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Acidification and change of physicochemical properties of Mt. Heng soils in last 34 years

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Abstract—This paper concentrates on discussing the changes of acidity, exchangeable calcium, magnesium and aluminium, and of base saturation of Mt. Heng soils on the basis of information in 1965 and analytical result in 1994, and discussing the relationship between the changes and acid precipitation. It was shown that there was a change tendency of the soil pH and exchangeable magnesium decreased from the foot of the mountain to the summit in the last 34 years. Base saturation of soils decreased at Zhurongfeng (the summit of the mountain), Shangfeng Temple and Wuyue Temple, but it increased at Yanshou Pavilion (lower part of the mountain). The significant decrease of soil pH in upper mountain are might be related with acid rain and acid fog, especially with acid fog.

Keywords: acidification; soil; acid rain; acid fog.

1 Introduction

Effect of acid precipitation on cations removal from terrestrial ecosystems has been studied by many scientists (Cole, 1977). A number of scientists have reported that acid precipitation reduced the content of exchangeable cations and base saturation of soils (Dai, 1993; Zhou, 1989; Haugbotn, 1976; Tamm, 1977). The effect of acid precipitation on soils is not only to accelerate leaching nutrient elements from soils, but also it can increase the content of active aluminium and accelerate soil acidification (Liao, 1991). Soil acidification is also related with acid precipitation (Kuylenstierna, 1991; Pan, 1993).

Acid fog might damage forest ecosystems heavier than acid rain in mountain areas, especially in tropic and subtropic mountain areas where have a long fog period each year. Ibrahim (Ibrahim, 1980) has discussed the effect of acid fog on plant growth. The problem of acid fog in China has been studied by many scientists (Pong, 1986; Zhang, 1988).

Acid rain and acid fog have been found in Mt. Heng area. The frequency of acid rain that pH of rain is smaller than 5.6 is near 100% in the area, average of pH was $\leqslant$4.5 (Tang, 1993) in 1988. Fog in the area is also nearly acid, average of pH was about 4.3 in 1989. Its frequency was about 90% in 1989.

This paper principally aims at discussing the changes of pH, exchangeable cations and base saturation of the soils in Mt. Heng area, and the changes that might be related with acid rain and acid fog.

2 General situation of Mt. Heng

Mt. Heng, located in middle - east part of Hunan Province, at about 27°12′ N latitude and 112°45′ E longitude, is about 1280m high above sea level. The bed rock is granite in the mountain. Soil types are meadow, zheltozem and red soils from the top of the mountain to the foot, all soils are acidic. Forest types are coniferous woods, mixed broad - leaved and coniferous woods, and broad - leaved woods. The climate of the Mt. Heng area belongs to subtropic monsoon climate. Because currents of air from north and south often go through the mountain or come together at this area, it is hot in summer and cold in winter, and rainfall is abundant. There is no significant change of dry and humid seasons, but temperature and humidity change obviously with altitude. Annual average temperature is about 17. 5°C in the area below 500m high above sea level. Average temperature is about 29. 7°C in July, about 5°C in January. Annual rainfall is about 1510 mm. Relative humidity is more than 80%. In the area of 500—1200m above sea level, temperature decreases with altitude increase, but the change of humidity is contrary. Annual rainfall in the rangement of 500—1200m height is higher than that in the area below 500m. In the area above 1200m height, it is cloudy, foggy and windy. Thus it is low temperature, high humidity and short sunshine. It is, therefore, due to the climate and geographic conditions that acid material from pollution sources near the area and from transportation is easy to form acid rain and acid fog in the mountain area.

3 Materials and analysis

There were 4 sampling sites for collecting soil samples in 1994 which were close to the sites chosen by Gao and Dou (Gao, 1965), they collected soil samples at these four sites in 1960. The sampling sites are Zhurongfeng (about 1253m above sea level in 1960, 1250m in 1994), Shangfeng Temple (about 1180m in 1960 and 1994), Wuyue Temple (about 800m in 1960 and 1994) and Yanshou Pavilion (about 400m in 1960 and 380m in 1994). The soil type is meadow soil (near planted pines at Zhurongfeng), zheltozem (at Shangfeng Temple and Wuyue Temple) and red soil (at Yanshou Pavilion). The soil samples were dried in air, crushed by wood stick and removed >2 mm gravel, roots and so on to be used for analysis.

Analysis of total exchangeable acid and exchangeable ionic hydrogen is as follows: at first, soil sample was extracted by 1. 0 mol/L KCl. 50 ml filter liquor was boiled about 5 minutes, added phenolphthalein indicator and titrated immediately 0. 02 mol/L NaOH for measurement of total exchangeable acid. Another 50 ml filter liquor was boiled about 5 minutes, added 3 ml solution of 3. 5% NaF, and titrated by 0. 02 mol/L NaOH after it was cool and added phenolphthalein indicator for exchangeable ionic hydrogen. Exchangeable aluminium is the difference between total exchangeable acid and exchangeable ionic hydrogen.

Cation exchange capacity (CEC) and exchangeable K, Na, Ca and Mg were analyzed as follows: soil sample was extracted by 1. 0 mol/L NH_4OAC. Then NH_4^+ in filter liquor was measured by IC, and CEC was calculated. K, Na, Ca and Mg in the filter liquor were measured by AAS.

pH of soils was measured by pH - meter with the ratio of water to soil sample that is 5:1.

4 Result and discussion

The results of organic matter, cation exchange capacity, pH and base saturation of soils of Mt. Heng are listed in Table 1. It was found that there was no remarkable change tendency for content of organic matter between 1960 and 1994, but content of organic matter in soils at Zhurongfeng and Wuyue Temple in 1960 was slight higher than in 1994, it was higher in 1994 than in 1960 at Shangfeng Temple and close to between 1960 and 1994 at Yanshou Pavilion. There was no significant difference for CEC between 1960 and 1994, except at Shangfeng Temple where it was higher in 1994 than in 1960. Base saturation of soil at Zhurongfeng in 1960 was higher than in 1994. At Shangfeng Temple, it was lower in 1994 than in 1960 in depth above 50 cm of the soil profile. Decrease in base saturation of soils in the last 34 years at the two sites might be related with soil pH decrease, the decrease value of pH was about 1 pH unit. Base saturation was increase in 1994 at sites of Wuyue Temple and Yanshou Pavilion. At these two sites, pH of soils was hardly different between 1960 and 1994, except in subsoil at Wuyue Temple

Table 1 Organic matter content, CEC, BS and pH of soils at Mt. Heng

Site	Depth, cm	pH	Orgm, %	CEC, me/100g	BS, %	Year	Altitude, m
Zhurongfeng	2—24	5.5	11.56	31.72	10.49	1960	1230
	24—55	5.6	5.43	25.21	7.06		
	0—24	4.39	9.89	30.40	5.58	1994	1250
	24—45	4.47	3.99	20.63	4.12		
	45—57	4.81	3.20	20.89	5.23		
Shangfeng Temple	5—35	5.0	5.61	19.28	8.29	1960	1180
	43—53	5.4	1.98	14.41	11.79		
	67—77	5.7	0.34	21.20	3.59		
	86—96	5.2	/	14.11	3.75		
	0—10	3.93	6.88	33.61	5.99	1994	1180
	10—20	4.13	3.17	31.18	5.22		
	20—30	4.29	3.50	22.50	5.23		
	30—50	4.18	2.27	22.16	5.96		
	50—60	4.25	4.37	21.47	5.79		
Wuyue Temple	5—25	4.7	7.88	20.88	6.26	1960	800
	26—36	4.9	5.09	16.41	4.32		
	48—58	5.2	2.30	15.20	6.10		
	77—87	5.2	/	9.56	5.43		
	0—6	4.91	2.93	24.80	14.89	1994	800
	6—20	4.37	3.12	20.56	7.69		
	20—60	4.55	0.6	16.94	9.77		
Yanshou Pavilion	2—15	4.90	1.74	20.74	5.54	1960	400
	15—25	4.70	1.28	18.30	12.29		
	40—50	4.85	0.31	14.40	6.24		
	70—80	5.20	/	11.28	14.18		
	0—16	4.91	1.97	18.78	20.45	1994	380
	16—60	4.93	1.26	19.49	17.30		
	60—80	5.25	0.79	23.13	33.36		

where pH was slightly lowerin 1994 than in 1960.

Change of soil pH at Zhurongfeng and Shangfeng Temple at Mt. Heng is given in Fig. 1. It was found that there was a remarkable difference for soil pH at the sites between 1960 and 1994, and that the differential value of pH between 1960 and 1994 in topsoil was similar to that in subsoil and bottom soil. The differential value was about 1.1 in topsoil at Zhurongfeng and in subsoil at Shangfeng Temple, but it was about 0.9—1.0 in topsoil at Shangfeng Temple and in subsoil at Zhurongfeng.

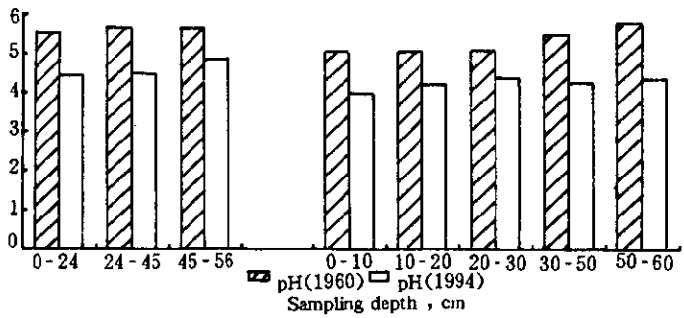

Fig. 1 Change of soil pH at Zhurongfeng and Shangfeng Temple

Change of soil pH at Wuyue Temple and Yanshou Pavilion is given in Fig. 2. It was found that there was hardly different at these sites between 1960 and 1994, but there was a small difference in subsoil at Wuyue Temple. It was seen on the basis of the figures that change of soil pH at Mt. Heng was obviously different. The change of soil pH at higher places of the mountain was larger than at lower places even if soil type was the same. It was possible that there was a change tendency of soil pH between 1960 and 1994. The tendency might be that the decrease value of soil pH in the last 34 years at Mt. Heng was larger at higher place, vice versa, and the decrease value was near zero below 400m.

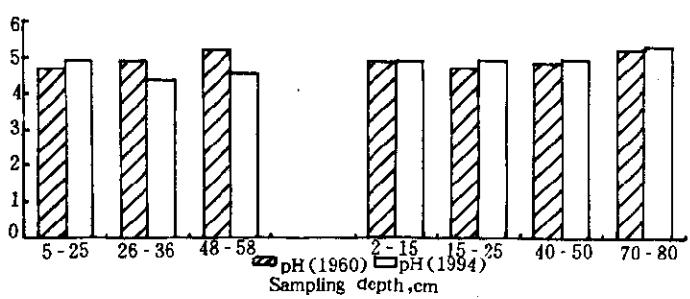

Fig. 2 Change of soil pH at Wuyue and Yanshou Pavilion

Contents of exchangeable acid, calcium and magnesium in soils of Mt. Heng are listed in

Table 2. It was found that there was obviously different between 1960 and 1994 for exchangeable acid in soils of Zhurongfeng and Shangfeng Temple, especially in topsoil and subsoil that exchangeable acid in 1994 was much higher than 1960. But there was not remarkable different at Wuyue Temple and Yanshou Pavilion. The change tendency of exchangeable acid in soils between 1960 and 1994 was in accordance with pH change. Although exchangeable acid increase in soils at Zhurongfeng and Shangfeng Temple was principally increased exchangeable aluminium, ratio of exchangeable ionic hydrogen increase in the last 34 years was considerably high, it was obvious higher than that of aluminium increase. There was no increase in exchangeable acid in soils at Wuyue Temple and Yangshou Pavilion, but exchangeable ionic hydrogen was obviously increased in the soils in the last 34 years.

Table 2 Content of exchangeable acid, Ca and Mg of soilsat Mt. Heng

Unit: me/100g

Site	Depth, cm	ExAcid	ExH	ExAl	ExCa	ExMg
Zhurongfeng	2—24	4.28	0.1	4.18	3.00	0.33
	24—55	1.50	0.1	1.47	1.04	0.78
	0—24	7.46	4.62	2.82	0.81	0.29
	24—45	12.95	0.75	12.20	0.32	0.12
	45—57	5.02	1.64	3.38	0.81	0.04
Shangfeng Temple	5—35	3.45	0.18	3.27	0.50	1.10
	43—53	2.79	0.08	2.71	0.50	1.20
	67—77	2.55	0.02	2.53	0.20	0.73
	86—96	3.17	0.05	3.12	/	0.53
	0—10	12.02	1.03	10.99	1.46	0.16
	10—20	24.23	4.27	19.96	1.30	0.05
	20—30	9.46	0.46	9.03	0.81	0.04
	30—50	7.96	0.64	7.32	0.65	0.02
	50—60	6.40	0.46	5.94	0.81	0.05
Wuyue Temple	5—25	5.08	0.11	4.97	0.55	0.72
	26—36	3.97	0.08	3.89	0.48	0.23
	48—58	3.70	0.03	3.67	0.20	0.73
	77—87	3.30	0.03	3.29	0.20	0.32
	0—6	4.70	0.25	4.45	2.92	0.18
	6—20	3.34	0.46	2.88	1.14	0.02
	20—60	3.73	0.39	3.34	1.14	0.15
Yanshou Pavilion	2--15	3.86	0.10	3.76	0.40	0.75
	15—25	3.87	0.08	3.79	0.40	1.85
	40—50	4.09	0.08	4.01	0.15	0.75
	70—80	3.00	0.08	2.92	0.05	1.55
	0—16	3.38	0.36	3.02	2.41	1.01
	16—60	4.12	0.21	3.91	2.38	0.69
	60—80	2.53	0.43	2.10	6.81	0.55

Content of exchangeable calcium and magnesium in soils at Mt. Heng between 1960 and 1994 was different. Content of exchangeable calcium in soils was increased from 1960 to 1994, but it was decreased at Zhurongfeng. Content of exchangeable magnesium in these soil profiles of the mountain was decreased, but the ratio of its decrease in different profile was different. The ratio was decreased with decreasing altitude.

Changes of soil physicochemical properties of soils in the mountain area might be closely related with acid rain because acid rain could accelerate cations released from soils. Between 1988

and 1989, pH of rain in Mt. Heng area was 3.83—5.02, the average was 4.47 in 1988 and 4.26 in 1989. The result showed that acid rain is heavier in the mountain area. Therefore, it caused accumulation of exchangeable acid in the soils, base saturation decrease and exchangeable calcium and magnesium transportation.

Acid fog might be one of important factors changing soil physicochemical properties because there are about 240 days of fog around Mt. Heng above 1000 m height each year. Fog at the mountain area was acid. pH of fog was 3.28—6.06 between 1988 and 1989, average was 4.22 in 1988 and 4.33 in 1989. And cloud water was also acid, pH was 4.08 in March 1988. Acid fog and cloud water were absorpted by surface earth, so that soil acidification could be accelerated. It might be, therefore, the reason that the degree of soil acidification above 1100m height at the mountain was higher than that blow 800m height. Acid rain and acid fog had exchangeable acid obviously accumulated in soils at Zhurongfeng and Shangfeng Temple since 1960, and had exchangeable calcium in soil at Zhurongfeng and exchangeable magnesium in soils at Zhurongfeng and Shangfeng Temple leached out.

5 Conclusion

Soil physicochemical properties have been changed since 1960 in Mt. Heng area. Soil pH has been decreased at Zhurongfeng and Shangfeng Temple, about 1100m height of the mountain. Exchangeable acid, exchangeable ionic hydrogen and aluminium have been obviously increased at these sites since 1960. The obvious change of soil physicochemical properties might be related with acid rain and acid fog, especially with acid fog at the site of Zhurongfeng and Shangfeng Temple.

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