Net primary production and its change in Chinese plantation

Shi Jun\textsuperscript{a,b}, Zhiqiang Gao\textsuperscript{b}, and Cui Linli\textsuperscript{c}

\textsuperscript{a}Shanghai Climate Center, Shanghai Meteorological Bureau (SMB), Shanghai, China;

\textsuperscript{b}Institute of Geographical Science and Natural Resources Research, CAS, Beijing, China

\textsuperscript{c}Shanghai Marine Meteorological Center in Remote Sensing, SMB, Shanghai, China

**ABSTRACT**

NPP is not only the original driver of carbon cycle, but also has significance in global change research. In this study, NPP data from GLO-PEM model and Chinese plantation data were used to explore the spatial and temporal changes of NPP in Chinese plantation area from 1981 to 2000. As the results, mean annual NPP in Chinese plantation area was about 663.37 g C m\textsuperscript{-2}yr\textsuperscript{-1} in the past 20 years, with higher NPP in several provinces in South China, and lower NPP in some arid and semi-arid regions in Northeast China, North China and Northwest China. NPP increased more in the eastern part of North China and in Central China and South China, but decreased in most regions of West China, North Liaoning, East Jilin and North Heilongjiang in the past 20 years. Monthly variation of plantation NPP was mainly in phase from June to September, especially in July and August during the 4\textsuperscript{th} times from 1996 to 2000, monthly NPP increased most. Mixed plantation had the highest mean annual NPP and coniferous plantation had the least. Plantation in East China had higher mean annual NPP, annual NPP increase rate and monthly NPP variation than that in West China. The increment of total annual NPP in Chinese plantation from 1980’s to 1990’s was 84.51 × 10\textsuperscript{4} t C yr\textsuperscript{-1}. Plantation in Hainan province had the highest mean annual NPP and NPP increase, and plantation in Guangdong province had the largest total annual NPP increase in the past 20 years, but in Xinjiang province, mean annual NPP in plantation area was lowest and decreasing.

**Keywords:** GLObal Production Efficiency Model (GLO-PEM), net primary production (NPP), plantation, China

1. INTRODUCTION

Global climate change and land use change represent the influence of natural and human activities on terrestrial ecosystem. Afforestation and forest management, as land-use change and terrestrial management activities can increase carbon stocks and account for emission reductions according to the Kyoto Protocol\textsuperscript{1}, thus has been the subject of significant attention recently from international society and government. The contribution of afforestation to the global carbon cycle has been estimated by many studies on regional\textsuperscript{2-6} and global scales\textsuperscript{7-9}. Study on the influence of afforestation on terrestrial carbon stock has become one of the research hotspots in global change and forestry practice.

Net primary production (NPP) is not only the original driver of carbon cycle, but also the main factors to determine the carbon source/sink and condition the ecological process\textsuperscript{10}. Its alteration greatly affects global carbon cycle and global climate\textsuperscript{10-12}. So the dynamic monitoring of NPP has significance in global climate change and terrestrial carbon cycle research.

China has the largest area of plantation in the world. According to the fifth National Forest Resource Inventory conducted from 1994 to 1998, the plantation area in China was about 46.67 million hectares\textsuperscript{13}, which was about one third of the overall plantation area in the world. The carbon storage in plantation biomass has been studied systematically by many scholars based on the plot surveyed data or national statistic data. For example, Fang et al.\textsuperscript{6} used a forest biomass database obtained from direct field measurements and the National Forest Resource Inventory database for China to estimate forest biomass C storage in plantations (including afforestation and reforestation) was about 0.72

---

\textsuperscript{1} Corresponding Author. Email: shiji@lreis.ac.cn; Tel: 86-21-64380306; Fax: 86-21-64272407.
petagram C, and planted forests have sequestered 0.45 petagram in their biomass since the mid-1970s. But little study has focused on the spatial distribution and variations of Chinese plantation NPP at the national scale or regional scale, which could partly decrease the uncertainty of the large sink of atmospheric CO$_2$ in the mid-latitudes of the Northern Hemisphere or northern Asia. GLO-PEM model, a full remote sensing model, along with plantation map and concurrent plantation area from National Forest Resource Inventory database, was applied to explore the spatio-temporal differences and dynamics of Chinese plantation NPP from 1981 to 2000.

2. DATASETS AND METHODS

2.1 Data Sources

The datasets used in this research included: GLO-PEM simulating NPP data, Chinese plantation map, Chinese administrative and regionalization map and statistic plantation area of each province from the third and fifth Forest Resource Inventory of China (FRIC). The NPP data was produced by Department of Geography, University of Maryland at a spatial resolution of 8 ×8 km$^2$ with a ten-day interval for the times of 1981-2000. Chinese plantation map was digitized from Atlas of China’s Forest with the scale of 1:1000000, which was produced according to the fifth FRIC and Landsat TM images in 1990’s.

![Figure 1. (a) Digitized Chinese plantation map and (b) Chinese administrative and regionalization map](image)

2.2 GLO-PEM model

GLO-PEM (Global Production Efficiency Model) is a NPP model driven entirely with remote sensing data, including both the normalized difference vegetation index (NDVI) and meteorological variables. It consists of linked components that describe processes of canopy radiation absorption, utilization, autotrophic respiration, and the regulation of these processes by environmental factors such as temperature, water vapor pressure deficit, and soil moisture:

$$\text{NPP} = \sum_t \left( \frac{S_t}{N_t} \right) \epsilon_g (NPP - R)$$

Where $S_t$ is the incident PAR in time $t$; $N_t$ is the fraction of incident photosynthetically active radiation (PAR) absorbed by vegetation canopy (FAPAR), calculated as a function of NDVI; $\epsilon_g$ is the light utilization efficiency of the absorbed PAR by vegetation in terms of gross primary production; $R$ is autotrophic respiration calculated as a function of standing aboveground biomass, air temperature, and photosynthetic rate.

GLO-PEM includes algorithms to calculate NDVI, FAPAR, biomass, air temperature, and VPD from the AVHRR data. The algorithms for calculating these variables are described in others and have been validated with field observational data, and GLO-PEM model has been used successfully to estimate and evaluate the spatiotemporal pattern of vegetation NPP in regional and global scale.

GLO-PEM model can be use with higher spatial resolution for both the photosynthetically active radiation (PAR) and...
the climate data used in GLO-PEM model all come from remote sensing. Pathfinder AVHRR Land (PAL) data at resolutions of 8 km and 10 days were used to drive GLO-PEM. They were derived from channels 1, 2, 4, and 5 of the sensors aboard the NOAA -7, -9, -11, and -14.

2.3 Estimation of mean annual NPP and total annual NPP

Mean annual NPP was estimated from the simulating NPP of GLO-PEM model and the digitized plantation area. The digitized area of Chinese plantation was $2.252.82 \times 10^4 \text{hm}^2$, which was near the statistic plantation area of $2.137.29 \times 10^4 \text{hm}^2$ in the fourth FRIC. In most provinces, the digitized area was relatively near the statistic area in the fifth FRIC, and could generally represent the status of plantation in those provinces in the late 1990’s. Considering no better plantation map in China available, we used these map to estimate the NPP status and its change in the past 20 years. With the help of ArcGIS 9.0, mean annual NPP of Chinese plantation was analyzed spatially and temporally.

Total annual NPP was estimated from the mean annual NPP and contemporaneous plantation area in each province. Plantation area in 1980’s and 1990’s in each province was estimated according to the stand area in the third and fifth Forest Resource Inventory of China (FRIC). The difference was the total annual NPP change from 1980’s to 1990’s. Due to the absence of plantation in Shanghai and Xizang in the Atlas of China’s Forest, Mean annual NPP in Shanghai and Xizang was assumed as the same value as Jiangsu and Qinghai province respectively.

2.4 Differences of NPP status and change in plantation types, provinces and times

According to the Atlas of China's Forest, plantation was also divided into three types, i.e. coniferous plantation, broad-leaved plantation and mixed plantation (Fig.1 (a)), and the NPP of each plantation type was analyzed by ArcGIS and other tools respectively.

In China, more plantations are distributed in East China, especially in the ten provinces in Central and South China, i.e. Zhejiang, Anhui, Fujian, Jiangxi, Hubei, Hunan, Guangdong, Guangxi, Hainan and Guizhou, so in this paper, we not only analyzed the plantation NPP in the whole China, but also analyzed the plantation NPP in East China and West China respectively. The division between East China and West China was according to the administrative map. West China includes 11 provinces, i.e. Neimenggu, Shanxi, Gansu, Qinghai, Ningxia, Xinjiang, Sichuan (including Chongqing), Guizhou, Yunnan and Xizang province (Fig. 1(b)); the others are included in East China.

To analyze the annual variation and monthly variation of plantation NPP further, and to eliminate the impacts of NPP variation in individual year on the results, we divided the past 20 years from 1981 to 2000 into 4 times, each 5 years as one times, i.e. the 1st times is from 1981 to 1985, the 2nd times is from 1986 to 1990, the 3rd times is from 1991 to 1995, and the 4th times is from 1996 to 2000. Mean monthly NPP in each times was used to analyze the monthly variation in the past 20 years.

3. RESULTS AND DISCUSSION

3.1 Spatial distribution and change of NPP in Chinese plantation area

![Figure 2. (a) Spatial distribution and (b) change of mean annual NPP in Chinese plantation area during the times from 1981 to 2000. Based on the NPP data simulated by GLO-PEM, spatial distribution and change of NPP in Chinese plantation area was analyzed with ArcGIS 9.0 during the times from 1981 to 2000. Mean annual NPP in Chinese plantation area was](image)
663.37 g Cm⁻² yr⁻¹ in the past 20 years. Plantation NPP had great difference in different regions in China (Fig. 2(a)), with higher mean annual NPP in several provinces in South China, such as in Guangdong and Hainan, mean annual NPP in most regions was more than 900 g Cm⁻², and lower mean annual NPP in some arid and semi-arid regions in Northeast China, North China and Northwest China, such as in Northwest Liaoning, Northwest Shanxi, Northwest Hebei, Shanxi, Gansu, Qinghai, Xinjiang, North Heilongjiang and West Sichuan, plantation NPP was less than 350 g Cm⁻² yr⁻¹.

The change of mean annual NPP in Chinese plantation area was estimated by subtracting the mean annual NPP during the times from 1981 to 1985 from that during the times from 1995 to 2000, and in the past 20 years, there was great difference among the change in different regions (Fig. 2(b)). Mean annual NPP in Chinese plantation area decreased in most regions of West China, North Liaoning, East Jilin and North Heilongjiang, most with a decrement of less than 100 g Cm⁻², and increased more in Hebei, Liaoning, Shandong and several provinces in Central China and South China, most with an increase of more than 100 g Cm⁻². This partly indicated that Chinese plantation influenced more by natural conditions, and less by human activities.

3.2 Temporal change of NPP in Chinese plantation area

Annual and monthly variation of Chinese plantation NPP was also analyzed. Mean annual NPP in Chinese plantation area increased obviously in the past 20 years (Fig. 3(a)), from 623.85 g Cm⁻² yr⁻¹ in 1981 to 672.37 g Cm⁻² yr⁻¹ in 2000, with an increment of 48.52 g Cm⁻² and an increase rate of 0.39%. In both East China and West China, plantation NPP increased in the past 20 years. In East China, where most Chinese plantations are distributed, mean annual NPP increased 54.50 g Cm⁻², which was more than double of the increase in West China (25.46 g Cm⁻²), and the annual increase rate in East China and West China was 0.41% and 0.27% respectively. In the ten provinces in Central China and South China, as main plantation distribution area in China, plantation NPP increased with an annual increase rate of 0.43%. In Northeast China, the increase rate was about 0.68%, but in Northwest China, plantation NPP decreased with an annual rate of 0.18% (Figure omitted).

![Graph showing annual and monthly variation of Chinese plantation in the past 20 years](image)

Figure 3. (a) Annual and (b) monthly variation of Chinese plantation in the past 20 years

In each year, plantation NPP in China as a whole increased from April, and got its maximum in August, then decreased and in November it neared the same NPP level as in April (Fig. 3(b)). In all four times from 1981 to 2000, plantation NPP changed according to the forenamed trends. Monthly variation of Chinese plantation in four times was mainly in the period from June to September. During preceding 3 times from 1981 to 1995, besides in August, when plantation NPP during the 2nd times from 1985 to 1990 and during the 3rd times from 1991 to 1995 decreased a little compared with that during the 1st times from 1981 to 1985, monthly NPP variation of Chinese plantation was little (Fig. 3(b)). But during the 4th times from 1996 to 2000, compared with preceding 3 times, monthly NPP had great increase from March to October, especially in July and August, NPP increased more, the increment was 15.26 and 16.26 g Cm⁻² compared with the corresponding month during the 1st times.

Monthly NPP variation in East China was not completely consistent with that in West China. In East China, monthly NPP variation was basically consistent with that of China, for most plantations in China are distributed in East China. Monthly NPP in East China had an obvious increase from May to September during the 4th times compared with that of the preceding 3 times. In July, August and September, monthly NPP during the 4th times increased 17.21 g Cm⁻², 19.46 g Cm⁻² and 10.67 g Cm⁻² compared with that during the 1st times. Monthly variation in East China during the preceding 3 times was little, and all was less than 5 g Cm⁻². In West China, monthly NPP variation was less than that in
East China, and the variation was mainly in July and August. In July, monthly NPP during the 4th times increased 7.59gCm⁻² compared with that during the 1st times, and in August, it increased 10.03gCm⁻² during the 4th times compared with that during the 2nd times. NPP variation in other months and in other times was all less than 5gCm⁻².

3.3 Variation of annual and monthly NPP in different plantation types

Mean annual NPP was different for different plantation types. Whether in the whole China or in East China or West China, mixed plantation had the highest mean annual NPP and coniferous plantation had the least, and mean annual NPP in East China was higher than that in West China with same plantation type (Tab. 1). In China, mean annual NPP in mixed plantation area was 834.94gCm⁻²yr⁻¹, and that in coniferous plantation was 599.69gCm⁻²yr⁻¹. In East China, mean annual NPP in coniferous, broad-leaved and mixed plantation was 642.49gCm⁻²yr⁻¹, 761.21gCm⁻²yr⁻¹ and 844.53gCm⁻²yr⁻¹ respectively, and in West China, the corresponding NPP was 464.79gCm⁻²yr⁻¹, 571.34gCm⁻²yr⁻¹ and 623.62gCm⁻²yr⁻¹ respectively. For coniferous plantation and mixed plantation, Northwest China had the least mean annual NPP in China, which was 263.98gCm⁻²yr⁻¹ and 325.57gCm⁻²yr⁻¹ respectively, and for broad-leaved plantation, North China had the least nationally, which was 410.77 gCm⁻²yr⁻¹. In Northwest China, mean annual NPP of broad-leaved plantation was 440.78gCm⁻²yr⁻¹.

Table 1. Area and mean annual NPP of each plantation type during the period from 1981 to 2000    Units: 10⁶hm², gCm⁻²yr⁻¹

<table>
<thead>
<tr>
<th>Regional</th>
<th>Coniferous plantation</th>
<th>Broad-leaved plantation</th>
<th>Mixed plantation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (10⁶hm²)</td>
<td>NPP (gCm⁻²yr⁻¹)</td>
<td>Area (10⁶hm²)</td>
</tr>
<tr>
<td>China</td>
<td>1316.72</td>
<td>599.69</td>
<td>679.74</td>
</tr>
<tr>
<td>East China</td>
<td>1000.03</td>
<td>642.49</td>
<td>551.57</td>
</tr>
<tr>
<td>West China</td>
<td>315.61</td>
<td>464.79</td>
<td>127.96</td>
</tr>
</tbody>
</table>

In the past 20 years, mean annual NPP in coniferous, broad-leaved and mixed plantation increased about 45.00 gCm⁻², 51.87 gCm⁻² and 57.52 gCm⁻² respectively in China, with an annual increase rate of 0.40%, 0.37% and 0.37% respectively. For each plantation type, NPP increment in East China was also greater than that in West China. Annual increase rate of coniferous, broad-leaved and mixed plantation in East China was 0.43%, 0.40% and 0.37% respectively, and in West China, the corresponding increase rate was 0.30%, 0.20% and 0.31%.

Monthly variation of each plantation type was also consistent with that of all plantations in China, with greater variation in the phase from June to September. In this four months, compared with the 1st times, monthly NPP of three plantation types all increased largely during the 4th times, but the changing process was different. For broad-leaved and mixed plantation, monthly NPP decreased in the 2nd times and continuously decreased to the minimum in the 3rd times, but for coniferous plantation, monthly NPP varied little in the 2nd and 3rd times. In July and August, compared with the 1st times, monthly NPP of coniferous plantation increased 15.16gCm⁻² and 16.42gCm⁻² in the 4th times respectively, broad-leaved plantation increased 15.94 gCm⁻² and 15.34 gCm⁻² respectively, and mixed plantation increased 13.79 gCm⁻² and 17.99 gCm⁻² respectively. Monthly NPP of all plantation types decreased in November in the 4th times, and the decrease was from 1gCm⁻² to 5gCm⁻².

3.4 Estimation of Total NPP and change in different provinces

Tab. 2 was the mean annual NPP and total annual NPP in 1980’s and 1990’s, and the change of total annual NPP from 1980’s to 1990’s in each province in China. Mean annual NPP in 1980’s in Chinese plantation was about 6.46tChm⁻³yr⁻¹, and that in 1990’s was about 6.81 tChm⁻³yr⁻¹. Total annual NPP in 1980’s in Chinese plantation was about 114.61×10⁴tCyr⁻¹, and that in 1990’s was about 199.12×10⁴tCyr⁻¹. The increment of total annual NPP from 1980’s to 1990’s was 84.51×10⁴tCyr⁻¹.

In the past 20 year, mean annual NPP in Hainan and Guangdong was highest, about 10.71 and 10.06 tChm⁻³yr⁻¹ respectively. It was also higher in Fujian and Guangxi, about 8.94 and 8.74 tChm⁻³yr⁻¹ respectively. Mean annual NPP in Xinjiang, Ningxia and Qinghai was less than 2.00 tChm⁻³yr⁻¹. Compared with that of 1980’s, mean annual NPP in 1990’s increased in most provinces. Hainan had the most increase, from 10.15 tChm⁻³yr⁻¹ in 1980’s to 11.28tChm⁻³yr⁻¹ in 1990’s, then was Shandong, Tianjing and Beijing, the increment was 0.84, 0.76 and 0.72 tChm⁻³yr⁻¹ respectively, but in Xizang, Qinghai and Gansu, mean annual NPP in 1990’s decreased.

In 1990’s, the total annual NPP in Guangdong, Fujian and Guangxi was most, about 31.65×10⁴, 21.72×10⁴ and 17.61×10⁴tCyr⁻¹ respectively, and the total annual NPP in Xizang, Shanghai and Qinghai was least, all less than 0.05×10⁴tCyr⁻¹. Total annual NPP increased more in Guangdong, Guangxi and Fujian from 1980’s to 1990’s, with an
increment of $17.20 \times 10^4$, $10.20 \times 10^4$ and $10.20 \times 10^4$ tC yr$^{-1}$ respectively, and decreased in Xinjiang by $0.04 \times 10^4$ tC yr$^{-1}$.

### Table 2. Annual NPP of plantation area in each province

<table>
<thead>
<tr>
<th>Province</th>
<th>Mean NPP in 1980's (t Chm$^{-2}$ yr$^{-1}$)</th>
<th>Mean NPP in 1990's (t Chm$^{-2}$ yr$^{-1}$)</th>
<th>Mean NPP during 1980 to 2000 (t Chm$^{-2}$ yr$^{-1}$)</th>
<th>Total NPP in 1980's (10$^4$ tC yr$^{-1}$)</th>
<th>Total NPP in 1990's (10$^4$ tC yr$^{-1}$)</th>
<th>Total NPP change from 1980's to 1990's (10$^4$ tC yr$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>4.59</td>
<td>5.31</td>
<td>4.95</td>
<td>0.31</td>
<td>0.56</td>
<td>0.25</td>
</tr>
<tr>
<td>Tianjing</td>
<td>4.61</td>
<td>5.37</td>
<td>4.99</td>
<td>0.16</td>
<td>0.21</td>
<td>0.05</td>
</tr>
<tr>
<td>Hebei</td>
<td>3.60</td>
<td>4.25</td>
<td>3.92</td>
<td>1.03</td>
<td>3.67</td>
<td>1.75</td>
</tr>
<tr>
<td>Shanxi</td>
<td>3.32</td>
<td>3.69</td>
<td>3.51</td>
<td>0.71</td>
<td>1.72</td>
<td>1.00</td>
</tr>
<tr>
<td>Neimenggu</td>
<td>3.05</td>
<td>3.53</td>
<td>3.29</td>
<td>3.36</td>
<td>5.72</td>
<td>2.36</td>
</tr>
<tr>
<td>Liaoning</td>
<td>4.92</td>
<td>5.31</td>
<td>5.12</td>
<td>7.00</td>
<td>7.92</td>
<td>0.93</td>
</tr>
<tr>
<td>Jilin</td>
<td>4.90</td>
<td>5.05</td>
<td>4.97</td>
<td>4.65</td>
<td>6.78</td>
<td>2.14</td>
</tr>
<tr>
<td>Heilongjiang</td>
<td>4.22</td>
<td>4.43</td>
<td>4.33</td>
<td>6.82</td>
<td>8.45</td>
<td>1.63</td>
</tr>
<tr>
<td>Shanghai</td>
<td>5.88</td>
<td>6.49</td>
<td>6.18</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>5.88</td>
<td>6.49</td>
<td>6.18</td>
<td>1.17</td>
<td>1.27</td>
<td>0.09</td>
</tr>
<tr>
<td>Zhejiang</td>
<td>7.65</td>
<td>8.10</td>
<td>7.88</td>
<td>6.18</td>
<td>8.60</td>
<td>2.42</td>
</tr>
<tr>
<td>Anhui</td>
<td>7.74</td>
<td>8.18</td>
<td>7.96</td>
<td>6.86</td>
<td>8.81</td>
<td>1.95</td>
</tr>
<tr>
<td>Fujian</td>
<td>8.76</td>
<td>9.13</td>
<td>8.94</td>
<td>11.51</td>
<td>21.72</td>
<td>10.20</td>
</tr>
<tr>
<td>Jiangxi</td>
<td>7.69</td>
<td>8.25</td>
<td>7.97</td>
<td>6.38</td>
<td>15.90</td>
<td>9.51</td>
</tr>
<tr>
<td>Shandong</td>
<td>5.32</td>
<td>6.16</td>
<td>5.74</td>
<td>3.21</td>
<td>3.27</td>
<td>0.07</td>
</tr>
<tr>
<td>Henan</td>
<td>5.47</td>
<td>5.92</td>
<td>5.70</td>
<td>2.19</td>
<td>3.19</td>
<td>1.00</td>
</tr>
<tr>
<td>Hubei</td>
<td>6.81</td>
<td>7.35</td>
<td>7.08</td>
<td>4.64</td>
<td>6.21</td>
<td>1.57</td>
</tr>
<tr>
<td>Hunan</td>
<td>7.09</td>
<td>7.41</td>
<td>7.25</td>
<td>8.49</td>
<td>15.02</td>
<td>6.53</td>
</tr>
<tr>
<td>Guangdong</td>
<td>9.84</td>
<td>10.29</td>
<td>10.06</td>
<td>14.45</td>
<td>31.65</td>
<td>17.20</td>
</tr>
<tr>
<td>Guangxi</td>
<td>8.67</td>
<td>8.81</td>
<td>8.74</td>
<td>7.41</td>
<td>17.61</td>
<td>10.20</td>
</tr>
<tr>
<td>Hainan</td>
<td>10.15</td>
<td>11.28</td>
<td>10.71</td>
<td>1.56</td>
<td>3.40</td>
<td>1.84</td>
</tr>
<tr>
<td>Sichuan</td>
<td>5.10</td>
<td>5.25</td>
<td>5.18</td>
<td>7.47</td>
<td>11.73</td>
<td>4.26</td>
</tr>
<tr>
<td>Guizhou</td>
<td>6.48</td>
<td>6.49</td>
<td>6.48</td>
<td>2.67</td>
<td>5.61</td>
<td>2.94</td>
</tr>
<tr>
<td>Yunnan</td>
<td>6.11</td>
<td>6.27</td>
<td>6.19</td>
<td>2.08</td>
<td>5.44</td>
<td>3.36</td>
</tr>
<tr>
<td>Xizang</td>
<td>1.59</td>
<td>1.53</td>
<td>1.56</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Shanxi</td>
<td>4.88</td>
<td>5.00</td>
<td>4.94</td>
<td>1.89</td>
<td>3.14</td>
<td>1.25</td>
</tr>
<tr>
<td>Gansu</td>
<td>2.83</td>
<td>2.80</td>
<td>2.82</td>
<td>1.10</td>
<td>1.16</td>
<td>0.06</td>
</tr>
<tr>
<td>Qinghai</td>
<td>1.59</td>
<td>1.53</td>
<td>1.56</td>
<td>0.04</td>
<td>0.04</td>
<td>0.00</td>
</tr>
<tr>
<td>Ningxia</td>
<td>1.32</td>
<td>1.32</td>
<td>1.32</td>
<td>0.08</td>
<td>0.08</td>
<td>0.00</td>
</tr>
<tr>
<td>Xinjiang</td>
<td>0.82</td>
<td>0.87</td>
<td>0.85</td>
<td>0.26</td>
<td>0.22</td>
<td>-0.04</td>
</tr>
<tr>
<td>China</td>
<td>6.46</td>
<td>6.81</td>
<td>6.63</td>
<td>114.61</td>
<td>199.12</td>
<td>84.51</td>
</tr>
</tbody>
</table>

### 4. CONCLUSIONS

The knowledge of plantation NPP and its change is important to understand the carbon sink in the northern middle and
high latitudes and regional NPP increase. In this study, GLO-PEM simulating NPP data and plantation map was used to explore the spatio-temporal changes of plantation NPP in China, each province and plantation type. The major findings are summarized as follows:

(1) Mean annual NPP in Chinese plantation area was about 663.37gCm⁻²yr⁻¹ in the past 20 years, with higher NPP in several provinces in South China, and lower NPP in some arid and semi-arid regions in Northeast China, North China and Northwest China. Plantation in Hainan and Guangdong had the highest NPP, and in Xinjiang, Ningxia and Qinghai, plantation NPP was lowest.

(2) Mean annual NPP in Chinese plantation area increased more in the eastern part of North China and in Central China and South China, but decreased in most regions in West China, North Liaoning, East Jilin and North Heilongjiang in the past 20 years. The annual increase rate of plantation NPP was 0.39% in China. Hainan had the highest increase in 1990’s, but in Xizang, Qinghai and Gansu, NPP decreased.

(3) Monthly variation of Chinese plantation was mainly in phase from June to September, and largest monthly NPP increase was during the 4th times from 1996 to 2000, especially in July and August, monthly NPP increased most.

(4) Mixed plantation had the highest mean annual NPP and coniferous plantation had the least. Plantation in East China had higher mean annual NPP, annual NPP increase rate and monthly NPP variation than that in West China.

(5) The increment of total annual NPP in Chinese plantation from 1980’s to 1990’s was 84.51×10⁴tCyr⁻¹. Total annual NPP increased more in Guangdong, Guangxi and Fujian from 1980’s to 1990’s, and decreased in Xinjiang.

ACKNOWLEDGMENTS

This work was supported by the National 973 Key Project of China (2002CB412507), National Natural Science Foundation of China (Project: 40471097 and 30371192) and Phosphor Project of Shanghai Meteorological Bureau (No. 2005Q5), USDA UV-B Monitoring and Research Program under a grant from USDA CSREES 2005-34263-14270.

REFERENCES


