.94	$30.45	$33.07	$20.24	$21.99	$13.03	$14.16	$8.30	$9.02	$5.27	$5.72	$3.34	$3.63	$20.08	$21.81
Total Net Benefits																		
Private: West		-$22		$55		$60		$65		$69		$73		$75		$78		$63
Private: South		-$23		$50		$53		$55		$57		$60		$61		$63		$53
Prvate: East		-$22		$53		$57		$60		$63		$66		$68		$70		$58
Public		-$46		$53		$52		$53		$54		$57		$58		$58		$48

MEDIUM TREE Benefits	Year 5 Res units	Year 5 $	Year 10 Res units	Year 10 $	Year 15 Res units	Year 15 $	Year 20 Res units	Year 20 $	Year 25 Res units	Year 25 $	Year 30 Res units	Year 30 $	Year 35 Res units	Year 35 $	Year 40 Res units	Year 40 $	40 year average Res units	40 year average $
Electricity (kWh)																		
Private: West	6	0.76	28	3.34	52	6.26	76	9.15	99	11.85	114	13.70	127	15.28	138	16.61	80.16	$9.62
Private: South	-1	-0.12	6	0.67	16	1.90	28	3.30	38	4.61	48	5.75	56	6.68	62	7.41	31.45	$3.77
Prvate: East	3	0.31	14	1.66	28	3.42	44	5.25	58	6.95	69	8.30	78	9.41	86	10.31	47.50	$5.70
Public	2	0.22	10	1.15	21	2.52	33	3.97	44	5.32	54	6.48	62	7.43	68	8.17	36.75	$4.41
Natural Gas (kBtu)																		
Private: West	-29	-0.23	-43	-0.35	-52	-0.42	-52	-0.42	-53	-0.43	-49	-0.40	-46	-0.38	-45	-0.36	-46.01	-$0.37
Private: South	-44	-0.35	-68	-0.55	-86	-0.70	-93	-0.76	-99	-0.81	-98	-0.80	-98	-0.80	-99	-0.80	-85.63	-$0.70
Prvate: East	-14	-0.12	-18	-0.14	-17	-0.14	-11	-0.09	-6	-0.05	0	0.00	6	0.04	9	0.08	-6.41	-$0.05
Public	2	0.02	10	0.08	21	0.17	33	0.27	45	0.36	54	0.44	62	0.51	68	0.56	36.88	$0.30
Net Energy (kBtu)																		
Private: West	34	0.52	236	2.99	470	5.84	710	8.73	935	11.42	1,093	13.30	1,227	14.91	1,339	16.25	755.57	$9.24
Private: South	-53	-0.47	-12	0.12	72	1.20	182	2.55	285	3.80	381	4.95	458	5.88	518	6.60	228.90	$3.08
Prvate: East	11	0.19	121	1.51	268	3.28	426	5.16	573	6.90	692	8.30	790	9.46	868	10.38	468.54	$5.65
Public	20	0.24	106	1.23	231	2.69	364	4.24	488	5.69	595	6.93	681	7.94	749	8.73	404.39	$4.71
Net CO2 (lb)																		
Private: West	7	0.11	67	1.00	124	1.86	164	2.46	183	2.75	185	2.77	180	2.70	173	2.59	135.23	$2.03
Private: South	-2	-0.03	41	0.62	83	1.24	110	1.65	117	1.75	113	1.69	102	1.53	89	1.34	81.50	$1.22
Prvate: East	6	0.09	57	0.86	107	1.60	139	2.09	151	2.27	149	2.24	141	2.11	131	1.96	110.23	$1.65
Public	8	0.12	58	0.87	106	1.59	136	2.04	147	2.20	144	2.16	134	2.02	123	1.85	107.05	$1.61
Avoided pollutants (lb)																		
NO2	-0.001	-0.00	0.062	0.31	0.148	0.74	0.243	1.21	0.331	1.65	0.401	2.01	0.460	2.30	0.507	2.54	0.27	$1.35
PM10	-0.000	-0.00	0.003	0.01	0.007	0.02	0.012	0.04	0.017	0.05	0.020	0.06	0.023	0.07	0.026	0.08	0.01	$0.04
VOC's	-0.000	-0.00	0.002	0.01	0.005	0.01	0.009	0.02	0.012	0.03	0.015	0.04	0.017	0.05	0.018	0.05	0.01	$0.03
Pollutant uptake (lb)																		
O3	0.067	0.34	0.315	1.57	0.727	3.64	1.211	6.06	1.690	8.45	2.198	11.00	2.558	12.80	2.917	14.60	1.46	$7.31
NO2	0.025	0.12	0.116	0.58	0.267	1.33	0.443	2.22	0.617	3.09	0.801	4.01	0.931	4.66	1.061	5.31	0.53	$2.67
PM10	0.081	0.26	0.309	0.98	0.644	2.04	1.005	3.18	1.336	4.23	1.682	5.33	1.904	6.03	2.134	6.76	1.14	$3.60
O2																		
Total avoided and uptake	0.172	0.71	0.807	3.46	1.799	7.79	2.923	12.74	4.001	17.51	5.118	22.45	5.892	25.91	6.663	29.33	3.42	$14.99
Hydrology (gal)																		
Rain Intercept	77.67	0.62	184.63	1.48	279.41	2.24	356.62	2.85	415.85	3.33	458.18	3.67	488.04	3.90	539.91	4.32	350.04	$2.80
Environ. Subtotal																		
Private: West		$1.97		$8.93		$17.73		$26.77		$35.00		$42.19		$47.42		$52.49		$29.06
Private: South		$0.83		$5.67		$12.47		$19.78		$26.39		$32.75		$37.22		$41.59		$22.09
Prvate: East		$1.62		$7.31		$14.91		$22.83		$30.01		$36.66		$41.38		$46.00		$25.09
Public		$1.70		$7.04		$14.30		$21.88		$28.72		$35.20		$39.77		$44.23		$24.10

MEDIUM TREE Costs ($/yr/tree)	Year 5 Private	Year 5 Public	Year 10 Private	Year 10 Public	Year 15 Private	Year 15 Public	Year 20 Private	Year 20 Public	Year 25 Private	Year 25 Public	Year 30 Private	Year 30 Public	Year 35 Private	Year 35 Public	Year 40 Private	Year 40 Public	40 year average Private	40 year average Public
Tree & Planting	60	50.00															$1.50	$1.25
Pruning	2.06	2.58	3.26	4.17	4.28	5.36	4.98	6.24	5.48	6.87	5.82	7.30	6.04	7.57	6.16	7.73	$4.50	$5.90
Remove & Dispose	0.48	0.48	0.39	0.40	0.53	0.53	0.63	0.63	0.72	0.72	0.79	0.79	0.84	0.84	0.89	0.89	$0.61	$0.61
Pest & Disease	0.25	0.04	0.40	0.07	0.52	0.08	0.61	0.10	0.67	0.11	0.71	0.12	0.74	0.12	0.75	0.12	$0.55	$0.09
Infrastructure		0.00		0.00		0.00		0.00		2.72		2.89		2.99		3.05		$1.17
Irrigation	0.51	36.10	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	$0.04	$4.61
Clean-Up		0.35		0.56		0.72		0.84		0.93		0.99		1.02		1.04		$0.76
Liability & Legal		0.00		0.00		0.00		0.00		0.17		0.19		0.19		0.20		$0.08
Admin & Other		0.05		0.08		0.11		0.13		0.14		0.15		0.15		0.16		$0.11
Total Costs	63.30	89.61	4.05	5.28	5.33	6.81	6.22	7.94	6.87	11.65	7.32	12.40	7.62	12.90	7.81	13.18	$7.20	$14.58
Property Values and Other Benefits	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public
	$11.61	$12.61	$17.01	$18.48	$18.60	$20.21	$18.08	$19.64	$16.53	$17.95	$14.57	$15.82	$12.54	$13.62	$10.63	$11.54	$14.95	$16.23
Total Net Benefits																		
Private: West		-$50		$22		$31		$39		$45		$49		$52		$55		$37
Private: South		-$51		$19		$26		$32		$36		$40		$42		$44		$30
Prvate: East		-$50		$20		$28		$35		$40		$44		$46		$49		$33
Public		-$75		$20		$28		$34		$35		$39		$40		$43		$26

SMALL TREE Benefits	Year 5 Res units	Year 5 $	Year 10 Res units	Year 10 $	Year 15 Res units	Year 15 $	Year 20 Res units	Year 20 $	Year 25 Res units	Year 25 $	Year 30 Res units	Year 30 $	Year 35 Res units	Year 35 $	Year 40 Res units	Year 40 $	40 year average Res units	40 year average $
Electricity (kWh)																		
Private: West	3	0.32	13	1.53	24	2.85	35	4.16	45	5.38	52	6.19	57	6.89	62	7.48	36.25	$4.35
Private: South	-1	-0.07	2	0.20	5	0.63	10	1.15	14	1.63	17	2.05	20	2.40	22	2.67	11.10	$1.33
Prvate: East	1	0.10	5	0.62	11	1.29	17	1.99	22	2.64	26	3.16	30	3.59	33	3.93	18.05	$2.17
Public	1	0.09	4	0.45	8	0.97	13	1.54	17	2.06	21	2.51	24	2.87	26	3.16	14.21	$1.70
Natural Gas (kBtu)																		
Private: West	-22	-0.18	-34	-0.28	-45	-0.36	-49	-0.40	-54	-0.44	-54	-0.44	-55	-0.45	-56	-0.45	-46.00	-$0.37
Private: South	-18	-0.15	-28	-0.23	-37	-0.30	-40	-0.32	-43	-0.35	-43	-0.35	-43	-0.35	-43	-0.35	-36.80	-$0.30
Prvate: East	-7	-0.06	-10	-0.08	-11	-0.09	-10	-0.08	-8	-0.07	-6	-0.05	-4	-0.04	-3	-0.03	-7.45	-$0.06
Public	1	0.01	4	0.03	8	0.07	13	0.10	17	0.14	21	0.17	24	0.20	26	0.21	14.26	$0.12
Net Energy (kBtu)																		
Private: West	5	0.14	93	1.25	193	2.49	297	3.76	395	4.95	462	5.75	519	6.44	567	7.03	316.48	$3.98
Private: South	-24	-0.22	-12	-0.04	16	0.34	56	0.83	93	1.28	128	1.71	157	2.05	179	2.32	74.18	$1.03
Prvate: East	1	0.04	41	0.54	96	1.20	156	1.91	212	2.58	257	3.11	295	3.55	325	3.91	173.05	$2.11
Public	8	0.09	41	0.48	89	1.04	141	1.64	189	2.20	230	2.68	263	3.07	290	3.37	156.32	$1.82
Net CO2 (lb)																		
Private: West	-6	-0.08	16	0.24	32	0.47	44	0.67	52	0.78	55	0.83	56	0.84	56	0.84	38.20	$0.57
Private: South	-8	-0.12	6	0.09	15	0.23	22	0.33	24	0.36	24	0.35	22	0.33	19	0.29	15.39	$0.23
Prvate: East	-5	-0.07	12	0.19	25	0.37	34	0.50	38	0.57	39	0.58	38	0.57	36	0.54	27.01	$0.41
Public	-4	-0.06	13	0.20	25	0.38	34	0.50	37	0.56	38	0.57	37	0.55	35	0.53	26.91	$0.40
Avoided pollutants (lb)																		
NO2	-0.003	-0.01	0.022	0.11	0.055	0.28	0.093	0.46	0.128	0.64	0.155	0.78	0.178	0.89	0.197	0.99	0.10	$0.52
PM10	-0.000	-0.00	0.001	0.00	0.003	0.01	0.005	0.01	0.006	0.02	0.008	0.02	0.009	0.03	0.010	0.03	0.01	$0.02
VOC's	-0.000	-0.00	0.001	0.00	0.002	0.01	0.003	0.01	0.005	0.01	0.006	0.02	0.006	0.02	0.007	0.02	0.00	$0.01
Pollutant uptake (lb)																		
O3	0.009	0.05	0.040	0.20	0.088	0.44	0.141	0.70	0.190	0.95	0.241	1.21	0.278	1.39	0.314	1.57	0.16	$0.81
NO2	0.003	0.02	0.015	0.07	0.032	0.16	0.051	0.26	0.069	0.35	0.088	0.44	0.101	0.51	0.114	0.57	0.06	$0.30
PM10	0.011	0.04	0.040	0.13	0.078	0.25	0.117	0.37	0.150	0.48	0.185	0.58	0.207	0.66	0.230	0.73	0.13	$0.40
O2																		
Total avoided and uptake	0.020	0.08	0.118	0.52	0.259	1.14	0.410	1.82	0.548	2.44	0.683	3.05	0.780	3.49	0.872	3.91	0.46	$2.06
Hydrology (gal)																		
Rain Intercept	11.11	0.09	23.86	0.19	36.19	0.29	47.12	0.38	56.61	0.45	64.69	0.52	71.32	0.57	81.54	0.65	49.05	$0.39
Environ. Subtotal																		
Private: West		$0.23		$2.19		$4.40		$6.62		$8.63		$10.15		$11.34		$12.43		$7.00
Private: South		-$0.17		$0.76		$2.00		$3.35		$4.53		$5.63		$6.44		$7.17		$3.71
Prvate: East		$0.14		$1.43		$3.00		$4.61		$6.04		$7.26		$8.18		$9.01		$4.96
Public		$0.21		$1.38		$2.85		$4.34		$5.65		$6.81		$7.68		$8.46		$4.67

SMALL TREE Costs ($/yr/tree)	Year 5 Private	Year 5 Public	Year 10 Private	Year 10 Public	Year 15 Private	Year 15 Public	Year 20 Private	Year 20 Public	Year 25 Private	Year 25 Public	Year 30 Private	Year 30 Public	Year 35 Private	Year 35 Public	Year 40 Private	Year 40 Public	40 year average Private	40 year average Public
Tree & Planting	60	50.00															$1.50	$1.25
Pruning	0.90	1.13	1.39	1.74	1.78	2.23	2.09	2.62	2.34	2.94	2.55	3.20	2.72	3.41	3.03	3.80	$1.96	$2.58
Remove & Dispose	0.21	0.21	0.17	0.17	0.22	0.22	0.27	0.27	0.31	0.31	0.35	0.35	0.38	0.38	0.41	0.41	$0.27	$0.27
Pest & Disease	0.11	0.02	0.17	0.03	0.22	0.04	0.26	0.04	0.29	0.05	0.31	0.05	0.33	0.05	0.37	0.06	$0.24	$0.04
Infrastructure		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		$0.00
Irrigation	0.18	36.10	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	$0.02	$4.61
Clean-Up		0.15		0.24		0.30		0.35		0.40		0.43		0.46		0.51		$0.33
Liability & Legal		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		$0.00
Admin & Other		0.02		0.03		0.04		0.05		0.06		0.06		0.07		0.08		$0.05
Total Costs	61.40	87.64	1.73	2.21	2.21	2.83	2.61	3.33	2.94	3.75	3.21	4.09	3.43	4.37	3.81	4.86	$3.99	$9.13
Property Values and Other Benefits	$4.83	$5.25	$6.35	$6.90	$6.47	$7.03	$6.03	$6.54	$5.39	$5.85	$4.73	$5.13	$4.11	$4.46	$3.56	$3.87	$5.18	$5.63
Total Net Benefits																		
Private: West		-$56		$7		$9		$10		$11		$12		$12		$12		$8
Private: South		-$57		$5		$6		$7		$7		$7		$7		$7		$5
Prvate: East		-$56		$6		$7		$8		$8		$9		$9		$9		$6
Public		-$82		$6		$7		$8		$8		$8		$8		$7		$1

Appendix B. Funding and Program Resources for Local Governments