Carbon Emissions from Forest Vegetation Caused by Three Major Disturbances in China

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Abstract: To investigate forest carbon sequestration and its role in addressing global climatic change, it is important to assess carbon emissions caused by major disturbances from forest ecosystems to the atmosphere. Based on forestry statistics on the occurrence of each disturbance and acceptable assumptions on the process and proportion of biomass carbon transferred to other pools due to each disturbance, this paper estimates the direct carbon emission from Chinese forest vegetation caused by three major disturbances, that is, wood harvesting, fire, and DPR, from 1990 to 2009. Results showed that over the past two decades, Chinese forests have been disturbed rather intensively by wood harvesting, fires, and DPR, with clear upward occurrence trends of the three disturbances in the early 21st century. As a result, the average annual carbon emissions caused by wood harvesting, fires, and DPR were 34.25 Tg, 1.61 Tg, and 4.29 Tg, respectively, during 1990–2009. The aggregate annual carbon emission due to these three major disturbances was 40.15 Tg during 1990–2009, which was 30.79 Tg during 1990–1999 and 49.51 Tg during 2000–2009. According to the analysis of carbon emissions from different forest regions, there were obvious regional characteristics of the average annual carbon emission caused by each disturbance. However, it was difficult to identify clear cause and effect relationships among disturbances to explain the spatial variation of carbon emissions from forest vegetation in China. Disturbances have significant influences on carbon balance of forest ecosystems in China. This finding suggests the opportunities for increasing forest carbon sequestration by disturbance-aimed sustainable long-term management of forest resources, as well as the necessity of considering the role of major disturbances in carbon budget models for forest ecosystems or terrestrial ecosystems.

Key words: disturbance; forest; carbon emission; harvesting; forest fires; diseases, pests and rats (DPR)

1 Introduction

Forests contribute about 56% of terrestrial ecosystem carbon pools (Dixon et al. 1994). Meanwhile, forest vegetation could absorb CO2 at a rather high rate. Forest ecosystems are thus playing a crucial role in the global carbon cycle. However, disturbances have great effect on the carbon cycle of forest ecosystems, which will lead to significant changes in carbon balance of terrestrial ecosystems at the regional or global scale (Houghton et al. 2000). Common disturbances in forest ecosystems are harvesting, fire, disease and insects, storms, etc (Chen and Fu 2000). Long-term observations showed that disturbances had a large effect on the carbon balance of North American forests. Forests lost massive carbon immediately following stand-replacing harvesting and fire, becoming a carbon sink again by 10–20 years. Silvicultural thinning, disease and insects, and storms also caused a net carbon loss in the short term (Amiro et al. 2010). Overharvesting and deforestation in low latitude forests, especially in tropical forests, have caused significant decrease in the forest area and carbon stock of the world.
China ranks the fifth in the world regarding forest area (FAO 2010). With the development of forestry and frequent occurrence of meteorological disasters, disturbances have been important features of Chinese forests. Specifically, the timber output and the occurrence area of diseases, pests and rats (DPR) have showed upward trends over the past 20 years, while the forest fire area rose sharply in the early 21st century (Chen et al. 2010). Researches have been performed extensively on the carbon stock and sequestration of forest vegetation in China (Fang et al. 2001, 2007; Wang et al. 2001a; Zhao and Zhou 2004), most of which were based on national forest resource inventories. Further researches are still necessary to understand the impact of specific disturbances on the carbon stock change of Chinese forest vegetation. Direct carbon emissions caused by forest fires during 1950–2000 have been reported (Lv et al. 2006), providing a meaningful reference to accurately evaluate the carbon balance of terrestrial ecosystems in China (Piao et al. 2009). To date, few studies have been focused on carbon losses from forest vegetation due to timber harvesting and DPR outbreaks recently in China.

To improve the understanding on carbon sequestration as well as reduce the uncertainty in estimates of carbon balance of Chinese forest ecosystems, this paper is aimed to estimate the direct carbon emission from forest vegetation caused by three major disturbances, that is, wood harvesting, fire, and DPR, over the past two decades in China.

2 Methods and Data

As a result of man-made or natural disturbances, there is usually an immediate carbon loss from the vegetation of disturbed ecosystems, with subsequent recovery over some period. This loss is mainly caused by death of photosynthesizing vegetation, harvest removals, biomass combustion, or insect herbivory. Through continuous measurement and comparative analysis of the pre- and post-disturbance biomass (Bryan et al. 2010) or CO₂ flux (Grant et al. 2007), the net carbon budget can be estimated for a full disturbance cycle. At the regional scale, it was suggested that the amount of carbon lost from disturbances be estimated by considering all possible carbon transfers between biomass, dead organic matter, and soil carbon pools, as well as to harvested wood products (HWP) and to the atmosphere (IPCC 2006). Based on available forestry statistics on the occurrence of each disturbance and acceptable assumptions on the process and proportion of biomass carbon transferred to other pools due to each disturbance, we estimated the amounts of biomass carbon from Chinese forest vegetation caused by the above-mentioned three major disturbances. Annual emissions from 1990 to 2009 were estimated at province level. China’s total emissions were obtained by adding the emissions of all 31 provincial administrative districts (excluding Hongkong, Macao and Taiwan).

2.1 Calculation of the carbon emission from wood harvesting

From China Forestry Statistics 1990–1997 (Ministry of Forestry 1991–1998) and China Forestry Yearbook 1998–2009 (State Forestry Administration 1999–2010), we took the annual productions of wood (divided into roundwood and fuelwood) and bamboo from 1990 to 2009 in each province. Based on the data available, the calculation of the carbon emission from wood harvesting and related assumptions were as follows:

First, since harvesting reduced the aboveground biomass most immediately (Bryan et al. 2010), we did not consider its influence on the existing pools of underground biomass, litter, dead wood, or soil organic carbon. A part of the aboveground biomass of cleared forests remained on harvest sites as newborn residues, assumed to be oxidized and released to the atmosphere in the year of harvesting. The rest of the aboveground biomass was removed from the ecosystem as roundwood, fuelwood, and bamboo.

Here, all the biomass carbon in fuelwood was assumed to be rapidly oxidized and released in the harvest year. By contrast, only about one third of the biomass carbon in roundwood and bamboo was assumed to be rapidly oxidized and released, while the rest transferred to and stored in HWP (Ge et al. 2008). Finally, the slow and long-term oxidation of carbon in HWP was not considered. The method for calculating the carbon emission due to wood harvesting in the harvest year in this paper can be expressed as:

\[
C_{\text{Harvest}} = C_{\text{Residue}} + \frac{(C_{\text{Roundwood}} + C_{\text{Bamboo}})/3 + C_{\text{Fuelwood}}}{3} (1)
\]

\[
C_{\text{Residue}} = \frac{(C_{\text{Roundwood}} + C_{\text{Fuelwood}} + C_{\text{Bamboo}})}{(1/E - 1)} (2)
\]

\[
C_{\text{Roundwood/Fuelwood}} = V_{\text{Roundwood/Fuelwood}} \cdot D_{\text{Wood}} \cdot 0.5 (3)
\]

\[
C_{\text{Bamboo}} = N_{\text{Bamboo}} \cdot D_{\text{Bamboo}} \cdot 0.5/1000 (4)
\]

where \(C_{\text{Harvest}}\) is the annual carbon emission in the harvest year (tonnes C y⁻¹); \(C_{\text{Residue}}\), \(C_{\text{Roundwood}}\), \(C_{\text{Bamboo}}\), and \(C_{\text{Fuelwood}}\) are the amount of biomass carbon in harvest residues, roundwood, bamboo, and fuelwood (tonnes C y⁻¹), respectively; \(V_{\text{Roundwood/Fuelwood}}\) and \(N_{\text{Bamboo}}\) are the annual production of roundwood/fuelwood (m³ y⁻¹) and bamboo (individuals y⁻¹), respectively; \(E\) is the utilization rate of forest resources, that is, the ratio of wood/bamboo production to growing stock volume (dimensionless); \(D_{\text{Wood}}\) is the basic density of wood (tonnes dry matter m⁻³); \(D_{\text{Bamboo}}\) is the average biomass per individual of bamboo (kg dry matter individual⁻¹); 0.5 is the carbon fraction of dry
matters (tonne C (tonne dry matter))

This paper determines E as 0.65, the mean value of national utilization rates of forest resources during 1990–2003 (Ministry of Forestry 1991–1998; State Forestry Administration 1999–2004). In addition, $D_{\text{Wood}}$ is determined as 0.53 tonne dry matter m$^{-3}$ (Bai et al. 2007), and $D_{\text{Bamboo}}$ is 63.46 kg dry matter individual$^{-1}$ (Chen et al. 2008).

### 2.2 Calculation of the carbon emission from forest fires

Once it happens, fire consumes most of carbon in aboveground biomass and dead organic matter accumulated over the years very quickly. Fire can also reduce soil organic carbon, especially the carbon in surface soil, to some extent, as determined by fire frequency and intensity. Furthermore, there are postfire indirect biogenic emissions due to decomposition of uncombusted organic matters, enhanced soil respiration, loss of tree productivity, and shrub and herb regrowth (Aulair and Carter 1993; Dixon and Krankina 1993). This paper estimates the direct carbon emission from aboveground biomass and dead organic matter (ground litter and dead wood) pools, but it does not evaluate carbon emission from SOC pools or postfire indirect biogenic emissions. Referring to several previous studies (Seiler and Crutzen 1980; Wang et al. 2001b), the method for calculating the carbon emission due to forest fires can be expressed as:

$$C_{\text{Fire}} = \sum (A \cdot M_i \cdot CF_i) \cdot 0.5 \tag{5}$$

where $C_{\text{Fire}}$ is the annual carbon emission caused by fires (tonnes C y$^{-1}$), $A$ is the burned area (ha y$^{-1}$), $M$ is fuel density (mass of fuel available for combustion per unit area burnt, tonnes dry matter ha$^{-1}$), $CF$ is combustion factor (i.e., the fraction of fuel consumed during fires, dimensionless), $i$ is fuel component (aboveground biomass, ground litter and dead wood), and 0.5 is the carbon fraction of dry matter(tonne C (tonne dry matter)$^{-1}$).


We calculated average aboveground biomass densities of forests in each province mainly from three national forest inventories (Ministry of Forestry 1994; State Forestry Administration 2000, 2005). These inventories provide statistical data at the province level about forest area and growing stock volume associated with 36 forest types and five age classes. Using an age-based volume-to-biomass method developed by Pan et al. (2004), we first calculated average biomass density for each forest type, age class, and province. The biomass density was then converted to aboveground biomass density after multiplying it by the ratio of aboveground to total biomass for each forest type (Fang et al. 1996). Finally, using areas and aboveground biomass densities of all forest types in each province, we calculated average aboveground biomass densities in each province. We assigned the value 16.4 tonnes dry matter ha$^{-1}$ to the average density of forest ground litter in China according to a literature review by Zhou et al. (2000), and assumed that the amount of dead wood in forests is about 10% of the aboveground biomass in the forests of China (Delaney et al. 1998; Tang and Zhou 2005).

The combustion factor (CF) is a measure of the proportion of the actually combusted fuel, which varies with the size and architecture of the fuel load, the moisture content of the fuel, and the type of fire (IPCC 2006). There are no measured data that can be used to compute CFs in China. We assumed CF of the aboveground biomass was closely related to forest type. Based on the classification of forest types in China presented by Lv et al. (2006) and the default CFs presented by IPCC (2006) for tropical forest, temperate forest, and boreal forest, we compiled a new set of CFs for a range of forest types in China by interpolating CFs for transitional forest types, such as the subtropical forest, tropical–subtropical mixed forest, and temperate–subtropical mixed forest (Table 1). We assumed CF of the dead organic matter (ground litter and dead wood) 0.50 as adopted by Lv et al. (2006).

### 2.3 Calculation of the carbon emission from diseases, pests and rats (DPR)

Diseases, pests and rats also affect the C balance, but their impacts are often difficult to quantify because they result in decreased growth without initial catastrophic removals.

#### Table 1 Combusation factors of the aboveground biomass for various forest types.

<table>
<thead>
<tr>
<th>Forest type</th>
<th>Province</th>
<th>Combustion factor (Mean±SD, dimensionless)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical forest</td>
<td>Hainan</td>
<td>0.55 ± 0.06</td>
</tr>
<tr>
<td>Tropical-subtropical mixed</td>
<td>Guangdong, Guangxi, Yunnan</td>
<td>(0.52 ± 0.09)</td>
</tr>
<tr>
<td>Subtropical forest</td>
<td>Guizhou, Hunan, Jiangxi, Fujian, Zhejiang, Shanghai</td>
<td>(0.50 ± 0.11)</td>
</tr>
<tr>
<td>Temperate-subtropical mixed</td>
<td>Sichuan, Chongqing, Hubei, Anhui, Jiangsu</td>
<td>(0.48 ± 0.13)</td>
</tr>
<tr>
<td>Temperate forest</td>
<td>Beijing, Tianjin, Hebei, Inner Mongolia, Shanxi, Shandong, Henan, Liaoning, Jilin, Shanxi, Gansu, Qinghai, Ningxia, Xinjiang, Tibet</td>
<td>0.45 ± 0.16</td>
</tr>
<tr>
<td>Boreal forest</td>
<td>Heilongjiang</td>
<td>0.34 ± 0.17</td>
</tr>
</tbody>
</table>

Note: *Derived from IPCC (2006). Values in parenthesis were obtained through linear interpolation.
of C. According to the losses of the timber volume caused by some main forest diseases and pests, Su et al. (2004) calculated the direct economic losses and the ecological losses due to forest disease and pest disasters in China. Similarly, this paper calculates the annual biomass carbon loss caused by DPR, using the annual occurrence area of DPR and the annual loss of the timber volume per unit area. The method for calculating the biomass carbon loss (tonnes C y$^{-1}$), here, regarded as the carbon emission to the atmosphere due to DPR, can be expressed as:

$$C_{DPR} = \sum \sum S_{ij} \cdot V_{ij} \cdot D_{Wood} \cdot 0.5$$  \hspace{1cm} (6)

where $S$ is the annual occurrence area of forest diseases, pests, or rats (ha y$^{-1}$); $V$ is the annual loss of the timber volume per unit area (m$^3$ ha$^{-1}$); $i$ is disaster type, including diseases, pests, and rats; $j$ is disaster class, including mild, moderate, and severe disaster; $D_{Wood}$ is the basic density of wood (tonnes dry matter m$^{-3}$); 0.5 is the carbon fraction of dry matter (tonne C (tonne dry matter)$^{-1}$). As mentioned above, $D_{Wood}$ is determined as 0.53 tonne dry matter m$^{-3}$.

From China Forestry Statistics 1990–1997 (Ministry of Forestry 1991–1998) and China Forestry Yearbook 1998–2009 (State Forestry Administration 1999–2010), we took the annual occurrence areas of diseases, pests, and rats, respectively, from 1990 to 2009 in each province. DPR disasters were divided into three classes: mild, moderate, and severe, only in the area statistics from 1998 to 2009. For example, rat disasters were divided into the following three classes: mild (5%–10% of trees infected), moderate (10%–20% of trees infected), and severe (more than 20% of trees infected).

Su et al. (2004) analyzed the annual losses of the timber volume caused by some main forest diseases and pests in China. Based on their findings, we calculated the average annual timber volume loss per unit area for each class of disease and pest disasters (Table 2). With respect to the average annual timber volume loss per unit area caused by rats, we assumed it to be the mean of those caused by diseases and pests. We regarded all the disasters during 1990–1997 as moderate for calculation.

3 Results and Discussion

3.1 Occurrence trends of three major disturbances in Chinese forests

In recent 20 years, Chinese forests have been disturbed rather intensively by wood harvesting, fires, and DPR. Generally speaking, there are clear upward occurrence trends of the three disturbances in the early 21$^{\text{st}}$ century. Figure 1 illustrates the occurrence trend of each disturbance.

Statistics show that on average the annual productions of roundwood, fuelwood, and bamboo in China are 5.38 × 10$^6$ m$^3$, 4.77 × 10$^6$ m$^3$, and 7.18 × 10$^8$ individuals, respectively. Around 2002, the falling tendency of roundwood and fuelwood productions was curbed and began to pick up, while the growth of bamboo production speeded up (Fig. 1a). The forest cutting quota system established in 1987 has effectively protected Chinese forest resources from excessive exploitation. Especially, due to the implementation of the Natural Forest Conservation

![Figure 1](image-url)
Program from 1998, the annual cutting quota in China had decreased by $5 \times 10^6$ m$^3$ y$^{-1}$ (Wan and Li 2007) until the year 2002, in which the wood (roundwood and fuelwood) production was only $4.44 \times 10^5$ m$^3$.

During 1990–2009, on average, there were 7105 forest fires and $9.74 \times 10^4$ ha forests burnt annually. As a comparison, in the period of 1950–1992, the average annual occurrence of forest fires in China amounted to 16 212, and the average annual area of burned forests amounted to $9.46 \times 10^6$ ha (Wang et al. 1996). However, the annual burned forest area rose sharply in 2003, and maintained high level in the following three years. During 2007–2009, annual burned forest areas belong with those in 1990s (Fig. 1b).

During 1990–2009, the total annual occurrence area of DPR in Chinese forests averaged $9.18 \times 10^6$ ha, with the minimum value $7.01 \times 10^6$ ha in 1998 and the maximum $1.21 \times 10^7$ ha in 2007, showing a downward at first and then upward trend. Regarding the annual occurrence area, pests ranked the first among the three types of disasters all the time, while diseases ranked the second before 2000, and rats ranked the second after 2000 (Fig. 1c). Statistical analysis revealed that the annual occurrence areas of diseases, pests, and rats were all highly correlated with time series (Chen et al. 2010). Annual occurrence areas of pests and diseases were lowest in 1996 and 2003, respectively, and kept growing ever since. Annual occurrence area of rats increased rapidly after 2000.

### 3.2 Trends of carbon emissions caused by three major disturbances in Chinese forests

Our estimates showed that in recent 20 years, three major disturbances had resulted in quantities of carbon emissions from Chinese forest vegetation to the atmosphere (Fig. 2). During 1990–2009, the annual carbon emission due to wood harvesting averaged 35.25 Tg ($1 \text{Tg} = 1 \times 10^{12}$ grams). It kept growing in most of years after 2002 and reached 54.90 Tg in 2009. The annual carbon emission due to forest fires averaged 1.61 Tg. It rose sharply in 2003, and maintained high level until 2006. The total annual carbon emission due to DPR averaged 4.29 Tg, of which 80% was contributed by pests. With the change in occurrence areas, it dropped to the lowest point, 3.38 Tg in 1998. And then it kept rapid growth and reached 5.15 Tg in 2007. The aggregate annual carbon emission due to three major disturbances was 40.15 Tg during the period 1990–2009. Specifically, it was 30.79 Tg during 1990–1999 and 49.51 Tg during 2000–2009. The decadal increase was very significant.

### 3.3 Spatial distribution of carbon emissions caused by three major disturbances in Chinese forests

In this paper, annual carbon emissions from 1990 to 2009 were estimated at province level. To discuss spatial distribution of carbon emissions due to disturbances, we calculated the average annual emissions during 1990–1999 and during 2000–2009 in forest regions with different
forest types (see Table 1 and we listed Inner Mongolia as a separated forest region, considering significant forest fires there). Results showed that there were obvious regional characteristics of carbon emissions due to each disturbance (Fig. 3). Carbon emissions caused by wood harvesting mainly occurred in three southern forest regions, that is, the regions with the tropical–subtropical mixed forest, subtropical forest, and temperate–subtropical mixed forest. Carbon emissions caused by fires mainly occurred in the subtropical forest region, Inner Mongolia forest region, and boreal forest region. Carbon emissions caused by DPR mainly occurred in the temperate forest region. Compared with that during 1990s, variation of the average annual carbon emission during 2000–2009 were different from one region to another. In terms of wood harvesting, from 1990s to the last decade, the average annual carbon emission increased substantially in southern forest regions, but decreased in regions of temperate and boreal forests. In terms of forest fires, the average annual carbon emission increased substantially in subtropical and boreal forest regions, but decreased slightly in the others. In terms of DPR, variations of the average annual carbon emissions were well in agreement with, but smaller than, those due to wood harvesting in most forest regions.

It is obvious that spatial distribution and variation of carbon emissions caused by wood harvesting are chiefly determined by the pattern and intensity of harvesting, due to the method for calculating carbon emissions based on wood productions in this paper. Nevertheless, those by fires and DPR are not only directly affected by climatic change and forestry management (Williams et al. 2010), but also relevant to interactions among the three major disturbances (James et al. 2011). In regions with two or more disturbances, harvesting usually increases the risk of wildfires and pest outbreaks (Naficy et al. 2010); fires can reduce the effects of pest outbreaks (Bergeron et al. 1995); pest outbreaks can also temporarily increase the risk of wildfire by increasing fuel availability (Fleming et al. 2002). At the coarse spatial and temporal scales involved in this paper, it was difficult to identify clear cause and effect relationships among human and natural disturbances to explain the spatial variation of carbon emissions from forest vegetation in China.

3.4 Influences of three major disturbances on the carbon stock and sequestration of forest vegetation in China

With the Gain–Loss Method recommended by IPCC (2006) for estimating carbon stock changes in biomass, the carbon sequestration (the net change of carbon stock) equals the biomass carbon gain through biomass growth subtracted the biomass carbon loss due to disturbances. The carbon stock and sequestration of Chinese forest vegetation have been well assessed. We also presented a systematic estimation on carbon emissions from Chinese forest vegetation caused by three major disturbances in this paper. Here, through a comparison between results in this paper and those in existing reports, we discussed influences of three major disturbances on the carbon stock and sequestration of forest vegetation in China.

Since 1990s, based on six national forest resource inventories, several researches have evaluated the carbon stock of forest vegetation in China. It was estimated that the biomass carbon stock of Chinese forest ecosystems increased from 4.02 ± 0.35 Pg (in the second forest resources inventory, 1977–1981) to 5.68 ± 0.24 Pg (in the sixth forest resources inventory, 1999–2003) (1 Pg = 1 ×10¹⁵ grams), which increased about 1.20–1.90 Pg C (Yu et al. 2010). The carbon sequestration of Chinese forest vegetation was significant and increased quickly from the early 1980s to the early 21st century. It was estimated to be 0.058 Pg C y⁻¹ in 1980s, 0.092 Pg C y⁻¹ in 1990s, and 0.17 Pg C y⁻¹ in the last inventory (1999–2003) (Fang et al. 2007).

Results in this paper showed that due to wood harvesting, forest fires, and DPR, the total carbon emission from Chinese forest vegetation was about 40.15 Tg y⁻¹ during 1990–2009, which was 30.79 Tg y⁻¹ during 1990–1999 and 49.51 Tg y⁻¹ during 2000–2009. However, owing to excluding the carbon transferred to and stored in HWP, postfire indirect carbon emissions, or carbon losses in cases where DPR killed trees, these results should underestimate the carbon loss from Chinese forest vegetation caused by disturbances. Our preliminary estimate showed that the carbon transferred to and stored in HWP equaled to the direct carbon emission due to harvesting in the same year. In addition, postfire indirect carbon emissions usually exceed direct carbon emissions in fires. Therefore, we inferred that the carbon loss from Chinese forest vegetation caused by three major disturbances was about the double of the direct carbon emission to the atmosphere. Accordingly, the carbon loss was 80.30 Tg y⁻¹ during 1990–2009, which was 61.69 Tg y⁻¹ during 1990–1999 and 99.02 Tg y⁻¹ during 2000–2009. Half of the carbon loss entered into the atmosphere in the same year, while the rest was transferred to and stored in HWP or dead organic

![Fig. 4 Carbon sequestration and carbon loss due to disturbances in Chinese forest vegetation.](image)
Acknowledgements

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4 Conclusions

Over the past two decades, Chinese forests have been disturbed rather intensively by wood harvesting, fires, and DPR, with clear upward occurrence trends of the three disturbances in the early 21st century.

From 1990 to 2009, the average annual carbon emission caused by wood harvesting, fires, and DPR were 34.25 Tg, 1.61 Tg, and 4.29 Tg, respectively. The aggregate annual carbon emission due to these three major disturbances was 40.15 Tg during the period 1990–2009, which was 30.79 Tg during 1990–1999 and 49.51 Tg during 2000–2009.

According to the analysis of carbon emissions from different forest regions, there were obvious regional characteristics of the average annual carbon emission caused by each disturbance. However, it was difficult to identify clear cause and effect relationships among disturbances to explain the spatial variation of carbon emissions from forest vegetation in China.

The carbon loss from Chinese forest vegetation due to three major disturbances was about the double of the direct carbon emission to the atmosphere and considerable when compared with the carbon sequestration of forests. Disturbances have significant influences on carbon balance of forest ecosystems in China. This finding suggests the opportunities for increasing forest carbon sequestration by disturbance-aimed sustainable long-term management of forest resources, as well as the necessity of considering the role of major disturbances in carbon budget models for forest ecosystems or terrestrial ecosystems.

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References


三种主要干扰造成中国森林植被向大气中的碳排放量

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摘要：对重要干扰过程导致森林植被向大气中的碳排放量进行评估，对于合理评估森林碳汇功能及其在应对全球气候变化中的作用是具有重要意义的。本文基于有关森林干扰发生情况的林业统计资料和有关干扰引起生物量C转移过程与比例的假设条件，估算了近20年来采伐、火灾与病虫鼠害三种主要干扰每年从森林植被直接排放到大气中的C量。结果表明，近20年来，中国森林遭受了比较强烈的采伐、火灾与病虫鼠害干扰，并且这三种干扰在进入21世纪后有着比较明显的增加趋势。相应地，在1990-2009年间，采伐、火灾与病虫鼠害的C排放量年均分别为3425.16万t C、161.29万t C、428.80万t C，合计为4015.24万t。三种干扰的总C排放量在1990-1999年间年均为3079.40万t，2000-2009年间年均为4951.09万t。从不同森林类型分布区的排放来看，中国森林主要干扰的年均C排放量及其年代际变化呈现比较明显的区域特征。干扰对中国森林碳平衡有着重大影响，针对干扰的森林管理可能具有较大的增汇潜力，并且在未来有关森林与陆地生态系统碳收支的模型研究中需考虑主要干扰的影响。

关键词：干扰；森林；碳排放；采伐；火灾；病虫鼠害（DPR）