13.7 EFFECTS OF URBAN TREES ON REGIONAL ENERGY USE AND AVOIDED CARBON

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1. INTRODUCTION

Urban forests can reduce atmospheric carbon dioxide in two ways. As long as trees are actively growing, their rate of CO_2 uptake through photosynthesis is greater than CO_2 release through respiration, resulting in net storage of carbon as biomass (referred to as sequestered CO_2 on an annual basis), hence net reduction of CO_2 in the atmosphere. Secondly, trees around buildings, through their moderating influence on solar gain, wind speed, and air temperature, can reduce demand for heating and air conditioning. This reduces associated emissions from fossil fuels associated with heating and production of electric power, primarily for cooling, referred to as avoided CO_2.

On the other hand, CO_2 is released by vehicles, chain saws, chippers, and other equipment during the process of planting and maintaining trees. Eventually, all trees die, and most of the CO_2 that has accumulated in their woody biomass is released into the atmosphere through decomposition. Nonetheless, an urban forest can become an important storage site for carbon through tree planting and stewardship that increases canopy cover, as well as through strategic planting that cools urban heat islands and saves energy used for space heating and air conditioning.

A number of factors suggest important regional differences in potential CO_2 reduction. Foremost among these is climate, which plays an important role in determining the magnitude of both sequestered and avoided CO_2. Regional climate differences influence tree growth rates, which are directly proportional to sequestration rates, and mature size. Similarly, avoided energy use is directly related to tree size and growth rate. Climate also determines relative importance of heating and cooling, which is particularly important since trees can increase as well as decrease heating loads. Other regional factors which may play a role are building construction practices (which are also influenced by climate), and fuel types used for space conditioning. Fuel type is important since it determines emissions per unit of energy produced.

2. OBJECTIVES

The purpose of this paper is to quantify the effects of regional differences in climate, trees, housing construction and fuel mix on space conditioning energy use and avoided CO_2, and demonstrate some practical applications of the results for selecting and locating urban trees. With the goal of maximizing avoided carbon for each region, areas considered are:

What are optimum tree placements, and which should be avoided?
Which circumstances favor deciduous over evergreen trees?
What generalizations can be made about tree selection and placement for heating-dominated versus cooling-dominated regions?
What is the effect of different fuel types on atmospheric CO_2 reductions?

3. METHODS

An overview of the methods are treated here; details are given by McPherson and Simpson (1999).

3.1 *Avoided CO_2*

Energy used for cooling is reduced in summer by tree shade. Although use of heating energy in winter can be increased because of reduced solar gain caused by tree shade, sheltering of buildings by nearby trees tends to reduce heating energy use. In addition to localized shade and wind speed reductions, lowered air temperatures and wind speeds from increased regional tree produce a net decrease in demand for cooling (reduced wind speeds by themselves may increase or decrease cooling demand, depending on the circumstances). In winter, reduced wind speeds decrease heating requirements

A series of computer simulations were done for 11 climate regions in the United States to estimate the regional effects of these factors on avoided CO_2. Simulations accounted for regional differences in utility, building, site, tree, and program characteristics. Carbon dioxide emissions avoided due to these energy savings are calculated using region-specific emission factors for electricity, and appropriate emissions factors for natural gas and other heating fuels. Results are computed over a 40 year time span to account for the change of tree size with age.

3.2 *Sequestered CO_2*

Tree growth rates and size influence the stream of benefits from CO_2 sequestration and energy savings, as well as CO_2 release rates due to tree maintenance and decomposition. Large, fast-growing trees provide greater benefits sooner than small, slow-growing trees. Tree growth rates in urban landscapes are highly variable, reflecting differences among species, growing conditions, and level of care. Relatively few studies have quantified growth rates of urban trees in different regions of the United States. Given this lack of data on urban tree growth we identify three Tree Growth Zones (North, Central, and South) based on mean length of the frost-free period, and assign one to each climate region based

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on geographic and demographic similarities. Tree growth curves were estimates for each zone based on limited data available in the literature.

4. RESULTS

Total avoided and sequestered CO_2 over the 40 year time span of the analysis result. Avoided emissions are further broken down to compare heating versus cooling, and net changes due to shade compared to those from lowered air temperatures and wind speed (climate).

Projected CO_2 savings (positive) and releases (negative) for 300 trees planted in Tucson, Arizona (Figure 1) illustrate the change in benefits with time in one climate region. Values are plotted are for 5-year periods. Heating impacts both from shade and climate were near zero. Effects of shading and climate were approximately equivalent. Air temperature reduction was estimated to be 1 °C for each 10 percent increase in canopy cover, and canopy cover was estimated to increase by 34% over 40 years. The relatively high tree survival used (67 percent after 40 years) contributes to the steady increase in benefits over time, and the relatively low level of total releases.

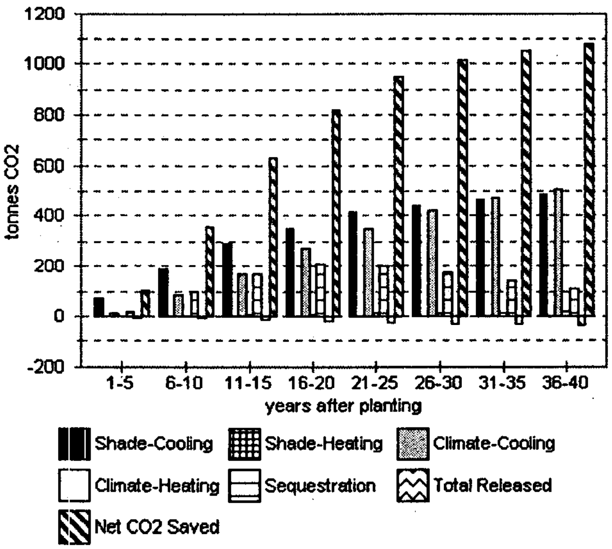

Figure 1. Projected CO_2 impacts for Tucson, Arizona

Large differences in climate aren't necessary to achieve a much different result. For example, consider the effect of planting 10,000 trees in Boulder City, Nevada, population 14,000, located 32 km south of Las Vegas (Figure 2). In this example, a moderate survival rate (49% after 40 years) results in reduced benefits in later years and releases large in relation to the previous example. Sequestration is a much larger component of net CO_2 savings in Boulder City due to the much smaller electricity emissions factor there (0.754 t/MWh in Boulder City compared to 1.27 t/MWh in Tucson), and the avoided CO_2 forgone by locating 50 percent of trees far from buildings in Boulder City in parks and downtown streets. Over 95 percent of the trees in the Tucson example were positioned to shade residences.

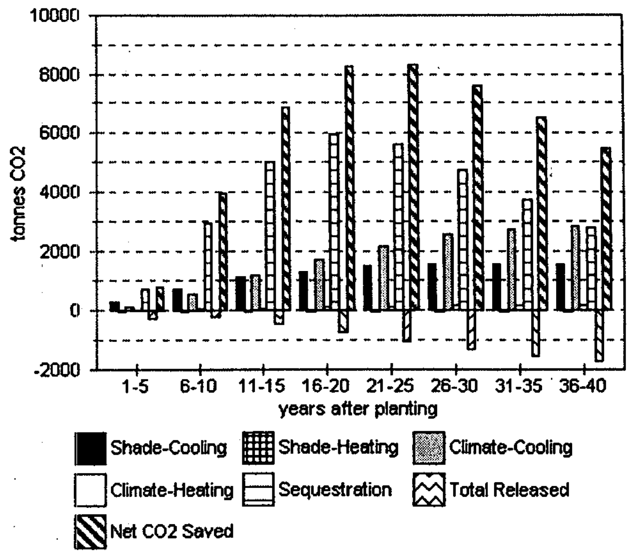

Figure 2. Projected CO_2 impacts for Boulder City, Nevada

Additional examples illustrating the effects of contrasting climate regimes will be presented. These results are approximate due to the limited nature of some input data and model components. Current information available in the literature indicates that predicted reductions are conservative. Until improved alternatives become available, these data will provide a widely applicable tool to aid in selection and placement of urban trees in different regions of the United States to maximize their energy and carbon reduction potential.

5. References

McPherson, E. G. J. R. Simpson, 1999: Carbon Dioxide Reduction Through Urban Forestry–Guidelines for Professional and Volunteer Tree Planters. Gen. Tech. Rep. PSW-GTR-171. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 237 p.