Investigation on Carbon Sequestration Capacity of Typical Subtropical Evergreen Broad-leaved Forest in Jiulianshan Nature Reserve

Qiugen Zhang, Wei Xia, Yuan Ding and Jian Li
School of Environment and Chemistry Engineering, Nanchang HangKong University, 330063, China
Corresponding author: niatzqg@nchu.edu.cn

Abstract. Nine investigation sample plots (each 20m×20m) were set up to investigate the biomass and soil bulk density of three typical subtropical evergreen broad-leaved forests (Castanopsis eyrei, Schima superba, Cyclobalanopsis glauca) in Jiulianshan National Nature Reserve in Jiangxi Province in 2015 and 2020. The vegetation carbon density and carbon storage, soil carbon density and carbon storage, the carbon density and carbon storage of the investigation sample plots were calculated according to the organic carbon content of vegetation and soil. In addition, the changes in carbon sequestration capacity of three typical subtropical evergreen broad-leaved forests in Jiulianshan National Nature Reserve in Jiangxi Province in 2015 and 2020 were analyzed. The investigation results had shown that: Compared with 2015, the average organic carbon content of Castanopsis eyrei, Cyclobalanopsis glauca, and Schima superba of Jiulianshan National Nature Reserve in Jiangxi Province increased by 10.36%, 10.13% and 7.73% in 2020. The average organic carbon content of leaf, branch, stem and root increased also by 10.60%, 10.38%, 11.13% and 5.29% respectively. The soil organic carbon content of different soil layers in 2020 and 2015 were all decrease with the increase of soil depth. Compared to 2015, the organic carbon content increased while the soil bulk density decreased in 2020.

The average carbon density of the forest vegetation layer in the investigation plots of Jiulianshan National Nature Reserve in Jiangxi Province had increased from 82.63t/hm² in 2015 to 108.94t/hm² in 2020. The carbon density of the arbor layer had increased from 76.11t/hm² in 2015 to 106.09t/hm² in 2020, while the carbon density of the shrub layer, herbaceous layer and litter layer in 2020 was lower than that in 2015. In 2015 and 2020, the carbon density of different vegetation layers in the three typical subtropical evergreen broad-leaved forest of Castanopsis eyrei, Schima superba and Cyclobalanopsis glauca were all ranked as arbor layer, shrub layer, litter layer and herbaceous layer.

The average soil carbon density (calculated by 10cm) at different depths in 2020 and 2015 in Jiulianshan National Nature Reserve of Jiangxi Province all decreased with the increase of the soil depth. The total average soil carbon density in 2020 was 168.03t/hm², which was 35.4% lower than that of 2015(288.05t/hm²).

The average carbon storage in the sample plot (20m×20m) in Jiulianshan National Nature Reserve in Jiangxi Province decreased from 13771.04kg in 2015 to 10688.11kg in 2020 with a decrease of 22.38%. The average carbon storage of vegetation decreased from 3305.20kg in 2015 increased to 4357.60kg in 2020 with an increase of 31.8%, while the average soil carbon storage decreased from 10137.04kg in 2015 to 6475.51kg in 2020 wht a decrease of 36.1%.
1. Introduction
The total area of Jiulianshan National Nature Reserve in Jiangxi Province is 13411.6hm², of which the core area, buffer zone and experimental area are 4283.5hm², 1445.2hm² and 7682.9hm² respectively. Subtropical evergreen broad-leaved forests, evergreen broad-leaved and deciduous mixed forests, and hilltop dwarf forests are the vegetation types in Jiulianshan National Nature Reserve. Among them, subtropical evergreen broad-leaved forests are the most important vegetation types. *Castanopsis eyrei*, *Schima superba* and *Cyclobalanopsis glauca* are the typical subtropical evergreen broad-leaved forests in Jiulianshan National Nature Reserve [1-2]. In order to understand the changes of carbon sequestration capacity of the forest ecosystem in Jiulianshan National Nature Reserve in Jiangxi Province, the biomass and soil bulk density of three typical subtropical evergreen broad-leaved forests (*Castanopsis eyrei*, *Schima superba* and *Cyclobalanopsis glauca*) in 2015 and 2020 were investigated by setting up investigation sample plots. The vegetation carbon density, soil carbon density, vegetation carbon storage, soil carbon storage and forest carbon storage were calculated to comparative analysis and dynamic evaluate the carbon sequestration capacity of typical subtropical evergreen broad-leaved forests in Jiulianshan National Nature Reserve in Jiangxi Province.

2. Investigation analysis and calculation method

2.1. Investigation method
Nine investigation plots (20m×20m) were set up in Jiulianshan National Nature Reserve in Jiangxi Province, with 3 plots each of *Castanopsis eyrei*, *Schima superba* and *Cyclobalanopsis glauca*. In each investigation plot, 3 shrub plots (2m×2m) were set up according to the diagonal method, and 1 herbaceous plot (1m×1m) and 1 litter plot (1m×1m) were randomly set among of three shrub plots. The plant biomass of the arbor layer, shrub layer, herbaceous layer and litter layer were investigated. At the same time, a soil profile (100cm) in the investigation sample plot was dug, and the soil samples of 0-10cm, 10-20cm, 20-30cm, 30-50cm and 50-100cm in soil profile were collected with a ring knife. The soil samples of 0-10cm, 10-20cm, 20-30cm, 30-50cm and 50-100cm in the center position of each shrub plot were drilled separately by using a soil drill. Each stratified soil was mixed into each stratified soil sample.

2.2. Analytical method
The plant samples collected in the investigation sample spot were dried to a constant weight in the laboratory and their dry weight was determined to calculate the moisture content and biomass. The soil samples obtained by ring knife and soil drill were natural air dried to a constant weight to determine their dry weight, and the moisture content and soil bulk density were calculated. The analysis and detection of the organic carbon content of samples were completed by Jiangxi Nuclear Industry Environmental Protection Research Center according to the national standard method. The organic carbon content of plant tissues was determined by dry burning method and elemental analyzer, and the soil organic carbon content was determined by potassium dichromate oxidation-spectrophotometry.

2.3. Calculation method

2.3.1. Biomass calculation. The biomass of the arbor layer of the typical subtropical evergreen broad-leaved forest in the investigation plot in Jiulianshan National Nature Reserve was estimated by establishment a single tree biomass regression equation through regression analysis. The biomass of the shrub layer, herbaceous layer and litter layer were calculated by multiplying the biomass per unit area of the small sample plot in the investigation plot and the area of the entire investigation plot [3-4].

2.3.2. Calculation of vegetation carbon density. First, the carbon storage of each vegetation layer in the investigation plot was calculated by multiplying the biomass of each vegetation layer and the corresponding organic carbon content, and added them up to get the vegetation carbon storage of the
investigation plot. Secondly, the carbon density of each vegetation layer was obtained by dividing the carbon storage of each vegetation layer by the area of the investigation sample plots, and the average value of the carbon density of the three investigation sample plots for each forest species is used as the vegetation carbon density [4].

2.3.3. Calculation of soil bulk density. Soil bulk density was calculated by formula (1).

\[ \rho = \frac{M}{V - m \rho} \]  

(1)

Where \( \rho \) refers to soil bulk density, \( M \) is the mass of the soil sample after drying and constant weight, \( V \) is the volume of the soil, \( m \) is the mass of coarse fragments, and \( \rho \) is the density of coarse fragments.

2.3.4 Soil carbon density calculation. Soil carbon density was calculated by soil bulk density, organic carbon content and the thickness of each soil layer, as shown in formula (2).

\[ \rho_c = \rho \times H \times C \]  

(2)

Where \( \rho_c \) refers to soil carbon density (t·hm\(^{-2}\)), \( \rho \) is soil bulk density (g·cm\(^{-3}\)), \( H \) is the thickness of the soil layer (cm), \( C \) is the organic carbon content (%).

The sum of the carbon density of each soil layer was the total soil carbon density in the investigation sample plot [5-7].

3. Analysis of investigation results

3.1. Organic carbon content of major organs

The organic carbon content of the leaf, branch, stem and root of arbor layer, shrub layer and herbaceous layer of *Castanopsis eyrei*, *Schima superba* and *Cyclobalanopsis glauca* in Jiulianshan National Nature Reserve in 2015 and 2020 was shown in figure 1 to figure 3.

![Figure 1. Organic carbon content of arbor layer main organs in 2015 and 2020](image)

As can be seen from figure 1, compared with 2015, the average organic carbon content of arbor layers of *Castanopsis eyrei*, *Cyclobalanopsis glauca* and *Schima superba* in Jiulianshan National Nature Reserve in 2020 increased by 10.36%, 10.13% and 7.73% respectively. In 2020, the average organic carbon content in the arbor layer of each forest species was in the order of *Schima superba*, *Castanopsis eyrei* and *Cyclobalanopsis glauca*. Compared with 2015, the average organic carbon content of leaf, branch, stem and root in the investigation sample plots increased by 10.60%, 10.38%, 11.13% and 5.29% in 2020. In 2015 and 2020, the highest organic carbon content in different organs of plants was the leaves, the comprehensive average increased by 9.41%.
Figure 2. Organic carbon content of shrub layer main organs in 2015 and 2020

It can be seen from figure 2 that the average organic carbon content of Castanopsis eyrei, Schima superba and Cyclobalanopsis glauca of shrubs layer in Jiulianshan National Nature Reserve in 2020 increased by 10.02%, 15.01% and 9.94% compared with 2015. In 2020, the organic carbon content of shrub layer leaf of each forest species was in the order of Schima superba, Cyclobalanopsis glauca and Castanopsis eyrei, and the organic carbon content of branch was in the order of Castanopsis eyrei, Schima superba and Cyclobalanopsis glauca. In 2015, the average organic carbon content of shrub layer of each forest species was in the order of Schima superba, Castanopsis eyrei and Cyclobalanopsis glauca. However, the order changed to be Castanopsis eyrei, Cyclobalanopsis glauca and Schima superba in 2020. It was mainly due to changes in organic carbon content of root, which may be related to the shrub species in the investigated shrub plots.

Figure 3. Organic carbon content of herbaceous layer main organs in 2015 and 2020

As can be seen from figure 3, compared with 2015, the average organic carbon content of herbaceous layer of Castanopsis eyrei and Cyclobalanopsis glauca in Jiulianshan National Nature Reserve of Jiangxi Province in 2020 increased by 9.87% and 0.8% respectively. While Schima superba decreased by 6.36%. This may be related to the herbaceous species in the investigation herbaceous sample.

3.2. Vegetation carbon density

The vegetation carbon density of the three typical subtropical evergreen broad-leaved forests in Jiulianshan National Nature Reserve in Jiangxi Province in 2015 and 2020, Castanopsis eyrei, Cyclobalanopsis glauca and Schima superba was shown in table 1.
Table 1. Carbon density of vegetation layer in 2015 and 2020

|                | Castanopsis eyrei (t/hm²) | Cyclobalanopsis glauca (t/hm²) | Schima superba (t/hm²) | Average carbon density (t/hm²) |
|----------------|---------------------------|-------------------------------|------------------------|--------------------------------|
|                | 2015  | 2020  | 2015  | 2020  | 2015  | 2020  | 2015  | 2020  |
| Arbor layer    | 85.04 | 141.42| 52.16 | 46.86 | 91.14 | 130.00| 76.11 | 106.09|
| Shrub layer    | 4.84  | 3.09  | 4.38  | 1.43  | 2.20  | 0.62  | 3.81  | 1.71  |
| Herbaceous layer| 0.24  | 0.29  | 0.13  | 0.14  | 0.56  | 0.18  | 0.31  | 0.20  |
| Litter layer   | 3.96  | 1.46  | 1.48  | 0.64  | 1.78  | 0.71  | 2.41  | 0.94  |
| Total          | 94.09 | 146.24| 58.14 | 49.07 | 95.67 | 131.51| 82.63 | 108.94|

It can be seen from table 1, in 2015 and 2020, the carbon density of different vegetation layers in the three typical subtropical evergreen broad-leaved forest investigation plots of Castanopsis eyrei, Schima superba and Cyclobalanopsis glauca were in the order of arbor layer, shrub layer, litter layer and herbaceous layer. The carbon density of arbor layer had an absolute advantage in the vegetation layer. In 2015 and 2020, the lowest total carbon density of the vegetation layer was Cyclobalanopsis glauca. In 2020, the total average carbon density (108.94t/hm²) of the three typical subtropical evergreen broad-leaved forests increased by 31.8% compared with 2015 (82.63 t/hm²), the carbon density of the arbor layer had changed from 76.11t/hm² in 2015 to 106.09t/hm² in 2020. However, the carbon density of the shrub layer, herbaceous layer and litter layer in 2020 was lower than that of in 2015.

3.3. Soil bulk density

The soil bulk density of three typical subtropical evergreen broad-leaved forests of Schima superba, Cyclobalanopsis glauca and Castanopsis eyrei in Jiulianshan National Nature Reserve in 2015 and 2020 was shown in table 2.

Table 2. Soil bulk density in 2015 and 2020

|          | Soil bulk density (g/cm³) |
|----------|---------------------------|
|          | Castanopsis eyrei  | Cyclobalanopsis glauca | Schima superba | Average bulk density |
|          | 2015     | 2020     | 2015     | 2020     | 2015     | 2020     | 2015     | 2020     |
| 0-10     | 1.473    | 0.911    | 1.258    | 0.861    | 1.282    | 1.068    | 1.338    | 0.947    |
| 10-20    | 1.473    | 1.283    | 1.558    | 0.900    | 1.446    | 1.117    | 1.492    | 1.100    |
| 20-30    | 1.377    | 1.384    | 1.422    | 0.903    | 1.515    | 1.166    | 1.438    | 1.151    |
| 30-50    | 1.705    | 1.405    | 1.551    | 0.911    | 1.540    | 1.129    | 1.599    | 1.148    |
| 50-100   | 1.430    | 1.261    |          |          | 1.042    | 1.558    | 1.165    | 1.494    | 1.040    |

It can be seen from table 2 that the average soil bulk density of each layer within 0-100cm in 2020 (0.947-1.151 g/cm³) was smaller than the average soil bulk density in 2015 (1.338-1.599 g/cm³). The main reason may be the increase in carbon storage of the vegetation layer, which increased the litter amount which entered the soil layer, then the organic matter content of the soil was increased and the soil bulk density was decreased. This result was consistent with the research results of Ma Junyong on the effect of fertilization on soil organic carbon and bulk density.

3.4. Soil organic carbon content

The soil organic carbon content of three typical subtropical evergreen broad-leaved forests of Cyclobalanopsis glauca, Schima superba and Castanopsis eyrei in Jiulianshan National Nature Reserve in 2015 and 2020 was shown in table 3.
Table 3. Soil organic carbon content in 2015 and 2020

| Soil Layer | Castanopsis eyrei (%) | Cyclobalanopsis glauca (%) | Schima superba (%) | Average organic carbon content (%) |
|------------|----------------------|----------------------------|--------------------|-----------------------------------|
|            | 2015        | 2020        | 2015        | 2020        | 2015        | 2020        | 2015        | 2020        |
| 0-10       | 3.69        | 2.58        | 4.78        | 3.64        | 2.76        | 2.36        | 3.58        | 2.86        |
| 10-20      | 2.46        | 1.06        | 3.74        | 3.05        | 2.09        | 1.88        | 2.76        | 2.00        |
| 20-30      | 1.88        | 0.41        | 2.96        | 3.13        | 1.73        | 1.71        | 2.19        | 1.75        |
| 30-50      | 1.57        | 0.24        | 2.82        | 3.19        | 1.37        | 1.18        | 1.92        | 1.54        |
| 50-100     | 1.48        | 0.26        | /           | 2.55        | 1.35        | 0.84        | 1.42        | 1.22        |

As can be seen from table 3, in 2020 and 2015, the soil organic carbon content of different soil layers in Jiulianshan National Nature Reserve all decreased with the increase of soil depth. The average soil organic carbon content of each soil layer in 2020 (1.22%-2.86%) was lower than 2015 (1.42%-3.58%). The highest organic carbon content in each soil layer of the three subtropical evergreen broad-leaved forests was *Cyclobalanopsis glauca* in the investigation sample plots in 2020 and 2015.

3.5. Soil carbon density

The soil carbon density of three typical subtropical evergreen broad-leaved forests of *Cyclobalanopsis glauca*, *Schima superba* and *Castanopsis eyrei* in Jiulianshan National Nature Reserve in 2015 and 2020 was shown in table 4.

Table 4. Soil carbon density in 2015 and 2020

| Soil Layer | Castanopsis eyrei (t/hm²) | Cyclobalanopsis glauca (t/hm²) | Schima superba (t/hm²) | Average carbon density (t/hm²) |
|------------|--------------------------|-------------------------------|-----------------------|--------------------------------|
|            | 2015        | 2020        | 2015        | 2020        | 2015        | 2020        | 2015        | 2020        |
| 0-10       | 54.35       | 23.50       | 60.13       | 31.34       | 35.38       | 25.20       | 47.90       | 27.08       |
| 10-20      | 36.24       | 13.60       | 58.27       | 27.45       | 30.22       | 21.00       | 41.18       | 22.00       |
| 20-30      | 25.89       | 5.67        | 42.09       | 28.26       | 26.21       | 19.94       | 31.49       | 20.14       |
| 30-50      | 53.54       | 6.74        | 87.48       | 58.12       | 42.20       | 26.64       | 61.40       | 35.36       |
| 50-100     | 105.82      | 16.39       | /           | 132.86      | 105.17      | 48.93       | 106.07      | 63.44       |
| Total      | 275.83      | 65.92       | 247.97      | 278.03      | 239.18      | 141.72      | 288.05      | 168.03      |

It can be seen from table 4 that the average soil carbon density (calculated by 10cm) of the soil layers at different depths in the investigation sample plots of Jiulianshan National Nature Reserve in 2020 and 2015 all decreased with the increase of soil depth. That was consistent with the change in average soil organic carbon content. In general, the total soil carbon density (168.03t/hm²) of the three typical subtropical evergreen broad-leaved forests of *Cyclobalanopsis glauca*, *Schima superba* and *Castanopsis eyrei* in Jiulianshan National Nature Reserve in 2020 was lower than that of in 2015 (288.05t/hm²). It because that soil organic carbon content and soil bulk density in 2020 were all lower than that of in 2015. The total soil carbon density in 2015 (288.05t/hm²) was higher than the average carbon density of forest soil in China (193.55t/hm²) [9] while the total carbon density in 2020 (168.03t/hm²) was lower than its.

4. Investigation conclusions

According to the carbon density and the investigation sample area, the vegetation carbon storage and soil carbon storage of subtropical evergreen broad-leaved forest in Jiulianshan National Nature Reserve in 2015 and 2020 can be calculated, as shown in table 5 and table 6 respectively.
Table 5. Vegetation carbon storage in 2015 and 2020

|          | Castanopsis eyrei (kg) | Cyclobalanopsis glauca (kg) | Schima superba (kg) | Average carbon storage (kg) |
|----------|------------------------|-----------------------------|---------------------|-----------------------------|
|          | 2015 | 2020 | 2015 | 2020 | 2015 | 2020 | 2015 | 2020 |
| Arbor layer | 3401.60 | 5656.80 | 2086.40 | 1874.40 | 3645.60 | 5200.00 | 3044.40 | 4243.60 |
| Shrub layer | 193.60 | 123.60 | 175.20 | 57.20 | 88.00 | 24.80 | 152.40 | 68.40 |
| Herbaceous layer | 9.60 | 11.60 | 5.20 | 5.60 | 22.40 | 7.20 | 12.40 | 8.00 |
| Litter layer | 158.40 | 58.40 | 59.20 | 25.60 | 71.20 | 28.40 | 96.40 | 37.60 |
| Total | 3763.60 | 5849.60 | 2325.60 | 1962.80 | 3826.80 | 5260.40 | 3305.20 | 4357.60 |

As can be seen from table 5, in the vegetation layer of subtropical evergreen broad-leaved forest in Jiulianshan National Nature Reserve in 2015 and 2020, *Cyclobalanopsis glauca* had the smallest carbon storage. The average carbon storage of each vegetation layer was ranked as arbor layer, shrub layer, litter layer and herbaceous layer. The total vegetation layer carbon storage (4357.60kg) of the investigation sample in 2020 was 1.318 times that of 2015 (3305.20kg). It may mainly be due to the increase of the organic carbon content of the vegetation layer and the carbon storage of the arbor layer.

Table 6. Soil carbon storage in 2015 and 2020

|          | Castanopsis eyrei (kg) | Cyclobalanopsis glauca (kg) | Schima superba (kg) | Average carbon storage (kg) |
|----------|------------------------|-----------------------------|---------------------|-----------------------------|
|          | 2015 | 2020 | 2015 | 2020 | 2015 | 2020 | 2015 | 2020 |
| 0-10     | 2174.15 | 940.15 | 2405.30 | 1253.62 | 1415.33 | 1008.19 | 1998.26 | 1067.32 |
| 10-20    | 1449.43 | 543.99 | 2330.77 | 1098.00 | 1208.86 | 839.98 | 1663.02 | 827.33 |
| 20-30    | 1035.50 | 11.60 | 1683.65 | 1130.56 | 1048.38 | 797.54 | 1255.84 | 718.36 |
| 30-50    | 2141.48 | 269.76 | 3499.06 | 2324.87 | 1687.84 | 1065.78 | 2442.79 | 1220.14 |
| 50-100   | 4232.80 | 655.72 | / | 5314.20 | 4206.60 | 1957.20 | 2813.13 | 2642.37 |
| Total    | 11033.36 | 2636.60 | 9918.77 | 11121.24 | 9567.00 | 5668.70 | 10173.04 | 6475.51 |

It can be seen from table 6 that the average soil carbon storage of 10-100cm soil layers in the subtropical evergreen broad-leaved forest in Jiulianshan National Nature Reserve in 2020 (718.36-2642.37kg) were all lower than that of in 2015 (1255.84-2813.13kg). The total soil carbon storage (10173.04kg) of the investigation sample in 2015 was 1.57 times that of in 2020 (6475.51kg), which was mainly due to the decrease of soil bulk density and soil organic carbon content in 2020.

The forest carbon storage of the evergreen broad-leaved forest on the investigation plot in 2015 and 2020 can be obtained by adding the vegetation carbon storage and soil carbon storage of the subtropical evergreen broad-leaved forest in Jiulianshan National Nature Reserve, as shown in table 7.

Table 7. Forest carbon storage in 2015 and 2020

|          | Castanopsis eyrei (kg) | Cyclobalanopsis glauca (kg) | Schima superba (kg) | Sum of average carbon storage (kg) |
|----------|------------------------|-----------------------------|---------------------|-------------------------------------|
|          | 2015 | 2020 | 2015 | 2020 | 2015 | 2020 | 2015 | 2020 |
| Vegetation | 3763.60 | 5849.60 | 2325.60 | 1962.80 | 3826.80 | 5260.40 | 3305.20 | 4357.60 |
| Soil     | 11033.36 | 2636.60 | 9918.77 | 11121.24 | 9567.00 | 5668.70 | 10173.04 | 6475.51 |
| Forest   | 14986.96 | 7846.60 | 12488.37 | 14488.84 | 13838.2 | 9726.3 | 13771.04 | 10687.11 |

It can be seen from table 7 that the vegetation carbon storage of subtropical evergreen broad-leaved forest in Jiulianshan National Nature Reserve increased from 3305.20kg in 2015 to 4357.60kg in 2020,
however, the soil carbon storage decreased from 10137.04kg in 2015 to 6475.51kg in 2020, which resulted in a decrease of 22.38% in total forest carbon storage in 2020 (10688.11kg) compared with 2015 (13771.04kg).

In 2020, the total soil carbon storage of investigation sample plot in Jiulianshan National Nature Reserve was 3.08 times the total vegetation carbon storage, while it was 1.49 times in 2015. In general, the carbon density and carbon storage of forest vegetation are lower than those of forest soil, it because that the vegetation layer participated in the forest ecosystem carbon cycle process for a short time, the carbon in the vegetation entered the litter layer from the fallen leaves, and entered the soil layer under the action of soil microorganisms. The soil layer participates in the ecosystem carbon cycle process for a longer time. Usually, it needs to go through a certain chemical conditions before it can be converted into atmospheric carbon.

Acknowledgement
This study was financially supported by Key research and development program of Jiangxi province (grant number: 20181ACG70021).

References
[1] Juan Fan, Xiuhai Zhao and Jinsong Wang 2012 Acta Ecologica Sinica 32 2729-2737.
[2] Minfei Jian, Qijing Liu and Yuelong Liang 2008 Journal of Zhejiang A&F University 25 458-463.
[3] Qingfang Sun, Liming Jia and Yulong Liu 2016 Environmental Chemistry 35 1741-1744.
[4] Lei Deng, Zhou Ping and Shangguan 2011 Northwestern Journal of Botany 31 2310-2320
[5] Bin Li, Xi Fang and Yan Li 2015 Acta Ecologica Sinica 35 4265-4278.
[6] Seedre M, Kopáček J and Janda P 2015 Forest Ecology and Management 346 106-113.
[7] Domke G M, Woodall C W and Smith J E 2012 Forest Ecology and Management 270 108-116.
[8] Junyong Ma, Caiyun Cao and Chunlian Zheng 2010 China Soil and Fertilizer 6 38-42.
[9] Haikui Li, Yuancai Lei and Weisheng Zeng 2011 Forestry Science 47 7-12.