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**Edited By:**

Cheryl Kollin
Director of Urban Forestry
AMERICAN FORESTS

Michael Barratt
AMERICAN FORESTS

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# Results of the Chicago Urban Forest Climate Project

*E. Gregory McPherson[1], David Nowak[2], Gordon Heisler[2], Sue Grimmond[3], Catherine Souch[4], Rich Grant[5], and Rowan Rowntree[6]*

Abstract: The 3-year Chicago Urban Forest Climate Project examined how trees affect components of the regional urban ecosystem. During 1991, the region's trees removed an estimated 6,145 tons of air pollutants, providing air cleansing worth $9.2 million. Planting about three trees per building lot is estimated to save annual heating and cooling costs by $50 to $90 per dwelling unit. The net present value of services trees provide is estimated as $38 million, or $402 per planted tree. The present value of long-term benefits are more than twice the present value of costs.

## INTRODUCTION

Chicago's landscape has evolved from a mixture of prairie, wetlands, and oak-hickory forests into a major metropolis of 6 million people. With urbanization there has been increased concentrations of ozone and other air pollutants, increased rainfall and flooding, warmer summer temperatures, and increased energy use for air conditioning. The Chicago Urban Forest Climate Project (CUFCP) was a 3-year (1991-1993) interdisciplinary study that examined interactions between vegetation and other aspects of the urban ecosystem such as hydroclimate, air quality, and the economic benefits and costs associated with tree planting and management (McPherson et al., 1993, 1994; Nowak and McPherson, 1993). This paper highlights results of the CUFCP. Complete reports can be obtained at no cost from the USDA Forest Service (ask for GTRs NE-186 and NE-169 when calling 614-368-0127).

## URBAN FOREST STRUCTURE

The region's tree cover has increased from a presettlement level of about 13 percent to nearly 20 percent today. Canopy cover is 11 percent in Chicago, where dense development restricts opportunities for trees; 23 percent in Cook County, where older neighborhoods are well-stocked; and 19 percent in DuPage County, where new developments are being planted. The distribution of tree density along an urban-rural gradient from Chicago to DuPage County parallels the pattern of tree cover (Nowak, 1994a).

Many benefits trees produce are related to their leaf-area (e.g., interception, evapotranspiration, and shading). Trees growing on low-density (1-3 family) residential land and institutional lands dominated by vegetation (e.g., parks, forest preserves, golf courses) account for 50 and 38 percent of total tree leaf-surface area, respectively. Therefore, trees in these areas are likely to play large roles in creating regional benefits.

There are an estimated 50.8 million trees in the region; 66 percent in good or excellent condition. The diameter distribution of trees in Chicago, Cook, and DuPage Counties are relatively similar. The trees tend to be small (77 percent less than 16 cm dbh), but larger trees dominate along the streets. The relative importance of street trees in Chicago is indicated in that although street trees comprise only 10 percent of the city's tree population, they comprise 24 percent of total leaf-surface area due to their relatively large size.

Buckthorn (*Rhamnus spp.*), an exotic and highly invasive species, is the most common tree, accounting for about 13 percent of the tree population, but only 3 percent of total leaf area due to its small size. Managing urban forest stands to control the invasion and spread of trees such as buckthorn continues to be a formidable challenge.

The distribution of street tree species is less

even than for all trees, with four species comprising two–thirds of the population. Reliance on this few species suggests need to be concerned for the population's overall stability.

## URBAN HYDROCLIMATE

Above and below–canopy microclimate research examined the degree to which tree cover influences the climate surrounding people and houses (Grimmond et al., 1994; Heisler et al., 1994). Measurements of windspeed, air temperature, and relative humidity were made in residential neighborhoods with four portable meteorological stations from July 1992 through June 1993. Air temperatures at three residential sites were slightly warmer (0.4°C), on average, than the O'Hare International Airport reference site. Windspeed at the neighborhood sites was reduced by 84 percent on average compared to the airport during one July week. This research will result in predictive equations that can be used with building energy performance models to simulate effects of trees on energy use for heating and cooling buildings.

## AIR POLLUTION AND ATMOSPHERIC CARBON DIOXIDE REMOVAL

The region's urban forest was estimated to provide $9.2 million dollars in air quality improvement by removing 5,575 metric tons (t) of air pollutants during 1991 (Nowak 1994b). Average hourly improvement (in–leaf season) in air quality ranged from 0.002 percent for CO to 0.4 percent for PM10. Maximum hourly improvement was estimated at 1.3 percent for $SO_2$, though localized improvement in air quality can reach 5 to 10 percent or greater in areas of high tree cover. Trees were most effective at removing $O_3$ (2,000 t/yr) and PM10 (1,840 t/yr). Removal rates for these two pollutants peaked during summer when trees were in–leaf and their concentrations were often the highest. Large healthy trees were estimated to remove 60 to 70 times more pollution than small trees due to their proportionately greater amount of leaf–surface area. Hence, sustaining the health and longevity of mature trees will benefit air quality.

Increasing the region's tree cover by 4 percent, from 19 to 23 percent, was estimated to remove an additional 1,180 metric tons of pollution in 1991, thereby reducing concentrations another 0.05 percent. Air quality benefits can be maximized by planting pollution–tolerant species in areas where concentrations are highest. Providing ample soil volume for tree roots and adequate irrigation is critical to achieving long–term benefits from transplants.

Trees throughout the region are estimated to store about 5.6 million t of carbon, about 14 to 18 t/ha (6 to 8 tons/acre) (Nowak, 1994c). Trees on residential and institutional lands dominated by vegetation (e.g., forest preserves, parks) account for 54 and 33 percent of total carbon storage, respectively. Carbon storage per hectare increases with tree density along the urban–rural gradient. Net annual sequestration (average growth minus mortality) by the region's trees is 140,600 t of carbon (0.42 t/ha).

## ENERGY CONSERVATION

Chicago area residents spend about $660 million annually for natural gas to heat their homes ($755/household), and $216 million for air conditioning ($216/household). Urban forests can mitigate urban heat islands and conserve cooling energy by shading buildings and other heat–absorbing surfaces and lowering summer air temperatures through evapotranspirational (ET) cooling (Akbari et al., 1992). Trees can save space heating energy by reducing windspeeds; thereby reducing the amount of cold outside air that infiltrates buildings (Heisler, 1986).

Increasing tree cover by 10 percent (corresponding to about three trees per building) could reduce total heating and cooling energy use by 5 to 10 percent ($50 to $90) (McPherson, 1994b). On a per–tree basis, annual heating energy can be reduced by about 1.3 percent ($10), cooling energy by about 7 percent ($15), and peak cooling demand by about 6 percent.

Street trees are a major source of building shade within the City of Chicago. Shade from a large street tree located to the west of a typical brick residence can reduce annual air–conditioning energy use by 2 to 7 percent ($17 to $25) and peak cooling demand by 2 to 6 percent. Street trees that shade the east side of buildings can produce similar cooling savings, have a negligible effect on peak cooling demand, and can slightly increase heating costs. Shade from large street trees to the south increase heating costs more than they decrease cooling costs. Planting

"solar friendly" trees (i.e., dense crown when in leaf and open crown when out of leaf) to the south and east can minimize this energy cost.

For typical suburban wood-frame residences, shade from three trees can reduce annual heating and cooling costs by $29 to $50 20 years after planting. Savings in annual air-conditioning energy per tree range from 6 to 7 percent ($15 to $23) assuming a 25-foot-tall tree opposite the west wall.

Features of energy-efficient residential landscapes in the Chicago area include: 1) shade trees, shrubs, and vines located for shade on the west and southwest windows and walls; 2) solar friendly deciduous trees to shade the east and an open understory to promote penetration of cool breezes; 3) evergreen windbreaks to the northwest and west for protection from winter winds; and 4) shade on the air conditioner where feasible.

## NET BENEFITS OF TREE PLANTING AND CARE

In Chicago and most surrounding communities, trees have long been recognized as valuable community assets. However, dwindling budgets for planting and care of street and park trees is creating new challenges for urban forestry. Community officials are asking if trees are worth the price to plant and care for them over the long term. Similarly, some residents wonder whether it is worth the trouble of maintaining street trees in front of their home or in their yard. Certain species are particularly bothersome due to litterfall, roots that invade sewers or heave sidewalks, shade that kills grass, or exudates that foul cars and other objects. These and other problems are magnified when trees do not receive regular care, or when the wrong tree was selected for planting.

To provide initial answers to questions about the net worth of trees, benefit-cost analysis was used to estimate the annual dollar value of benefits and costs over a 30-year period associated with the planting and care of 95,000 new trees in Chicago. The estimated number of new trees and their management costs were based upon interviews with entities responsible for much of the tree planting and care in the city. The Cost-Benefit Analysis of Trees (C-BAT) computer model was used to calculate the present value of future management costs and environmental benefits (McPherson, 1994c).

Findings suggest that energy savings, air-pollution mitigation, avoided runoff, and other benefits associated with trees in Chicago can outweigh planting and maintenance costs. Given the assumptions of this analysis (30 years, 7-percent discount rate, 95,000 trees planted), planting and maintaining trees cost $21 million, while the benefits conferred by the trees was $59 million, for a net present value of $38 million or $402 per tree planted. A benefit-cost ratio of 2.83 indicates that the value of projected benefits is nearly three times the value of projected costs.

Benefit-cost ratios were projected to be positive for plantings at park, yard, street, highway, and public housing locations at discount rates ranging from 4 to 10 percent. Assuming a 7-percent discount rate, ratios were largest for trees in residential yard and public housing (3.5) sites. Traits associated with trees in these locations were: relatively inexpensive to establish, low mortality rates, vigorous growth, and large energy saving. Because of their prominence in the landscape and existence of public programs for their management, street and park trees frequently receive more attention than yard trees. By capitalizing on the many opportunities for yard-tree planting in Chicago, residents can gain additional environmental, economic, social, and aesthetic benefits.

Findings from the C-BAT simulations suggest several strategies to maximize net benefits from investment in Chicago's urban forest that also have application in communities outside Chicago.

Select the right tree for each location and reduce initial costs. Because tree planting and establishment costs often account for 80 percent or more of total costs, investing in trees that are well suited to their sites can pay dividends. Strategies to reduce up-front costs include the use of trained volunteers, smaller tree sizes, and follow-up care to increase survival rates.

Plan for long-term tree care. Benefits from trees increase as they grow, especially if systematic pruning and maintenance result in a healthy tree population (Miller and Sylvester, 1981). The costs of providing regular tree care are small compared to the value of benefits forgone when maturing trees become unhealthy and die. Efficiently delivered tree care can more than pay for itself by improving health, increasing growth, and extending longevity.

A healthy urban forest can produce long-term benefits that all residents can share. To improve the health and increase the productivity of Chicago's

urban forest will require increased support from agencies and local residents. Information on the value of some of these benefits, as well as the costs, could be part of public education programs aimed at making more residents aware of the value their trees add to the environment in which they live.

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[1] McPherson, Pacific Southwest Research Station, USDA Forest Service, Davis, CA

[2] Nowak, USDA Forest Service, Northeastern Forest Experiment Station, Syracuse, NY

[3] Heisler, Department of Geography, Indiana University, Bloomington, IN

[4] Grimmond, Department of Geography, Indiana University/Purdue University, Indianapolis, IN

[5] Souch, Department of Agronomy, Purdue University, West Lafayette, IN

[6] Grant, USDA Forest Service, Pacific Southwest Research Station, Albany, CA