Effects of different management types on soil nutrients and microbial biomass of *Moso* bamboo forest

Xiaomin Guo[A,C], Shunbao Lu[A,B], Dekui Niu[A], Dongnan Hu[A] and Tianzhen Du[A]

[A]College of Landscape and Art Jiangxi Agricultural University/The Key Laboratory of Genetic Resources and Use of Bamboo in Jiangxi Province, Nanchang China 330045, Email luxunbao8012@126.com
[B]College of Life Science Jiangxi Normal University, Jiangxi Nanchang China 330022.
[C]Corresponding author. Email gxmjxau@163.com

Abstract
The spatial variability of soils nutrients and microbial biomass of *Moso* bamboo forest under different management types was investigated in Jiangxi Province, China in this study and results showed soil nutrients decreased gradually from intensive management (IM) to general management (GM) and to extensive management (EM) types. Besides some fluctuations in the concentrations of available K(AK) and total N(TN), soil nutrients in Fengxin country (FXC) turned out to be relatively high while they were relatively low in Tonggu country (TGC). There were extremely significant difference for available N (AN) in 0-10EM, 10-30EM in TGC and Yongfeng country (YFC), 30-50EM in TGC, 0-10EM and 30-50EM soil layer of available K(AK) in Jing'an country (JAC). There was no spatial effect on TN of 0-10EM in TGC. Interactions were significant among different management types and experimental sites on soil organic matter (SOM) in 0-10EM, AN and AK in 10-30EM soil layer. However, there were very significant interactions for SOM in 0-10EM and 10-30EM, AN and AK in 10-30EM. The available P (AP) and TN concentrations were not sensitive to interactions. Bacteria constituted the largest part of soil microbes, followed by actinomycetes and fungi. The amount of bacteria listed from highest to lowest as FXC, TGC, JAC, YFC in the IM and EM, while the sequence was FXC, JAC, YFC and TGC in the GM. The amount of fungi was listed from highest to lowest as in FXC, JAC, TGC and YFC. The amount of actinomycetes of JAC was largest, and was least in FXC. Very significant difference appeared in the amount of actinomycetes with different management types. The correlation was extremely significant of SOC, AN to amount of bacteria and fungi, as well as AP to bacteria, AK to fungi. There was little difference among five kinds of soil nutrients to actinomyces.

Key Words
Management types, *Moso* bamboo (*Phyllostachys heterocyla* cv. Pubescens), spatial variability.

Introduction

Soil fertility is a comprehensive reflection of various aspects of soil and also an indicator of forest productivity. It will directly influence the growth of bamboo (Huang 2000). Microorganisms are important and active components of soil in forest ecosystems and almost all the biochemical reactions are involved in the soil (Zhou 2007). They play an important role in cycling of materials, energy transformations and maintenance of ecosystem functions (Jin 1991; Xu 1993; Jiao *et al.* 1997; Nation Biodiversity research 1998). Many important biochemical processes and material cycling of soil can objectively reflect the soil fertility status (Guan 1986; Zhang 1987; Jin 1991; Chen 1993; Zheng 1995). Therefore, it is of great significance to carry out research on forest soil nutrients and microorganisms, which will help us to use soil appropriately, maximise eco-efficiency of the stands, prevent soil fertility from declining and improve the ecological quality of the environment. However, due to the complexity of forest soil conditions, terrains, spatial and temporal variability of forest soil nutrients results in soil spatial variability. Research on nutrients and microorganisms of soil *in Moso* bamboo forestry will help us understand geographic variability and develop theory and techniques to study accurate fertilization and protection *of Moso* bamboo forest, and provide a scientific basis to establish *Moso* bamboo forest soil nutrient management systems.

Materials and methods

Experimental forest overview

Experimental sites are located in northwest Jiangxi Province. It is typical subtropical humid monsoon climate in this region and as well as a main producing region of *Moso* bamboo in Jiangxi province. The investigation point are JAC, FXC, TGC and YFC (114º31'-115º55'E, 25º14'-28º88' N). Experimental plots were set in the central area of bamboo forest. Altitude at the sites is about 200-800 m above sea level. The soil is yellow red, more than 60 cm in depth, 8-16°C in slope, 4.12-5.5 of pH. The climate is mainly humid and mild, with abundant rainfall and sunshine. The average annual temperature is 16.2-19.7°C, with a long frost-free period of 240-307d. Daily average temperature is stable and activities above 0°C accumulated temperature is 5926-6478°C; ≥10°C accumulated temperature is 5050-5644°C. Extreme maximum temperature could be 41.6°C while extreme minimum temperature could be -5.8°C. Average annual precipitation is 1624.9mm. Average sunshine hours were 1737.1 hours (1986). Water, heat, soil and habitat conditions are very suitable for bamboo growth. The experimental plots are mainly occupied by bamboo and most bamboo appear to be pure forest, while there are still a substantial proportion of some broad-leaved mixed forest with fir, natural defective forest.

Description of the sites, experimental design and soil sampling
Three different management types: IM, GM and EM. Each type was set to repeat three times, namely, three plots. The experimental plots were fertilized with bamboo fertilizer in the last ten days of February 2009 (375kg/hm^2). Soil samples were collected in July 2009. Three points for sampling were selected in each plot, and at each point soil was divided into three layers, namely, 0-10 cm, 10-30 cm and 30-50 cm. These soil samples of the same point with the same level were mixed and 1 kg from mixture was taken out and packed with sterile bags, and as soon as possible returned to the laboratory and processed within 2 days. 20 g fresh soil from samples of the 0-10cm soil layer were taken out and placed into sterile bags at 4°C preservation for microbial analysis. The sub-samples of soil were air-dried for several days and processed through a 2-mm sieve for analysing physical and chemical properties.

Analysis of soil nutrients and microbial biomass
A sub-sample from each plot was analysed for chemical properties and microbial biomass. The chemical properties analysis was carried using the methods described by Lu (1998), and soil microbial biomass was followed methods described by Cheng (2000).

Results
Variability characteristics of soil nutrients for different management types
Soil pH varied from 4.12 to 5.5, appearing to be strong acid. Soil nutrients of the same experimental plots under different management types showed different features (Figure 1). Soil nutrients gradually decreased from IM to GM and EM in all depths.

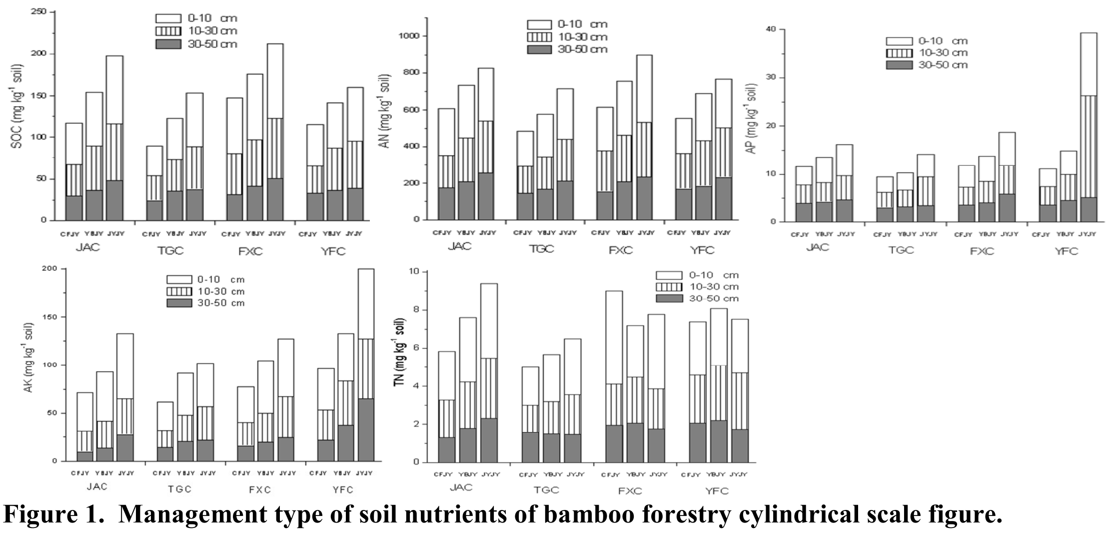

Figure 1. Management type of soil nutrients of bamboo forestry cylindrical scale figure.

The nutrients were relatively high in all soil layers except soil AK and TN in FXC, while being low in TGC. We found that bamboo grew better in TGC than in FXC. The difference was in relation with sites conditions. SOM in 0-10 cm was three times than in 30-50 cm within same experimental plots. There was extremely significant difference among management types and SOC in 0-10 cm soil in TGC, and significant difference 10-30 cm and 30-50 cm in TGC, and SOM in 10-30 cm in YFC. AN in 0-10 cm was higher than in the 30-50 cm soil layer (Figure 1). The difference was very significant between management types for AN in 0-10 cm and 10-30 cm soil layers in TGC and YFC, and significant for the 30-50 cm layer in TGC. Soil AP was low in the experimental region, which suggested P fertilizer should be added and soil P content for bamboo should be increased. There was extremely significant difference among management types and nutrients in 0-10 cm and 10-30 cm in JAC, AP in 0-10 cm in TGC. Soil AK in TGC was lower than 50mg/kg (Figure 1). Part of the forest soil should be replenished with K fertilizer in order to meet the needs of growth of bamboo.

Soil AK was more than 70 mg/kg only in YFC. There was significant difference by ANOVA among management types and AK of 0-10 cm and 30-50 cm in JAC. Soil TN in 0-10 cm was 2-3.92g/kg in JAC. The difference was not significant among management types to TN except 0-10 cm soil layer in TGC. The difference was extremely significant among alternate management types and experimental zones of SOM in 0-10 cm, AN and AK in 10-30 cm (Table 1). There was significant difference of SOM and AP in the 30-50 cm soil layer. There was no effect of interactions on AP for the 0-10 cm and 10-30 cm and TN for the 30-50 cm soil layer.

Table 1. Two-factor (management and zone) analysis of variance P value of interaction.

	0-10EM		10-30EM		30-50EM	
O.M	PM=0.000**	PZ=0.000**	PM=0.000**	PZ=0.002**	PM=0.003**	PZ=0.092
Available N	PM=0.006**	PZ=0.031*	PM=0.000**	PZ=0.000**	PM=0.000**	PZ=0.015*
Available P	PM=0.079	PZ=0.346	PM=0.179	PZ=0.331	PM=0.024*	PZ=0.053
Available K	PM=0.002**	PZ=0.039*	PM=0.001**	PZ=0.002**	PM=0.053	PZ=0.040*
Total N	PM=0.556	PZ=0.408	PM=0.079	PZ=0.019*	PM=0.768	PZ=0.334

Note: P_M: accompanied probability of management, PZ: accompanied probability of zone, * correlation is significant (P<0. 05) ; ** Correlation is very significant(P<0. 01). The same as below.

Differences in the number of soil microbes for different management types of bamboo forestry

There was an obvious difference in the quantity of soil microbes in bamboo forest (Table 2). Bacteria biomass had the largest amount, followed by actinomycetes and fungi. The proportion of bacteria, fungi and actinomycetes varied with bamboo forestry soil.

Table 2. the same experimental area of different treatments on soil microbial quantity and LSD comparison

Sample	Manage	Becteria×107cfu·g -1		Fungi×105cfu·g-1		Actinomyces×106cfu·g-1		Total Micro.×107cfu·g-1
	JYJY	4.80±0.035Aa		1.67±0.38Aa		6.0±0.59Aa		5.42
JA	YBJY	3.83±0.035Bb	**	2.00±0.38Aa	*	1.5±0.59Bb	**	4.00
	CFJY	0.70±0.035Cc		0.50±0.38Bb		1.25±0.59Bb		0.83
	JYJY	5.43±0.42Aa		1.75±0.30Aa		1.80±0.39Aa		5.63
TG	YBJY	1.75±0.42Bb	**	0.3±0.30Bb	**	1.50±0.39Aa	**	1.90
	CFJY	1.20±0.42Aa		0.05±0.30Bb		0.10±0.095Bb		1.21
	JYJY	10.80±0.54Aa		2.50±0.34Aa		1.10±0.095Aa		10.94
FX	YBJY	9.65±0.54Aa	**	1.31±0.34Bb	*	0.90±0.095Aa	**	9.87
	CFJY	6.05±0.54Bb		1.01±0.34Bb		0.50±0.095Bb		6.11
	JYJY	3.39±0.43Aa		1.88±0.25Aa		1.33±0.13Aa		3.54
YF	YBJY	2.07±0.43Bb	**	1.02±0.25Bb	**	1.29±0.13Aa	**	2.21
	CFJY	0.41±0.43Cc		0.46±0.25Bb		0.51±0.13Bb		0.47

Note: The data in the table for the various parties mean ± SD; the same experimental area with the columns of different letters that significant differences.

The quantity of bacteria in a decreasing order was as FXC, TGC, JAC and YFC in IM and EM, and FXC, JAC, YFC and TGC in GM (Table 2). The largest amount of bacteria in IM in FXC was 26.3 times than in EM in YFX, indicating that rich microbial resources in FXC. The quantity of bacteria biomass was greater than other plots in FXC. There was extremely significant difference among management types in the quantity of bacteria, which meant that management types had great impact on soil bacteria in bamboo forest soil. The quantity of fungi in a decreasing order was as FXC, JAC, TGC and YFC, the quantity of fungi in FXC was 1.5 times JAC in IM, 500 times than TGC in EM (Table 2.). There was extremely significant management type effect on the quantity of fungi in TGC and YFC, and significant difference in JAC and FXC. The quantity of Actinomycetes was greater in JAC than the others, while it was the lowest in FXC and 18.3% times in JAC. There was an extremely significant difference among management types and in the quantity of soil actinomycetes.

Correlation analysis of soil nutrients and microorganisms

The quantity of soil microorganisms and nutrients showed that there were extremely significant relationships with SOM, AN, AP and bacteria, and no correlation with soil AK and TN (Table 3). The difference was very significant (P<0. 01) for SOM, AN and AK and fungi. There was a significant correlation between Fungi and AP, while no relationship for TN. No significant difference existed among five soil nutrients and actinomyces, with a positive correlation to some extent. It showed the quantity of actinomycetes was not sensitive to soil nutrients.

Table 3. Correlation among soil quantity of microorganism and nutrient

microorganism	SOM		Available N		Available P		Available K		Total N	
	R	P	R	P	R	P	R	P	R	P
Bacteria	0.879**	0.000	0.803**	0.002	0.717**	0.009	0.422	0.172	0.509	0.091
Fungi	0.847**	0.001	0.866**	0.000	0.664*	0.018	0.746**	0.005	0.508	0.091
Actinomces	0.444	0.148	0.327	0.299	0.504	0.094	0.573	0.051	0.288	0.364

Conclusions

(1) Bamboo forestry soil was strongly acidic. The soil nutrients in a decreasing order were IM, GM and EM. The soil nutrients were high except for AK and TN for the soil layers in FXC, while low in TGC. There was extremely significant difference SOM in 0-10 cm and AN and AK in 10-30 cm of interaction of management types and the experimental sites, and significant difference of SOM and AP in 30-50EM soil layer on management types, while no significant difference to experimental sites. There was no effect on interaction on AP in 0-10 cm and TN in 30-50 cm.

(2) The quantity of bacteria was of the largest amount, followed by actinomycetes and fungi at least. The quantity of bacteria in a decreasing order was as FXC, TGC, JAC and YFC in IM and EM conditions, and FXC, JAC, YFC and TGC in GM. The order of the quantity of fungi was FXC, JAC, TGC and YFC, and a great influence of fungi to management types. The quantity of actinomycetes was higher in JAC than for the others, while it was lowest in FXC.

(3) There was extremely significant relationship of bacteria with SOM, AN, AP, and no correlation to AK and TN. There were correlations between fungal and SOM, AN, AK, and a very significant difference and significantly correlation with AP, while little relationship with TN. The difference among five kinds soil nutrients and actinomyces was not significant, but a positive correlation to some extent. It showed the quantity of actinomycetes was not sensitive to soil nutrients.

Acknowledgements

The work reported here has been funded by IPNI, National Natural Science Foundation of China(30860226), Agricultural Scientific and Technological Production Funds Project of Ministry of Science and Technology(2008C50040562), National Science and Technology Support Project(2008BADA9B0802)), Excellent funded projects for returnee of Ministry of Personnel (2007-170 watershed ecology), Projects for academic leader of Jiangxi province(030008), Superior Ph.D. thesis in Jiangxi Province incubation program, Teaching Reform of key projects in Jiangxi Province (JXJG-O7-3-44) (graduate students), Jiangxi Provincial Educational Science, *Eleventh Five-Year Plan* Key Project (07ZD038). The authors want to take this opportunity to thank all of the supporters.

References

Biodiversity of China situation report compile team (1998) Nation Biodiversity research [M]. pp. 105-121. (Environment Press, Beijing).

Huang CY (2000) 'Pedology' (China Agricultural Press, Beijing).

Zhang DH, Chen YQ (1987) Forest soil enzymes and soil fertility. *Forestry Science and Technology Communication* **4**, 1-3.

Chen HJ, Li CH (1993) Soil enzyme and fertility of fir young forest. *Forest Research* **6**(3), 321-326.

Jin JM, Wang LQ (1991) 'Nature Conservation Conspectus'. pp. 15-46. (Beijing: Environmental Science Press).

Jiangxi Forest Editorial committee (1986) 'Jiangxi Forest'. (Beijing: China Forestry Press).

Cheng LJ, Xue QH (2000) 'Microbiology experiment technology'. (The World Publish Company, Beijing)

Zhou LX (2007) Microbiological characteristics of soil the instructions of the role of soil health. *Biodiversity Science* **15** (2), 162-171.

Lu RK (1999) 'Soil Agricultural Chemical Analysis Method'. (Agricultural Sci-Tech. Press, Beijing: China).

Jiao RZ, Yang CD, Tu XN (1997) The change of undergrowth, soil microorganism, enzyme activity and nutrient in different developing stage of the Chinese fir Plantation. *Forest Research* **10** (4), 373-379.

Guan SY (1986) Soil enzyme and its research method. Beijing :Agricultural Press, pp.260-332.

Zheng WJ, Wang LM, Lin P (1995) soils activity in subtropical rain forest Fujian He Xi. *Journal of Ecology* **14**(2), 16-20.

Xu YB, Chen HY (1993) P. massoniana and C. fissa Rehd.et Wilsmixed forest soil fertility levels. In 'China Southern mixed forest research'. (Eds HZ Wang *et al.*) pp. 235-241. (China Forestry Publishing Press, Beijing).