



# Physico-chemical protection, rather than biochemical composition, governs the responses of soil organic carbon decomposition to nitrogen addition in a temperate agroecosystem



Wenbing Tan <sup>a,b</sup>, Guoan Wang <sup>c</sup>, Caihong Huang <sup>b</sup>, Rutai Gao <sup>b</sup>, Beidou Xi <sup>a,b,\*</sup>, Biao Zhu <sup>d,\*\*</sup>

<sup>a</sup> State Key Laboratory of Environmental Criteria and Risk Assessment, Chinese Research Academy of Environmental Sciences, Beijing 100012, China

<sup>b</sup> State Environmental Protection Key Laboratory of Simulation and Control of Groundwater Pollution, Chinese Research Academy of Environmental Sciences, Beijing 100012, China

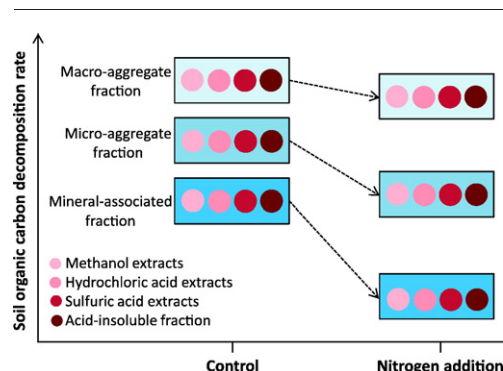
<sup>c</sup> College of Resources and Environmental Sciences, China Agricultural University, Beijing 100193, China

<sup>d</sup> College of Urban and Environmental Sciences, and Key Laboratory for Earth Surface Processes of the Ministry of Education, Peking University, Beijing 100871, China

## HIGHLIGHTS

- We used <sup>13</sup>C natural abundance method to assess soil carbon turnover with N addition.
- N addition inhibited turnover across bulk soil, aggregate fractions, and organic compounds.
- The intensity of inhibition increased with the level of N addition.
- The intensity of inhibition increased with decreasing aggregate size.
- The intensity of inhibition did not vary among organic compound classes.

## GRAPHICAL ABSTRACT



## ARTICLE INFO

### Article history:

Received 15 March 2017

Received in revised form 19 April 2017

Accepted 19 April 2017

Available online 23 April 2017

Editor: Elena Paoletti

### Keywords:

Soil organic carbon turnover

N addition

Aggregate size fraction

Organic compound class

<sup>13</sup>C natural abundance

Physico-chemical protection

## ABSTRACT

The heterogeneous responses of soil organic carbon (SOC) decomposition in different soil fractions to nitrogen (N) addition remain elusive. In this study, turnover rates of SOC in different aggregate fractions were quantified based on changes in  $\delta^{13}\text{C}$  following the conversion of  $\text{C}_3$  to  $\text{C}_4$  vegetation in a temperate agroecosystem. The turnover of both total organic matter and specific organic compound classes within each aggregate fraction was inhibited by N addition. Moreover, the intensity of inhibition increases with decreasing aggregate size and increasing N addition level, but does not vary among chemical compound classes within each aggregate fraction. Overall, the response of SOC decomposition to N addition is dependent on the physico-chemical protection of SOC by aggregates and minerals, rather than the biochemical composition of organic substrates. The results of this study could help to understand the fate of SOC in the context of increasing N deposition.

© 2017 Elsevier B.V. All rights reserved.

\* Correspondence to: B. Xi, State Key Laboratory of Environmental Criteria and Risk Assessment, Chinese Research Academy of Environmental Sciences, Beijing 100012, China.

\*\* Corresponding author.

E-mail addresses: [xibeidou@yeah.net](mailto:xibeidou@yeah.net) (B. Xi), [biaozhu@pku.edu.cn](mailto:biaozhu@pku.edu.cn) (B. Zhu).

## 1. Introduction

Atmospheric deposition of reactive nitrogen (N), originating mainly from artificial fertilizer applications and fossil-fuel combustion (Davidson, 2009), has increased 3–5 fold over the past century, and is expected to further increase in this century (Galloway et al., 2004). The increased availability of biologically reactive N has widespread effects on terrestrial and aquatic ecosystems. For example, N deposition can lead to soil acidification, stimulation of plant growth, eutrophication, as well as loss of biodiversity (Vitousek et al., 1997; Höglberg et al., 2006; de Vries et al., 2007; Maskell et al., 2010; Thomas et al., 2010; Shi et al., 2016). In addition, perturbation of the global N cycle may influence the global carbon cycle as well (Reay et al., 2008). Soil organic carbon (SOC), which is the largest carbon reservoir in the terrestrial biosphere, contains two to four times the amount of carbon in the atmosphere. Consequently, either positive or negative changes of soil carbon storage, in response to N deposition, could lead to significant alteration in the carbon dioxide (CO<sub>2</sub>) concentration of atmosphere (Riggs et al., 2015; Zak et al., 2017), and thus have implications for future global climate change.

There is a significant body of work on the effects of nutrient availability on microbial decomposer and organic carbon dynamics in soils (Craine et al., 2007; Manzoni et al., 2012; Kirkby et al., 2014; Mooshammer et al., 2014). Previous studies revealed that soil N input has the potential to decrease microbial decomposition of SOC and thereby increase soil carbon storage (Ramirez et al., 2012; Zhou et al., 2014; Riggs et al., 2015). Although this negative effect of N input on microbial decomposition of SOC seems paradoxical since the increased input of plant litter and root exudates induced by N enrichment may increase carbon availability to microbes (Liu and Greaver, 2010), a number of microbial mechanisms have been proposed to explain why microbial decomposition of SOC decreases with N addition (Riggs and Hobbie, 2016). The hypothesized mechanisms by which N addition reduce microbial decomposition of SOC include increased microbial carbon use efficiency (Ågren et al., 2001; Manzoni et al., 2012), decreased ligninolytic enzyme activity (Fog, 1988; Eisenlord et al., 2013), and decreased microbial biomass (Treseder, 2008; Liu and Greaver, 2010).

SOC comprises a vast range of different functional fractions with differential physico-chemical protection and biochemical composition (von Lützow et al., 2007; Lehmann and Kleber, 2015). Recent evidences suggest that physico-chemical protection (or microbial accessibility), rather than biochemical composition (or molecular structure), controls the turnover rate of SOC and its response to climate change (Marschner et al., 2008; Schmidt et al., 2011). Thus, responses of SOC decomposition to N addition may be more strongly associated with the level of physico-chemical protection (aggregate occlusion and mineral association) than with the biochemical composition of organic substrates. Although previous studies have documented the effects of N additions on the distribution of SOC in different functional fractions (Cusack et al., 2011; Riggs et al., 2015; Xu et al., 2016; Zak et al., 2017), very few studies examined the heterogeneous responses of SOC decomposition rates in different physical and chemical fractions to N enrichments (but see Neff et al., 2002; Cusack et al., 2010). Clearly, the mechanisms regarding these heterogeneous responses warrant investigation given their expected importance to understand soil carbon emissions in the context of increasing N deposition.

In the present study, we collected soils under different levels of N additions, separated SOC into different physico-chemical fractions by a method combining physical and chemical fractionations, and estimated their turnover rates based on changes in <sup>13</sup>C natural abundance in a long-term field experiment. The main objectives of this study were (1) to verify the effects of N additions on SOC decomposition rates, and (2) to test whether decomposition rates of SOC in different particle-size aggregate fractions and organic compound classes have differential responses to N additions.

## 2. Material and methods

### 2.1. Study area and soil sampling

The study site is located at 40°12'N, 116°35'E at an altitude of 44 m above sea level, North China. Climate is typically temperate continental, with a mean annual rainfall of 625 mm (75% in June–August) and mean annual temperature of 11.5 °C. The vegetation at the site was switched from C<sub>3</sub> (wheat) to C<sub>4</sub> (corn) in 2004. The main soil type is Cambisol (mainly containing hydromica, montmorillonite and kaolinite) (Gong et al., 2007). Total organic carbon, total nitrogen, and clay contents vary from 16.5 to 20.3 g kg<sup>-1</sup>, from 1.3 to 2.2 g kg<sup>-1</sup>, and from 26 to 32%, respectively, and pH 6.7–7.2 across the site.

At the site, twelve 25 m × 25 m plots were subjected to four treatments (three replicate plots for each treatment): unfertilized control, low, medium and high N addition (100, 200, 300 kg N ha<sup>-1</sup> yr<sup>-1</sup> respectively). These rates of N addition were within the range of applied fertilizer rates in the corn field of the North China plain (Chen et al., 2014). The N fertilizer was urea, 38.8%, 11.2%, 37.6% and 12.4% of which were applied at base-fertilizer, 6 leaf, 10 leaf and silking stages, respectively. Soil samples were collected in June 2004 (prior to vegetation change) and June 2016 (12 years after vegetation change), respectively. At each plot, 10 randomized uppermost 10 cm of soils were collected and mixed. Each composed sample was sieved (2 mm diameter) to remove soil fauna, fine roots and rock fragments.

### 2.2. Soil organic matter fractionation

A method combining physical and chemical fractionations (Fig. S1) was employed to separate SOC fractions. Briefly, bulk SOC was physically fractionated into macro-aggregate (>250 μm), micro-aggregate (53–250 μm) and mineral-associated (<53 μm) SOC using wet sieving on a micro-aggregate isolator (Six et al., 2000). Then SOC in each aggregate size fraction was chemically separated into four organic compound classes (Wang et al., 1998): dichloromethane and methanol extracts (DME), hydrochloric acid extracts (HAE), sulfuric acid extracts (SAE), and acid-insoluble organic matter (AIOM), which were originally called lipids, hydrolysable amino acids, hydrolysable carbohydrates, and acid-insoluble fractions, respectively.

### 2.3. Soil analysis for organic carbon and δ<sup>13</sup>C

Bulk soils and aggregate size fractions were pretreated with 1 M HCl and chemical compound classes were acidified with 1% H<sub>3</sub>PO<sub>4</sub>, in order to remove carbonates or atmosphere CO<sub>2</sub> introduced during chemical fractionations. Organic carbon contents and δ<sup>13</sup>C<sub>org</sub> of bulk soils, aggregate size fractions, and organic compound classes were measured using an Elementar Vario EL elemental analyzer and Finnigan Delta-plus XP isotope ratio mass spectrometer, respectively.

### 2.4. SOC decomposition rates and CO<sub>2</sub> fluxes of bulk soil and soil fractions

The natural isotopic (δ<sup>13</sup>C) difference due to different photosynthetic pathways allows for the proportion of organic carbon derived from C<sub>4</sub> (corn) plants to be calculated through a two-compartment mixing-model (Balesdent and Mariotti, 1996):

$$C_B = (\delta_X - \delta_A)C_X / (\delta_{plant} - \delta_A) \quad (1)$$

where C<sub>B</sub> is the stock of new SOC derived from C<sub>4</sub> plants in 2016, δ<sub>X</sub> is the δ<sup>13</sup>C of total SOC in 2016 (Table S1), δ<sub>A</sub> is the average δ<sup>13</sup>C of the corresponding SOC under the initial C<sub>3</sub> plants in 2004 (Table S1), C<sub>X</sub> is the stock of total SOC in 2016 (Table S2), and δ<sub>plant</sub> is the δ<sup>13</sup>C value of plant (C<sub>4</sub>) litter inputs to the SOC pool and deemed to be the average δ<sup>13</sup>C value of corn litter collected from 2005 to 2016 (Table S3).

Download English Version:

<https://daneshyari.com/en/article/5750943>

Download Persian Version:

<https://daneshyari.com/article/5750943>

[Daneshyari.com](https://daneshyari.com)