ICLEI
Local Governments for Sustainability

TALKING TREES

An Urban Forestry Toolkit for Local Governments

November 2006

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Introduction

Local governments across the United States are recognizing the shared importance and the interconnectedness of their social, economic, and environmental goals. Many have been developing active programs and policies to improve the sustainability of their operations and the communities they govern. Urban forestry offers a set of opportunities for creating a wide range of community benefits.

Healthy urban forests can help municipalities achieve goals of environmental, social, and economic sustainability while reducing greenhouse gas emissions and removing carbon from the atmosphere. The urban landscape can be understood as an urban ecosystem, with each part relating to and affecting the whole. The urban forest functions in this urban ecosystem by mitigating harmful environmental issues, such as air and water pollution. It also functions as a location for recreation and escape from the stresses of urban life. By shading and sheltering buildings, trees reduce cooling and heating costs and, simultaneously, greenhouse gas emissions. Even in urban settings, our health and welfare can benefit from exposure to natural settings. The benefits of urban trees are many.

This toolkit is designed to communicate the benefits of the urban forest and provide policy guidelines to enable municipalities to move toward achieving a sustainable urban ecosystem. Fact sheets about carbon dioxide, energy, air quality, water quality and runoff, economics, social benefits, and planting and maintenance describe the various benefits that urban trees provide in a form that is both understandable and informative. These fact sheets are reinforced with a policy guide, three case studies, an assessment of software tools, and a protocol that will better illustrate how cities can achieve healthy urban forests.

This document and the emissions quantification protocols presented herein are designed to complement the emissions analysis protocols that underlie the foundation of ICLEI's Cities for Climate Protection (CCP) campaign.

Fact Sheet #1: **Trees and Carbon Dioxide**

Rising levels of human-induced atmospheric carbon dioxide (CO2) are dangerously accelerating global warming. Human activities, like fossil fuel combustion and deforestation, are the greatest contributors to increased atmospheric CO2. However, as humans continue to emit billions of tons of CO2 and other greenhouse gases into our atmosphere each year, trees actively remove CO2 from the air. This natural process offers significant potential to help counteract anthropogenic CO2 emissions.

Carbon Sequestration

Through the process of ***photosynthesis***,[1] trees remove CO_2 from the atmosphere, use the carbon to form the physical structure of the tree (roots, trunk, branches and leaves), and return the oxygen to the atmosphere. The process by which carbon is removed from the atmosphere and stored in the tree structure is called ***carbon sequestration***. Urban forests thus function as long-term carbon storehouses, or ***carbon sinks***.

Reducing deforestation and planting new trees can potentially slow the accumulation of CO_2 in the atmosphere. For example:

- A single mature tree can absorb as much as 48 lbs of CO_2 per year and release enough oxygen into the atmosphere to support two human beings.[2]
- It is estimated that between 660 and 990 million tons of carbon is stored in our urban forests nationally.[3]
- Urban forests have positive energy benefits that impact greenhouse gas emissions, such as reducing heating and cooling costs by sheltering and shading buildings. See: *Trees Save Energy*.
- Urban forest carbon sequestration is only a fraction (4.4 percent) of the amount of carbon stored in rural forests. Although this number may seem low, urban trees have a greater per-tree effect on reducing greenhouse gas concentrations than trees in rural forests. This is due to the secondary effects that urban trees have on reducing energy use.

Even though all plants contribute to the sequestration of carbon, trees and shrubs have the highest capacity to store carbon. Twenty-one times more carbon stored in trees and shrubs than in herbaceous plants and grasses. Therefore the best landscape designs include as many trees and shrubs as possible.

Most of the carbon stored in the organic material of a single tree resides in the trunk and stems (79 percent) and in the root system (18 percent). Only 3 percent of the carbon stored in a tree is found in the foliage that the tree continually or annually sheds.

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[1] A glossary of terms is provided later in this toolkit.
[2] Alexander, Katherine. *Benefits of Trees in Urban Areas.* www.coloradotrees.org/benefits.htm
[3] Ibid.

Carbon Release
However, this is not the whole story. When a tree decomposes, the stored carbon is either deposited and stored in the soil, or released back into the atmosphere as CO_2. As generations of the urban forest grow, die, and decay, new generations take up the CO_2 lost through the decomposition of previous generations. Thus, the net carbon storage of the urban forest cycles as populations grow and decline. When the net growth rate of the forest is greater than the decomposition rate, carbon storage increases. If the growth rate is stable or declines, and removed trees are not replaced, then the decomposition of the urban forest could be a source of emissions. Thus, if cities plan to continually increase or maintain the canopy cover of their urban forest, the carbon storage capacity will be greater than the rate of decomposition.

Tree Maintenance
Maintaining an urban forest with tools requiring fossil fuels (chainsaws, chippers, trucks, leaf-blowers etc.) is necessary to maintain tree health and prolong the lifespan of trees. If these carbon-based activities do not prolong the life of trees, their carbon storage capacity will be reduced. Planting species that require less maintenance over the long-term and reducing the use of tools requiring fossil fuels will help to lower the emissions cost of tree maintenance.

Prolonging and Maximizing Carbon Storage
By maintaining a healthy urban forest, prolonging the life of trees, and continually increasing tree stock, communities can increase their net carbon storage over the long term. It is important to note that simply increasing tree stock is not necessarily sufficient to maximize benefits. Large trees have a greater capacity to store carbon and shade buildings, and therefore will reduce atmospheric CO_2 much more than small trees.

- Large healthy trees (greater than 30 inches in diameter) sequester 90 times more carbon annually than small trees (less than 4 inches in diameter).[4]
- Large trees store approximately 1000 times more carbon than small trees at maturity.[5]
- Large trees with long life spans will have the greatest overall positive effect on emissions because emissions associated with planting and removal will occur less frequently.

Various strategies can help enhance the long-term carbon storage benefits of urban forests. Although the decomposition rate of woody material disposed in landfills decreases, the methane (CH_4) emitted is twenty-one times more potent as a greenhouse gas than CO_2. Therefore, to most effectively reduce carbon emissions, utilize the products of your urban forests. For example:

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[4] Nowak, David and Daniel E. Crane. *Carbon Storage and Sequestration by Urban Trees in the USA*. USDA Forest Service. Syracuse. 2001
[5] Ibid

- Instead of dumping woody material in landfills, utilize chipping and mulching to dispose of tree material that cannot be used as long-lived products. Mulch can be added as organic material to the soil to enhance its quality without the need for fertilizers whose manufacture releases high quantities of CO_2. Placing chipped bark over exposed soils in the pedestrian right-of-way is the best way to protect soils from pedestrian compaction and can increase the soil's water storage capacity. By increasing soil fertility and maintaining a healthy soil structure, the health and lifespan of urban trees can be increased.
- Utilize urban trees as long-lived products such as building materials, furniture, and woodcrafts to delay their decomposition into CO_2. The use of urban wood has become increasingly easier as organizations have come together to facilitate the milling of urban wood by supplying portable saw mills to those ready to sell trees. Cities can use these services and possibly make a profit by selling valuable urban trees as lumber.
    - See: www.harvestingurbantimber.com and www.ufei.org for more information.
- Utilize wood fuel in place of fossil fuels. Substituting carbon emissions from fossil sources with carbon from ***biogenic*** sources reduces a jurisdiction's total greenhouse gas emissions. Selling urban forest **biomass** as firewood is a good way for homeowners to reduce their energy costs and reliance on fossil fuels, and for cities to cover some of their maintenance costs. In addition, cities can sell excess chips to a local cogeneration plant.

A more complete consideration of the impacts of urban forests on carbon dioxide and how local governments can account for this in their emissions analyses is provided later in this report.

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Journal of Arboriculture vol. 28 no. 3
2002
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Fact Sheet #2: **Trees Save Energy**

The primary way that cities can achieve an immediate reduction in emissions by their urban forests is through energy savings and the reduction of the urban heat island effect. Trees shade and shelter buildings reducing energy associated with cooling and heating and reducing overall local temperatures of the urban heat island, which can further reduce cooling-related energy use.

Trees Reduce Energy Costs
Trees properly planted with energy savings in mind can reduce the amount of energy (electricity, natural gas, or other fuel) used to heat and, primarily, cool buildings. This not only reduces associated emissions, but also saves money.

- The shade from a single well-placed mature tree reduces annual air conditioning use two to eight percent (often in the range of 40-300 kWh) and peak cooling demand two to ten percent (often as much as 0.15-0.5 kW).[6]
- Planting 100 million mature trees in US cities (three trees for every other single family home) could reduce annual energy use by 30 billion kWh, saving $2 billion in energy costs and reducing CO_2 emissions by nine million tons per year.[7]

Of course the amount of energy savings created by trees depends on the local climate and the age of nearby buildings. Older buildings with less insulation and out-dated technologies will have a greater energy savings from trees than newer buildings with better insulation and technology. Homes in climates like that of the Pacific Northwest that do not heavily rely on air conditioning will not gain as much in energy savings from air conditioning as homes in warmer climates like those in the Southwest where energy savings can be significant. When planting projects are designed, these regional considerations must be weighed.

Trees Reduce Local Air Temperatures and the Urban Heat Island Effect
In addition to direct energy savings in buildings, a healthy urban forest can help to reduce the impact of the ***urban heat island effect***. On hot summer days, cities can be up to eight degrees Fahrenheit hotter than their suburban and rural surroundings. This phenomenon occurs because urban development results in large amounts of paved and dark colored surfaces like roofs, roads, and parking lots that absorb and store energy rather than reflect the sun's heat, causing surface and ambient air temperatures to rise.

Not only do trees shade surfaces and reflect sunlight to reduce temperatures, but the physiological processes of trees also help to cool the air. When trees transpire water through leaf stomates, energy is absorbed by the evaporating water. The energy is removed from the

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[6] Simpson, Jim and Greg McPherson. *Estimating Urban Forest Impacts on Climate-Mediated Residential Energy Use.* American Meteorological Society. 1996. http://www.fs.fed.us/psw/programs/cufr/products/cufr_34_JS96_48.pdf
[7] Dwyer, John, Gregory McPherson, Herbert W. Schroeder, and Rowan A. Rowntree. *Assessing the Benefits and Costs of the Urban Forest.* Journal of Arboriculture. 1992. http://www.fs.fed.us/psw/programs/cufr/products/cufr_61_JD92_4.pdf

leaf and its environment, thus lowering local air temperatures. The shade of trees reduces radiation absorption and heat storage by buildings, roads, and other infrastructure. Reduced temperatures not only lessen the need for air conditioners, but they can also improve air quality. See *Air Quality and Pollution* for more on the air quality benefits of trees.

Planting Strategies to Reduce Energy Costs
Energy savings can only be realized by using appropriate management and planting strategies. For example:

- An energy-efficient planting design of a typical home in Madison, Wisconsin incurs $671 in heating and cooling costs. Heating and cooling costs for a home without trees are $700, and $769 for a home with an energy-inefficient planting design.[8]

Shade from trees is more effective at cooling a building than blinds or reflective coatings on windows. This is because trees not only block radiation from heating a building, but also reduce air temperatures surrounding the building.

Plant on the West and East, but Avoid the South
In the summer most solar energy hits the east and west walls of buildings. In the winter most solar gain is received on the south wall.

- Trees should be planted to shade windows on the east and west sides of buildings.
- West shading is most important because peak demand for energy occurs in the afternoon when the sun shines on the west face of buildings and overall ambient temperatures are higher.
- Avoid shading the southern sides of buildings in the winter to allow for the winter sun to provide heat. ***Deciduous trees*** that drop their leaves in winter are most appropriate on the south.
- Savings are inversely proportional to a tree's distance from the building. The closer a tree is to a building, the more shade it provides and the more energy is saved.
- Trees should not be placed too close to a building, however, in order to prevent damage to the building's foundation or piping. For more tips on planting see the *Planting and Maintenance Guide*.

When choosing trees, select large trees to provide the most shade and shelter and hence the greatest benefits. ***Evergreen trees*** with dense foliage are the best shade trees. Deciduous trees that drop their leaves during the winter are appropriate to plant on the southern side of buildings, but avoid evergreens on the south!

Shade the Air Conditioner!
Since air conditioners run more efficiently when kept cool, another way to increase energy savings is to shade the air conditioner.

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[8] Dwyer, John, Gregory McPherson, Herbert W. Schroeder, and Rowan A. Rowntree. *Assessing the Benefits and Costs of the Urban Forest.* Journal of Arboriculture. 1992. http://www.fs.fed.us/psw/programs/cufr/products/cufr_61_JD92_4.pdf

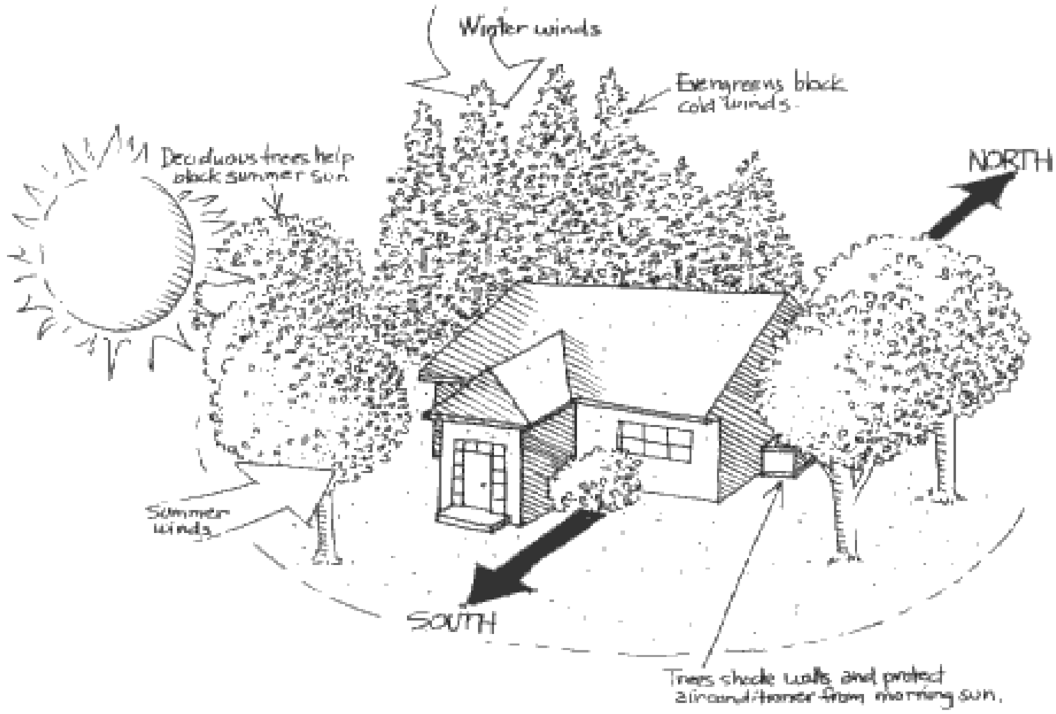
- Planting trees or erecting a trellis with vines around an air conditioner can reduce air temperatures around it by six to seven degrees Fahrenheit.
- This reduction in temperature can increase the efficiency of the air conditioner by ten percent during peak periods.
- It is best to plant several trees around the air conditioner to ensure that after a five year growth their canopies will completely shade the air conditioner and adjacent area.

Direct Summer Breezes Through Windows
In areas where little air conditioning is used, trees and shrubs can be pruned to funnel breezes that will naturally cool the building through open windows. It is important not to use this method when air conditioning is used because warm winds can increase interior temperatures. This is generally only a problem in the Southwest.

Reduce Wind Speeds
Trees can also reduce heating energy use by blocking cold winter winds. Although buildings help to keep wind speeds down, increasing the number of surrounding trees can reduce winds further. Note, however, that while this may create a benefit in the winter, this strategy can also work to deter cooling breezes in the summer, and can thus be counterproductive depending on local conditions.

Evergreen trees with foliage extending to the ground are the most effective windbreak trees. Plant windbreak trees upwind of the area to be protected. This often means planting on the west, northwest, and north sides of buildings. However, local conditions may cause prevailing winds from other directions.

- With a 10 percent increase in canopy cover, wind-speed can be reduced 10-20 percent.
- With a 30 percent increase in canopy cover, wind-speed can be reduced 15 to 35 percent.
- During the winter, deciduous trees can still provide a windbreak, still reducing wind-speeds as much as 50 to 90 percent of what they would with full leaf cover.



[9]

Windbreaks

Where appropriate, trees can be planted to create windbreaks around buildings. In these instances, tall trees should be used to guide winds up and over buildings. Trees are the best form of windbreak because they filter and absorb the wind without creating ***turbulence***. Very dense windbreaks, like walls, create turbulence on the leeward side of a windbreak, which can cause winds to be pulled downward, thus reducing the effect of the protection.

- The best windbreak trees are dense evergreens that are at least twice as tall as the building they are sheltering.
- Deciduous trees are only five to twenty percent as effective as conifers as windbreaks.
- Locate trees on the north and west sides of property since cold winds generally come from the north and west.
- Trees should be placed upwind and close enough together to create a dense screen.

Remember these general tree planting guidelines:

- West is best
- Let the sun shine in from the south
- Big trees are better
- Keep the air conditioner cool
- Direct winds up and over buildings
- The more trees the merrier

[9] American Forests. "How to Plant a Tree." http://www.americanforests.org/planttrees/howto.php

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Fact Sheet #3: **Air Quality and Pollution**

As cities struggle to comply with federal and state air quality standards, the powerful ways that trees can help to clean the air should not be overlooked. The most troublesome pollutants in our atmosphere are ***ozone***, ***nitrogen oxides*** (NO_x), ***sulfuric oxides*** (SO_x) and ***particulate pollution***. Ground-level ozone, or ***smog***, is created by chemical reactions between NO_x and ***volatile organic compounds*** (VOCs) in the presence of sunlight. High temperatures increase the rate of this reaction. Vehicle emissions, emissions from industrial facilities, gasoline vapors, and chemical solvents are the major sources of NO_x and VOCs. Particulate pollution, or particulate matter (PM_{10} and $PM_{2.5}$), is made up of microscopic solids or liquid droplets that can be inhaled and retained in lung tissue causing serious health problems. Most particulate pollution begins as smoke or diesel soot and can cause serious health risk to people with heart and lung diseases and irritation to healthy citizens. Trees are an important, cost-effective solution to reducing pollution and improving air quality.

Trees Reduce Temperatures & Smog

With an extensive and healthy urban forest, air quality can be significantly improved. Trees help to lower air temperatures and the urban heat island affect in urban areas (see: *Trees are Energy Savers* for more information on this process). This reduction of temperature not only lowers energy use, it also improves air quality, as the formation of ozone is dependent on temperature.

- As temperatures climb, the formation of ozone increases.
- Healthy urban forests decrease temperatures, and reduce the formation of ozone.
- Large shade trees can reduce local ambient temperatures 5 to 10°F. [10]
- Maximum mid-day temperature reductions due to trees range from 0.072°F to 0.36°F per each one percentage increase in canopy cover.[11]
- In Sacramento County it was estimated that doubling the canopy cover to five million trees would reduce summer temperatures by 3 degrees. This reduction in temperature would reduce peak ozone levels by as much as 7 percent and smoggy days by 50 percent!

Lower Temperatures Reduce Emissions in Parking Lots

Temperature reduction from shade trees in parking lots lowers the amount of evaporative emissions from parked cars. Unshaded parking lots act as miniature heat islands, where temperatures can be even higher than surrounding areas. Tree canopies can reduce air temperatures significantly. Although the bulk of hydrocarbon emissions come from tailpipe exhaust, 16 percent of hydrocarbon emissions are from evaporative emissions that occur

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[10] Arzamassova, Ekaterina, Jessica Lerner and Christopher Peterson. *The Economic Benefits of Urban/Suburban Forestry*. Brown University Center for Environmental Studies. 2003. http://envstudies.brown.edu/classes/es201/2003/Forestry/econbene.htm

[11] Nowak, David. *The Effects of Urban Trees on Air Quality*. USDA Forest Service. http://www.fs.fed.us/ne/syracuse/gif/trees.pdf

when the fuel delivery systems of parked vehicles are heated. These evaporative emissions and the exhaust emissions of the first few minutes of engine operation are sensitive to local microclimate. If cars are shaded in parking lots, evaporative emissions will be greatly reduced.

- Cars parked in parking lots with 50 percent canopy cover emit eight percent less pollution through evaporative emissions than cars parked in parking lots with only eight percent canopy cover.[12]
- Due to the positive effects trees have on reducing temperatures and evaporative emissions in parking lots, cities like Davis, CA, have established parking lot ordinances that mandate 50 percent canopy cover over paved areas.
- Similarly, emissions of nitrogen compounds (NO_x) are reduced during the start of "cold" engines when the parking lot in which a vehicle is parked is shaded by trees.

Active Pollutant Removal

Trees also reduce pollution by actively removing it from the atmosphere. Leaf ***stomata***, the pores on the leaf surface, take in polluting gasses which are then absorbed by water inside the leaf. Some species of trees are more susceptible to the uptake of pollution, which can negatively affect plant growth. Ideally, trees should be selected that take in higher quantities of polluting gasses and are resistant to the negative affects they can cause.

- A study across the Chicago region determined that trees removed approximately 17 tons of carbon-monoxide (CO), 93 tons of sulfur dioxide (SO_2), 98 tons of nitrogen dioxide (NO_2), and 210 tons of ozone (O_3) in 1991.[13]

Interception of Particulate Matter

In addition to the uptake of harmful gasses, trees also act as filters intercepting airborne particles and reducing the amount of harmful particulate matter in the air. Particulate matter is captured by the surface area of the tree and its foliage. These particles temporarily rest on the surface of the tree, as they can be washed off by rainwater, blown off by high winds, or fall to the ground with a dropped leaf. Although trees are only a temporary host to particulate matter, they help to keep some particulate matter out of the air where it could be harmful to humans. Increased tree cover will increase the amount of particulate matter intercepted from the air.

- Large evergreen broad-leafed trees with dense foliage collect the most particulate matter.
- The Chicago study determined that trees removed approximately 234 tons of particulate matter of less than 10 microns (PM_{10}) in 1991.[14]

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[12] McPherson, E. Gregory, James Simpson and Klaus Scott. *Actualizing Microclimate and Air Quality Benefits with Parking Lot Shade Ordinances*. Wetter und Leben. vol. 4 no. 98. 2002. http://www.fs.fed.us/psw/programs/cufr/products/11/cufr_69.pdf

[13] McPherson, R. Simpson, J. Peper, L. Gardner, E. Vargas, E. Maco and Q. Xiao. *Piedmont Community Tree Guide: Benefits, Costs and Strategic Planting*. December 2005. http://www.fs.fed.us/psw/programs/cufr/products/2/cufr_647_Piedmont%20Tree%20Guide.pdf

[14] Powe and G. Willis. Mortality and Morbidity Benefits of Air Pollution Absorption by Woodland, Report to Forestry Commission, Edinburgh. December 2002. http://www.forestry.gov.uk/pdf/airpollf.pdf/$FILE/airpollf.pdf

Large trees remove the most pollution!

- Large healthy trees greater than 30 inches in diameter remove approximately 70 times more air pollution annually (1.4 kg/yr) than small healthy trees less than four inches in diameter (0.02 kg/yr).[15]

Biogenic Volatile Organic Compounds

One important thing to consider when assessing the urban forest's effect on air quality is that trees actually emit ***biogenic volatile organic compounds*** (BVOCs). These are the chemicals (primarily isoprene and monoterpenes) that make up the essential oils, resins, and other organic compounds that plants use to attract pollinators and repel predators. As mentioned above, VOCs react with nitrogen oxides (NO_x) to form ozone. BVOCs account for less than ten percent of the total amount of VOCs emitted in urban areas. However, BVOC emissions from trees can contribute to the formation of ozone. Although their contribution may be small compared with other sources, BVOC emissions could exacerbate a smog problem.

Not all species of trees, however, emit high quantities of BVOCs. Here is a list of the types of trees with the highest isoprene emission rate. Plant these trees with caution:[16]

- Beefwood (*Casuarina*)
- *Eucalyptus*
- Sweetgum (*Liquidambar*)
- Black gum (*Nyssa*)
- Sycamore (*Platanus*)
- Poplar (*Populus*)
- Oak (*Quercus*)
- Black locust (*Robinia*)
- Willow (*Salix*)

Do not replace trees that are well adapted to thrive in certain environments just because they may be high BVOC emitters. The amount of emissions spent on maintaining a tree that may emit low amounts of BVOCs, but is not well suited to an area, could be considerable and outweigh any possible benefits of low BVOC emission rates.

This story, however, is not all doom and gloom. Trees should not be labeled as polluters because their total benefits on air quality and emissions reduction far outweigh the possible consequences of BVOC emissions on ozone concentrations. Emissions of BVOCs increase exponentially with temperature. Therefore, higher emissions will occur at higher temperatures. In desert climates, however, native trees adapted to drought conditions emit significantly less BVOCs than plants native to wet regions. As discussed above, the formation of ozone is also temperature dependent. Thus, the best way to slow the production of ozone and emission of BVOCs is to reduce urban temperatures and the effect

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[15] Nowak, David. *Tree Species Selection, Design, and Management to Improve Air Quality.* Construction Technology: Annual meeting proceedings of the American Society of Landscape Architects, 2000.
http://www.fs.fed.us/ne/syracuse/Pubs/Downloads/00_DN_Tree.pdf

[16] Ibid

of the urban heat island. As suggested earlier, the most effective way to lower temperatures is with an increased canopy cover.

These effects of the urban forest on ozone production have only recently been discovered by the scientific community, so extensive and conclusive research has not yet been conducted. Some studies have been conducted quantifying the effect of BVOC emissions on the formation of ozone, but none have conclusively measured the effect of the urban forest. Important questions remain unanswered. For instance, it is unknown if there are enough chemical reactions between BVOC emissions and NO_x to produce harmful amounts of ozone in urban environments. It is therefore, important for cities to be aware that this research is still continuing and conclusions should not be drawn before proper evidence has been collected. Be on the lookout for new research that will resolve these issues.

Best Ranked Trees for Improving Air Quality

Below is a list of the best ranked tree species for improving air quality as determined by David Nowak and the USDA Forest Service, Northeastern Research Station. This information is based on a study that rated trees on the combined effects of pollution removal, BVOC emissions, and air temperature reduction. Trees listed are tolerant to the pollutant under which they are ranked. Overall rankings are based on the individual pollutant effects weighted with an estimate of their cost on society.

Best Ranked Trees for Improving Air Quality[17]

Ozone	Carbon Monoxide	Overall
English Elm *Ulmus procera*	American Linden *Tilia Americana*	English Elm *Ulmus procera*
European Linden *Tilia europea*	American Beech *Fagus grandifolia*	European Linden *Tilia europea*
American Beech *Fagus grandifolia*	Silver Linden *Tilia tomentosa*	Tulip Tree *Liriodendron tulipifera*
Yellow Birch *Betula alleghaniesis*	Yellow Birch *Betula alleghaniesis*	Dawn Redwood *Metasequoia glyptostroboides*
Tulip Tree *Liriodendron tulipifera*	Redmond Lindontil *Tilia euchlora*	American Beech *Fagus grandifolia*
American Linden *Tilia Americana*	English Elm *Ulmus procera*	Yellow Birch *Betula alleghaniesis*
European Beech *Fagus sylvatica*	Ginkgo *Ginkgo bilboa*	European Beech *Fagus sylvatica*
Dawn Redwood *Metasequoia glyptostroboides*	Tulip Tree *Liriodendron tulipifera*	American Linden *Tilia Americana*
Paper Birch *Betula papyrifera*		American Elm *Ulmus Americana*
Particulate Matter	**Sulfur/Nitrogen Dioxide**	**Overall**
English Elm *Ulmus procera*	English Elm *Ulmus procera*	Port Orford Cedar *Chamaecyparis lawsoniana*
American Sycamore *Platanus occidentalis*	European Linden *Tilia europea*	Western Hemlock *Tsuga heterophylla*
Cupressocyparis *Cupressaceae leylandii*	Eastern Cottonwood *Populus deltoids*	Littleleaf Linden *Tilia cordata*
Port Orford Cedar *Chamaecyparis lawsoniana*	American Sycamore *Platanus occidentalis*	Mountain Hemlock *Tsuga mertensiana*
Black Walnut *Juglans nigra*	London Plane Tree *Plantanus acerifolia*	Silver Linden *Tilia tomentosa*
Blue Gum *Eucalyptus globules*	Dawn Redwood *Metasequoia glyptostroboides*	Paper Birch *Betula papyrifera*
European Linden *Tilia europea*	Tulip Tree *Liriodendron tulipifera*	Sugar Hackberry *Celtis laevigata*
European Larch *Larix decidua*	Black Walnut *Juglans nigra*	European Ash *Fraxinus excelsior*
Yellow Birch *Betula alleghaniesis*	Yellow Birch *Betula alleghaniesis*	Cedar Elm *Ulmus crassifolia*
Red Spruce *Picea rubens*	American Beech *Fagus grandifolia*	River Birch *Betula nigra*
		European Larch *Larix decidua*

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Fact Sheet #4: **Water Quality and Runoff**

Another very important role of the urban forest is its ability to reduce ***water runoff*** and protect water quality. High percentages of impervious surfaces in urban areas increase the amount and rate of stormwater runoff. In addition, pollution released by vehicles accumulates on roadways, parking lots, and on other surfaces, and rain washes these pollutants into nearby waterways. This increased contaminated runoff can cause great damage to riparian ecosystems. High peak flows displace sensitive flora and fauna and can cause harmful erosion, and hazardous compounds accumulate in wetlands and sediments. Trees not only can help to keep harmful pollutants out of waterways, but they also can help to decrease the amount of storm runoff.

Reduction of Runoff

Trees intercept and store rainwater, reducing runoff volume and delaying peak flows. Tree leaves, branches, and bark temporarily store rainwater, which eventually drips off to the ground, flows down the trunk, or evaporates into the atmosphere. The exposed soil directly surrounding the tree, or root zone, has a higher infiltration rate than compacted soil. This is because roots loosen the soil and increase water penetration. These processes change urban runoff patterns as they reduce the flow rate and lengthen flows over a longer period of time to help prevent storm surges.[18]

- A typical urban forest of 10,000 trees can retain approximately 10 million gallons of rainwater per year. That's approximately equal to the amount of water a three story building with the footprint size of an acre could hold![19]
- One large deciduous tree in coastal southern California reduces storm water runoff by over 4,000 gallons per year.[20]
- For every five percent of increased canopy cover, storm water drainage is reduced by two percent.

Of course the amount of rainwater a tree retains depends on its species and size. Broadleaf evergreen trees, like camphor trees, intercept the most water, followed by conifers (e.g., Monterey pines) and then broadleaf deciduous trees (e.g., London planetrees). Large mature trees (as usual) provide the greatest benefit, since they have the most surface area to retain water. In regions where most precipitation falls in winter, evergreen trees play the most important role. Where summer precipitation is greatest, deciduous trees also retain substantial amounts of water. In drought-prone regions it is important to plant trees that are drought-resistant so that excess watering is not necessary.

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[18] Cities should not, however, rely solely on trees for flood control. During very large storms when floods can occur, the canopy storage capacity is exceeded.
[19] Center for Urban Forest Research, *Is All Your Rain Going Down the Drain? Look to Bioretainment—Tress are a Solution.* http://www.fs.fed.us/psw/programs/cufr/products/newsletters/UF4.pdf
[20] Center for Urban Forest Research, *Is All Your Rain Going Down the Drain? Look to Bioretainment—Tress are a Solution.* http://www.lgean.org/documents/bioretainment.pdf

Urban forests also reduce soil erosion by sheltering the ground and minimizing the impact of raindrops on barren surfaces. Root growth and the decomposition of biomass also increase the water capacity and rate of soil infiltration by rainfall, further reducing overland flow.

Pollution Removal

Stormwater pollution is comprised of sediments and chemicals that are washed into natural waterways during rainfall. These pollutants include everything from motor oil and gasoline to fertilizers, pesticides, heavy metals and sediments, which have harmful effects on drinking water, wildlife, recreation, and fisheries. The establishment of vegetated areas designed to intercept storm water, called ***bioretention*** areas, is extremely important for reducing runoff in urban settings. Stormwater can be directed into bioretention areas which act as pollutant filters and water retention zones. The increased permeability of soil due to root growth allows for pollutants to infiltrate the soil and possibly be decomposed and/or absorbed by plant roots. Vegetation functions as a natural filter by retaining sediment and organic matter from overland flow. The reduction of flow volume and rate reduces flooding hazards and decreases surface pollutant wash off. Runoff from small storms is responsible for the highest percentage of annual pollutant loading. Decreasing runoff during these small storms with increased tree cover can greatly reduce water pollution.

- Properly designed bioretention areas, often called "rain gardens," can effectively trap and retain up to 99% of common pollutants.
- A study conducted in Maryland measured two well-designed bioretention areas and found that they removed roughly 95 percent of copper, 98 percent of phosphorous, 20 percent of nitrogen, and 20 percent of calcium from stormwater.[21]

Other Strategies

Overall, the best strategy is to plant more trees and improve the health of the existing forest. (See *Planting and Maintenance Guide* for a comprehensive list of strategies to improve forest health). However, there are a few other strategies to increase runoff and water quality benefits:

- Plant trees that require little supplemental watering.
- Plant trees in small groves where possible.

[21] Begin, Lisa, StormwaterAuthority.org. http://www.stormwaterauthority.org/assets/Bioretention.pdf

- Match trees to rainfall patterns so they are in-leaf when precipitation is greatest.
- Plant large evergreen and broadleaf trees where appropriate.
- Increase amounts of pervious pavement.
- Build recharge areas under parking lots and holding tanks and cisterns under playfields.
- Allow for surface area ponds to accumulate water.
- Construct riparian retention and treatment areas.

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Fact Sheet #5: **Economics: The Bottom Line**

So far we have mentioned various ways that healthy urban forests can enhance quality of life, reduce energy costs, sequester carbon, improve air and water quality, and reduce storm runoff, but what about the bottom line?

Too often, urban trees are viewed as low-priority spending items, and in the budget process funds are deferred to other civic projects that are seen as more directly addressing issues of health, welfare, and safety. Civic leaders should view their urban forests as "green" infrastructure, providing tangible benefits and values that enhance quality of life, safety, and public health. A healthy urban forest is one of the only municipal capital investments that will appreciate in value over time. As urban forests grow, their environmental, social and economic benefits increase.

- For every dollar spent on the urban forest in Fort Collins, CO, the forest returns a benefit equivalent to $2.18.[22]
- Economic benefits will increase as healthy trees grow and require less maintenance.

The most tangible economic benefit that urban forests bring to cities are the enhancement of property values, energy savings, reduced costs associated with poor air quality, and increased commercial activity. If urban forests and their products are managed properly, they can even return profits.

Property Values

Numerous studies have concluded that urban forests and parks have a positive economic affect on adjacent and nearby properties. Properties adjacent to parks can have property values eight to twenty percent higher than comparable properties elsewhere. Municipalities can benefit from higher property values when property taxes are assessed and taxes are paid upon the sale of the property.

- A study performed in 1988 in Athens, Georgia found that a single large front-yard tree can increase home sale price by almost one percent ($336 in 1985 dollars). The increase in property values due to trees across the city resulted in an estimated increase of $100,000 (1988 dollars) in the city's property tax revenues.
- A greater value of nine percent ($15,000) was determined by a U.S. Tax Court case for the loss of a large black oak on a property valued at $164,500.[23]
- The Center for Urban Forest Research estimates that properties with trees are valued five to fifteen percent higher than comparable properties without trees. Increased value depends on the species, maturity, location, and quality of the trees.

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[22] Center for Urban Forest Research: Pacific Southwest Research Station. *Save Dollars with Shade: A Community Tree Planting Solution to Conserve Energy.* 2005. http://www.fs.fed.us/psw/programs/cufr/products/3/cufr_149.pdf

[23] McPherson, Gregory, James Simpson, Paula Peper, Scott Maco and Qingfu Xiao. *Benefit-Cost Analysis of Fort Collins' Municipal Forest.* Center for Urban Forestry Research, Southwest Station. 2003. http://www.fs.fed.us/psw/programs/cufr/products/cufr430_Ft.CollinsBCAFinal.pdf

- The Center for Urban Horticulture at the University of Washington, Seattle estimates that rental rates for commercial property are about seven percent higher in areas with quality landscaping and trees.

Deferred Street Maintenance Costs

Paved surfaces that are shaded by trees have a longer life span. Asphalt paving is made up of a stone aggregate and oil binder. When it is unshaded and exposed to heat, the oil binder volatizes and leaves the stone aggregate unprotected. Vehicles then loosen the aggregate, which consequently grinds down the pavement.

- A study performed by the Center for Urban Forest Research found that repaving could be deferred ten years on a well-shaded street and potentially 25 years on a heavily shaded street.
- The same study projected that the shade from large trees reduced repaving costs by 58% over a thirty-year period. Shade from small trees saved costs by only 17%. The study not only demonstrated that trees help to reduce street repaving costs, but also that large trees provide greater benefits.[24]

Energy Savings

According to Greg McPherson of the Center for Urban Forestry, "if you plant a tree today on the west side of your home, in five years your energy bills should be three percent less. In fifteen years the savings will be nearly twelve percent." By planting two more trees—one on the west and one on the east—this savings can increase another ten percent. This amounts to almost one-fourth of a typical month's energy bill.[25]

Reduced Healthcare Costs Associated with Poor Air Quality

Planting urban trees is one of the least expensive ways to decrease unhealthy amounts of air pollution. They can not only help cities to comply with national and state standards for air quality, but also decrease pollution-related health problems, which in turn can save money spent on healthcare.

- In 1994, New York City's urban trees removed an estimated 2,007 tons of air pollution with an estimated value to society of $9.5 million.[26]
- Sacramento County's 6 million trees removed approximately 1,606 tons of air pollution in 1990, with an estimated value to society of $28.7 million.[27]

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[24] McPherson, Gregory and Jules Muchnick. *Effects of Street Tree Shade on Asphalt Concrete Pavement Performance.* Journal of Arboriculture vol. 31 no. 6. November 2005. http://www.fs.fed.us/psw/programs/cufr/products/cufr639mcpherson-JOA-pavingshade.pdf

[25] These numbers are typical savings amounts for homes in the southwestern US, so numbers may be less in cooler climates.

[26] *A Snapshot of the Northeastern Forests,* A publication of the Northeastern Area State and Private Forestry, October 2005 , http://www.na.fs.fed.us/pubs/misc/snap_shot/ss.pdf

[27] http://www.fs.fed.us/psw/programs/cufr/products/cufr562_Newsletter_Jan05_Special_Edition.pdf

Stormwater and Water Quality Benefits

By reducing runoff flows and improving water quality, trees benefit cities in avoided stormwater treatment and flood control costs.

- In 2002, Santa Monica's 29,299 street and park trees intercepted 51,030,000 gallons of annual rainfall. Avoided stormwater treatment and flood control costs were estimated at $110,890 or $3.60 per tree.
- Milwaukee's urban forest, with 16 percent canopy cover, reduces runoff flow by 22 percent and provides an estimated $15.4 million in benefits.[28]

Commercial Benefits

A study performed by Kathleen Wolf at the Center for Urban Horticulture at the University of Washington, Seattle determined that urban trees improve economic stability of retail environments by attracting businesses and consumers. Well maintained landscaping, including canopy trees, attracts consumers and increases their rate of return by setting a positive mood and sending messages of quality.

- In business districts with trees consumers are willing to pay 11 percent more for goods than in treeless districts.
- In addition, consumers give 30 percent higher ratings to the quality of goods, and 80 percent higher amenity and comfort ratings for tree-lined commercial streets.[29]
- Vehicles parked in the shade of a tree will have an interior temperature twenty to thirty degrees Fahrenheit cooler than a vehicle parked in the sun. This can increase the duration and frequency of consumer visits and their willingness to pay for parking.

Using the Urban Forest

There are many ways that cities can utilize their urban forest material. (For more information see: *Trees and Carbon Dioxide*) It is possible that cities may break-even, or even make a profit if they take advantage of the most economically valuable uses of their urban trees. Below are a few tips for realizing economic benefits from urban forest products.

- Mill any valuable timber using a local portable mill. Unique hardwoods found in the urban forest can be used by private companies, woodworkers, and furniture makers to make beautiful and useful products. The utilization of urban wood has become increasingly easier as organizations have come together to facilitate the milling of urban wood by supplying portable saw mills to those ready to sell trees. Cities can use these services and possibly make a profit by selling valuable urban trees as lumber.
    - The most valuable species suitable for milling are walnut, butternut, ash, oak, cherry and paulownia. Hard Maple, Elms, fruitwoods, basswood, sycamore, cedar and yellow poplar are also good species to consider.

[28] Cole, Preston et al. *The Milwaukee Green Team's Report to Mayor Tom Barrett.* October 2005. http://www.ci.mil.wi.us/display/displayFile.asp?docid=13213&filename=/Groups/cityGreenTeam/documents/88841_LowRes.pdf

[29] Alexander, Katherine. *Benefits of Trees in Urban Areas.* www.coloradotrees.org/benefits.htm

    - Larger trees of these species are the most valuable for milling.
    - See: www.harvestingurbantimber.com or www.ufei.org for more information.
- Know your local industries. Municipalities with local wood-using industries, like furniture making, may have more opportunities to utilize their urban wood.
- Consider selling any wood that is unsuitable for milling as firewood. This encourages citizens to heat their homes with non-fossil fuel energy sources and keeps large woody debris out of landfills.
- Chip and mulch the biomass of the urban forest to enhance soil quality at low cost. The nutrients found in the organic material should be recycled into the soil to support the next generation of urban trees. A healthier urban forest will last longer and provide maximum benefits.
- In addition, if there is a co-generation plant near your city, consider selling your excess wood chips to efficiently produce both electricity and heat.

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Fact Sheet #6: **Social Benefits of Trees**

In addition to providing a city with environmental and economic benefits, urban forests also provide a wealth of social benefits to a city's population. A recent study at Washington State University found that city dwellers overwhelmingly desired trees in the urban environment. Eighty-three percent of those surveyed agree that trees are important to their quality of life. In addition, attractive and historic trees can imbue a community with an individual spirit and inspire feelings of civic pride. When communities radiate feelings of pride and vitality, people are attracted both as tourists and residents.

Psychological Benefits

Trees and urban natural places can affect the day-to-day moods, activities, and emotional health of the people who encounter them. An influential theory proposed by S. Kaplan (1995) called the Attention Restoration Theory proposes that natural environments and vegetation can assist in the functioning of attention. Kaplan proposes that daily life includes tasks that require long periods of ***directed attention***, and that the execution of these tasks can be fostered by views of nature. People whose minds are constantly directed towards these types of tasks can become fatigued, stressed, anxious, irritable, and can loose their ability to concentrate ("directed attention fatigue"). Urban forests provide a restorative escape from activities that require directed attention by allowing people to rest their minds and effortlessly contemplate their environment. Studies have shown that:

- People with views of nature from their work environment are less frustrated, more patient, have greater enthusiasm for their job, better health, and overall have a higher life satisfaction than those without views of nature.
- Those without views of nature in the workplace complain 23 percent more often of illness than those with views of nature.
- Urban forests help children cope with Attention Deficit Disorder (ADD). A study conducted in 2001 by the Human-Environment Research Laboratory (HERL) demonstrated that ADD symptoms are more manageable after activities in green settings, and that the greener a child's everyday environment, the more manageable their ADD symptoms are in general.

Health Benefits

In addition to the psychological health benefits mentioned above, trees can also affect the physical health of a population. Kathleen Wolf at the Center for Urban Horticulture at the University of Washington has explored the idea that trees and parks can help urban dwellers to make better, more active choices about their routine activities. She asserts that with an aesthetically pleasing urban forest, people are encouraged to walk in their neighborhoods during their daily activities or for recreation. The encouragement of physical activity in the urban forest can help to reduce high occurrence of obesity and weight-related diseases.

By lowering the temperatures of the urban heat island (discussed in the *Trees are Energy Savers* section), trees can help lower the risk of heat-related health problems, like heat stroke, dehydration, and skin cancer. Finally, by lowering pollution levels (discussed in the *Air Quality and Pollution* section), trees can help to decrease respiratory ailments caused by pollutants. It has also been observed that patients in hospitals who have a view of a tree outside their window recover quicker than patients who do not.

Crime Reduction

The Human-Environment Research Laboratory has conducted multiple studies determining that trees can help to reduce crime. Frances Kuo and William Sullivan, the two primary researchers at HERL, suggest that trees reduce crime in two important ways.

First, frequent encounters with nature can help to soothe violent temperaments. As discussed above, trees help to mitigate mental fatigue which can cause outbursts of anger and potentially violence in some people.

- A survey of households in two nearly identical housing projects, differing primarily in the amount of trees and plants surrounding them, showed that residents living in areas with trees use more constructive methods to deal with conflict.
- A higher incidence of domestic violence was reported in the housing project without surrounding vegetation. Fourteen percent of residents living in housing projects without vegetation threatened to use a knife or gun against their children versus only three percent of residents living in vegetated areas.

Second, trees deter crime by increasing surveillance on city streets. People tend to use spaces with trees more than they use treeless spaces. Vegetation on the street will encourage more people to use the outdoor space, thereby defending the community from crime. Even if people do not frequently use a vegetated space, there is an implied surveillance. Well groomed vegetation and trees imply that residents care about their home and community, signaling that an intruder could be noticed and/or confronted. In addition, people perceive neighborhoods with blighted streetscapes and unhealthy urban forests as threatening and dangerous. Healthy urban forests, therefore, can diminish feelings of fear and reduce incidences of crime and violence.

Neighborhood Improvement

Healthy urban forests can further improve neighborhoods by calming traffic, reducing noise pollution, encouraging pedestrian traffic, and fostering stronger community relationships.

Trees can help to reduce traffic speeds if they are strategically placed on the street in extended curbs, roundabouts, or lining the sidewalk to narrow the street. Tall and closely spaced trees give a perception of speed in a narrower space. Trees also forewarn drivers of approaching curves. These perceptions will induce people to slow down.

Paved surfaces that are shaded by trees have a longer life span. Asphalt paving is made up of a stone aggregate and oil binder. When it is unshaded and exposed to heat, the oil binder volatizes and leaves the aggregate unprotected. Vehicles then loosen the aggregate, which consequently grinds down the pavement.

- A study performed by the Center for Urban Forest Research found that repaving could be deferred ten years on a well-shaded street and potentially twenty-five years on a heavily shaded street.

Noise pollution is also significantly reduced with a healthy urban forest. Trees act as a buffer to reduce noise pollution, and can absorb as much as 50 percent of urban noise.

Trees lining the sidewalk serve as a protective barrier between vehicles and pedestrians. Residents who feel safe walking on the street will be more likely to do so. Increased pedestrian traffic encourages neighborhood interactions and fosters the development of community identity. Casual social relationships develop when individuals have opportunities for face-to-face contact. Neighbors who have frequent face-to-face contact maintain social ties and can even become acquaintances or friends.

Community interactions can be further developed in common spaces populated by trees and vegetation. According to the Human-Environment Research Laboratory, a greater number of people use common spaces that contain trees than those without. People are also more inclined to spend time in common spaces as the number of trees populating those spaces rises, creating opportunities for increased community interaction. Furthermore, residents who actively participate in caring for trees and vegetation in outdoor common spaces are more likely to have strong social ties with neighbors. The more residents socialize with their neighbors, the stronger their sense of community pride and identity. The urban forest, thus, provides neighborhoods with a unique and stimulating location for social interaction.

Business District Enrichment
A recent study conducted by the Center for Urban Horticulture at the University of Washington has shown that trees in business districts can help to draw in more people. Trees do this by creating a positive mood (especially during seasonal changes), by creating a distinctive pace, by making that space memorable, and by delineating the boundaries of the shopping district. Healthy and aesthetically pleasing trees outside businesses illustrate that businesses not only care about the quality inside their doors, but also care about the quality of the outside community. (For more details on economic impacts see *Economic Benefits: The Bottom Line*)

- Consumers surveyed in business districts with and without urban vegetation show that in business districts with trees they are willing to pay 11 percent more for goods than in treeless districts.

Wildlife Preservation

Healthy urban forests support urban wildlife by providing food, cover, and living space for various animals. A high percentage of native trees can provide indigenous wildlife species with habitat and food and help to integrate the urban area into its natural surroundings. Populations of birds, squirrels, rabbits, and other creatures give observers entertainment and delight. Supporting a wildlife population is an indicator that a city is a healthy, livable place for humans, plants, and animals.

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Fact Sheet #7: **Management Guidelines**

A healthy urban forest maintains benefits and services over the long term and is managed to maximize return on investment. The most efficient way to manage a municipal urban forest is to begin with a long-term management plan that outlines specific goals, procedures, costs, and benefits, rather than following a strictly reactionary and emergency management system. An urban forest management plan should be regionally focused and locally minded in order to be most effective. This fact sheet offers a few guidelines that urban forestry plans should incorporate if regionally appropriate.

Potential Management Goals

While the ultimate goal of an urban forestry program should be to maximize the health and size of the urban forest, and thereby the benefits provided to the community, several subsidiary goals can help to achieve that objective.

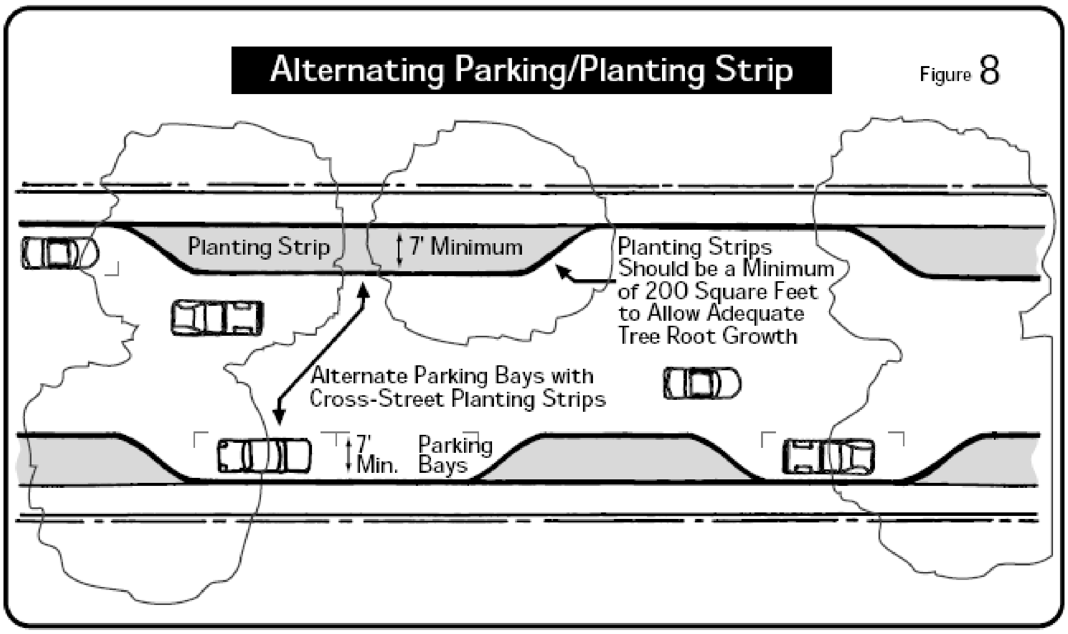
- Increase public involvement and environmental stewardship. If there are easy ways for citizens to be involved in the planting and maintenance of the forest, they will be more likely to support ongoing management programs. Without strong support from citizens, urban forestry programs are liable to face funding cuts.
- Develop a database of information that will help to define, detect, and predict the health and status of the urban forest. Without relevant or long-term data, planners cannot properly apply appropriate management prescriptions. With more information the future health of the forest can be maximized.
- Encourage inter-agency participation. Many urban foresters are frustrated by lack of cooperation between their departments and other municipal agencies. In order to maximize benefits and cost effectiveness, various agencies must work together to reach one goal.
    - The San Francisco Department of Environment has created a position with responsibility for fundraising, interagency coordination and budget responsibilities to ensure that "San Francisco realizes the full range of tree benefits into the future." These types of positions can ensure that the long-range goals of a program are realized.

Planting Guide

Select Planting Locations Wisely

- Give trees as much space as possible. The longevity, health, and size of a tree will be greatly increased if it has ample access to soil nutrients. If a city wishes its trees to live longer and grow larger, and consequently provide the most benefits, then precautions must be taken in order to ensure that this occurs.

- Look for innovative ways to incorporate green spaces.
    - Replace impervious areas in medians, shoulders, and traffic circles or triangles with vegetation.
    - Calm traffic and plant trees with the addition of traffic circles, bulb-outs/neckdowns, and medians.
    - Decrease width of car lanes and plant trees in this freed space.
    - Convert parking spaces into green spaces.
    - Integrate tree wells into existing parking spaces, creating space for a tree while retaining compact parking.
    - Encourage public use of tree lined streets by placing furniture and benches (potentially made from milled urban timber) in green spaces.



Example of Innovative Incorporation of Trees into a Streetscape
Graphic Courtesy of the City of Eugene, OR

- Plant trees in wide soil bands between the curb and sidewalk. Avoid individual planting holes and tree pits. Small groves of trees are stronger and healthier. With more space, clusters of trees are able to develop better root systems that protect each other from wind, disease, and drought. If planting holes are the only available option, make them as long and wide as possible.
- Plant trees in small groves to minimize stormwater runoff.
- Maximize the use of pervious pavement. Substitute impervious pavement with pervious pavement to allow for better nutrient, water, and oxygen flow.
- Plant trees to help reduce vehicular traffic. Street improvements that include trees not only increase canopy cover and encourage pedestrian activity, but can also reduce vehicle miles traveled and pollution emitted.

    - An improvement of pedestrian, mass transit, and bicycling right of ways including increased tree planting in Portland, Oregon resulted in an eight percent decrease in the amount of vehicle miles traveled, a six percent decrease in nitrogen oxide emissions, and a three percent decrease in carbon dioxide emissions.

Protect Your Soils

- Provide one cubic yard of soil volume for every five cubic yards of crown volume of a mature tree.
    - Mature shade trees require 75-95 cubic yards of soil.
    - Smaller trees require 10-30 cubic yards of soil.
- Meet or exceed minimum width requirements of planting zone:
    - Lawn or herbaceous plants: three feet
    - Shrubs: five feet
    - Single row of trees: eight feet
    - Double/staggered row of trees: 12-18 feet
- Use low fencing, bark mulch, or herbaceous plants should protect the soil underneath trees from compaction and erosion.
- Use tree grates to allow for soil protection along with an increased pedestrian right of way. Tree grates are appropriate only when they have easily removable rings to allow for tree growth.
- Ensure that soils are healthy and aerated. Trees need nutrients, oxygen, moisture and a sturdy soil structure in order to grow and remain healthy.
- Use structural soils where appropriate. Structural soils are an engineered mix of gravel and soil that prevent soil compaction, facilitate drainage and access to nutrients and oxygen, and allow for deep root growth. These soils should be used in areas where trees are planted near or adjacent to pavement. Structural soils provide a good mix of nutrients for plant health and structural support for the surrounding pavements. Using structural soils will help to minimize future maintenance costs and maximize tree growth and health.
    - The life expectancy of a tree is four to five times greater when adequate soil volume is provided for root growth.

Save Energy by Planting Trees

- Follow the planting guidelines in the *Trees Save Energy* fact sheet in this toolkit to reduce energy costs due to the cooling and heating of buildings. Remember these tips:
    - West is best
    - Let the sun shine in from the south
    - Big trees are better
    - Keep the air conditioner cool
    - Direct winds up and over
    - The more trees the merrier

Choose the Right Species

- Plant the right species for the location. Understanding the physiological requirements of different tree species is crucial to ensuring the health and longevity of the urban forest. Foreseeing potential conflicts with power lines, sidewalks, and underground utilities during the planting stage will reduce maintenance costs in the long run.
- Choose large shade trees over small trees since they will provide the most benefits over the long term. Large trees provide greater energy savings, air and water pollution mitigation, runoff reduction, visual impact, traffic calming, increase in property values, and carbon sequestration.
- Ensure the urban forest has a high diversity of species. Low diversity makes urban forests more susceptible to disease and insect infestation. The USDA recommends that any one species does not account for more than five percent of an urban forest. This may also help to mitigate potential widespread mortality related to climate change.
- Plant native species. Because native plants are best adapted to the local climate and site conditions they will be more resistant to drought and will require less fertilizer. In addition, natural wildlife habitats will be preserved.
- Plant low-maintenance trees. Choose trees that require less pruning and trimming and are more adapted to local climate and site conditions. In turn, this will reduce the amount of greenhouse gas and air pollutant emissions released due to maintenance activities.
- Reduce water consumption by planting drought-resistant species. If necessary use efficient irrigation systems to water the landscape.
- Plant trees that emit low amounts of biogenic volatile organic compounds.
- Choose trees that are in-leaf when precipitation is greatest to maximize water storage capacity and reduce run off.

Maintenance Guide

"Since the up-front costs to establish trees have already been made, keeping these trees healthy and functional is one of the best investments communities can make." *-Greg McPherson, director of the Center for Urban Forest Research, Southwest Station.*

Successful Strategies

- Get volunteers to do the work! Start a new program or work with already established non-profit groups to engage volunteers to plant and maintain trees. This will reduce costs and get the work done.
    - Oakland, CA gives away free street trees to homeowners/property owners who are willing to care for the tree. The city will plant the tree and provide future maintenance if homeowners will agree to water the tree and protect the

soil with mulch or woodchips for the first 3 years. These types of programs help to ensure that sensitive new trees will survive.

- Establish a graduated maintenance cycle that includes all trees in the municipality. Prune small trees every eight years, medium trees every seven years, and large trees every twelve years
- Prune early. Pruning soon after the establishment of a tree will train young trees to have strong branching structures that require less frequent trimming and shaping in the future.
  - Ideally young trees should be pruned every other year for the first five years after planting.
  - Pruning costs increase as the tree matures, so get it done when it's cheapest.
- Reduce the use of maintenance activities that release emissions. When appropriate, use rakes instead of leaf blowers and handsaws instead of chainsaws.
- Protect trees in construction zones. Make sure the trunk, canopy, and roots are protected.
- Survey trees for pest infestation and disease. By catching pests and diseases early, widespread outbreaks can potentially be evaded.
- Create a list of resources, including nurseries, arborists, landscape architects, and consultants, that homeowners and city officials can draw on to plant, maintain, and dispose of trees. These contacts should be provided with a list of species acceptable to your local climate. Accessible and environmentally responsible resources will help to make sure that urban forests on private and civic land are properly taken care of.

Other Innovative Strategies

- Build recharge areas under parking lots and holding tanks and cisterns under playfields.
- Allow for surface area ponds to accumulate water.
- Construct riparian retention and treatment areas, or "rain gardens."

Following this planting and maintenance guide will help to reduce costs in the long run, increase the vitality of the urban forest, and decrease emissions released to unnecessary maintenance activities. By allowing trees to have adequate growing space, future maintenance costs will be lowered and trees will be healthier, larger, and longer-lived. In the long run, healthy and sustainable urban forests will provide more environmental, social, and economic benefits.

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Successful Policies and Programs

The following section is a guide to inform city officials of the ways to achieve a successful urban forestry program. Included is an outline of the things to consider as components of an urban forestry division, important partnerships and liaisons, and sample ordinances. This outline is followed by case studies of three municipal urban forestry programs that highlight different best practices in program development and implementation.

Program Organization

- Establish a distinct urban forestry division in order to elevate and bring attention to concerns and budgetary needs of the urban forester.
- Hire a city urban forester to manage the division and oversee all urban forestry programs.
- Include district managers, administrative support, maintenance and nursery crews, and field operations staff within the urban forestry division.
- Support all new staff through an in-house training program to ensure quality.
- Establish an urban forestry maintenance shop to oversee equipment inventory, maintenance, and repair.
- Establish a municipal nursery to ensure planting of appropriate and attractive trees and vegetation.

Program Goals and Operations

- Establish an urban forest management plan that specifies the goals, best management practices, and aspirations of the urban forestry division. Included in this management plan should be a cost/benefit analysis to convince municipal leaders of the viability and advantages of the program.
- Continuously monitor progress of plan implementation to ensure compliance and make revisions when necessary.
- Create an inventory of city trees in order to most appropriately manage the forest.
- Continuously update this inventory with new information including: date and extent of pruning, tree health, signs of disease or infestation, and where and when new trees are planted.
- Utilize software programs like Stratum or City Green to quantify the benefits of the urban forest.
- Implement a regular maintenance cycle to ensure that future hazards and risks are avoided by proper pruning, removal, and replanting.
- Utilize the products of the urban forest in the most cost-effective, efficient, and environmentally friendly manner.

- Launch a comprehensive outreach and education campaign to educate the public about the benefits of urban forestry and gain support for the program.
- Design the urban forestry program to meet community goals and build on civic pride and history.

Partnerships

- Partner with local non-profit groups to supplement municipal programs with volunteer tree planting and maintenance programs.
- Encourage the participation of volunteers and neighborhood groups since they are crucial to build support and get work done.
- Secure strong support from the mayor, city council and other municipal leaders in order elevate program goals and obtain necessary funding.
- Create solid liaisons with other city agencies to make sure that the vision of the urban forestry division is not undermined or diluted by other departments. Hiring a staff person to foster and maintain these relationships could be instrumental to the success of a program.
- Integrate urban forestry into other municipal environmental initiatives, climate action plans, and sustainability plans.
- Work with local researchers and universities to create, monitor, and evaluate management practices to guarantee excellence.
- Build relationships with educators to involve students in urban forestry by offering internships, training programs, field trips, demonstrations, and lesson plans.
- Team up with local utility companies to encourage energy reduction through tree planting.
- Engage with local arborists, landscape architects, landscape maintenance firms, and nurseries to secure their commitment to the goals of the urban forestry division.
- Construct a resource guide for citizens and municipal leaders of these individuals, companies, and firms to ensure that the division's goals and guidelines are followed.

Sample Ordinance Topics

- Require tree planting with all new development, construction and roadway improvements.
- Require new tree planting on public and private property to attain a goal of at least 25 percent canopy cover. Approval for tree removal in the form of a permit should be required to assure new trees are planted in place of trees being removed.

Example Urban Forestry Ordinances

Swiecki, T.J. and E.A. Bernhardt

Guidelines for Developing and Evaluating Urban Forestry Ordinances

2001

http://www.isa-arbor.com/publications/ordinance.aspx

- Require new and refurbished parking lots to attain 50 percent canopy cover after 15 years.
- Regulate tree planting by specifying species and placement of trees.
- Require new construction or significant redevelopment to meet a certain percentage of canopy coverage or pay impact fees that the local government can use to preserve tree tracts and plant trees in other locations.
- Require an assessment and approval of tree removal requests. Protect historic, memorial, and native trees by restricting and regulating terms of removal.

Case Study #1: **Milwaukee: Financing & Managing the Urban Forest**

Milwaukee's urban forestry program is acknowledged as one of the most successful in the United States. The program has a long history, dating to the establishment of the Forestry Section in 1917. At that time the city employed a city forester, Otto Spidel, whose strong leadership built the structural and philosophical basis on which the present Forestry Section rests. After 1918 the section quickly grew and by 1925 the department employed over fifty people. Today the City Forester manages a team of three District Managers, who each manage Forestry Operations Managers, Technicians, and Crew Leaders. Spidel also oversaw the establishment of the Municipal Nursery and Forestry Maintenance Shop, which both continue to offer operational support to the section by supplying plants and repairing tools. This strong operational structure and staff allow for efficient, productive, successful, and innovative management. This historical tradition coupled with successful management practices is crucial to the continued success and financial support of the section.

Present Section Structure

Milwaukee's Forestry Section is located within the City of Milwaukee's Department of Public Works. A department commissioner, who reports to the mayor, is responsible for all operations of the department. He meets with section heads separately and in broader department-wide meetings to ensure that the voice of each section is heard by the mayor and that close connections are maintained between departments. The Forestry Section thus has the advantage of being aware of potential problems that may otherwise have gone unseen. Any work conducted by another department that has an impact on city trees (e.g., road and sidewalk construction, new building development, storm drainage development, transportation issues) must be reviewed by the Forestry Section. This allows the department to minimize damage to trees, maximize tree replacement and planting, and hold contractors responsible for tree damage or loss. This inter-departmental communication and support is essential for proper forest management and care.

Budgeting on Outcomes

In addition to inter-departmental support, the Forestry Section boasts strong support from the Mayor and Common Council. This support is manifested in their willingness to continue to allocate appropriate funding. In order to secure funding the Forestry Section must first submit a budget proposal to the Department of Public Works. The budget proposal that the Forestry Section writes is concise and is based on outcomes. Extensive initial analysis of its operations forms the basis on which each budget proposal rests. For example, for a budget of $8 million, the Forestry Section guarantees a 70 percent favorable rating or customer satisfaction, as well as 80 percent satisfaction for $9 million, and 90 to 100 percent satisfaction for $10 million. Another tactic the section uses to directly frame the effect of funding levels on mortality rates is to convey that a certain amount of funding will support a mortality rate of a particular percent. With any decrease in funding the mortality rate will rise. This type of budget is much easier for city leadership to understand because it does not have to analyze the costs of maintaining, planting, and removing trees. This budget strategy has also proven to be highly successful, since at $11 million ($18.50 per capita) annually, the Forestry Section budget is the highest in the country.

Once the Department of Public Works has reviewed the budget proposal, it submits a departmental budget to the mayor, who makes appropriate changes and submits his budget to the Common Council. In recent years, both the mayor and council have been reluctant to cut planting budgets. They are more willing to cut tree maintenance budgets in order to retain funds for planting. In some instances the council has even vetoed some of the mayor's cuts to planting budgets. Although these small victories are significant to the Forestry Section, section staff are adamant that forest management funds should not be cut so as to ensure their top priority of public safety.

In addition to receiving money from the City, the Forestry Section also looks to receive grants from both State and Federal sources. The section was successful in acquiring $350,000 from the FY 2006 Interior and Related Agencies Appropriations bill passed by the Senate Appropriations Committee in the summer of 2005. This grant was given to the Forestry Section to replace asphalt playgrounds with trees to reduce stormwater runoff and improve school grounds. Senator Herb Kohl (Wisconsin), understands that, "projects like this that serve a dual purpose are good investments of our scarce federal dollars," and that, "urban forestry programs have been used with great success in other communities,"[30] With support from important political leaders, Milwaukee's urban forest flourishes.

Forest Management Goals

With support from the mayor, council, and other departments, and a relatively healthy budget, the Milwaukee Forestry Section is able to manage the city's urban forest with innovation and excellence. The Forestry Section's primary forestry goals are to maintain public safety, sustain a healthy urban forest, to beautify city streets and neighborhoods, and thereby provide a better quality of life for citizens and visitors. The section also seeks to "maximize the environmental and psychological benefits of the urban forest, while enhancing both landscape and property values."[31]

An Excellent Workforce

One reason the Forestry Section is particularly successful is that it has implemented a comprehensive employee training program. All entry-level "Urban Forestry Specialists" must go through a six-month training program that results in a professional workforce with a common work-ethic and set of goals. The two groups of field employees, Arborists and Landscape Gardeners, are cross-trained in order to increase efficiency and allow for year-round employment. Year-round employees, such as Arborists, offer many more long-term benefits and contributions than seasonal employees. Arborists, usually in charge of tree

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[30] Senator Kohl's webpage: www.khol.senate.gov

[31] Forestry Division website

planting and removal, structural pruning, lift truck operation, cable and bolting techniques, and plant health care, are also trained in landscape gardening techniques such as irrigation installation and repair, planting and maintenance of annuals, perennials, turf, and shrubs. Landscape Gardeners are in turn trained to perform the tasks of Arborists. This cross-trained, flexible, and stable workforce is able to reduce the time necessary to complete an operation. This comprehensive training has greatly increased the efficiency and stability of the Forestry Section and has enabled it to allocate funds more diligently.

Forestry Section staff are not only trained in all urban forest operations, they are also encouraged to make creative suggestions to ensure maximum efficiency. The section believes that employees who interact with the public and are familiar with on-the-ground practices should be able to make innovative choices, suggestions, and decisions about their job duties. This type of "teamwork" approach not only empowers employees, but fosters innovation and success. The City has also made an effort to increase the diversity of the Forestry workforce to be more representative of Milwaukee's demography. The section can even boast that it has trained and hired the first two African-American female arborists in the United States. The inclusion of women and people of a variety of ethnic backgrounds has enabled the Forestry Section to be more sensitive to reaching out to the whole Milwaukee community.

Partnerships

In addition to these training programs, employee support, and encouragement of diversity, the Forestry Section has partnered with the University of Wisconsin-Stevens Point (UWSP), which has one of the best collegiate Urban Forestry Programs in the U.S., to provide undergraduate and graduate students with internship work experience. These internships not only provide valuable work experience for the students, they also provide the city with employees who have a vested interest in urban forestry in Milwaukee. The partnership with UWSP also allows for research opportunities like maintenance modeling of the city's urban forestry program.

Superior Management

When Dutch elm disease hit Milwaukee in the 1950s, public support for the program grew due to widespread dismay over the destruction. The disease killed approximately 200,000 elm trees in Milwaukee causing the city's canopy cover to fall to 16 percent. This figure was determined by the use of the CITYgreen software developed by American Forests. The software enabled the Forestry Section to quantify many different aspects of the urban forest, like percent canopy cover. The software also calculated that the urban forest reduced stormwater flow up to 22 percent and was worth $15.4 million in benefits, annually sequestered 1,677 tons of carbon with a value of $1.5 million, and provides $25 annually in direct energy savings per household. With these numbers, the section adopted a new goal to increase the canopy cover to 40 percent initiating new policies and changes.

The most significant change was the establishment and funding of a non-profit group, GreeningMilwaukee. The Common Council founded the new organization with the primary objective to increase tree planting and encourage proper maintenance of trees on private property, which the City felt it did not have proper access to. This allocation of responsibility enabled the City to more confidently attempt to reach its goal of 40 percent canopy cover. GreeningMilwaukee has been able to increase tree planting on private property through the "Adopt a Tree" program. This program offers homeowners a free tree if they are willing to go through a tree planting, care, and maintenance training session, plant the tree, and maintain it for its lifetime. The organization first evaluates the available space and recommends an appropriate species before they choose a tree. This program enables homeowners to not only have a new tree, but also helps to provide for its proper care.

The Forestry Section is responsible for the care and maintenance of all trees on civic property. The city is broken up into 160 acre management units that are maintained with regular pruning cycles. Trees smaller than 12 inches in diameter are pruned every three years and trees larger than 12 inches in diameter are pruned every six years. This proactive management enables the Forestry Section to detect problems early, prevent future problems, and prolong the lifespan of its trees. Large mature trees that have long lifespans not only require less maintenance over the course of their lives, but also provide greater environmental, psychosocial, and economic benefits. Milwaukee's proactive management practices pay off with an average street tree age of 62 years – twice the national average!

The continued success of Milwaukee's Forestry Section is dependant on its ability to maintain this level of high quality management. Since Milwaukee's proactive management prolongs the lifespan of trees and increases tree health, the Forestry Section can report higher numbers of benefits to the community. Providing these positive numbers to policy makers secures adequate funding, which will in turn continue to benefit the urban forest. Overall, this encouraging cycle demonstrates that the urban forest is an investment opportunity for cities that will continually appreciate in value over time.

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Case Study #2: **Sacramento: Fostering Regional Partnerships & Adopting a Guiding Framework**

The citizens of Sacramento have valued their trees as an important resource since the city was established in 1839. In the 1870s, after Sacramento became the permanent capitol of the state of California, a large-scale planting program intended to beautify the city adorned downtown streets with American and English elms that are still inspiring Sacramento's citizens today. As these trees grew, so did public support of the city's urban forest. This was partly due to the editor of the *Sacramento Bee*, C.K. McClatchy, whose paper continuously published articles declaring Sacramento a "City of Trees." Today Sacramento boasts that it has the most trees per capita (one tree to every two citizens) of any city in the world. This long history of investment and continued active public support strengthens the city's ongoing dynamic urban forestry program.

Two aspects of Sacramento's urban forestry program have been crucial to its success. First, city officials have been willing to adjust their programs in order to reach their goals to build, in the words of Joe Benassini, City Tree Services Manager, "the best urban forest possible." Sacramento has a guiding framework for its urban forestry program, complete with goals, best management practices, and ordinances to help facilitate achievement of this goal. Second, and perhaps most important, the City of Sacramento has developed strong alliances with the Sacramento Tree Foundation (STF—a non-profit urban forest advocate group), the Sacramento Municipal Utility District (SMUD), and other cities within Sacramento and Yolo counties. These alliances have benefited the city by providing citizen, volunteer, executive, and peer support. Without this cooperation and encouragement, the city's own programs would not be as successful as they are today.

A Willingness to Adapt

The willingness of city officials to modify existing programs has empowered the current urban forestry division with tools to build a strong program. The City created its first Urban Forest Management Plan (UFMP) in 1994 as a guide to provide a sound basis for the management of the urban forest. However, in the nine years following its publication, the city was only able to reach one of the many goals outlined in the UFMP. These original goals included:

- Establish the value of the urban forest;
- Develop a pro-active approach to tree management;
- Integrate design guidelines into a city-wide plan;
- Document accepted management practices;
- Establish adequate funding sources; and,
- Increase public awareness, stewardship, and support.

Realizing that the UFMP was not successful, the City initiated a new report to explore opportunities for improvement. The Sacramento Tree Services Best Management Practices Report (BMP), issued in 2003, revealed past failures and again outlined future goals for the management of the urban forest. The BMP concluded that earlier goals had not been reached because the Tree Services Department suffered from an insufficient number of staff, inadequate funding, and a high level of reactive maintenance issues, and was not following recommended management practices. The goals of the BMP report were to evaluate past practices and failures and to provide tangible ways for these goals to be reached.

Following the city council's adoption of the BMP as an action plan, Robert Overstreet, director of Parks and Recreation, with the support of the mayor and city council, began a major re-organization of his department. Tree Services, formerly a section of Parks and Recreation, became its own division. This meant that the concerns and issues of the city urban forester (a new position) would not only be elevated in importance, but that he could also bring them to the budgeting table.

Today the department has fifty-four full and part-time staff under the management of the city urban forester. These people are responsible for carrying out the new management goals outlined in the 2003 BMP. In the two years since its inception, the new division has been successful in initiating some of its most critical objectives. For instance, the City has begun a tree inventory to understand what comprises its urban forest and to identify critical issues. This inventory will be the factual basis on which all future management decisions will be based. Sacramento's determination to create a model urban forest has succeeded through its ability to evaluate, monitor, and transform existing programs.

Partnerships

The partnerships Sacramento has forged and continues to maintain with the Sacramento Municipal Utility District (SMUD), the Sacramento Tree Foundation (STF), and other surrounding cities have been vital to the success of its urban forestry programs. Since 1990, SMUD and STF have encouraged utility customers to plant trees to reduce energy costs by providing free trees (courtesy of SMUD) and expert advice (courtesy of STF) to residents who agree to plant and maintain them. Not only does SMUD offer a free tree, but also an online calculator tool. The "Tree Benefits Estimator" estimates the annual amount of electricity saved and annual carbon dioxide sequestration of trees shading buildings in Sacramento County. SMUD also provides a list of landscape contractors and planting instructions to ensure that trees are planted and cared for appropriately. This technical support has not only encouraged thousands of customers to plant more trees, but informs them of the important energy saving benefits of trees. Together SMUD and STF have planted over 350,000 trees across Sacramento County.

The Sacramento Tree Foundation has been integral to the development of Sacramento's urban forest by implementing sustained and aggressive public outreach programs and developing a comprehensive regional urban forestry initiative called Greenprint. From its inception in 1981, when Sacramento's Mayor Phil Isenberg called for the creation of a non-profit organization dedicated to urban trees, STF has held close ties with the city of Sacramento. At once STF began an aggressive tree planting program which succeeded in planting 400 trees in the first year, and an education program, *Seed to Seedling*, both of which continue to thrive today. *Seed to Seedling* teaches elementary school children of the importance of native oaks and volunteerism. Students learn through hands-on activities from planting the seed, taking care of it for five months, and participating in volunteer planting days.

Greenprint

In the last few years STF has shifted its focus to the development of a new regional urban forest initiative called Greenprint. Greenprint is a policy guidebook aimed at helping cities to achieve sustainable urban forests. Along with the continued achievement of its planting and outreach programs, STF has been highly successful in gaining county-wide support for Greenprint and the policy guidelines it promotes. Greenprint addresses local elected and staff officials, and offers them a framework of guiding principles highlighting best management practices, partnerships, ordinances, and organizational structures to support a sustainable urban forestry program. One of its unique attributes is an emphasis on a regional approach that does not place borders around the urban forest. Since Greenprint's publication in June of 2005, STF has been incredibly successful in securing regional support for its efforts. By the end of 2005, 24 of the 28 cities in Sacramento County had unanimously voted to adopt the Greenprint program as a guiding framework to enhance existing programs and initiate new programs benefiting the urban forest.

The Greenprint program will continue to achieve results because it is based on solid scientific research that irrefutably proves the economic and environmental benefits of the urban forest. STF has collaborated with the Center for Urban Forest Research (CUFR) at the USDA Forest Service's Pacific Southwest Research Station to develop Greenprint to meet the needs of communities in Sacramento County. Grants written by both organizations have secured ample funding to conduct research in Sacramento and surrounding cities. STF disseminates this information in numerous ways including compelling fact sheets, a CD-ROM video illustrating the value of a tree, press releases, and other STF publications.

Once cities have been convinced of the numerous benefits of trees, Greenprint offers them tangible ways to achieve a sustainable urban forest. Greenprint's Growth Ring methodology outlines a step-by-step approach that provides benchmarks for progress in three key areas: management, community partnerships, and policies and ordinances. Each key area is comprised of four Growth Rings that encourage cities to implement increasingly more involved management practices, community partnerships, and policies. For example the management area Growth Rings include:

- Growth Ring 1: Become a participant of Greenprint.
- Growth Ring 2: Conduct an urban forest value assessment.

- Growth Ring 3: Adopt an urban forest master plan.
- Growth Ring 4: Publish a "state of the urban forest" report every five years.

By following and adopting the Growth Ring methodology, cities can easily measure their progress and report their achievements. Early successes of the Greenprint program are encouraging to supporters of the urban forest and indicate that its future impact will be great. This progressive and innovative program offers potential as a model for regions across the United States.

By adopting and following the Greenprint program the City of Sacramento aims to reach the goals of its Best Management Practices Report. The continued development of Sacramento's urban forestry program and the city's willingness to maintain important partnerships are key indicators of its success. As long as Sacramento's officials and citizens continue their impressive support of their urban forest, the health, vitality, and benefits of their trees will be sustained and maximized in the years to come.

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Case Study #3: **Fort Collins: Integrating Urban Forestry into Climate Protection Plans**

The City of Fort Collins has one of the most comprehensive and well respected urban forestry programs in the United States. Since its settlement, trees have been planted across the city and have left a lasting legacy in support of urban forests. The city has a proud history of achievement in urban forestry and has received recognition from the National Arbor Day Foundation as a Tree City USA[32] for over twenty-five years. The strong political support of Fort Collins' urban forestry program stems from the Forestry Division's articulate communication of the economic and environmental benefits of their urban forest. In addition to strong support and communication, Fort Collins' urban forestry program stands out because it is well integrated into the city's Climate Protection Plan.

Quantifying the Benefits
Fort Collins' Forestry Division justifies its large annual budget of almost one million dollars by calculating the economic benefit produced by their trees. The budget for Forestry is allocated from the general fund by budgeting for outcomes. This means that the division must appeal for funding by articulating all possible benefits of the urban forest. It is therefore paramount that the city council understands that the urban forest brings financial and environmental returns back to citizens. In 2003, the Center for Urban Forest Research conducted a study entitled *Benefit-Cost Analysis of Fort Collins' Municipal Forest*. The study concluded that Fort Collins' relatively large urban forestry budget was fully justified because its net annual benefits total $1.17 million. Total benefits of the urban forest equaled $2.17 million. With these numbers in hand, Tim Buchanan, the city's urban forester, convinced city officials of the imperative to invest in the development of a healthy and sustainable urban forest.

This relatively large budget has enabled the Forestry Division to manage its urban forest with smart and effective management tools. One overarching goal is to manage the urban forest with a more proactive and less reactive approach. For example, the Forestry Division has adopted an innovative "graduated rotation cycle" that seeks to address the needs of trees at critical times during their lifetime. The goal is to prune small trees every eight years, medium trees every seven years, and large trees every twelve years. This type of pruning cycle enables the Forestry Division to attack problems before they occur, make sure that the health of each tree is properly maintained, and that excess pruning does not occur.

To address water shortages in its arid climate, the Forestry Division has implemented a program entitled "Save our Shade" to help residents protect existing trees and plant drought-resistant trees. To implement this program, the Forestry Division has teamed up with a

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[32] In order to become recognized as a Tree City USA, cities must have a tree board or department, a tree care ordinance, a community forestry program with a budget of at least two dollars per capita, and an arbor day observance and proclamation.

coalition of supporting local non-profit organizations like Trees, Water, and People, The Colorado Tree Coalition and Plant It 2020. The program's objectives are to increase public awareness of the importance of protecting trees during drought, educate citizens of the benefits of urban trees, and promote responsible and sustainable tree planting and care appropriate to the local dry climate. The Forestry Division has also collaborated with Colorado State University and other local research groups to put together a list of acceptable species to plant. These aspects and many others make Fort Collins' forest management efforts stand out among other programs.

Trees and Climate Protection

One unique aspect of Fort Collins' urban forestry program is that they are integrated into the city's Climate Protection Plans. After joining ICLEI in 1997, Fort Collins embarked on a campaign to reduce emissions by up to thirty percent below worst-case levels predicted for the year 2010. In order to maximize the reduction of emissions, Fort Collins has included tree planting and maintenance goals in its Municipal Climate Protection Plan written in 2001 by the city's Energy Management Team. The vegetation measures, "strive to increase the health, stability, and diversity of the urban forest" by increasing or at least maintaining the stocking level, raising the average mortality age, and planting in strategic energy-saving locations.

Two important vegetation measures were adopted in 1999 as a part of the *Fort Collins Local Action Plan to Reduce Greenhouse Gas Emissions*. The first measure, whose goal is to increase tree-plantings city wide so that restocking levels equal tree mortality and removal levels, estimates carbon dioxide savings to be 125 tons in 2010. This goal will be reached by offering matching funds to support non-profit tree planting and/or tree education grant proposals, developing an education campaign to raise awareness of the benefits of trees, compiling a list of the most appropriate species for planting, and conducting a study to determine the percent of canopy cover to improve accuracy of carbon sequestration estimates. This measure also requires that the city plant large canopy trees to maximize energy savings.

The second measure seeks to increase the life span of trees on city property. This requires that the majority of new plantings consist of large canopy shade trees that produce the most environmental and energy savings benefits. Under this measure existing trees will be preserved to the maximum extent possible. The measure recommends expanding funding of tree maintenance activities to extend the life of trees, planting in all available sites, and that species requiring less maintenance be planted in appropriate locations.

These progressive initiatives of the Fort Collins' Forestry Division demonstrate the city's commitment to promote a sustainable urban forest while reducing greenhouse gas emissions. By including the benefits of the urban forests in its climate action plan, Fort Collins has positioned itself as a leader both in urban forestry and climate protection.

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Protocol for Including Urban Forestry in an Emissions Reduction Plan

Two factors are of primary importance when considering the relationship between urban forests and climate change:

1) Direct carbon dioxide sequestration, and
2) The ambient climatic effects that shade, solar energy reflection, and transpiration have on energy use.

Issues to Consider Before Including Urban Forestry in an Emissions Analysis
Currently, ICLEI's emissions analysis protocol and software does not include the impact of tree cover as an emissions reduction measure. If communities wish to include this activity in their local climate action plans, there are existing protocols (see below) that can assist in this process. The results of these urban forestry calculations can be included in the "Other" sectors of ICLEI's Clean Air and Climate Protection (CACP) software. Before local governments make a large investment into quantifying these programs for inclusion in a climate protection strategy, ICLEI encourages consideration of the following discussion.

The first point to consider is that the CCP campaign prefers to emphasize actual emissions reductions. Reducing greenhouse gas production is the surest way to prevent climate change. The impact of biological sequestration and other technological options are less certain and can be less permanent. Most tree planting programs confer relatively small reductions and time and effort is usually more productively spent concentrating on quantifying larger reduction activities.

Second, there are a number of inherent difficulties involved in quantifying the sequestration effect of trees. The rate of sequestration varies depending on the planting location and climate, as well as the tree species, size, health, maintenance regime, and age. This causes difficulties in creating an easy model that will accurately account for actual sequestration taking place in a jurisdiction. For these reasons it is not possible to provide generic coefficients for 'sequestration rate / tree planted' as is the case for other emissions reductions programs.

In addition, sequestration rates change over time. Therefore jurisdictions should use caution in including this effect in a local climate action plan. The sequestration rate will not be the same in the target year as it was in the year the trees were planted, nor will sequestration levels be expected to be maintained indefinitely – at some point carbon sequestration begins to plateau and even decline. This could make it more difficult for a jurisdiction to continue to meet it emissions goals if forestry makes up a significant portion of planned emissions reduction measures.

There are also a number of accounting issues that should be considered before embarking on sequestration quantification. The first concerns communities that want to include the benefits of trees that were in place before the base year of their analysis. As these trees were sequestering carbon and providing shade during the base year, their preservation should not be considered a new reduction measure to help reach a target. Preserving these trees is a continuation of the status quo, not an action that reduces emissions from the baseline inventory. For this reason, only new trees planted post-base year should be included in a local climate action plan.

Another accounting problem concerns the tendency to only consider one side of the forestry equation. Most new developments remove large amounts of native vegetation, which is rarely counted as a new emissions source in the carbon inventory. Including the positive impact of planting a handful of trees in the subsequent development, or preserving a small tree tract, will lead to an improper conclusion that the development has a net positive effect on carbon emissions – whereas, in reality, the net effect of the development is to decrease the overall sequestration potential of the region. Therefore it is questionable as to whether tree planting in new developments (built post-base year) should be included.

Additionally it is important to remember that there are a number of emissions associated with tree programs – including various types of gasoline-powered maintenance equipment such as pruners, chippers, augers, saws, etc. These are the sources of emissions that often slip between the cracks and are not counted in an emissions inventory, thereby overstating the net impact that urban tree cover has on greenhouse gas emissions.

It is also important to remember that the effect of urban tree cover tends to be transient. Urban trees tend to have a greatly shortened life expectance (street trees often live less than 15 years). Once a tree dies, most of the carbon sequestered over the life of the tree is released back into the atmosphere. This differs from other reduction measures where, if the measure is not maintained, the amount of carbon previously avoided is not released. In the case of urban forestry, if the measure is not kept up (i.e. trees are not replaced upon death), their stored carbon is released back into the atmosphere - as if the measure had never been undertaken. Studies indicate that an urban tree will release 80% of its carbon back into the atmosphere within a year of death and 15% of the carbon sequestered is released each year due to the dropping of leaves, branches, etc. This brings up another accounting issue when a community attempts to quantify a sequestration value of trees without also including emissions from decomposition.

Similarly, the effects of urban forests on CO_2 tend to diminish over time. Even if the program is maintained and all trees are replaced at the end of their lives, after the first generation of trees die, they begin to release an amount of CO_2 similar to the amount that will be sequestered by a replacement tree. Therefore, over time, the urban forest reaches an equilibrium state where it is no longer removing CO_2 emitted by the community but rather is simply offsetting the emissions being released through decomposition of the previous generation of trees. In effect, the urban forest ceases to become an emissions reduction measure unless the number of trees planted continues to increase indefinitely.

This effect can be visualized by considering the atmosphere as a bathtub with a slow drain and CO_2 emissions as the water flowing in. In its natural state, the system is at equilibrium with water entering and exiting at the same rate. However, human activity has turned up the flow from the tap causing the tub to fill. Increasing tree cover is like putting a bucket under the faucet. For a while, the bucket prevents water from entering the tub but eventually the bucket fills and water spills out and continues to fill the tub. As we have done nothing to slow the rate of input into the system, over time the bucket ceases to have an impact. Relying on tree cover doesn't solve the problem, only delays it.

Finally, remember that there is still a great deal of uncertainty in the field of carbon sequestration. Recently studies offer different perspectives on the amount and permanence of sequestration activities. Quantification of the effects of sequestration should be considered as approximations at best and subject to change in the future.

Options for Including the Benefits of CO_2 Sequestration in the Emissions Analysis and Local Climate Action Plan

All of that being said, a number of existing quantification models are available to communities wishing to account for the greenhouse gas sequestration resulting from tree planting (discussed in the next section). In general, any inclusions of urban forestry sequestration should be for new tree plantings, on sites that were developed before the base year, and should take into consideration the fact that sequestration rates change over time. If a jurisdiction feels that urban forestry is an important component of its emissions reduction plan and can address the above discussion points satisfactorily they are encouraged to use one of the emissions quantification tools discussed in the next section and include those greenhouse gas benefits in their emissions reduction and sustainability plans. Jurisdictions using ICLEI's emissions analysis software may include the benefits of urban forestry in their action plans by proceeding through the following steps.

Whichever method is chosen for quantifying the sequestration benefits of the urban forest, carbon dioxide sequestration can be included in the "Other" sector of the CACP Software. Changes in the sequestration rate over time can be accounted for using the "Implementation Year" and "Ramp-In-Schedule" features of the CACP software.

First, calculate the net annual sequestration rate for the trees being planted for each year included in the model used. The number to be entered into the "Other" sector of the software (as an "Absolute Emissions Reduction CO_2") is the net sequestration rate when sequestration levels are at their maximum (this is usually in the 16-20 year time frame).

The next step is to determine what percent of the maximum net sequestration rate occurs in the emissions reduction target year and at other intervals along the way. For example, if 200 tons of CO_2 are being sequestered in the 16-20 time frame and 160 tons are being sequestered in the 10-15 year time frame, the earlier sequestration rate would be expressed as 80% of the maximum rate.

Enter the "Year Implemented" for the measure. Next, open the "Ramp-In-Schedule" and insert the percent of maximum sequestration rates for the each year as appropriate. In the above example, a value of 100% should be entered for years 16 through 20, with 80% entered for years 10 through 15. This allows the software to more accurately account for changes in sequestration rate over time when calculating measures for the local action plan.

Overview of Tools Available for Quantifying the Impacts of Urban Forestry

Although the benefits that urban forestry can provide to communities are well documented, it is often difficult to adopt local policies promoting forestry without information on the impacts that a specific community can expect. Similarly, if urban forestry is going to be integrated into a community's emissions reduction plan, the local government needs specific numbers on the impacts that trees can provide.

A number of tools, models, and software packages are now available for calculating the costs and benefits created by urban forests. This section provides a brief overview of some of the most common tools available to local governments. These tools provide various levels of detailed analysis and have different cost and manpower requirements to use. As each tool is different, users are encouraged to have a strong understanding of what they hope to accomplish by performing a local analysis and what the results will be used for. This section is provided as a quick overview of available tools. Users should conduct their own research into which will work best for their community before embarking on an involved analysis.

Carbon Dioxide Reduction Through Urban Forestry: Guidelines for Professional and Volunteer Tree Planters

In 1999 the U.S. Forest Service released the "Carbon Dioxide Reduction Through Urban Forestry" guidelines to help local governments and other decision makers incorporate consideration of the impacts of urban forestry into efforts to fight global climate change. These guidelines were developed by the Forest Service's Western Center for Urban Forest Research and Education and are aimed at utilities, urban foresters and arborists, municipalities, consultants, non-profit organizations, but also available publicly.

Carbon dioxide impacts are calculated based on sequestration rates and changes, tree impacts on heating and cooling through direct shading, changes in wind speeds, and modification to regional climatic conditions. The greenhouse gas impacts take into consideration mortality rates and are modified by projected decomposition. Cost impacts look at planting and maintenance of the trees over their lifetimes. Results are reported in terms of 5-year increments. Estimations of impacts extend for 40 years beyond the first year of the analysis. This allows users to track the impact of a project over time. Users of the guidelines can apply their results to:

- Report current or future CO_2 reductions through a standardized accounting process
- Evaluate cost-effectiveness of urban forestry programs with other CO_2 reduction measures
- Compare benefits and costs of alternative urban forestry program designs

- Produce educational materials that quantify potential CO_2 reduction benefits and provide guidelines on tree selection, placement, planting and stewardship.

These Guidelines contain both a short form utilizing regional defaults to complete a quicker analysis and a long form that increases the accuracy of the results by allowing users to adjust the regional variables to their specific situation. The short form is best used when a quick initial analysis is desired and when detailed data is unavailable. The long form can be used when more accurate results are desired and additional time is available to complete the additional data collection and calculations.

Data Needs

The short form requires information on:

1. % existing tree + building cover
2. % distribution of homes by age class
3. Climate region in which the city falls
4. Electricity emissions factor
5. Number of trees by:
    - Type (evergreen / deciduous)
    - Size (small, medium, large)
    - Placement to structure (near or far)
6. Planting and Stewardship costs (tree planting, tree care, and other costs)

The guidebook contains default data for the first four criteria above but those can be modified by the user to better reflect local conditions.

The long form requires the same data as the short form but allows the user many more options to modify the default assumptions to refine the calculation. This includes incorporating local information on building heating and cooling fuel use and equipment in place, etc.

How long will the analysis take?

Time required depends on the user's intent, complexity in the shade tree program, and data availability. When the basic information needed to calculated CO_2 reductions is easily available, an analysis can be done in less than a day, especially when regional default values are used in the short form. The long form will increase the data requirements and therefore the length of time required to complete the calculations, but discounting the time needed to collect regional data, the calculations should still be able to be completed in less than a day. The guidelines can also be used to set up spreadsheets to automate the calculations, so that multiple scenarios can be completed relatively rapidly.

Applicability

The error associated with the results produced in these calculations is likely to be moderate due to assumptions made about tree growth and survival rates, CO_2 sequestration rates of urban trees, impacts of trees on summer air temperatures in different climate regions and the rate of CO_2 release from decomposition and tree care activities. The model balances ease of calculation with accuracy and is a good initial analysis to return reasonable numbers without a huge investment of time or requiring advanced software. This tool is ideal for performing quick and accurate analysis of the impacts of urban forestry.

iTree

The iTree software package is a software suite designed to integrate three Forest Service urban and community forestry inventory, analysis and forecasting tools which can be used together or as independent components: The Urban Forest Effects Model (UFORE), Mobile Community Tree Inventory (MCTI) and the Street Tree Resource Analysis Tool of Urban forest Managers (STRATUM). It is designed to be a complete software package for urban forest analyses. In addition to facilitating street tree inventories and management tracking, the iTree software suite facilitates suburban forest structure, function and value analyses for both on- and off-street resources. Reports consist of graphs, charts, and tables that will enable managers to legitimize funding, create program enthusiasm and investment, and promote sound decision making and management.

ITree is a Windows based program which requires the use of an Arc Geographic Information System (GIS) program. City-level GIS data will often be available from US Geological Survey Satellite data. From the satellite data, an accurate estimate of canopy cover can be determined. Projected increased canopy cover can be estimated using iTree and its benefits analyzed. This can help a local government to quantifiably estimate canopy cover. ITree also generates detailed reports automatically and includes an analysis of management costs associated with the urban forest. Local urban foresters will be able to use this program to conduct tree inventories and automatically transfer that data into cost/benefit reports that can be used both for management and policy decisions.

STRATUM

The Street Tree Resource Analysis Tool for Urban Forest Managers (STRATUM) is the tool in the iTree suite designed to analyze the effect that street trees have on the urban eco-system. It is designed to be used by urban foresters but can be used by local non-profits and individuals who have the resources to operate the program. This program analyzes the structure of the street tree infrastructure and the functions that those trees play in terms of influencing energy use, local air pollution, stormwater runoff, carbon dioxide emissions and reductions, and local property values. This program also reports on the value of those trees to the community in dollar amounts and estimates management needs to ascribe a cost to maintaining the street trees in a community.

The foundation of the STRATUM analysis is a street tree inventory that can be stand alone or integrated into a UFORE GIS layer (as part of the iTree suite). Jurisdictions can import existing street tree inventories if one was previously created. If a street tree inventory has not already been created, it will be necessary to perform one. This inventory can be either a full inventory of the entire jurisdiction, or a sample inventory based on test plots.

Once an inventory is completed and input into STRATUM, the software can report on:

Street Tree Population Summaries

- Species distribution
- Relative age distributions
- Stocking levels
- Land use

Tree Specific Information

- Importance values
- Tree conditions
- Relative performance index
- Maintenance tasks and recommendations
- Location
- Conflicts
- Canopy cover

Benefit-Cost Analysis

Annual impacts of trees on:

- Energy use
- Storm water runoff
- Air quality
- Carbon dioxide
- Aesthetic
- Management costs
- Net annual benefits

The information provided by STRATUM can be useful in creating a Community Forest Management Plan. This information can be used to increase public safety, facilitate long and short term planning, increase efficiency of the urban forestry program (targeting maintenance), improve public relations by justifying budgets in terms of returns, document actions taken, and calculate benefits provided by street trees.

Data Needs

The primary data need is a completed street tree inventory. A complete inventory including 100% of the community's street trees is ideal for completeness of results and accuracy, but can be time and cost prohibitive to complete. STRATUM can also utilize either a partial inventory that includes just one section of the community for analysis, or a sample inventory that relies on randomly selected tree samples that are used for interpretation to the community scale. These options range from fairly time involved and expensive to compete (full inventory) to fairly cost-effective and easy to complete (sample inventory). The former provides information for day-to-day management of the urban forest, but the latter are adequate for a rough planning exercise.

Both inventory approaches require the following data for each tree included:

1. Tree ID #
2. Street Segment ID (to identify location)
3. Species
4. Tree size measured in terms of diameter at breast height (DBH)

If STRATUM is being integrated into a GIS mapping system, various other files are needed to create useful maps, such as TIGER Line files showing street segments and shape files showing buildings and other features.

Additionally STRATUM requires basic information about the jurisdiction being analyzed. This requires the user to select one of several reference cities most similar to the jurisdiction being analyzed. Data from these reference cities are used to complete an economic analysis to determine tree growth rates, etc. These variables can be modified to better reflect conditions in the community being analyzed if data is available.

How long will the analysis take?
The STRATUM analysis can be completed relatively quickly once the street tree inventory has been finished (results are generated instantly). Full street tree inventories can be quite expensive and take years to complete. For communities without a street tree inventory, a methodology for conducting a sample inventory is presented. The methodology was designed to be efficient, with a minimal input of time and resource investment. Using a team of two paid personnel or volunteers, experience has demonstrated that this technique can be completed from start to finish within four to six weeks (although this will vary greatly depending on the size of the jurisdiction).

To increase the ease of completing an inventory, the iTree software (and by extension STRATUM) can import data from handheld PDA-based devices that automatically upload field data to the central computer performing the analysis. This significantly decreases costs associated with data entry and reduces data input error.

Applicability
The results returned from this analysis will quite accurate with a low degree of error and the benefit /cost analysis can be used for making important policy decisions. However, the STRATUM analysis takes a significant amount of person-hours (if an inventory has not been completed), and is therefore not recommended for situations requiring quick results (see the Carbon Dioxide Reduction Through Urban Forestry Guidelines discussed earlier). Numbers produced by STRATUM are also less locally accurate than those produced by the UFORE model, as results are based on data collected from a reference city.

The results provided by STRATUM only reflect an analysis of street trees and not that of the entire city. This can be useful for the analysis of city investment in urban forests as 'green infrastructure' because the numbers will often only reflect city property and investment. However, the numbers returned do not quantify the overall benefits of the entire urban forest.

Urban Forest Effects (UFORE) Model

The Urban Forest Effects (UFORE) model is a Windows and GIS-based program designed to use standardized field data from randomly located plots, and local hourly air pollution and meteorological data, to quantify urban forest structure and numerous urban forest effects for cities across the world. Although this model has existed for many years for use by professional researchers at the U.S. Forest Service, it has recently been integrated into iTree to make it available to all practitioners and improve data analyses and reporting.

The UFORE model currently quantifies:

- Urban forest structure by land use type (e.g., species composition, tree density, tree health, leaf area, leaf and tree biomass, species diversity);
- Hourly amounts of pollution removed by the urban forest, and its associated percent air quality improvement throughout the year. Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<10 microns);
- Hourly urban forest volatile organic compound (VOC) emissions and the relative impact of tree species on net ozone and carbon monoxide formation throughout the year;
- Total carbon stored and net carbon annually sequestered by the urban forest;
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants;
- Compensatory value of the forest, as well as the value of air pollution removal and carbon storage and sequestration;
- Potential impact of Gypsy moth and Asian longhorned beetle infestation;
- Stormwater quantity and quality impacts; and,
- Tree transpiration.

The UFORE analysis can be tailored to meet the needs of its users. Its analysis can be based on sample tree inventory data, a complete tree inventory, or specialty inventories (e.g. only street trees). The analysis can also be expanded depending on identified information of interest. Therefore it is important to have a firm understanding of the goals of the analysis before beginning. Model outputs are given for the entire population and individual trees measured.

Data Requirements

The UFORE model is designed to be relatively low cost, with much of the data readily available from other sources. As with STRATUM, field data must be collected on the trees that will be included in the analysis.

Community-scale data requirements include:

- Various meteorological data (available from the National Climatic Data Center)
- Pollutant concentrations (available from the US EPA Aeromatic Information Retrieval System)
- Boundary layer height measurements – twice daily sounding measurements needed to calculate percent air quality improvement due to pollution removal (available from NOAA)

The required field inventory used to complete the forestry analysis includes some minimum characteristics for the sample area and the tree inventory.

Sampling area data requirements:

1. Plot ID
2. Land use from map
3. Land use
4. Ground cover percentages
5. Plot tree cover (%)

Tree inventory requirements:

1. Tree ID
2. Tree species
3. Diameter at breast height
4. Total height
5. Height to crown base
6. Crown width
7. Percent canopy missing
8. Dieback
9. Percent impervious surfaces or shrubs beneath tree
10. Crown light exposure
11. Direction to building (needed for energy conservation only)
12. Shortest distance to building (needed for energy conservation only)

Complete data requirements are described in the UFORE Field Data Collection Manual: http://www.fs.fed.us/ne/syracuse/Tools/downloads/UFORE_Manual.pdf

Time involvement

Completing a UFORE tree inventory is much more involved than that required by STRATUM because UFORE includes trees on private property as well. However, the results of a UFORE model are much more detailed and can save time and money involved in making future urban forestry management decisions. The time commitment for completing the inventory will vary by the comprehensiveness of the analysis and the results desired.

Applicability

UFORE is the most comprehensive urban forestry analysis tool currently available and provides the most accurate and detailed data results that are useful for management decisions or for developing a comprehensive urban forest master plan. Results are representative of the local climate and are not based on reference cities (as in STRATUM). However, running UFORE is fairly costly in terms of time and measurement equipment and software requirements. Also the program only reports the benefits of the urban forest, and does not take into consideration management costs.

Results from completed UFORE projects can be used in a variety of formats for a variety of purposes, from educating the public on the benefits of maintaining a healthy urban forest to justifying funding expenses for all types of urban forest management. UFORE is also a valuable forestry management tool as its results reflect scientifically tested and statistically valid projections of the benefits and value of the urban forest in the community. The analysis describes the structure and composition of large diverse areas and is not limited to street trees or park tree inventories. The results can also be used to evaluate various "what if" scenarios (loss or addition of individual trees, species or portions of forest) and will quantify them in terms of environmental and economic benefits.

CITYgreen

CITYgreen is a GIS application produced by American Forests, a nonprofit organization working to create healthy urban forests in all communities. The CITYgreen tool calculates the ecosystem services provided by a community's forests and calculates the dollar benefits of those services. Specific conditions considered include urban forest impacts on:

- Stormwater runoff;
- Air quality;
- Summer energy savings; and
- Carbon storage, sequestration, and avoided emissions.

CITYgreen is designed for local government staff and citizens groups interested in modeling development scenarios or calculating the financial and economic impacts of increasing or decreasing local tree cover. It has also been used extensively by school groups interested in providing hands-on lessons in environmental management.

There are two (Windows based) versions of CITYgreen, one that uses ArcView and is applicable for use by the layperson. The second uses ArcGIS and is designed for use by professional GIS departments. These versions help ensure compatibility with existing GIS data maps and other information.

Results are presented graphically and can be used for broad regional studies or to create detailed small site assessments. The CITYgreen program also contains algorithms for tree growth to allow users to create maps of future tree cover and estimate the benefits provided by those larger trees.

Data Requirements

As the CITYgreen tool bases its calculations on digital maps, users must create detailed GIS drawings that identify individual water bodies, structures, and impervious surfaces. Many of these data maps are available from local planning authorities, but tree cover maps usually need to be created. This is most easily accomplished by digitizing trees that appear in aerial photographs. Once these maps are created, field data must be gathered on individual trees. This field data includes:

- New trees or trees that have been removed since the aerial photo was taken;
- Species;
- Diameter at breast height;
- Height class;
- Tree health; and,
- Whether the tree had been topped.

This data must then be entered into the GIS database. CITYgreen also allows data to be collected using handheld PDA-based devices that automatically upload field data to the central computer performing the analysis. This significantly decreases costs associated with data entry and reduces data input error.

Time involvement
The time required is primarily associated with completing field inventories and digitizing data from the aerial photos, and can be significant depending on the jurisdiction. It is not recommended that sampling be used; therefore, a full inventory must be completed. Time involvement can vary greatly based on size of the area to be analyzed (from small developments to the jurisdiction as a whole).

Applicability
Data estimates provided by the CITYgreen software are moderately accurate although not as comprehensive as that provided by the iTree tools (STRATUM and UFORE). Reports indicate that the results are appropriate for policy decisions but are less than what is needed for developing long range urban forest management plans. CITYgreen is easy to use and its value as an educational tool can be significant.

Two sources of error introduced into the analysis come from the reliance on digital maps and the lack of accounting for air pollution and carbon dioxide emissions from maintenance activities. Often tree canopies are not well separated and overlap and irregular shapes are likely to introduce error (drawing irregular shapes for trees or around clumps of trees can exclude those trees from certain analyses). In addition, this model does not account for maintenance impacts. Some research indicates that, over the life of the tree, maintenance emissions of carbon (from equipment, natural decomposition, etc.) could cause the amount of carbon released to exceed that stored by the tree.

Estimating Benefits for Small Communities

Many small communities do not possess the means to conduct adequate research of their urban forests to use some available tools. Small budgets often do not allow for the monetary or technical resources to conduct a comprehensive tree analysis of structure, tree growth rates, and benefits and costs.

The U.S. Forest Service's Center for Urban Forest Research has produced regional Community Tree Guides to quantify the benefits and costs of the urban forest that combine street tree growth data from a representative city in the same region with a street tree inventory to calculate benefits. This methodology was summarized by Scott Maco and Gregory McPherson in the March 2003 Journal of Arboriculture in an article called *A Practical Approach to Assessing Structure, Function, and Value of Street Tree Populations in Small Communities.*

This model produces the following information for urban foresters and interested individuals living in smaller communities that will benefit from an estimation of their forestry resources:

- Resource structure (species composition, diversity, age distribution, condition);
- Resource function (magnitude of environmental and aesthetic benefits);
- Resource value (dollar value of benefits realized); and,
- Resource management needs (sustainability, canopy cover, pruning and young tree care, planting and conflict mitigation).

Data Requirements

As with other tools and models described previously, this method requires the completion of a tree inventory, but it relies on a stratified random sampling methodology to gather this information as simply as possible, assuming no pre-existing information is known about the jurisdiction's urban forest. This methodology requires the user to:

1. Stratify the city's area into homogenous "zone segments" with similar characteristics, such as layout, building vintage, demographics, political boundaries, etc.
2. Divide each zone into multiple uniform "sampling units"
3. Conduct a pre-sample to estimate the tree density in each zone segment and determine the necessary number of sampling units to be inventoried per zone segment
4. Select the units for sampling at random
5. Survey all trees in public areas (maintained by the City or privately) with attention to specific attributes (species, dbh, tree maintenance priorities, plantable spaces, etc.)

Once the trees samples are completed a series of simple equations can be applied to extrapolate the citywide tree population. Benefits can then be estimated by using the diameter of each tree to estimate tree age and subsequently applying generic cost and benefits multipliers.

Applicability

This methodology provides very generic results, as it is based on multiple assumptions. However, this simple analysis does provide a picture of benefits provided by street trees and can be used to inform the decision making process, potentially acting as a starting point for long-term urban forest management.

Links and Resources

General Urban Forestry Informational Links

Benefits of Trees in Urban Areas
www.coloradotrees.org/benefits.htm

Benefits of the Urban Forest
http://cufr.ucdavis.edu/products/CUFR_180_UFfactsheet2.pdf

The Forest Where We Live
http://www.lpb.org/programs/forest/

Urban Forestry Bibliography
http://web1.msue.msu.edu/msue/imp/modb1/masterb1.html

Air Quality Issues

Urban Tree Cover and Air Quality Planning
www.treescleanair.org

Carbon Dioxide

American Forests' Climate Change Calculator allows individual households to calculate their annual emissions and how many trees they need to plant to offset those emissions. This is a great tool to recommend to your citizens!
http://www.americanforests.org/resources/ccc/

The Ideal World of Urban/Suburban Carbon Sequestration in Rhode Island
http://envstudies.brown.edu/classes/es201/2003/Forestry/perfect.htm

Quantifying the Impact of Trees: The Chicago Urban Forest Climate Project
http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/u9300e/u9300e08.htm

Economics

Economic Benefits of Urban/Suburban Forestry in Rhode Island
http://envstudies.brown.edu/classes/es201/2003/Forestry/econbene.htm

How to Prepare for a Budget Cut
http://cufr.ucdavis.edu/products/CUFR_183_UFfactsheet5.pdf

Save Dollars with Shade
http://cufr.ucdavis.edu/products/CUFR_180_UFfactsheet2.pdf

Utah State Forestry Extension
Valuation of Landscape Trees
http://extension.usu.edu/forestry/HomeTown/HO_Valuation.htm

Energy

Green Plants or Power Plants?
http://cufr.ucdavis.edu/products/3/cufr_148.pdf

Sacramento Municipal Utility District, Tree Benefits Estimator
http://usage.smud.org/treebenefit/

US Department of Energy consumer guide to energy efficiency and renewable energy
www.eere.energy.gov/consumer/your_home/landscaping/index.cfm/mytopic=11910

Utah State Forestry Extension
Trees and Energy Use
http://extension.usu.edu/forestry/HomeTown/HO_Energy.htm

Wind, Sun, and Noise Screens
http://extension.usu.edu/forestry/HomeTown/HO_TreeScreens.htm

Urban Forest Management

The Elements of Sustainability in Urban Forestry
Thomson, Richard, Norman Pillsbury and Richard Hanna
A paper outlining sustainable urban forestry practices that encourage urban wood utilization.
http://www.ufei.calpoly.edu/Files/ufeipubs/ElementsofSustainability.pdf

Harvesting Urban Timber
A website that promotes the utilization of urban timber by providing those with mills and those who need timber with a forum to exchange information.
www.harvestingurbantimber.com

TLC for Trees
http://www.tlcfortrees.info/home.htm

Tree Care Industry Association
TCIA, formerly the National Arborist Association (NAA) provides a website on tree care. It also publishes the Tree Care Industry magazine and holds a TCI exposition yearly.
www.natlarb.com

Urban Forestry Ecosystems Institute
Over 1400 listings of mill operations, manufacturers and retailers in California. It also provides information on wood properties, grading, milling information and other useful links about utilizing urban wood.
http://www.ufei.calpoly.edu/

Utah State Forestry Extension
General information on Tree Planting
http://extension.usu.edu/forestry/HomeTown/HO_Planting.htm

Guidelines to protect trees from Construction
http://extension.usu.edu/forestry/HomeTown/HO_Construction.htm

Policy and Management

The Garden Project: San Francisco
The garden project is a partnership between the Department of Public Works and Sheriff's office of San Francisco designed to give horticultural job training to inmates. Its main goal is to give inmates opportunities to get meaningful jobs and reasons to stay out of jail.
http://www.gardenproject.org/homepage/index.htm

Guidelines for Developing and Evaluating Tree Ordinances
Swiecki, T.J. and E.A. Bernhardt 2001
http://www.isa-arbor.com/publications/ordinance.aspx

TreeLink Funding Tutorial
http://www.treelink.org/grants/index.phtml

Urban Tree Cover and Air Quality Planning
This website is designed to provide policy makers with material concerning the relationship between trees, air and policy to facilitate the inclusion of tree planting into a SIP.
www.treescleanair.org/policymakers.htm

Social Benefits

Social Benefits of Urban/Suburban Forestry
http://envstudies.brown.edu/classes/es201/2003/Forestry/sociobene.htm

Psycho-Social Dimensions of People and Plants
http://www.cfr.washington.edu/research.envmind/UF/PsychBens-FS1.pdf

Storm Runoff & Water Quality

Control Stormwater Runoff with Trees
http://cufr.ucdavis.edu/products/CUFR_182_UFfactsheet4.pdf

Is All Your Rain Going Down the Drain? Look to Bioretainment—Tress are a Solution
http://cufr.ucdavis.edu/products/cufr_392_rain_down_the_drain.pdf

StormwaterAuthority.org
www.stormwaterauthority.org

Urban Forestry and Related Organizations

Alabama Urban Forestry Association
AUFA is a statewide non-profit organization with a diverse membership including arboricultural professionals, horticulturists, landscape workers, community tree board members, tree-care volunteers and interested citizens. They develop partnerships to further better tree management, promote professionalism, and increase knowledge about urban forest issues.
www.aufa.com

Alliance for Community Trees is a membership organization for nonprofit urban forestry organizations. It provides a network of peers, conferences, educational forums, and grants to members.
www.actrees.org

American Forests
American Forests, founded in 1875, is one of the oldest nonprofit citizens' conservation organizations in the United States. American Forests provides publications, support, software (CITYgreen), and an extensive planting program to the entire United States.
www.americanforests.org

American Horticultural Society
http://www.ahs.org/

American Society of Consulting Arborists
http://www.asca-consultants.org/

American Society of Landscape Architects
http://www.asla.org/

California Releaf
http://www.nationaltreetrust.org/releaf/

California Urban Forest Council
http://www.caufc.org/index.html

Chicago Gateway Green
www.gatewaygreen.org

Friends of the Urban Forest, San Francisco
www.fuf.net

Friends of Trees, Portland
www.friendsoftrees.org

Greening Milwaukee
www.greeningmilwaukee.org

Interface South
http://www.interfacesouth.org/

International Society of Arboriculture
ISA has served the tree care industry for over eighty years as a scientific and educational organization. ISA continues to be a dynamic medium through which arborists around the world share their experience and knowledge for the benefit of society.
www.is-arbor.com

National Arbor Day Foundation
http://www.arborday.org/

National Association of State Foresters
http://www.stateforesters.org/

National Tree Trust
http://www.nationaltreetrust.org/index.cfm

National Urban and Community Forestry Advisory Council
http://www.treelink.org/nucfac/

National Wildlife Federation
http://www.nwf.org/

Our City Forest, San Jose
http://www.ourcityforest.org/

People For Trees, San Diego
www.peoplefortrees.org

Plant it 2020
A non-profit dedicated to planting indigenous trees in the United States and Internationally.
http://plantit2020.org

Sacramento Municipal Utility District
This website outlines a program to plant shade trees to decrease energy use.
http://www.smud.org/residential/saving/trees/index.html

Sacramento Tree Foundation
http://www.sactree.com/

Society of American Foresters
http://www.safnet.org/

Society of Municipal Arborists
www.urban-forestry.com/mc/page.do

Trees Atlanta
www.treesatlanta.org

TreeCity USA
http://www.arborday.org/programs/treecityusa.cfm

Tree Folks, Austin and Central Texas communities
www.treefolks.org

Trees Forever, Iowa
www.treesforever.org

Trees For Tucson
http://www.ci.tucson.az.us/tcb/tcbtothp.htm

Trees New York, New York City
www.treesny.com

Tree People, Los Angeles
www.treepeople.org

Tree Trust, Minnesota Twin Cities Metropolitan area
www.treetrust.org

USDA Forest Service
http://www.fs.fed.us/

Wisconsin Department of Natural Resources, Urban and Community Forestry
http://www.dnr.state.wi.us/org/land/forestry/uf/

Urban Forestry Research Groups

Center for Urban Forest Research
An incredibly rich resource for cutting edge research on urban forests. Funded by the USDA Forest Service, its mission is to demonstrate new ways that trees add value to communities and convert the results into financial terms in order to stimulate more investment in trees.
http://wcufre.ucdavis.edu/

Center for Urban Horticulture, University of Washington, College of Forest Resources
This center studies the human dimensions of urban forestry and urban greening. Directed by Kathleen L. Wolf.
http://www.cfr.washington.edu/research.envmind/

Florida Urban Forests and Wildland-Urban Interface Program
http://sfrc.ufl.edu/urbanforestry/

Human-Environment Research Laboratory, University of Illinois at Urbana Champaign
Iowa State University, Department of Forestry
Urban and Community Forestry Research
http://www.forestry.iastate.edu/res/urban.html

Urban Forestry South Expo
A supportive research organization that provides useful tools, events, and links specific to urban forestry in the Southern US.
http://www.urbanforestrysouth.org/

USDA Forest Service, Northeastern Research Station
This research station researches the effects of urban forests and their management on human health and environmental quality. It provides many useful studies available for downloading off the web.
http://www.fs.fed.us/ne/syracuse/

Utah State Forestry Extension
http://extension.usu.edu/forestry/
A source of information about Utah trees and forests.

Municipal and Regional Urban Forestry Programs

City of Ann-Arbor, Forestry and Park Operations
http://www.ci.ann-arbor.mi.us/PublicServices/FieldOperations/ForestryParkOps/parkoper.html

City of Austin, Urban Forestry: Tree Preservation and Replenishment
http://www.ci.austin.tx.us/trees/

City of Greensboro, NC Urban Forestry Program
http://www.ci.greensboro.nc.us/forestry/

City of Cambridge, MA Urban Forestry
http://www.cambridgema.gov/TheWorks/departments/parks/forestry.html

City of Chicago, Department of the Environment
http://www.cityofchicago.org/Environment/index.text.html

City of Berkeley, Urban Forestry
http://www.ci.berkeley.ca.us/trees/

City of Boulder, Urban Forestry
http://www.ci.boulder.co.us/parks-recreation/FORESTRY/forestry_main.htm

City of Fort Collins, Forestry and Horticulture
http://fcgov.com/horticulture/

City of Jamestown, NY, Urban Forestry Program
http://www.jamestownparksrec.com/forestryindex.html

City of Milwaukee, Forestry Division
www.forestry.mpw.net/frontpage.htm

Ohio Department of Natural Resources, Urban Forestry
http://www.dnr.ohio.gov/forestry/Urban/urbanfor.htm

City of Portland, Parks and Recreation
http://www.portlandonline.com/parks/

City of San Francisco, Urban Forest Council
http://www.sfenvironment.com/aboutus/openspaces/urbanforest/

City of Sacramento, Urban Forest Services
http://www.cityofsacramento.org/parksandrecreation/urbanforest/

City of St. Paul, Forestry and Trees, Parks and Recreation Department
http://www.stpaul.gov/depts/parks/forestry/

City of Seattle, Office of Sustainability and Environment, Urban Forestry
http://www.seattle.gov/environment/urban_forest.htm

Tennessee Urban Forestry Council
A non-profit dedicated to public awareness, understanding and improving Tennessee's Urban Forests. It serves as a resources, catalyst and liaison concerning urban forestry issues within the state, region, and nation.
http://www.tufc.com/

Other Resources

SelecTree
SelecTree is a guide to urban trees that grow in California. It may be useful to cities outside California, but will not be as comprehensive. This is meant to be a resource guide and is not a definitive source of information.
www.selectree.calpoly.edu

Department of Defense Urban Forestry Manual
1996
https://www.denix.osd.mil/denix/Public/Library/Forestry/forestry.html

Chapters from the *Urban Forestry Manual*
An educational tool for state forestry employees and those who work with communities on urban forestry issues, developed by the USDA Forest Service, Southern Region, the Southern Research Station and the Southern Group of State Foresters
2005
https://www.denix.osd.mil/denix/Public/Library/Forestry/forestry.html

Contact List of State Urban Forestry Coordinators
http://www.na.fs.fed.us/spfo/pubs/uf/techguide/coord.htm

Glossary

Biogenic : Produced by living organisms

Biogenic volatile organic compounds : Organic chemicals that contain the molecule carbon that are released from vegetation. Biogenic volatile organic compounds make up the essential oils, resins, and other organic compounds that plants use to attract pollinators and repel predators.

Biomass : 1. (Potential) fuel material derived immediately from living matter.
2. The total mass of organic matter in a given area

Bioretention : An engineered process to manage stormwater runoff, using the chemical, biological and physical properties afforded by a natural, terrestrial-based community of plants, microbes and soil. Bioretention provides two important functions: (i) water quantity (flood) controls; and (ii) improved water quality through removal of pollutants and nutrients associated with runoff.

Carbon sequestration : The uptake and storage of carbon.

Carbon sink : Part of the biosphere (ex. forest or ocean) that removes carbon dioxide from the atmosphere.

Deciduous tree : A tree that loses its leaves at the end of a growing season.

Directed attention : voluntary attention concentrated on tasks and situations that require sustained attention and are not inherently easy to attend to.

Evergreen tree : A tree that bears foliage year-round.

Greenhouse gas *:* Any gas in the Earth's atmosphere that traps heat and can contribute to global warming and associated climate change. Greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halogenated fluorocarbons (HCFCs), ozone (O_3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs)

Nitrogen oxides (NO_x) : Gasses containing one nitrogen molecule and varying number of oxygen molecules. A criteria air pollutant that is formed when burning fuels like coal and gasoline.

Ozone *:* An unstable, poisonous form of oxygen, O_3, that is formed naturally in the ozone layer in the upper atmosphere. It is also produced in the lower atmosphere by photochemical reactions between volatile organic compounds and nitrogen oxides.

Particulate pollution/matter (PM_{10} and $PM_{2.5}$) : A criteria air pollutant composed of microscopic solid and liquid particles of human and natural origin. PM_{10} is any particulate matter with a diameter less than 10 microns. $PM_{2.5}$ is any particulate matter with a diameter less than 2.5 microns.

Photosynthesis : The process by which carbon dioxide is converted into organic matter. Carbon dioxide and water are combined with light to produce carbohydrates and oxygen.
$CO_2 + H_2O + \text{sunlight} \rightarrow \text{Carbohydrates} + O_2$

Smog : Air pollution containing ozone and other chemical compounds created by the reaction of hydrocarbons (volatile organic compounds), nitrogen oxides, and sunlight.

Storm runoff : Water from precipitation or irrigation that flows over ground into larger bodies of water. It can contribute to soil erosion and can carry pollutants into natural waterways.

Stomata : Pores on leaf surfaces that act as ports for the exchange of gases entering and exiting the plant.

Sulfuric oxides (SO_x) : Formed by the combustion of sulfur-containing fuels, primarily fossil fuels.

Turbulence : Irregular motion of the atmosphere, as indicated by gusts and lulls of wind.

Urban heat island effect : Warmer air temperatures in urban areas than rural/suburban areas, due to the low albedo of streets, sidewalks, parking lots, and buildings. These surfaces absorb solar radiation during the day and release it at night, resulting in higher night-time temperatures, as well.

Volatile Organic Compounds : Organic chemicals that contain the molecule carbon. Volatile Organic Compounds easily evaporate from fuel oil, vehicle exhaust, paints, and fossil fuel combustion.