A Tool for Evaluating Carbon Reduction by Urban Forestry Programs

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Abstract: Electric utility companies are showing increased interest in urban forestry programs as a means of reducing the net amount of carbon dioxide resulting from their operation. This paper describes a study in which lookup tables are being developed as a planning tool to estimate carbon stored and avoided by urban trees in 11 climate regions for the United States.

Introduction

Increasing concentrations of greenhouse gases in the atmosphere has prompted electric utilities and other organizations to examine alternative actions to offset emissions associated with power generation. The 1992 Framework Convention on Climate Change challenged industrial countries to return greenhouse gases to 1990 levels by the year 2000.

In response, the U.S. Climate Change Action Plan outlined nearly 50 initiatives to cost effectively reduce emissions. The Climate Challenge, a partnership between the U.S. Department of Energy (DOE) and electric utilities, is one initiative to voluntarily reduce greenhouse gases to 1990 levels. It builds upon an innovative government/industry partnership authorized under Section 1605(b) of the Energy Policy Act of 1992, in which participants report historic emission baselines and submit periodic reports of actions taken to reduce emissions.

Under auspices of the Edison Electric Institute, the Utility Forest Carbon Management Program was established to share information concerning the potential effects of forestry activities. Urban forestry was recognized as one strategy for reducing emissions in the Section 1605(b) General Guidelines for Reporting of Greenhouse Gases.

Urban forestry can be a cost effective option to achieve substantial greenhouse gas reduction in addition to other social, economic, and ecological benefits. The paper describes an analysis tool that utilities and other organizations can use to evaluate and report carbon emissions avoided and sequestered by urban forestry programs. The result combines regional default data from look-up tables with user supplied data to compute net CO_2 reduction from these programs.

Uses include 1) projecting future CO_2 reductions from proposed programs, 2) reporting CO_2 reductions from existing programs, and 3) design of cost effective urban forestry programs. Development and application of this tool is demonstrated here using the Sacramento Shade program as an example. Sacramento Shade is a partnership between the Sacramento Municipal Utility District (SMUD) and the Sacramento Tree Foundation (STF).

The program's goal is to plant 500,000 shade trees by the year 2000, and thus far over 250,000 trees have been planted. The program has produced a considerable database of information regarding structure and function of Sacramento's urban forest (e.g. Hildebrandt, 1996; Joanna Julien, personal communication).

Methods

Quantifying net CO_2 reduction from an urban forestry program is a three step process. The user first enters input data using regional defaults or locally specified values of utility, building, site, tree and program delivery information. Second, regional data on CO_2 impacts (e.g. lbs CO_2 per tree or per building) are combined with the input data to estimate annual impacts for mature trees. Finally, mature results are adjusted to account for tree growth and mortality and to calculate net CO_2 reduction every 5 years. A 40 year planning horizon is used. Benefits accounted for are carbon sequestration in tree biomass and CO_2 emissions avoided due to reduced space conditioning demand fostered by trees. CO_2 released through decomposition of dead trees, maintenance, nursery, and other program activities are included.

Avoided CO_2

Space conditioning energy use is reduced in summer by tree shade (direct effect). In addition, lowered air temperatures and wind speeds from increased regional tree cover (indirect effects) produce a net decrease in cooling demand (reduced wind speeds by themselves tend to increase cooling demand). In winter, reduced wind speeds decrease heating requirements, while shading has the opposite effect. A combination of extensive energy analysis computer simulations and results taken from the literature are used to quantify these effects for 11 climatic regions of the United States, accounting for regional differences in utility, building, site, tree, and program characteristics. Carbon dioxide emissions avoided due to these energy savings are calculated using utility-specific emission factors. Energy savings attributed to shading and climatic amelioration can be accounted for separately or added together using the "Direct Shade" and "Indirect Effects" tables.

Trees must be enumerated by 3 size classes (small, medium, large), 5 direction classes (E, SE/S/SW, W, NE/NW, and N/no shade), and 3 building vintages (dates of construction) by the user. Much of the remaining data are assigned regional values. This includes relationships between tree age, height, crown spread, and trunk diameter at breast height (DBH), which are based on limited tree measurements and geometric sine functions. Default or user supplied values can be used for utility emission factors, building heating and cooling equipment saturations, efficiencies, conditioned floor area, and typical energy use by vintage. Adjustments for magnitude of indirect air temperature and wind effects, as well as for shade cast on adjacent buildings by program trees, are optional.

Sequestration

Carbon sequestration rates (expressed as equivalent mass of CO_2/tree/year) are determined from biomass equations based on tree dimensional relationships (stem diameter, tree height, crown spread), growth rates, and species commonly planted in each region. For Sacramento, biomass equations were selected from a number of sources and evaluated for accuracy in predicting dry weights for several tree species for which actual weights were known. Volume equations from Pillsbury and Thompson (1995) for Chinese elm (*Ulmus parvifolia*) were selected as the best predictor of biomass for deciduous trees in Sacramento. Whole tree biomass is assumed to be 50% carbon, which is converted to CO_2 by multiplying by 3.667 (molecular weight of CO_2/molecular weight of C). Sequestration rate is determined as difference in CO_2 storage between current and previous year for each tree size.

Decomposition

It is conservatively assumed that dead trees are removed and mulched in the year that death occurs, and that 80% of the carbon is volatilized as CO_2 in the same year. Total annual decomposition is based on the number of trees of each size class that die in a given year combined with calculated biomass for those trees. The user can select from a menu of mortality rates or enter custom values.

Maintenance

City arborists, private tree service providers and the literature were used to estimate work and equipment operation time as a function of tree DBH and height; e.g. more maintenance was required for larger trees. Equipment running time was converted to CO_2 emissions with estimates of vehicular and maintenance equipment (chain saws, chippers, equipment trucks) fuel consumption.

Nursery and Program

CO_2 emissions result from nursery operations and program administration, including office space electricity and natural gas use, vehicle use and tree production area energy use. Energy consumption (kWh, MBtu or gallons) estimated by one of three optional methods is converted to pounds of CO_2 released.

Sacramento Demonstration

The tool was used to estimate net effects on carbon emissions for a 40 year analysis period from the 188,000 trees planted during 1991-95 by Sacramento Shade. Tree mortality after 40 years was estimated to be 48, 38 and 42% for small, medium and large trees, respectively, based on initial survival (first 5 years) and 0.5% mortality/year thereafter. Projected net CO_2 savings were 350,000 tons. Savings from sequestration were 60% of the net benefit (210,000 tons), with the remainder (180,000 tons) a result of avoided energy use (Figure 1). Releases were small, equivalent to 11% of the net benefit (40,000 tons). Cost of conserved carbon, defined as program costs ($9 million for years 1991-1995) divided by net CO_2 savings over the 40 year analysis period (350,000 tons), is $26/ton CO_2. Net CO_2 impacts increase for the first 25 years before starting to slowly decline, largely in response to reduced sequestration rates as trees mature (Figure 1).

These results are strongly influenced by SMUD's low utility emissions factor (880 lbs CO_2/MWh), a result of hydroelectric generation being a principal fuel source. Net CO_2 savings for Sacramento would approximately double if the national average emissions factor was applied (2900 lbs CO_2/MWh, Huang et al. 1990). Also, this would reduce the ratio of direct heating penalty to cooling savings from about 80% to 25%, and reduce cost of conserved carbon to $11/ton CO_2. This cost compares favorably to $12/ ton calculated for rural forest management (McPherson 1994).

Conclusions

The lookup tables and supporting technical documentation for this carbon estimation tool are scheduled to be published as a Forest Service General Technical Report in the summer of 1998.

References

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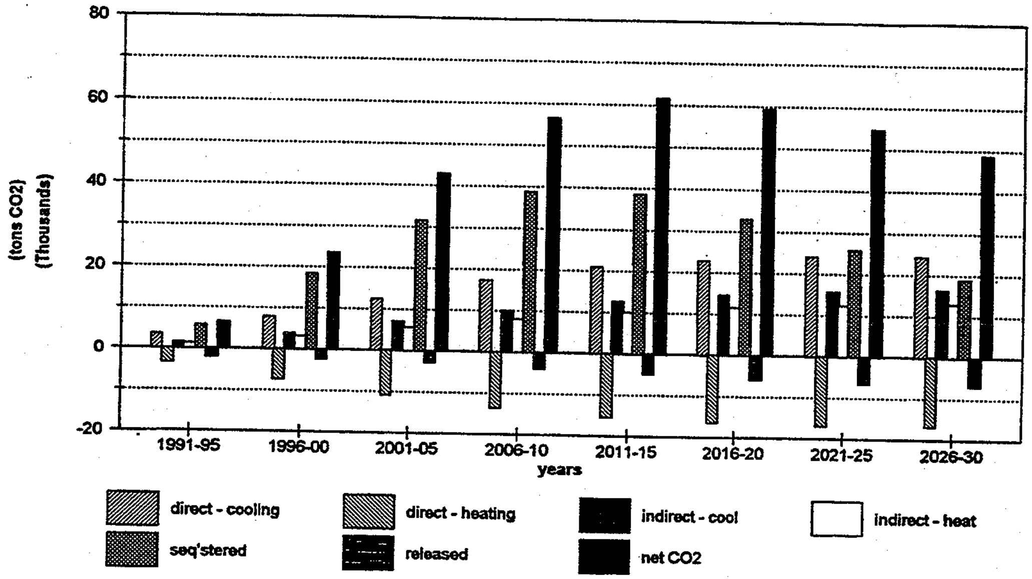

Figure 1. Projected impacts of 1991-1995 Sacramento Shade tree planting on CO_2 emissions.