Carbon Storage and Uptake by Street Trees in Seoul

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Abstract

This study quantified the carbon storage and uptake by street trees in Seoul and explored suitable planting and management strategies. A systematic sampling model was used to select 50 plots to survey the structures of street trees. The average density and cover of street trees were approximately 5.8 trees/100 m² and 12.1%, respectively. Trees with a dbh of less than 30 cm accounted for about 66.3% of the total number of trees surveyed. The total carbon storage and uptake by the street trees were approximately 103,641 t and 10,992 t/yr, respectively. The total carbon uptake equaled the amount of annual carbon emissions from driving of about 11,000 cars. Street tree planting and management strategies were proposed to enhance carbon uptake. They included multi-layered and multi-aged planting, securing ground and space for plant growth, and avoiding excessive tree pruning.

Key Words: species, tree density, tree size, planting, management

Introduction

The growing awareness about the need for carbon reduction has evoked interest in the effect of planting trees on the urban environment. Planting and management of street trees are becoming increasingly important due to their carbon absorption ability and various other benefits. Studies on carbon reduction by trees in the urban environment have been carried out globally (Jo 1999; Nowak and Crane 2002; Nowak et al. 2013; Russo et al. 2015; Gratani et al. 2016; McGovern and Pasher 2016). However, information is limited on carbon reduction effects of street trees. The purpose of this study was to quantify the carbon storage and uptake by street trees in Seoul, Korea and to suggest suitable planting and management strategies. In this study, carbon storage refers to the total amount of carbon accumulated by the trees over growth years, while carbon uptake refers to the amount of carbon sequestered by the trees in one year.

Materials and Methods

Sampling and field survey

To survey the structures of street trees, stratified sampling method was used to extract 50 plots from aerial photographs with a scale 1:1,000 (Fig. 1). Eight straight lines radiating from the center of the study city were drawn in eight different directions. Subsequently, circles were drawn 40 cm apart. The points at which the circles and lines coincided were subject to sample extraction. One-lane roads or streets with no sidewalks were excluded from this study. The number of samples was determined based on whether the sam-
Fig. 1. Depiction of the systematic sampling method used in this study.

The sample points were visited, and a survey plot for each point was established up to 40 m for each side in length from the point (total: 80 m) and up to architectural boundaries of both sidewalks in width. Field survey data included species, stem diameter, height, crown width, and density of street trees. Stem diameter was measured at a breast height of 1.2 m (dbh) for trees and at 15 cm above ground for shrubs (2 cm or less in dbh). These data were used to estimate the carbon storage and uptake per unit area.

Estimation of carbon storage and uptake

The carbon storage and uptake by each tree species were estimated using quantitative models for carbon storage and uptake per tree. The quantitative models, which apply the stem diameter as an independent variable, were derived from the annual measurement of CO2 exchange rates or a direct harvest method (Jo and Cho 1998; Jo 1999; Jo and Ahn 2001; Jo and Ahn 2012; Jo et al. 2013; Jo et al. 2014). The tree density was applied to determine the carbon storage and uptake per unit area. Subsequently, total carbon storage and uptake by street trees were computed using total street area in the study city.

Results and Discussion

Distribution of street trees

The average density and cover of street trees and shrubs were approximately 5.8 trees/100 m² and 12.1%, respectively. Trees with dbh of less than 30 cm accounted for approximately 66.3% of the total number of trees surveyed (15.8% for less than 10 cm, 14.9% for 10-20 cm, and 35.6% for 20-30 cm). The total number of species was 34, which suggests significant species diversity. The dominant tree and shrub species (based on importance values) planted as street trees were Ginkgo biloba (25.0%), Platanus occidentalis (17.8%), Buxus microphylla var. koreana (7.8%), Pinus densiflora (6.4%), Zelkova serrata (5.8%), and Chionanthus retusa (4.9%). Street tree cover and density in the study city were 1.4-2.8 times higher than those in Chuncheon (Jo et al. 2017).

Carbon storage and uptake

Carbon storage and uptake per unit area by street trees were approximately 13.2 t/ha and 1.4 t/ha/yr, respectively (Table 1). Total carbon storage and uptake of the entire street area were about 103,641 t and 10,992 t/yr, respectively. The carbon storage per unit area in the study city was 52% of that (25.1 t/ha) by urban trees in the United States (Nowak and Crane 2002). This difference appears to be due to lower planting density, smaller tree sizes, and poorer growth conditions in the study city. Carbon uptake per street tree averaged approximately 16 kg/yr (mean dbh: 26 cm).
Table 1. Carbon storage and uptake by street trees in Seoul

<table>
<thead>
<tr>
<th>Carbon</th>
<th>Per unit area (ha)</th>
<th>Total area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage (t)</td>
<td>13.19±1.66</td>
<td>103,641</td>
</tr>
<tr>
<td>Uptake (t/yr)</td>
<td>1.36±0.36</td>
<td>10,992</td>
</tr>
</tbody>
</table>

Annual carbon emissions from gasoline consumption per car were about 1 t/yr in Korea (KEA 2017). The total carbon uptake by street trees in the study city equaled the amount of carbon annually emitted by driving of approximately 11,000 cars. Thus, street trees played a significant role in reducing atmospheric carbon levels in urban environments with limited greenspace.

Planting and management

The structures of street trees in the study city were characterized by single-layered and single-aged planting. Single-layered planting accounted for about 73% of all the survey plots. Majority of the trees were in the young and growing stages. These structures should be replaced by multi-layered and multi-aged planting to improve carbon storage and uptake per unit area. Available growing spaces were limited due to aboveground utility lines, street furniture, and impervious pavement. It is essential to maintain productive growth of the trees to enhance performance of carbon reduction. A desirable space for normal crown and root growth must be supplied through relocation of the utility lines and reduction of unnecessary pavement. Severe tree pruning to protect the utility lines was found at approximately 58% of all the survey plots. This excessive pruning should be avoided not to hinder normal tree growth. This study is expected to contribute to globally sharing the role and importance of urban street trees in reducing atmospheric carbon levels.

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References