STUDY ON CARBON STORAGE OF URBAN GARDEN VEGETATION

------A CASE STUDY OF JIANGNAN UNIVERSITY

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***Abstract*-In the process of exploiting low carbon economy, carbon storage plays an important role in counteracting greenhouse gases. Even though various researches have been done on carbon storage of forests and soil, the study of urban gardening is only 1.27%. But the proportion is increasing in recent years. Our research is aiming to get original statistics of the carbon storage of the targeted school "Jiangnan University" via direct harvest method, different speed growth equation method ①, and biological expansion factorization method, to analyze individual tree and to provide reference in choosing dominant tree species and generating proper plantation strategy.**

Keywords- urban gardening; carbon storage; metering method; dominant tree species;

I. THE INTRODUCTION OF EXISTING RESEARCH ON THE URBAN GARDEN VEGETATION CARBON STORAGE

With the signing of "the United Nations Climate Change Convention" and "the Kyoto Protocol", China on one hand actively explores new ways of energy conservation. On the other hand provides a specific emission reduction targets. Though in the study, the scholars have found that forests play an obvious role on reducing greenhouse gases and absorbing carbon dioxide. As global urbanization is gradually accelerating, the urban gardens develop rapidly. As a special unit, forest ecosystem has a huge potential of carbon sinking②.

Developed countries are the forerunner of carbon storage. During the decades of observation and monitoring activities, long-term research network and test station have been built up. Pouyat (2002), Liski (2002), and other foreign scholars have done deep research for forest and soil carbon storage. The Chinese scholar,Fang Jingyun (2001), had used the improved biomass conversion factor method to draw a conclusion that developed deforestation and other human activities lead to the decrease in carbon stocks in the 1970s, while the increase in reserves is from the past two decades forestation. Wei Wenjun etc. (2007) studied on the tree layer of the forest vegetation in Jiangxi Province and summed up the distribution law of the different ages, carbon storage and densities on different communities. Zhang Mingkui (2006), comprehensively analyzed the soil spatial variability, the soil organic storage capacity and the oxidation state of carbon under the influence of human factors. The Chuai Xiaowei (2011) explored the impact of land using changes on soil carbon storage and found that soil organic carbon densities were increased over the classes. In addition, against the urban gardens carbon reserves, Wang Disheng (2010), Wu Shanshan (2010) also had explorations in Beijing and Hefei separately. Their measurement methods have significant values. The increasingly sophisticated carbon accounting system and more practices provide a reliable foundation for deeper research on the urban gardens carbon reservation.

Although there are various types of research results, the limitations are also clear: First, though the integration analysis on more than 800 carbon in the 1982 -2012, Wanfang database reserved literatures, we found the percentage of the articles themes is: 49.31% on soil carbon reserves; 34.84% on forest carbon stocks; 7.99% on the grass; 6.60% on farmland; only 1.27% on garden carbon stocks. The data shows that the countries carried out little researches on the garden vegetation carbon reserves, but this condition has changed significantly in recent years. Based on the study of inventory data, Li Haikui (2011) estimated the forest vegetation carbon reserves and found that the Chinese arbores carbon reserves in carbon stocks is more than 15%, which means the garden carbon reserves has a huge potential for region carbon accounting③; second, the sited conclusions is static and macro, which can not be adapted to local conditions and reflect the dynamic urban garden vegetation carbon reserves information; third, due to the complex structure of urban gardens, the collection of data and

① Directly harvest method, different speed growth equation method, biological expansion factorization method: the appropriate measurement of carbon reserves' details in chapter 2.1

② Carbon currency: the process, action and the mechanism of eliminating the carbon dioxide from atmosphere

③ Carbon measurement：Estimation on the anticipate neat carbon currency quantity, which is pre-estimate.

information is trapped. The uncertainties are hardly under control. On addition, our research started very late. Forestry and garden manage separately, and the garden workers pay more attention to the urban landscape greening features, thus increase the difficulty of the research.

Based on "the afforestation projects and monitoring guidelines" (IPCC 2006) (hereinafter referred to as the Guide), this article, combined with the urban landscape vegetation characteristics and existing theory, considering the urban garden management and the lack of information, learned from the technology and methods, and has a conduct and in-depth research on the garden schools Jiangnan University. We help the relevant departments to obtain the raw data, verify, amend and supplement the default value of the Wuxi region, select the dominant species, develop an appropriate garden strategy to spread gardening carbon stocks measurement methods, and improve carbon accounting system.

II. STUDY METHOD

A. General measurement methods

According to the Guide, carbon measurement concluded with the different speed equations method and biomass expansion factor method. Taking into consideration that regional differences and data deletion, direct harvest method can be more accurate and reliable access to affect the value of the species physical characteristics. Between the two methods, different speed equation method in priority, the biomass expansion factor method should be used if there are no available biomass equations or significant differences between the equations and the actual situations.

To measure carbon stocks, we must first define the carbon pool④:

$$C_{PROJ,\ t} = C_{PROJ,AB,t} + C_{PROJ,BB,t} + C_{PROJ,DW,t} + C_{PROJ,L,t} + C_{PROJ,SOC,t} \quad (1)⑤$$

In the above formula: $C_{PROJ,t}$ represent the t year's total carbon reserves for the program; $C_{PROJ,AB,t}$ represent the t year's aboveground biomass carbon stocks in the carbon pools; $C_{PROJ,BB,t}$ represent the t year's underground biomass carbon stocks in the carbon pools; $C_{PROJ,DW,t}$ represent the t year's litter material carbon reserves in the carbon pools; $C_{PROJ,L,t}$ represent the t year's dead wood carbon stocks in the carbon pools; $C_{PROJ,SOC,\ t}$ represent the t year's carbon storage in soil organic in the carbon pool; t represent the project year.

Aboveground biomass and belowground biomass can not be omitted under any circumstances. Because litter, dead wood accounted relatively smaller when measuring the carbon stocks and the human management in Jiangnan University garden environment. These parts can be neglected; Considering the lack of advanced equipment and technical support when measure soil carbon storage, the study's carbon pools only consists of total aboveground biomass and vegetation underground biomass.

1) Directly harvest method

By field measurements, this method harvest physical values of the vegetation. Due to the large number of vegetation and the distribution of scattered of Jiangnan University, our research uses the average measured data as the value of the standard wood, uses average standard wood carbon stocks as the species' individual biomass carbon reserves and uses individual biomass carbon reserves multiplied by the number of species to calculate the total carbon stock.

2) Difference speed growth equation method

The method measure the representative plants DBH, tree height, crown size, high value under live branches, layered cut the plants, measure organ fresh weight. Laying samples under ≤ 70 ° C conditions and then drying to constant weight to calculate the sample moisture, and the dry weight of each organ. Different speed growth equations have two forms; Biomass (B), diameter at breast height (DBH) (element equation) or DBH and height (H) (binary) (two elements equation), for example:

$$\ln B = a_1 + a_2 \ln(DBH) \quad (2)$$

or

$$\ln B = a_1 + a_2 \ln(DBH) + a_3 H \quad (3)$$

In the above formula: B represent Biomass (t DM. per plant); a1-a3 are parameters

3) Biomass expansion factor method

The method use the measured diameter at breast height (DBH) and high (H) of the trees in the sample ground to build one element or two elements standing tree trunk volume formula, then use Trunk volume density and biomass expansion factor to calculated aboveground biomass and calculated belowground biomass by root - stem ratio, for example:

Aboveground biomass:

$$Tab = \sum_{i=1}^{n} V_i \times D_i \times R_i \times C_i \times N_i \quad (4)$$

underground biomass:

$$Tbb = \sum_{i=1}^{n} V_i \times D_i \times R_i \times C_i \times N_i \times R \quad (5)$$

In the above formula: i is the trees type; the Tab is the trees' aboveground biomass carbon reserves; Tbb is trees underground biomass carbon reserves; Vi is trunk volume quantity of i type plant; Di is the trunk density of i type plant; Ri is biomass expansion factors of i type plant; Ci for carton content of i type plant; Ni is the number of i type plant; R is the root - stem ratio.

Aboveground biomass plus below-ground biomass is total biomass.

Tree wood product formula:

④ Carbon pools：including aboveground biomass, underground biomass, death plant, litter material and soil organic

⑤ Formula 1-5 and relatively parameters，refer to "the afforestation projects and monitoring guidelines"

$$Vi = g1.2\ (H+3)\ f\text{ə}\text{⑥} \qquad (6)\text{⑦}$$

In the above formula: Vi is vegetation material product; H height; g1.2 is trunk area of 1.2 m above ground; fə = 0.44 is empirical coefficient.

B. The method using in this article

This article use a sample survey to the direct harvest two important variables: tree height and diameter values. Taking into account that trees almost never influenced by the human factor, we use the difference speed growth equation method. Referring the related shrubs carbon measurement methods, we found shrubs' carbon reserves are much lower. So the international community generally takes the shrubs' species as a whole, study the average tree height and average DBH, rather than specific to a particular species. Hence, shrubs data is in shortage; what's more, most of the other literatures study on shrubs rather than garden shrubs. These shrubs' height is almost two times more than the shrubs in Jiangnan University, which don't match the Jiangnan University's reality. Therefore, we use biomass expansion factor method to calculate the shrubs carbon stocks.

III. THE JIANGNAN UNIVERSITY OVERVIEW AND VEGETATION STATISTICS

A. Jiangnan University Overview

Jiangnan University is located in Wuxi City, Jiangsu Province (latitude 31 °7 'to 32 °2' N, 119 °33 'to 120 °38'), in the hinterland of the Yangtze River Delta, belonging the subtropical humid areas affected by the subtropical monsoon climate, mild climate, and rain is abundant. University covers an area of 3,200 acres, more than 100 million square meters of construction area. The majority of the trees are evergreen broad-leaved forest. The main tree species are such as camphor, beech and others.

Though the statistics⑧, Jiangnan University has 209 kinds of vegetations. Considering typicality and diversity of vegetation, this article divides vegetation into 11 categories, selects eight species distribution with higher density, and conducts a sample survey of some vegetation.

B. The classification of Jiangnan University's vegetation

(a) Classification of vegetation(according to quantity)

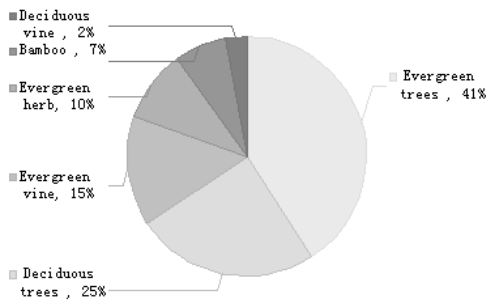

Figure 1. All the statistics are actual measured from Jiangnan University

(b) Classification of vegetation(according to areas)

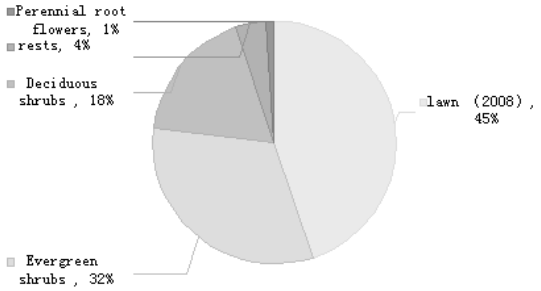

Figure 2. All the statistics are actual measured from Jiangnan University

In Jiangnan University garden's structure, arbor takes a higher percentage, which is 65.59%; lawn and shrub planting takes 44.81% and 50.03% respectively. Taking into account that some of the trees accounted for a smaller proportion of overall, subjected to technical conditions and the current level of scientific research, had migration phenomenon, or were unable to lock specific location, this article chooses evergreen arbor, evergreen shrubs, deciduous arbor, and deciduous shrubs to study.

C. the diameter of breast and the height of vegetation

Referred to relevant data, mainly Jiangnan University's vegetation, except the camphor and acacia minority planted for 30 years, only planted for 15 years. Limited by age and subtropical monsoon climate characteristics, the school trees' height and diameter at breast height (except the hibiscus) are generally small. Arbors' height are raging from 5 to 6 meters, Except for oleander and osmanthus' height beyond two meters, other shrub species' height are more or less than one meter. The average tree height of the evergreen tree is higher than deciduous tree, but average height of deciduous shrub tree is higher than the evergreen shrub. Arbors' DBH value is in the range of 0.008 to 0.271. However, the deciduous arbors' average DBH is generally greater than the evergreen arbors'; shrubs' DBH value small and approximate.

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⑥ fə ： fə is a parameter，refer to" the carbon reserves of different community types in hefei city crossing park" ， its range is 0.4~0.44. Considering the trunk，its up range is smaller，but the acreage of down range is bigger，approximate to the cylinder. Fə is the ratio parameter of the differences between the reality shape of the trunk and the cylinder. Considering the plant in Jiangnan university is very young, and the up surface and down surface is of the near size, more lean to cylinder, so chose fə =0.44 to estimate the trunk volume.

⑦ Formula 6，refer to"the carbon reserves of different community types in hefei city crossing park" and "the research on measurement method of single standing trunk volume"

⑧ Refer to "the statistic of plants on the north area of Jiangnan University" 2011

IV. THE CARTON STORAGE OF DIFFERENT VEGETATION IN JIANGNAN UNIVERSITY

A. The statistic of The carton storage of different vegetation in Jiangnan University

TABLE I. CARBON STORAGE OF EVERGREEN ARBOR IN JIANGNAN UNIVERSITY

Name of Vegetation	DBH (m)	H(m)	Quantity (tree)	Total Carbon Storage (t)	Individual Carbon Storage (t/tree)
Camphor	0.216	7.2	3508	469.816	0.134
Elaeocarpus decipiens	0.105	5.76	1827	11.729	0.006
Cedar	0.153	5.425	891	47.491	0.053
Southern magnolia	0.127	6.594	541	5.308	0.01
Smiling lechang	0.08	2.1	87	0.16	0.002
Total				534.504	0.205
Average	0.136	5.416		106.901	0.041

All the statistics are actual measured from Jiangnan University

TABLE II. CARBON STORAGE OF DECIDUOUS ARBOR

Name of Vegetation	DBH (m)	H(m)	Quantity (tree)	Total Carbon Storage (t)	Individual Carbon Storage (t/tree)
Metasequoia	0.095	6.08	255	88.205	0.3459
Metasequoia 2	0.127	6.4	156	5.53	0.0355
Weeping willow	0.271	6.885	505	10.999	0.0218
Koelreuteria paniculata	0.236	6.765	116	1.882	0.0162
Liriodendron	0.134	6.72	172	1.487	0.0086
Albizzia ulibrissin	0.166	5.6	292	1.992	0.0068
Zelkova serrata	0.159	6.16	418	2.822	0.0068
Ginkgo biloba	0.137	6.63	1038	5.506	0.0053
Soapberry	0.11	6.28	564	1.834	0.0033
Magnolia	0.105	5.928	204	0.576	0.0028
Total				120.833	0.453
Average	0.154	6.345		12.083	0.0453

All the statistics are actual measured from Jiangnan University

After the measurement, we calculated that the total carbon stock of Jiangnan University's evergreen trees, evergreen shrubs, deciduous trees and deciduous shrubs were 534.504t 120.834t, 34.839t and 40.070t. Average carbon stocks for four sorts per plant were 0.041t / plant, 0.045t / plant, 0.0008 t / m ² and 0.0013t / m ². Evergreen vegetation in Jiangnan University grows better, which camphor is adapted better, denser, faster growth and have the largest carbon stocks in the evergreen trees. Deciduous arbors have larger carbon stocks per plant, in addition to the weeping willow, and Huangshan Luan tree. Other deciduous tree carbon stocks per plant relative to the average carbon stock, especially Metasequoia play a greater role in increasing carbon sink. Shrub carbon stocks are smaller. Normally, evergreen shrub carbon reserves locate in 0.007t / m ² ~ 0.008 t / m ², the deciduous shrubs carbon reserves are generally more than 0.01 t / m ², which, oleander, sweet-scented osmanthus, pomegranate and hibiscus carbon sequestration potential are anticipated to be discovered.

B. The analysis of Jiangnan University vegetation's total carbon reserves and singale plant reserves

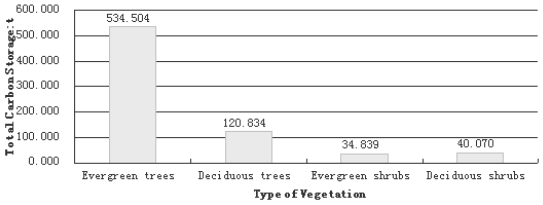

Figure 3. The total carbon storage of different vegetation

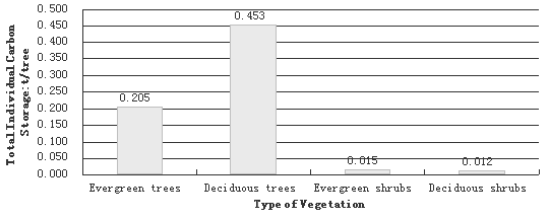

Figure 4. The total individual carbon storage of different vegetation

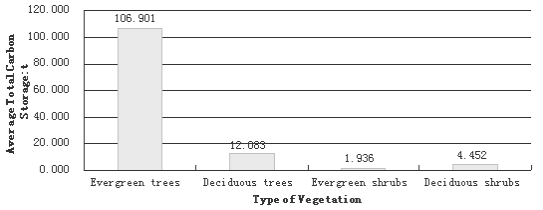

Figure 5. The average total carbon storage of different vegetation

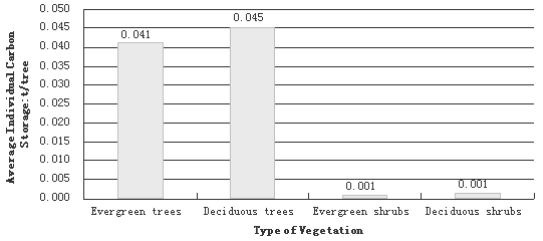

Figure 6. The average individual carbon storage of different vegetation

Compared to other areas, Jiangnan University's evergreen species have a larger total amount of carbon sinks, which is due to the subtropical monsoon climate impact, the sequence of total carbon reserves is evergreen tree> deciduous tree> deciduous shrubs> evergreen shrubs, but deciduous tree> evergreen trees in other regions, which are in the temperate climate zone,. But there is no doubt that the trees attribute more to sinks reduction utility than the shrub. However, in the individual biomass aspect, the sequence is the deciduous trees> evergreen trees> evergreen shrub> deciduous shrub, which is no different with other study conclusions.

The sequence of Jiangnan University's vegetation average carbon stocks: evergreen tree> deciduous tree> deciduous shrub> evergreen shrubs; evergreen tree's average carbon stock is far greater than the deciduous tree's; shrubs carbon stocks is smaller, which carbon stocks per plant is between 0.008 and 0.0013.

V. CONCLUSION

1, Through the integrated analysis of more than 800 carbon reserves literatures, from1982 -2012, we found that 84.15% is about forest and soil carbon storage, only 1.27% is about urban gardens carbon reserves study, but in recent years, this area of research continues to heat up. With the accelerated process of urbanization, urban gardens carbon stock has great potential on energy saving and carbon dioxide reduction;

2, In the structure of Jiangnan University garden, arbor's number is larger, possessing 65.59% of 209 species in the 11 types; shrubs' is larger, with a 50.03% proportion. And the sequence of the four types plants' number is deciduous tree> evergreen shrubs> evergreen tree > deciduous shrubs. Although the plants are still young, with the rapid growth of the trees, carbon reserves have a promising increase.

3, The Jiangnan University's evergreen tree total carbon stocks is 534.504t, average to 0.041t / plant; the deciduous tree total carbon stocks is 120.834t, average to 0.045t / plant; evergreen shrub total carbon stock is 34.839t, average to 0.0008t / m², the deciduous shrub total carbon reserves is 40.070t, average to 0.0013t / m².

4, Influenced by subtropical monsoon climate, evergreen vegetation grows well in Wuxi. Therefore, the sequence of total carbon stocks is evergreen tree> deciduous tree> deciduous shrub> evergreen shrubs; on the other hand, because deciduous tree have a larger density. The sequence of biomass per plant is deciduous tree > evergreen trees> evergreen shrub> deciduous shrub.

5, Metasequoia, camphor, cedar, pool fir, weeping willow, Huangshan Luan tree, Magnolia grandiflora, Liriodendron chinense, acacia and beech tree have a larger carbon stocks than any other plants, Under the same condition, plantings trees, especially the top ten ranked tree species in carbon stocks can do more for the environment purification.

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