Study on the Carbon Stocks of Soils under Five Kinds of Plantations

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Abstract Based on the field data and laboratory analysis, we studied the soil organic carbon storage and vertical distribution features about five kinds of plantations in Xuyi, and the results showed that soil carbon density in the five forest types changed greatly, with a range of 0.8 – 3.04 kg/m^2 for five soil layers. Furthermore, soil carbon density decreased generally with the depth, as well as carbon content. In the whole soil profile, the range of carbon density in these five forests was from 4.79 kg/m^2 to 5.62 kg/m^2. However, 60% carbon was concentrated in 40 cm depth of soil. The calculated result of soil organic carbon reserve was as follows: *Cupressus lusitanica* (50.264 t/hm^2), *hackberry* (47.859 t/hm^2), *Populus* L. (53.216 t/hm^2), *Red bayberry* (49.581 t/hm^2), *Amygdalus persica* L. (58.202 t/hm^2), with the average storage of 51.824 t/hm^2, lower than the national average level, so, people should pay attention to the artificial forest tending and management. According to the above analysis, this paper concluded that the afforestation was the effective measure for increasing the soil organic carbon accumulation, and the effects of planting the indigenous tree species *Cupressus lusitanica* and *Amygdalus persica* L. were best.

Key words Organic carbon density of soils, Carbon stocks, Plantations, Xuyi County

Volcanic rocks are widely distributed in various regions of China, and due to sparse vegetation, shallow soil and little surface water in the volcanic mountain, the success rate of afforestation is low and tree growth is slow. Afforestation has always been difficult for the volcanic mountain, while the plantation is considered to be one of the main media for increasing forest cover and implementing carbon emission reduction plan[1]. It plays an important role in the evaluation of the contribution of forests to the terrestrial carbon sink[2]. Therefore, with Yueliangshan Ecological Park in Xuyi County, Huai'an City, Jiangsu Province as the study area, we study the soil carbon stocks under five kinds of plantations in order to provide a theoretical basis and technical reference for the choice of most appropriate tree species and ecological restoration in volcanic mountain of northern Jiangsu.

1 Overview of the study area

Xuyi County (32°43′ – 33°13′N, 118°11′ – 118°54′E) is under the administration of Huai'an, Jiangsu Province, China. As the southernmost of Huai'an's county-level divisions, it borders the prefecture-level cities of Suqian to the north and Chuzhou (Anhui) to the south and west. It has a prominent monsoon climate with four distinct seasons. The annual sunshine duration averages 2224.2h, the average annual temperature is 14.7 ℃, and the average annual precipitation is 985.3mm. Due to prominent interseasonal and interannual variation, the drought and waterlogging disasters are frequent and serious, affecting wide areas. The soil develops from the volcanic rock, and the zonal yellow brown soil occupies the largest area, accounting for 36.2%, followed by volcanic ash soil, paddy soil and moisture soil, with poor fertility and sticky structure. The low-yielding fields account for nearly two-thirds.

2 Research methods

2.1 Sample plot setting and sampling methods On the basis of the actual survey in the study area, we select five kinds of plantations (*Cupressus lusitanica*, *Celtis sinensis Pers.*, *Populus* L., *Amygdalus persica* L. and *Myrica rubra* (*Lour.*) *S. et Zucc.*), and set 20m × 20m standard plots in each plantation and control barren hill, respectively. In each sample plot, we dig 3 S-shaped soil profiles and perform the 0 – 10, 10 – 20, 20 – 40, 40 – 60cm stratified sampling in the profiles, respectively. Then we mix the soil samples in the same plot, dry them to be sifted by 0.25mm sieve, seal them with a plastic bag and store them for chemical analysis. At the same time, we use the ring knife to take three samples in each layer and bring them back to laboratory to measure soil density.

2.2 Sample testing method We use potassium dichromate-external heating method to test the soil organic matter and use cutting ring method to test the soil density.

2.3 Calculation of soil carbon stocks The data processing method[3] is as follows: 60cm soil carbon stocks S (t · hm^2) is calculated using soil density D_i (g · cm^3), carbon content C_i (g · kg^{-1}), thickness of each layer of soil E_i (cm) and percentage (%) of gravel with volume greater than 2mm G_i.

The formula is as follows: $S = \sum_{i=1}^{4}[(C_i \times D_i \times E_i) \times (1 - G_i)]$

where i is the soil layer.

2.4 Calculation of soil carbon density The soil organic carbon density refers to the organic carbon reserve of soil per unit area at a certain depth. The organic carbon density in soil layer i (T_0, kg · m^{-2}) is calculated as follows:

$$T_0 = C_i D_i E_i (1 - G_i)/100$$

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where C_i is the soil organic carbon content ($g \cdot kg^{-1}$); D_i is the soil density ($g \cdot cm^{-3}$); E_i is the soil thickness (cm); G_i is the percentage (%) of gravel with volume greater than 2mm.

2.5 Data processing Excel2010 and SPSS18.0 are used for data calculation and statistical analysis.

3 Results and analysis

3.1 The soil organic carbon content of plantation and control wasteland Yueliangshan Ecological Park covers an area of 333.3 ha, and the soil is formed from lava. Due to vegetation-soil-human activity intervention, there have been some differences in the physical and chemical composition of soil under different vegetation, and soil organic carbon content and density have showed different features. The soil carbon and soil density determination of woodland can be shown in Table 1. Table 1 indicates that under the effect of different vegetation, the topsoil has high organic carbon content, but it decreases with the increase of soil depth. Based on the multiple comparisons of average soil organic carbon content under different vegetation, we get the following results (Table 2): there are no significant differences in the organic carbon between wasteland soil and soil under *Myrica rubra* (*Lour.*) *S. et Zucc.* and *Cupressus lusitanica*, but there are significant differences in the organic carbon between soil under *Myrica rubra* (*Lour.*) *S. et Zucc.* and *Cupressus lusitanica* and soil under other standing forests; there are significant differences in the soil among *Celtis sinensis Pers.*, *Amygdalus persica* L., and *Populus* L. Based on the actual measured data, the soil under *Cupressus lusitanica* shows the highest level of organic carbon, with an average of 0.08712, significantly higher than the average carbon content of other species, while the soil under *Celtis sinensis Pers.* shows the lowest level of organic carbon, as can be shown in Table 2.

Table 1 The organic carbon content and soil density of soil profile of plantations and wasteland

	Soil depth/cm	≧0–10	≧10–20	≧20–40	≧40–60
Cupressus lusitanica	*C*	14.751a	11.340b	5.529c	3.255d
	Soil density	1.12	1.14	1.17	1.21
Celtis sinensis Pers.	*C*	13.379a	8.850b	4.288c	3.287d
	Soil density	1.29	1.26	1.21	1.38
Populus L.	*C*	12.365a	10.279b	5.129c	4.039d
	Soil density	1.29	1.32	1.31	1.27
Myrica rubra (Lour.) S. et Zucc.	*C*	13.356a	11.351b	5.357c	4.274d
	Soil density	1.08	1.11	1.14	1.21
Amygdalus persica L.	*C*	13.317a	9.582b	5.236c	5.621c
	Soil density	1.19	1.45	1.29	1.33
Wasteland	*C*	18.446a	7.968b	2.969c	2.245d
	Soil density	1.65	1.5	1.79	1.77

Note: Data in the table are all averages, and different letters in the same line indicate significant difference ($P<0.05$); *C* represents organic carbon content (unit: $g \cdot kg^{-1}$); soil density (unit: $g \cdot cm^{-3}$).

Table 2 Duncan multiple comparison of average organic carbon content

Plantation type	*Cupressus lusitanica*	*Celtis sinensis Pers.*	*Populus* L.	*Myrica rubra* (*Lour.*) *S. et Zucc.*	*Amygdalus persica* L.	Wasteland
Mean	0.08712	0.07450	0.07953	0.08584	0.08240	0.08512
Standard error	0.084	0.084	0.084	0.084	0.084	0.084
Difference significance	d	a	b	d	c	d

Note: The same letters in the same line indicate that the difference is not significant ($P<0.05$).

3.2 Organic carbon density of plantations and wasteland As can be seen from Table 3, there are significant differences in soil carbon density between the five plantations and wasteland, and the soil layer variation range is $0.8-3.04 kg \cdot m^{-2}$. For the whole soil layer, the soil carbon density of five plantations and wasteland is $4.79-6.46 kg \cdot m^{-2}$. The soil carbon density of all plantations basically shows the same regularity as carbon content, in descending order of wasteland > *Amygdalus persica* L. > *Populus* L. > *Cupressus lusitanica* > *Myrica rubra* (*Lour.*) *S. et Zucc.* > *Celtis sinensis Pers.* The carbon density of wasteland is 1.34 times that of *Celtis sinensis Pers.* In terms of the vertical section of soil, soil organic carbon density decreases with the increase of soil depth, and there are significant differences between the soil layers. Meanwhile, the analysis of contribution rate of soil organic carbon density of five plantations and wasteland indicates that for the layer (≧0–10 cm), the contribution rate of soil organic carbon density is 34.12%; for the layer (≧0–40 cm), the contribution rate of soil organic carbon density averages 60.12%. It indicates that for the soil layer (≧0–40cm) occupies a position that can not be ignored in the study of forest soil organic carbon density.

3.3 The organic carbon storage of plantations and wasteland Based on the above experimental data, we use the previous formula to calculate the soil organic carbon stocks under various land use modes, respectively, and get the following results: *Cupressus lusitanica* ($50.264 t \cdot hm^{-2}$); *Celtis sinensis Pers.* ($47.859 t \cdot hm^{-2}$); *Populus* L. 53.216 ($t \cdot hm^{-2}$); *Myrica rubra* (Lour.) S. et Zucc. ($49.581 t \cdot hm^{-2}$); *Amygdalus persica* L. ($58.202 t \cdot hm^{-2}$); wasteland ($60.964 t \cdot hm^{-2}$) (Fig. 1). The vegetation soil organic carbon is mainly from plant and animal residues and litters transformed by microbial decomposition and chemical leaching. In this study, the size of carbon stocks is in the order of *Amygdalus persica* L. > *Populus* L. > *Cupressus lusitanica* > *Myrica rubra* (*Lour.*) *S. et Zucc.* > *Celtis sinensis Pers.* As the local native species, *Amygdalus persica* L. has the largest carbon stocks, and there are little differences in the carbon stocks between *Populus L.* and *Cupressus lusitanica*. However, the soil carbon stocks of five plantations are all lower than the organic carbon stocks of wasteland due to the thin soil and selection of biennial plants which absorb large amounts of carbon and some other nutrients for their growth.

Table 3 The soil organic carbon density of different plantations ($kg \cdot m^{-2}$)

Plantations	Organic carbon density ≧0 – 10 cm	≧10 – 20 cm	≧20 – 40 cm	≧40 – 60 cm	≧0 – 60 cm
Cupressus lusitanica	1.64b	1.29b	1.30a	0.79a	5.02
Celtis sinensis Pers.	1.72c	1.12a	1.04c	0.91b	4.79
Populus L.	1.60a	1.36c	1.34a	1.03c	5.33
Myrica rubra (*Lour.*) *S. et Zucc.*	1.45b	1.26b	1.22c	1.03c	4.96
Amygdalus persica L.	1.59a	1.39c	1.35b	1.29d	5.62
Wasteland	3.04d	1.56d	1.06a	0.8a	6.46

Note: Different letters in the same column indicate significant differences ($P < 0.05$).

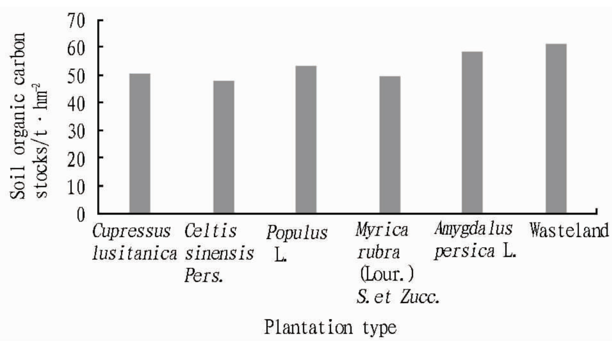

Fig. 1 Comparison of soil organic carbon stocks under different plantations

4 Conclusions

Currently, there are many studies on the soil organic carbon in China, but the difference is large. Li Kerang *et al.* [4] use CEVSA model to estimate the average soil organic carbon stocks nationwide at 91.7 $t \cdot hm^{-2}$, but the result is 115.9 $t \cdot hm^{-2}$ for Xie Xianli et al. [5] and 193.6 $t \cdot hm^{-2}$ for Zhou Yurong *et al.* [6]. The experimental results in this paper indicate that the soil organic carbon stocks of five plantations in Yueliangshan Ecological Park of Xuyi County are as follows: *Cupressus lusitanica* (50.264 $t \cdot hm^{-2}$); *Celtis sinensis Pers.* (47.859 $t \cdot hm^{-2}$); *Populus* L. 53.216 ($t \cdot hm^{-2}$); *Myrica rubra* (*Lour.*) *S. et Zucc.* (49.581 $t \cdot hm^{-2}$); *Amygdalus persica* L. (58.202 $t \cdot hm^{-2}$). The soil organic carbon stocks average 51.824 $t \cdot hm^{-2}$. It can be seen that the soil carbon stocks of plantations in the study area are lower than the national average, so it is necessary to strengthen the tending and management of plantations to enhance their ability to sequester carbon. The soil carbon density of five plantations is 4.79 – 5.62 $kg \cdot m^{-2}$, and the soil carbon density of all plantations basically shows the same regularity as carbon content, in descending order of wasteland > *Amygdalus persica* L. > *Populus* L. > *Cupressus lusitanica* > *Myrica rubra* (*Lour.*) *S. et Zucc.* > *Celtis sinensis Pers.* The carbon density of wasteland is 1.34 times that of *Celtis sinensis Pers.* In terms of the vertical section of soil, soil organic carbon density decreases with the increase of soil depth, and there are significant differences between the soil layers, which is the same as the results of many studies[7-11]. Overall, *Cupressus lusitanica* and *Amygdalus persica* L. are better than other tree species, so it is necessary to promote the cultivation of the two species in this region.

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