

ASSESSING THE BENEFITS AND COSTS OF THE URBAN FOREST

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Abstract. With effective planning and management, urban trees and forests will provide a wide range of important benefits to urbanites. These include a more pleasant, healthful, and comfortable environment to live, work, and play in, savings in the costs of providing a wide range of urban services, and substantial improvements in individual and community well-being. Urban forestry plans should begin with consideration of the contribution that trees and forests can make to people's needs. Planning and management efforts should focus on how the forest can best meet those needs. Past planning and management efforts have not been as effective as they might have been because planners and managers have underestimated the potential benefits that urban trees and forests can provide, and have not understood the planning and management efforts needed to provide those benefits, particularly the linkages between benefits and characteristics of the urban forest and its management.

Urban forests are a significant and increasingly valuable component of the urban environment. However, with the limited information on the benefits and costs of urban trees and forests currently available to decision makers, management of these valuable assets continues to be inadequate. Urban forest resources are declining in many cities, and the resulting benefits are only a fraction of what they could be. In many instances costs are higher than necessary. We are just beginning to learn about the extent and magnitudes of the many benefits and costs associated with urban trees and forests, as well as the many ties between urban forest resources and the quality of urban life. Research in a number of areas suggests that we have vastly underestimated the many ways that the urban forest touches the lives of urbanites, as well as the deep significance that many people attach to trees. Furthermore, we often lack reliable information on how to most effectively manage urban forests to provide many of these benefits.

A sound understanding of the full range of

benefits and costs associated with urban forests, as well as how various management practices, programs, and policies influence those benefits and costs, is essential for action to enhance urban forests and the associated well-being of urbanites. Benefits to consider include the goods and services produced by urban trees and forests that are valuable to people. These benefits vary over space and time according to changes in the urban environment, its inhabitants, and their needs. Some benefits are easily expressed in dollars or other numbers, while others are difficult to quantify using such measures; but in the aggregate they are highly significant to urbanites.

The long life of urban trees and forests mandates planning with a view to future needs. Investments in the planting and care of trees represent a long term commitment of scarce dollars, and improper plantings can increase costs and reduce benefits. Therefore, it is important to do it right and plan for future management. The effectiveness of urban trees and forests in providing benefits to people depends on their species composition, diversity, age, and location with respect to people and other elements in the landscape. An ecosystem approach that recognizes people as the central component offers the best means to assess the complex interactions between urban trees and forests and the well-being of urbanites, linking management actions with their effects on urban forests and the associated benefits and costs.

The following discussion begins with the influence of urban trees and forests on the physical and biological environment and continues with the socio-economic importance of urban trees and the environments that they create.

Physical/Biological Environment and Processes

Urban and community forests can strongly influence the physical/biological environment and mitigate many impacts of urban development by moderating climate, conserving energy, carbon dioxide, and water, improving air quality, controlling rainfall runoff and flooding, lowering noise levels, harboring wildlife, and enhancing the attractiveness of cities. These benefits may be partially offset by problems that vegetation can pose such as pollen production, hydrocarbon emissions, green waste disposal, water consumption, and displacement of native species by aggressive exotics (15). Urban forests can be viewed as a "living technology," a key component of the urban infrastructure that helps maintain a healthy environment for urban dwellers.

Energy and carbon dioxide conservation.

Trees can contribute to energy conservation because they help to reduce the cost of heating and cooling buildings. Projections from computer simulations indicate that 100 million mature trees in U.S. cities (three trees for every other single family home) could reduce annual energy use by 30 billion kWh, saving about 2 billion dollars in energy costs (1). Savings associated with avoided investment in new power supplies could augment these savings considerably. Also associated with this energy savings is a 9 million ton per year reduction in carbon dioxide emissions from power plants. At present, U.S. urban forests are estimated to store approximately 800 million tons of carbon, nearly 5 percent of live tree carbon storage in all US forests (19). Recent studies by scientists and energy utilities show that when the costs of planting, watering, and maintaining trees are considered, tree planting is a more cost-effective energy and carbon dioxide conservation strategy than many other fuel-saving measures (13).

As with most urban forest benefits, energy savings can only be realized through appropriate management strategies. With poor management, important benefits can be lost and increased costs incurred. For example, annual space air conditioning and heating costs for a typical home in Madison, Wisconsin increase from \$671 for an energy-efficient planting design, to \$700 for no trees, to

\$769 for trees that block winter sunlight and provide little summer shade (11). Costs for water, pruning, removal, litter clean-up, pollen, health-related problems, and liability can also offset benefits, particularly if the wrong tree is planted in the wrong place.

Air quality. Trees exchange gases with the atmosphere and capture particulates that can be harmful to people. The rate at which trees remove gaseous pollutants such as ozone, carbon monoxide, and sulphur dioxide depends primarily on the amount of foliage, number and condition of the stomata, and meteorological conditions. Results from computer studies indicate that trees can reduce appreciably the amount of ozone in polluted air. Pine trees in Los Angeles were projected to remove from the atmosphere (under 400 meters) about 8% of the ozone and decrease the concentration around the leaves by 49% (18).

Urban ozone concentrations go up with increases in ambient temperatures. One study found that the incidence of smoggy days increased 1% for each 1°C increase in temperature (26). Because urban forests can reduce summertime temperatures they provide another means of improving air quality.

By extrapolating from studies for non-urban forests we can infer that a mature urban tree can intercept up to 50 pounds of particulates per year. Planting of 500,000 trees in Tucson was projected to reduce air-borne particulates by 6,500 tons per year. The annual implied value of particulate matter control was estimated at \$4.16 per tree per year on average or \$1.5 million for all trees each year (12).

Citizens spend millions of dollars annually to control gaseous and particulate pollutants through programs for vehicle inspection and maintenance, oxygenated fuels, rideshare, and street paving and sweeping. To the extent that trees can control pollutants there is potential for improved air quality and substantial cost savings. Urban forests can be viewed as components of an overall strategy to restore air quality in our cities. Improved air quality will enhance physical and mental health, resulting in substantial savings in expenditures for health care. Improvements in air quality also reduce the costs of repairing damage to buildings, statuary, etc. that poor air quality causes.

Urban hydrology. Urban forests can play an important role in urban hydrologic processes by reducing the rate and volume of stormwater runoff, flooding damage, stormwater treatment costs, and water quality problems. Runoff estimates for an intensive storm event in Dayton, Ohio showed that the existing tree canopy reduced potential runoff by 7% and a modest increase in canopy cover would reduce runoff by nearly 12% (20). Runoff reductions could be further enhanced by directing runoff to landscape plantings.

By reducing runoff, trees function like retention/detention structures that are essential to many communities. Savings in stormwater management costs from trees in Tucson were calculated at \$0.18 per tree per year or \$600,000 over 500,000 trees and 40 years (12). Reduced runoff due to rainfall interception can also reduce stormwater treatment costs in many communities.

Water use by landscape vegetation is an important issue in arid and semi-arid regions where water resources are increasingly scarce; but also in other areas where drought can bring about restrictions on watering. We know that annual water costs can be twice as great as cooling energy savings from shade for high water use species such as mulberry (14). However, energy savings have the indirect effect of conserving water at power plants. In Tucson, 16% of the annual irrigation requirement for each tree was offset by water conserved at the power plant due to energy savings provided by the tree.

Because of recent regulations by the Environmental Protection Agency aimed at improving the quality of urban runoff and growing interest in water conservation, these hydrologic benefits will increase in importance over time.

Noise reduction. Field tests have shown that properly designed plantings of trees and shrubs significantly reduce noise. Wide belts of tall dense trees combined with soft ground surfaces can reduce apparent loudness by 50% or more (4,17). Noise reduction from plantings along roadsides in urbanized areas is often limited due to narrow roadside planting space. Buffer plantings in these circumstances are typically more effective at screening views than reducing noise.

Ecological benefits. Urban forests promote

ecological stability by providing habitat for wildlife, conserving soil, and enhancing biodiversity. Although the value of these benefits is seldom quantified, they are important to many urban dwellers and to the long term stability of urban ecosystems. Surveys have found that most city-dwellers enjoy and appreciate wildlife in their day-to-day lives (25). To enhance wildlife habitat, numerous communities have developed programs to preserve valuable existing natural areas and to restore the habitat on degraded lands. For example, restoration of urban riparian corridors and their linkages to surrounding natural areas have facilitated the movement of wildlife and dispersal of flora. Usually habitat creation and enhancement increases biodiversity and complements many other beneficial functions of the urban forest (10). Because of the growing environmental awareness and concern for quality of life in our cities, ecological benefits such as these will increase in significance over time. There can also be problems or costs associated with urban wildlife, including damage to plants and structures, droppings, threats to domestic pets, disease, etc.

Social Dimensions

All of the benefits associated with the physical/biological environment and processes discussed above have significant implications for people who live in urban areas. We now turn our attention to critical people/forest interactions.

Desirable environments. The presence of urban trees and forests can make the urban environment a more pleasant place to live, work, and spend leisure time. Studies of urbanites' preferences and behavior confirm the strong contribution that trees and forests make to the quality of life in urban areas. Trees and forests are a prominent component of the landscape in most urban areas. Urban forests provide significant outdoor leisure/recreation opportunities for urbanites. Based on nine visits per year to local parks per person, and \$1.00 per visit in value added by the presence of well managed urban forest resources, the total contribution of urban trees and forests in park and recreation areas to the value of recreation experiences provided in the USA could exceed \$2 billion (8). These are

both conservative estimates based on studies in the Midwest (6,7), and do not include benefits from trees on residential lots and other "non-designated" areas.

The Forest Preserve District of Cook County, Illinois provides more than 40 million visits per year from a base of 66,000 acres of urban forests. In addition to parks and preserves, urban greenways provide a wide range of recreational opportunities. Bicycle trails in river corridors in the Chicago Metropolitan area support up to 5,000 bicycles per day passing a given point on a single trail. To the extent that urban trees and forests increase the quality of the urban environment and make spending leisure time there more attractive, there will be substantial savings in fuel consumed because people will not drive to distant recreation sites as often. At \$1.25 per gallon, the savings to individuals across the U.S. total \$300 million per year if just one gallon per individual is saved by reduced leisure trips. It would seem that the potential savings in fuel costs from an urban environment that is enhanced by well managed trees and forests might be five times that amount or \$1.5 billion per year (8). Reduced fuel consumption would substantially reduce air pollution and related problems.

Medical. Reduced stress and improved physical health for urban residents have been associated with the presence of urban trees and forests. Studies have shown that landscapes with trees and vegetation produce more relaxed physiological states in humans than landscapes that lack these natural features. Hospital patients with window views of trees recover significantly faster and with fewer complications than comparable patients without access to such views (27). Future research will identify specific situations (e.g., urban commuting) in which urban forests can offset stress, and measure the amount of stress reduction that occurs. The benefits to public health from using trees to reduce urban stress are potentially very significant. In addition, cleaner air can be expected to improve health. There may be health-related costs as well, such as allergies to plants, pollen, or associated animals and insects.

Psychological. Urban forest environments provide esthetic surroundings, increased enjoy-

ment of everyday life, and a greater sense of meaningful connection between people and the natural environment. Trees are among the most important features contributing to the esthetic quality of residential streets and community parks (21). Perceptions of esthetic quality and personal safety are very sensitive to features of the urban forest such as number of trees per acre and view distance (22). Park and arboretum visitors have reported that trees and forests provide settings for significant emotional and spiritual experiences (3,23,24). These experiences are extremely important in people's lives, and can lead to a strong feeling of attachment to particular places and trees (9). An improved understanding of the emotional and symbolic meanings of trees will enable managers to provide the kind of settings that contribute to a meaningful and satisfying sense of place in the urban environment. Costs include fear of trees, forests, and associated environments.

Real estate values. The sales value of real estate reflects the benefits that buyers attach to the attributes of that property, including the trees and forest resource found on the property, along the street, and in neighboring parks and greenways. An individual's willingness to pay for a residential property is likely to reflect the value of benefits that they expect from these forest environments, including opportunities for leisure out in the yard or in the neighborhood, reduced heating and cooling costs, privacy, and the lack of a need to construct fences or screens. The variation in sales prices over a large number of residential properties with different forest resources on the property and nearby can be used to infer the willingness of users to pay for those urban forest resources (2). These increases in property values are not a separate category of value that is distinct from the goods and services provided; but rather one means of reflecting or capturing the values of the many important services that urban residents receive from urban forests.

The ties between trees and property values provide an incentive for homeowners to invest in trees since increased revenues can be received at the time of sale of that home (i.e., an advertisement mentioning well landscaped yard, shaded patio, close to parks and bicycle trails, and an

energy efficient home).

Economic values of trees and forests that are expressed as increased real estate values also produce direct economic gains to local communities through property taxes. Consequently, tree planting and tree care on public and private lands can be viewed as an investment that achieves an annual return in property taxes. A conservative estimate of a 5 percent increase in property values due to trees and forests on residential properties (several studies suggest higher values) represents \$25 per year on a conservative property tax bill of \$500, and quickly adds up to \$1.5 billion per year over the 62 million single family detached housing units in the USA. A more realistic estimate is two to three times that amount.

Parks and greenways have been associated with increments in the value of nearby real estate (5,16). Some of these increments have been substantial and it appears that parks with an "open space character" add most to the value of nearby real estate. We have yet to identify the increments in real estate value associated with urban forest resources in street corridors.

Residential properties are not the only real estate that gains in value from urban trees and forests. Shopping centers frequently landscape their surroundings in an effort to provide a pleasing environment that will attract shoppers, thereby increasing the value of businesses and the shopping center. While we are currently unaware of research that documents the increased business and tax receipts that are associated with such efforts, trees and forests may make an important contribution to the economic vitality of these businesses, and the private sector is currently making substantial investments in this area—far in excess of what is required by local regulations. One neighborhood shopping district in Chicago has concluded that planting trees along the street in front of their establishments increased their business activity. Similarly, employers invest in landscaping, beyond what is required, to enhance worker productivity and morale. While there is currently no research to document the increased worker productivity in such environments, building owners are generally able to obtain higher rents for offices that overlook well-landscaped

areas.

In short, trees and forests can make a substantial contribution to property tax revenues, thereby providing annual returns on municipal investments in urban trees and forests. These benefits are offset, in part, by the costs of managing the forests and repairing damages that may be associated with them, such as disruption of sidewalks, sewers, powerlines, etc.

Local economic development. Urban forest resources also make a broad contribution to the economic vitality of a city, neighborhood, or subdivision. While this is particularly difficult to quantify, it is apparently no accident that many cities and towns are named after trees and forests (i.e., Elmhurst and Oak Park) as are subdivisions (i.e., Tall Timbers and Timber Trails) and many areas strive to be designated as a "Tree City USA." Many neighborhoods select tree planting as a community improvement project. Trees can dominate the urban environment and contribute much to its character. In the Chicago area, communities such as Evanston, Oak Park, and Elmhurst are well known for their mature forest environments. Atlanta's large investment in downtown tree plantings has paralleled an upswing in convention business and contributed to its image of a progressive, livable city.

Community action programs that start with trees and forests often spread to other aspects of the community and result in substantial economic development. Often trees and forests on public lands—and to some extent those on private lands as well—are significant "common property" resources that contribute to the economic vitality of an entire area. The substantial efforts that many communities undertake to develop and enforce local ordinances and manage urban forest resources attests to the substantial return that they expect from these investments.

Societal. Stronger sense of community, empowerment of inner city residents to improve neighborhood conditions, and promotion of environmental responsibility and ethics can be attributed to involvement in urban forestry efforts. Active involvement in tree-planting programs has been shown to enhance a community's sense of social identity, self-esteem, and territoriality, and

it teaches residents that they can work together to choose and control the condition of their environment. Community tree planting programs can help alleviate some of the hardships of inner city living, especially for low-income groups. Research on environmental education is exploring ways of teaching children about their responsibility in caring for trees, and can provide badly needed opportunities for inner city children to experience nature. Researchers are examining how such early experiences with nature influence the willingness to adopt an environmental ethic later in life.

Summary and Conclusions

With effective planning and management, urban trees and forests will provide a wide range of important benefits to urbanites. These include a more pleasant, healthful, and comfortable environment in which to live, work, and play, savings in the costs of providing a wide range of urban services, and substantial improvements in individual and community well-being.

Urban forests can enhance the city environment by influencing temperature, wind, humidity, rainfall, soil erosion, flooding, air quality, scenic quality, and plant and animal diversity. Each of these influences has significant implications for the well-being of urbanites. But there are also environmental problems that may be associated with the urban forest, such as the generation of pollen, hydrocarbons, and green waste; water and energy consumption; obscured views; and displacement of native species of plants.

A well planned and managed urban forest can reduce costs for heating and cooling, health care, driving to exurban areas for recreation and leisure, stormwater management, and damage from flooding, erosion, and polluted air. Substantial increases in revenues can also be associated with urban trees and forests, including the sale of real estate (individual gains), real estate and business taxes (government gains), and tourism (individuals and government may gain). Costs associated with urban forests include establishment and care of the forest; repair of forest-induced damage to other parts of the urban infrastructure (particularly sidewalks and utilities); blocked solar collectors, and foregone opportunities for activities such as

gardening and sports.

Many important benefits and costs of urban forests that contribute significantly to the well-being of urbanites are not easily reflected in dollars and cents. Psychological benefits associated with urban forests include more pleasant environments for a wide range of activities, improvements in the esthetic environment (sights, sounds, smells), relief from stress (which can lead to improved physical health), enhanced feelings and moods, increased enjoyment of everyday life, and a stronger feeling of connection between people and their environment. Psychological costs can include fears of crime, animals, insects, disease (i.e., Lyme disease), darkness, and falling trees or limbs; and the displeasure of messiness and clutter.

Benefits attributed to urban trees and forests extend beyond individuals to society. Societal benefits include a stronger sense of community, empowerment to improve neighborhood conditions, promotion of environmental responsibility and ethics, and enhanced economic development (business, commerce, employment). Societal costs include money and other resources that must be diverted from other social programs.

The challenge faced by urban forest resource managers and planners is to balance the many benefits and costs that are associated with urban trees and forests. Lack of information about the extent and magnitude of these benefits and the best approaches for providing them often makes that task a very difficult one.

Urban forestry plans should begin with consideration of the contribution that trees and forests can make to people's needs. Planning and management efforts should focus on how the forest can best meet those needs. Past planning and management efforts have not been as effective as they might have been because planners and managers have underestimated the potential benefits that urban trees and forests can provide, and have not understood the planning and management efforts needed to provide those benefits, particularly the linkages between benefits and characteristics of the urban forest and its management.

Research continues to document new ways in which trees and forests can benefit urbanites, as well as the magnitudes of these benefits. The

efforts of urbanites to protect and preserve trees as well as their enthusiastic involvement in tree planting programs reflects their high regard for urban forest benefits.

Urban trees and forests promise to be even more consequential in the years ahead. Increasing interest in cost-effective and "minimum impact" approaches for improving the quality of the urban environment suggests that trees will play increasingly important roles in efforts to enhance air quality and improve urban hydrologic processes. Worldwide concern for "global warming" suggests increasing interest in trees for sequestering carbon and reducing carbon dioxide emissions. Associated concern for efficient use of energy resources will bring increasing attention to trees as a means of reducing heating and cooling costs as well as for encouraging urbanites to spend leisure time in the urban environment rather than driving to more remote areas. As we learn more about the functioning of the urban ecosystem and the role of trees and forests in that system, it is likely that these resources will assume new roles in efforts to manage the urban environment.

With increasing emphasis on improving the quality of life for urbanites and in "wellness" programs overall, increasing attention will be given to trees and forests as a means for enhancing the quality of urban life. This is likely to include efforts aimed specifically at stress reduction and improved public health. As we learn more about the deep psychological ties between urbanites and trees and forests, it is likely that urban trees and forests will assume new roles in efforts to increase the quality of urban life.

As we learn more about the contribution of trees and forests to the value of residential and commercial real estate it is likely that owners will make increasing investments in their trees and forests. Local governments and energy utilities will undertake programs to encourage such efforts, due in part to the increased tax revenues that will result, and to avoid energy costs.

Education regarding the planting and care of appropriate tree species in desirable locations will be critical to the long term cost-effectiveness of these programs.

With increased evidence of the boost that trees

and tree planting can give to local economic development and the sense of community, more community organizations will become involved in tree planting and tree care and tree and forest-related projects will be increasingly sponsored as a means of enhancing community spirit and organization. These projects will also be increasingly seen as a means of providing a sense of empowerment of inner city residents to improve neighborhood conditions and for promoting environmental responsibility and ethics!

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Résumé. Les arbres et les forêts urbaines sont des composantes significatives et de grandes valeurs pour l'environnement urbain et peuvent pourvoir un large éventail de bénéfices pour les citoyens. Ceux-ci incluent un environnement plus agréable, sain et confortable dans lequel vivre, travailler et jouer; des économies dans les coûts de fourniture d'une large gamme de services urbains; et des améliorations substantielles de la qualité de vie individuelle et communautaire. Ces bénéfices et coûts sont analysés en débutant avec l'influence des arbres et des forêts urbaines sur l'environnement physique et biologique et se poursuit avec l'importance socio-économique des arbres urbains et la multitude d'environnements qu'ils créent pour les individus et les communautés..

Zusammenfassung. Stadtbäume und Stadtwälder sind wichtige und wertbestimmende Komponenten der städtischen Umwelt und können zahlreiche Wohlfahrtswirkungen für die Stadt haben. Diese beinhalten eine schönere, gesündere und komfortablere Umwelt zum Leben, Arbeiten und Spielen, Kostenersparnis auf vielen Gebieten städtischer Dienstleistungen und substantielle Verbesserung beim individuellen und gemeinschaftlichen Wohlbefinden. Diese Vorteile und Kosten werden diskutiert, angefangen mit dem Einfluß der Stadtbäume und Stadtwälder auf die physikalische und biologische Umwelt, und führen fort mit der sozioökonomischen Bedeutung der Stadtbäume und die Umgebung, die sie schaffen für den

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