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Responses of peat carbon at different depths to simulated warming and oxidizing

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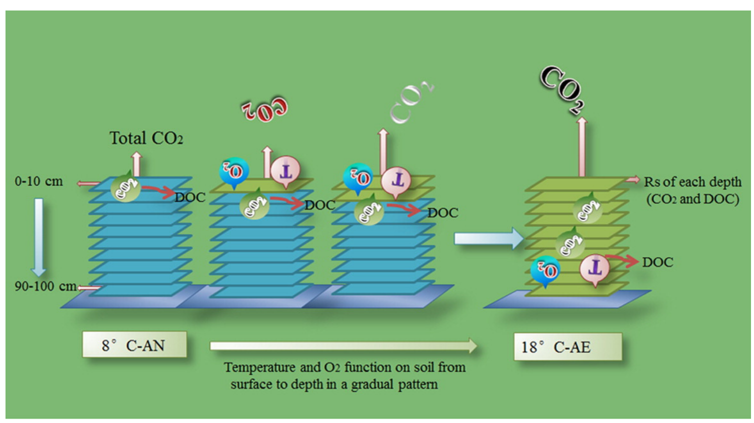
HIGHLIGHTS

- Advanced temperature and O_2 increased soil respiration much with different increments.
- Old soil accounted for a larger proportion of soil respiration and increased increments.
- Much difference was observed between our peatlands and others of higher latitudes.

GRAPHICAL ABSTRACT



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ABSTRACT

Warming and water table drawdown greatly reshape peatland carbon cycle, especially when considering the old carbon stored under the peatland subsurface. However, little is known about the effects of warming, oxidizing by drying or their combination on carbon decomposition at different depths (0–100 cm) of peat. In this research, soil of different depths from Zoige Plateau was incubated in four scenarios (8 °C-anaerobic, 8 °C-aerobic, 18 °C-anaerobic and 18 °C-aerobic) to detect the exported carbon. Our result showed that soil respiration (Rs) increased obviously with enhanced temperature and oxygen. The total CO_2 fluxes of 2400.22 ± 57.69 mg m^{-2} d^{-1} under 8 °C-anaerobic condition increased by 73.6%, 40.7% and 176.5% with warming, oxidizing and their combined effect, respectively. The average dissolved organic carbon (DOC) concentration was 74.90 ± 8.09 mg kg^{-1} under 8 °C-anaerobic condition, but increased by 53.5%, 44% and 159.4%, respectively under the condition of warming, oxidizing and their combination. Rs and its variation under warming and oxidization differed significantly among

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different depths, probably caused by the differences of soil substrate, especially the variation in distribution of soil microbes and enzymes among depths of peatlands. By classifying the source of Rs as young soil (YS: 0–20 cm) and old soil (OS: 21–100 cm), this reseaerch found that OS accounted for a huge part of total Rs under 8 °C-anaerobic condition (CO_2: 74.2%; DOC: 60.7%). Such relative contribution of OS to total Rs did not change obviously with warming or oxidizing. Though YS and OS responded equally to warming and oxidizing, OS was responsible for a larger proportion of total increase in Rs. Compared with other studies, we concluded that peatlands soil in our field of mid-latitude and high altitude is less sensitive to warming and oxidizing than peatlands of higher latitude, but that OS of this peatlands is more critical in predicting regional carbon cycle.

1. Introduction

With 15–30% of total world soil carbon, peatlands, mainly distribute in the northern high latitude areas, are an important carbon sink for the atmosphere (Gorham, 1991; Knoblauch et al., 2013; Lee et al., 2012). Large quantity of carbon deposits in peatlands is a result of the imbalance between production and decomposition (Knoblauch et al., 2013; Laiho, 2006). The decomposition was much lower than production for water saturated condition in peatlands and the consequent anaerobic environment accompanied with low temperature (Bubier et al., 2003; Griffis et al., 2000). In the changing environment, the fate of carbon in peatlands will depend on the response of soil substrate to the changes of water regime, O_2 abundance and temperature (Avis et al., 2011; Chen et al., 2014).

Just like soil characters that are determined by vegetation and vary markedly with climate (Chu et al., 2010; Zak and Kling, 2006), peat as the remains of vegetation may also differ among the whole depth profile as a result of climate change during peat development (Moore and Dalva, 1997) and cryoturbation (O'Donnell et al., 2012; Rinkes et al., 2013; Treat et al., 2014; Wickings et al., 2012). Under a warm and humid climate, peat mainly derives from *Cyperaceae* and *Equisetaceae*; under a cool and dry climate, however, it mainly consists of *Picea* remains (Guo et al., 2013). Cryoturbation can redistribute carbon among the whole depth profile (Schuur et al., 2008). With comparatively high water table, low oxygen diffusion and low temperature in peatlands, carbon is protected from decomposition and seldom participates in carbon cycle since its formation (McCallister and Del Giorgio, 2012; Singer et al., 2012).

Global warming have increased air temperature by 0.88 °C from 1988 to 2012, and even more at the end of the 21 century (IPCC, 2013). Climate warming, land use changes and hydrologic redistribution have changed local, regional and global carbon cycle (Hicks Pries and Schuur, 2013) and have the potential to shift peatlands from a carbon sink to a carbon source (Dorrepaal et al., 2009; Knoblauch et al., 2013; Schuur et al., 2009; Wang et al., 2013; Yan et al., 2014). High altitude areas where climate is sensitive to warming are experiencing a "much larger than average" increase in temperature (Knoblauch et al., 2013; Lee et al., 2012; Liu and Chen, 2000; Peng et al., 2014). Besides warming, water table drawdown is the other very important cause for the degradation of peatlands in recent decades on Zoige Plateau peatlands - one of the largest alpine peatlands in the world (Bai et al., 2013; Chen et al., 2010; Gao, 2006; Li et al., 2010). Water table drawdown may destroy the stable environment in peatlands, exposing the preserved carbon to aerobic (AE) environment (Oechel et al., 1998), and together with the optimum soil moisture creating an available environment for microbes (Serreze et al., 2000; Yan et al., 2014; Zimov et al., 2006). Water table drawdown also shifts soil respiration (Rs) pathway from anaerobic (AN) to aerobic environment, which responds to climate change differently (Knoblauch et al., 2013; Lee et al., 2012; Schuur et al., 2008; Treat et al., 2014; Yang et al., 2014). Studies showed that the stored old carbon in deep soil of degraded peatlands had participated in modern carbon cycle (McCallister and Del Giorgio, 2012; Schuur et al., 2009; Singer et al., 2012). However, the responses of peat of different depths to the changing environment remains poorly understood.

The main factors in Rs include soil microbial communities, enzyme diversity and nutrient condition (Lawrence et al., 2009; Moorhead and Sinsabaugh, 2006) which all vary with temperature and O_2 conditions (Kim et al., 2012). Most microbes and enzymes are sensitive to temperature and O_2 change, and so is soil nutrient determined by vegetation that varies with climate (Mikan et al., 2002). Warming leads to an earlier spring thawing in peatlands (Briones et al., 2014) with an advanced increase in microbial activity, as well as Rs. O_2 can activate most oxygen enzyme activities which could be a proximate control of soil organic matter (SOM) dynamics, especially in plateau peatlands (Laiho, 2006; Sinsabaugh et al., 2008; Tian and Shi, 2014). O_2 also relieves the inhibition effect of polyphenolic on soil hydrolase and microbial activity (Freeman et al., 1997; Freeman et al., 2001a). Therefore, understanding the response of soil microbes, enzymes and nutrient condition to the changes of temperature and O_2 is important to predict peatland carbon cycle.

The main objective of this study was to detect the response of peat at different depths to warming and oxidizing. The specific objectives were to: 1) determine the changes of peat Rs under warming and oxidizing conditions; 2) quantify the Rs increase increment of each layer in warming and oxidizing conditions, the contribution of young soil (YS: 0–20 cm) and old soil (OS: 21–100 cm) to total Rs and their contribution to the increased Rs in warming and oxidizing conditions; 3) detect the roles of microbes, enzymes and nutrient conditions in soil carbon decomposition.

2. Materials and methods

2.1. Sampling sites

Samples were collected from the Zoige Peatland and Global Change Research Station, Chinese Academy of Sciences (33°06′25″ N, 102°38′33″ E), located at the Riganqiao Provincial Wetland Reserve (av. 3400 m a.s.l.) in the northeastern Qinghai-Tibetan Plateau (Fig. 1). Zoige peatlands cover an area of about 4605 km^2, with about 3179 km^2 intact peatlands and 1426 km^2 degraded peatlands. The basal age of carbon ranges from 1635 to 14095 cal yr BP (Chen et al., 2014). In an orbicular shape, Zoige plateau is surrounded by a series of alpine mountainsand affected by the southwest monsoon and southeast monsoon, it belongs to the cold Qinghai-Tibetan climatic zone with an annual average temperature of 1.5 °C and precipitation of 720 mm. The warmest monthly temperature (10.9 °C) is recorded in July and the coolest in January (-10 °C) (Yang et al., 2014).

The peatland on Zoige plateau has a peat depth of 0.2–6.0 m (mean depth about 1.39 m), an average pH of 6.6–7.0 (Tian et al., 2012), and a mean peat accumulation rate of 0.39 mm yr^{-1} (from 0.12 to 0.85 mm yr^{-1}) (Chen et al., 2014). The water table, though fluctuating seasonally, was approximately 0 cm during our sampling in October 2013. So the sampled soil was in water saturated condition. The dominant vegetation at Riganqiao is herbaceous plants including *Carex muliensis, Trollius farreri, Gentiana formosa,* and *Caltha palustris* (Yang et al., 2014).

2.2. Experiment design

Soils of each depth (0–100 cm, with intervals of 10 cm) were incubated under four scenarios: (1) anaerobic at 8 °C (8 °C-AN); (2) aerobic at 8 °C (8 °C-AE); (3) anaerobic at 18 °C (18 °C-AN); (4) aerobic at 18 °C (18 °C-AE). Rs of each depth and each condition were monitored during