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Response of soil labile organic carbon fractions to forest conversions in subtropical China

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Abstract: In order to determine the impact of forest conversions on labile organic carbon fractions, soils at depths of 0 - 10, 10 - 30 and 30 - 50 cm were collected from three types of forest: secondary monsoon evergreen broadleaved forest (BF), mixed pine and broadleaved forest (MF) and Masson pine forest (PF) in subtropical China. The light fraction organic carbon (LFOC), particulate organic carbon (POC) and microbial biomass carbon (MBC) in the soils were determined. The results showed that soils, the top soils (at depths of 0 - 10 cm) in particular, in BF had significantly higher LFOC, POC and MBC than those in MF and PF, indicating that forest conversions influenced the labile organic carbon fractions in subtropical China, and this influence mainly occurred in the top soils. The significantly higher ratios of labile organic carbon to soil organic carbon in BF than those in MF and PF confirmed that forest conversions from BF to MF could lead to a considerable reduction in soil labile organic carbon. In all three types of forest, the reduction of soil organic carbon in the rainy season was higher than that in the dry season.

Key words: Forest types, labile fractions, seasonal variation, soil organic carbon, subtropical China.

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Introduction

Soil organic carbon (SOC) plays a crucial role in the improvement of physical and chemical characteristics of soils. It has been reported that SOC is about 2.6 times the biotic pool and twice the atmospheric pool (Knorr *et al.* 2005; Worrall *et al.* 2013). Acting either as a source or a sink of

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atmospheric CO_2 (Knorr *et al.* 2005), soil carbon pools affect global changes (Fang *et al.* 2001). The composition, dynamic and role of various fractions of SOC have been the focus of international research (Worrall *et al.* 2013). The SOC is usually divided into labile, intermediate and recalcitrant organic carbon according to its resistance to mineralization. Some of the labile fractions of SOC, such as microbial biomass carbon (MBC), light fraction organic carbon (LFOC) and particulate organic carbon (POC) are frequently used as indicators of soil quality. The LFOC was defined by the density separates extracted using sodium polytungstate solution (Christensen *et al.* 1992). Because of its rapid turnover (less than 10 years) and high C/N ratio, LFOC fraction was considered a good indicator of labile organic carbon (LOC) (Christensen *et al.* 1992). The POC, defined based on the particle size, was easily decomposable by microorganisms and was sensitive to the changes in vegetation (Christensen *et al.* 2001). The MBC, although accounting for only up to 5 % of the total SOC, contributed considerably to the cycling of the total SOC (Lützow *et al.* 2007). The labile fractions of SOC were frequently used as indicators to the changes in land use, climate, environments and vegetation due to their particular effect on soil function (Ussiri & Johnson 2007). For instance, the LFOC was rapidly mineralized because of its labile nature without the protection of soil colloids (Christensen *et al.* 2001), the POC was biologically available for microorganisms which played a critical role in synthesizing organic compounds (Ussiri & Johnson 2007).

Forest ecosystems were important potential carbon sinks (Zhang *et al.* 2007). Forest SOC could be influenced by the complex interactions of climate, soil types, forest management and vegetation (Fang *et al.* 2001; Sahu *et al.* 2015). The conversions of forest types were reported to influence the turnover of soil C (Wang *et al.* 2013; Zhang *et al.* 2007). In many subtropical regions in China (especially in the Pearl River Delta in Guangdong province), large areas of secondary monsoon evergreen broadleaved forest (BF) have been converted to mixed pine and broadleaved forest (MF) and even to pure Masson pine forest (PF) since the 1970s. Researchers estimated that the large scales of new plantations might have become an important C sink in this region (Wang *et al.* 2013) and the forest conversions could considerably influence the dynamic and the pool of forest SOC (Huang *et al.* 2011; Zhang *et al.* 2013). However, the effects of forest conversions on stability of SOC in subtropical China have been underestimated (Yang *et al.* 2009). Scientific questions arising from the large scale of forest conversions are: (1) can the labile organic carbon fractions sensitively respond to the conversions? (2) do the forest conversions equally influence the labile organic carbon fractions at the forest soil depths? Targeting these questions, we selected three types of forest (PF, MF and BF) from the Pearl River Delta in subtropical China for forest soil sampling and labile organic carbon analysis.

Material and methods

Experimental site

This study was conducted in the Pearl River Delta Forest Ecosystem Research Network located in Guangdong province of southern China. The Network was established in 2003 to study the influence of urbanization on the forest ecosystems in the Pearl River Delta. Permanent plots representing different forest types (BF, MF and PF) across the Pearl River Delta were designed. The Delta features a subtropical climate with mean annual precipitation of 1,700 mm and average annual temperature of 21.8 °C. The precipitation distributed seasonally with a ~80 % fall from April to September (rainy season) and ~20 % from October to March (dry season). Most of the soils among the forest plots had granite bedrock and average depths ranging from 60 to 100 cm. The soils were classified as yellowish red type with pH values ranging from 4.0 to 4.9 in the top 10 cm layer (Chen *et al.* 2011). The plots of the three forest types designed in the Network were topographically similar with a slope of 2 - 5° from shoulder to middle and less than 3° from middle to toe position. Routine monitoring using catchment weirs by the Network presented a surface soil erosion of 0.20, 0.24 and 0.28 t ha^{-1} for the BF, MF and PF forest plots respectively (unpublished data). Other characteristics of the soils as well as the meteorological data among the three forest types were listed in Table 1.

The BF plots dominated by tree species of *Machilus chinensis*, *Cinnamomum porrectum*, *Castanopsis chinensis*, *C. fissa* and *Schima superba* were selected from northeastern Guangzhou. The mean stand diameter at breast height (DBH), the average height and the canopy density was 21.3 cm, 12.8 m and 0.81, respectively. The MF plots, featuring presence of some pioneer

Table 1. Characteristics of the meteorology and the soil physico-chemistries among various forest types. Data were from the Pearl River Delta Forest Ecosystem Research Network.

Site	MAT (°C)	MAP (mm)	Litter mass (t ha^{-1} $year^{-1}$)	Sampling depth (cm)	SOC (Mg C ha^{-1})		Soil moisture (%)		Bulk density (g cm^{-3})	pH
					Rainy season	Dry season	Rainy season	Dry season		
BF	21.8	1680	7.94 ± 0.78A	0-10	36.31 ± 7.04Aa	27.06 ± 6.17Aa	21.16Aa	13.18Aa	1.05 ± 0.14Bc	4.16 ± 0.51Ab
				10-30	21.87 ± 2.26Ab	16.15 ± 1. 73Ab	18.65Ab	13.59Aa	1.18 ± 0.11Bb	4.28 ± 0.37Aa
				30-50	13.36 ± 1.07Ac	10.74 ± 1.49Ac	18.54Ab	14.23Aa	1.27 ± 0.15Ba	4.30 ± 0.29Aa
MF	22.0	1750	6.17 ± 0.49B	0-10	31.66 ± 4.58Ba	23.06 ± 4.16Ba	22.18Aa	14.04Aa	1.28 ± 0.16Ac	4.13 ± 0.35Ab
				10-30	13.05 ± 1.14Bb	12.64 ± 1.24Ab	17.66Ab	15.26Aa	1.41 ± 0.13Ab	4.34 ± 0.52Aa
				30-50	5.54 ± 1.02Bc	6.38 ± 1.03Bc	18.12Ab	15.89Aa	1.50 ± 0.19Aa	4.55 ± 0.48Aa
PF	22.0	1750	2.53 ± 0.53C	0-10	21.49 ± 4.61Ca	16.99 ± 1.93Ca	19.49Ba	15.45Aa	1.32 ± 0.21Ab	4.21 ± 0.44Ab
				10-30	7.41 ± 1.11Cb	5.42 ± 0.98Bb	16.32Ab	14.91Aa	1.44 ± 0.27Ba	4.47 ± 0.31Aa
				30-50	3.46 ± 0.62Bc	2.62 ± 0.67Bc	16.07Ab	15.67Aa	1.61 ± 0.25Aa	4.64 ± 0.43Ba

Data were presented as Mean ± SD. MAT, mean annual temperature; MAP, mean annual precipitation; SOC, Soil organic carbon; BF: the secondary monsoon evergreen broadleaved forest; MF: the mixed pine and evergreen broadleaved forest; PF: pine forest. Abbreviations of forest type were the same as below. Different capital letters show the significant differences among the forest types. Lowercase letters show the significant differences among the depths within the same forest at $P = 0.05$ levels.

species, i.e. *Pinus massoniana, Cratoxylon ligustrinum, Litsea glutinosa* and *Broussonetia papyrifera* with a mean DBH, height and canopy density of 18.8 cm, 10.8 m, and 0.76, respectively, were selected from southern Guangzhou. The PF plots dominated by *P. massoniana* with other tree species (*Ligustrum sinense, L. glutinosa, Tristania conferta*) understory were adjacent to the MF ones. The mean DBH, height and canopy density was 15.62 cm, 13.5 m and 0.72, respectively. Both the MF and PF were converted from BF since the late 1970s. The BF was seldom disturbed and thus was considered as a reference forest in this study.

Soil sampling

Soils were separately collected from the permanent plots of the three forests in rainy (August) and dry seasons (January) from 2011 to 2013, respectively. In each season, 60 soil samples were collected from four replicated plots (20 m × 30 m) at each forest. A total of five cores per sample was randomly collected at three depths (0 - 10, 10 - 30, and 30 - 50 cm) using an 8.5 cm diameter stainless steel corer and then pooled by depth. After they were taken to the laboratory, a sub-sample of the fresh soils was sieved (the sieve pore size was 2 mm) to remove coarse living roots and gravel and then stored at 3 °C. Subsequently, MBC of the soils were measured within seven days. Another sub-sample of the soils was air-dried and sieved (the sieve pore size was 2 mm) before determining SOC, LFOC and POC fractionation.

Analytical methods

The LFOC was determined according to Compton & Boone (2002). Briefly speaking, 10 grams of air-dried soil was placed in a centrifuge tube with 20 ml of sodium polytungstate solution. The tubes were shaken for 30 seconds and then centrifuged at 1,000 rpm for 15 minutes. The supernatant was siphoned with a syringe fitted with 2 cm long section of Tygon tube and then filtered using a Whatman GF A/E filter. This process was repeated at least four times. The material retained by the filter was washed with 0.01M $CaCl_2$ and distilled water, dried at 65 °C for

12 hours, weighed, and analyzed to obtain the C concentration. POC (53 - 2,000 μm) was determined using the method described by Cambardella & Elliot (1992). Twenty grams of the < 2 mm air-dried soil were dispersed in 100 mL of 5 g l^{-1} sodium hexametaphosphate solution by shaking for 15 hours. Subsequently, the dispersed soil sample was sieved (pore size of 53 μm) and rinsed with distilled water. The soil suspension on the sieve, defined as the POC fraction, was dried at 50 °C for 12 hours, weighed and finely ground. The MBC was measured using the chloroform fumigation–extraction method described by Brookes *et al.* (2001). Five grams of fresh soil were extracted using a 25 ml 0.5 M K_2SO_4 solution by shaking for 30 minutes. The mixture was centrifuged at 2,000 rpm for 5 minutes and then filtered through Whatman 42 filter paper. The total organic C in the filtrate as well as LFOC and POC were analyzed by a C analyzer (Shimadzu TOC-VCPH, Kyoto, Japan) and the latter were expressed as organic C mass in the whole soil or fractions of the whole soil mass. After determining the bulk density using the cylinder method according the standard proposed by the Chinese Ecosystem Research Network (Liu *et al.* 1996), the C contents were presented as Mg C ha^{-1}.

Statistical analysis

Mean and standard deviation (Mean ± SD) of LOC in both rainy and dry seasons for each forest were used to evaluate the influence of forest conversion. The interaction effects between forest types and within soil depths on LOC fractions were determined with ANOVA. Seasonal variations of LOC within the same forest type were detected by the pair-sample *t*-test. Effects of vegetation, litter mass, soil moisture and soil depth on LOC were determined by the correlation matrix. Least significant difference (LSD, $P < 0.05$) was used to separate the means when differences were significant. All statistical analysis was performed using the statistical package SPSS 17.0 for windows.

Results and discussion

Contents of soil LOC among various forests

Mean contents of soil LFOC, POC and MBC among the three forests were presented in Fig. 1. Obviously, labile organic carbon in the soils was forest-dependent, at the upper soils (0 - 10 and 10 - 30 cm depths) in particular. The BF always had significantly higher LOC in comparison with the MF and PF. For instance, at the 0 - 10 cm depth, the LFOC in BF soils was 1.2 to 3.0 times as much as that in MF and PF, MBC in BF soils was 1.5 to 2.1 times as much as that in MF and PF, and POC in BF soils was 1.5 to 4.6 times as much as that in MF and PF. At the 10 - 30 cm depth, the soils in BF had 6.02 ± 0.89 Mg C ha^{-1} (n = 120) of LFOC, 0.39 ± 0.06 Mg C ha^{-1} (n = 120) of MBC and 8.91 ± 1.05 Mg C ha^{-1} (n = 120) of POC, respectively, which were significantly higher than those in MF (4.55 ± 0.46 Mg C ha^{-1}, $P = 0.046$, n = 120; 0.26 ± 0.07 Mg C ha^{-1}, $P = 0.002$, n = 120 and 3.63 ± 0.67 Mg C ha^{-1}, $P = 0.019$, n = 120, respectively) and PF (1.50 ± 0.26 Mg C ha^{-1}, $P = 0.007$, n = 120; 0.15 ± 0.02 Mg C ha^{-1}, $P < 0.0001$, n = 120; and 1.98 ± 0.25 Mg C ha^{-1}, $P = 0.013$, n = 120, respectively). In deeper soils (30 - 50 cm), no significant MBC or POC difference was found between MF and PF.

The maintenance of SOC in forests was essential worldwide against the background of elevated atmospheric CO_2 level (Fang *et al.* 2001). Constituting a small part of total SOC, labile organic carbon was important to the forest ecosystem productivity in the short term and could be affected by changing temperature and soil moisture (Zak *et al.* 1999). The temperature and soil moisture were similar among various forest types (Table 1), and their effects on soil LOC were not significant (Table 2). We thus speculated that the temperature and soil moisture had no special effect on LOC changes in this study. Notably, the significantly lower bulk density in BF soils than in MF or PF soils (Table 1) might considerably contribute to the changes in LOC (Chen *et al.* 2014).

Changes in land use and forest type had considerable effects on LOC fractions via changing the moisture, temperature and regulating inputs and decomposition of litter fall (Zhou *et al.* 2007). In this study, we found that forest type had significant effects on the soil LOC (Table 2). The contents of LOC with the order of BF > MF > PF (Fig. 1) matched well with the forest biomass and productivity (Pan *et al.* 2013), the litter fall production (Zhou *et al.* 2007) and decomposition (Huang *et al.* 2011) among various forest types. Since the MF and PF were converted from the BF (with the same bedrock) more than 40 years ago, the significant difference in soil LOC fractions among various forest types might be a result of the conversion, which could lead to great changes in the quantity and quality of organic matter and the

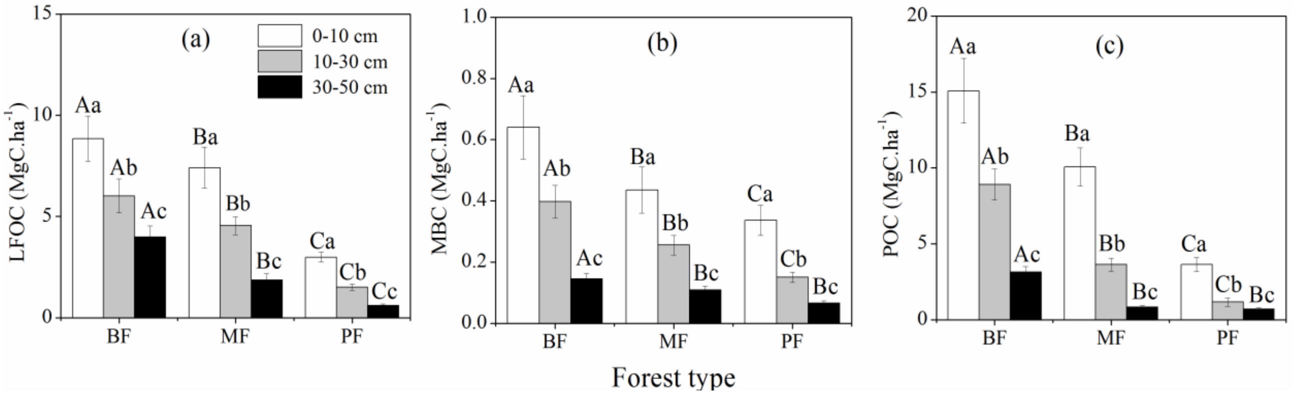

Fig. 1. Mean contents of the soil light fraction organic carbon (LFOC, a), microbial biomass carbon (MBC, b) and particulate organic carbon (POC, c) among various forest types. The capital, lowercase letters above the columns indicated the significant differences among the same soil layer among the forests, the soil depths within the same forest, respectively, at $P = 0.05$ levels. The column showed the data averaged from the dry and rainy seasons through 2011 to 2013. Bars showed the standard deviation of those data.

Table 2. Effects of forest type, soil physical characteristics and litter mass on soil LOC.

Source of variation	LFOC		MBC		POC		SOC	
	R^2	*P*	R^2	*P*	R^2	*P*	R^2	*P*
Forest type	0.91	< 0.001	0.82	< 0.001	0.84	< 0.001	0.63	0.04
Soil moisture	0.25	0.25	0.17	2.34	0.20	1.63	0.34	0.77
Soil temperature	0.22	0.49	0.31	0.884	0.42	0.16	0.41	0.09
Litter mass	0.70	0.04	0.71	0.02	0.66	0.03	0.69	0.03
SOC	0.63	0.03	0.67	0.02	0.72	0.02	--	--

LFOC: Soil light fraction organic carbon; MBC: Microbial biomass carbon; POC: Particulate organic carbon; SOC: Soil organic carbon.

turnover of fine roots (Chen *et al*. 2006; Zhang *et al*. 2007) under the similar microclimatic condition (Huang *et al*. 2011). Similarly, the changes in vegetation could significantly reduce the LFOC (Yang *et al*. 2009) and the MBC (Zhang *et al*. 2007). We, thus, inferred that forest conversions influenced the LOC fractions in forest soils in this study.

Vertical distribution of LOC density among various forests

In general, the soil LOC density followed the same trends and decreased gradually with increasing soil depth among various forest types (Fig. 1). However, the drops in LOC density with increases of soil depths varied among forests. Taking the 0 - 10 cm soil as the benchmark, LFOC, MBC and POC in BF reduced by about 30, 38 and 41 %, respectively, in the 10 - 30 cm soils; and about 55, 78 and 80 %, respectively, in the 30 - 50 cm soils. For MF, the corresponding drops in LFOC, MBC and POC were 40, 45 and 58 % at 10 - 30 cm depth, and 75, 75 and 89 % at 30 - 50 cm depth, respectively. For PF, the contents of LFOC, MBC and POC reduced by 49, 55 and 68 %, respectively, in the 10 - 30 soils, and 79, 82 and 91 % in the 30 - 50 cm soils. The density of LFOC, MBC and POC witnessed the fastest decline in the PF.

The vertical distribution of LOC among various forests was consistent with that in forest and agriculture soils from subtropical Australia (Chen *et al*. 2004), southeastern USA (Chodak & Nikliñsha 2010) and subtropical China (Yang *et al.*

Table 3. Seasonal changes in soil POC, LFOC and MBC at different soil layers under the same forest type. Different lowercase letters indicate the significant difference at the same layer between the seasons, at $P < 0.05$ level.

C Fraction (Mg C ha^{-1})	Forest type	Season	Soil depth (cm)		
			0 - 10	10 - 30	30 - 50
LFOC	BF	Rainy season	9.52 ± 1.27a	6.23 ± 1.27a	4.03 ± 1.07a
		Dry season	7.16 ± 1.28b	4.89 ± 1.18a	3.82 ± 0.76a
	MF	Rainy season	7.92 ± 1.91a	5.41 ± 1.71a	1.92 ± 0.72a
		Dry season	6.37 ± 0.94b	4.46 ± 1.42a	1.76 ± 1.16a
	PF	Rainy season	3.29 ± 0.76a	1.67 ± 0.73a	0.69 ± 0.43a
		Dry season	2.09 ± 0.21a	1.08 ± 0.25a	0.53 ± 0.12a
MBC	BF	Rainy season	0.87 ± 0.13a	0.48 ± 0.18a	0.20 ± 0.12a
		Dry season	0.36 ± 0.06b	0.18 ± 0.05b	0.12 ± 0.06a
	MF	Rainy season	0.63 ± 0.09a	0.39 ± 0.17a	0.14 ± 0.09a
		Dry season	0.15 ± 0.04b	0.14 ± 0.05b	0.08 ± 0.03a
	PF	Rainy season	0.46 ± 0.06a	0.22 ± 0.08a	0.11 ± 0.07a
		Dry season	0.09 ± 0.02b	0.06 ± 0.01b	0.05 ± 0.01a
POC	BF	Rainy season	19.92 ± 3.78a	11.35 ± 2.46a	3.47 ± 0.45a
		Dry season	12.88 ± 1.83b	5.68 ± 1.07b	2.62 ± 1.04a
	MF	Rainy season	14.91 ± 2.36a	5.17 ± 1.69a	1.92 ± 0.62a
		Dry season	6.17 ± 0.74b	3.05 ± 0.36b	1.47 ± 0.17a
	PF	Rainy season	4.46 ± 0.98a	2.64 ± 1.02a	0.77 ± 0.53a
		Dry season	1.82 ± 0.33b	0.84 ± 0.21b	0.61 ± 0.12a

2009). In this study, we found the drop of LOC in upper soils was smaller than that in deeper soils, which coincided well with the distribution of LOC fractions in wetland, upland forest and farmlands (Zhang *et al.* 2006). The explanation on the vertical distribution of LOC is complicated and it varies. The rapider litter decomposition (Zhou *et al.* 2007), the larger biomass and faster turnover of fine roots (Zhang *et al.* 2013), the higher moisture (in the rainy season, Table 1) in the upper soils and the less amount and activities of microorganisms (Jiang *et al.* 2006), the bigger bulk density (Table 1) in deeper soils might contribute to the vertical patterns of LOC. Forest SOC primarily comes from litter decomposition on the soil surface, followed by the fine roots (Gale *et al.* 2000). The smaller amount and fewer activities of microorganisms in the deeper soils were related to the notable reduction in MBC and POC (Burton *et al.* 2010). Soil LFOC and POC were produced by decomposition of soil organic matter, mainly from roots' C intake (Cromack *et al.* 2013). The vertical distribution of fine roots was a major determinant of the SOC distribution (Liang *et al.* 2000). Our results implied that the effects of forest conversions on LOC occurred mainly in the upper soils, which supported the result that LOC loss after the forest transitions could appear in soils at 0 - 30 cm depth (Guo *et al.* 2002; Sarkhot *et al.* 2008).

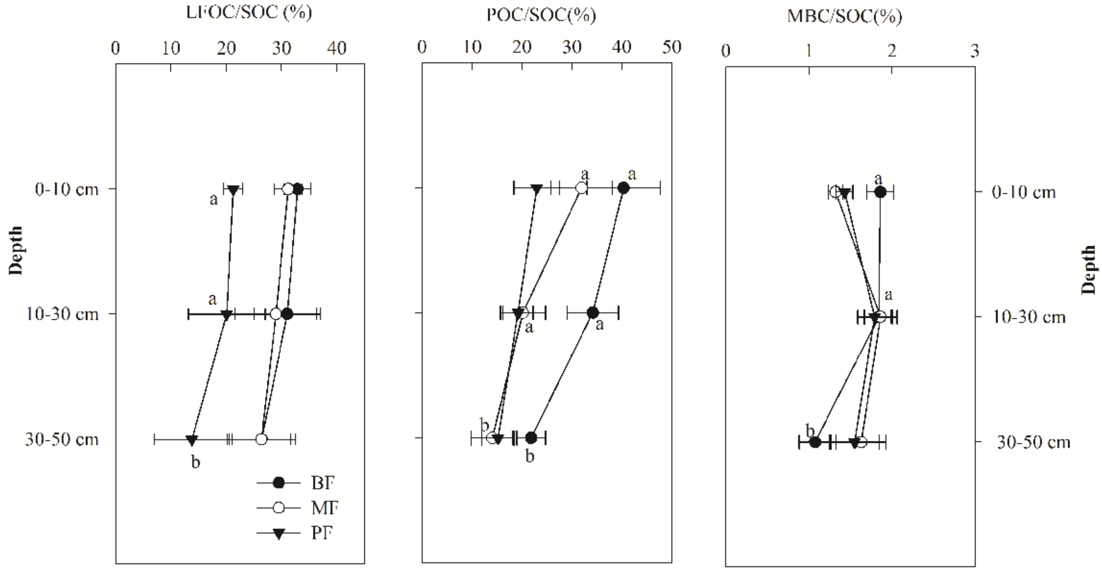

Fig. 2. The proportion of labile organic carbon to total soil organic carbon through the soil profiles in the forests. LFOC/SOC was the proportion of the light fraction organic carbon to total soil organic carbon, POC/SOC was the proportion of the particulate organic carbon to total soil organic carbon and MBC/SOC was the microbial biomass carbon to total soil organic carbon. Letters show significant difference at $P = 0.05$ level among soil depths.

Seasonal variations of LOC and LOC/SOC among various forest types

Seasonal changes in LFOC, MBC and POC at different soil depths among various forest types were presented in Table 3. In the rainy season, the top soils (0 - 10 cm depth) in the three forests had significantly higher LFOC, MBC and POC than in the dry season. However, the significant seasonal variations disappeared when soil depth increased. The variation implied that LOC in the top soils of the forests was seasonally sensitive.

The ratios of soil LOC to SOC (LOC/SOC) in the forests were shown in Fig. 2. The ratios declined with increasing soil depths in the three forests, but only PF had significantly higher LFOC/SOC in the upper soils than in the deeper soils. The difference is: the significant decrease of POC/SOC from the upper to the deeper soils was found in both BF and MF, while significantly higher ratios of MBC/SOC in the upper soils were only found in BF.

Seasonal changes in SOC could be ascribed to many factors. For example, the soil POC could be influenced by soil moisture (Liang *et al.* 2000), precipitation (Zhang *et al.* 2013), forest vegetation (Tang *et al.* 2010) and land use (Conant *et al.* 2004). Although the temperature and soil moisture of the three forests were similar (Table 1), the temperature (22.9 °C), moisture (18.6 %) and precipitation (1,400 mm) in the rainy season was much higher than those in the dry one (16.1 °C, 13.6 % and 300 mm, respectively) among the forests (Chen *et al.* 2011). In subtropical China, the hotter season usually had more abundant soil MBC comparatively (Wang *et al.* 2013). The significantly higher MBC detected in the rainy season might result from the increased activities of microorganisms and the higher microbial biomass (Burton *et al.* 2010; Huang *et al.* 2014). Soil LFOC and POC could be produced by leaching fresh organic material controlled by precipitation (Tang *et al.* 2010), which gave a possible explanation for the notably higher LOC fractions in the rainy season (Table 3).

The ratios of LFOC/SOC in forest soils in subtropical China were much lower (ranging from 20 to 32 % at 0 - 10 cm depth, Fig. 2) than that of Douglas fir plantation (40 %) (Sarkhot *et al.* 2008), but they coincided with the average (~31 %) of secondary forests in subtropical China (Yang *et al.* 2009). Generally, the POC represented ~10 – 20 % of SOC in tropical and subtropical regions (Bayer *et al.* 2002). The POC accounted for 20 - 40 % of SOC at 0 - 10 cm depth, which was similar to the proportions obtained by Wang *et al.* (2013) in three subtropical plantations (18 - 35 %), and in tropical plantation soils (21 - 43 %) (Tang *et al.* 2010). The lower proportions of LFOC/SOC and the similar ratios of POC/SOC in this study probably relate to the warm and wet subtropical climate, which facilitates the biological decomposition of organic material, leading to less accumulation of POC and LFOC (Yang *et al.* 2009). The ratios of MBC/SOC in forest soils, usually within the range of 1 - 4 %, indicated the proportion of organic C that could readily be metabolized (Sparling *et al.* 1992). In this study, the ratios of MBC/SOC ranging from 1 to 2 % at various soil depths were within the above threshold and consistent with the range of forest soils in subtropical China (0.7 - 3.7 %) (Yang *et al.* 2009).

Conclusions

The soils (the upper layer in particular) in the BF had significantly higher concentrations of LOC than those in the MF and PF in subtropical China, indicating that the soil LOC was sensitive to forest conversions. The variations of LOC caused by transition from BF to MF and to PF were mainly found in the top soils (0 - 10 cm depth), implying that LOC in the top soils was a sensitive indicator of the changes in forest types. The conversion from BF to MF and to PF led to a reduction in LOC in forest soils. The seasonal changes in soil LFOC, POC and MBC among different forests and the higher ratios of LOC to SOC in BF than in MF and PF implied that BF can well maintain LOC in forest soils.

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