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Increasing biomass carbon stocks in trees outside forests in China over the last three decades

Z. D. Guo[1,3], H. F. Hu[2], Y. D. Pan[4], R. A. Birdsey[4], and J. Y. Fang[1,2]

[1]Department of Ecology, College of Urban and Environmental Science, and Key Laboratory for Earth Surface Processes of the Ministry of Education, Peking University, Beijing 100871, China
[2]State Key Laboratory of Vegetation and Environmental Change, Institute of Botany, Chinese Academy of Sciences, Beijing 100093, China
[3]National Satellite Meteorological Center, China Meteorological Administration, Beijing 100081, China
[4]USDA Forest Service, Northern Research Station, Newtown Square, PA 19073, USA

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Correspondence to: J. Y. Fang (jyfang@urban.pku.edu.cn, fangjingyun@ibcas.ac.cn)

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Abstract

Trees outside forests (TOF) play important roles in national economies, ecosystem services, and international efforts for mitigating climate warming. Detailed assessment of the dynamics of carbon (C) stocks in China's TOF is necessary for a full picture evaluating the role of the country's trees in the national C cycle. In this study, we first explore the changes in biomass C stocks of China's TOF over the last three decades, using the national forest inventory data in six periods from 1977 to 2008. According to the definition of the forest inventory, China's TOF could be categorized into three groups: woodlands, shrubberies, and trees on non-forest lands (including four-side greening trees and scattered trees). We estimated biomass C stocks of woodlands and trees on non-forest lands by using the provincial biomass-volume conversion equations derived from the data of low canopy forests, and those of shrubberies with the mean biomass density method. Total TOF biomass C stock increased by 63.1 % from 827 Tg C (1 Tg = 10^{12} g) in the initial period of 1977–1981 to 1349 Tg C in the last period of 2004–2008. As a result, China's TOF have accumulated biomass C of 522 Tg during the study period, with 12 Tg, 276 Tg, and 234 Tg in woodlands, shrubberies, and trees on non-forest lands, respectively. The annual biomass C sink of China's TOF averaged 19.3 Tg C yr^{-1}, offsetting 2.2 % of the contemporary fossil-fuel CO_2 emissions in the country. These estimates are equal to 16.7 ~ 20.7 % of the contemporary total forest biomass C stock and 27.5 % of the total forest biomass C sink in the country, suggesting that TOF are substantial components for accounting China's tree C budget.

1 Introduction

Contrary to popular perception, trees and forests are not synonymous; trees alone do not make up forests, and trees are not found only in forests (Long and Nair, 1999). As the largest part of terrestrial ecosystems, a number of studies have paid attention to the role of forests in mitigating climate change, carbon (C) sequestration and biodiversity conservation (e.g., IPCC, 2007; Pan et al., 2011; Dolman et al., 2012). In recent decades, trees outside forests (TOF) have begun to attract more and more attention with growing acknowledgement of their potential economic importance, and political interest in their environmental services (de Foresta et al., 2013). Because TOF are typically splintered among the components of agroforestry, urban and rural forestry, and other sectors, they tend to be left out of forest statistics, natural resource assessments, policy, and legislation (de Foresta et al., 2013). A major challenge for a better valuation of trees and their services globally is to improve understanding of the status and dynamics of all tree resources, including TOF (FAO, 2001; de Foresta et al., 2013).

The concept of "Trees Outside Forests" first appeared in 1995 to indicate trees growing outside the forest and not belonging to forest or other wooded land (Bellefontaine et al., 2002). TOF can be found in all climates, land types, land uses and regions, and have important economic, social, and environmental implications at local, national, and global scales (de Foresta et al., 2013). For instance, in Kerala State, India, TOF are the major source of local wood production, which account for 90.1 % of the timber production and meet 89.2 % of local fuelwood supply during the year 2000–2001 (Krishnankutty et al., 2008). Based on biomass equation of species, Nowak and Crane (2002) estimated that urban trees in the USA currently store 700 Tg ($1\,\mathrm{Tg} = 10^{12}\,\mathrm{g}$) of carbon (C) with a gross C sequestration rate of $22.8\,\mathrm{Tg\,C\,yr^{-1}}$. Focusing on trees on land used for agriculture, Zomer et al. (2009) made the first TOF assessment at global scale, and concluded that agroforestry is a significant feature of agriculture in all regions, with 46 % of the total agriculture land (about 1×10^9 ha) having more than 10 % tree cover. In the current context of climate change, biodiversity crisis, financial crises, and food insecurity, the contributions of TOF are significant for improving people's livelihoods and national economies, especially in developing countries (de Foresta et al., 2013). More recently, their importance has gained more attention with appreciation of the role of TOF in C sequestration, biodiversity conservation, anti-desertification, and poverty alleviation (Nair, 2011; de Foresta et al., 2013).

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In order to investigate the status and changes of its forest resources, China has implemented a national forest resource inventory every 5 years since the 1970s. Seven categories of forests or trees were periodically surveyed and reported in each inventory period, including: (1) *forest stands* [land spanning more than 0.0667 ha with trees and a canopy cover of > 0.3 (before 1994 when a different criterion were applied) or ≥ 0.2 (after 1998)], (2) *economic forests* (woods with the primary objective of production of fruits, edible oils, drinks, flavorings, industrial raw materials, and medicinal materials), (3) *bamboos*, (4) *woodlands* covered by trees with canopy coverage between 0.1 and 0.2 or 0.3 (before 1994) (Fig. 1a), (5) *shrubberies* covered by shrubs with canopy coverage > 0.3 or 0.4 (before 1994) (Fig. 1b), (6) *four-side greening trees* distributed along the sides of the houses, roads, rivers, and crop lands (Fig. 1c), and (7) *scattered trees* growing alone along with bamboos, economic forests, or non-forest lands (Fig. 1d). In China, forest stands, economic forests, and bamboos are usually treated as forests (e.g., Fang et al., 1998, 2001, 2007; Guo et al., 2010, 2013), while the other four categories (woodlands, shrubberies, four-side greening trees, and scattered trees) are regarded as TOF, of which biomass C stocks and changes over time have rarely been estimated.

Although several previous studies have estimated biomass C stocks for certain types of China's TOF (e.g., Hu et al., 2006; Li et al., 2011; Zhang et al., 2013), they lack comprehensive and systematic analysis on the dynamics of biomass C stocks and their regional distribution for all components of China's TOF. Based on the up-to-date national forest inventory data since the late 1970s, this study aims to explore the temporal changes and regional distributions of biomass C stocks for each TOF group and for total TOF between 1977 and 2008.

2 Datasets and methods

China's forest inventory data used in this study included six periods: 1977–1981, 1984–1988, 1989–1993, 1994–1998, 1999–2003, and 2004–2008 (Chinese Ministry

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of Forestry, 1983, 1989, 1994, 2000, 2005, 2010). The forest inventory provides different information for different TOF categories: it documents total area and total timber volume in each province for woodlands, total area in each province for shrubberies, and total timber volume in each province for four-side greening trees and scattered trees. We estimated their biomass C stocks for each inventory period based on the available inventory information. Note that TOF in Hong Kong, Macao and Taiwan were not included in this study due to the lack of data. A ratio of 0.5 was used to convert biomass to C stock.

2.1 Woodlands

Since 1994, the definition of woodlands in China's forest inventory has been changed from canopy coverage between 0.1 and 0.3 to canopy coverage between 0.1 and 0.2 to be consistent with the FAO criteria. In order to make our results comparable among different inventory periods, we analyzed the 1994–1998 inventory data which provided both criteria (0.1 ~ 0.3 and 0.1 ~ 0.2 canopy coverage), and found that there existed power function relationships for the woodland area and volume between the two criteria at the provincial level (Fig. 2):

$$\mathrm{AREA}_{(0.2)} = 0.2731 \times \mathrm{AREA}_{(0.3)}^{0.9602} \quad (R^2 = 0.865,\ n = 30) \tag{1}$$

$$\mathrm{VOLUME}_{(0.2)} = 0.2319 \times \mathrm{VOLUME}_{(0.3)}^{0.9605} \quad (R^2 = 0.904,\ n = 30) \tag{2}$$

where AREA and VOLUME are woodland area (10^4 ha) and volume (10^4 m^3) in a province; subscripts 0.3 and 0.2 represent the criterion of 0.1 ~ 0.3 and 0.1 ~ 0.2 canopy coverage, respectively. Equations (1) and (2) can therefore be used to adjust the area and timber volume of woodlands reported before the inventory period of 1994–1998.

Because forest inventory data only document total area and volume of woodlands for each province, it is necessary to develop empirical relationship between the provincial biomass and volume of woodlands. The 1994–1998 inventory data provided total area

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and timber volume of forest stands at both criteria of > 0.3 and ≥ 0.2 canopy coverage for each province, and the corresponding biomass was hence derived based on the continuous biomass expansion factor (BEF) method (for details, see Fang et al., 1998, 2001, 2007, 2014; Guo et al., 2010, 2013). Therefore, we could use the differences in biomass, timber volume and area based on two criteria to obtain the estimates of the provincial biomass density and volume density for forest stands between the criteria of 0.2 and 0.3 canopy coverage for the 1994–1998 inventory period. Previous studies (Fang and Chen, 2001; Guo et al., 2013) have showed a robust linear relationship between the provincial biomass density and volume density for forest stands at both criteria (> 0.3 and ≥ 0.2 canopy coverage). Similarly, we also established a robust linear relationship between biomass density and volume density at the provincial level for forest stands with canopy coverage between 0.2 and 0.3 (Fig. 3a).

$$\mathrm{BD} = 0.8749 \times \mathrm{VD} + 13.507 \quad (R^2 = 0.969,\ n = 28) \tag{3}$$

where BD and VD are biomass density ($\mathrm{Mg\,ha^{-1}}$, $1\,\mathrm{Mg} = 10^6\,\mathrm{g}$) and volume density ($\mathrm{m^3\,ha^{-1}}$) of forest stands with canopy coverage between 0.2 and 0.3 in each province in 1994–1998, respectively.

Equation (3) can be used to estimate biomass density using volume density for sparse canopy forest stands (e.g., woodlands) for each province and each inventory period. We therefore can estimate biomass C stocks of woodlands by multiplying biomass densities with their corresponding areas.

2.2 Shrubberies

Because forest inventory only documents the area of shrubberies in each province, we established a literature-reviewed database of shrubbery biomass, which contained 54 sets of biomass data for 30 types of shrubberies (Table A1, Supplement). Based on the database, the mean biomass density of shrubberies was estimated as $22.92\,\mathrm{Mg\,ha^{-1}}$. We obtained biomass C stocks in different inventory periods for China's shrubberies by multiplying the mean biomass density of shrubberies with the area in each province.

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2.3 Trees on non-forest lands

In this study, we combined four-side greening trees and scattered trees into the same group of trees on non-forest lands. In China, we define four-side greening trees as trees grow and distribute along the sides of the houses, roads, rivers, and crop lands. Forest inventory only documents total volume of trees on non-forest lands for each province, and so we used the 1994–1998 inventory data, similar to the analysis for woodlands, to establish a robust linear relationship between total biomass and total volume at the provincial level for coarse canopy forest stands with canopy coverage of $0.2 \sim 0.3$ (Fig. 3b).

$$B = 1.2091 \times V \quad (R^2 = 0.953,\ n = 28) \tag{4}$$

where B and V are biomass stock (10^6 Mg) and volume ($10^6\ \mathrm{m}^3$) of forest stands with canopy coverage between 0.2 and 0.3 in each province in 1994–1998, respectively.

Equation (4) can be used to calculate biomass of trees on non-forest lands because four-side greening trees and scattered trees generally grow in sparse, open habitats (Guo, 2011).

3 Results

3.1 Biomass C stocks and C sinks of China's TOF

Total TOF biomass C stock increased by 63.1 % from 827 Tg C in the initial period of 1977–1981 to 1349 Tg C in the last period of 2004–2008, with a net accumulation of 522 Tg C (Table 1). Over the 30 years, net C gain was found between every two sequential inventory periods and the annual biomass C sink averaged 19.3 Tg C yr^{-1} with a range from 8.2 Tg C yr^{-1} in 1999–2003 to 30.9 Tg C yr^{-1} in 1989–1993.

Storing $48.3 \sim 60.1$ % of the total biomass C stock and accounting for 44.8 % of the total biomass C sink during the study period, trees on non-forest lands released 47 Tg C

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between 1994 and 2003 and sequestered 281 Tg C in other periods, resulting in a net accumulation of 234 Tg C for the whole study period. The mean biomass C sink was 8.7 Tg C yr^{-1}, ranging from –7.0 Tg C yr^{-1} in 1999–2003 to 27.3 Tg C yr^{-1} in 1989–1993.

Shrubberies stored 33.8 ~ 45.6 % of the total biomass C stock and accounted for 52.9 % (276 Tg C) of the total biomass C sink over the past three decades, with a persistent C sink rate of 10.2 Tg C $year^{-1}$ (Table 1). Woodlands stored 6.1 ~ 9.0 % of the total biomass C stock and accounted for 2.3 % (12 Tg C) of the total biomass C sink over the study period, with a small overall C sink rate of 0.5 Tg C yr^{-1}.

3.2 Spatio-temporal distribution of biomass C stocks and C sinks of China's TOF

There is considerable spatial (or regional) and temporal variability in biomass C stocks and C sinks among the entire TOF and each group (Fig. 3; Table B1, Supplement). About 34.0 ~ 43.0 % of the total TOF biomass C stock occurred in the southwestern region, followed by 10.0 ~ 18.2 % in the northern region, 12.3 ~ 15.3 % in the southern region, 9.6~ 17.5 % in the eastern region, 8.6 ~ 15.7 % in the northwestern region, and 8.8 ~ 11.5 % in the northeastern region. Over the study period, overall net C accumulation was found in all regions, except for a release of 14.9 Tg C in the eastern region, equaling 2.9 % of the total TOF biomass C sink. The largest TOF biomass C sink was in the northern region (163.4 Tg C), accounting for 31.3 % of the total TOF C sink, followed by the northwestern (140.3 Tg C, 26.9 %), the southwestern (103.8 Tg C, 19.9 %), the southern (76.6 Tg C, 14.6 %), and the northeastern region (52.8 Tg C, 10.1 %).

For trees on non-forest lands, the largest biomass C sink occurred in the northern region with an accumulation of 76.0 Tg C (accounting for 32.5 % of total biomass C sink in China's trees on non-forest lands). The next largest biomass C sinks were in the northeastern (64.3 Tg C, 27.5 %), southwestern (43.6 Tg C, 18.7 %), southern (36.5 Tg C, 15.6 %), and northwestern regions (20.6 Tg C, 8.8 %). However, trees on non-forest lands in the eastern region have functioned as a C source with a release of 7.3 Tg C over the past three decades.

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For shrubberies, the largest biomass C sink occurred in the northwestern region with a gain of 106.3 Tg C, accounting for 38.5 % of the total shrubbery biomass C sink, followed by the northern (83.6 Tg C, 30.3 %), southwestern (50.3 Tg C, 18.2 %), and southern regions (42.6 Tg C, 15.4 %). However, shrubberies in the northeastern and eastern regions have acted as C sources with an accumulated loss of 4.3 and 2.4 Tg C, which equaled 1.6 and 0.9 % of the total shrubbery biomass C sink in these two regions, respectively.

Woodlands in the northwestern, southwestern, and northern regions have all functioned as C sinks with an accumulation of 13.4, 9.9, and 3.9 Tg C, respectively, which accounted for 110.0 %, 81.1 %, and 31.6 % of the total woodland biomass C sink. On the other hand, woodlands in the other three regions have all released C with the largest loss in the northeastern region (7.3 Tg C, 59.5 %), followed by the eastern (5.2 Tg C, 42.5 %) and southern regions (2.5 Tg C, 20.6 %).

4 Discussion

4.1 Estimates of biomass C sink in China's TOF and their implications

TOF are trees that do not fulfill the criteria for defining forest, so the extent of their domain depends on the definition used for forest in any country or agency conducting an assessment. Many countries have their own definitions of forest for their forest assessments, which means that many countries have their own criteria regarding what they consider TOF (de Foresta et al., 2013). In this study, we defined China's TOF as comprising woodlands, shrubberies, four-side greening trees, and scattered trees based on the data collection from China's forest inventory. As a result, we estimated that total TOF biomass C stock increased to 1349 Tg C in the late 2000s (2004–2008) from 827 Tg C in an initial period of 1977–1981, and the net C sink was 522 Tg C, of which 12 Tg C was in woodlands, 276 Tg C in shrubberies, and 234 Tg C in trees on non-forest lands.

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We summarized total biomass C stocks and C sinks of China's forests and TOF during 1977–2008 in Table 2. Compared with forests, the total TOF biomass C stock was 16.7 % (1977–1981) ~ 20.7 % (1994–1998) of the contemporary total biomass C stock of forests; and the total TOF biomass C sink was 27.5 % of the total biomass C sink of forests, with a large fluctuation from 8.0 % in 1999–2003 to 66.4 % in 1984–1988.

We used the C estimates of China's TOF to assess their relative roles in offsetting fossil-fuel CO_2 emissions. Similar to Guo et al. (2013), we estimated China's fossil-fuel CO_2 emissions as 27.7 Pg C during 1977–2008, at an average rate of 895 $\mathrm{Tg\,C\,yr^{-1}}$, using the data of energy consumption and cement production recorded in "China Statistical Yearbook" (http://www.tjnj.org/diqu/china/). Therefore, the biomass C sink of 19.3 $\mathrm{Tg\,C\,yr^{-1}}$ in China's TOF offsets 2.2 % of the contemporary fossil CO_2 emissions in the country, of which shrubberies and trees on non-forest lands offset about 1.1 and 1.0 %, respectively.

4.2 Regional patterns and dynamics of TOF biomass C stocks

Although there were some periodic variations, the total TOF biomass C stocks in China has been steadily increasing over the last three decades (Fig. 4b). The biomass C stock in woodlands was small and has remained relatively stable because of limited areas that were suitable for woodlands. Shrubberies and trees on non-forest land had comparable shares in terms of contributing to the total TOF biomass C stock and sink over the study period although their contributions to the C sink were periodically varying (Fig. 4b; Table 1).

Different from forested lands and forest C stocks in China, which echo strongly forest management programs and policies by the central government, the regional patterns and dynamics of C stocks in TOF more likely illustrate complex interactions among regional climate, energy use, and socio-economic influences during China's rapid economic growth. For instance, in the dry northwest region where there are fewer trees, shrubberies dominate the biomass C stocks of TOF (Fig. 4h). There was a remark-

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able increase in shrubberies biomass C stocks over the decades, probably reflecting a switch of energy use by local people from reliance on fuelwood to more efficient coal or natural gas. The southwest region of China covers the Tibetan highlands and shrubberies are also dominant natural vegetation. However, because nomadic people in the plateau have kept their living traditions and use animal wastes as fuels, there were no particular changes in biomass C stocks of each TOF group besides slow increases (Fig. 4g). China's interior regions from the northern plateau to the southern mountains (Fig. 4c and f) have climates that can support more trees, and as in the northwest region, local people also heavily relied on fuelwood a few decades ago. These regions now have significant increases of biomass C stocks in both trees on non-forest land and shrubberies (Fig. 4c and f).

In contrast, climates in both eastern and northeastern China are suitable for trees (Fig. 4d and e). The east, both historically and in modern times, is the most affluent and economically advanced region in China, and the biomass C stock in trees on non-forest land has been quite consistent (Fig. 4e). In the northeastern region, the biomass C stock in trees on non-forest land was low in the 1970s and increased abruptly in the 1980s and 1990s (Fig. 4d). However both eastern and northeastern regions experienced some declines of biomass C stocks in trees on non-forest land in the last decade, which was likely attributed to the increased pressure of urban development.

The diverse regional patterns and dynamics of TOF C stocks reveal complex interactive relationships between people, natural resource and economic development, and their feedbacks on the C dynamics of TOF. It is inevitable that a country like China with a high population density and limited arable lands, many natural forests have given a way to other land uses. Because TOF are likely less demanding for lands and maintenance and more integral to people' daily life, promotion of TOF in a highly populated country may provide social, economic, and environmental synergies for achieving both C benefits and many other ecosystem services.

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4.3 Error of estimations

Based on the provincial biomass-volume conversion equations derived from forest stands with canopy coverage of 0.2 ~ 0.3, we estimated biomass C stock of woodlands (Eq. 3) and trees on non-forest lands (Eq. 4) in each inventory period. Therefore, the most important error may be derived from these regression models. For woodlands, we found that about 87 % (151 of 173) of the predicted data was within the range of our regression model; for trees on non-forest lands, this proportion was up to 99 % (336 of 340). Combined with their high *R* square values, biomass estimates for woodlands and trees on non-forest lands are of relatively high precision.

For shrubberies, the major error may be generated from the use of the mean biomass density. In general, the method could result in some overestimation of biomass C stocks of shrubberies because collected data were usually from shrub stands with better growing conditions (Guo et al., 2010).

5 Conclusions

Assessing TOF poses different challenges than assessing forests, especially for the variability and heterogeneity of TOF systems, because of their sparse distributions, and complex ownerships and institutional arrangements (de Foresta et al., 2013). Despite measurable progress, hard data on TOF across large areas (regional and national levels) remains scarce (de Foresta et al., 2013). In this study, based on six periods of forest inventory data, we made the first TOF assessment for China at the national scale, and concluded that the total TOF biomass C stock increased to 1349 Tg C from an initial stock of 827 Tg C and China's TOF have accumulated C of 522 Tg between 1977 and 2008, with the average C sink of 19.3 Tg C yr^{-1}. These estimates equaled 16.7 ~ 20.7 % of the contemporary biomass C stock in the country's forests and 27.5 % of the total forest biomass C sink between 1977 and 2008. Furthermore, the biomass C sink in China's TOF offsets 2.2 % of the contemporary fossil CO_2 emissions in the country.

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This study highlights the importance of TOF in estimating regional and global terrestrial C budget, given the magnitude of contributions that they can make to C stocks and sinks in China. TOF in countries with high populations or dry environments with low forest coverage may have a particular role for social, economic, and environmental synergies because of their multi-beneficial functions for ecosystem services, including the service of C sequestration that helps mitigate global climate change. Understanding diverse regional dynamics of TOF is important not only for predicting the impact on the national C budget, but also for evaluating other ecosystem services they may provide to humanity.

Supplementary material related to this article is available online at http://www.biogeosciences-discuss.net/11/3777/2014/ bgd-11-3777-2014-supplement.pdf.

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Table 1. Biomass C stocks and C sinks in China's TOF during 1977–2008.

Period	C stock (Tg C)[a]				C sink ($Tg\,C\,yr^{-1}$)			
	Total	Woodlands	Shrubberies	Trees on non-forest lands	Total	Woodlands	Shrubberies	Trees on non-forest lands
1977–1981	827	70 (8.5)	339 (41.0)	418 (50.5)	–	–	–	–
1984–1988	964	74 (7.7)	354 (36.7)	535 (55.6)	19.6	0.5	2.2	16.8
1989–1993	1118	69 (6.1)	377 (33.8)	672 (60.1)	30.9	−1.1	4.7	27.3
1994–1998	1199	108 (9.0)	431 (36.0)	660 (55.0)	16.3	7.9	10.8	−2.4
1999–2003	1241	97 (7.8)	519 (41.8)	625 (50.4)	8.2	−2.3	17.6	−7.0
2004–2008	1349	83 (6.1)	615 (45.6)	651 (48.3)	21.6	−2.8	19.2	5.3
1977–2008	522	12 (2.3)	276 (52.9)	234 (44.8)	19.3	0.5	10.2	8.7

[a] The figures in parentheses show the proportion (%) of C stock for each TOF group to total C stock. The last row shows the total change in C stock and the average sink over the period.

Table 2. Comparison of biomass C stocks and C sinks between China's forests and China's TOF during 1977–2008. The C estimates of China's forests are based on Guo et al. (2013).

Period	C stock (Tg C)		C sink ($Tg\,C\,yr^{-1}$)	
	TOF	Forests	TOF	Forests
1977–1981	827	4972	–	–
1984–1988	964	5178	19.6	29.5
1989–1993	1118	5731	30.9	110.6
1994–1998	1199	5781	16.3	10.1
1999–2003	1241	6293	8.2	102.3
2004–2008	1349	6868	21.6	114.9
1977–2008	522	1896	19.3	70.2

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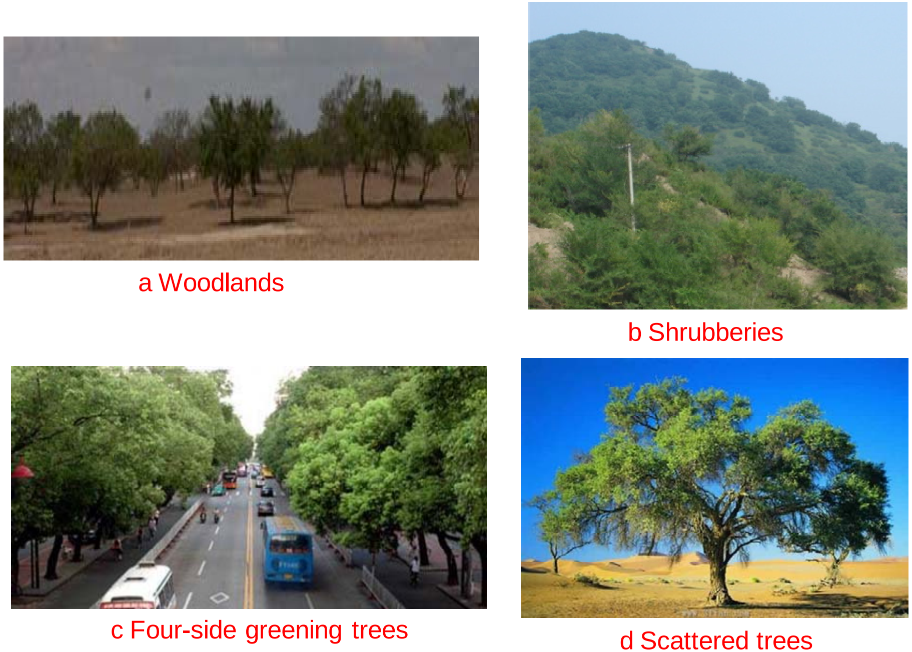

Fig. 1. Examples of different TOF types in China. **(a)** Woodland; **(b)** shrubberies; **(c)** four-side greening trees; **(d)** scattered trees.

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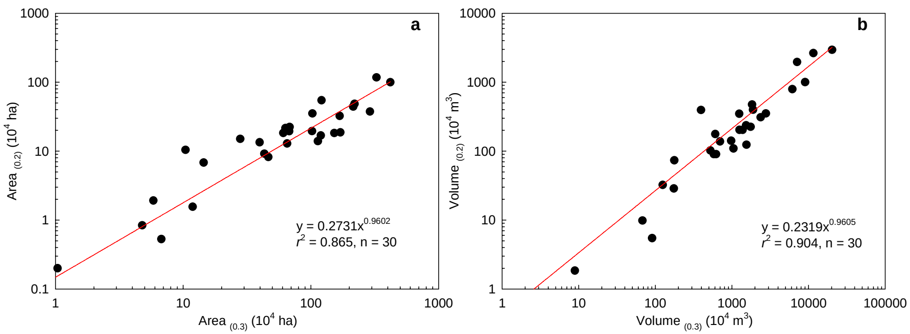

Fig. 2. Relationships of the woodland area and volume between the two criteria at the provincial level in 1994–1998. **(a)** Area, **(b)** volume. The subscripts 0.3 and 0.2 in parenthesis represent the criterion of 0.1 ~ 0.3 and 0.1 ~ 0.2 canopy coverage, respectively.

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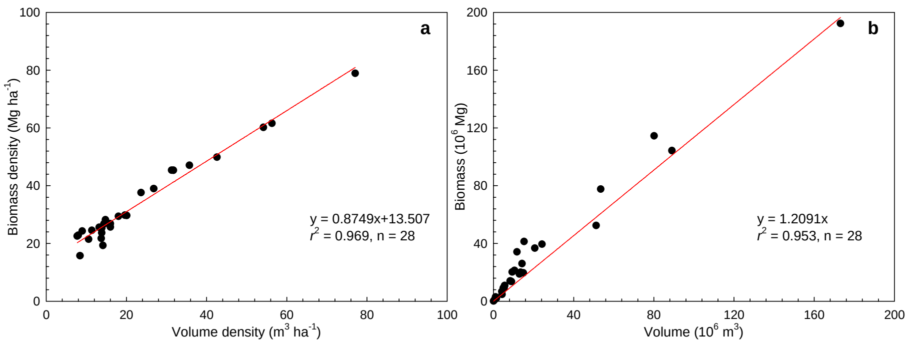

Fig. 3. Relationships between biomass density (Mg ha^{-1}) and volume density (m^3 ha^{-1}) **(a)** and between biomass (10^6 Mg) and volume (10^6 m^3) **(b)** for forest stands with canopy coverage of 0.2 ~ 0.3 at the provincial level in 1994–1998.

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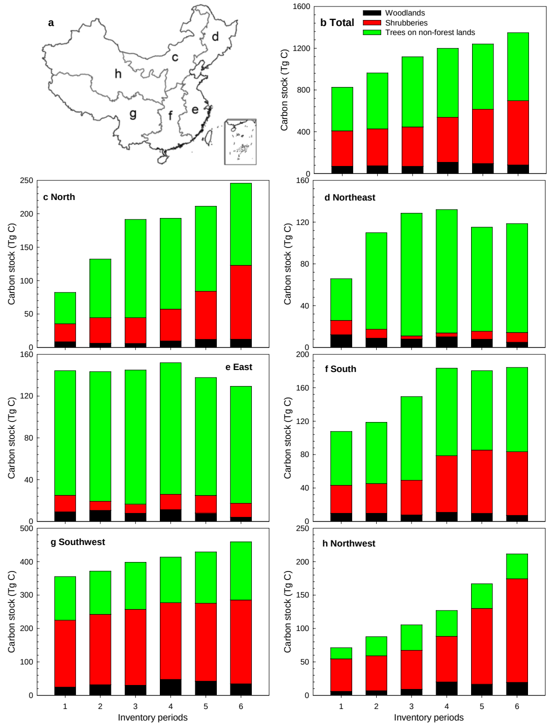

Fig. 4. Spatio-temporal distribution of biomass C stocks among the entire TOF and each group. **(a)** Regional map; **(b)** total; **(c)** Northern China (including Beijing, Tianjin, Hebei, Shanxi, and Inner Mongolia); **(d)** Northeastern China (including Liaoning, Jilin, and Heilongjiang); **(e)** Eastern China (including Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, and Shandong); **(f)** Southern China (including Henan, Hubei, Hunan, Guangdong, Guangxi, and Hainan); **(g)** Southwestern China (including Chongqing, Sichuan, Guizhou, Yunnan, and Tibet); **(h)** Northwestern China (including Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang). The number 1 through 6 represent the inventory periods of 1977–1981, 1984–1988, 1989–1993, 1994–1998, 1999–2003, and 2004–2008, respectively.

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