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RESPONSES OF PEAT CARBON AT DIFFERENT DEPTHS TO SIMULATED WARMING AND OXIDIZATION

Liangfeng Liu[1, 2, 3] and Huai Chen[1, 2, 3*]

[1]*Chengdu Institute of Biology, Chinese Academy of Sciences, China*
[2] *College of Forestry, Northwest A&F University, China*
[3]*Zoige Peatland and Global Change Research Station, Chinese Academy of Sciences, China*

[*]*Corresponding author: chenhuai@cib.ac.cn*

SUMMARY

Warming and water table drawdown greatly reshapes carbon cycle in peatlands, especially when the old carbon stored under the peatland subsurface is considered. However, little is known about the effects of warming, oxidization or their combination on carbon decomposition at different peat depths (0-100 cm). In this research, soil from different depths from the Zoige Plateau, China was incubated under four scenarios to detect the exported carbon. Our result showed that with enhanced temperature and oxygen, total carbon dioxide (CO_2) fluxes increased by 40.7-176.5%, and average dissolved organic carbon (DOC) concentration increased by 44-159.4%. Soil respiration (Rs) rates and variability under warming and oxidization differed significantly with depth, probably caused by the differences of soil substrate distribution at the various depths. By classifying the source of Rs as young soil (YS: 0-20 cm) and old soil (OS: 21-100 cm), this research found that the OS accounted for a large proportion of total Rs under 8°C-anaerobic conditions (CO_2: 74.2%; DOC: 60.7%). The relative contribution of OS to total Rs did not show an obvious change with warming or oxidization. Although YS and OS responded equally to warming and oxidization, OS was responsible for a larger proportion of total increase in Rs. Compared with other studies, we conclude that the peat samples at our site are less sensitive to warming and oxidization than peatlands at higher latitudes, but that the OS at this site may be more critical in predicting the regional carbon cycle.

Keywords: *Zoige plateau, peatlands, incubaiton, aerobic environment, anaerobic environment*

INTRODUCTION

With 15-30% of total global soil carbon, peatlands, mainly distributed in the northern high latitude areas, are an important carbon sink (Gorham, 1991). The large quantities of carbon deposited in peatlands have resulted from water saturated conditions and the consequent anaerobic environment accompanied with low temperature (Griffis *et al.*, 2000). In a changing environment, the fate of carbon in peatlands will depend on the response of the soil substrate to changes of water regime, oxygen (O_2) abundance and temperature (Chen *et al.*, 2014). Global warming has increased mean global air temperatures by 0.88°C from 1988 to 2012, and temperatures are predicted to increase even more by the end of the 21st century (IPCC, 2013). Climate warming and hydrologic redistribution have changed the global carbon cycle (Hicks Pries & Schuur, 2013) and have the potential to shift natural peatlands from a carbon sink to a carbon source (Schuur *et al.*, 2009; Yan *et al.*, 2014). High altitude areas are experiencing a much larger than average increases in temperature (Peng *et al.*, 2014). In recent decades, water table drawdown has resulted in degradation of peatlands on the Zoige Plateau (Chen *et al.*, 2010). Water table drawdown has exposed the preserved carbon to aerobic (AE) environment (Oechel *et al.*, 1998), resulting in a shift in the soil respiration (Rs) pathway from anaerobic (AN) respiration to AE respiration, which responds to climate change differently (Schuur *et al.*, 2008; Yang *et al.*, 2014). Studies have shown that the stored older carbon in the deep soil of degraded peatlands participates in the contemporary carbon cycle (Schuur *et al.*, 2009). However, the responses of peat to the changing environment at different depths remains poorly understood. The main objective of this study was to detect the response of peat at different depths to warming and oxidization. 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 with warming and oxidization, the contribution of young soil (YS: 0-20 cm) and old soil (OS: 21-100 cm) to total Rs and their contribution to increased Rs under warming and oxidization conditions.

METHODS

Samples (0-100 cm, at 10 cm intervals) were collected randomly from the Zoige peatland and the Global Change Research Station, Chinese Academy of Sciences (33°06′25″ N, 102°38′33″ E) in October 2013. Soil at each depth was divided into two parts; one for incubation and the other for DOC analysis. Soils of each depth 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). The Rs rates at each depth and under each scenario were monitored during a 35-day incubation. The presumption was that warming and oxidization function in a gradual pattern on the soil from the surface to a depth (Figure 1). We recorded total Rs (the sum of Rs at all ten depths) and the source of Rs was classified as YS and OS. We detected the proportion of YS and OS to total Rs under each scenario, and the relative contribution of OS to the total Rs increment in response to warming and oxidization. DOC concentration was detected before and after incubation and the concentration differences as exported DOC during incubation. One way analysis of variance (ANOVA), linear regression analytical methods and SPSS 20.0 for Windows (SPSS Inc., Chicago, IL, USA) were used in statistical analysis. All data were checked and confirmed to be normally distributed before ANOVA analysis (K-S test).

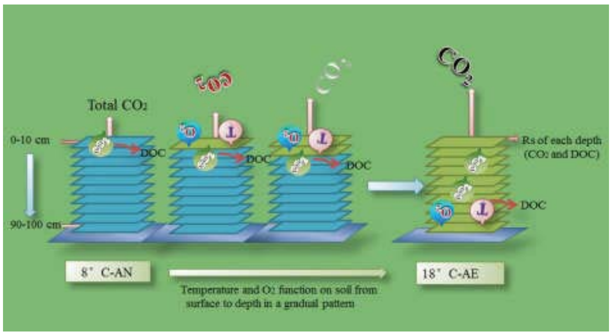

Figure 1: Gradual pattern of warming and oxidization functions on soil from surface to depth of 100 cm (10 cm as a depth).

RESULTS

The CO_2 and DOC exported rates were significantly related to temperature and O_2 concentration ($P < 0.01$ for both).Total CO_2 emissions integrated over the whole depth was 2400.2 ± 57.7 mg m^{-2} d^{-1} under the 8°C-AN scenario, and it increased by 40.7%, 73.6% and 176.5% under the 8°C-AE, 18°C-AN and 18°C-AE scenarios, respectively. The highest DOC concentration was 194.3 ± 11.9 mg kg^{-1} at 18°C-AE and the lowest was 74.9 ± 8.1 mg kg^{-1} at 8°C-AN, an increase of 44% and 53.5% in response to a 10°C warming and aerobic conditions. CO_2 and DOC export showed significant variations among all depths under the four scenarios ($P < 0.01$ for all). Both CO_2 emission and DOC concentrations at 0-20 cm depth was higher than those of the deeper layers, but the variation pattern at deeper depths was different among the four scenarios. For example, CO_2 emissions at 8°C-AN were similar among depths, although a considerable difference was observed under the other three scenarios. By classifying the peat into YS and OS, we found that OS was the major carbon contributor to total Rs under all four scenarios (CO_2: 65.9-74.2%; DOC: 60.7-70.6%). Rs and DOC showed a substantial increase under the 8°C-AE, 18°C-AN and 18°C-AE scenarios, but at different degrees at each depth. Over the whole depth profile, OS was responsible for 59.6-67.5% and 71.7-76.9% of the total increase in CO_2 and DOC.

DISCUSSION

The effect of temperature on Rs has been illustrated in a wide range of studies (Eliasson *et al.*, 2005; Tucker *et al.*, 2013). Biasi *et al.* (2005) reported that temperature could influence the utilization of carbon source by microbes or microbial metabolism leading to changes in Rs rates. Treat *et al.* (2014) found that a warmer and drier climate could result in a substantial increase in carbon loss (Biasi *et al.*, 2005; Treat *et al.*, 2014). DOC also was driven by rising temperature (Freeman *et al.*, 2001b). Water table drawdown in peatlands could supply more soil porosity for gas diffusion, permitting O_2 to increase Rs by being the terminal electron acceptor during Rs (Kane *et al.*, 2013). The increased CO_2 and DOC export rate in this study under the warming and oxidization scenario was lower than in other incubation studies, demonstrating that our soil from mid- and high altitudes had a lower sensitivity to warming and oxidization, which can be explained by the difference of climate and vegetation between sites.

Rs differed significantly throughout the whole peat profile demonstrating the high variation in the response of the different peat depths to warming and oxidization. Higher CO_2 and DOC export rates at the 0-20 cm depth was consistent with other studies (Biasi *et al.*, 2014) and in agreement with the idea that older carbon in deeper layers is more "recalcitrant" than younger carbon at the surface (Bosatta & Agren, 1999; Knorr *et al.*, 2005). CO_2 emissions from deeper depths (21-100 cm) were stable under the 8°C-AN scenario but had unequal increases under warming/oxidization conditions. This was probably because in a restricted environment, environment factors restricted Rs; but in a looser environment with higher temperature and more O_2, soil substrate character was the main factor controlling Rs. The unequal increases also reflected the variation of soil substrate among all profiles (Treat *et al.*, 2014).

By classifying the source of Rs into YS and OS, we found OS was a major contributor to total Rs and responsible for a large part of the total increase in Rs. With climate warming and increased oxidization, most peatland carbon pools may become destabilized, releasing their stored carbon (Freeman *et al.*, 2001a; Freeman *et al.*, 2004). Aged carbon exporting DOC to rivers is receiving increasing attention (Butman *et al.*, 2015). The contribution of OS to total Rs was much higher in our study than that in other studies (6-18% in Hicks Pries & Schuur, 2013; 7-41% in Schuur, 2009) and this difference may be due to wide differences in peat type, climate and carbon cycle patterns among the studied peatlands.

CONCLUSION

This study showed that enhanced temperature and O_2 levels substantially increased Rs, at different rates among all layers of our study site, suggesting that soil substrate characteristics vary among the whole profile of peat. By dividing the source of Rs into YS and OS, we found that OS was responsible for a large proportion of the total increase in Rs. Compared with other peatlands studies, this research observed lower rates of Rs with 10°C warming or oxidization, but higher contribution of OS to total Rs. We can conclude that the soil in our study site is less sensitive to warming and oxidization than other peatlands and that OS in this peatlands is more critical in predicting regional peatland carbon cycle. Our results could be very useful for modeling scientists to calibrate their models.

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