A Study of Carbon Storage in Beijing's Parkland Based on Biomass Method--Take Changyang Park as an Example

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Abstract. Greenhouse gas emissions are particularly severe in cities. Urban plant carbon sinks are currently one of the main means of indirectly achieving carbon neutrality. Based on the perspective of urban park green space, this paper analyzes the structure and types of trees and shrubs in Changyang Park, Fangshan District, Beijing, and then calculates their carbon storage capacity by biomass method, and analyzes the tree species with strong and economic carbon sink capacity to provide some practical data and theoretical reference for the construction of suburban parks of the same type in Beijing, and to provide a scientific basis for the selection of landscape carbon sequestration in urban green space. It also provides a scientific basis for the selection and community configuration of the tree species in urban green areas, which can reduce the CO₂ concentration in the atmosphere, alleviate the urban heat island effect and improve the ecological environment.

1. Background

Currently, human society is facing many environmental problems, and global warming is one of the most concerning environmental problems among many environmental factors. As we all know, the most important factor causing global warming is the large amount of CO₂ emitted by human activities. Moreover, the content of carbon dioxide in the air is still rising. As China's rapid economic development, resource consumption is increasing and carbon emissions are increasing, a series of environmental problems have aroused widespread concern in the society, and China, as a large carbon emitting country, should pay attention to the issue of energy saving and emission reduction, and develop a low-carbon economy[1].

With the progress of urbanization in China, the problem of urbanization has become more and more serious. How to solve the heat island effect of urban people, purify the air and reduce excessive urban carbon emissions is an important issue today. Urban vegetation has important ecological service functions. They include carbon sequestration, microclimate regulation, water conservation, biodiversity protection, social cohesion enhancement, and stress relief of residents' life. Urban vegetation is an important reservoir in the carbon cycle of urban ecosystems. Urban vegetation has higher heterogeneity than natural forests, and there are differences in growth environments. Urban vegetation is mostly at a young age and has higher carbon sequestration intensity than wild forests, and urban vegetation carbon sequestration contributes to offsetting CO₂ emissions in built-up areas. With the continuous increase of urbanization rate and the rapid expansion of built-up area, the relationship between urban vegetation and hot ecological issues such as carbon cycle has become closer. Urban vegetation can directly or indirectly reduce the carbon content of the atmosphere [2].
direct way is carbon sequestration by vegetation growth, and the indirect way is urban vegetation offsetting or replacing fossil fuel use. The indirect emission reductions from urban vegetation are likely to be greater than their own carbon sinks, with one tree saving one to three times more carbon per year in energy consumption than it absorbs on its own[3].

In this paper, from the perspective of urban park green space, we conducted a field survey of plants in Changyang Park, Beijing, and used the biomass method to calculate the biomass of plants in this park to derive the carbon stock of plants. This study provides some practical data and theoretical references for the construction of suburban parks of the same type in North China, and provides a scientific basis for the selection of landscape carbon sequestering tree species and their community configuration in urban green areas, thus achieving the purpose of reducing atmospheric CO₂ concentration, alleviating urban heat island effect and improving ecological environment.

2. Overview of Changyang Park
Changyang Park, located in Fangshan District, Beijing, is the park with the largest area, the most advantageous location, the most complete greening tree species and the most perfect infrastructure in Fangshan District. In the park, the combination of artificial landscape and ecological landscape has formed a colorful plant community, creating a rich botanical landscape in the city and providing a very ideal place for citizens to relax and play. The area of Changyang Park is 46.2 hectares as measured by satellite images. A total of 53,550 trees, 199,120 shrubs, 210,000 hostas and 105,700m² of lawn.

3. Technical route and methodology of the study

3.1 Technical routes

![Diagram of technical routes]

3.2 Research Methodology

3.2.1 Selection of sample plots in the park Based on the plant growth and tree species in the park, with Changyang Park as the boundary of the system, and considering the typicality and diversity of vegetation, six study areas with diverse tree species and dense distribution were selected as survey sample plots, and each sample plot was set up with a 20m×20m sample square. The distribution map
of the sample plots is shown in Figure 2, and the status map of the sample plots is shown in Figure 3.

![Sample plot distribution plan (source: author's own drawing)](image1)

![Sample plot status map (source: photo by author)](image2)

**Figure 2** Sample plot distribution plan (source: author's own drawing)

**Figure 3** Sample plot status map (source: photo by author)

3.2.2 Plant Community Survey and Biological Factor Measurements  From June to September 2021, the plants in the selected sample plots in Changyang Park were surveyed in the field, the species and number of tree species and their growth and development were recorded, and the ground diameter (diameter at 20cm above the ground) of shrubs and the diameter at breast height of trees at 1.3m in the sample plots were measured using a tape measure, and the TRUPULSE200 infrared altimeter was used to The height of each tree was measured and the height was recorded.

3.2.3 Calculation of tree and shrub biomass  Using the average standard sample wood method, tree biomass was measured by selecting different layers of tree species based on plant survey results and determining standard wood based on the range of existing specifications for different plants in the park, using the biomass expansion factor method, substituting the plant density and biomass expansion factor (IPCC parameter of BEF) determined by IPCC into the biomass formula, the The specific steps of the algorithm are.
(1) The wood volume of a tree is calculated [4] using the stem shape indicator, experimental row number \((f_\sigma)\), using the following formula.

\[
V = g_{1.3}(h + 3)f_\sigma
\]

Where:

- \(V\) - tree wood volume \((m^3)\)
- \(g_{1.3}\) - area at breast height of tree at 1.3 m \((m^2)\)
- \(h\) - tree height \((m)\)
- \(f_\sigma\) - number of experimental rows (dimensionless, mean 0.4)

(2) The above-ground biomass was calculated using the trunk bulk density and biomass expansion factor, and the below-ground biomass was calculated from the root-to-stem ratio of 0.26, the sum of which gave the total biomass of the above- and below-ground parts of the plant[5], calculated as follows.

\[
M = V \times D \times \text{BEF} \times (1 + R)
\]

Where:

- \(M\) - plant biomass \((t)\)
- \(V\) - tree timber volume \((m^3)\)
- \(\text{BEF}\) - plant biomass expansion factor, see Table 1 for details
- \(R\) - tree root to stem ratio (0.26)

| Tree species                      | Density \((t/m^3)\) | BEF  | Tree species                      | Density \((t/m^3)\) | BEF  |
|-----------------------------------|---------------------|------|-----------------------------------|---------------------|------|
| Metasequoia glyptostroboidea Ht. & W. C. Cheng | 0.278               | 1.49 | Pinus massoniana Lamb.            | 0.380               | 1.46 |
| fir Cunninghamia lanceolata (Lamb.) Hook. | 0.307               | 1.53 | Cinnamomum camphor (L.) Presl     | 0.460               | 1.42 |
| Quercus L.                        | 0.676               | 1.56 | Populus L.                        | 0.378               | 1.59 |
| hard class                        | 0.598               | 1.79 | soft class                        | 0.443               | 1.54 |
| mixed wood                        | 0.515               | 1.30 | dioecious                         | 0.515               | 1.75 |

The biomass of the average standard wood was used as the biomass of this species, and the biomass of multiple average standard woods in the type was averaged to obtain the average individual plant biomass of each type, which was used to measure the existing plant biomass in the park, and the total biomass \((M)\) of trees and shrubs in the park was calculated by combining the formulas in the first and second steps, as follows.

\[
M = \sum_{i=1}^{m} \sum_{j=1}^{n} \left( g_{ij.3}(h_{ij} + 3)f_\sigma \times D_{ij} \times \text{BEF}_{ij} \times (1 + R_{ij}) \times N_{ij} \right)
\]

where.

- \(g_{ij.3}\) - Area of broken breast height at 1.3 m for the jth plant of type i \((m^2)\)
- \(h_{ij}\) - The height of the jth plant of type i \((m)\)
- \(f_\sigma\) - Number of experimental rows (0.4)
- \(D_{ij}\) - density of the trunk of the jth plant of type i \((t/m^3)\)
- \(\text{BEF}_{ij}\) - The biomass expansion factor of the jth plant species of type i
- \(R_{ij}\) - Tree rootstock ratio (0.26)
\[ N_{ij} \] - Number of jth plant strain of type i
\( i \) - Major plant species
\( j \) - Number of major plant types

3.2.4 Calculation of plant carbon stock

The total biomass of the community can be derived by extrapolating the biomass of tree species in the tree layer and shrub layer of the community from the biomass of major tree species, and the plant carbon stock (C) can be calculated by multiplying the resulting plant biomass by the carbon content factor of 0.5 as follows.

\[ C = M \times 0.5 \]

4. Analysis of plant carbon stocks and plant communities in Changyang Park

4.1 Plant community analysis

| Table 2 Flora of Changyang Park Table |
|--------------------------------------|
| **level** | **Type of vegetation** | **ecological community** |
| upper class | evergreen tree | Pinus tabuliformis Carr., Pinus bungeana Zucc., Cedrus deodara (Roxb.) G. Don, etc.; Juglans regia L., Platanus × acerifolia, Salix matsudana Koehne, Populus × canadensis Moench.Oinoko biloba L., etc. |
| deciduous tree | | |
| middle-ranking | Evergreen Trees and Shrubs | Juniperus chinensis Linn., Platycladus orientalis (L.) Franco, Buxus megistophylla Engl., Buxus sinica var. pervfolia M. Cheng; Prunus cerasifera f. staurapetraea, Amygdalus persica L. var. persica f. duplex Rehd., Armeniaca vulgaris Lam., Cerasus serrulata (Lindl.) G. Don ex Londo. var. lanuginosa (Carri) Makino, Lonicera maackii (Rupr.) Maxim., Ligustrum × victori Rehder, etc. |
| | Deciduous trees and shrubs | |
| lower class | herbaceous plant | Hosta plantaginea (Lam.) Aschers., Arrhenatherum elatius (L.) Presl, Cypripedium rotondum L., Humerochilus fulva, etc. |

We can easily see from Table 2 that Changyang Park pays much attention to the combination of trees, shrubs and herbs in the selection of plants. Native plants have been chosen as ornamental plants in all of Beijing, together with the planting of fruit trees, such as apricot trees, to give Changyang Park a colorful landscape effect in all seasons.

4.2 Analysis of plant carbon stocks

The carbon stocks of the major tree species in Changyang Park were calculated by the formula presented in this paper, and the results showed that the carbon stocks of evergreen trees > deciduous trees > evergreen shrubs. The evergreen tree with the largest single carbon stock was cedar; the deciduous tree with the largest single carbon stock was poplar; and the carbon stocks of evergreen shrubs and deciduous shrubs were almost equal.
Table 3 Carbon stocks of major tree species in Changyang Park

| Name of tree species | Monocotyledon carbon stocks (t) | Total carbon stocks (t) | Name of tree species | Monocotyledon carbon stocks (t) | Total carbon stocks (t) |
|----------------------|---------------------------------|-------------------------|----------------------|---------------------------------|-------------------------|
| evergreen tree        | 0.306                           | 1297.31                 | Prunus cerasifera f. atropurpurea | 0.014                           | 7.084                   |
| Pinus tabuliformis Carr. | 0.326                         | 391.2                   | Anagyris aestivalis foliosa | 0.028                           | 9.66                    |
| Pinus bungeana Zucc.    | 0.462                           | 369.6                   | Armeniaca vulgaris Lam.  | 0.018                           | 5.76                    |
| Cedrus deodara (Roxb.) G. Don | 0.475                     | 273.125                 | Cedrus sempervirens (Lindl.) ex. London var. isemniana (L.) Makino | 0.056                           | 14.56                   |
| Juniperus chinensis | 0.124                           | 138.26                  | Lonicera maackia (Bunge) Maxim. | 0.034                           | 5.1                     |
| Platycodon orientalis (L.) Franq. | 0.143                | 125.125                 | Cercis chinensis | 0.004                           | 0.86                    |
| deciduous tree         | 0.699                           | 446.736                 | Buxus megistophylla Lev. | 0.003                           | 58.5                    |
| Juglans regia L.       | 0.079                           | 44.655                  | Buxus sinica (Rehd. et Wils.) Cheng sp. sinica var. sinica B. Cheng | 0.001                           | 8.55                    |
| Platycladus × acuminata | 0.043                         | 43.086                  | Ligustrum × vicaryi Rehder | 0.002                           | 12.7                    |
| Salix matsudana Koiz.    | 0.302                           | 164.892                 | Forsythia viridissima Lindl. | 0.001                           | 2.45                    |

5. Conclusion
The role of urban green space in cities is important, and garden plants play an important role in the process of carbon dioxide absorption. In this paper, the carbon storage of the main garden plants in Changyang Park in Beijing was studied based on the biomass method, and the results showed that evergreen trees have the highest carbon storage, which is because in winter evergreen trees can already photosynthesize and accumulate carbon dioxide in the atmosphere. However, it is not the right choice to plant more evergreen trees, but to combine more deciduous trees with shrubs and herbs. This is because the leaves that fall from deciduous plants in the fall can be broken down and stored by microorganisms in the soil, which increases the carbon content of the soil.

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References
[1] Li Chaonan. Analysis of carbon emission from urban road traffic and carbon sink of road area vegetation[D]. Nanjing Forestry University,2016.[in chinese]
[2] GALINA CHURKINA, DANIEL G. BROWN, GREGORY KEOLEIAN. Carbon stored in human settlements: the conterminous United States [J]. Global Change Biology, 2010, 16(1). [in chinese]

[3] Wang Disheng. Study on the net carbon stock of urban landscape in Beijing based on biomass measurement[D]. Beijing Forestry University, 2010. [in chinese]

[4] Lin, C.G.. The problem of stem shape control in forest stock measurement techniques [J]. Forestry Science, 1964(04): 87-97. [in chinese]

[5] Zeng W.S., Chen X.Y., Pu Y., Yang X.Y.. A comparative analysis of different biomass and carbon stock estimation methods based on national forest inventory data[J]. Forestry Science Research, 2018, 31(01): 66-71. [in chinese]

[6] Jin Lihao. Research on carbon storage and carbon sink benefits of landscape plants [D]. Zhejiang Agriculture and Forestry University, 2019. [in chinese]