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# Distribution characteristics and factors influencing the ecosystem in western Hubei☆

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ABSTRACT

Western Hubei is the most concentrated area of forest resources in Hubei Province, and the knowledge of the distribution characteristics of ecosystem carbon density is important to understand the regional characteristics of carbon density and its mechanism of formation. Carbon density and factors influencing different layers in the ecosystem were studied by using field data. The average carbon density of ecosystems in western Hubei was 159.05 t/hm$^2$; the carbon density of different forest types in descending order was *Abies fargesii* forests (362.25 t/hm$^2$), mixed broadleaf-conifer forests (154.13 t/hm$^2$), broad-leaved forests (146.09 t/hm$^2$), and coniferous forests (135.76 t/hm$^2$), and ecosystem carbon density increased with increasing age. The carbon density of the arborous layer, shrub layer, and soil layer of *A. fargesii* forests was significant higher than that of the other forests ($P < 0.05$), indicating the carbon storage per unit area of *A. fargesii* forests, which grow at higher elevations, was the greatest. The carbon density in arborous layers of broad-leaved forests, mixed broadleaf-conifer forests, and coniferous forests was 39.29 t/hm$^2$, 48.99 t/hm$^2$, and 48.39 t/hm$^2$, respectively. Those of the soil layer were 102.96 t/hm$^2$, 100.97 t/hm$^2$, and 82.37 t/hm$^2$, respectively, and there were no significant differences among them. Among the three forest types, carbon density in the litter layer was greater than that of the shrub layer, which indicated the litter layer plays an important role in carbon storage. The carbon density of mixed broadleaf-conifer forests was greatest, excluding *A. fargesii* forests, in medium (58.71 t/hm$^2$) and mature forests (79.66 t/hm$^2$). Thus, the carbon sink of mixed broadleaf-conifer forests had more potential than the others at the medium and mature forest stage. The soil layer carbon density in different forests constituted 60.67—70.48% of the entire ecosystem, and was 1.70—2.62 times greater than that of the arborous layer. There are many factors influencing ecosystem carbon density, which result from the interaction of environmental and topographical factors. The main explanatory variables of carbon density of the region were altitude, precipitation, and canopy density. The vegetation and soil layer carbon density increased as altitude increased, and the rate of change for every vertical 100 m was 1.3 t/hm$^2$ and 1.9 t/hm$^2$, respectively ($P < 0.05$). Although the annual average precipitation only affected the carbon density of the vegetation, it increased to 4 t/hm$^2$ ($P < 0.01$) when average precipitation was >100 mm.



## 1. Introduction

Forests are the main component of terrestrial ecosystem, with whose carbon storage accounting for 82%–86% [1] of the carbon pools on the ground and 40% [2] of the below-ground carbon pools, which play an irreplaceable role in the global climate change, regulating carbon balance and slowing down the greenhouse effects. Therefore, evaluation the forest ecosystem carbon distribution pattern and its influence factors is very important to understand the ecosystem carbon distribution and develop forest management practices for improving forest quality.

There are lots researches about forest ecosystem carbon density [3–8], but the results vary from each other because of the difference of evaluating methods, underlying data [9] and the spatial and temporal heterogeneity [10]. The forest ecosystem carbon density changes with the years of implement of returning farmland to forests, forest conservation policy, hence, it is significant to evaluate the forest ecosystem carbon density accurately based on the field data. As so far, provinces such as Shanxi (123.7 t/hm$^2$), Zhejiang (120.8 t/hm$^2$), Hubei (111.51 t/hm$^2$) and Neimenggu (184.5 t/hm$^2$) have took provincial districts as units to carry out studies with field data [9,11–13]. In this study, we took western Hubei as the study area, employed temperature, relative humidity and precipitation as meteorological factors for the first time,

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and along with other topography factors to figure out the carbon density characteristics and formation mechanism, which was important for the relevance of carbon density characteristics and providing reference for protection and utilization of forest resources.

Western Hubei is the most concentrated areas of forest resources in Hubei, and the top of Shennongjia area is the highest point in subtropical region in China, which is very sensitive to the climate change, so, the responses to global climate change in this region could reflect to some extent how the subtropical forest vegetation in China tackles the global climate change. Based on the sixth Review outcome data of continuous forest inventory in Hubei Province, with measured field data, we studied the carbon density of different layers in different forest types, and explored the influence factors.

## 2. Materials and methods

### 2.1. General situation

Western Hubei is constituted with the cities of Shiyan, Shennongjia, Enshi, Xiangyang and Yichang, 108°23′12″—113°43′00″E,29°07′10″—33°15′29″N,and the total area is about $9.19 \times 10^4$ km$^2$. The annual average temperature ranges from 15 °C to 17 °C, and the annual precipitation is 800—1600 mm, and this area belongs to subtropical monsoon climate zone. Average altitude is about 1000 m, and the highest top is located in Shennongding, which reaches 3105 m. Red soil, yellow brown soil, mountain yellow brown soil and mountain brown soil are the main soil types in this area. The vegetation types are rich, broadleaf evergreen trees mainly cotain *Cinnamomum camphora* and *Phoebe Nees*, while deciduous trees mainly include *Quercus variabilis*, *Castanea seguinii*, *Quercus aliena Bl.* var. *acuteserrata Maxim. ex Wenz.*, *Betula albosinensis*, *Populus davidiana*, *Carpinus turczaninowii*, *Sassafras tzumu*, *Platycarya strobilacea*, and Coniferous trees mainly include *Pinus massoniana*, *Cunninghamia lanceolata*, *Pinus armandii*, *Abies fargesii*.

### 2.2. Research methods

#### 2.2.1. Field measurement

Based on the 2009 6th review of outcome data on inventories of forest resources in Hubei Province, we investigated 3 forest types included mixed broadleaf-conifer, broadleaf and coniferous forests with knowing the distribution of forest resources in the Qinling Mountains eastward extension, Wudang mountain, Daba mountain eastward, the three gorges and Jingshan Mountain. Age group information was obtained from local history documents, and was divided by: <40a was for young forests, 41-60a was for middle age forests, and >60 was for the mature forest. 87 standard samples were set in total, as shown in Fig. 1 (GCS_WGS1984 projected coordinate system), in which Shiyan contained 22, Enshi contained 15, Shennongjia contained 11, Xiangyang contained 14 and Yichang contained 25, specific information was as shown in Table 1.

The plots area were 25.8 m × 25.8 m, the sample survey were carried on the tree layer, shrub layer, litter layer, and soil layers, respectively. The tree layer surveyed all the trees whose diameter at breast height (DBH) is up to 5 cm and also recorded the DBH, tree height and species information. 3 shrub samples of 2 m × 2 m were randomly set along the two diagonal in the standard samples, and record all the young trees with whose DBH did not reach 5 cm, epithet, and strains (bundle) number, and crown diameter, and cover degrees, height and stems, after that, selected 3 average size of shrubs (if insufficient 3 strains then selected all) or 1–2 bundle, used full strains harvest method [14], weighed all the fresh heavy organ and took the mixed samplings indoor for the containing water rate determination. In each shrub sample, we selected a small sample of 1 × 1 m to investigate the litter layer, recorded the thickness and collect all litter within the quadrat, including branches, leaves and fruits, weighing fresh banding and then drying them to get dry weight. Soil profiles were digging in every standard sample, and got cutting ring samples in the layers of 0–10, 10–30 cm and 30–100 cm, and took about 1 kg soil samples in each profiles, at the same time, the type of soil and gravel content were recorded, at last, samples were bought back to the interior, to measure the soil bulk density and soil organic carbon [15].

#### 2.2.2. The calculation of vegetation carbon density

Based on the volume formula of Hubei province, tree volume was calculated with field data, and then biomass volume was calculated by using the method of biomass models provided by IPCC [16].

$$B = V_g \mathrm{D_g} \mathrm{BEF_g}(\mathrm{R}+1)$$

In the formula, $V_g$ is the forest stock volume (m$^3$), $\mathrm{D_g}$ is the average wood density (t/m$^3$), $\mathrm{BEF_g}$ is the average biomass expansion factor, R is the root shoot ratio. The parameters for different forest types are given by the People's Republic of China initial national communications on climate change [17].

Drying all the shrub and litter sample at 80 °C to constant weight, then combine the fresh weight with dry weight, total fresh weight of sample and sample area, calculating the total dry weight within the quadrat, biomass. Using the biomass per unit area multiply by the conversion factor 0.5 [18–19] to get the carbon stock per unit area, which is the density. Vegetation carbon density is the sum of arborous layer, the shrub layer and the litter layer carbon density.

#### 2.2.3. The calculation of soil carbon density

The formula to calculate soil carbon density is as follows:

$$SOC = \sum_{i=1}^{n} C_i D_i E_i (1-G_i)/10$$

In the formula, $C_i$, and $D_i$, and $E_i$ and $G_i$ representing the i-layer soil organic carbon content (g/kg), soil bulk density (g/cm$^3$), soil thickness (cm) and gravel content (%) that diameter ≥2 mm. Soil organic carbon content is measured by the method of potassium dichromate sulfuric acid oxidation. Ecosystem carbon density is the sum of all the layers'.

#### 2.2.4. The collection and processing of meteorological data

Average annual temperature, annual precipitation and average annual relative humidity data were collected from the Chinese weather data network access for 30-year from 1981–2010a, within Western Hubei and along with the sites located in Henan, Hunan, Chongqing, Shaanxi where were surrounding western Hubei, 72 site data were collected in total. Digital elevation model (DEM) were downloaded data from the NASA website. Ordinary kriging interpolation method based on DEM [20] was employed to calculate average annual temperature, and the ordinary kriging interpolation method was hired to calculate the annual precipitation and relative humidity, then processed the interact validation, the accuracy of average annual temperature, annual precipitation and relative humidity is 89.21%, 96.34% and 98.36%, respectively, which met the needs of this study. At last, extracted all the sites meteorological data by use their corresponded coordinate, and all data processing above were done in the ArcGIS 10.2.

#### 2.2.5. Correlation analysis and regression

Basic data statistics was done in Excel, correlation and multiple regression were completed in SPSS 22.0. According to the results of multiple regression, and considering the actual number of samples, annual precipitation range was divided into 7 levels with the interval of 100 mm, altitude range was divided into 8 levels with the interval of 200–500 mm, and canopy density was divided into 5 levels by the interval of 0.1. Calculated vegetation and soil layer carbon density, respectively, linear fitting and mapping were completed in Origin 8.0.