Carbon storage in vegetation and soil in Chinese ecosystems estimated by carbon transfer rate method

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Abstract. Terrestrial carbon storage is split predominantly between vegetation and soils. However, the spatial distribution of terrestrial carbon and its presence in each carbon pool remains unclear. This study explored the spatial distribution of terrestrial carbon in these two carbon pools across Chinese ecosystems, which differ in vegetation types. Carbon storage was estimated using the carbon transfer rate method, which uses net primary productivity (NPP) and the turnover rate to estimate vegetation and soil carbon pools under the assumption of steady state. The distribution of carbon storage per unit area (carbon density) was shown based on the latest vegetation map (2008). Compared with recent estimates of 89.27 Pg C, our results showed that a total of only 55.46 Pg C have been stored over recent decades. Of this total, 18.19 and 37.27 Pg C were stored, respectively, in vegetation and in soil carbon pools. Among the eleven vegetation types in this study, needleleaf forest had the largest carbon storage (13.57 Pg C). The eleven vegetation types were classified into four major vegetation classes (forest, scrub, grass, and cultivated), of which forests had the higher carbon storage (21.7 Pg C) and the highest carbon density. Our estimates of the spatial distribution of carbon were consistent with previous studies. Both terrestrial and soil carbon pools exhibited higher carbon density in northeast China and the southeastern part of the Tibetan Plateau. Vegetation exhibited a high carbon density in eastern China but low carbon density in western China. Furthermore, our results had a higher spatial resolution of carbon distribution (75,000 polygon patches of the latest vegetation map) than previous studies. These results contribute to understanding carbon accumulation in different ecosystems.

Key words: carbon density; carbon storage; soil carbon pool; vegetation carbon pool; vegetation ecosystems.

INTRODUCTION

Terrestrial carbon storage is one component of the global carbon cycle, and it is often used in policymaking decisions to control CO2 emissions (Zhang et al. 2011). Terrestrial carbon storage has two important carbon pools, the vegetation carbon pool and the soil carbon pool (Li et al. 2007). Quantification of terrestrial carbon in each of these carbon pools is important for assessing carbon budgets and for predicting ecosystem carbon response to climate change (Fang et al. 2007, Peng et al. 2009). Both vegetation and soil carbon pools have relatively stable carbon storage (Yang et al. 2010, Fang 2011), even though carbon is continuously moving between among vegetation, soil, and the atmosphere (Dixon et al. 1994, Wang et al. 2001).

Carbon storage in vegetation and soil in China has been quantified based on inventory data, remote sensing data, and models, but these methods have not agreed on how much carbon is
stored in terrestrial ecosystems in China (Xu et al. 2018). For example, Peng and Apps (1997) estimated the total terrestrial carbon storage to be 157.9 Pg C (57.9 Pg C in vegetation and 100 Pg C in soil) in China by using the Osnabrück biosphere model. However, their result was calculated from only nine potential vegetation types and relatively sparse grids (0.5° × 0.5°). Using different spatial resolutions (10° × 10° grid, 20° × 20° grid and 30° × 30° grid) can lead to different estimates of carbon storage (Ni 2001). Using the median resolution (20° × 20° grid), the carbon storage in terrestrial ecosystems in China was estimated to be 154.99 Pg C, of which 35.23 Pg C was in biomass, and 119.76 Pg C was in soil (Ni 2001). However, the carbon storage was derived from a global average carbon density rather than a carbon density specific to China. Based on literature published between 2004 and 2014, the average carbon storage in China’s terrestrial ecosystems was estimated to be 99.15 ± 8.71 Pg C in total, with 14.60 ± 3.24 Pg C in vegetation and 84.55 ± 8.09 Pg C in soil (Xu et al. 2018).

In the Chinese grassland ecosystem, the terrestrial carbon storage was 44.09 Pg C according to a nationwide grassland resource survey (Ni 2001), and this was later reduced to 29.1 Pg C in a later report (Fang et al. 2010). In Chinese forests, terrestrial carbon storage reached a minimum of 4.3 Pg C in 1980 due to deforestation prior to the 1980s and then increased to 5.9 Pg C in 2000 following subsequent reforestation projects (Fang et al. 2001, 2007, Fang and Chen 2001). The terrestrial carbon storage in the forest ecosystem was forecasted to be 10.23 Pg C in 2050 under natural growth conditions (Xu et al. 2010).

Some studies have attempted to assess the spatial distribution of vegetation or soil carbon density in China (Wang et al. 1999, Wu et al. 2003) or have provided carbon storage according to the administrative region or ecosystem type (Li et al. 2007, Fang et al. 2001, Zhang and Wang, 2010). For example, Fang et al. (2001) presented the spatial distribution of carbon density in forest biomass (Fang et al. 2001), and Li et al. (2007) presented the spatial distribution of carbon density in soil in six major geographic regions of China. Nonetheless, there remains a lack of detailed information about the distribution of carbon storage in China.

Despite various methods and data sources having been used to estimate actual carbon storage in China, the actual carbon storage in China remains unclear. A detailed assessment of the spatial distribution of carbon for ecosystems differing in their vegetation type is also lacking. Here, we sought to generate a more accurate estimate of carbon storage across eleven ecosystem types using higher resolution spatial data, thus providing a more detailed spatial analysis carbon distribution across China. We use the most authoritative vegetation map available (Vegetation Map of the People's Republic of China), which was co-produced by vegetation ecologists in 2008, to obtain accurate area estimates for 875 vegetation types based on 75,000 patches. We used the carbon transfer rate (or turnover time) method to calculate carbon storage in vegetation and soil pools. These results will aid in assessing carbon budgets and in predicting ecosystem carbon responses to climate change.

**DATA AND METHODS**

The carbon transfer rate (or turnover time) method was adopted to calculate carbon storage in the vegetation soil carbon pools (Wang et al. 2011, Carvalhais et al. 2014). This method is based on the assumption that carbon movement between pools is at steady state. In other words, it assumes that the transfer rate of carbon from vegetation to soil by litter production and the transfer rate of carbon from soil organic matter to atmosphere by decomposition are both equal to the rate of carbon transfer from atmosphere to vegetation. The vegetation carbon pool density \(C_{\text{veg}}\) and soil carbon pool density \(C_{\text{soil}}\) under steady-state conditions can be calculated based on NPP and the turnover rates \(r_{\text{veg}}\) and \(r_{\text{soil}}\) of these pools (Wang et al. 2011):

\[
C_{\text{veg}} = \text{NPP} \times r_{\text{veg}}. \quad (1)
\]

\[
C_{\text{soil}} = \text{NPP} \times r_{\text{soil}}. \quad (2)
\]

The turnover rate of the vegetation carbon pool \(r_{\text{veg}}\) is mainly controlled by the life history of different vegetation types, and so it can be treated as constant for a given biome or vegetation type. We calculated \(r_{\text{veg}}\) for each vegetation type from the average NPP and the average carbon storage from previously published papers (Ni 2001, 2002, Wang et al. 2011).
The turnover rate of the soil carbon pool ($\tau_{\text{soil}}$) was assumed to depend strongly on temperature, based on previous studies (Carvalhais et al. 2014, Dash et al. 2019). The $\tau_{\text{soil}}$ was calculated from soil temperature ($T$), reference temperature ($T_{\text{ref}}$), and the turnover rate of soil carbon under a reference temperature ($\tau_{\text{soil-ref}}$) as:

$$\tau_{\text{soil}} = \tau_{\text{soil-ref}} \times \exp[-k(T - T_{\text{ref}})].$$

(3)

where $k = 0.034$ as an empirical coefficient.

The 875 vegetation types in the latest Vegetation Map of the People's Republic of China (2008) at 1:1,000,000 scale were assigned into 28 biomes in according to floristic and bioclimatic criteria (Ni 2001). Thus, regardless of whether they came from previous vegetation types or from previous biomes, parameters ($\text{NPP}$, $\tau_{\text{veg}}$, $\tau_{\text{soil}}$) could be used to calculate carbon storage for a given vegetation type in the vegetation map. The amounts of carbon stored in vegetation and in soil were calculated from Eqs. 1, 2 based on NPP, $\tau_{\text{veg}}$, $\tau_{\text{soil}}$, and the area of each vegetation type. The vegetation, soil, and terrestrial carbon pool densities in each ecosystem type were derived from the ratio of carbon storage and land area (Table 1).

For each polygon patch of the latest vegetation map, the total carbon storage ($C_{\text{total}}$) was calculated by vegetation carbon pool density ($C_{\text{veg}}$), soil carbon pool density ($C_{\text{soil}}$), and the area of the polygon patch (Eq. 4).

$$C_{\text{total}} = \text{Area} \times (C_{\text{veg}} + C_{\text{soil}}).$$

(4)

For a given vegetation type, the total carbon storage is the sum of carbon storage in the polygon patches of the vegetation type. Across all the

| Ecosystem                           | $C_{\text{veg}}$ (g C/m²) | $C_{\text{soil}}$ (g C/m²) | $\text{NPP}$ (g C·m⁻²·yr⁻¹) | $\tau_{\text{veg}}$ (year) | $\tau_{\text{soil}}$ (year) | Ratio $C_{\text{soil}}/C_{\text{veg}}$ |
|------------------------------------|---------------------------|-----------------------------|-----------------------------|----------------------------|-----------------------------|----------------------------------|
| Tropical evergreen forest          | 15,500                    | 5000                        | 1100                        | 14                         | 5                           | 0.32                             |
| Tropical semi-deciduous forest     | 22,000                    | 4500                        | 1000                        | 22                         | 5                           | 0.20                             |
| Tropical deciduous forest/woodland | 12,500                    | 4000                        | 750                         | 17                         | 5                           | 0.32                             |
| Temperate deciduous forest         | 4500                      | 6500                        | 500                         | 9                          | 13                          | 1.44                             |
| Temperate conifer forest           | 4500                      | 7500                        | 375                         | 12                         | 20                          | 1.67                             |
| Warm-temperate evergreen           | 9000                      | 5500                        | 725                         | 12                         | 8                           | 0.61                             |
| deciduous broadleaf mixed forest   |                           |                             |                             |                             |                             |                                  |
| Cool mixed forest                  | 5000                      | 8500                        | 550                         | 9                          | 15                          | 1.70                             |
| Cool conifer forest                | 7000                      | 9500                        | 375                         | 19                         | 25                          | 1.36                             |
| Cold mixed forest                  | 6000                      | 10,000                      | 600                         | 10                         | 17                          | 1.67                             |
| Evergreen taiga/montane forest     | 11,000                    | 12,500                      | 425                         | 26                         | 29                          | 1.14                             |
| Deciduous taiga/montane forest     | 7500                      | 11,500                      | 460                         | 16                         | 25                          | 1.53                             |
| Tropical savanna                   | 3500                      | 3000                        | 250                         | 14                         | 12                          | 0.86                             |
| Tropical xerophytic shrubland      | 2000                      | 2500                        | 200                         | 10                         | 13                          | 1.25                             |
| Temperate xerophytic shrubland     | 1500                      | 2500                        | 150                         | 10                         | 17                          | 1.67                             |
| Temperate sclerophyll woodland     | 3500                      | 3500                        | 300                         | 12                         | 12                          | 1.00                             |
| Temperate broadleaved savanna      | 2500                      | 2500                        | 100                         | 25                         | 25                          | 1.00                             |
| Open conifer woodland              | 3750                      | 7500                        | 250                         | 15                         | 30                          | 2.00                             |
| Boreal parkland                    | 5500                      | 8000                        | 400                         | 14                         | 20                          | 1.45                             |
| Tropical grassland                 | 450                       | 2500                        | 400                         | 1                          | 6                           | 5.56                             |
| Temperate grassland                | 200                       | 1500                        | 200                         | 1                          | 8                           | 7.50                             |
| Temperate desert                   | 250                       | 1000                        | 75                          | 3                          | 13                          | 4.00                             |
| Steppe tundra                      | 1500                      | 6000                        | 200                         | 8                          | 30                          | 4.00                             |
| Low and high shrub tundra          | 3000                      | 7500                        | 250                         | 12                         | 30                          | 2.50                             |
| Erect dwarf shrub tundra           | 900                       | 5000                        | 175                         | 5                          | 29                          | 5.56                             |
| Prostrate dwarf shrub tundra       | 600                       | 5000                        | 125                         | 5                          | 40                          | 8.33                             |
| Cushion-forbs lichen and moss tundra| 400                   | 5000                        | 75                          | 5                          | 67                          | 12.50                            |
| Bare land                          | 0                        | 0                           | 0                           | 0                          | 0                           | 0                                |
| Ice and glacier                    | 0                        | 0                           | 0                           | 0                          | 0                           | 0                                |

Notes: $C_{\text{veg}}$ is vegetation carbon pool density, $C_{\text{soil}}$ is soil carbon pool density, $\tau_{\text{veg}}$ is the turnover rate of vegetation carbon, $\tau_{\text{soil}}$ is the turnover rate of soil carbon.
vegetation types, the total carbon storage is the sum of carbon storage in the 75,000 polygon patches present in the latest vegetation map. The distribution maps of soil, vegetation, and total terrestrial carbon pools were drawn with ArcGIS10.2 (http://www.esri.com/software/arcgis), based on the carbon pool density in the 75,000 polygon patches.

RESULTS

Terrestrial carbon storage in different ecosystems

The total terrestrial carbon storage in the eleven ecosystem types across China was 55.46 Pg C, of which 18.19 Pg C was in the vegetation carbon pool and 37.27 Pg C was in the soil carbon pool. The average terrestrial carbon density (carbon storage per unit area) of the ecosystem types was 7036 g C/m² (Table 2). The carbon density in the soil carbon pool was higher than that in the vegetation carbon pool, because the average carbon density in the soil carbon pool was 4477 g C/m², while the average carbon density in vegetation carbon pool was 2559 g C/m².

Among the eleven ecosystems, the needleleaf forest ecosystem (with an area of 92.9 × 10⁴ km²) had the largest terrestrial carbon storage of 13.57 Pg C and a carbon density of 6994.6 g C/m² in the vegetation carbon pool and 7608.8 g C/m² in the soil carbon pool. The cultivated land ecosystem (with an area of 190.4 × 10⁴ km²) had the second highest terrestrial carbon storage (7.91 Pg C), in despite a lower carbon density of 259.0 g C/m² in the vegetation carbon pool and 3895.1 g C/m² in the soil carbon pool. In contrast, the mixed forestry ecosystem (with a smaller area of 2.3 × 10⁴ km²) had the lowest terrestrial carbon storage of 0.28 Pg C, despite the higher carbon density of 5178.1 g C/m² in the vegetation carbon pool and 7252.8 g C/m² in the soil carbon pool (Table 2 and Fig. 1).

Table 2. Terrestrial carbon storage and carbon density (carbon storage per unit area) in different vegetation ecosystems in China.

| Ecosystem       | Area (10⁴ km²) | Terrestrial carbon storage (Pg C) | Terrestrial carbon per unit area (g C/m²) |
|-----------------|---------------|----------------------------------|----------------------------------------|
| Grassland       | 34.1          | 0.60                             | 1.41                                   |
| Meadow          | 103.6         | 0.84                             | 4.26                                   |
| Steppe          | 140.6         | 1.40                             | 7.36                                   |
| Marsh           | 7.3           | 0.15                             | 0.41                                   |
| Alpine vegetation | 32.4     | 0.12                             | 1.59                                   |
| Scrub           | 90.4          | 3.20                             | 7.37                                   |
| Broadleaf forest | 70.9       | 4.05                             | 8.85                                   |
| Needleleaf forest | 92.9     | 7.07                             | 13.57                                  |
| Mixed forest    | 2.3           | 0.12                             | 0.28                                   |
| Cultivated vegetation | 190.4 | 7.42                             | 7.91                                   |
| Deserts†        | 119.8         | 2.48                             | 3.45                                   |
| Total           | 884.7         | 37.27                            | 55.46                                  |

† Deserts with sparse grass. The total terrestrial carbon storage does not include the carbon in non-vegetated desert, saline-alkali land, water, and glaciers.
To provide a general understanding of terrestrial carbon storage, the eleven ecosystem types were classified into four major ecosystem types (forest, grassland, scrub, and cultivated). The results showed that the forest ecosystem had the highest terrestrial carbon storage of 21.7 Pg C, with an area of $166.1 \times 10^4$ km$^2$. The grassland ecosystem had the second highest carbon storage of 16.89 Pg C with an area of $405.4 \times 10^4$ km$^2$. The cultivated land ecosystem had the lowest carbon storage of 7.91 Pg C because of its low carbon density (Fig. 2).

The spatial distribution of terrestrial carbon storage

Terrestrial carbon storage in vegetation and soil varied considerably across China. For the vegetation pool, the average vegetation carbon density was 2559 g C/m$^2$, with a gradient in carbon density from high levels in eastern China to low levels in western China. The ecosystems in eastern China mainly consisted of forest and cultivated land. Carbon density of more than 3000 g C/m$^2$ was observed in the forest ecosystems in eastern China, with the highest vegetation carbon density occurring in needleleaf forests. In contrast with the high vegetation carbon density in the forest ecosystem, vegetation carbon density of less than 500 g C/m$^2$ was observed in cultivated farmland in eastern China. The ecosystems in western China mainly consisted of grassland and desert, which had a carbon density of less than 2000 g C/m$^2$ (Fig. 3).

The average soil carbon density across China was 4477 g C/m$^2$. There was considerable spatial heterogeneity in soil carbon density, varying between 2000 and 11,700 g C/m$^2$. Soil carbon density was higher on the Tibetan Plateau and in northeast China, where lower temperatures might prevent soil carbon from being lost as CO$_2$. Soil carbon density was lower (below 3700 g C/m$^2$) in northwest China, which is covered with sparse arid grassland or desert (Fig. 4).

The distribution pattern of total carbon (both vegetation carbon and soil carbon) was similar to that of soil carbon, because much more carbon was stored in the soil carbon pool than in the vegetation carbon pool. Total terrestrial carbon density was higher in northeast China and the southeast part of the Tibetan Plateau, varying between 1700 and 23,340 g C/m$^2$. In contrast, terrestrial carbon density was lower in western and northwest China, varying between 0 and 3000 g C/m$^2$ as these areas are covered with sparse arid grassland or desert (Fig. 5).

DISCUSSION

Causes of different estimations of carbon storage

Previous studies have presented highly variable estimates of carbon storage in Chinese ecosystems. By comparing a series of results, methods, and vegetation areas (Table 3), we believe that these highly variable estimates are due mainly to differences in methods and data sources (Tang et al. 2018). Different statistical methods might result in the different estimates of carbon storage. Taking the forest ecosystem as an example, our results using the carbon transfer rate method revealed that vegetation carbon accounted for 10.42 Pg C. Guo et al. (2010) applied three methods to estimate China’s forest biomass carbon (i.e., vegetation carbon) and found that the continuous biomass expansion factor method produced the lowest estimate (4.0–5.9 Pg C), that the mean ratio method produced an intermediate estimate (4.2–6.2 Pg C), and that the mean biomass density method produced the estimate (5.7–7.7 Pg C).

Variability in carbon storage estimates may also result from variability in how much area is
occupied by each vegetation or ecosystem type. For example, among studies forests varied from $102.3 \times 10^4 \text{ km}^2$ to $217.9 \times 10^4 \text{ km}^2$, and grasslands varied from $167 \times 10^4 \text{ km}^2$ to $405.4 \times 10^4 \text{ km}^2$ (Table 3). This high variation among studies in how the land surface area is classified among vegetation types can lead to highly variable estimates of carbon storage. In combination, different methods and variability in vegetation classification can produce
highly variable estimates of carbon storage. Recent studies suggested that the terrestrial carbon pool in China was 79.24 Pg C (Tang et al. 2018), but our results showed a lower terrestrial carbon storage of 55.46 Pg C. The estimate of 79.24 Pg C was calculated using the carbon density method with a vegetation area of $946.4 \times 10^4$ km$^2$. Our estimate of 55.46 Pg C was calculated using the carbon transfer rate method with a vegetation area of $884.7 \times 10^4$ km$^2$. The
smaller vegetation area in our study might be the primary cause leading to the smaller estimate of total terrestrial carbon. However, our estimates of vegetation are likely more reliable because they relied on the most recent Vegetation Map of the People's Republic of China that more accurately estimated vegetation cover across China. This vegetation map was co-produced by Chinese vegetation ecologists and has been recognized as the most...
The authoritative vegetation map currently available. The map provided much more detailed distribution information using 75,000 polygon patches distributed among 875 vegetation types. Recent studies have estimated the total carbon pools using the China Cover map, which classified vegetation with less precision and detail than the latest Vegetation Map of the People’s Republic of China. Therefore, the estimate for carbon storage in our study is likely more accurate than that of previous studies.

**Distribution patterns of carbon storage**

Despite differences between our study and previous studies in the total amount of carbon storage in China, our results for the spatial distribution of carbon were consistent with previous studies. The distribution of carbon storage was highly variable across China. Wang et al. (1999) reported that eastern China had a higher carbon density in vegetation than western China, with the highest vegetation carbon density occurring in natural needleleaf forests in northeast China (Wang et al. 1999). We also report a higher vegetation carbon density in eastern China than in other regions, with a vegetation carbon density of 2000–11,900 g C/m². Previous studies have reported higher soil carbon density in northeast China and the southeastern part of the Tibetan Plateau (Wu et al. 2003, Li et al. 2007, Yang et al. 2007). Similarly, we found the highest soil carbon density in northeast China with an average of

| Ecosystem     | Area (10⁴ km²) | Vegetation carbon (Pg C) | Soil carbon (Pg C) | Terrestrial carbon (Pg C) | Methods                      | Reference               |
|---------------|----------------|--------------------------|--------------------|---------------------------|------------------------------|-------------------------|
| Forestry      | 118.0          | 17                       | 16                 | 33                        | Carbon budget method         | Dixon et al. (1994)      |
| 108.6         | 6.1            | 21.023                   | 28.16              |                           | Biomass and conversion ratio | Zhou et al. (2000)        |
| 102.3–105.8   | 5.06–4.75      |                          |                    |                           | The volume-derived method    | Fang et al. (2001)        |
| 217.9         | 11.51          | 35.49                    | 47                 |                           | CEVSA model                  | Li et al. (2003)          |
| 116.5–142.8   | 4.30–5.85      |                          |                    |                           | Biomass expansion factor     | Fang et al. (2007)        |
| 142.8         | 7.47           | 22.31                    | 29.77              |                           | Summarize previous results   | Yu et al. (2010)          |
| 188.2         | 10.48 ± 2.02   | 19.98 ± 2.41             | 30.83 ± 1.57       |                           | Carbon density method        | Tang et al. (2018)        |
| 166.1         | 10.42          | 11.28                    | 21.7               |                           | Carbon transfer rate method  | This paper                |
| Scrubs        | 216.5          | 0.23                     | 11.77              | 12                        | CEVSA model                  | Li et al. (2003)          |
| 178           | 0.85           | 9.10                     | 9.95               |                           | Summarize previous results   | Yu et al. (2010)          |
| 74.3          | 0.71 ± 0.23    | 5.91 ± 0.43              | 6.69 ± 0.32        |                           | Carbon density method        | Tang et al. (2018)        |
| Grassland     | 122.8          | 3.32                     | 5.64               | 8.96                      | Carbon transfer rate method  | This paper                |
| 298.97        | 1.67–7.08      | 34.52–46.37              | 36.18–53.44        |                           | Carbon density method        | Ni (2002)                 |
| 167           | 0.56           | 16.7                     | 17.26              |                           | Carbon density method        | Fang et al. (2007)        |
| 331           | 1.13           | 43                       | 45.51              |                           | Summarize previous results   | Yu et al. (2010)          |
| 355.05        | 1.61           | 29.37                    | 30.98              |                           | Carbon density method        | Ma et al. (2016)          |
| 281.3         | 1.35 ± 0.47    | 24.03 ± 2.52             | 25.40 ± 1.49       |                           | Carbon density method        | Tang et al. (2018)        |
| 405.41        | 3.96           | 12.93                    | 16.89              |                           | Carbon transfer rate method  | This paper                |
| 172.9         | 0.98           | 18.73                    | 19.71              |                           | CEVSA model                  | Li et al. (2003)          |
| 108           | 2              | 11.18                    | 13.18              |                           | Summarize previous results   | Yu et al. (2010)          |
| 171.3         | 0.55 ± 0.02    | 15.77 ± 0.57             | 16.32 ± 0.41       |                           | Carbon density method        | Tang et al. (2018)        |
| 190.4         | 0.49           | 7.42                     | 7.91               |                           | Carbon transfer rate method  | This paper                |
| Cultivated land | 968            | 57.9                     | 100                | 157.9                     | Osnabruck biosphere model    | Peng and Apps (1997)      |
| Terrestrial ecosystem | 960 | 35.23–57.74 | 117.84–119.76 | 153.07–177.5 | Carbon density method | Ni (2001) |
| 901.1         | 13.29          | 82.68                    | 95.97              |                           | CEVSA model                  | Li et al. (2003)          |
| 13.71 ± 0.35  | 84.24 ± 5.56   | 97.95                    | Summarize previous literature | Yu et al. (2010) |
| 925.64        | 14.60          | 84.55                    | 99.15              |                           | Summarize previous literature | Xu et al. (2018) |
| 946.4         | 14.29 ± 0.74   | 74.98 ± 1.28             | 89.27 ± 1.05       |                           | Carbon density method        | Tang et al. (2018)        |
| 884.7‡        | 18.19          | 37.27                    | 55.46              |                           | Carbon transfer rate method  | This paper |

† Including desert with sparse grass.
‡ Unvegetated land is not included.
8300 g C/m², and the second highest soil carbon density in the southeastern part of the Tibetan Plateau with an average of 7100 g C/m².

Using higher resolution vegetation maps, our analysis of the spatial distribution of carbon storage is likely more accurate than that of previous studies. The differences in spatial accuracy among studies are largely due to relying on different data sources. For example, Li et al. (2003) used a less precise global database to draw distribution maps of vegetation carbon and soil carbon based on the CEVSA (carbon exchange between vegetation, soil, and atmosphere) model. Tang et al. (2018) used the China Cover map to draw the spatial pattern of carbon density by the Random Forest simulation, a machine learning approach. The China Cover map had a lower resolution vegetation classification than the detailed classification of the Vegetation Map of the People’s Republic of China. We provided more accurate maps of carbon storage in both vegetation and soil because the maps in the Vegetation Map of the People’s Republic of China were drawn based on about 750,000 polygon units for 875 vegetation types.

**Conclusions**

Our results showed that the terrestrial carbon storage over China was 55.46 Pg C, of which 18.19 Pg C was in the vegetation carbon pool and 37.27 Pg C in the soil carbon pool. Our estimate of the total terrestrial carbon storage was lower than that reported in recent studies (89.27 Pg C), probably because of differences in methods and vegetation classification. The ecosystem average terrestrial carbon storage per unit area (carbon density) was 7036 g C/m². Among the eleven ecosystem types, the needleleaf forest ecosystem had the highest terrestrial carbon storage (13.57 Pg C). Our results agreed with prior estimates of how terrestrial carbon is distributed spatially. Northeast China and the southeastern part of the Tibetan Plateau had the highest soil carbon densities, while vegetation carbon density was highest in eastern China and lowest in western China. These results will be important in policymaking decisions about carbon storage and accounting.

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