URBAN FOREST LANDSCAPES

Integrating Multidisciplinary Perspectives

Edited by GORDON A. BRADLEY

University of Washington Press
SEATTLE AND LONDON

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Net Benefits of Healthy and Productive Urban Forests

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ABSTRACT In California, urban forestry programs are facing new challenges due to dwindling municipal budgets, fewer trees, planting of smaller trees, and declining government support. However, changes in environmental policy, such as the use of market incentives to promote environmentally sound behavior, are providing new opportunities for urban forestry to broaden its base of support. Quantifying the benefits and costs associated with tree planting and care is fundamental to the development of economic incentives aimed at sustaining healthy and productive urban forests. Use of benefit-cost analysis to evaluate the economics of urban forestry policies and programs is illustrated with an example from the Chicago Urban Forest Climate Project. The thirty-year annual costs and benefits associated with planting 95,000 trees were estimated using the computer model Cost-Benefit Analysis of Trees (C-BAT) and discount rates of 4, 7, and 10 percent. Net present values were positive, and projected benefit-cost ratios were greater than 1.0 at all discount rates. Assuming a 7 percent discount rate, a net present value of $38 million, or $402 per planted tree, was projected. Benefit-cost ratios were largest for trees planted in residential yards and public housing sites (3.5), and least for park (2.1) and highway (2.3) sites. Discounted payback periods ranged from nine to fifteen years. Strategies for strengthening connections between city residents and city trees, as well as maximizing return on investment in the urban forest, are presented.

Although urban forests are capable of supplying substantial economic, environmental, and social benefits (Akbari et al. 1992; Anderson and Cordell 1988; Dwyer et al. 1992; McPherson and Nowak 1993; Rowntree and Nowak 1991; Sampson et al. 1992; Sanders 1986), local governmental support for city and county programs appears to be declining. Dwindling budgets are prompting community officials to ask if trees are worth the price to plant and care for over the long term. Urban forestry programs must now prove their cost-effectiveness. Similarly, some residents wonder if it is worth the trouble to maintain street trees in front of their homes or in their yards. Certain species are particularly bothersome due to litterfall, roots that invade sewers or heave sidewalks, shade that kills grass, or sap from aphids that fouls cars and other objects. Branches broken by wind, ice, and snow can damage property. Thorns and low-hanging branches can be injurious. These problems are magnified when trees do not receive regular care, or if the wrong tree was selected for planting.

This chapter highlights disturbing trends affecting urban forestry, but also looks at changes that provide new opportunities to broaden its base of support. Benefit-cost information for evaluating the economics of urban forestry policies and programs is discussed with reference to the Chicago Urban Forest Climate Project (CUFCP), a three-year study to quantify some of the environmental effects of urban vegetation in the Chicago area (McPherson et al. 1993, 1994). Based on findings of this study, strategies for increasing net benefits are considered. The chapter concludes with several ideas for strengthening the support of residents for their city trees.

THE STATE OF URBAN FORESTRY

Public attitudes about community forests are ultimately reflected in the health and productivity of city trees. Declining support for street tree management may show up first in the form of fewer replacement plantings and increased numbers of dead and unhealthy trees. Longer pruning cycles can result in a greater amount of tree cover being removed each time trees are pruned, as well as progressively shorter rotations due to increased mortality caused by larger wounds and inadequate care.

A 1992 survey of urban forestry in California focused on the changes in city and county tree programs since 1988 (Bernhardt and Swiecki 1993). Among the findings: (1) the average percentage of city operating budgets that goes to tree programs has dropped to less than 1 percent, thus declining over 18 percent between 1988 and 1992; (2) about 38 percent of the cities reported that they care for fewer trees now than in 1988; (3) there is a continued trend away from planting large-scale trees (90 percent of the street trees and 80 percent of the park trees planted are of small or medium stature); and (4) 20 percent of the respondents, compared to about 15 percent in 1988, report that government support is less than citizen support.

Given these trends, it is not surprising that when respondents ranked their three most pressing needs, 48 percent of the first-place votes were for increased program funding; second place went to improved tree maintenance. Although first-rate urban forestry programs abound in California, data from this survey suggest that municipal budgets for urban forestry are dwindling. Results from two similar independent surveys now under way will help determine if this trend is confined to California or is larger in scope.

NEW DIRECTIONS IN ENVIRONMENTAL POLICY

Timothy Duane recently (1992) addressed the policy and planning implications of emerging trends in environmental problems. Several of these trends pertinent to the field of urban forestry are summarized below.

- *Pollution is a transboundary issue.* The impact of acidic deposition in New England from air pollution generated in the Midwest is a prime example. It is no longer acceptable to export pollution. How would planting trees along all streets in the Los Angeles basin affect pollution concentrations and human health on those streets? The health of ecosystems in the nearby mountains? Air quality and visibility at the Grand Canyon?
- *Pollution control is shifting to nonpoint sources.* The easy gains in pollution abatement have been made through traditional technology-based, centralized command and control procedures. Now pollution control is shifting from industrial smokestacks to individual behavior (such as automobile use, or the use of lighter fluid for backyard grills). Water quality regulations have traditionally addressed end-of-

pipe treatment, but runoff prevention is beginning to gain attention under section 31a of the Clean Water Act amendments of 1987. How would increased tree cover affect runoff volume and quality? Would incorporating landscape mulch into urban soils and collecting rainwater on individual properties have a beneficial effect on water quality and the demands for landscape irrigation?

- *Life-cycle analysis is important.* Recycled products may be cheaper than products using virgin materials if their prices capture all environmental externalities associated with production, utilization, and disposal. Corporations are beginning to take "cradle-to-grave" responsibility for their products, and electric utilities are incorporating environmental externalities into their resource planning process. Conserving energy through some demand-side management programs is proving to be less expensive than purchasing power from other sources or constructing power plants. Partly because of their cost-effectiveness, shade tree programs for energy conservation are now sponsored by utilities in Washington, D.C., Maryland, Texas, Arizona, Utah, and California (McPherson 1993).
- *Market incentives are emphasized.* Approaches that modify consumer behavior by offering economic incentives are receiving greater support by planners. For example, sulfur dioxide emission permits are now being traded in the marketplace, and this is expected to reduce the annual cost of compliance by over a billion dollars nationwide (Alm 1992). Urban forestry can offer one means for meeting policy objectives aimed at improving environmental health. The extent to which environmental planners use economic tools to this end will be related to their ability to identify connections between the economics of urban forest management and its environmental and social impacts. Quantifying benefits and costs associated with tree planting and care is a first step toward developing new market incentives aimed at sustaining healthy and productive urban forests.

CHICAGO BENEFIT-COST STUDY

Current efforts to determine the value of greenspace do not include a broad range of important benefits and costs or how they vary across time and location. Nor do they allow comparison of future cost-benefit relationships associated with alternative management scenarios (McPherson 1992). In response to these limitations, the Cost-Benefit Analysis of Trees (C-BAT) computer model was developed to quantify various management costs and environmental benefits. C-BAT as applied here quantifies annual benefits and costs for a thirty-year period associated with the establishment and care of 95,000 trees in Chicago. Contact persons from organizations responsible for much of the tree planting and care in Chicago were interviewed to estimate the number of trees to be planted annually over a five-year period (1992 to 1997), growth and mortality rates, and planting and management practices and costs (Table 17-1).

Quantifying benefits and costs associated with these plantings provides initial answers to the following questions: (1) Are trees worth it? Do their benefits exceed their costs? If so, by how much? (2) In what locations do trees provide the greatest net benefits? (3) How many years does it take before newly planted trees produce net benefits in Chicago? (4) What planting and management strategies will increase net benefits derived from Chicago's urban forest?

Table 17-1. Typical locations, planting sizes and costs, tree growth rates, and organizational roles in a Chicago computer modeling study (C-BAT).

Location	Planting size (caliper), cost per tree	Average annual growth rates: tree height, dbh	Organization and tree planting/care activity
Park	4-inch, $470	0.8-ft, 0.4-inch	Chicago Park District plant and maintain
Residential yard	2-inch, $250	0.8-ft, 0.4-inch	Residents plant and maintain small trees; arborists maintain/remove large trees
Residential street	2-inch, $162	0.67-ft, 0.33-inch	Bureau of Forestry plant and maintain
Highway	3-inch, $250	0.67-ft, 0.33-inch	Gateway Green, Illinois Department of Transportation, and arborists plant and maintain
Public housing	2.5-inch, $150	0.8-ft, 0.4-inch	Openlands, treeKeepers, and residents plant and maintain while young; arborists maintain larger trees

dbh = diameter at breast height.

Although Chicago's urban forest is planted with many tree species (Nowak 1994), the scope of this analysis is limited to planting and caring for a single typical species, green ash (*Fraxinus pennsylvanica*), in each of five typical locations: parks, residential yards, residential streets, highways, and public housing sites. Locations were selected to represent the types of trees, management approaches, socioeconomic situations, and growing conditions that influence tree health and productivity in Chicago. Green ash was selected because it is one of the most widely planted and successful tree species in Chicago.

C-BAT estimates annual benefits and costs for newly planted trees in different locations over a specified planning horizon. It is unique in that it directly connects tree size with the spatial-temporal flow of benefits and costs. Prices are assigned to each cost (e.g., planting, pruning, removal, irrigation, infrastructure repair, liability, waste disposal) and benefit (e.g., heating/cooling energy savings, absorption of air pollution, reduction in stormwater runoff) through direct estimation and implied valuation of benefits as environmental externalities (Chernick and Caverhill 1991). C-BAT incorporates data on different rates of growth and mortality as well as different levels of maintenance associated with typical trees. Hence this greenspace accounting approach "grows trees" in different locations and directly calculates the annual flow of benefits and costs as trees mature and die (McPherson 1992).

In this computer modeling study, trees were "planted" during the first five years and their growth was assumed to follow an S-shaped curve that incorporates a slow start after transplanting. As trees aged, their numbers decreased. Transplanting-related losses occurred during the first five years after planting, and age-independent losses occurred over the entire thirty-year analysis period. Transplanting-related losses were based on annual loss rates reported by local managers and other studies (Miller and Miller 1991; Nowak et al. 1990). Age-independent losses were assumed to be equally likely to occur in any year (Richards 1979). Tree growth (Table 17-1) and mortality reflected rates expected for the green ash on each type of site.

C-BAT directly connects selected benefits and costs with estimated leaf-surface area or, as in the case of carbon sequestered and "other" benefits, the tree's annual trunk diameter growth. Because many functional benefits of trees are related to leaf-atmosphere processes (e.g., interception, transpiration, photosynthesis), benefits increase as leaf-surface area increases. Similarly, pruning and removal costs usually increase with tree size. To account for these time-dependent relationships, benefits and costs are assumed to vary with leaf area (LA) and trunk girth.

For most costs and benefits, prices were obtained for large trees (assumed to be 20 inches in dbh or about 45 feet tall and wide) and estimated for trees of smaller size using different functions (e.g., linear, sine, cosine). These prices were divided by the tree's leaf area to derive a base price per unit LA for different tree size classes (e.g., $20 per 10,000 square feet LA = $0.002 per square foot LA). C-BAT multiplied the base price by the total LA of trees in that size class to estimate the total annual nominal value of each benefit and cost. Once the nominal values were calculated for each year into the future, they were discounted to a present value. Discount rates of 4, 7, and 10 percent were used to account for the different costs of capital faced by tree managers. Thus both tree size and the number of live trees influenced the dollar value of each benefit and cost. More detailed information on assumptions and pricing for each benefit and cost can be found in McPherson (1994).

This analysis was complicated by incomplete information on such critical variables as tree growth and mortality rates, the value of social, aesthetic, and economic benefits that trees produce, and costs associated with infrastructure repair, litigation, and program administration. When data from local sources were not available, it was necessary to use the best available data. As a result, some variables were excluded from this analysis (e.g., costs of litter cleanup, and health care benefits and costs). Estimating the value of social, aesthetic, and economic benefits—called "other benefits" in this study—is uncertain because we have yet to identify the full extent of these benefits or their implications. Additional problems emerge, since many of these benefits are not exchanged in markets and it is often difficult to estimate appropriate dollar values. Therefore, this study provides an initial approximation of those benefits and costs for which information is available. As our understanding of urban forest structure, function, and values increases, and we learn more about urban forestry programs and costs, these assumptions and methods used to estimate benefits and costs will be improved.

Mortality and Leaf Area

Mortality rates reflect the anticipated loss associated with growing conditions, care, and likely damage from cars, vandalism, pest/disease, and other impacts. Loss rates were projected to be greatest along residential streets (42 percent), where trees are exposed to a variety of human and environmental abuse (Table 17-2). A 39 percent loss rate was projected for trees planted in parks, on public housing sites, and along highways. About 18 percent of the trees planted in residential yards were expected to die. Of the 95,000 trees planted, 33,150 (35 percent) were projected to die, leaving 61,850 trees alive at the end of the thirty-year analysis (Figure 17-1).

The total amount of leaf area varies according to tree numbers and size. Although twice as many trees were projected to be planted along residential streets than in yards,

Table 17-2. C-BAT results.

Planting location	No. trees planted	Mortality rate (%)[a]	New tree cover[b]	NPV in $1,000[c]	Benefit/ cost[d]	Per planted tree (dollars)[e] PV benefit	PV cost	NPV
Park	12,500	39	190	5,592	2.14	840	393	447
Yard	25,000	18	433	14,637	3.51	818	233	585
Street	50,000	42	489	15,160	2.81	471	168	303
Highway	5,000	39	58	1,606	2.32	564	243	321
Housing	2,500	39	34	1,155	3.52	645	184	461
Total	95,000	35	1,204	38,150	2.83	621	219	402

[a] Percentage of trees planted expected to die during thirty-year planning period.

[b] Estimate of new tree cover in acres provided by plantings in thirty years (2022) assuming listed mortality and no replacement planting after five years.

[c] Net present values assuming 7 percent discount rate and thirty-year analysis period.

[d] Discounted benefit-cost ratio assuming 7 percent discount rate and thirty-year analysis period.

[e] Present value of benefits and costs per planted tree assuming 7 percent discount rate and thirty-year analysis period.

total leaf area for both was about 100 million square feet at year 30 because yard trees were faster growing (i.e., larger trees) and had a lower mortality rate. Because relatively few trees were projected to be planted in highway and public housing locations, thirty years after planting their projected total leaf area was about one-tenth that of street and yard trees.

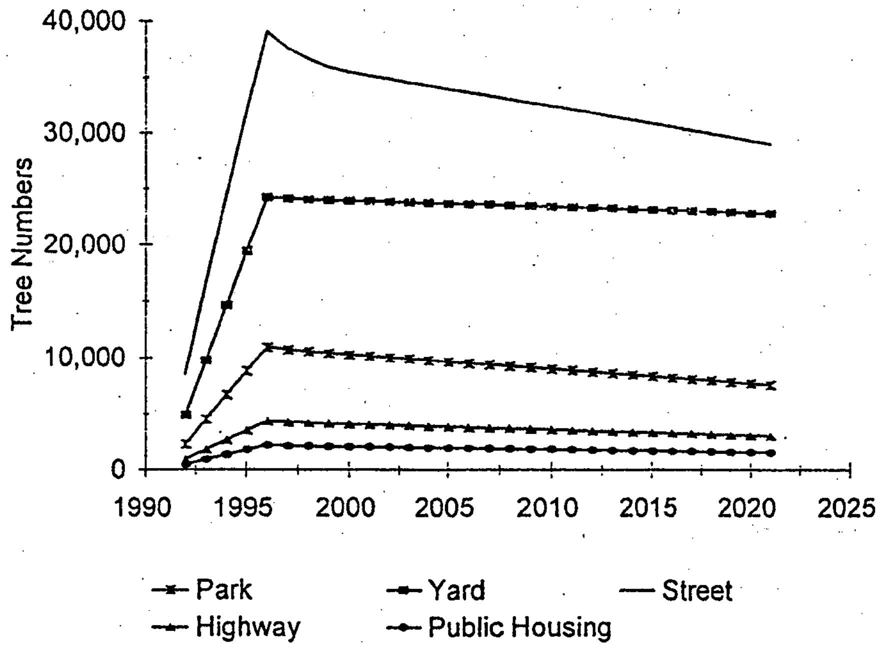

Figure 17-1. Projected number of live trees at each location, assuming planting and replacement during the first five years only.

Net Present Values and Benefit-Cost Ratios

The net present value (NPV) reflects the magnitude of investment in tree planting and care at each location, as well as the flow of benefits and costs over time. The projected NPVs were positive at all discount rates, ranging from $638,153 at public housing sites with a 10 percent discount rate to $30.6 million for street trees with a 4 percent discount rate. At a 7 percent discount rate, the NPV of the entire planting (95,000 trees) was projected to be $38 million, or about $402 per planted tree (Table 17-2). This means that on average the present value of the yield on investment in tree planting and care in excess of the cost of capital was $402 per tree. The NPV of street and yard trees was projected to be about $15 million each, while the NPV for park tree plantings was $5.6 million. The NPVs were lower for planting and care of trees along highways ($1.6 million) and at public housing sites ($1.2 million), because fewer trees were projected to be planted than in the other locations.

The discounted benefit-cost ratio (BCR), or the present value of benefits divided by the present value of costs, was greater than 1.0 at all discount rates. The BCRs ranged from 1.49 for park trees with a 10 percent discount rate, to 5.52 for residential yard trees with a 4 percent discount rate. At a 7 percent rate, the BCR for all locations was 2.83, meaning that $2.83 was returned for every $1.00 invested in tree planting and care in excess of the 7 percent cost of capital (Table 17-2). BCRs were projected to be greatest for residential plantings (3.5 for yard and public housing at 7 percent) and least for park trees (2.14), although actual BCRs will vary with the mix of species used and other factors influencing growth, mortality, and tree performance.

Although NPVs and BCRs vary considerably with discount rate, these results indicate that economic incentives for investing in tree planting and care exist, even for decision makers who face relatively high discount rates. While the rate of return on investment in tree planting and care was less at higher discount rates, benefits still exceeded costs for this thirty-year analysis. Given this result, a 7 percent discount rate is assumed for the findings that follow.

Present Values of Costs and Benefits per Planted Tree

Differences in return on investment can be understood by examining the present value of costs and benefits per planted tree at different planting locations (Figures 17-2 and 17-3). Even though trees of similar size and wholesale price were projected for planting in all locations, the present value of planting costs varies markedly, ranging from $109 per tree at public housing sites, where volunteer assistance kept costs down, to $341 in parks, where costs for initial irrigation added to the planting expenditures. Participation by residents of public housing in tree planting and care can reduce initial tree loss to neglect and vandalism. Similarly, initial watering of park trees can increase survival rates by reducing tree loss to drought.

The present value of pruning costs was only $12 per planted street tree, even though trees were assumed to be pruned more frequently along streets (every six years) than at other locations. In fact, the present value of total costs was only $168 per tree for street trees (Figure 17-2). Cost-effective planting and care of street trees is important because they account for about one-third of Chicago's overall tree cover (McPherson et al. 1993).

The present value of removal costs was projected to be highest for trees planted in parks and public housing sites ($16 to $22 per tree). Costs for infrastructure repair, pest and disease control, and liability/litigation were relatively small. The present value of

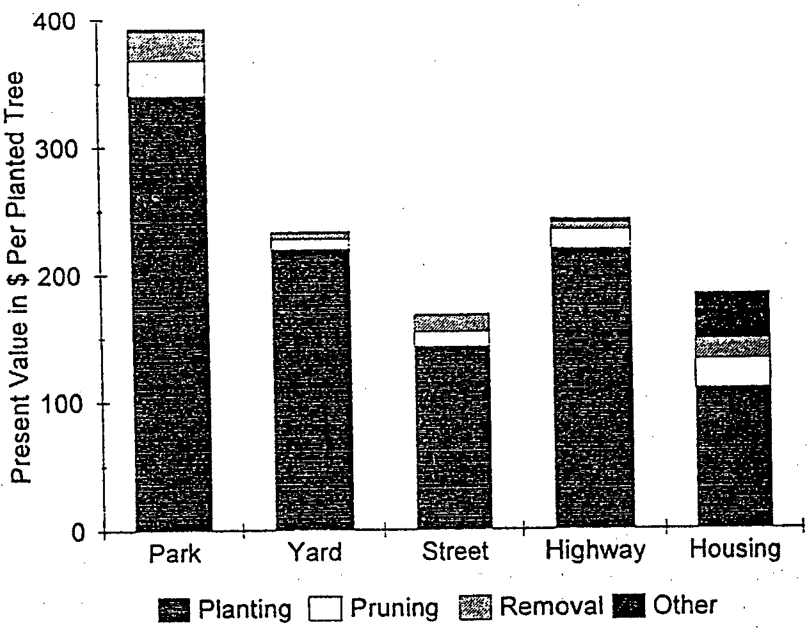

Figure 17-2. Present value of costs per tree planted at each location, assuming a thirty-year analysis period and a 7 percent discount rate. "Other" includes costs for sidewalk and sewer repair, liability/litigation, program administration, and pest/disease control.

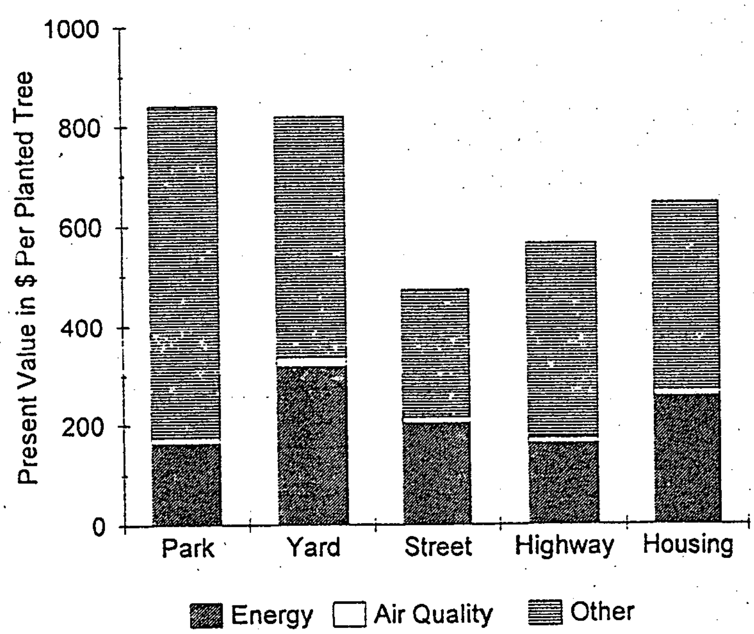

Figure 17-3. Present value of benefits per tree planted at each location, assuming a thirty-year analysis period and a 7 percent discount rate. Air quality benefits are totals for PM10, ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, and carbon dioxide. Hydrologic benefits from reduced stormwater runoff and avoided water consumption at power plants are small and included with the "Other" category, which also includes benefits such as scenic beauty, wildlife habitat, outdoor recreation, stress reduction, noise abatement, and soil conservation. These other benefits were calculated as the total compensatory value minus explicitly valued energy, air quality, and hydrologic benefits. See McPherson (1994) for additional information on benefit estimation.

program administration costs for tree plantings by Openlands and trained volunteers was $35 per planted tree. Generally, nonprofit tree groups have higher administrative costs than municipal programs using in-house or contracted services because of their small size and the expense of organizing and training volunteers. These additional expenditures somewhat offset savings associated with reduced labor costs for planting and initial tree care compared to municipal programs.

The projected present value of benefits per planted tree was $471 and $564 for street and highway plantings respectively, $645 for public housing sites, and more than $800 for trees planted in parks and residential yards (Figure 17-3). Lower benefits for street and highway trees can be attributed to their slower growth, smaller total leaf area, and relatively smaller energy and other benefits, due to locational factors.

The amount of annual benefits the typical tree produces depends on tree size and the relation between location and functional performance. Larger trees can produce more benefits than smaller trees because they have more leaf-surface area. Because yard trees exert more influence on building energy use than highway trees do, they produce greater energy savings per unit leaf area. To illustrate how these factors influence benefits, nondiscounted annual benefits were estimated for the typical tree at year 30 in each typical location (Table 17-3). Estimated savings in annual air-conditioning energy from the 36 foot (14 inches dbh) yard tree were 201 kWh (0.7 GJ) ($24 nominal) compared to 102 kWh (0.4 GJ) ($12 nominal) for a 34 foot (13 inches dbh) tree along a highway. Differences in benefits from the uptake of air pollutants by trees, including carbon sequestered, were assumed to be solely due to differences in tree size, because little is known about spatial variations in pollution concentrations that influence rates of vegetation uptake. However, location-related differences in cooling energy savings translated into differences in avoided emissions and water consumed in the process of electric power generation. For instance, trees were projected to intercept more particulate matter and absorb more ozone and nitrogen dioxide directly than in avoided power-plant emissions. But energy savings from the same trees resulted in greater avoided emissions of sulfur dioxide, carbon monoxide, and carbon dioxide than was gained through direct absorption and sequestration. Street trees were projected to provide the greatest annual reductions in avoided stormwater runoff: 327 gallons (12.4 kl) for the 32 foot tree (12 inches dbh) compared to 104 gallons (3.9 kl) avoided by a park tree of larger size. More runoff was avoided by street trees than by trees at other sites because street tree canopies intercept rainfall over mostly paved surfaces. In the absence of street trees, rainfall on paving begins to run off quickly. Trees in yards and parks provided less reduction in avoided runoff because in their absence more rainfall infiltrated into soil and vegetated areas; thus less total runoff was avoided. Assumed differences in economic, social, aesthetic, and psychological values attached to trees in different locations were reflected in the projected value of "other benefits" (Table 17-3).

Discounted Payback Periods

The discounted payback period is the number of years before the benefit-cost ratio exceeds 1.0 and net benefits begin to accrue. Assuming a 7 percent discount rate, projected payback periods ranged from nine years for trees planted and maintained at public housing sites to fifteen years for plantings in parks and along highways (Figure 17-4). Yard and street trees were projected to have thirteen- and fourteen-year discounted payback periods, respectively. As expected, payback periods were slightly

Table 17-3. Projected annual benefits produced thirty years after planting by the typical green ash tree at typical locations in Chicago.

Tree location and benefit categories	Park	Residential yard	Residential street	Highway	Public housing
Tree size (height in feet)	39	36	32	34	37
dbh (inches)	16	14	12	13	14.5
Energy					
Cooling (kWh)	116	201	152	102	179
Heating (MBtu)	5.1	8.3	6.5	4.5	7.7
Total dollars	39.42	65.62	50.74	34.74	59.98
PM10 (lb)					
Direct uptake	2.19	1.8	1.41	1.67	1.93
Avoided emissions	0.02	0.30	0.02	0.01	0.02
Total dollars	1.44	1.37	0.93	1.09	1.27
Ozone (lb)					
Direct uptake	0.79	0.65	0.51	0.60	0.70
Avoided VOC emissions	0	0.01	0.01	0	0.01
Total dollars	0.19	0.16	0.13	0.15	0.17
Nitrogen dioxide (lb)					
Direct uptake	0.55	0.45	0.36	0.42	0.48
Avoided emissions	0.15	0.26	0.19	0.13	0.23
Total dollars	1.54	1.56	1.21	1.21	1.56
Sulfur dioxide (lb)					
Direct uptake	0.51	0.42	0.33	0.39	0.45
Avoided emissions	0.79	1.37	1.03	0.69	1.22
Total dollars	1.07	1.47	1.12	0.89	1.37
Carbon monoxide (lb)					
Direct uptake	0.04	0.03	0.03	0.03	0.04
Avoided emissions	0.08	0.13	0.10	0.07	0.12
Total dollars	0.06	0.07	0.06	0.05	0.07
Carbon dioxide (lb)					
Direct uptake	112	94	77	87	49
Avoided emissions	166	271	212	145	241
Total dollars	3.06	4.02	3.18	2.55	3.19
Hydrology (gal)					
Runoff avoided	104	177	327	132	187
Water saved	69	120	91	61	102
Total dollars	2.20	3.75	6.70	2.75	3.92
Other benefits (dollars)	196.46	233.82	247.69	231.07	190.2

Prices used to estimate benefits: \$0.12/kWh, \$5/MBtu, \$0.65/lb PM10, \$0.245/lb ozone and volatile organic compounds (VOC), \$2.2/lb NO_2, \$0.82/lb SO_2, \$0.46/lb CO, \$0.011/lb CO_2, \$0.02/gal runoff avoided, \$0.00175/gal water saved, \$27/inch dbh for other benefits (Neely 1988).
See McPherson (1994) for additional information on benefit estimation.

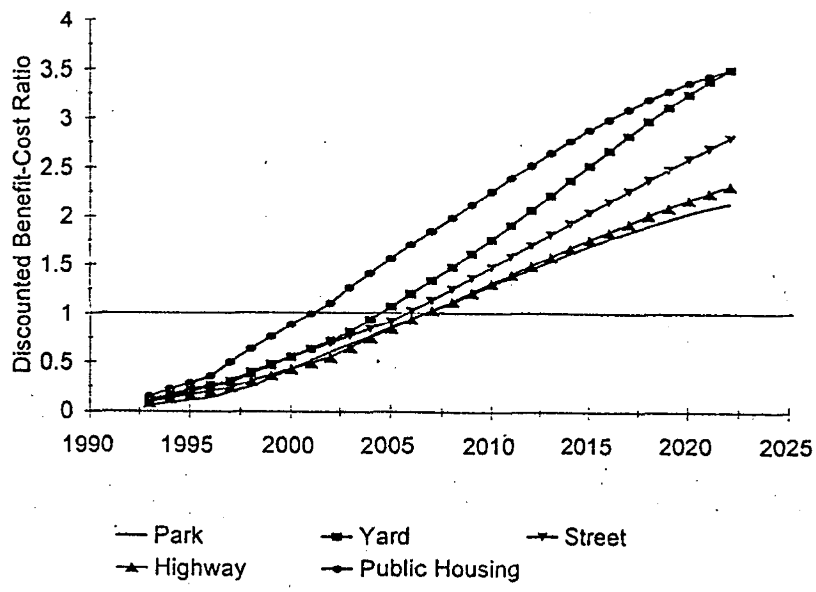

Figure 17-4. Discounted payback periods depicting the number of years before the benefit-cost ratio exceeds 1.0. This analysis assumes a thirty-year planning period and a 7 percent discount rate.

longer at the 10 percent discount rate (eleven to eighteen years), and shorter at most locations with a 4 percent discount rate (nine to thirteen years).

Early payback at public housing sites can be attributed to several factors. Trees were projected to add leaf area at a relatively rapid rate due to low initial mortality and fast growth compared to trees at other locations. These trees were relatively inexpensive to plant and establish due to participation by residents and volunteers. Thus the payback period was shortened because up-front costs, which are heavily discounted compared to costs incurred in the future, were low.

Summary

Are trees worth it? 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 (thirty years, 7 percent discount rate, 95,000 trees planted), the projected NPV of the simulated tree planting was $38 million, or $402 per planted tree. A benefit-cost ratio of 2.83 indicates that the value of projected benefits was nearly three times the value of projected costs.

In what locations do trees provide the greatest net benefits? 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, BCRs were largest for trees in residential yard and public housing (3.5) sites. The following traits were associated with trees in these locations: relatively inexpensive to establish, low mortality rates, vigorous growth, and large energy savings. 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. Residents on whose property such trees are located receive direct benefits (e.g., lower energy bills, increased property value), yet benefits accrue to the community as well. In the aggregate, private trees improve air quality, reduce stormwater runoff, remove atmospheric carbon dioxide, enhance the local landscape, and produce other benefits that extend well beyond the site where they grow.

How many years does it take before trees produce net benefits in Chicago? Payback periods vary with the species planted, planting location, and level of care that trees receive. C-BAT findings suggest that discounted payback periods for trees in Chicago can range from nine to eighteen years. Shorter payback periods were obtained at lower discount rates, while higher rates lengthened the periods.

What tree planting and management strategies will increase net benefits derived from Chicago's urban forest? Findings from the C-BAT simulations suggest several strategies to maximize net benefits from investment in Chicago's urban forest. These concepts are not new and most of the following recommendations have application in communities besides Chicago.

- *Select the right tree for each location.* Given that planting and establishment costs represent a large fraction of total tree expenditures, investing in trees that are well suited to their sites makes economic sense. Matching tree to site should take advantage of local knowledge of the tolerances of various tree species (Ware 1994). Species proven to be well adapted should be selected in most cases, though limited testing of new introductions increases species diversity and adds new horticultural knowledge (Richards 1993).
- *Weigh the desirability of controlling initial planting costs with the need to provide growing environments suitable for healthy, long-lived trees.* Because the initial investments in a project are high, ways to cut up-front costs should be considered. Some strategies include the use of trained volunteers, smaller tree sizes, and follow-up care to increase survival rates. When unamended growing conditions are likely to be favorable, such as yard or garden settings, it may be cost-effect to use smaller, inexpensive stock, thus reducing planting costs. However, in highly urbanized settings, money may be well spent by creating growing environments that improve the long-term performance of trees. Frequent replacement of small trees in restricted spaces may be less economical than investing initially in environments conducive to the culture of long-lived, vigorous shade trees.
- *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 (Abbott et al. 1991). Efficiently delivered tree care can more than pay for itself by improving health, increasing growth, and extending longevity. A long-term tree care plan should include frequent visits to each tree during the first ten years after planting, to develop a sound branching structure and correct other problems; thereafter less frequent but regular pruning, inspection, and treatment should be carried out as needed. Mature trees in Chicago provide substantial benefits today. Maintenance that extends the life of these trees will pay dividends in the short term, just as routine maintenance of transplants will pay dividends in the future.

CONCLUSIONS

Clearly, a healthy urban forest can produce long-term benefits that all city residents can share. The Chicago benefit-cost study illustrates the value of some of these benefits, as well as the costs. Improving the health and increasing the productivity of America's urban forests will require increased support from local residents, planners, and policy makers. Benefit-cost information can be part of public education programs designed to make residents more aware of the value their trees add to the environment in which they live. Also, it can be used by environmental planners to develop economic incentives for increased investment in urban forestry.

In summary, greater support for urban forestry programs will be predicated on stronger connections between city residents and city trees. Opportunities to strengthen these connections include:

- *Research and sound economic analyses that quantify the benefits and costs of trees.* If decision makers are asked to invest substantial amounts of money in the urban forest versus other investment opportunities, they must be provided with the best available information regarding the potential return on investment. Future analyses should consider who will bear the costs and who will receive the benefits, and how these will shift over time. For example, local investment in trees that reduce power plant emissions could benefit communities many miles downwind of the power plant.
- *Demonstrations of successful tree planting and management projects.* Numbers do not drive all decisions. A policy maker may be more influenced by experiencing the cooler temperatures and beauty of a shaded parking lot, compared to one with no trees, than by an exhaustive comparison of surface energy budgets and cost-benefit ratios.
- *Public awareness of the multiple benefits trees produce.* People are less aware of the environmental benefits trees produce than the aesthetic contributions of trees to community attractiveness (Gangloff 1993). More information regarding all benefits needs to be communicated to the public. A professionally produced television piece might reach a large segment of the general public, while children can be taught through science curriculums that include more materials on urban ecosystems.
- *"A bigger tent for urban forestry"* (Willeke 1994). New partners are needed to share the work of nurturing our urban forest resources. A key to creating a bigger tent lies in recognizing the urban forest as a community resource. Trees produce multiple benefits that extend well beyond the site where each tree grows. Our challenge lies in achieving a better understanding of these benefits and how the self-interests of new partners can advance the common interests of all residents through increased participation in stewardship of the urban forest resource.

ACKNOWLEDGMENTS

I wish to thank Paul Sacamano, Steve Wensman, Scott Prichard, Marcia Henning, and Lisa Blakeslee for their assistance with data collection and C-BAT modeling. Information on tree planting and care programs in Chicago was provided by Geri Weinstein and

Robert Megquier (Chicago Park District), Larry Hall (Hendrickson The Care of Trees), Steve Bylina (Bureau of Forestry), Vince Pagone (Chicago Gateway Green Committee), Rick Wanner (Illinois Department of Transportation), and Suzanne Malec-Hoer (Openlands). Helpful reviews of early versions of this manuscript were provided by Tim Duane (University of California, Berkeley) and Ray Aslin (Kansas State Forestry), and all errors of fact or interpretation are the responsibility of the author.

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