Ecological Economics 95 (2013) 1–10

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

The marginal cost of carbon abatement from planting street trees in New York City

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ARTICLE INFO

Article history:
Received 20 December 2012
Received in revised form 8 August 2013
Accepted 11 August 2013
Available online 5 September 2013

Keywords:
Cost-effectiveness
Carbon
Street trees
New York City

ABSTRACT

Urban trees can store carbon through the growth process and reduce fossil fuel use by lowering cooling and heating energy consumption of buildings through the process of transpiration, shading, and the blocking of wind. However, the planting and maintenance of urban trees come at a cost. We estimate the discounted cost of net carbon reductions associated with planting and caring for street trees in New York City (NYC) over 50- and 100-year horizons. Depending on the species planted, the cost of reducing carbon, averaged across planting locations, ranges from \$3133 to \$8888 per tonne carbon (tC), which is higher than current cost estimates of forest-based carbon sequestration. The London plane tree is the most cost-effective species because of its long life span and large canopy, and the marginal cost of carbon reduction for the species ranges from \$1553 to \$7396/tC across planting locations. The boroughs of Staten Island and Queens have planting locations with the lowest average costs of carbon reduction (\$2657/tC and \$2755/tC, respectively), resulting from greater reductions in energy consumption in nearby buildings, which have fewer stories and more residential use than buildings in the other boroughs.

1. Introduction

The concern about global climate change has led many U.S. cities to adopt local policies and programs to reduce greenhouse gases (GHGs) in the atmosphere. As of 2012, 1054 mayors across 50 states have signed the U.S. Conference of Mayors' Climate Protection Agreement (Mayors Climate Protection Center, 2012), and New York City has pledged to reduce GHG emission by 30% from 2005 levels by 2030 (City of New York, 2013). Under the agreement, cities vow to reduce carbon emissions below 1990 levels through programs that improve urban transit, reduce non-renewable energy consumption, restore urban forests, and many others. Restoring urban forests is a promising way to offset carbon emissions because the carbon storage attributed to U.S. cities is estimated at 10% of the total land carbon storage in the U.S., where more than half of this urban carbon storage is attributed to soils, 20% to vegetation, 11% to landfills, and 5% to buildings (Churkina et al., 2010). The carbon density of human settlements is high because carbon is stored not only in vegetation and soils, but also in buildings, furniture, printed materials, landfills, and people. Trees are more than 95% of the urban vegetation carbon pool (Davies et al., 2011).

Urban forests reduce GHGs in the atmosphere by capturing carbon as they grow (carbon sequestration). Total tree carbon storage in U.S. urban areas circa 2005 is estimated at 643 million tonnes of carbon (tC), about 3.2% of the estimated carbon stored in U.S. forestland and urban forest trees combined (Nowak et al., 2013). Annual carbon sequestration in U.S. urban forests is estimated at 25.6 million tC/year (Nowak et al., 2013). Urban forests also reduce energy use in nearby buildings (Donovan and Butry, 2009) and thereby indirectly reduce GHGs emitted from fossil-fuel-based combustion (energy conservation). As an example of trees reducing energy use, urban trees in California are estimated in 2008 to reduce annual air conditioning energy use by 2.5%, suggesting a reduction in 1.1 million tC/year (McPherson, 2008; McPherson and Simpson, 2003). In New York City, energy conservation from street trees reduces fossil-fuel emissions by an estimated 0.069 million tC/year (Peper et al., 2007). Trees on residential lots can reduce fossil-fuel emissions from the heating and cooling of homes, but the cost to plant and maintain private trees could be higher and is not explored in this study. Park trees are farther away from buildings and have less influence on a building's energy use, but park trees are less costly to plant and maintain than street trees. The reforestation of parks to reduce carbon is also not explored here.

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http://dx.doi.org/10.1016/j.ecolecon.2013.08.012

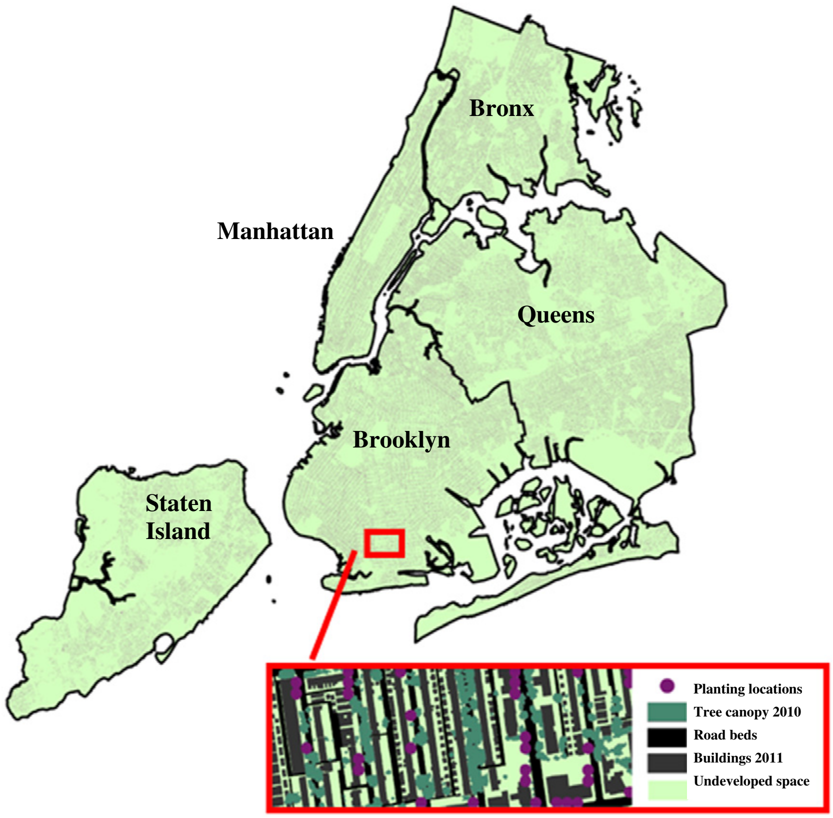

Fig. 1. Study area with street tree planting locations near buildings in 2011. Inset is a magnified section of the Homecrest neighborhood in Brooklyn with the planting locations, buildings, tree canopy, and road beds shown.

The carbon reductions from planting urban trees come at a cost in the form of expenditures for planting, pruning, and removal. We estimate the cost effectiveness of street tree planting for reducing carbon. The division of the discounted cost of tree care by the discounted tons of carbon abated from sequestration and energy reduction represents the cost effectiveness of a tree planting program. Only one study has been found that evaluates the cost effectiveness of urban tree planting to reduce atmospheric carbon (McHale et al., 2007). Street trees are more expensive to plant and maintain than park trees, but the proximity of street trees to buildings enables the trees to reduce building energy use.

Our measure of the cost-effectiveness of street tree planting focuses on carbon abatement and does not consider other services provided by street trees, such as reducing air and water pollution, increasing aesthetics, reducing crime, increasing property values, and mitigating heat-islands (Dwyer et al., 1992; Morani et al., 2011; Sander et al., 2010; Susca et al., 2011; Troy et al., 2012). Accounting for all of the tree services reveals the social gain of a forest (Feng and Kling, 2005; Plantinga and Wu, 2003), but the full suite of benefits may be secondary if the forestry program has the expressed purpose of reducing carbon (Lubowski et al., 2006). The aim of this paper is to estimate the carbon offset benefit of street trees, which may add to the attractiveness of urban forestry initiatives even if carbon abatement alone is not a cost effective strategy.

Our case study involves street tree planting in New York City (NYC). In recognition of the environmental, social, and economic benefits of urban trees, including the reduction of atmospheric carbon, NYC launched a program in April 2007 known as MillionTreesNYC, a city-wide, public–private initiative to plant and care for one million new trees across the city's five boroughs by 2017 (MillionTreesNYC, 2013). The Million TreeNYC initiative is in its fifth year, and more than 750,000 trees have already been planted (MillionTreesNYC, 2013). One of the most visible components of MillionTreesNYC is its commitment to street tree planting: 220,000 new street trees will be planted to bolster the 600,000 street trees that existed prior to the initiative.

In our study, we first identify public, street, planting locations near buildings in each of the five boroughs of NYC (Fig. 1). Next, we simulate the net carbon benefits and management costs over 50-year and 100-year planning horizons for four representative tree species in each location. Net carbon benefits include carbon sequestration and loss from tree growth and decay, avoided carbon emissions from energy savings, and carbon emissions from tree planting and maintenance (Nowak et al., 2002). Management costs include planting, pruning, and removal expenditures. Carbon benefits and management costs are discounted to the present to estimate the dollars per ton of carbon abated ($/tC). Finally, planting locations are ranked from lowest to highest $/tC to construct a marginal cost curve plotting cost ($/tC) versus cumulative carbon abated (tC/year) for additional tree planting.

2. Methods

2.1. Identifying Tree-planting Locations

The study area includes the five boroughs of NYC (Fig. 1). We identify potential tree-planting locations by dividing the study area into cells that are fifty feet square in size.[1] From this set, we restrict our analysis to cells on public land beside roads where the city can plant. Further, we restrict our analysis to cells that are within 100 ft of the nearest building, which is close enough to affect building energy use. We exclude planting locations on private land because the city cannot access these sites. We also exclude planting locations on public land that are further than 100 ft from buildings

[1] The borough boundaries are available in a geographic information system (GIS) at the NYC Data Mine http://www.nyc.gov/html/datamine/html/data/geographic.shtml.