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Consistent temperature sensitivity of labile soil organic carbon mineralization along an elevation gradient in the Wuyi Mountains, China

Qian Li[a], Xiaoli Cheng[b], Yiqi Luo[c], Zikun Xu[d], Li Xu[a], Honghua Ruan[e], Xia Xu[e,*]

[a] Advanced Analysis and Testing Center, Nanjing Forestry University, Nanjing, Jiangsu, 210037, China
[b] Key Laboratory of Aquatic Botany and Watershed Ecology, Wuhan Botanical Garden, Chinese Academy of Sciences, Wuhan, Hubei, 430074, China
[c] Department of Microbiology and Plant Biology, University of Oklahoma, Norman, OK, 73019, USA
[d] Administrative Bureau of Wuyishan National Nature Reserve, Wuyishan, Fujian, 354300, China
[e] College of Biology and the Environment, Nanjing Forestry University, Nanjing, Jiangsu, 210037, China

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A B S T R A C T

Labile soil organic carbon (LOC) is an essential component in the global carbon (C) cycling due to its fast turnover and sensitivity to environmental changes. However, responses of the mineralization of LOC to current global warming are still not fully understood. In this study, we investigated LOC mineralization at 5, 15, 25 and 35 °C incubation temperatures through laboratory incubation of soil samples and estimated the temperature sensitivity of LOC mineralization at various temperature ranges (i.e. 5–15, 15–25, and 25–35 °C) in an evergreen broad-leaf forest (EBF), a coniferous forest (CF), a sub-alpine dwarf forest (SDF), and an alpine meadow (AM) along an elevation gradient in the Wuyi Mountains in southeastern China. Our results showed that mineralization of LOC significantly increased along the elevation gradient and with increasing incubation temperatures. The interaction of elevation and incubation temperatures was additive on LOC mineralization. Moreover, the temperature sensitivity (Q_{10}) of LOC mineralization significantly decreased with increasing incubation temperature ranges. However, elevation gradient had no statistically significant impact on Q_{10} within each incubation temperature range. Our results suggest that soil organic C (SOC) at high elevations is more vulnerable to global warming. Moreover, consistent Q_{10} of LOC mineralization along the elevation gradient indicates that locally, C quality maybe a minor factor in affecting LOC mineralization and it may be adequate to use a constant Q_{10} value to represent the response of LOC mineralization to warming in regional climate-C cycling models.

1. Introduction

Global mean temperature is predicted to increase another 0.3 to 4.8 °C by the end of this century (IPCC, 2013). Temperature, which has captured much attention in the global carbon (C) cycling, is undoubtedly one of the most important variables that can regulate mineralization of soil organic C (SOC) (Davidson and Janssens, 2006; Xu et al., 2012; Sierra et al., 2015). SOC decomposition is one of the two aspects that determine soil C balance in terrestrial ecosystems (Davidson et al., 2000; Wetterstedt et al., 2010). The potential loss of soil-stored C due to an increase in temperature may result in a buildup in atmospheric CO_2 concentration as well as a positive feedback on climate change (e.g. Xu et al., 2010b). However, accurate prediction of future climate change is greatly limited by our understanding of the land C cycling (Friedlingstein et al., 2006, 2014; Luo et al., 2016). There is thus an urgent need for more empirical knowledge of soil C decomposition and its temperature sensitivity (Q_{10}).

The process by which organic C (OC) are broken down and transformed into inorganic C is known as mineralization. Conceptually, SOC is usually divided into two fractions, labile OC (LOC) and recalcitrant OC (ROC), in laboratory studies (e.g. Fang et al., 2005b; Conant et al., 2008; Xu et al., 2010b). In comparison to ROC, LOC functions as a good indicator for predicting minor changes in SOC. LOC, a type of microbially degradable C associated with microbial growth (Zou et al., 2005), is considered to be the labile C pool. It is easily biodegradable and physically accessible by soil microbes and accounts for a small part of the SOC pool, typically less than 8% (Xu et al., 2010a). However, the rapid turnover of LOC is one of the main aspects in the flux of CO_2 between terrestrial ecosystems and the atmosphere. It might be a potential C source since microbial decomposition of SOC is sensitive to warming (Wetterstedt et al., 2010; Wang et al., 2013; Luo et al., 2016).

* Corresponding author.
E-mail address: xuxia.1982@yahoo.com (X. Xu).

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Consequently, temperature sensitivity (Q_{10}) of SOC mineralization has received much attention (e.g. Fang et al., 2005b; Davidson and Janssens, 2006; Sierra et al., 2015). In climate-C modeling studies, Q_{10} of SOC decomposition is always considered to be a constant constraint in prediction of the impact of climate change on soil C stock (Luo et al., 2016). However, many empirical studies have proposed to use different Q_{10} values to represent mineralization of LOC and ROC to temperature changes in models (e.g. Liski et al., 2000; Melillo et al., 2002; Conant et al., 2008; Hartley and Ineson, 2008; Xu et al., 2010b, 2012). Moreover, one of the opinions in the SOC mineralization-temperature relationship studies is that the mineralization of LOC is sensitive to temperature variation (Liski et al., 2000; Fang et al., 2005b). To better project future climate change, we undoubtedly need more knowledge on Q_{10} of LOC mineralization and to find out whether LOC's mineralization is in accordance with the "C quality-temperature hypothesis", which suggests that Q_{10} of C mineralization is inversely related to the C quality of the SOC (Bosatta and Agren, 1999; Davidson and Janssens, 2006).

Soils in boreal forests and tundra at high latitudes are believed to expect a high loss of C under current global warming due to the predicted experience of the greatest temperature rise in these regions (Dorrepaal et al., 2009). Elevational gradient of temperature changes in mountains can be similar to that caused by latitudes (Smith et al., 2002), which make mountains important regions in climate change research. In this study, we aimed to: (1) assess the mineralization rates of LOC and (2) estimate the temperature sensitivity of LOC mineralization along the elevation gradient in the Wuyi Mountains. The Wuyi Mountains have a typical vertical, well-reserved zonation of vegetation communities in the subtropics in the southeastern China (Wang et al., 2009; Xu et al., 2010b). The elevational temperature gradient, which could resemble those observed along latitudinal gradients (Niklinska and Klimek, 2007), provides us an ideal model ecosystem to investigate the mineralization of LOC.

2. Materials and methods

2.1. Site description

The experimental sites are located in the Wuyishan National Reserve Area in Fujian Province, China (27°33′—27°54′N, 117°27′—117°51′E), a 56,527 ha forested area in the southeast of China. Mean annual temperature (MAT) is 15 °C and mean annual precipitation (MAP) is 2,000 mm. The four typical, different vegetation types along the elevation gradient are evergreen broad-leaf forest (EBF), coniferous forest (CF), sub-alpine dwarf forest (SDF), and alpine meadow (AM). See detailed site information in Table 1.

2.2. Experimental design and soil sampling

Four replicate plots (50 × 60 m) at each vegetation type (EBF, CF, SDF and AM) were set along the elevation gradient in the Wuyi Mountains. Each 50 m × 60 m plot was divided into four 25 m × 30 m subplots. Soil samples were randomly collected (0–25 cm in depth) in all the subplots in November 2016 using a 2 cm-diameter soil corer. Ten soil cores were taken from each subplot and pooled together, as a replicate. Samples were immediately sieved (< 2 mm) to remove soil fauna, rocks and fine roots, thoroughly hand-mixed and placed in plastic bags and transported in several coolers to the ecological laboratory at the Nanjing Forestry University.

2.3. Methods

The LOC content was estimated using a sequential fumigation-incubation method according to Zou et al. (2005) and Liu and Zou (2002). Brief procedures were as follows: 30 g of fresh soil samples were fumigated for 36 h with purified chloroform in a desiccator with

Table 1
Site conditions and soil characteristics along the elevation gradient.

Site	Elevation (m)	MAT (°C)	MAP (mm)	T_{soil} (°C)	M_{soil} (%)	MBC (mg g^{-1})	SOC (mg g^{-1})	TN (mg g^{-1})	C:N	pH	Litter mass (t hm^{-2} y^{-1})	Fine root biomass (kg m^{-3})	Dominant species
EBF	500	18.5	1,700	15.12 ± 0.05	21.91 ± 1.01	1.09 ± 0.09d	38.50 ± 1.77c	5.10 ± 0.10c	7.55 ± 0.32b	4.65 ± 0.03a	5.63 ± 0.51b	1.90 ± 0.16c	*Castanopsis carlesii*, *Castanopsis eyrei*
CF	1,150	14.5	2,000	13.73 ± 0.08	28.93 ± 0.52	1.60 ± 0.12c	39.85 ± 2.76c	5.11 ± 0.58c	7.80 ± 0.50b	4.31 ± 0.08b	8.08 ± 0.65a	2.05 ± 0.15c	*Pinus taiwanensis*, *Oligostachyum oedogonatum*
SDF	1,750	11.2	2,200	11.04 ± 0.14	40.43 ± 0.64	2.07 ± 0.05b	59.46 ± 2.90b	7.06 ± 0.28b	8.42 ± 0.45b	4.58 ± 0.05a	2.92 ± 0.46c	2.74 ± 0.21b	*Symplocos paniculata*, *Stewartia sinensis*
AM	2,150	9.7	3,100	10.63 ± 0.02	52.96 ± 0.83	3.19 ± 0.04a	102.59 ± 3.58a	10.60 ± 0.56a	9.68 ± 0.56a	4.78 ± 0.11a	1.94 ± 0.22d	5.48 ± 0.10a	*Calamagrostis brachytricha*, *Miscanthus sinensis*, *Lycopodium clavatum*

Note: MAT: mean annual soil temperature; MAP: mean annual precipitation, T_{soil}: soil temperature; M_{soil}: soil moisture; MBC: microbial biomass carbon; SOC: soil organic carbon; TN: total nitrogen. Values are mean ± SE. Different lower case letters indicate statistically significant difference along the elevation gradient. EBF: evergreen broad-leaf forest; CF: coniferous forest; SDF: sub-alpine dwarf forest; AM: alpine meadow.