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Reducing Air Pollution through Urban Forestry

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Abstract

This paper presents a brief review of ways that urban forests positively and negatively impact air quality. It provides an overview of our research on air quality effects from parking lot shade and guidelines to estimate atmospheric carbon dioxide reductions through urban forestry.

Introduction

California's urban forests provide habitat for over 90% of the state's population and their impact on human and environmental health is a significant concern. Because urban forests contain a diverse mix of tree species (over 200 species in most cities) arranged in sometimes heterogenous patterns it is difficult to precisely characterize their impact on air quality. Uncertainty related to urban climatology and atmospheric processes further complicate determination of net effects.

Urban forests have a positive impact on air quality through deposition of pollutants to the vegetation canopy, sequestration of atmospheric CO_2 in woody biomass, and reduction of summertime air temperatures. Air temperature reductions affect air quality by 1) changing chemical reaction rates in the atmosphere that result in ozone formation, 2) decreasing temperature-dependent emissions of hydrocarbons from biogenic and anthropogenic sources, 3) decreasing emissions of pollutants from electric power plants due to reduced air conditioning demands, and 3) changing the depth of the mixing layer. City trees can have a negative impact on air quality by 1) reducing the dispersion of pollutants within the urban canopy layer, 2) emitting biogenic volatile organic compounds (BVOCs) that are involved in ozone formation, and 3) indirectly increasing emissions of pollutants associated with tree care activities (e.g., chain saws, chippers, trucks, and decomposition).

The net effect of urban forests on air quality has not been fully determined, and results from modeling studies reflect local differences in climate, air pollutant concentrations, and urban forest structure. Assuming 1990 air pollutant concentrations, our model simulations estimated that approximately 1,457 metric tons of air pollutants are absorbed annually by Sacramento County's 6 million trees, at an implied value of $28.7 million (Scott et al. 1998). Pollutant uptake rates decreased with decreasing tree canopy cover along an urban-to-rural gradient. This study did not include effects from air temperature decrease or BVOC emissions. A study of a hypothetical shade tree planting in Sacramento that included costs associated with BVOC emissions found that benefit-cost ratios ranged from 2.2:1 to -0.8:1 depending on assumptions regarding rates of pollutant deposition and BVOC emissions (McPherson et al. 1998). Another study found increased ozone concentrations resulting from increased planting of tree species in Los Angeles that are medium- and high-emitters of BVOCs (Taha 1996).

Urban foresters are interested in quantifying net impacts because credits for criteria pollutants (NO_2, SO_2, PM_{10}) are actively traded in California, and trading in greenhouse gas (GHG) emission offset credits are likely to follow. For example, net benefits from municipal street and park trees could be traded to an industry needing pollution offset credits and payments for these credits could help fund urban forestry management activities. This would allow emitters with expensive reduction options (e.g., industry) to offset their emissions by financing lower cost reductions possible from urban tree programs. The purpose of this paper is to present preliminary results of ongoing research to evaluate the net cost of reducing air pollution through urban forestry. Two areas of study are discussed: tree shade in parking lots and atmospheric CO_2 reductions.

Can Parking Lot Trees Improve Air Quality?

Ozone is a serious air pollution problem in most large U.S. cities. In the Sacramento County metropolitan area, motor vehicles are a major source of ozone precursors, contributing approximately 59 tons per day (tpd)(68% of total) nitrogen oxides (NO_x) and 59 tpd (49% of total) anthropogenic hydrocarbon (HC) emissions.

While the bulk of HC emissions are from tailpipe exhaust, approximately 9.7 tpd (16%) are from evaporative emissions that occur during daytime heating of fuel delivery systems of **parked vehicles**. Evaporative emissions, as well as exhaust emissions during the first few minutes of engine operation (primarily NO_x), are sensitive to local microclimate.

Many municipalities in California have parking lot shade tree ordinances that require 50% tree canopy over paved areas within 15 years of construction. Although the original impetus for these ordinances was energy conservation and aesthetic amenity, parking lot trees can provide important air quality and stormwater runoff reduction benefits. In the pilot study described here, we posit a relationship between tree cover, parking lot microclimate and vehicle emissions (McPherson et al. 1999, Scott et al. 1999).

Experiment Overview

Microclimate measurements were taken to quantify the moderating influence of tree canopy on parking lot microclimate via shading and evaporative cooling from leaves. These estimates were used to calculate potential temperature-dependent emissions reductions from parked vehicles using the California Air Resources Board MVEI7G model.

Measurements

Two automated weather stations and instrumented passenger cars were located in unshaded and shaded portions of a parking lot in Davis, CA for a week in August 1997. Air temperature, solar and net radiation, wind speed and direction, and vehicle cabin and fuel tank temperatures were measured. Shaded surface area was approximately 30%, and canopy density was sparse and variable due to leaf drop.

Peak daytime air temperatures at the shaded parking lot averaged 1 to 2°C cooler than the unshaded site. Temperature differences here are considered conservative due to the relatively sparse tree cover. *Fuel tank temperatures of the shaded car were 2 to 4°C cooler than fuel tank temperatures of the unshaded car.* Larger temperature differences between fuel tanks of shaded and unshaded cars, compared to air temperature differences between shaded and unshaded lots, indicate that direct shading of the vehicle influenced fuel tank temperature (hence HC evaporation rates) as much as, or more than, the aggregate effect of trees on air temperature. *Average vehicle cabin temperature was 26C cooler in the shaded vehicle for the period 1300 to 1600 PST.*

Emissions Modeling

Observed air temperature regimes at the Davis parking lot were used to design "base case" and "treatment" cases for hypothetical changes in parking lot tree canopy. These temperature regimes were used as input to the MVEI7G model to simulate vehicle emissions in Sacramento County. ROG emissions (reactive organic gases) were reduced by 2% (0.85 tpd) for an increase in canopy cover from 8% to 50%. NO_x emissions from cooler engine starts were reduced by 0.1 tpd (0.2%).

Though modest, projected ROG reductions were equivalent to projected hydrocarbon emission reductions for existing Sacramento Metropolitan Air Quality Management District control measures for graphic arts, ethylene oxide sterilizers, alternative fuel stations and waste burning (totaling 0.89 tpd). Projected NO_x emission reductions were equivalent to reductions projected from the district's light-duty vehicle scrappage program (0.1 tpd).

What's Next?

Parking lots occupy about 30 percent of the land in the core area of our cities. They are often significant sources of heat, water pollutants, and visual blight. Mitigating these pollutant "hot-spots" with tree shade is a Cool Communities strategy. While many jurisdictions have implemented ordinances over the last 15 years that require shading of paved areas by trees, little has been done to assess their effectiveness. Consequently, we have begun research in Sacramento to investigate:

i. if requirements for parking lot shade are being met,
ii. how existing parking lot tree shade ordinances can be amended to increase their effectiveness,
iii. the potential to plant and manage trees and provide stormwater treatment for parking lot runoff as retrofit measures for existing lots, and
iv. the potential to reduce overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, and using pervious materials in spillover parking areas?

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

This Forest Service General Technical Report (McPherson and Simpson 1999) is a tool for utilities, urban foresters, arborists, municipalities, consultants, non-profit organizations and others to determine the effects of urban forests on atmospheric carbon dioxide (CO_2) reductions. It provides information that allows decision-makers to incorporate urban forestry into their efforts to protect our global climate. This information can be used to:

- report current or future CO_2 reductions through a standardized accounting process
- evaluate the cost-effectiveness of urban forestry programs with other CO_2 reduction measures
- compare benefits and costs of alternative urban forestry program designs
- produce educational materials that quantify potential CO_2 reduction benefits and provide guidelines on tree selection, placement, planting, and stewardship.

The report's four chapters and appendices provide basic information to calculate CO_2 reductions through urban forestry programs.

Chapter 1: Urban Forests and Climate Change

Chapter 1 presents readers with background information on global climate change and the role of urban forests as one strategy for reducing atmospheric CO_2 concentrations. The implication of global climate change on communities is described, and our current knowledge regarding urban forestry as a CO_2 reduction measure is reviewed.

Chapter 2: Program Design and Implementation

Chapter 2 provides information on the design and implementation of urban forestry programs specifically aimed at reducing atmospheric CO_2. We share lessons learned from previous programs that have succeeded and failed, as well as general guidelines for selecting and locating trees to maximize energy and CO_2 reduction benefits. Current information on tree planting and stewardship techniques is presented as well as sources of technical assistance.

Chapter 3: General Information about These Guidelines for Calculating CO_2 Reductions from Urban Forestry Programs

Chapter 3 presents a general description of methods and assumptions for calculating CO_2 reductions from urban forestry programs. The objectives are to describe (1) the data collection and calculation process, (2) what data are required and how they can be obtained, and (3) certain key modeling assumptions.

Chapter 4. Illustrative Examples

Chapter 4 provides case studies of how to apply these guidelines. In one example, estimates of future CO_2 reductions for a proposed utility-sponsored program are described. The second example reports future reductions from an existing planting in a residential neighborhood.

Appendices

The Appendices contain information to reference while applying the guidelines. They also contain more detailed information on techniques used to develop the guidelines.

Conclusion

The quality of the air we breathe is of concern to many Californians. City trees have been historically regarded as amenities that make communities more attractive. Research described here is helping decision-makers and the public better understand how urban forests can positively and adversely impact air quality. This information is being used to plan and manage trees for air quality benefits.

References

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