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C-N Isotope Coupling along the vertical profiles under different land use in a typical karst area, Guizhou, southwest China

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Abstract

The soil stable carbon and nitrogen isotopic compositions characterize its fate and identify the different land use. In this study, carbon concentration and isotope component, nitrogen concentration and isotope component, and C/N ratios in soils collected from Puding, southwest of China were determined. The carbon and nitrogen content data range from 7.92% to o.48%, and 0.77% to 0.05%, respectively. Soil δ^{13}C ranged from -25.49‰ to -17‰, soil δ^{15}N varied from 1.11‰ to 9.46‰. The concentrations of SOC and SON decrease with depth along the vertical profiles. In addition, combined the SOC and δ^{13}C or SON and δ^{15}N could obtained the possibility of distinguish the replaced of C3 and C4 plants. However the pattern of distribution in soil organic δ^{13}C is different from that in soil organic δ^{15}N at the subsoil (deeper than 30cm). With correlation analyses with C/N ratios and δ^{13}C, it reveals that subsoil carbon microbial derived carbon due to root activity.

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*Keywords:*soil organic carbon; soil organic nitrogen;carbon isotopic composition; nitrogen isotopic composition;landuse

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1. Introduction

The Earth’s critical zone is a dynamic and generally self-sustaining system [1] featuring complex interactions between different compartments, based on physical, chemical and biological process [2]. Multiple studies have

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focused on soil organic matter transfer process and persistence. In order to reveal the influence of environmental factors and anthropogenic pressure on the soil organic carbon pool, the stable isotope natural abundance of C and N can be used.

Regional rock desertification is a serious ecological problem in the subtropical karst regions of southwest China, as it ultimately lead to the progressive impoverishment of local residents [3]. However, little research has been carried out on changes to the stable carbon and nitrogen composition of modern soils at different depths, and under different types of land in karst areas [4]. In order to investigate the pattern of soil organic matter persistence in karst ecosystems of SW China, we report C and N isotope analyses on soil organic matter over several depth-profiles.

2. Samples and methodology

The study area is located within Chenqi, Puding, west of China, Guizhou Province (Fig.1). Puding is underlain by Permian and Triassic carbonate rocks at 1042-1846m above mean sea level. These basin rocks are usually exposed on the surface, and the soils are thin and discontinuous, resulting in highly fragile environments. The average rainfall of Puding is 1400 mm/year, the daily mean humidity is 79%, and the average annual temperature is 15.1℃.

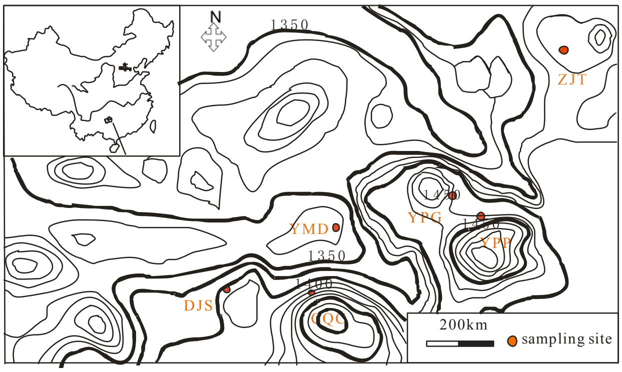


Fig.1 Map of Puding showing the locations of sampling site

105 soils samples were collected at 5 cm intervals in 2012 from six soil profiles with six different land use, including forested (ZJT, YPP, DJS), shrubbery (YPG), grassland (CQC) and cropland (YMD). The unified tendency of natural profiles (except agriculture site) is that the surface soil layer exhibits a dark grey, coarse material, and is abundant in fine roots, while the soil color changes downward from black to yellow brown. However, the thickness of different layers is variable.

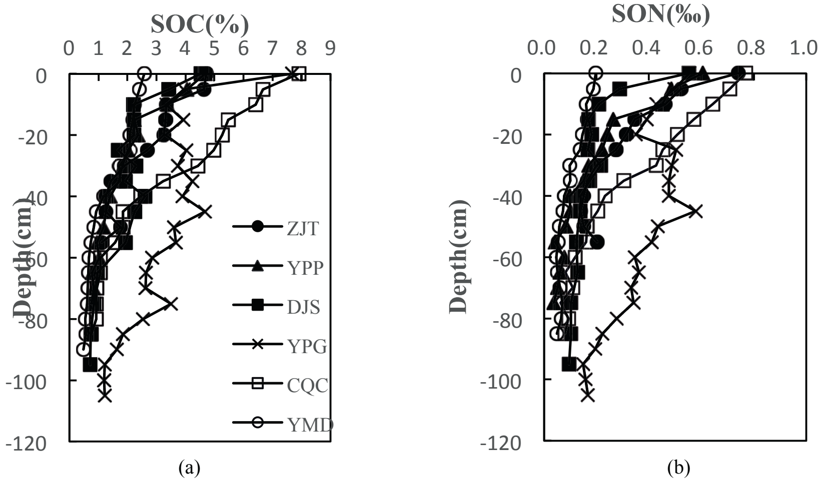
Soil samples were air dried and then dried at 40℃ for 48 h to a constant weigh, and roots and plant debris were removed. Soil samples were treated with 0.5 mol/L HCL at 25℃ for 24 h to remove carbonates, washed to neutrality with distilled water, centrifuged and dried at 60℃, then pulverized and saved for carbon, nitrogen and isotopic analyses. Organic carbon and nitrogen content was analyzed via combustion in an elemental analyzer (PE2400, Perkon Elmer, USA). The precision of the analysis was ≤0.1%. Carbon and nitrogen isotopic compositions were measured using a Finnigan MAT 252 mass spectrometer, and were reported in the traditional "δ" denotation relative to Pee Dee Belemnite (PDB) and atmospheric nitrogen, respectively.

We tested for significant differences in soil $\delta^{13}C$ and $\delta^{15}N$ for the different land use site between surface soil (upper 30 cm) and subsoil (lower 30 cm) using statistical analysis.(Sigmastat 16.0, SPSS Inc., Chicago).

3. Results

The concentrations of soil organic carbon and nitrogen of samples collected from the karst catchment are showed in Fig.2. The concentration of SOM generally decreases with depth [5]. The carbon and nitrogen content data range from 7.92% to 0.48%, and from 0.77% to 0.05%, respectively. This trend is a consistent feature across the sampled soil profiles, independent of soil physical and chemical properties and land use.

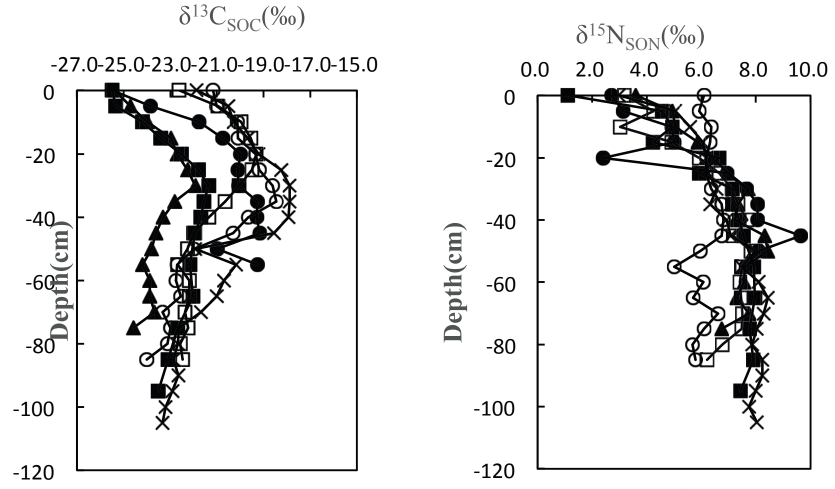
The pattern of SOC along the vertical profiles is similar to that of SON (Fig. 2). The SOC and SON contents of YPG (shrubbery site) and CQC (grassland) are significantly higher and much more variable with depth than in forested (ZJT, YPP, DJS) and cropland (YMD) profiles. This can be attributed to the high productivity of the gramineous plants resulting in elevated SOM inputs on the top of the profile. The YMD profiles display the lowest SOC and SON concentrations most likely because of harvesting.



(a) (b)

Fig. 2. Vertical distribution of soil organic carbon (a) and nitrigen (b) contents

The $\delta^{13}C$ and $\delta^{15}N$ of SOM are presented in Fig.3. While $\delta^{13}C$ of SOM ranges from -25.49‰ to -17.0‰, $\delta^{15}N$ of SOM varies from 1.11‰ to 9.46‰. The patterns of $\delta^{13}C$ and $\delta^{15}N$ in the soil reveal different processes. In the upper 30 cm, the $\delta^{13}C$ shows a clear enrichment while deeper in the soil the $\delta^{13}C$ values are more depleted. Contrastingly, a consistent downward increase in $\delta^{15}N$ of SOM is observed.



(a) (b)

Fig. 3. Vertical distribution of soil organic carbon (a) and nitrogen (b) isotopic composition. Symbols are the same as those in Fig. 2.

Values of $\delta^{13}C$ reflect the dominant vegetation type in each of the sampling sites. For example, the $\delta^{13}C$ values of forested sites (ZJT, YPP, and DJS) are typical of C3 plants, while the profiles of shrubbery (YPG), grassland

(CQC), and cropland (YMD) sites were dominated by C4 plants. The impact of vegetation type on soil δ^{15}N is not significant as on the δ^{13}C.

4. Discussion

Comparing the vertical distribution of SOC, SON, δ^{13}C and δ^{15}N for the six profiles studied here, the most striking observation is the difference in soil organic carbon composition at in the deep soil, where δ^{13}C values decrease while δ^{15}N increase. In previous studies, increasing δ^{13}C values with depth were attributed to isotopic fractionation during decomposition of plant material and humification [6, 7]. The challenge here is to interpret the inverse pattern if depleted ^{13}C at greater depths.

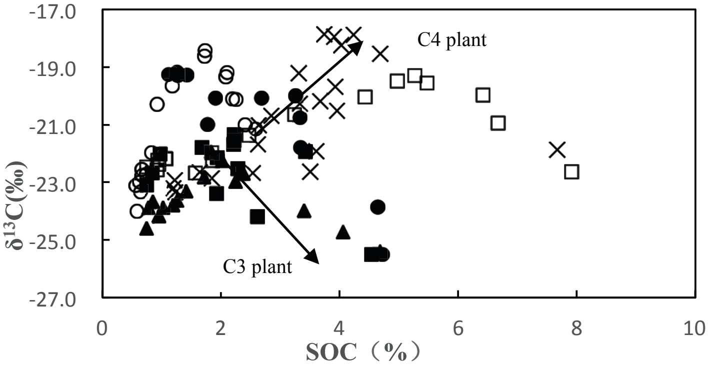


Fig. 4. Soil organic carbon concentration vs. carbon isotopic composition. Symbols are the same as those in Fig. 2.

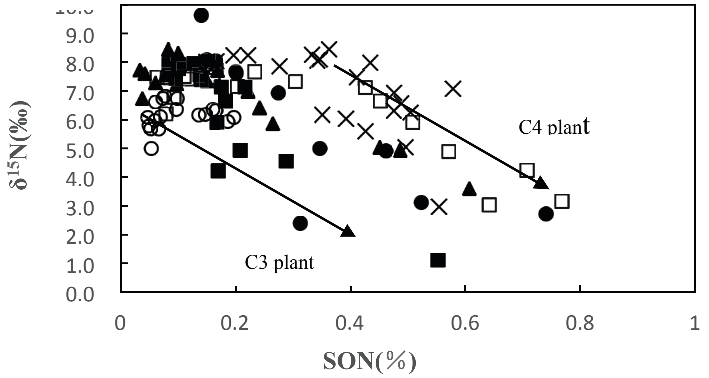


Fig. 5. Soil organic nitrogen concentration vs. nitrogen isotopic composition. Symbols are the same as those in Fig. 2.

The relationship between SOC and δ^{13}C in Fig. 4 reveals that the vegetation type exerts a major control on the distribution of SOC content and δ^{13}C values. The evolution of δ^{13}C in the forested sites (ZJT, YPP, and DJS) is dominated by C3 plants, while shrubbery (YPG) and grassland (CQC) are dominated by C4 plants. The relationship between SON and δ^{15}N in Fig.5 are similar for C3 and C4 plants.

In most soils, C/N ratio is tending to downward that of microbes [8]. We used simple correlation analyses of C/N against δ^{13}C and δ^{15}N across the different layers of the soil to test for the influence of microbial activity (Table 1). The correlation between δ^{13} and C/N in forested sites is stronger in deep soils than in surface soils, while in shrubbery, grassland, and cropland the opposite is observed. Regardless of land use, the correlation between δ^{15} and C/N is higher in surface soil than in the deep soil. Therefore, the reason for depleted ^{13}C in deep soil might be that deep soil carbon is microbial derived [9, 10]. In subsoil, plant roots are an important source of organic matter. Specific allocation patterns of roots in soils through vegetation types were also found to govern vertical SOC distribution [11]. The influence of root inputs may prime microbial activity, leading to faster decomposition of older organic matter [12].

Table 1. Linear correlation coeffieients between C/N, δ^{13}C and δ^{15}N in surface soils and subsoils

Sites	ZJT	YPP	DJS	YPG	CQC	YMD
δ^{13}C—C/N$_S$	-0.075	0.707	0.296	-0.648	0.136	0.907
δ^{13}C—C/N$_D$	-0.769	-0.759	0.542	-0.043	0.033	0.569
δ^{15}N-C/N$_S$	-0.687	0.783	0.593	-0.802	0.505	0.733
δ^{15}N-C/N$_D$	0.450	-0.087	-0.200	-0.106	0.297	0.197
δ^{15}N-δ^{13}C$_S$	0.327	0.962	0.762	0.895	0.670	0.745
δ^{15}N-δ^{13}C$_D$	0.157	-0.020	-0.450	-0.732	0.092	0.462

S = surface soil; D = deeper soil (subsoil); ZJT, YPP, DJS are forested sites, YPG is a shrbubbery; CQC a grassland; YMD a cropland

The correlation between δ^{15} and δ^{13}C is higher in surface soil than in subsoil. It has been suggested that the ^{15}N gradient in soils is mainly due to the mineralization-plant uptake pathway followed by the deposition of ^{15}N depleted litter to the soil surface [13], under the general assumption that saprotrophic fungi carry out mineralization and that the ectomycorrhizal fungi take up the mineral elements resulting from this process. However, this assumption probably results from a simplistic view. So the deeper soil organic carbon are sequestration in microbial production, and soil organic nitrogen is experienced in decomposition and uptakes, theses lead to the difference distribution of δ^{15}N—δ^{13}C along the vertical profiles.

5 Summary

The relationships between isotopic compositions and concentrations of carbon and nitrogen in surface soil and subsoil show the influence of the different land use on the distribution of SOM in the karstic area of Puding, China. Combining the SOC and δ^{13}C signatures allows us to distinguish the influence of C3 and C4 plants. The pattern of δ^{13}C distribution is attributed by microbial production resulting from root activity.

Acknowledgements

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