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Soil properties and water conservation function of the natural secondary broad-leaved forests in North sub-tropical China

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Natural secondary broad-leaved forest

1. Introduction

- In the subtropical China, the typical vegetation types are evergreen broad-leaved forests. Despite of their formerly widespread geographical distribution, the majority of evergreen broad-leaved forests now exists as secondary forests（En-Rong et al. 2009; Yan et al. 2007; Wang et al. 2007b）.
- The change of soil nutrient and water conservation function etc. of subtropical secondary forest succession with forest succession process are researched extensively, but most of which are for evergreen broad-leaved forests (Cindy et al. 2010; En- Rong et al. 2009; Feng et al. 2011; Qingkui et al. 2005; Yihe et al. 2011; Xiuli et al. 2010; Xuemei et al. 2008; Xijun et al. 2008).
- The research of soil nutrients, water conservation of north-subtropical natural secondary broad-leaved forests are reported less relatively (Qian et al. 2010; Qingfeng et al. 2002).
- So we selected the natural secondary broad-leaved forests enclosed in 1950’s in low mountain areas of Anhui province as the research object, and explored relationships of different secondary forest types with soil properties and water conservation function, which had important practical significance to prevent soil declining, secondary forest resources sustainable management, water conservation function evaluation and so on.

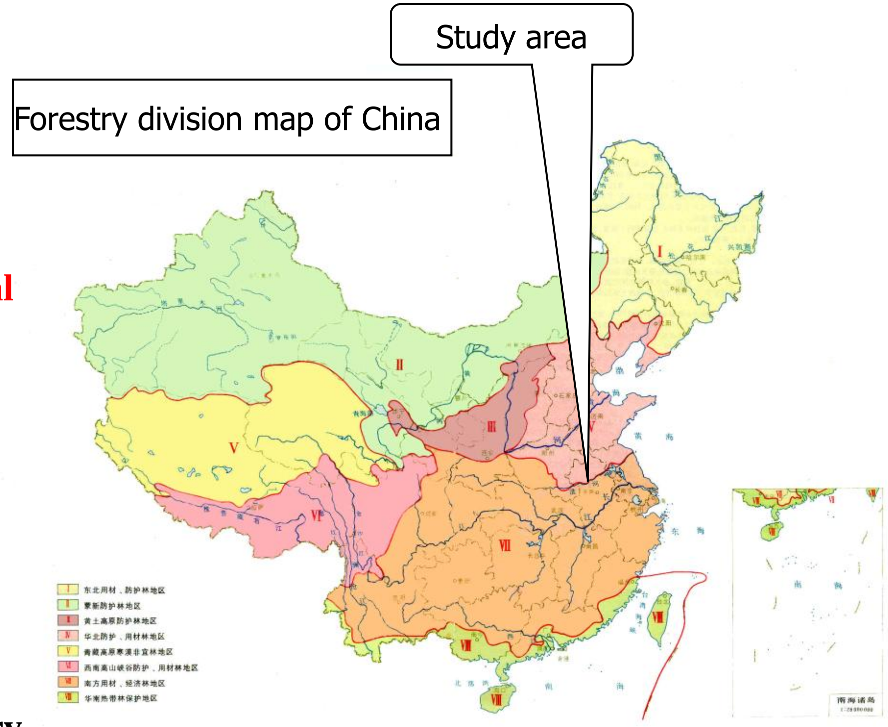
2. Study area

- The study area is located in southern portion of the middle and lower of Yangtze river in Anhui Province (30° 54′41″N , 117° 57′36″E) , east China.

- With the subtropical moist monsoon climate, the weather is warm and wet, the average annual temperature was 16.2 ℃ , and the average annual rainfall 1370 mm.

- The topography type is low hills, with yellow red soil.

- The zonal forest vegetation types are north subtropical deciduous broad-leaved and evergreen broad-leaved forests, but due to the reasons such as artificial damage, the existing vegetations are plantations and natural secondary forests.



3. Methods

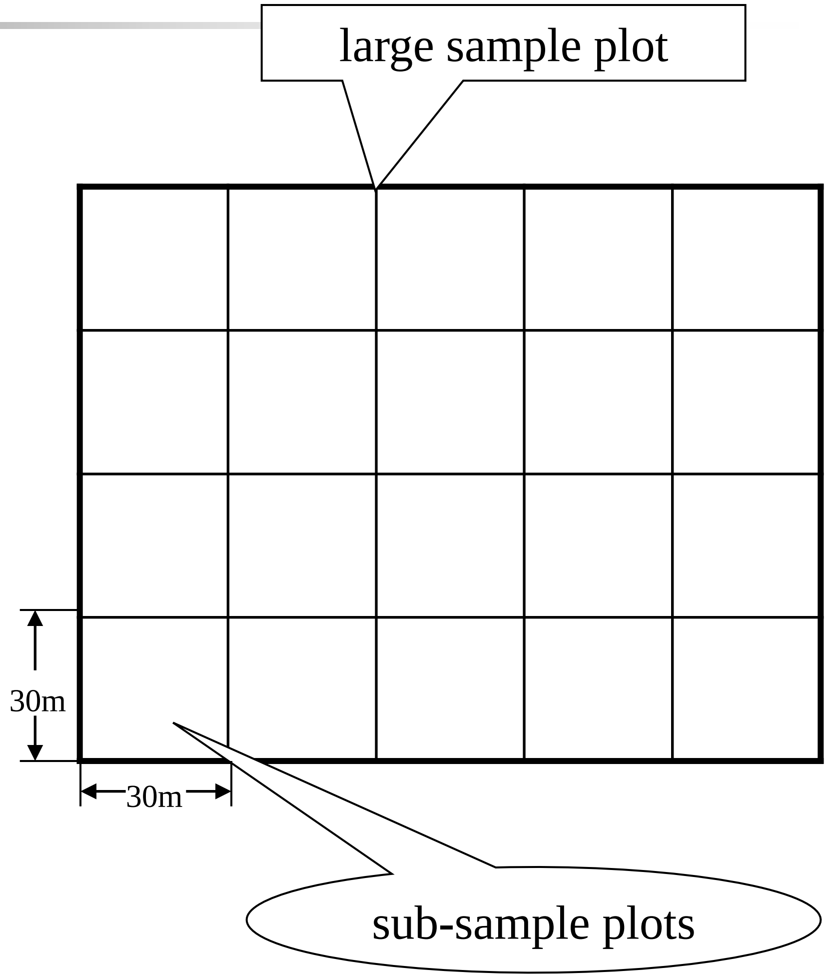
3.1 Data collection

3.1.1 Vegetation survey

- **Two natural secondary forest types enclosed in 1950's were selected in Tongling county of Anhui Province. The first forest type (Type A) is deciduous and evergreen broad-leaved mixed forest. The second forest type (Type B) is deciduous broad-leaved mixed forest.**

- **Two 1.80 hm^2 and 1.08 hm^2 large sample plots were established in Type A and Type B respectively, and then were divided into twenty 30m×30m sub-sample plots and twelve 30m×30m sub-sample plots respectively.**

- **All trees with DBH ≥5.0cm in the tree layer were counted, and identified to species in each sub-sample plot.**



3. Methods

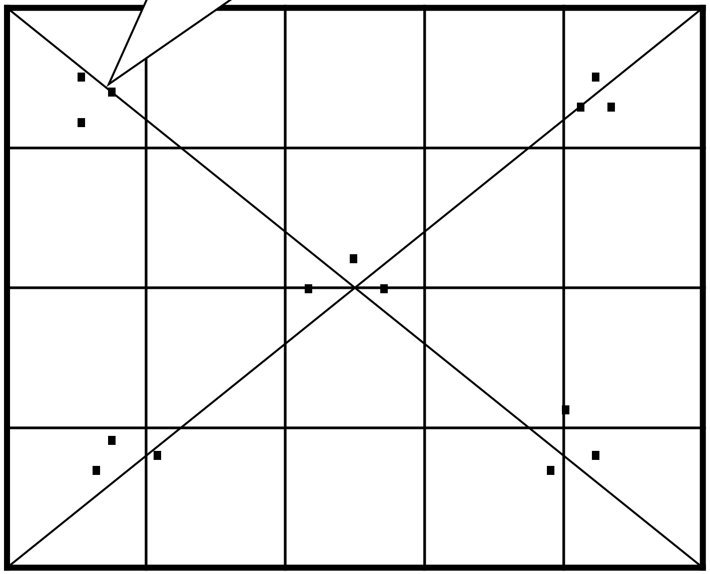
3.1.2 Soil sampling

- **Fifteen soil profiles were dug by diagonal and random method in each large plot.**

- **Soil samples were taken from different soil horizons (0-20cm、20-40cm、40-60cm) using an cutting ring (100cm^3) , and used to the analysis of soil physical properties.**

- **Meanwhile 1Kg mixed soil samples from different soil horizons were collected.**

- **Prior to analysis, soil samples were air dried, ground, and then passed through a 2-mm sieve to separate roots and the gross fraction of soil, and used to the analysis of soil chemical properties.**



3. Methods

- *3.2 Data analysis*
- **Important value is a comprehensive index to measure the position and role of the plant species in the community. We used a combination of the relative density (*RD*) and relative frequency (*RF*) and relative basal area (*RBA*) of tree species per sampling plot as important value (*IV*), which was estimated as:**
- ***IV* = (*RD* + *RF* +*RBA*) / 3**
- ***IV* was calculated in detail according to the methods described by Keping Ma (1994).**

- **Soil pH , N (nitrogen), P (phosphorus), K (potassium), available N, P ,K and organic matter were tested according to methods described by The Institute of Soil Science, Chinese Academy of Sciences (1978). Every soil sample was tested repeat three times and calculated the average value.**

- **Soil bulk density was calculated by the method of cutting ring soil moisture content, soil porosity, soil capillary porosity and non-capillary porosity, soil water holding capacity, soil capillary water holding capacity and non-capillary water holding capacity were determined and calculated according to methods described by Xiao-qing Xu (1986).**

4. Results

- ***4.1 Stand structure***
- Type A was natural secondary deciduous and evergreen broad-leaved mixed forest.
  - Stem density with DBH ≥5.0 cm was 922 stems·hm^{-2}.Important value of *Quercus acutissima* was 136.3 (Table1), and play an important rule in the community environment, and was a dominant tree species. Sub-dominant tree species included *Cyclobalanopsis glauca*, *Pinus massoniana*, *Castanopsis sclerophylla* and *Lithocarpus glaber* . The important value of four tree species were 48.2, 32.8, 25.4 and 18.1 respectively.
- Type B was natural secondary deciduous broad-leaven mixed forest.
  - Stem density with DBH ≥5.0 cm was 660 stems·hm^{-2}. Important value of *Quercus acutissima* was 105.3, and play an important rule in the community environment, and was dominant tree species. Important value of associated trees such as *Platycarya strobilacea*, *Liquidambar formosana* etc. were 65.1 and 36.3 respectively.

4. Results

Table 1 Tree important value in tree layer of different forest types

Type A		Type B	
Tree species	Important value	Tree species	Important value
Q．acutissima	136.3	*Q．acutissima*	105.3
C．glauca	48.2	*Platycarya strobilacea*	65.1
P．massoniana	32.8	*Liquidambar formosana*	36.3
C．sclerophylla	25.4	*Sophora japonica*	18.6
L．glabra	18.1	*Sassafras tzumu*	17.1
Q．fabri	13.4	*Pistacia chinensis*	12.4
L．formosana	5.5	*Cunninghamia lanceolata*	11.0
Litsea cubeba	4.2	*Celtis tetrandra*	8.7
Aluerites fordii	3.0	*Castanea seguinii*	5.3
Dalbergia hupeana	2.2	*Quercus fabri*	4.2
Mallotus tenuifolius	1.9	*Cyclobalanopsis glauca*	2.2
Albizzia kalkora	1.9	*Ulmus pumila*	2.1
Quercus stewardii	1.2	*Cudrania tricuspidata*	1.9
Tilia henryana	1.1	*Fortunearia sinensis*	1.8
Meliosma oldhami	1.1	*Albizia kalkora*	1.7
Diospyros kaki var. silvestris	1.0	*Diospyros kaki vingar. silvestris*	1.6
Ilex micrococca	1.0	*Quercus aliena*	1.6
Juniperus formosana	0.9	*Dalbergia hupeana*	1.6
Rosa cymosa	0.9	*Vernicia fordii*	1.5

4. Results

- *4.2 Soil nutrient*

Table 2 The nutrient content of soil of different forest types

Forest type	Soil depth (cm)	Total N/g.kg^{-1}	Total P/g.kg^{-1}	Total K/g.kg^{-1}	Available N/mg.kg^{-1}	Available P/mg.kg^{-1}	Available K/mg.kg^{-1}	organic matter /g.kg^{-1}	pH
Type A	0-20	1.57	0.73	6.82	100.13	10.97	77.55	43.05	4.14
	20-40	0.95	0.53	6.66	65.59	7.09	65.52	24.77	4.14
	40-60	0.93	0.49	7.08	58.22	7.51	63.84	21.30	4.18
	Mean	1.15	0.58	6.85	74.65	8.52	68.97	29.71	4.15
Type B	0-20	1.94	0.97	5.89	126.34	8.05	97.76	31.75	4.50
	20-40	1.50	0.77	5.92	100.10	6.78	80.60	23.72	4.54
	40-60	1.30	0.66	6.29	82.35	6.22	86.52	20.06	4.52
	Mean	1.58	0.80	6.03	102.93	7.02	88.29	25.18	4.52

4. Results

- **Soil organic matters was decreased with the increase of soil depth.**
- **Soil organic matter contents in 0-20cm was highest in three soil depth layer for two forest types, which was shown that the soil organic matter mainly came from the decomposing of forest litter.**
- **The soil organic matter in Type A (29.71 $g.kg^{-1}$)was higher than Type B (25.18 $g.kg^{-1}$), which was shown that the soil fertility conditions was better than Type B.**
- **Soil pH value of Type A and Type B was 4.14-4.54, are all acidic soil, but the mean pH of three soil layers was different between two forest types, and was 4.15 and 4.52 in Type A and Type B respectively, which was shown that the former soil acid was stronger than the latter.**

4. Results

- **The mean value of soil total N, P and K were 1.15-1.58 g.kg^{-1}, 0.58-0.80 g.kg^{-1} , 6.03-6.85 g.kg^{-1} for two forest types respectively, which shown soil total K content was higher than total N, P.**
- **The mean value of available N, P and K were 74.65-102.93 mg.kg^{-1}, 7.02-8.52 mg.kg^{-1}, 68.97-88.29 mg.kg^{-1} respectively.**
- **Available N content was higher than available P, K. Available P content was lowest among 0-20cm, 20-40cm, 40-60cm soil layers.**
- **Contents of total N, P, available N, P and K of two forest types in 0-20cm soil layer were higher 20-40cm, 40-60cm soil layers, which was indicated that soil nutrient had the characteristic of concentration in the surface layer, which was associated with the decomposition of forest litters.**
- **Contents of total K were relatively lower in 0-20cm soil layer than 20-40cm and 40-60cm soil layer, the possible reason was that the parent rock contains a lot of K, another reason was that K element easily migrated to deep soil layer through soil column leaching.**

4. Results

- The contents of soil total N, P, available N, K of Type B were higher than Type A, but total K and available P contents were lower than Type A, which was shown that the comprehensive fertility of Type B was better than type A.

- The possible reasons were that Type B was deciduous broad-leaved forest, and the forest canopy was loose, fallen leaves in autumn and winter, light enough in forest, litters decomposed faster so as to nutrient return to the soil.

4. Results

- ***4.3 Soil bulk density and porosity***
- **Soil bulk density was increased with increase of soil depth, but on contrary, soil porosity was decreased with the increase of soil depth, which was associated with soil organic matter contents and structure.**
- **Surface layer (0- 20 cm) was rich in humus because of the influence of forest litters, which caused soil aggregate quantity increased in this soil layer, thus soil physical structure changed, soil porosity increased and soil bulk density being relatively small.**
- **Soil layer (20- 40cm) was main distribution area of tree roots. The soil physical structure was improved, and soil bulk density was lower than 40-60cm soil layer because of tree roots growth.**
- **Soil bulk density of 20-40cm soil layer in Type B was lower than 0-20cm and 40-60cm soil layers, which were shown the tree roots growth of this forest type affected soil physical properties greatly, and improved the soil texture obviously.**

- **The mean soil bulk density was Type A (1.324) ＞Type B (1.045), which was shown that soil texture of Type B was more loose.**

Table 3 The bulk density and porosity value of soil of different forest types

Forest type	Soil /cm	Bulk density		Saturated moisture content/%	Total porosity/%		capillary water holding capacity/%	capillary porosity /%	non-capillary porosity/%
Type A	0-20	1.179	↑	43.616	48.354	↓	33.708	38.088	10.267
	20-40	1.363		36.976	45.486		28.886	36.559	8.927
	40-60	1.430		28.469	39.878		22.642	31.872	8.007
	Mean	1.324		36.354	44.573		28.412	35.506	9.067
Type B	0-20	1.080	↑	51.111	53.587	↓	42.520	44.700	8.887
	20-40	0.987		58.109	56.641		47.205	46.474	10.167
	40-60	1.069		51.482	54.255		43.330	45.808	8.447
	Mean	1.045		53.568	54.827		44.352	45.661	9.167

4. Results

- **Soil porosity was the migration channels of moisture, air, microbial and so on in the soil, the quantity and distribution of which were the foundation of the forest soil physical properties. From Table3, soil saturated moisture contents, total porosity, capillary porosity and non-capillary porosity were decreased with the increase of soil depth in Type A, which was also effected by forest-land surface humus layer and plant roots system growth, but the change tendency of which was on the contrary to the soil bulk density.**
- **If soil bulk density increased that the soil porosity will be reduced, soil permeability and water storage and transferring ability will be decreased.**

Table 3 The bulk density and porosity value of soil of different forest types

Forest type	Soil /cm	Bulk density	Saturated moisture content/%	Total porosity/%	capillary water holding capacity/%	capillary porosity /%	non-capillary porosity/%
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	40-60	1.069	51.482	54.255	43.330	45.808	8.447
	Mean	1.045	53.568	54.827	44.352	45.661	9.167

- **Soil saturated moisture contents, total porosity, capillary porosity and non-capillary porosity of 0-20cm soil layer were lower among three soil layers, and then above soil physical factors of 20- 40cm and 40- 60cm soil layers were decreased with the increase of soil depth in Type B.**

4. Results

- *4.4 Soil water conservation ability*
- **Soil saturated water holding capacity of 0-60cm soil layer in Type A and Type B were 2674.4 t.hm^{-2} and 3289.6 t.hm^{-2} respectively, which shown that the water conservation potential of Type B was larger than Type A.**
- **Soil non-capillary water holding capacity in Type A and Type B were 544.0 t.hm^{-2} and 550.0 t.hm^{-2} respectively, which showed the same change rule as non-capillary porosity change.**
- **The non-capillary water capacity of different soil layers in Type B are lager than Type A apart from the 0- 20 cm soil layers, which showed that soil non-capillary porosity of Type B was larger, the soil water conservation ability was stronger (Table4).**

Table 4 The water holding capacity of different forest types

Forest type	Soil depth /cm	water holding capacity		
		non-capillary /t.hm^{-2}	Capillary /t.hm^{-2}	Saturated/ t.hm^{-2}
Type A	0-20cm	205.3	761.8	967.1
	20-40cm	178.5	731.2	909.7
	40-60cm	160.1	637.4	797.6
	0-60cm	544.0	2130.4	2674.4
Type B	0-20cm	177.7	894.0	1071.7
	20-40cm	203.3	929.5	1132.8
	40-60cm	168.9	916.2	1085.1
	0-60cm	550.0	2739.6	3289.6

4. Results

- Mean total soil porosity of Type A and Type B were 44.573% and 54.827% respectively, which was showed soil permeability was best for Type B.
- Soil non-capillary porosity of Type A and Type B were 9.067% and 9.167% respectively, which was no significant differences between two forest types (Table3).

Table 3 The bulk density and porosity value of soil of different forest types

Forest type	Soil /cm	Bulk density	Saturated moisture content/%	Total porosity/%	capillary water holding capacity/%	capillary porosity /%	non-capillary porosity/%
Type A	0-20	1.179	43.616	48.354	33.708	38.088	10.267
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	Mean	1.045	53.568	54.827	44.352	45.661	9.167

5. Disscussion

- **Deciduous-evergreen broad-leaved mixed forest was poorer in light conditions contrast to the deciduous broad-leaved mixed forest, so that forest litters decomposed slowly, which was advantageous to the formation and increase of soil humus and organic matter contents etc..**
- **Deciduous broad-leaved forest canopy was loose, lighting sufficient in forest and higher soil temperature, which were advantageous to activity of the microbes, and to forest litters decomposed and nutrient returning to the soil, so as to have thin soil humus layer and lower organic matter contents.**
- **Just for reasons as above, soil organic matters in Type A was higher than Type B.**

5. Disscussion

- High soil organic matter contents are beneficial to the formation of soil aggregation, thus changing the physical structure of the soil layer, porosity increased, making surface soil loose and bulk density relatively small.
- Soil organic matters in Type A was higher than Type B, but the soil bulk density was Type A(1.324) higher than Type B(1.045), which can been only explained that trees roots in Type B was vigorous growth, and that had bigger influence on the soil physical properties, improving the soil texture obviously.
- Total water holding capacity of subtropical evergreen broad-leaved forests were 65 year (2 415.645 $t.hm^{-2}$) higher than 48 year (2 407.634 $t.hm^{-2}$) higher than 36 year (2 273.562 $t.hm^{-2}$) higher than young forest (2 079.462 $t.hm^{-2}$) (Xiao-niu et al.2009) .
- Total water holding capacity of two secondary broad-leaved forests was 2674.4-3289.6 $t.hm^{-2}$, more than 65 year evergreen broad-leaved forest maximum water holding capacity, which showed that two kinds of secondary forest are well protected and restored, and have a strong function of water conservation.

Thank you for your attention