The Biomass Allocation Feature of Pine-oak Mixed Forest on the Xiaolong Mountain in Gansu Province

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Abstract. The composition of natural forest was relatively complex. The research of its biomass allocation could lay a foundation for the carbon storage study. The biomass allocation of pine-oak mixed forest in Xiaolong mountain was analyzed through plot survey. The average individual biomass of Quercus aliena var. acuteserrata, Pinus armandi, Pinus tabulaeformis, and broad-leaved tree species was 67.86±21.21kg, 104.58±61.02kg, 32.07±9.37kg, 30.05±9.19kg and the average individual volume was 0.08±0.02 m³, 0.11±0.06 m³, 0.05±0.02 m³, 0.03±0.01 m³. The biomass of tree layer for each tree species was 56.47±25.80 t/hm², 18.88±15.99 t/hm², 17.26±11.66 t/hm², 17.99±16.38 t/hm², and the average volume were 66.96±32.60 m³/hm², 19.47±16.44 m³/hm², 28.82±20.19 m³/hm², 22.82±15.61 m³/hm². The biomass among different organs in the same tree species and among different tree species in the same organ were significant differences. Taking the organ carbon content as 0.5, the carbon storage of each tree species was 28.24±12.9 t/hm², 9.44±7.99 t/hm², 8.63±5.83 t/hm², 8.99±8.19 t/hm², respectively.

1. Introduction

Forest biomass, which is the energy foundation and material source of the forest ecosystem, is the total plant organic matter in the forest. The biomass research can provide important data for further research on the forest structure and function, and is the basis for the regional forest carbon pool study and function evaluation of carbon sinks[1].

Xiaolong Mountain Nature Reserve is the most complete preservation of the original forest ecosystem areas in the warm temperate - subtropical region. However, since the middle of last century, because of the large-scale deforestation and destruction, the original forest area was plummeted. The Quercus aliena var. acuteserrata natural secondary forest became the most representative forest type in this region. Cheng et al(2007)[2] established the common tree species allometric equation in Xiaolong mountain and estimated the biomass of the major forest types in this region by the forest inventory data. In plot-scale, the biomass and carbon storage distribution of the Quercus aliena var. acuteserrata natural secondary forest ecosystem were researched. However, the associated tree species biomass distribution characteristics were ignored, such as pine and other broadleaf species. In this study, the...
The biomass distribution feature of main tree species in this region was analysed through plot investigation, which could be benefit for the future estimation on the forest ecosystem carbon storage in this region. It would also provide theoretical foundation for the evaluation of forest carbon sink.

2. Material and Method
The Xiaolong mountain is located in the southeast of Gansu province, west part of Qilian mountain. This site is in the transitional region between the warm temperate and northern subtropical zones, and has a mainland monsoon type climate. Annual average temperature is 7-12°C, and the annual rainfall is 460-900mm, about approximately 70–80% of which occurs between July and September. Annual evaporation is 989–1658 mm, and relative humidity is 68–78%. It contains more than 30 tree species in the pine-oak mixed natural secondary forest, such as Quercus aliena var. acuteserrata, Pinus armandi, Pinus tabulaeformis, Lauraceae. obtusiloba Bl, Deyeuxia langsdorffii, Ulmus pumila, Tilia tuan Szyszyl, Betula platyphylla, and so on.

We established 5 plots in the pine-oak mixed forest, three 400m², one 900 m², and one 2500m². We investigated the tree species with DBH≥5cm, and recorded essential information, such as the DBH, tree height, canopy and so on. The basic information of these plots was showed in table 1.

Table 1. The basic parameters of the five plots

| plots | DBH (cm) | Tree height (m) | density (trees/hm²) |
|-------|----------|----------------|---------------------|
|       | range    | mean          | range   | mean   |                     |
| 1     | 5-29     | 11.1          | 5.8-15.6 | 10.5   | 2125                |
| 2     | 5-37.8   | 10.03         | 4-16.9  | 9.21   | 1575                |
| 3     | 5-20     | 10.2          | 4.9-13.8 | 10.0   | 2650                |
| 4     | 5-29     | 11.2          | 4.4-16.2 | 10.8   | 2144                |
| 5     | 5-27.3   | 10.1          | 4.0-17.5 | 10.5   | 3092                |

The plant organs biomass was calculated according to the allometric growth equation of different tree species. The plant biomass was the summation of each organ biomass. The plot biomass was the summation of all the plant biomass in the plot. Then convert it to the biomass per unit area. Forest growth equations of different tree species were shown in table 2. In this paper, QA, PA, PT, BL stand for Quercus aliena var. acuteserrata, Pinus armandi, Pinus tabulaeformis, and broad-leaved tree species, respectively.

Table 2. Forest growth equations of different tree species

| Tree species organs | lnw=a+blnD | r   |
|---------------------|------------|-----|
| QA                  |            |     |
| stem                | -2.9678    | 0.9851 |
| branch              | -7.0805    | 0.9652 |
| leaf                | -7.1844    | 0.9379 |
| fur                 | -3.6377    | 0.9660 |
| root                | -2.8660    | 0.9964 |
| total               | -2.5070    | 0.986 |
|          |           |     |
| PT                   |            |     |
| stem                | -2.8101    | 0.9919 |
| branch              | -5.1822    | 0.9893 |
| leaf                | -4.4174    | 0.9603 |
| fur                 | -4.1587    | 0.9878 |
| root                | -4.0294    | 0.9820 |
| total               | -2.4587    | 0.9920 |
|          |           |     |
| PA                   |            |     |
| stem                | -3.1480    | 0.9872 |
| branch              | -3.6496    | 0.9682 |
| leaf                | -4.4190    | 0.9730 |
The calculation of volume was similar to biomass. The plant volume was calculated according to the monadic formula of volume. The plot volume is the summation of all the plant volume in the plot. The main tree volume formulas were showed in table 3. The average volume for individual tree was the ratio of total volume and strains.

| Tree species | Volume formula |
|--------------|----------------|
| PA           | \( V=1.485 \times 10^{-4}D^1.852486H^0.538748 \) |
| QA           | \( V=6.0970532 \times 10^{-5}D^1.8735078H^0.94157465 \) |
| PT           | \( V=6.0970532 \times 10^{-5}D^1.8735078H^0.94157465 \) |
| BL           | \( V=5.7887451 \times 10^{-5}H^1.8445849H^0.98088457 \) |

Data were statistically analyzed using procedures of SPSS (v. 13.0), and the accepted significance level was \( \alpha=0.05 \). A one-way analysis of variance (one-way ANOVA) was conducted for testing the significant difference among different organs in the same tree species and the significant difference among different tree species in the same organ. If the sample variance is homogeneity, the one-way ANOVA method could be used directly, otherwise the logarithmic transformation could be used to make the data reach the homogeneity of variance, and then to analysis the variance.

### 3. Result and discussion

For individuals, the organ biomass of different tree species had significant difference (Pinus armandi<0.05, Pother tree species<0.01). The stem and branch biomass of Pinus armandi was significant larger than the leaf and fur biomass. There was significant difference in the biomass among stem, branch, leaves, fur and root for the Quercus. The order is: stem> root> fur> leaf. The branch biomass had no significant difference with the root and fur biomass, but significant lower than the stem biomass and higher than the leaf biomass. The biomass distribution characteristics of Pinus and other broad-leaved tree species were relatively similar. The stem biomass was significant higher than the root and branch biomass, and the leaf and fur biomass was significant lower than the root and branch biomass. The root and branch biomass had no significant different, and the leaf and fur biomass were also the same.

The biomass allocation characteristics varied in the same organ among different tree species. The stem biomass had no significant difference among different tree species (\( P=0.190 \)), but for the stem and total biomass, the difference is significant (\( P<0.05 \)), and the branch, fur, and leaf biomass was extremely difference (\( P<0.01 \)). Specifically, the stem and fur biomass of Pinus armandi and Quercus was significant higher than that of Pinus tabulaeformis and broad-leaved tree species. The branch biomass of Pinus armandi was significant higher than the other three tree species, but among which, there was no significant difference. The leaf biomass of Pinus armandi was significant higher than that of Quercus. Multiple comparison results showed in Table 4.
Table 4. The biomass allocation characteristics of different tree species for individuals (kg)

| Tree species | leaf (kg)       | branch (kg)    | stem (kg)      | fur (kg)       | root (kg)      | total (kg)     |
|--------------|----------------|----------------|----------------|----------------|----------------|----------------|
| PA           | 4.49±2.45Ba    | 28.2±16.39Aa   | 49.39±28.79Aa  | 6.14±3.32Ba    | 16.35±10.28A Ba| 104.58±61.02a  |
| QA           | 0.99±0.34Dc    | 9.27±4.00BCb   | 37.57±11.69Aa  | 7.46±1.99Ca    | 12.57±3.21Ba   | 67.86±21.21ab  |
| PT           | 2.44±0.69Cab   | 5.53±1.76Bb    | 15.86±4.57Ab   | 2.69±0.74Cb    | 5.54±1.62Ba    | 32.07±9.37bc   |
| BL           | 1.42±0.32Cbc   | 5.39±2.00Bb    | 14.65±4.68Ab   | 1.85±0.46Cb    | 6.74±1.76Ba    | 30.05±9.19c    |

Note: Different capital letters meant significant difference among different organs for the same tree species at 0.05 level, and different small letters meant significant difference among different tree species for the same organ at 0.05 level.

The stem biomass of Pinus armandi was significantly higher than the leaf biomass, and there was no significant difference among branch, fur, and root biomass. The stem biomass of Quercus was significantly higher than the branch, fur, and root biomass, and the leaf biomass was lowest. The stem biomass of Pinus tabulaeformis was significantly higher than branch and root biomass, which were significantly higher than fur and leaf biomass. The stem, branch, and root biomass of broad-leaved tree species was significantly higher than leaf and fur biomass.

Table 5. The tree layer biomass allocation characteristics of different tree species (t/hm²)

| Tree species | Leaf (t/hm²) | Branch (t/hm²) | Stem (t/hm²) | Fur (t/hm²) | Root (t/hm²) | Total (t/hm²) |
|--------------|--------------|----------------|--------------|-------------|--------------|---------------|
| PA           | 0.81±0.68Ba  | 5.09±4.32ABa   | 8.92±7.58Ab  | 1.10±0.93Ab  | 2.96±2.50Ab  | 18.88±15.99b  |
| QA           | 0.82±0.37Ca  | 7.39±3.45Ba    | 31.29±14.32Aa| 6.30±2.92Ba  | 10.67±4.96Ba | 56.47±25.80a  |
| PT           | 1.32±0.89Ca  | 2.96±2.00Ba    | 8.54±5.78Ab  | 1.45±0.98Cb  | 2.98±2.02Bb  | 17.26±11.66b  |
| BL           | 0.83±0.68Ba  | 3.30±3.21Aa    | 8.80±8.13Ab  | 1.09±0.92Bb  | 3.97±3.44Ab  | 17.99±16.38b  |

Note: Different capital letters meant significant difference among different organs for the same tree species at 0.05 level, and different small letters meant significant difference among different tree species for the same organ at 0.05 level.

The organ biomass varied among different tree species in the tree layer. The leaf and branch biomass of different tree species had no significant difference (P<0.584; Pbranch=0.181), but the stem, fur, and root biomass were significant difference (P<0.01). The stem, root, and fur biomass of Quercus were significantly higher than the other three tree species. The tree density, volume, and total biomass were also significant differences. Specifically, the tree density of Quercus and broad-leaved tree species were significant higher than that of Pinus armandi, and the density of Pinus tabulaeformis had no significant difference with the other three tree species. The density difference will affect the biomass and volume directly. The biomass and volume of Quercus were significant higher than that of the other three tree species. Multiple comparison results showed in Table 5, 6.

Table 6. The density and volume of different tree species.

| Tree species | Density (tree/hm²) | Tree layer volume (m³/hm²) | Individual volume (m³/hm²) |
|--------------|--------------------|-----------------------------|-----------------------------|
| PA           | 161±97b            | 19.47±16.44b                | 0.11±0.06a                  |
Biomass allocation patterns, which on the one hand reflects the plant adaptation to the environment, but also play an important role in the global climate change research, namely the biomass distribution in different organs (branch, leaf, stem, root), is a basic problem in ecology [5-8]. In this study, for the individuals, the order of total biomass was as following: Pinus armandi > Quercus > Pinus tabulaeformis > broad-leaved tree species. This order was similar with that of stand average DBH. Ground - underground biomass allocation patterns could affect the functional performance of individuals and populations [9-11]. In this research, the order of Ground - underground biomass ratio was as following: Pinus armandi > Pinus tabulaeformis > Quercus > broad-leaved tree species. The conifer tree species were greater than the hardwood species, which reflected the adaptations of different plant to the environment. From the proportion of different organs, stem biomass had the largest share, each species was about 50%. Followed by branch and root biomass, the proportion was between 13% - 26%, and the leaf and fur shared the smallest proportion in the range of 1.4% - 11.1%. Similar with other studies, the organs with higher wood fiber content, such as the stem, root and branch, had a larger proportion of the total biomass.

Note: Different small letters meant significant difference among different tree species at 0.05 level.

Fig1. The biomass and volume allocation features of different tree species.
Scale is one of the most complexity problems in ecology. Pushing some individual features to community or ecosystem level is one of the core issues in ecology. If this push is feasible, it will accelerate the integration of ecological disciplines[12]. In this paper, we calculated the tree layer biomass of each species through the single tree biomass (showed in Tab.5). Because of the density various, the tree layer biomass of each tree species was difference with that of individuals. The tree layer biomass of Quercus was significant higher than other tree species. The proportion of different organs for tree layer was the same with individuals. The forest biomass is important parameter to calculate the carbon stock. In this study, according to the international general transformation parameters(0.5), the tree layer carbon storage of Pinus armandi, Quercus, Pinus tabulaeformis and broad-leaved tree species were 9.44±7.99t/hm², 28.24±12.9t/hm², 8.63±5.83t/hm², 8.99±8.19t/hm², respectively.

4.Conclusions

The results of the study infer the following conclusions:

(1) The average individual biomass of Quercus aliena var. acuteserrata, Pinus armandi, Pinus tabulaeformis, and broad-leaved tree species on the Xiaolong Mountain in Gansu Province was 67.86±21.21kg, 104.58±61.02kg, 32.07± 9.37kg, 30.05± 9.19kg and the average individual volume was 0.08±0.02 m³, 0.11±0.06 m³, 0.05±0.02 m³, 0.03±0.01 m³

(2)The biomass of tree layer for each tree species was 56.47 ±25.80t/hm², 18.88±15.99 t/hm², 17.26±11.66 t/hm², 17.99±16.38 t/hm², and the average volume was 66.96±32.60m³/hm², 19.47±16.44 m³/hm², 28.82±20.19 m³/hm², 22.82±15.61 m³/hm².

(3) The biomass among different organs in the same tree species and among different tree species in the same organ were significant differences.

(4) Taking the organ carbon content as 0.5, the carbon storage of each tree species was 28.24±12.9t/hm², 9.44±7.99t/hm², 8.63±5.83t/hm², 8.99±8.19t/hm².

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