

Distribution of CO₂ in Soil Air Affected by Vegetation in the Shilin National Park

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Abstract This paper studies the CO₂ distribution of soil atmosphere in the Shilin National Park. The measurement sites were chosen according to different topographic features and different vegetations. Seven measurement sites on 3 cross sections were chosen to pass through 3 karstic depressions or on the slopes of depressions. All measurement results show soils with pH values lower than 7.0 (from 5.4 to 6.6). There are 2 cases for the pH values of soil in different topographic features: the pH values of 2 profiles on the ridges or upper slopes of depressions are lower than those in the depressions; and the pH values of 2 soil profiles on the slopes of depressions are higher than those in the depressions. Most samples show relatively low humidity and CO₂ contents on the ridges or slopes of depressions compared with soil profiles in the depressions. High CO₂ contents occur at depths from -40 to -80 cm and high and dense grassland shows high CO₂ contents in the soil atmosphere. Grass roots may grow and are distributed mainly at depths from -20 to -40 cm; while tree roots predominantly as deep as -60 cm even -80 cm. The influences of pine, cypress and eucalyptus on soil CO₂ have been studied. Soil CO₂ influenced by pine and cypress are generally concentrated in an area surrounding the tree with a diameter of 1 m and the strongly influenced distance is 50 cm. Eucalyptus will strongly affect the CO₂ contents in an area with a diameter of 2 m, especially 1 m distant from the tree. The highest concentration of soil CO₂ at a depth of -30 and 100 cm from the tree reaches 92000 ppm.

Key words: Shilin National Park, karstic depression, pH value, concentration of soil CO₂

1 Introduction

The Shilin (stone forest) National Park is 80 km to the southeast of Kunming, the capital of Yunnan Province. The landscape of in the shilin area chiefly includes stone teeth and stone columns on karst hills and in depressions, predominantly developing in pure and block limestone and dolomitic limestone of the lower Permian Qixia and Maokou Formations with siliceous pebbles (Zhang, 1984; Chen, Song and Sweeting, 1985; Song, 1986; Song and Li, 1997). Vertical joint sets have well developed and cut the limestones into blocks. The lithology and structures create favourable conditions for the outstanding stone forest and stone teeth landscape development under soil covers. The intensity of dissolution of soil water against the limestone is dependent on the CO₂ in the soil. More attention has been paid to the factors controlling the soil CO₂ distribution (Lin, 1997; Liang and Song et al., 2000). This paper stresses the variation and distribution of soil CO₂ depending on vegetation.

2 Principles for Choosing Measurement Sites

In this study, CO₂ measuring sites were chosen following the principles below.

2.1 Landform

To study the relationship between the soil CO₂ distribution and topographical features, measuring sites were chosen at different positions with particular geomorphological features. Generally, the sites were designed on the ridge between karst depressions, on the slope and the bottom of depressions. Three long measuring cross profiles were set in this study (Table 1). Cross profile 1 is from the Looking Landscape Pavilion Hill through the prehistorical painting on the stone column in the depression to the slope of the Lizhiqing Hill. There are 3 measuring sites on the profile. Cross profile 2 with 2 measurements sites is from the Nationality Style House to the Buxiaoshan. Profile 3 runs from the Lions Pavilion Hill slope to the Yunlin depression with 2 measuring sites. The characteristics of measuring sites are described in Table 1.

2.2 Vegetation

In the Shilin National Park, the human grassland (lawn) with regularly spray irrigation and without spray, natural grassland, pine, cypress, eucalyptus are the predominant vegetation in the study area. The influence of the vegetation on the soil CO₂ distribution has been studied. The designed distances from the trees for the measurement are 20 cm, 50 cm, 100 cm and 200 cm, and even 300 cm if necessary. The depths for the measurement are -20 cm, -40 cm, -60 cm, -80 cm and -100 cm with some measuring points at a depth of 200 cm. Roots of trees and grass grow usually at clepUas of 10-80 cm (Table 1), mainly 60 cm.

2.3 Soil

Laterite and yellow brown soil commonly cover a broad area where carbonate, sand and shale and basalts occur. In some places, there appears weathered grey basalt soil and at a few sites the measurement profiles commonly contain surface soil with a high content of organic matter, red leached layers and yellow layers at the bottom. The measuring points should be set in different layers.

Table 1 Characteristics of measurement profiles and sampling sites in Shilin

Profiles	Location	Altitude (m)	Depth (cm)	Texture and description
LLP-LZQ-1	24°48'51.08"N 103°19'22.11"E	1736	0-13	A: black organic soil
			13-25	B: brown clay soil
			25-60	C: yellow soil limestone
LLP-LZQ-2	24°48'47.30"N 103°19'28.92"E	1700	0-12	A: black organic soil
			12-36	B1: black clayey organic soil
			36-80	B2: purple weak choidal soil
>80	C: yellow soil			
LLP-LZQ-3	24°48'35.17"N 103°19'24.57"E	1723	0-15	A: grey soil with gossamer and stony of limestone and basalt
			15-62	B: purple-red choidal soil with little stony
			62-100	C: more clay, stony matrix nodules
NSH-BXS-1	24°48'57.12"N 103°19'45.84"E	1724	0-23	A: grey-purple organic soil
			23-55	B: purple soil with ferro-matter and green mats
			>55	C: yellow soil break stone and fermentation
NSH-BXS-2	24°48'00.79"N 103°19'45.57"E	1750	0-24	A: grey soil with organic matters
			24-76	B: purple soil with ferruginous nodules and limestone
			76-100	C: purple clay
LPS-YLD-1	24°48'13.84"N 103°18'18.17"E	1737	0-12	A: grey organic soil, grassroot
			12-56	B1: grey-purple soil with roots
			56-100	B2: purple soil with ferruginous deposit and roots
LPS-YLD-2	24°48'12.55"N 103°18'15.26"E	1710	0-36	A: purple and grey organic soil
			36-66	B: purple soil, grassroot
			66-96	Buried A: grey peaty soil
>96	B: purple soil with tree roots			
>70	C: yellow soil flame tooth			

2.4 Depth for the measurement

For better understanding the spatial and temporal distributions of CO₂, a depth of 20 cm was set for the measurement of CO₂ content, pH, humidity in the soil.

3 Measurement Methods

3.1 Gastec method for measuring soil CO₂

In this study, CO₂ content was directly measured in soil holes with the Gastec pump and CO₂ tube detector made in Japan. There are three types of tubes for different ranges of CO₂. The Model 2 LL tube detector is for CO₂ with content from 300-5000 ppm in the air, Model 2L for 2500-30,000 ppm and Model 2H for 10,000-100,000 ppm.

The measurement was performed in the following procedure. A hole of a diameter of 20 mm is made by a steel stick. The depth of the hole is determined according to the requirement of CO₂ measurements. If CO₂ in the soil is to be measured at a depth interval of 20 cm, the hole depth should be little deeper. When the hole is ready, CO₂ is measured immediately with the CO₂ detector at a definite depth. After the detector is put to the definite depth, the hole mouth is sealed before pumping soil air.

The CO₂ content in the soil air will be read directly according to the colour changing from white to purple on the detector.

3.2 PH and humidity metre

The pH and humidity were directly measured with a meter of soil, Type-36 Tester, made in Japan. pH and humidity should be read when the stable status was attained.

4 Results

All the measurement results are given in Table 2.

4.1 Soil pH

The measurements of soil pH show that the soils are acid with pH values lower than 7, varying from 5.4 to 6.6. The pH values of the soil have revealed 2 cases in the Shilin area. The first involves soil profiles LLP-LZQ-1 and LLP-LZQ-2. The soil pH of LLP-LZQ-1 on the ridge of the depression(No.1) is lower than that in the depression at LLP-LZQ-2. For LLP-LZQ-1, the mean pH value is 5.55, ranging between 5.3 and 5.8, but the mean pH value for LLP-LZQ-2 is 5.86 in a range of 5.6-6.0. The same situation occurs in the section LPH-YLD. The mean pH value of LPH-YLD- 1 on the slope of the depression is 5.77, which is lower than the pH values of soil at LPH-YLD2 in the depression. The second case is the pH values on the slope are higher than that in the depressions. For example, the mean of soil pH of NSH-BXS-2 on the limestone slope is 6.37, while the pH of soil for NSH-BXS-1 in the depression is only 5.89.

In the Shilin area, the pH values near the ground surface are higher than those in

deep places at all soil measurement sites. For instance, pH 6.0 appears at depths of 0 - -5 cm, but it decreases down to 5.6 at a depth of -100 cm at LLP-LZQ-2. Another case can also be observed, that is, the highest pH values appear on the middle profile. For example, at LLP-LZQ-3, NSH-BXS-2 and LPH-YLD-1, high pH values appear at depths of -40 - -60 cm, which are higher than the values either above or below this depth range.

4.2 Humidity

The humidity in the soils at the 7 measurement sites shows great changes from 92% to 50%. From the macroscopic view, the humidity of soil on the slope or the ridge of the depression is lower than the values in depressions except LLP-LZQ-1. The average humidity of the soil at LLP-LZQ-1 is 71.8%, which is the highest in the study area. The soil humidity of LLP-LZQ-3, NSH-BXS-2 and LPH-YLD-1 on the upper slope of the depressions are 65%, 59.5% and 68.2%, respectively, lower than the mean humidity of the soil at LLP-LZQ-2, NSH-BXS-1 and LPH-YLD-2, which are 69.5%, 63.0% and 69.7% respectively.

In terms of vertical variation, most measurements show high humidity in the upper part of the profile and low values at the lower part. Especially, layer A (surface soil) has the highest humidity. Below the depth of -20 cm, the humidity is generally rather stable, being about 60%. High humidity values were measured at LPH-YLD-1 and LPH-YLD-2. As we dug the first soil pit, water flew out along tree roots as deep as -35 cm. We had to stop digging the measuring pit as water quickly seeped out and the water soon became 20 cm deep in 30 minutes.

4.3 Soil CO₂

CO₂ content in soil air was first measured just before the soil profile was made. The depth interval for the measurement was 20 cm, which was the same as in soil sampling and other parameters determination. When the soil CO₂ measurement hole is prepared, we had to stop the digging and determination if limestone blocks were encountered.

The soil CO₂ measurement results (Table 2) show that CO₂ contents at the measuring sites along the profile on the slope of the depressions are lower than those in the depressions. This is especially obvious in the case of cross profiles LLP-LZQ, NSH-BXS and LPH-YLD. The soil CO₂ content is below 2500 ppm in NSH-BXS-2, but in a range of 21,000-42,000 ppm for NSH-BXS-1. The CO₂ content of LPH-YLD-1 varies from 8000 to 17,000 ppm, while that in the depression is 11,000-40,000 ppm.

On the slope or ridge of the depressions, high concentration of CO₂ is shown from -20 to -40 cm, then decreases with depth.

Table 2 Soil pH, Humidity and CO₂ in Shilin National Park (August, 2000)

Profiles	Depth (cm)	pH	Hum. (%)	CO ₂ (ppm)	Remarks
LLP-LZQ-1	0—5	5.4	90		With Small stone teeth and limestone blocks at -65 cm
	-10	5.4	92		
	-20	5.8		24800	
	-30	5.3	57		
	-40	5.6	66	26200	
	-60	5.8	54	8000	
	-90			11000	
	-100		8500		
LLP-LZQ-2	0—5	6.0	88		Big roots down to -36 cm, but small roots occuring at -75 cm.
	-20	6.0	80	20000	
	-40	5.9	62	27000	
	-60	6.0	60	22000	
	-80	5.7	66	9000	
	-100	5.6	60	7000	
LLP-LZQ-3	-5	5.8	82		Rare grassland
	-20	5.9	62	2700	
	-40	6.0	68	7500	
	-60	6.3	58	7500	
	-80	5.7	62	2600	
	-100	5.8	58	2400	
NSH-BXS-1	-20	6.4	56	21000	Dense grassland about 50-60 cm high.
	-40	5.6	68	42000	
	-60	5.4	68	30000	
	-80	5.8	60	26000	
	-100			23000	
	-120			23000	
NSH-BXS-2	0—5	6.5	76		Sparse grassland
	-20	6.0	56	2500	
	-40	6.6	50	2450	
	-60	6.5	62	2050	
	-80	6.3	55		
	-100	6.3	58		
LPH-YLD-1	-5	6.0	71		Dense grassland
	-20	5.1	66	8000	
	-40	6.2	64	14500	
	-60	6.2	76	10000	
	-80	5.5	72	17000	
	-100	5.6	60		
LPH-YLD-2	-5	6.1	80		Dense grassland and pine tree and eucalyptus nearby
	-20	5.6	72	17000	
	-40	5.6	70	11000	
	-60	6.3	64	40000	
	-80	5.9	62	33000	
	-100	5.9	70	21000	

While measuring the CO₂ contents in soil profiles, this study also measured CO₂ of soil affected by pine, cypress and eucalyptus. The results are illustrated in Figs. 1, 2 and 3.

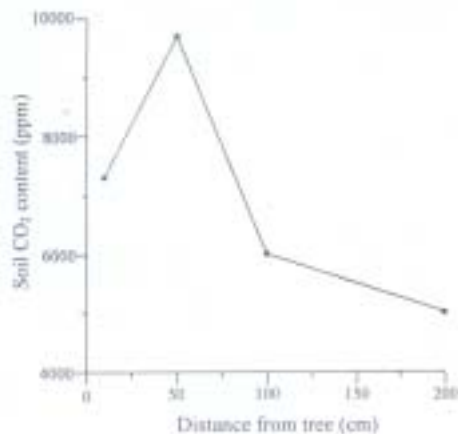


Fig. 1. Soil CO₂ influenced by cypress.

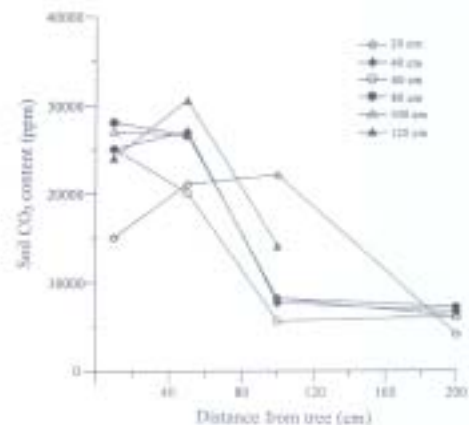


Fig. 2. Soil CO₂ influenced by pine.

Figure 1 shows soil CO₂ contents in soil air measured at 10 cm, 20 cm, 50 cm, 100 cm and 200 cm away from a cypress, about 7 m high and 87 cm in perimeter. A peak CO₂ content, 9700 ppm, appears at a point 50 cm from the cypress. The soil CO₂ increases from 7300 ppm at the point 10 cm from the tree to 9700 ppm at the point 50 cm from the tree, then decreases to 5000 ppm 200 cm from the cypress.

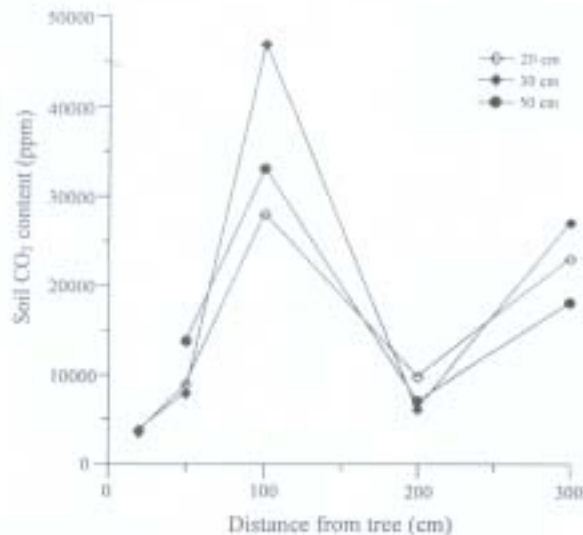


Fig. 3. Soil CO₂ influenced by eucalyptus.

Figure 2 presents different soil CO₂ distributions. Soil CO₂ at a depth of -20 cm below the surface increases from 15,000 ppm up to 21,000 ppm when the measuring point is 10 cm and 50 cm away from a pine tree respectively. The value will further increase to 22,000 ppm at the measuring site 100 cm from the tree and finally to 4000 ppm as the point is 200 m apart from the tree.

Distributions of soil CO₂ at depths of -40 cm and -120 cm are very similar to the fluctuation of soil CO₂ at a depth of -20 cm, while the soil CO₂ at depths of -60 cm, -80 cm and -100 cm exhibits a decrease pattern, that is, relatively high values were observed near a tree and decrease as moving away from the tree. The contents of soil CO₂ at depths of -60 cm and -100 cm at the points that are 10 cm away from the pine are 25,000 ppm and 27,500 ppm respectively, and 20,000 ppm and 26,000 ppm at depths of -60 cm and -100 cm at the points which are 50 cm from the tree. Then, the values greatly decrease to 7500 ppm and 8000 ppm at the points which are 100 cm from the pine. At the points that are 200 cm from the pine, the soil CO₂ contents are 6000 ppm for both depths.

Figure 2 also demonstrates that roots of a pine grow mainly in an area with a radius of about 0.5 m. In the area, the tree roots strongly effect the distribution of soil CO₂. The influence of tree roots almost disappears when the area is more than 1.5 m far from the pine. If the tree is bigger than the one in this study, the influence distance will be bigger.

The influence of eucalyptus about 10 m high and 160 cm in perimeter on the soil CO₂ was systematically studied. In the study area around a eucalyptus tree, sparse grass covers 10% of the total area. Figure 3 shows that 3 soil CO₂ distribution curves

are very similar. High soil CO₂ contents occur at the points that are 100 cm from the tree, while low CO₂ contents are observed at the site 200 cm from the tree and the values rise again at the site 300 cm from the tree. They might be effected by another eucalyptus tree. It is obvious eucalyptus strongly effect the soil CO₂ in an area that is 100 cm from the tree.

5 Conclusion

Soil CO₂ concentration is strongly affected by vegetation. The vegetation roots are grown at depths of- 20 cm - -80 cm, especially about -40cm - -60 cm. Relatively high concentration of soil CO₂ appears at depths form -40 to -80 cm.

Influences of such tress as cypress, pine and eucalyptus on soil CO₂ distribution have been studied. Cypress intensively effects soil CO₂ mainly in an area of about t m, especially 50 cm, in diameter surrounding the tree. The influence scope of pine is larger than that of cypress, and generally may reach an area with a radius of 1 m surrounding the tree and down to about 1.2 m in depth. Eucalyptus may affect soil CO₂ in areas about 2 m away from the tree.

The influence depth and scope of trees are dependent on the scale of trees and root systems in soils. The influence of smaller and younger trees on soil CO₂ is certainly weaker than that of big trees.

Soil properties also affect soil CO₂ distribution. All measurement results show that the soils have pH values lower than 7.0, from 5.4 to 6.6. There are 2 cases for the pH values of soil in different topographic features: the pH values of 2 profiles on the ridges or upper slopes of depressions are lower than those in the depressions; and the pH values of 2 soil profiles on the slopes of depressions are higher than that in the depressions. Most samples show relatively low humidity and CO₂ contents

on the ridges or slopes of depressions compared with the soil profiles in the depressions. High CO₂ contents are detected at depths from -40 cm to 80 cm.

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