Estimation of carbon storage and carbon density of forest vegetation in Ili River Valley, Xinjiang

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Abstract. Study on the forest carbon storage, carbon density and spatial distribution characteristic are helpful for improving the accuracy of carbon estimation and providing the practical basis for better policy making. In this research, the compiled data of 'Xinjiang Forest Resources Survey Results' in 2011 was used as a source data, by using the biomass-volume regression model and average biomass method, the carbon storage, carbon density and spatial distribution of forest resources in Ili River Valley region were analyzed. Results show that, the total biomass, carbon storage and average carbon density in Ili River valley were 69.647Tg, 34.823Tg and 41.45Mg/hm²C respectively. From the aspect of spatial distribution, the northwest region of Ili River Valley has high carbon storage and the southeast region has low carbon storage. The southwest region has low carbon density and the northeast region has high carbon density. The value of forest Carbon storage from high to low was: Arbor > Shrub > Sparse forest > Odd tree > Economic forest > Scattered trees. Mature arbor forest plays an important role in maintaining the balance of carbon dioxide and oxygen in Ili River Valley region.

1. Introduction

Forests compose a major part of terrestrial ecosystems, occupying about 30% of the world’s land area [1]. It is estimated that over 80% of global above ground carbon (C) is stored in forest vegetation [2], and the annual C flux between forests and the atmosphere through photosynthesis and respiration is up to 90% of the total annual flux of terrestrial ecosystems [3]. Owing to their huge C pool and high productivity, forest ecosystems play a leading role in the global C cycle [4]. Therefore, estimating carbon storage in forest ecosystems and evaluating their carbon sink capacities have been the focus of numerous studies. For example, the C storage of forest ecosystems has been estimated in the United States [5], Russia [6], China [7], and Europe [8, 9] based on forest inventory data.

Forest inventory data are valuable resources in forest carbon research because they provide true ground-based estimates of C stock and fluxes across heterogeneous regions, and are statistically representative of land-use change and disturbance [10, 11]. Thus, the forest inventory method has been used to evaluate C storage and its dynamics in forest vegetation in China [12-16] summarized C storage estimates for Chinese terrestrial ecosystems in these studies. Overall, the C storage estimation of forests in China differ substantially. The differences among estimates were partially caused by the differences in geography, vegetation, soil type boundaries, data measurement and use [17].

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The Ili River valley, where the forest cover rate is 7.9% and the vegetation cover rate of forest and grass is up to 67.7%, is a region with the most humid climate, the most abundant precipitation, and the most developed vegetation and soil in the Xinjiang and Tianshan regions and is regarded as a “wet island” and biotic resource storehouse in an arid region. There are some studies in which data from the Second National Soil Survey was used to estimate the soil organic carbon reserve in the Ili region [18], but there are few studies on the carbon cycle in forest ecosystems in the Ili River valley [19]. Therefore, in this study, based on the Forest Resource Inventory Data of Xinjiang (2011), we aimed to estimate forest vegetation carbon stocks and carbon density in Ili River valley by using the biomass and volume regression model and the average biomass method. In order to lay a foundation for further studies on a regional-scale forest vegetation carbon cycle.

2. Study area
The Ili River valley of Xinjiang, China is located in the westernmost part of the Tianshan Mountains in Xinjiang and on the south western edge of the Jungghar Basin. It is an inland continental river basin in the Central Asia region with fault basins and inter mountain valleys distributed alternately, and is isolated by the southern Tianshan Mountain and the northern Tianshan Mountain. The Ili River valley is located between 80°09′42″E–84°56′56″E and 42°14′16″N–44°50′30″N, its northern, eastern and southern sides are surrounded by high mountains, and the terrain here slopes from east to west and narrows from west to east, like a bell mouth facing westward. The average annual precipitation ranges from 200 mm to 800 mm, and the rainfall mainly occurs in spring and summer, when approximately 60%–70% of the total annual precipitation occurs. The average annual evaporation is 1260–1900 mm. The average annual temperature is 2.9–9.1°C. The frost-free period is 130–180 days. The average annual sunshine duration ranges 2700–3000 hours [18].

![Figure 1. Administration map of the study area](image_url)
The forest inventory data of Ili river valley was parts of the compiled data of 'Xinjiang Forest Resources Survey Results' in 2011, the data sets composed both in county (city) and the forest farm as a unit (including 9 counties (cities), nine forest farm): Ghulja city, Qapqal county, Tokkuztara County, Qorghas county, Nilka county, Tekes county, Kunas county, Mungghulkure county, Ghulja county; Forest farms are include: Kunas forest farm, qapqal forest farm, Tokkuztara forest farm, Qorghas forest farm, Mengmala forest farm, Nilka forest farm, Tekes forest farm, Ili forest farms, Mungghulkure forest farm , etc. The contents include detailed information relates to the forest type (species and origin), area, volume, extent, age class, etc. Due to the forest inventory data are not include the herb layer, litter layer, soil data, therefore, in this research only calculated the forest vegetation carbon storage.

3.2. Carbon storage calculation
The biomass of forest stands was calculated using the continuous biomass expansion factor (CBEF) method [7, 21]:

\[ B = a \cdot V + b \]  \hspace{1cm} (1)

Where B is the total stand biomass (Mg ha⁻¹); V is the stand volume (m³ha⁻¹), a and b are the coefficients for a specific forest type. During the calculation, for some specific trees which no significant correspondence between the parameters of the model, parameters were substituted by the approximate tree types in the local area [22]. The specific conversion parameters are shown in Table 1. The fraction of carbon in biomass is assumed to be 0.5 for all forest types, although it varies slightly for different forests [20].

**Table 1. Volume-biomass regression parameters of different type**

| Forest type                      | Volume-biomass regression parameters | references |
|----------------------------------|--------------------------------------|------------|
| Arboreal forest                  | B = 0.5751V + 38.706                 | [21]       |
| Shrubs                           | B = 12.49                            | [22, 23]   |
| Economic forest                  | B = 23.7                             | [23]       |
| Sparse forest                    | B = 0.5751V + 38.706                 | [21, 23]   |
| Mixed broad leaf-conifer forest  | B = 0.8119V + 12.2799                | [21, 23]   |
| Poplar /Odd-tree                 | B = 0.6255V + 91.0013                | [22]       |

4. Results and discussion

4.1. Carbon storage of different forest types
Forest vegetation total biomass and carbon storage were 69.647Tg and 34.823Tg C in Ili river valley based on our estimates, and varied largely for different forest types (Table 2). Among all the forest types, the Arboreal forest and Shrubs have the larger proportions, the total biomass were 62.794Tg and 2.813Tg respectively; the carbon storage were 31.397Tg and 1.406Tg respectively. The total biomass and carbon storage Sparse forest have the smaller proportion, about 0.18Tg and 0.09Tg respectively. The proportional order of different forest type’s carbon storage were: Arboreal forest > Shrubs > Sparse forest > Odd tree > Economical forest > Scattered forest, accounting for 90.16% 、4.04% 、3.64% 、1.44% 、0.46% and 0.26% of the total carbon storage. It can be inferred that, among the forest
vegetation in this region, arbor and shrub plays an important role in fixing carbon dioxide and release oxygen in the air, which maintains regional carbon and oxygen balance in this region.

The carbon density of forest vegetation in Ili river valley was 41.45 Mg/hm$^2$, higher than the average Chinese forest vegetation carbon density 41.32 Mg/hm$^2$ [23]. Distribution of carbon density among different forest types were uneven, sorting them from the high to low were as follows: arbor > odd trees > scattered tree > sparse forest > economic forest > shrub. The carbon density of arbor and odd were 78.95 Mg/hm$^2$ and 75.85 Mg/hm$^2$, shrub and economic forest have the lower carbon density, about 6.24 Mg/hm$^2$ and 11.87 Mg/hm$^2$ respectively.

|                | Arbor (hm$^2$) | shrub | economic forest | scattered tree | sparse forest | odd trees | Total   |
|----------------|---------------|-------|-----------------|----------------|---------------|-----------|---------|
| A (hm$^2$)     | 397693        | 225212| 13557           | 2027           | 40400         | 6592      | 685483  |
| P (%)          | 58.02         | 32.85 | 1.98            | 0.3            | 5.89          | 0.96      |         |
| B (Tg)         | 62.794        | 2.813 | 0.321           | 0.18           | 2.538         | 1.001     | 69.647  |
| C (Tg)         | 31.397        | 1.406 | 0.161           | 0.09           | 1.269         | 0.51      | 34.824  |
| P (%)          | 90.16         | 4.04  | 0.46            | 0.26           | 3.64          | 1.44      |         |
| D (Mg/hm$^2$)  | 78.95         | 6.24  | 11.87           | 44.40          | 31.41         | 75.85     | 41.45(AV)|

Note: A stands for area, B stands for Biomass, C stands for carbon storage, D stands for carbon density, P stands for proportion, AV stands for Average.

4.2. Spatial distribution analysis of carbon storage and density

The distribution of carbon storage and density for different sub-regions in Ili river valley were unevenness. It can be inferred from the Figure 2 that, the Tekes forest farm have the highest carbon storage of 7.613 Tg, accounted for 21.86% of total carbon in the study area; while the Ghulja city have the smallest carbon storage of 0.116 Tg, accounted for 0.33% of total carbon in the study area. The Tokkuztara forest farm have the largest carbon density of 88.8 Mg/hm$^2$, followed by the Kunas forest farm (63.6 Mg/hm$^2$), Tekes forest farm (60.4 Mg/hm$^2$), Mungghulkure county have the smallest carbon density of 19.9 Mg/hm$^2$ (Figure 3). Carbon density can reflect the quality of the forest, hence the quality of forest resources in Tokkuztara forest farm better than other counties, cities and forest farms in Ili river valley.
5. Conclusion
In this research, based on forest inventory data, the forest carbon storage and carbon density were successfully calculated by using the volume-biomass method. The result shows that total carbon storage and average carbon density of Ili River Valley were 34.823Tg and 41.45Mg/hm$^2$, respectively. Arbor and shrubs are the main sources of carbon storage which occupies 90.16% and 4.04% of the total carbon storage in this region. Further investigations are needed for calculating the blow ground carbon storage and analyzing the carbon storage of different forest age classes and their spatial distributions.

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