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Impacts of a large-scale reforestation program on carbon storage dynamics in Guangdong, China

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Abstract

In the early 1980s, the province of Guangdong, China implemented a 10-year, large-scale reforestation program to counter environment degradation as a result of rapid economic development. Quantification of the contribution of this forest restoration program to carbon storage will provide critical information and guidance for designing future forest restoration and management strategies at the provincial level.

The Guangdong Provincial Forest Inventory Database, together with our field sampling data was used to estimate carbon storage dynamics over the 10-year period of 1994–2003 for key restoration forest types as well as OBPA (open forest, bamboo forest, production forest and ambient trees). Various layers of forests were considered in calculating carbon storage: tree layers, understory vegetation and litterfall layers for the key forest types and bamboo forests; tree layers and litterfall layers for production forests; and only tree layers for open forest and ambient trees.

Our results show that over the 10-year period, the reforestation program has increased total carbon storage by 41.67 Tg and forest carbon density by 1.58 Mg C ha^{-1}. Carbon storage in tree layers was the greatest among all layers studied. Carbon storage in litterfall and understory layers amounted to approximately 38%–44% of the total carbon storage, demonstrating that litterfall and understory layers can not be neglected in estimating regional forest vegetation carbon storage in the sub-tropical forests. It was determined that coniferous forests provided the greatest contribution to total carbon, followed by broadleaved forests, OBPA, and mixed coniferous and broadleaved forests in decreasing order of magnitude. Among all key forest types, stands of *P. massoniana* had the greatest amount of carbon storage (from 59.65 to 65.87Tg) while *Albizia falcataria* (Linn.) *Fosberg* forest stands had the lowest (from 0.05 to 0.37 Tg). Over the 10-year period, carbon storage pools in maturescent forests, mature forests and post-mature forests were on the increasing trend, while those in young forests and middle-aged forests were declining and relatively stable, respectively. Our analysis also shows that the carbon accumulation rate in broadleaved forests (0.19–1.36 Mg ha^{-1} year^{-1}) was the highest among the key forest types in Guangdong, which has important implications for selection of future forest restoration species.

Keywords: Guangdong province; Forest restoration; Carbon storage; Carbon density

1. Introduction

Carbon (C) storage and fluxes in forest ecosystems have been the focus of research in recent years because of the role of CO_2 in global climate change (Davis et al., 2003). Forest ecosystems play an important role in influencing the global C cycle, because they store nearly two thirds of terrestrial C and have a larger carbon density (carbon mass per hectare) than any other land uses. Since forest ecosystems exchange large amounts of CO_2 with the atmosphere through photosynthesis and respiration, they have the potential to sequester large amounts of carbon in regrowth stages (Schimel, 2001). Estimates of temporal changes in forest vegetation carbon pools are useful for understanding carbon storage associated with forest changes or successions (e.g., Dixon et al., 1994; Birdsey et al., 1993; Grigal and Ohmann, 1992; Fang et al., 2001; Fang and Chen, 2001). However, many studies on forest carbon dynamics have been at local levels, targeted at specific forest types. There has been little research at a regional or provincial level mainly due to the difficulties in dealing with the

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many types of forests involved at a large-scale level. This highlights an important need to conduct a forest carbon dynamics study at a provincial or regional level.

Guangdong province, located in southern China, has a subtropical monsoon climate. With abundant moisture and heat, there is a high diversity of forest types and great forest growth potential in the province. Because of rapid economic development in Guangdong in the last few decades, many forest ecosystems have experienced various levels of deforestation and land use changes. These economic development driven disturbances have caused serious environmental problems such as severe soil erosion, loss of wildlife habitat and loss of forest cover. In order to reduce these environmental problems, the Guangdong provincial government launched a large-scale, 10-year reforestation program in the 1980s. Through implementation of this program, the forest coverage rate of the province increased from 26.2% in 1979, 30.0% in 1986, 50.1% in 1998 and 57.1% in 2003. It is expected that doubling of the forest coverage over the last two decades will have positive effects on the environment. Quantification of these impacts will be critical for the province to evaluate the effectiveness of the program, and to provide important guidelines for designing future reforestation strategies. In addition to other projects evaluating the effectiveness of the reforestation program, there is a need to examine the impacts of the program on carbon storage and to understand how this carbon storage is influenced by different types of reforestation forests.

There have been a number of studies in China on forest biomass carbon storage on a national scale (e.g., Fang et al., 2001; Wang et al., 2001; Zhao and Zhou, 2004; Zhou et al., 2000; Li et al., 2003; Liu et al., 2000) as well as at the local level (e.g., Guan et al., 1998; Zhang et al., 2002; Cao et al., 2002). These studies have been useful in expanding our understanding of forest vegetation carbon pools. However, none of them has dealt with long-term dynamics of forest carbon storage pools (temporal scales). In addition, full implementation of the Kyoto Protocol will eventually lead to the trading of carbon sink credits among regions and countries. An accurate estimate of net carbon sink increment for a region would become indispensable.

In this study, we tested the following hypotheses: (1) forest carbon storage increases with reforestation; (2) understory vegetation and litterfall carbon pools are significant components in total carbon storage in sub-tropical forest ecosystems; and (3) different forest types have different carbon accumulation rates during re-growth stages.

2. Methods

2.1. Description of Guangdong province

Guangdong is situated between N25°30′ and N20°18′ and E109°40′ and E117°15′. Located in southern China, the province has subtropical monsoon climate with 1366 mm of annual precipitation and a 22 °C annual mean temperature. Its land area is 180,000 km^2, including mountainous land (31.7%), hilly land (28.5%), mesa land (16.1%) and plain (23.7%).

2.2. Data source and forest inventory

Data on volume and growth for various forest types were collected from the Guangdong Provincial Forest Inventory Database. The database has been updated annually, and therefore provided us with an opportunity to monitor forest resource carbon dynamics on a temporal scale. All of the provincial forest inventories were carried out in accordance with technical standards developed by the Chinese Ministry of Forestry (Ministry of Forestry, 1982). In the provincial forest inventories, heights and diameters at breast height (DBH, 1.3 m) were measured for all trees with diameters (at DBH) > 4 cm. The total volume of timber in each plot was calculated using forest growth and yield tables complied by species and region by the Ministry of Forestry (Wang et al., 2001). Forest areas and volumes were separated by five age classes (young, middle-aged, maturescent, mature and post-mature) according to the national guidelines for forest resource inventory (Ministry of Forestry, 1982).

Table 1
Relationship between biomass (B) and volume (V) in forest tree layers[a]

Forest type	Equation of biomass and volume	N	R^2
Eucalyptus	$B = 0.8873V + 4.5539$	20	0.80
Castanopsis fissa	$B = 1.0357V + 8.0591$	17	0.89
Acacia confuse Merr.	$B = 0.8873V + 4.5539$	20	0.80
Albizia falcataria (Linn.) *Fosberg*	$B = 0.8873V + 4.5539$	20	0.80
P. elliottii Engelm	$B = 0.5168V + 33.2378$	16	0.94
P. massoniana	$B = 0.5101V + 1.0451$	12	0.92
Cunninghamia lanceolata	$B = 0.3999V + 22.5410$	56	0.95
Lucidophyllous forests	$B = 1.0357V + 8.0591$	17	0.89
Casuarina	$B = 0.7441V + 3.2377$	10	0.95
Coniferous forests	$B = 0.5168V + 33.2378$	16	0.94
Mixed coniferous and deciduous forests	$B = 0.8136V + 18.4660$	10	0.99
Non-merchantable wood forests	$B = 0.7564V + 8.3103$	11	0.98

The units of variables B and V are Mg and m^3, respectively.
[a] Modified from Fang et al. (1998, 2001).

2.3. Biomass estimation

2.3.1. Biomass of forest stand tree layers

We used the volume-derived method to obtain the estimation of biomass, based on the annual forest resource inventory database of Guangdong province (Wang et al., 2001). The volume-derived method has been widely used to estimate carbon storage at national and regional levels (Brown and Inveron, 1992; Turner et al., 1995; Alexeyew et al., 1995; Fang et al., 2001; Fang and Chen, 2001; Wang et al., 2001). The method needs a conversion factor to link vegetative carbon storage or biomass to forest volume. However, the conversion factor varies with forest types, site qualities, ages and human activities. There are two common methods available to derive the conversion factor (Wang et al., 2001). One is to construct the relationship between biomass and volume for the same plot using field data, while the other is to apply the product of the wood specific densities, the carbon contents and ratios of total biomass to stem biomass. The former method was adopted in the paper. Table 1 shows the relationship between biomass and volume of Guangdong forests developed by Fang et al. (1998, 2001), with modification by this study.

In Table 1, *Acacia confuse* Merr. and *Albizia falcataria* (Linn.) *Fosberg* are both pioneer succession species. Their forest structures are similar to those of *Eucalyptus*, so we estimated their tree layer biomass using the *Eucalyptus's* equation. *Castanopsis fissa* is a local species in Guangdong, and it resembles lucidophyllous forest. Therefore, we estimated the biomass of *Castanopsis fissa* forests based on the equation of lucidophyllous forests. Biomass of *P. elliottii Engelm* forests was estimated according to the formula of other pines and coniferous forests as described by Fang et al. (1998, 2001).

2.3.2. Biomass of understory and litterfall layers

There are no data on biomass of understory and litterfall layers in the Guangdong Provincial Forest Inventory Dataset. However, some studies (Wen et al., 1999; Tu et al., 1993; Fang and Mo, 2002; Fang et al., 2003) have reported the data for the main forest types in the province. We used these data to estimate the biomass of understory and litterfall layers for all Guangdong forests by combining the 11 forest types into 4 groups according to their similarity in structure and appearance as shown in Table 2. Biomass of understory and litterfall layers in groups 1–3 were obtained from published papers (Wen et al., 1999; Fang and Mo, 2002; Fang et al., 2003). In order to measure biomass of understory herb and litterfall layers in the *Casuarina* forest (group 4) in this study, five small plots (1 × 1 m) were randomly set up. Our estimates were 0.57 ± 0.16 t ha^{-1} and 1.5 ± 0.39 t ha^{-1} for understory and litterfall layers, respectively (Table 2).

Table 2
Biomass density of understory and litterfall layers for the four groups of forest types in Guangdong

Forest groups[a]	Understory (t ha^{-1})	Litterfall (t ha^{-1})	Reference
1	2.15	8.74	Wen et al. (1999)
2	14.41	9.03	Fang et al. (2003)
3	11.03	10.78	Fang and Mo (2002)
4	0.57	1.50	This paper

[a] Group 1 includes Eucalyptus, *Castanopsis fissa*, *Acacia confuse* Merr., *Albizia falcataria* (Linn.) *Fosberg* and Lucidophyllous; group 2 includes coniferous and deciduous forests; group 3 includes *Pinus elliottii Engelm*, *P. massoniana*, *Cunninghamia lanceolata* and Coniferous forests; and group 4 includes Casuarina.

2.3.3. Biomass of OBPA (open forest, bamboo forest, production forest and ambient trees)

For the open forest, bamboo forest and production forests in Guangdong, our field data checking showed that the conversion factors were suitable and could be used to estimate their biomass (Table 3). Ambient trees (including ambient trees, and standing and fallen deadwood) were treated as non-merchantable wood in our study so that their biomass could be calculated using the equation from Table 1. In addition, whole forest vegetation carbon pools include all major forest types as well as OBPA in this study.

2.4. Carbon storage and carbon density

Using the conversion coefficient 0.5, carbon storage can be estimated from forest biomass (Fang et al., 2001). Carbon density for each forest type was estimated by the following equation: $C_{\text{density}} = C_{\text{storage}}/A$, where A is the forest area for each forest type (Wang et al., 2001).

3. Results

3.1. Changes of whole forest vegetation carbon pool

Based on our study, it was determined that the whole forest vegetation carbon pool in Guangdong increased steadily from 169.61 Tg of total C in 1994 to 211.28 Tg of total C in 2003 (Table 4). The average C accumulation rate was 4.63 Tg year^{-1}. Forest C density during this period increased linearly from 20.02 Mg ha^{-1} in 1994 to 22.60 Mg ha^{-1} in 2003, with an average increased C uptake of 0.29 Mg ha^{-1} year^{-1}. Forest area increased from 8473.90×10^3 to 9346.64×10^3 ha during this 10-year period, with an average increased area of 96.97×10^3 ha year^{-1} (Table 4).

3.2. Changes of carbon pools in four forest types from 1994 to 2003

To compare the contribution of different forest types to C storage and pools, we also calculated total carbon pools and densities of four major forest types including broadleaved forests, coniferous forests, mixed broadleaved and coniferous forests and OBPA (Fig. 1). The carbon pool of coniferous forests was the largest, accounting for more than 50% of the whole forest vegetation carbon pool. Among the coniferous forests, C storage of *P. massoniana* forest stands (ranging from 59.65 to 67.81 Tg) was the largest contributor to this carbon pool. The other coniferous forest stands had the following ranking in terms of their C contributions: *Cunninghamia*

Table 3
The conversion factors of open, bamboo and production forest

Biomass type	Trees	Understory	Litterfall	References
Open forest	19.76 (t ha^{-1})	n.a.	n.a.	Fang et al. (1996)
Bamboo forest	22.5 (kg per individual)	1.91 (t ha^{-1})	3.16 (t ha^{-1})	Fang et al. (1996) and Nie (1994)
Production forest	23.7 (t ha^{-1})	n.a.	5.9 (t ha^{-1})	Fang et al. (1996)

Table 4
Changes in forest area from 1994 to 2003, Guangdong

Year	Total forest area (10^3 ha)	Carbon storage (TgC)	Carbon density (MgC ha^{-1})
1994	8473.90	169.61	20.02
1995	8998.60	180.86	20.10
1996	9201.94	188.47	20.48
1997	9207.89	191.00	20.74
1998	9218.71	193.79	21.02
1999	9265.62	196.99	21.26
2000	9276.95	200.30	21.59
2001	9301.62	203.99	21.93
2002	9315.42	207.46	22.27
2003	9346.64	211.28	22.60

lanceolata forest stands (ranging from 17.15 to 20.00 Tg), *P. elliottii Engelm* forest stands (ranging from 7.65 to 14.51 Tg) and the mixed coniferous forests (ranging from 5.76 to 6.51 Tg).

The broadleaved forests had the second highest C storage (about 50% of total C storage of coniferous forests). Among all six types of broadleaved forests studied, mixed broadleaved forests contain much higher C pool (from 31.66 to 40.02 Tg) than the other five types: *Eucalyptus* forest stands (4.43–7.39 Tg), *Castanopsis fissa* stands (2.25–4.00 Tg), *Acacia confuse* Merr. stands (0.28–1.63 Tg), *Albizia falcataria* (Linn.) *Fosberg* stands (0.05–0.37 Tg) and *Casuarina* stands (0.50–0.69 Tg).

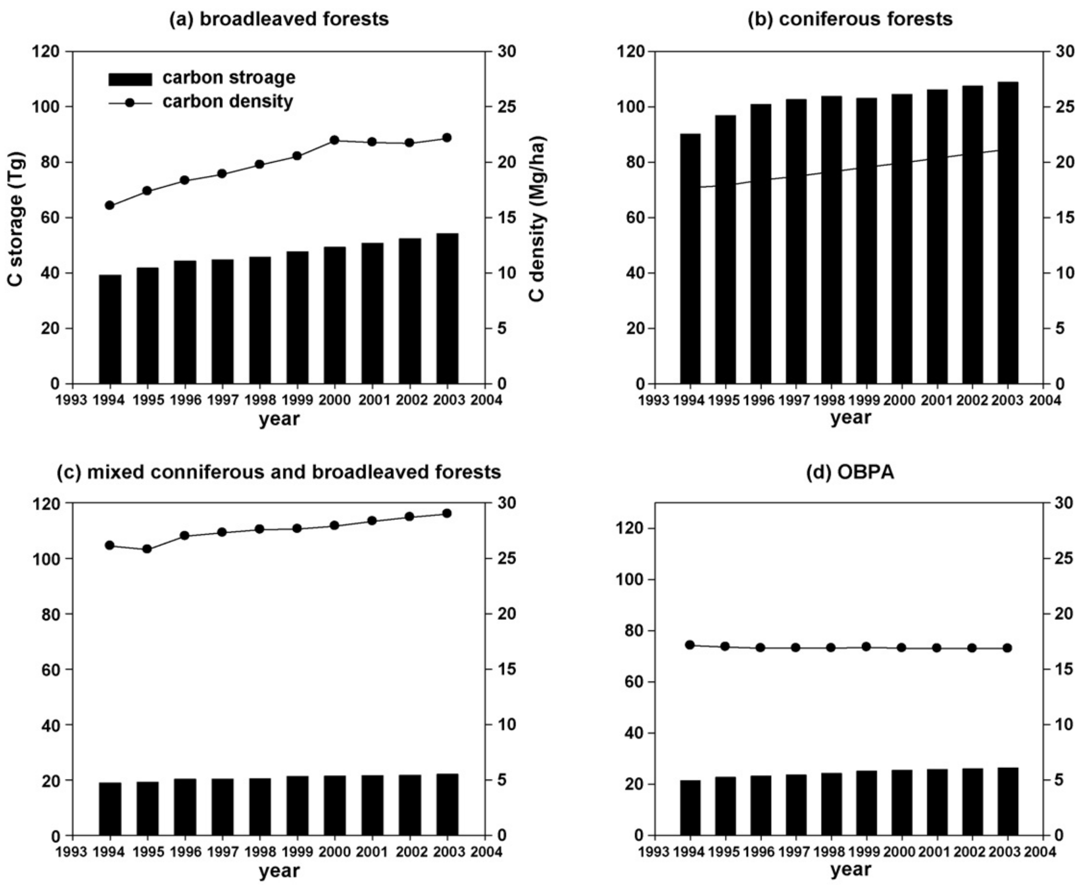

Fig. 1. Changes of carbon pools and densities of four forest groups in Guangdong from 1994 to 2003.

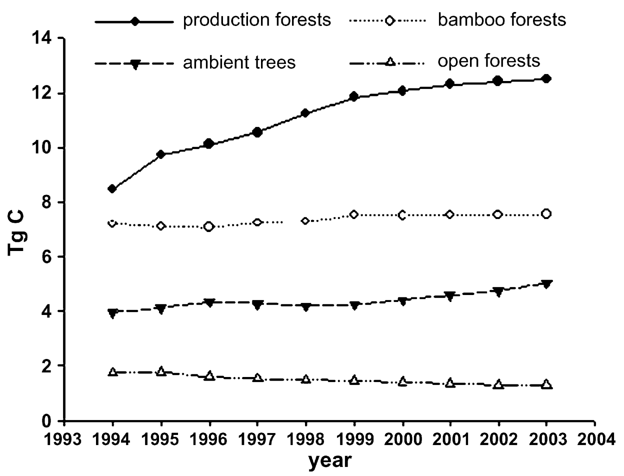

Fig. 2. Changes of carbon pools in open forests, bamboo forests, production forests and ambient trees.

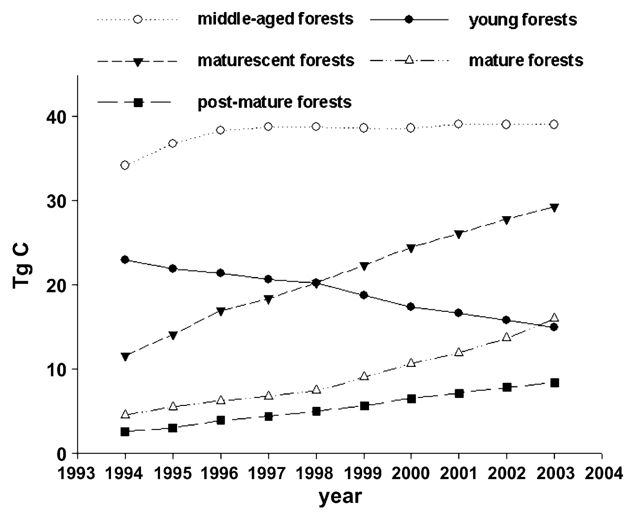

Fig. 4. Carbon storage in different forest age classes from 1994 to 2003.

OBPA was the third one and the mixed coniferous and broadleaved forest carbon pool was the smallest one among those four carbon pools. As shown in Fig. 2, carbon storage of production forests (ranging from 8.47 to 12.49 Tg) was the greatest among the OBPA types, and it had the highest accumulation rate over the 10-year period. Carbon storage of ambient trees (3.94–5.01 Tg) and bamboo forests (7.04–7.56 Tg) were relatively steady, with a slightly increasing. On the contrary, the open forest had a slightly decreasing of carbon storage (from 1.73 to 1.27 Tg).

Fig. 1 also showed the carbon densities of the broadleaved forests, coniferous forests and mixed coniferous and broadleaved forests were on increasing trends, while the carbon density of OBPA was stable. Mixed coniferous and broadleaved forests had the highest carbon density, even though its total carbon stock was the lowest.

3.3. Contributions of tree layers, understory vegetation and litterfall to carbon pools

Carbon pools of tree layers increased rapidly from 1994 to 2003 (ranging from 94.91 to 130.84 Tg). In Fig. 3, carbon storage of understory layer had an increasing trend from 1994 to 1996 (ranging from 34.88 to 37.79 Tg), followed by a slight decreasing trend from 1996 to 2003 (ranging from 37.79 to 36.79 Tg). Carbon storage of litterfall layer had a slightly increasing trend from 39.82 to 43.50 Tg over the 10-year period. Carbon storage of the understory vegetation layer was slightly less than that of the litterfall layer. Total carbon storage in understory vegetation and litterfall accounted for 38%–44% of the total forest carbon pools. This clearly shows that understory vegetation and litterfall should not be ignored when estimating total carbon pools in sub-tropical forest ecosystems.

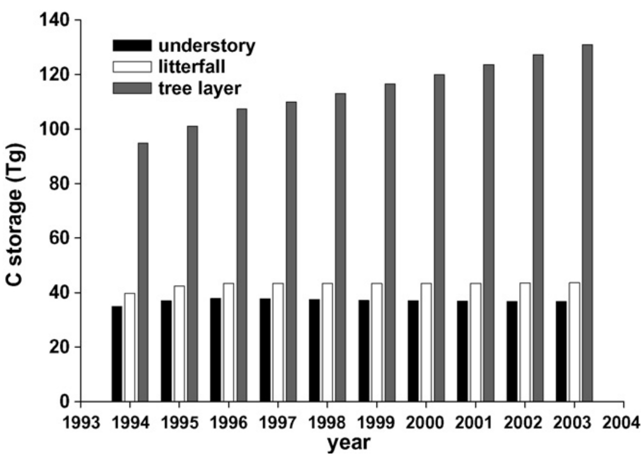

Fig. 3. Carbon pools of tree layers, understory vegetation and litterfall from 1994 to 2003.

3.4. Forest carbon storage with forest age classes

The Guangdong provincial forests are classified into five age classes: young forests, middle-aged forests, maturescent forests, mature forests and over-mature forests. Total forest carbon storage can then be allocated into each of five age classes over the 10-year study period. As shown in Fig. 4, the carbon pool of young forests decreased consistently. The carbon pool of middle-aged forests increased initially and then remained at a steady, high level (ranging from 38.32 to 39.08 Tg) after 1996. The carbon pool of maturescent forests increased consistently. The carbon pools in both mature and over-mature forests were relatively lower compared with other age classes, but are still on increasing trends. The carbon pool of mature forests surpassed that of young forests only after 2002. Fig. 4 also demonstrated that about 65%–70% of total carbon was stored in the middle and maturescent forests.

3.5. Carbon accumulated in different forest stand types

The carbon accumulation rates in1994–2003 for whole forest vegetation in Guangdong ranged from 0.27 to 1.19 Mg ha^{-1} $year^{-1}$ carbon. Fig. 5 showed that carbon accumulation rates varied with forest types and time. C accumulation rates of broadleaved forests were kept a relatively high level (ranging from 0.19 to 1.36 Mg ha^{-1} $year^{-1}$). Coniferous forest accumulation rates (ranging from −0.13 to

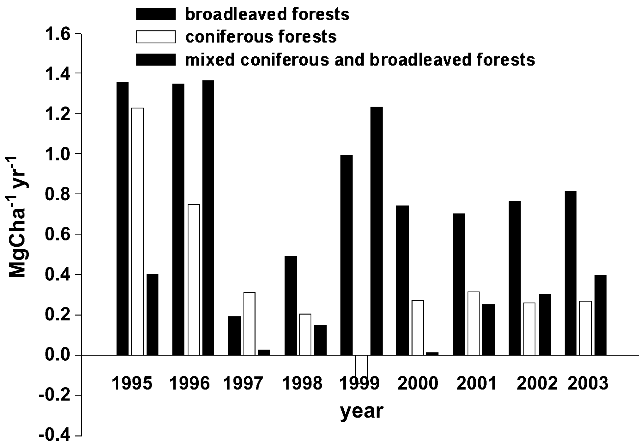

Fig. 5. Carbon accumulation rates for different forest stand types.

1.23 Mg Carbon ha^{-1} year^{-1}) were always below that of broadleaved forests except in 1997, while the rates in mixed coniferous and broadleaved forests fluctuated significantly (ranging from 0.01 to 1.36 Mg Carbon ha^{-1} year^{-1}).

4. Discussion

Fang et al. (1998) and Wang et al. (2001) previously studied forest carbon storage in Guangdong (Table 5). However, their results were much different from each other. Wang et al.'s estimate (34.81 Tg) was less than Fang et al's (ranging from 135.75 to 155 Tg). Our estimate (169.61–211.28 Tg) was more than those two studies. The main reason was that we developed a more detailed accounting of carbon than they did. Our result included OBPA (ranging from 21.32 to 26.33 Tg) (Fig. 1), understory (ranging from 34.88 to 37.79 Tg) and litterfall (ranging from 39.82 to 43.50 Tg) (Fig. 3) in addition to tree layer C storage of closed forests. We considered those layers to be integral components in estimating the whole forest vegetation carbon pool. Carbon storage pools in understory and litterfall layers were often ignored in previous carbon studies in China. Our results (Figs. 1 and 3) clearly demonstrated that ignorance of understory and litterfall layers can potentially lead to significant errors in estimating forest carbon budget in sub-tropical forest ecosystems.

The average forest carbon density in Guangdong from this study was lower than the estimates by Fang et al. (1998) (Table 5). This was mainly due to inclusion of the open forest and productive forests in our carbon density calculations. However, their respective carbon densities of 9.88 and 16.6 Mg ha^{-1} were lower than that of the forest stands studied.

Among the four major forest types (broadleaved forests, coniferous forests, mixed coniferous and broadleaved forests and OBPA), coniferous forests were the largest contributor (about 52% of total) to total vegetation carbon pool. The second largest contributor was the broadleaved forests (about 24% of total). The total contribution of these two forest types accounted for about 76% of total vegetation carbon pools. Judging from changes of both carbon pools and densities over the 10-year study period (Fig. 1), we believed that the carbon contributions from the coniferous forests and broadleaved forests were due to increasing of plantation areas as well as increasing of carbon accumulation rates over time. Interestingly, the mixed coniferous and broadleaved forests had the highest carbon density despite of its lowest carbon stock, which implies higher potentials for carbon stocks if more mixed coniferous and broadleaved forests are planted in the future.

Between 1949 and 2000, the area of degraded forest land decreased from 70.36% to 14.38%. By 1995 the amount of forest coverage percentage in Guangdong reached 55.9%, and 56.90% in 2000 (Table 6). However, there is still 1,550,000 ha of degraded land. Given the intensified forest management, the Guangdong province forest vegetation carbon pool will be increased further.

Some managed forests in Europe (Valentini et al., 2000) and in North America (Greco and Baldocchi, 1996; Goulded et al.,

Table 5
Various estimates of the Guangdong forest vegetation carbon pool

	Time						
	1949	1950–1962	1973–1976	1977–1981	1984–1988	1989–1993	1994–1998
Carbon density[a] (Mg ha^{-1})	34.7	33.9	31.5	30.5	27	26.1	29.4
Carbon density[b] (Mg ha^{-1})	–	–	–	–	<12.4	–	
Carbon density[c] (Mg ha^{-1})	–	–	–	–	–	–	17.56–20.23
Carbon pool[a] (Tg)	135.75	141.4	160.2	145.85	108.55	138.85	155
Carbon pool[b] (Tg)	–	–	–	–	34.81	–	–
Carbon pool[c] (Tg)	–	–	–	–	–	–	169.61–193.79

[a] From Fang et al. (1998).
[b] From Wang et al. (2001).
[c] This paper (11 closed forest types).

Table 6
Forest cover percent of different time in Guangdong province

	1949	1957	1964	1975	1978	1983	1988	1995	2000
Forest cover percent (%)	18.70	20.20	24.10	29.90	30.20	27.20	29.20	55.90	56.90
Degraded forest land ($\times 10^4$ ha)	766.80	678.13	664.07	577.47	535.33	556.60	517.13	176.53	155.00

1996a,b; Baldocchi et al., 1997) are able to take up as much as 2.5–6.6 Mg Carbon ha^{-1} $year^{-1}$. The study by Birdsey (1992) in United States found that the average net accrual of Carbon in the eastern deciduous forest region was from 1 to 2.4 Mg ha^{-1} $year^{-1}$. In our study, we found that between 1994 and 2003 whole forest vegetation in Guangdong stored up to 0.27–1.19 Mg ha^{-1} $year^{-1}$ carbon. C accumulation rates of broadleaved forests was kept a relatively high level (ranging from 0.19 to 1.36 Mg ha^{-1} $year^{-1}$), indicating that broadleaved forests had been in a state of high growth rate for most of years in the study period.

During the study period, the carbon density of mixed coniferous and broadleaved forests maintained a superior level ranging from 25.78 to 28.99 Mg Carbon ha^{-1}. The carbon density of mixed broadleaved forests was the highest among the all type of broadleaved forests, but after 1998 the carbon density of *Castanopsis fissa* forests, which was the fastest growing forest type—ranging from 18.74 to 32.66 Mg ha^{-1}, surpassed that of the mixed broadleaved forests. The carbon density of the coniferous forests was relatively low. From 1994 to 2003 the increasing ranges were as follows: *P. massoniana* forests (ranging from 18.38 to 20.76 Mg ha^{-1}), *P. elliottii Engelm* forests (ranging from 13.95 to 20.68 Mg ha^{-1}), *Cunninghamia lanceolata* forests (ranging from 19.18 to 21.31 Mg ha^{-1}), and mixed coniferous forest (ranging from 19.21 to 21.94 Mg ha^{-1}). The carbon density of bamboo forest was around 24.50 Mg ha^{-1}, with little changes over the same period. The carbon density of open forest was 9.88 Mg ha^{-1}, while that of productive forest is 16.60 Mg ha^{-1}. The large difference in carbon densities between various types of forests indicate that there is potential for increasing forest carbon pool in Guangdong through the intensified forest management and continuous reforestation programs in the future.

5. Conclusions

The 10-year reforestation program in Guangdong increased C storage by 41.67 Tg and carbon density by 1.58 Mg ha^{-1} from 1994 to 2003. Our results further support the conclusion from many other researches in that reforestation increases carbon sequestration in forest ecosystems.

Understory vegetation and litterfall are normally neglected in many forest carbon studies. Our results showed that these two components together accounted for about 38–44% of total forest carbon storage in the subtropical monsoon forests. This demonstrates that ignoring of understory and litterfall will likely introduce large errors in estimating total forest carbon storage and pools.

Different forest types and tree species have different C accumulation rates. C accumulation rate of broadleaved forests was higher than any other forest type studied. Among the forests studied, *P. massoniana* forest stands had the greatest carbon accumulation, while *Albizia falcataria* (Linn.) *Fosberg* forest stands had the least. Coniferous forest accumulation rates were always below that of broadleaved forests except in 1997 during the 10-year period. These results have important implications for selection of future forest restoration species.

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