THE ENVIRONMENTAL BENEFITS OF URBAN FORESTS

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Urban and community forests function to mitigate the environmental impacts of urbanization 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. The economic value of these environmental benefits exceeds 3 billion dollars a year and substantial additional value can be inferred for the less tangible benefits associated with wildlife and aesthetics. These benefits may be partially offset by problems vegetation can pose such as pollen production, hydrocarbon emissions, green waste disposal, water consumption, and displacement of native species by aggressive exotics. This paper outlines the need for research that urban forest managers can apply to maximize environmental benefits while minimizing costs.

BACKGROUND

An environmental benefit is a human good produced by an urban tree, or group of trees, in its interaction with the biophysical environment. Some benefits are tangible and can be ascribed an economic value, while others are intangible or very difficult to quantify. Environmental benefits vary over space and time because the urban environment is constantly changing. Some benefits occur in the present, while others occur primarily in the future. The functional effectiveness of urban vegetation is related to its structure (i.e., species composition, diversity, age, and location in the landscape). An ecosystem approach that links management actions with their effects on urban forest structure and function offers the best means to assess the complex relations between urban vegetation and the biophysical environment.

The following section of this paper summarizes what we know about urban forest environmental benefits. For each benefit category, we rate the return on research investment as low, moderate, or high in terms of potential for increased benefits to people.

Energy and Carbon Dioxide Conservation

Trees are economical energy conservation measures because they meet the need for energy services to heat and cool buildings at a lower cost than is needed to generate new energy supplies. 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 2 billion dollars in energy costs. 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. 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 most other fuel-saving measures.

Because of the potential impact of research in this area on national energy use and climate change, the rate of return on investment for future research is high. Some important issues future research might address follow:

1. Determine optimum tree selection and location around buildings in different climates to conserve energy and offset carbon dioxide emissions associated with heating and cooling the building.

2. Evaluate the cost-effectiveness of evapotranspirational cooling by trees that use water to lower air temperatures and save cooling energy.

3. Measure tree crown dimensions, density, foliation periods, and growth rates to better assess energy conservation potential.

4. Determine the extent to which increased canopy cover will reduce energy use at the neighborhood scale through shading, wind speed reduction, and cooling.

5. Quantify the rate at which urban forests remove and store carbon dioxide from the air, as well as quantify the hydrocarbon emission rates.

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 (0 to 400 meters) about 8% of the ozone and decreased the concentration around the leaves by 49%.

Urban ozone concentrations are increased by increases in ambient temperatures. One study found that the incidence of smoggy days increase 1% for each 1%C increase in temperature. 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 an urban tree can intercept from 40 to 400 pounds of particulates per year. Planting of 500,000 trees in Tucson was projected to reduce particulate emissions by 8,000 tons per year at an average annual avoided cost savings of 1.4 million dollars. Cleaner air will also result in reduced health care costs.

Research seeking an understanding of the relationship between urban forests and air quality will have a high return on investment because of the implication on human health, visual quality and the economic growth of cities. Specific issues to be addressed may include the following:

1. Measure the extent to which urban forests remove gaseous and particulate pollutants under different meteorological and growing conditions.

2. Determine optimal planting configurations for air quality improvement.

3. Identify tree species that most efficiently remove pollutants and their tolerance to polluted air.

4. Identify ways of reducing pollen production from popular species.

Urban Hydrology

Urban forests can play an important role in urban hydrological engineering 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%. Runoff reductions could be further enhanced by directing runoff to landscape plantings. Because trees can function like retention/detention basins, the value of this environmental benefit can be monetized. Planting of 500,000 trees in Tucson was projected to achieve an average annual avoided cost savings of about $70,000 through runoff reduction.

Water use by landscape vegetation is an important issue in arid and semi-arid regions, where water resources are increasingly scarce. Relatively little research has been done to measure consumptive use for various species or to quantify the effects of lush and xeric landscapes on water and energy use. Clearly, annual water costs can be twice as great as cooling energy savings from shade for high water use species such as mulberry. However, energy savings have the indirect effect of conserving water at power plants. In Tucson, 17% 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, research in urban hydrology will have a high return on investment. Potential research issues may include:

1. Measure rainfall interception rates and effects of stemflow on soil moisture for different tree species and types of landscapes.

2. Identify water conservation potential associated with on-site retention of rainfall and low-water-use species.

3. Measure consumptive water use, growth rates, and appearance for different species.

4. Evaluate the rate of evapotranspirational cooling provided by trees under different irrigation regimes, growing conditions, and planting configurations.

Noise Propagation

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. Noise reduction from plants 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.

Because previous research has documented effects of plantings on noise propagation for a range of situations the return on investment for future research is low. However, additional work is needed to translate existing data into useful design tools.

Ecological Benefits

The urban forest provides ecological benefits such as providing habitats for wildlife, conserving soil, and enhancing biodiversity. Although the value of these benefits is difficult to quantify, they are important to many urban dwellers and to the long term stability of urban ecosystems. Because of the growing environmental awareness and concern for quality of life in our cities, research on ecological benefits will provide a moderate return on investment. Potential research topics include the following:

1. Demonstrate techniques for successful restoration of riparian areas and degraded lands.

2. Evaluate measures for controlling the displacement of desirable native plant communities by invasive exotics.

3. Determine relations between vegetation structure and habitat suitability for desirable wildlife species.

4. Identify the impacts of urbanization on biodiversity and means for enhancing biodiversity through urban forest planning and management.

RATIONALE FOR NEW AND EXPANDED RESEARCH

Urban forests are a *living technology* that can substitute or complement traditional technologies used to maintain a healthy environment for urban dwellers. Additionally, trees provide aesthetic, psychological, spiritual, and economic benefits that other technologies do not provide. However, most policy makers, city officials, designers, and the general public are unaware of the potential environmental benefits associated with properly designed and managed landscapes. Adequate maintenance of the existing urban forest resource on public lands is frequently compromised due to insufficient budget allocations. The urban forest is viewed as a dispensable amenity, rather than a critical component of the urban infrastructure. A primary benefit of new and expanded research will be to demonstrate how the urban forest functions as an environmental control technology. Future research that quantifies the extent to which urban forests provide environmental benefits in a more cost-effective manner than traditional controls will help justify the support needed to properly plan and manage the resource.

POSSIBLE OBJECTIONS

Some may regard research on environmental benefits associated with urban forests as unnecessary because much work has already been done. In fact, we know relatively little about the structure and function of urban forests compared to nonurban forests. There is a paucity of information on the most basic aspects of urban forest ecology such as dominant species, leaf areas, and growth, mortality, planting, and interception rates. Furthermore, we lack the knowledge needed to link the implications of specific management actions with resulting environmental benefits. For instance, we know that daytime summer temperatures in a well-treed neighborhood may be 2–4C cooler than in a nearby untreed neighborhood, but we do not know what effect a 10% increase in tree canopy cover will have in either case. Observational research in urban environments is considerably more difficult and expensive than in most nonurban settings, but it is essential to the development and calibration of physically-based models that can be used by managers to maximize the long-term environmental benefits urban forests can provide.

SUMMARY

Urban and community forests can provide a myriad of environmental benefits that are important to quality of life for Americans. Because investments in the planting and care of trees represent a long-term commitment of scarce dollars, and improper plantings can reduce net benefits, it is important to do it right. New and expanded research is needed to provide urban forest design and management tools that will help to maximize the return on investment for all individuals who invest in trees. To sustain a desirable flow of environmental benefits while controlling costs will require a long term urban forest research program with resources well in excess of those in place at present.

SUGGESTED ACTION

We propose the establishment of regional centers for urban forestry research. Regional centers could address environmental issues of regional importance and conduct research that responds to the dominant tree species, climates, soils, cultural values, and political context of specific regions. A national research advisory committee composed of representatives from the green industry, funding agencies, citizens groups, and other related organizations could provide oversight and coordinate the activities of the regional centers. Similarly, regional advisory committees could identify locally important research areas and assist with technology transfer. We envision each regional center as a loosely formed confederation of scientists and technology transfer specialists from local universities and federal agencies who work in close collaboration with local professionals and citizen groups. Such a structure would make it possible to undertake long term projects, such as shade tree evaluation, as well as conduct short term studies that address issues of current importance.