Postprint: Above-Ground Phytolith Carbon Sequestration Potential of *Phyllostachys viridis* and *Dendrocalamus latiflorus*

Authors: Yin Shuai, Jiang Peikun, Meng Cifu, Wu Jiasen, Zhang Jinlin

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Abstract

Phytolith-occluded organic carbon (PhytOC), which can remain stable in soil for thousands or even tens of thousands of years, is one of the important mechanisms for long-term carbon sequestration in terrestrial plant ecosystems. Two important clumping bamboo species, Dendrocalamopsis oldhami (Munro) Keng f. and Dendrocalamus latiflorus Munro, from Nanjing, Fujian Province, were selected as research subjects. Samples of bamboo leaves, branches, and culms were collected, phytoliths were extracted using microwave digestion, and the carbon content in phytoliths was determined using alkaline dissolution to compare the phytolith carbon sequestration potential and sequestration rate of the two clumping bamboo species. The results showed that the Si content in different aboveground organs of D. oldhami and D. latiflorus forests ranged from 4.95-37.53 g/kg and 2.01-34.05 g/kg, respectively, while phytolith content ranged from 3.35-100.80 g/kg and 1.57-84.06 g/kg, respectively. The order of content in aboveground organs for both species was leaf > branch > culm. The PhytOC content in dry matter of different aboveground organs ranged from 0.51-2.85 g/kg for D. oldhami and 0.17-2.22 g/kg for D. latiflorus. The aboveground PhytOC storage in D. oldhami and D. latiflorus forests ranged from 5.1-13.9 kg/hm^2 and 1.2-6.3 kg/hm^2, respectively. The highest PhytOC storage in different organs of aboveground plants was found in branches for D. oldhami and in leaves for D. latiflorus. The total aboveground PhytOC storage was 24.3 kg/hm^2 for D. oldhami and 11.1 kg/hm^2 for D. latiflorus. The aboveground PhytOC sequestration rates for D. oldhami and D. latiflorus forests were 0.051-0.131 t-e-CO hm ^{2} a ^{1} and 0.0099-0.0139 t-e-CO hm ^{2} a ^{1}, respectively. Based on the maximum PhytOC sequestration rates of D. oldhami and D. latiflorus, the aboveground parts of D. oldhami and D. latiflorus forests in China could sequester 1965.29 t CO and 1520.11 t CO annually, respectively.

Full Text

Preamble

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PhytOC Sequestration Potential in Above-Ground Parts of *Dendrocalamopsis oldhamii* and *Dendrocalamus latiflorus*

YIN Shuai[1], JIANG Peikun[1]*, MENG Cifu[1,2], WU Jiasen[1,2], ZHANG Jinlin[1]
[1]School of Environmental and Resource Sciences, Zhejiang Provincial Key Laboratory of Carbon Cycling in Forest Ecosystems and Carbon Sequestration, Zhejiang Agriculture and Forestry University, Lin’ an 311300, China
[2]Zhejiang Agriculture and Forestry University, Lin’ an 311300, China

Abstract

Phytolith-occluded carbon (PhytOC), which can remain stabilized in soils for thousands to tens of thousands of years, represents an important mechanism for long-term carbon sequestration in terrestrial plant ecosystems. This study selected two typical sympodial bamboo species [*Dendrocalamopsis oldhamii* (Munro) Keng f. (DOK) and *Dendrocalamus latiflorus* Munro (DLM)] from the subtropical region of China as research subjects. Samples of leaves, branches, and culms were collected in Nanjing County, Fujian Province. Phytoliths were extracted using microwave digestion, and PhytOC content was determined using the alkaline dissolution method to compare the PhytOC sequestration rates and stocks between these two sympodial bamboo species.

The results showed that silicon (Si) content in above-ground parts of DOK and DLM ranged from 4.95-37.53 g/kg and 2.01-34.05 g/kg, respectively, while phytolith content ranged from 3.35-100.80 g/kg and 1.57-84.06 g/kg, respectively. In both species, Si and phytolith contents decreased in the order: leaves > branches > culms. PhytOC content in above-ground parts of DOK and DLM ranged from 0.51-2.85 g/kg and 0.17-2.22 g/kg, respectively, while PhytOC stocks ranged from 5.1-13.9 kg/hm^2 and 1.2-6.3 kg/hm^2, respectively. The highest PhytOC stocks in different above-ground organs were observed in leaves for DOK and in branches for DLM. Total PhytOC stocks in above-ground parts of DOK and DLM were 24.3 kg/hm^2 and 11.1 kg/hm^2, respectively.

The PhytOC sequestration rates of above-ground parts for DOK and DLM were 0.051-0.131 t-e-CO /hm^2/a and 0.0099-0.0139 t-e-CO /hm^2/a, respectively. Based on these rates, China’ s DOK and DLM stands are estimated to sequester 1965.29 t CO /a and 1520.11 t CO /a, respectively.

Keywords: *Dendrocalamopsis oldhamii* (Munro) Keng f.; *Dendrocalamus latiflorus* Munro; phytolith; PhytOC; PhytOC sequestration rate

Introduction

Global climate change caused by the greenhouse effect has attracted increasing attention, with global warming and frequent extreme weather events raising widespread societal concern [1]. As a major greenhouse gas, CO concentrations continue rising. Forests, the dominant component of terrestrial ecosystems, play a crucial role in the global carbon cycle, accounting for over 46% of terrestrial carbon storage and mediating more than 60% of CO exchange between terrestrial vegetation and the atmosphere [2-3].

Phytoliths, also known as plant opals, form when plants absorb soluble monosilicic acid (H SiO) from soil solution through their roots, which then precipitates as amorphous silica (SiO ·nH O) in cell walls and intercellular spaces through transpiration [4-6]. During silicification, small amounts of organic carbon become encapsulated within phytoliths, termed phytolith-occluded carbon (PhytOC) [7-9]. Protected by the durable phytolith 外壳, PhytOC exhibits exceptional resistance to high temperature, oxidation, and decomposition, persisting in soils and sediments for millennia without major geological disturbance [7]. As an important component of soil carbon pools, PhytOC contributes significantly to enhancing soil carbon sinks and maintaining global carbon balance, attracting widespread attention from environmental scientists [10-11].

Previous research has investigated PhytOC sequestration potential across various forest types, crops, bamboo species, wetlands, and grasslands [8,12-13,21-28]. Bamboo, a typical silicon-accumulating Gramineae plant, covers 2.2×10 hm^2 globally, with China accounting for one-third of this area (7.2×10 hm^2) [29-32]. Bamboo forests play important roles in forest ecosystem carbon sequestration [30-31]. Sympodial bamboos, comprising 80% of world bamboo species, are widely distributed in Southeast Asia, Central/South Africa, and Pacific islands. In China, sympodial bamboos cover 1.5×10 hm^2, with *D. oldhamii* and *D. latiflorus* being two economically and ecologically important species. *D. oldhamii* is mainly cultivated in Zhejiang Province (1.09×10 hm^2), while *D. latiflorus* is primarily grown in Fujian Province (1.5×10 hm^2), representing China’ s second most extensive sympodial bamboo [33].

Previous sympodial bamboo research has focused on timber utilization, shoot production, and silvicultural techniques [34], with ecological studies emphasizing community structure, nutrient cycling, and water conservation [35-36]. While studies have examined PhytOC sequestration in monopodial and mixed bamboos [7,11,14-20], research on sympodial bamboo PhytOC potential remains limited. This study investigates PhytOC distribution and sequestration potential in *D. oldhamii* and *D. latiflorus* to provide baseline data for accurately estimating PhytOC storage in China’ s bamboo forest ecosystems.

1. Study Area Overview

The study area is located in Nanjing County, Zhangzhou City, Fujian Province (117°42 E, 24°42 N), characterized by a typical south subtropical monsoon climate. The region has an average annual temperature of 20.4–22.3°C, extreme minimum temperature of -2.9°C, extreme maximum temperature of 40.3°C, average annual precipitation of 1798 mm (ranging from 1235–2481 mm), average annual sunshine of 1946 h, and frost-free period of 312 days. The terrain consists primarily of low hills with significant elevation differences, ranging from 5.6 m to 1390 m. Soils are red soils developed from granite. Basic soil chemical properties are shown in Table 1 .

Nanjing County is a major production area for *D. latiflorus*, with nearly 750 kg/hm^2 planting area and high management intensity. *D. oldhamii* planting area reaches 2×10 hm^2, with over half distributed in Chuanchang Town. Bamboo plantations are typically converted from wastelands or rice paddies, with understory vegetation dominated by *Commelina communis*, *Galinsoga parviflora*, and *Urena lobata*. Management practices include annual spring fertilization (primarily compound fertilizer, sometimes fermented manure) with simultaneous weeding and soil loosening, with average fertilizer application of 0.7-0.8 t/hm^2.

2. Samples and Methods

Based on local forestry records, farmer interviews, and field surveys, sampling was conducted across 12 townships in Nanjing County. Standard 20 m × 20 m plots were established in stands with similar site characteristics, stand structure, and growth conditions at elevations of 40–200 m and slopes of 10°–40°. For *D. oldhamii*, 5 standard plots were established; for *D. latiflorus*, 6 standard plots were established. All bamboo plants in each plot were measured for diameter at breast height (DBH). Representative sample plants matching the average DBH were selected, and leaves, branches, and culms were collected (500–1000 g per sample) for laboratory analysis.

To calculate PhytOC stocks, biomass of different organs must be determined. Based on biomass models for *D. oldhamii* and *D. latiflorus* in Fujian [35-36], the DBH of sample plants was measured to calculate leaf, branch, and culm biomass using established allometric equations. Total biomass was obtained by summing organ biomass.

3. Experimental Methods

After collection, plant samples were washed with deionized water, oven-dried at 75°C to constant weight, and ground using a high-speed mill. Ground samples were divided into two portions: one for total silicon analysis via lithium metaborate fusion-molybdenum blue colorimetry [37], and another for phytolith extraction via microwave digestion [38] and PhytOC determination via improved alkaline dissolution spectrophotometry [37]. Plant standard samples (GBW07602) were included for quality control, with each sample analyzed in triplicate.

Soil samples (0–20 cm) were collected from each plot using the quartering method. After removing roots and gravel, samples were analyzed for basic chemical properties: pH by potentiometry, organic matter by potassium dichromate external heating method, available phosphorus by molybdenum blue colorimetry, available potassium by ammonium acetate extraction-flame photometry, and hydrolyzable nitrogen by alkali diffusion method [38].

4. Parameter Calculation and Data Analysis

Phytolith content (g/kg) = Phytolith mass (g) / Sample dry mass (kg)
PhytOC content (g/kg) = PhytOC mass (g) / Sample dry mass (kg)
PhytOC stock (kg/hm^2) = PhytOC content (g/kg) × Biomass (kg/hm^2) × 10 ^{3}

Biomass was calculated as: Standard plant biomass × Clump density × Plants per clump. PhytOC sequestration rates for each organ were calculated as: Biomass × PhytOC content. Total stand sequestration rate was the sum of rates for leaves, branches, and culms. Data were processed using Microsoft Excel 2003 and DPS 7.5 software, with t-tests used to determine significant differences between samples (= 0.05).

2. Results and Analysis

2.1 Si and Phytolith Content in Above-Ground Organs

Si content in above-ground organs of *D. oldhamii* and *D. latiflorus* ranged from 4.95-37.53 g/kg and 2.01-34.05 g/kg, respectively, with *D. oldhamii* showing higher values in all organs, particularly in branches. Phytolith content ranged from 3.35-100.80 g/kg in *D. oldhamii* and 1.57-84.06 g/kg in *D. latiflorus*, following the same pattern of leaves > branches > culms. T-tests revealed that while leaf Si and phytolith contents did not differ significantly between species, *D. oldhamii* had significantly higher branch and culm Si and phytolith contents than *D. latiflorus* [Figure 1: see original paper].

2.2 PhytOC Content and PhytOC/Dry Biomass Ratio in Above-Ground Organs

PhytOC content in above-ground organs ranged from 0.51-2.85 g/kg in *D. oldhamii* and 0.17-2.22 g/kg in *D. latiflorus*, with culms showing significantly higher values than leaves and branches in both species. The PhytOC/dry biomass ratio ranged from 19.46-91.14 g/kg in *D. oldhamii* and 35.50-142.12 g/kg in *D. latiflorus*, with highest ratios in branches for *D. oldhamii* and leaves for *D. latiflorus*, and lowest ratios in culms for both species. Significant differences in PhytOC content and PhytOC/dry biomass ratio were observed between organs within each species [Figure 2: see original paper].

2.3 Biomass and PhytOC Stocks in Above-Ground Organs

Above-ground biomass of individual organs ranged from 3.22-10.13 t/hm^2 for *D. oldhamii* and 2.82-7.18 t/hm^2 for *D. latiflorus*, with total stand biomass of 18.24 t/hm² and 14.48 t/hm², respectively. Due to higher stand density, *D. oldhamii* had greater leaf, culm, and total biomass per unit area. PhytOC stocks in individual organs ranged from 5.1-13.9 kg/hm² for *D. oldhamii* and 1.2-6.3 kg/hm² for *D. latiflorus*, with highest stocks in culms for both species. Total above-ground PhytOC stocks were 24.3 kg/hm² for *D. oldhamii* and 11.11 kg/hm² for *D. latiflorus*, with the former being 2.2 times higher [Figure 3: see original paper].

2.4 Correlation Analysis

Correlation analysis revealed extremely significant positive relationships between Si content and phytolith content in leaves of both species ($r = 0.65$ for *D. oldhamii*, $r = 0.76$ for *D. latiflorus*, $p < 0.01$), with *D. latiflorus* showing a stronger correlation. No significant correlation was found between phytolith content and PhytOC/dry biomass ratio. However, extremely significant correlations existed between PhytOC content and PhytOC/dry biomass ratio ($r = 0.79$, $p < 0.01$ for *D. oldhamii*; $r = 0.25$, $p < 0.01$ for *D. latiflorus*), with *D. oldhamii* showing a significantly higher correlation coefficient [Figure 4: see original paper].

3. Discussion

3.1 Phytolith and PhytOC Content Variations

Si content is a key indicator of phytolith abundance, with significant positive correlations reported in various plants [11]. In this study, both bamboo species showed extremely significant positive correlations between leaf Si and phytolith content, consistent with previous bamboo research [7]. However, no significant correlation was found between phytolith content and PhytOC/dry biomass ratio, while PhytOC content and PhytOC/dry biomass ratio were extremely significantly correlated—aligning with studies on rice, wheat, and subtropical tree species [13,22] but differing from wetland plant research [26-27]. These discrepancies likely reflect species-specific differences and environmental influences (temperature, pH, organic matter) on phytolith formation and carbon occlusion capacity [7,13,26].

The distribution pattern of Si and phytolith content (leaves > branches > culms) matches trends reported in other bamboo species [17,18] and wetland plants [27], reflecting differences in transpiration rates and organ-specific tissue characteristics. Leaves, as the primary transpiration organs, showed similar Si and phytolith contents between species, while branches and culms exhibited greater variation.

3.2 Organ-Specific PhytOC Storage

Contrary to previous assumptions that leaves dominate PhytOC storage, this study found significantly higher PhytOC content in culms than in leaves and branches for both species. This pattern aligns with research on *Pleioblastus amarus* [17] but differs from some other bamboo studies [18]. The variation suggests that phytolith carbon content depends not only on phytolith abundance but also on phytolith morphology, surface area, and inherent carbon occlusion efficiency [7,13,26,40].

PhytOC stocks were highest in culms due to their substantial biomass contribution, despite lower phytolith concentrations. This finding emphasizes the importance of including culms in bamboo PhytOC assessments. Total above-ground PhytOC stocks in *D. oldhamii* (24.3 kg/hm^2) were 2.2 times higher than in *D. latiflorus* (11.1 kg/hm^2), reflecting both higher biomass and phytolith content.

3.3 Comparative PhytOC Sequestration Potential

Bamboo subfamily (Bambusoideae) and rice subfamily (Ehrhartoideae) species demonstrate strong PhytOC sequestration capacity [7,12-16,21-22]. China’ s DOK and DLM stands are estimated to sequester 1965.29 t CO /a and 1520.11 t CO /a, respectively, based on maximum sequestration rates of 0.131 t-e-CO /hm^2/a and 0.0139 t-e-CO /hm^2/a. These rates are comparable to rice (0.1229-0.3614 t-e-CO /hm^2/a) and wheat (0.0060-0.2460 t-e-CO /hm^2/a), higher than grassland (0.0016-0.0018 t-e-CO /hm^2/a) and some subtropical forests (0.0003-0.0193 t-e-CO /hm^2/a), but lower than sugarcane (0.0081-0.7090 t-e-CO /hm^2/a) .

Compared to China’ s most extensive bamboo species, *Phyllostachys edulis* (0.0367-0.0506 t-e-CO /hm^2/a), *D. oldhamii* showed higher sequestration rates, while *D. latiflorus* rates were lower. The substantial difference between the two sympodial species highlights how species biology, stand density, and management practices influence PhytOC sequestration.

4. Conclusion

PhytOC sequestration potential is largely determined by sequestration rates. This study demonstrates that: 1. *D. oldhamii* above-ground parts have PhytOC sequestration rates of 0.051-0.131 t-e-CO /hm^2/a, with maximum potential of 1965.29 t CO /a. 2. *D. latiflorus* above-ground parts have PhytOC sequestration rates of 0.0099-0.0139 t-e-CO /hm^2/a, with maximum potential of 1520.11 t CO /a. 3. *D. oldhamii* shows significantly higher PhytOC sequestration rates and stocks than *D. latiflorus*.

Given *D. oldhamii*’ s higher economic value and superior PhytOC sequestration capacity, expanding its cultivation could maximize carbon sequestration benefits. Future research should investigate silvicultural practices, particularly silicon and phosphorus fertilization strategies, to enhance PhytOC accumulation through silicon regulation mechanisms.

References

[1] Alkemade R, Bakkenes M, Eickhout B. Towards a general relationship between climate change and biodiversity: an example for plant species in Europe. Regional Environmental Change, 2011, 11(S1): 143-150.

[2] Research progress on carbon storage estimation of forest vegetation and soils in China. 2016, 35(8): 1741-1744.

[3] Pan Y D, Birdsey R A, Fang J Y, Houghton R, Kauppi P E, Kurz W A, Phillips O L, Shvidenko A, Lewis S L, Canadell J G, Ciais P, Jackson R B, Pacala S W, McGuire A D, Piao S L, Rautiainen A, Sitch S, Hayes D. A large and persistent carbon sink in the world' s forests. Science, 2011, 333(6045): 988-993.

[4] Parr J F, Sullivan L A. Soil carbon sequestration in phytoliths. Soil Biology and Biochemistry, 2005, 37(1): 117-124.

[5] Research and Application of Plant Phytoliths. Ocean Press, 1993: 267-267.

[6] Piperno D R. Quaternary environmental history and agricultural impact on vegetation in central America. Annals of the Missouri Botanical Garden, 2006, 93(2): 274-296.

[7] Parr J F, Sullivan L A, Chen B H, Ye G F, Zheng W P. Carbon biosequestration within the phytoliths of economic bamboo species. Global Change Biology, 2010, 16(10): 2661-2667.

[8] Parr J F, Sullivan L A. Phytolith occluded carbon and silica variability in wheat cultivars. Plant and Soil, 2011, 342(1/2): 165-171.

[9] Zuo X X, Lu H Y, Gu Z Y. Distribution of soil phytolith-occluded carbon in the Chinese Loess Plateau and its implications for silica-carbon cycles. Plant and Soil, 2014, 374(1/2): 223-232.

[10] Phytolith-occluded organic carbon in plant ecosystems and its important role in global soil carbon sinks. 2013, 30(6): 921-929.

[11] Song Z L, Liu H Y, Li B L, Li X M. The production of phytolith-occluded carbon in China' s forests: implication to biochemical carbon sequestration. Global Change Biology, 2013, 19(9): 2907-2915.

[12] Phytolith carbon in subtropical forest soils of southern Zhejiang. Journal of Natural Resources, 2015, 30(1): 133-140.

[13] Estimation of phytolith carbon sequestration potential of important tree species in subtropical China. Journal of Natural Resources, 2015, 52(6): 1365-1373.

[14] Huang Z T, Li Y F, Jiang P K, Chang S X, Song Z L, Liu J, Zhou G M. Long-term intensive management increased carbon occluded in phytolith (PhytOC) in bamboo forest soils. Scientific Reports, 2014, 4: 3602.

[15] Huang Z T, Jiang P K, Chang S X, Zhang Y, Ying Y Q. Production of carbon occluded in phytolith is season-dependent in a bamboo forest in subtropical China. PLoS One, 2014, 9(9): e106843.

[16] Li B L, Song Z L, Wang H L, Li Z M, Jiang P K, Zhou G M. Lithological control on phytolith carbon sequestration in moso bamboo forests. Scientific Reports, 2014, 4: 5262.

[17] Phytolith carbon and silicon in *Pleioblastus amarus* stands. Journal of Natural Resources, 2016, 31(2): 299-309.

[18] Yang J, Wu J S, Jiang P K, Xu Q F, Zhao P P, He S Q. A study of phytolith-occluded carbon stock in monopodial bamboo in China. Scientific Reports, 2015, 5: 13292.

[19] Study on phytolith carbon sequestration in *Phyllostachys praecox* ecosystem [D]. Zhejiang Agriculture and Forestry University, 2014.

[20] Distribution and influencing factors of phytoliths in *Phyllostachys edulis* forest ecosystem. Journal of Zhejiang Agriculture and Forestry University, 2014, 31(4): 547-553.

[21] Li Z M, Song Z L, Parr J F, Wang H L. Occluded C in rice phytoliths: implications to biochemical carbon sequestration. Plant and Soil, 2013, 370(1/2): 615-623.

[22] Parr J, Sullivan L, Quirk R. Sugarcane phytoliths: encapsulation and sequestration of a long-lived carbon fraction. Sugar Tech, 2009, 11(1): 17-21.

[23] Estimation of phytolith carbon sequestration potential of dryland crops foxtail millet and broomcorn millet in China. 2011, 56(34): 2881-2887.

[24] Song Z L, Wang H L, Strong P J, Li Z M, Jiang P K. Plant impact on the coupled terrestrial biogeochemical cycles of silicon and carbon: implications for biochemical carbon sequestration. Earth-Science Reviews, 2012, 115(4): 319-331.

[25] Song Z L, Parr J F, Guo F S. Potential of global cropland phytolith carbon sink from optimization of cropping system and fertilization. PLoS One, 2013, 8(9): e73747.

[26] Li Z L, Song Z L, Jiang P K. Biogeochemical sequestration of carbon within phytoliths of wetland plants: a case study of Xixi wetland, China. Chinese Science Bulletin, 2013, 58(20): 2480-2487.

[27] Li Z L, Song Z L, Li B L. The production and accumulation of phytolith-occluded carbon in Baiyangdian reed wetland of China. Applied Geochemistry, 2013, 37: 117-124.

[28] Song Z L, Liu H Y, Si Y, Yin Y. The production of phytoliths in China' s grasslands: implications to the biochemical sequestration of atmospheric CO . Global Change Biology, 2012, 18(12): 3647-3653.

[29] Carbon characteristics of bamboo forests in China. World Bamboo and Rattan, 2005, 3(3): 25-28.

[30] Zhou G M, Zhuang S Y, Jiang P K, Xu Q F, Qin H, Wong M, Cao Z H. Soil organic carbon accumulation in intensively managed *Phyllostachys praecox* stands. The Botanical Review, 2011, 77(3): 296-303.

[31] Jiang P K, Meng C F, Zhou G M, Xu Q F. Comparative study of carbon storage in different forest stands in subtropical China. The Botanical Review, 2011, 77(3): 242-251.

[32] Research progress on growth characteristics and management techniques of sympodial bamboos. Journal of Bamboo Research, 2004, 23(1): 1-5.

[33] Domestic sympodial bamboo resources and utilization. Journal of Bamboo Research, 1998, 18(3): 260-262.

[34] Nanjing County Local Chronicles Compilation Committee. Nanjing County Local Chronicles. Fangzhi Press, 2016.

[35] Study on biomass models of *Dendrocalamopsis oldhamii*. Journal of Bamboo Research, 1997, 16(4): 43-46.

[36] Study on individual plant biomass models of *Dendrocalamus latiflorus*. Journal of Fujian Forestry College, 2000.

[37] Soil Agricultural Chemical Analysis Methods. China Agricultural Science and Technology Press, 2000.

[38] Alkaline dissolution spectrophotometric method for phytolith carbon determination. 2014, 42(9): 1389-1390.

[39] He S Q, Song Z L, Liu H Y, Li B L, Wang Y J. Evolution of phytolith carbon in subtropical typical forest-soil systems. Chinese Journal of Applied Ecology, 2016, 27(3): 697-704.

[40] Bartoli F. Crystallochemistry and surface properties of biogenic opal. Journal of Soil Science, 1985, 36(3): 335-350.

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