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Effect of land use on microbial biomass-C, -N and -P in red soils*

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Abstract: Eleven red soils varying in land use and fertility status were used to examine the effect of land use on microbial biomass -C, -N and -P. Microbial biomass-C in the red soils ranged from about 68 mg C/kg to 225 mg C/kg, which is generally lower than that reported from other types of soil, probably because of low organic matter and high acidity in the red soils. Land use had considerable effects on the amounts of soil C_{mic}. The C_{mic} was the lowest in eroded fallow land, followed by woodland, tea garden, citrus grove and fallow grassland, and the highest in vegetable and paddy fields. There was significant correlation between C_{mic} and organic matter content, suggesting that the influence of land use on C_{mic} is mainly related to the input and accumulation of organic matter. Microbial biomass-N in the soils ranged from 12.1 Nmg/kg to 31.7 Nmg/kg and was also affected by land use. The change of N_{mic} with land use was similar to that of C_{mic}. The microbial C/N ratio ranged from 5.2 to 9.9 and averaged 7.6. The N_{mic} was significantly correlated with soil total N and available N. Microbial biomass-P in the soils ranged from 4.5 mg P/kg to 52.3 mg P/kg. The microbial C/P ratio was in the range of 4 - 23. The P_{mic} was relatively less affected by land use due to differences in fertilization practices for various land use systems.

Key words: Land use, Microbial biomass-C, -N and -P, Red soils
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INTRODUCTION

The importance of microorganisms to soil fertility and soil quality has been commonly accepted (Smith *et al.*, 1990; Brookes, 1995; Dalal, 1998; Wick *et al.*, 1998). Soil microbial biomass as an important microbial property has been extensively studied since it is the living component of soil organic matter (Jenkinson *et al.*, 1981), and serves as a labile pool of soil nutrients including carbon, nitrogen, and phosphorus (Sparling *et al.*, 1992; Diazravina *et al.*, 1993; Dalal, 1998; He, 1997a; He *et al.*, 1997b; Chen *et al.*, 1999). Microbial biomass is affected by many factors, of which land use effect has received more attention due to its impacts on soil organic matter (Lovell *et al.*, 1995; Warkle, 1998; Chen and Stark, 2000).

The change in microbial biomass had been reported to parallel the change in soil organic matter due to land use change (Sparling *et al.*, 1992; Bargett *et al.*, 1997; Garcia *et al.*, 1997; Islam *et al.*, 2000; Degens *et al.*, 2000). However, most of the studies on land use's effect on microbial biomass were conducted on temperate zones or tropical forest soils. Minimal information is available on acid red soils, which are widespread in the tropical and subtropical regions. Being highly weathered and subjected to soil erosion, nutrients released from minerals in red soils are very limited. The nutrient supply for plant growth mainly comes from the input of organic matter and its decomposition by microorganisms. Therefore, microbiological processes are more crucial for sustaining soil fertility in these soils. Moreover, microbial biomass may be more easily affected by land use change in acid red soils than in other types of soil.

The objectives of this study were to examine the effect of land use on microbial biomass-C, -N and -P as well as available N and P in red soils and to get understanding on the relation-

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ships of microbial biomass with organic matter and available nutrients.

MATERIALS AND METHODS

1. Soil

Eleven red soils with different land uses were sampled from the 0 cm – 20 cm depth in Lanxi City, Zhejiang Province. They were all derived from Quaternary red earths; some related properties of which are shown in Table 1. Soil organic C, total N and available N were determined by the dichromate oxidation method, Kjeldahl digestion-distillation method and Conway-diffusion method, respectively (Keeney, 1982; Nelson *et al.*, 1982). Soil pH was measured using a Beckman 120 pH meter (Beckman Inc, CA) at a soil: water ratio of 1:1. Total P and extractable P were measured by the $HCLO_4$-H_2SO_4 digestion method and the 0.025 mol/L HCL-0.03 mol/L NH_4F (Bray I) extraction method (Olsen *et al.*, 1982), respectively. Soil samples were sieved (< 2 mm) to remove plant roots, adjusted to 70% of water holding capacity, and stored at 4 ℃ prior to soil microbial biomass analysis.

Table 1 Basic properties of the tested soils

Soil No.	Land use	Organic C (g/kg)	Total N (g/kg)	Available N (mg/kg)	Total P (g/kg)	Available P (mg/kg)	pH (H_2O)
1	Eroded fallow	1.87	0.46	28.1	0.40	2.5	4.5
2	Woodland	7.42	0.63	60.8	0.38	3.4	4.5
3	Woodland	5.80	0.52	43.9	0.22	4.0	4.4
4	Woodland	10.61	0.76	91.7	0.40	4.1	4.5
5	Bamboo land	5.92	0.52	51.9	0.49	5.0	4.9
6	Citrus grove	6.90	0.64	64.1	1.25	175	5.0
7	Fallow grassland	4.00	0.55	35.5	1.12	165	5.9
8	Upland	5.57	0.70	55.4	1.13	170	6.1
9	Tea garden	6.84	0.50	46.1	0.43	5.5	4.2
10	Vegetable field	12.30	0.81	85.9	1.30	160	5.6
11	Paddy field	11.66	0.84	94.9	1.23	7.5	5.0

2. Determination of soil microbial biomass-C, -N and -P

Soil microbial biomass-C (C_{mic}), -N (N_{mic}) and -P (P_{mic}) were measured following the fumigation-extraction methods described by Brookes *et al.* (1982; 1985) and Wu *et al.* (1990), except that 0.5 mol/L $NaHCO_3$ was replaced by the 0.025 mol/L HCL-0.03 mol/L NH_4F as extractant (He *et al.*, 1997b). C_{mic}, N_{mic} and P_{mic} were calculated using a conversion factor of 0.45 (K_{EC}), 0.54 (K_{EN}), and 0.40 (K_{EP}), respectively (Wu *et al.*, 1990; Brookes *et al.*, 1985; He *et al.*, 1997b). Each measurement was carried out in triplicates.

RESULTS

Microbial biomass-C in the red soils varying in land use ranged from 68.3 mg/kg to 224.9 mg/kg, which are generally lower than those reported from other types of soil (Fig. 1), as the red soils had lower levels of organic C, ranging from 1.87 g/kg to 11.6 g/kg. A strong relationship existed between the C_{mic} and soil organic C

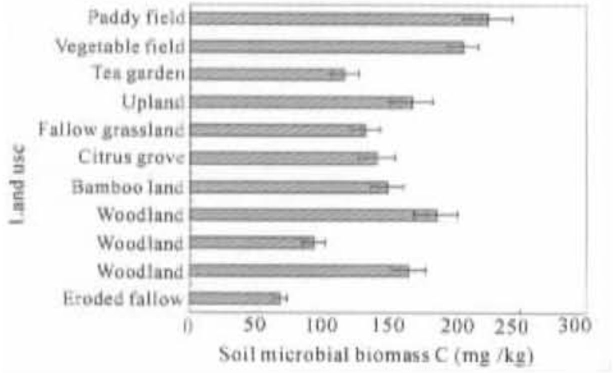

Fig.1 Effect of land use on microbial biomass C

(r = 0.869**) (Table 2). Land use had considerable effect on the amount of soil C_{mic}, which was the lowest in eroded fallow (68.3mg/kg), followed by woodland, tea garden, citrus grove and grassland (93.9 mg/kg – 186.1 mg/kg), and the highest in vegetable and paddy fields (206.6 mg/kg – 224.9 mg/kg) (Fig. 1).

Table 2 Coefficients of correlation between microbial biomass and soil chemical properties

	C_{mic}	N_{mic}	P_{mic}	C_{org}	N_t	N_A	P_t
C_{mic}							
N_{mic}	0.803**						
P_{mic}	0.550	0.184					
C_{org}	0.869**	0.687*	0.571				
N_t	0.928**	0.787**	0.611*	0.870**			
N_A	0.902**	0.794**	0.601	0.954**	0.930**		
P_t	0.557	0.216	0.480	0.342	0.598	0.379	
P_A	0.197	0.083	−0.107	0.000	0.269	0.015	0.808**

* significant at the level of 0.05; ** significant at the level of 0.01

C_{org}, organic C; N_t, total N; N_A, available N; P_t, total P; P_A, available P

Microbial biomass-N was also affected by land use although there was a smaller range in absolute values of N_{mic} (12.1 mg/kg – 31.7 mg/kg), as compared with C_{mic} (Fig. 2). The changes in N_{mic} were consistent with those in C_{mic}, as shown from the narrow range of microbial C/N (5.0 – 9.9) (Table 3) and the significant relationship between N_{mic} and C_{mic} (r = 0.803**) (Table 2).

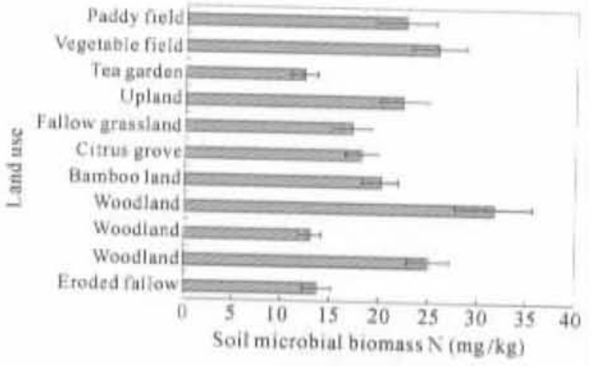

Fig. 2 Effect of land use on microbial biomass N

Total N and available N were also influenced by land use (Table 1). The trends in the changes of total N and available N were similar to those of N_{mic}. N_{mic} was significantly correlated with total N (r = 0.787**) or available N (r = 0.794**) (Table 2).

Compared with C_{mic} and N_{mic}, P_{mic} was less affected by land use. The P_{mic} ranged from 5.6 mg/kg to 13.8 mg/kg except for the paddy soil, where P_{mic} (52.38 mg/kg) was significantly higher than those of the other types of soils (Fig. 3). The microbial C/P ratio was in the range of 4.3 – 22.3 (Table 3).

Table 3 Biochemical properties of the tested soils

Soil No.	C_{mic}/C_{org} (%)	N_{mic}/N_t (%)	C_{mic}/N_{mic}	C_{mic}/P_{mic}
1	3.7	3.0	5.0	12.2
2	2.2	4.0	6.6	21.5
3	1.6	2.5	7.3	20.8
4	1.8	4.2	5.9	19.2
5	2.5	3.8	7.5	22.3
6	2.1	2.8	7.9	11.6
7	3.3	3.1	7.8	13.0
8	3.0	3.2	7.5	22.3
9	1.7	2.4	9.7	9.8
10	1.7	3.2	8.0	14.9
11	1.9	2.7	9.9	4.3

From the data of total P and available P (Table 1), it can be seen that total P and available P for soil No. 6, 7, 8, and 10 were significantly higher than those for the other soils, and obviously more P fertilizers were applied in these soils. For the other soils, total P and available P were not influenced by land use.

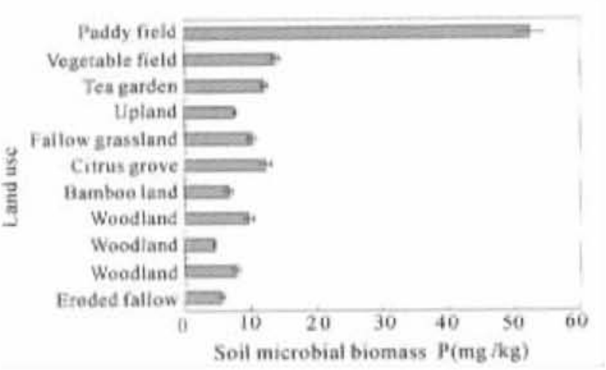

Fig.3 Effect of land use on microbial biomass P

DISCUSSION

Our results showed that the amounts of C_{mic} in the red soils under different land use were generally lower than that reported in temperate neutral soils. This was explained by two factors: firstly, these red soils have become strongly acidic mainly due to highly weathering of soil minerals, which limits the growth of microorganisms; secondly, rapid decomposition of soil organic matter under the warm and moist climate in the subtropical regions and less input of organic matter into these soils causes lower content of organic matter (< 13 g/kg). Therefore, there was a lack of energy resource for the growth of microorganisms in these soils. Land use had considerable effects on soil C_{mic}. Land use could cause changes in soil C and N cycling rates and accumulation of organic matter (Jackson *et al.*, 1993; Vinton *et al.*, 1995; Chen and Stark, 2000). Our results also showed that land use change had significant effects on the content of soil organic C. The correlation analysis showed the existence of significant relationship between soil C_{mic} and organic matter. Land use effects on C_{mic} were probably related to the changes in soil C cycling rate and in accumulation of soil organic matter, which is crucial for C_{mic} formation.

The similarity of the change in N_{mic} under different land uses to C_{mic} was mainly due to relatively stable microbial C/N ratio (ranging from 5.0 to 9.9). The mean microbial C/N ratio of 7.6 we obtained was close to that (6.7) reported by Anderson *et al.* (1980) from neutral soils in the temperate zones. This implied that there existed a relatively stable C/N ratio in the body of microorganisms of different types of soil. Good relationships of N_{mic} with total N and available N on one hand indicated that N_{mic} might be mainly controlled by total N and available N; on the other hand, it was evident that there existed a dynamic balance between N_{mic} and available N (Smith *et al.*, 1990). Microbial biomass-N might be a potential biological indicator of soil N-supplying level.

The chloroform fumigation – 0.5 mol/L $NaHCO_3$ extraction procedure proposed by Brookes *et al.* (1982) has been frequently used to measure soil microbial biomass-P. The 0.5 mol/L $NaHCO_3$ extraction method is subject to limitations of low P recovery when applied to highly weathered acid soils due to strong adsorption of P by variable-charge minerals (Feigl *et al.*, 1995; Chen *et al.*, 2000). Replacement of the 0.5 mol/L $NaHCO_3$ by 0.025 mol/L HCl + 0.03 mol/L NH_4F (Bray P1 reagent) improved P recovery and the reliability of the P_{mic} estimation (He *et al.*, 1997b; Oberson *et al.*, 1997), so 0.025 mol/L HCl + 0.03 mol/L NH_4F as an extractant was used for determining P_{mic} in this study.

Microbial biomass-P was less affected by land use, as compared with C_{mic} and N_{mic}. There was a wider range of microbial C/P ratio than microbial C/N ratio, mainly because there were lower contents but less stability of P inside soil microorganisms. Comparing the data on total P and available P of each soil, it could be seen that P fertilizers were obviously applied in the soils No.6, 7, 8 and 10. However, the amounts of P_{mic} in these soils were not significantly higher than those in the other soils. This implies that application of only P fertilizers, without the input of C and N elements such as farm manure and N fertilizers, may not increase P_{mic}.

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