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Short Communication

Wetland drying increases the temperature sensitivity of soil respiration

Hongyang Chen[a], Junyu Zou[a], Jun Cui[a,b], Ming Nie[a,*], Changming Fang[a,**]

[a] Ministry of Education Key Laboratory for Biodiversity Science and Ecological Engineering, Coastal Ecosystems Research Station of the Yangtze River Estuary, Shanghai Institute of Eco-Chongming (SIEC), Fudan University, 2005 Songhu Road, Shanghai 200438, China
[b] Jiangsu Provincial Key Laboratory for Bioresources of Coastal Saline Soils, Jiangsu Coastal Biological Agriculture Synthetic Innovation Center, Yancheng Teachers' University, Yancheng 224002, China

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ABSTRACT

Hydrological changes during wetland drying alter soil oxidation-reduction (redox) conditions such that soil organic carbon (SOC) decomposition is affected, which may influence global climate-carbon feedbacks. This study aimed to explore whether the temperature sensitivity of soil respiration is affected by changes in soil redox status. We created a gradient of redox potential in wetland soils by adjusting soil moisture content and O_2 concentration in microcosms, and incubated these soils under changing temperature to estimate the temperature sensitivity (indicated by Q_{10}) of soil respiration. Our results showed that Q_{10} values under aerobic conditions were 1.5–2.5 times higher than those under anaerobic incubations, with a significant positive correlation between Q_{10} and soil redox potential. This study suggested that SOC decomposition through soil respiration during progressive wetland drying may be increasingly sensitive to global warming, which may accelerate SOC loss from wetlands in the future.

Global climate change is expected to increase the frequency and intensity of drought in the 21st century (Cook et al., 2014). As transition zones between aquatic and terrestrial environments, wetlands are particularly vulnerable to hydrological changes in the context of global climate change (Cheng and Huang, 2016). Moreover, wetland hydrology is affected by locally intensive human activities, such as artificial drainage, resulting in gradual drying (Szafranek-Nakonieczna and Stêpniewska, 2014; Wu et al., 2017). It was estimated that more than half of world's wetlands disappeared in last century, and this tendency was expected to continue in the future (IPCC, 2014). Indeed, the drying of wetlands due to climate change and human activities has been widely observed in recent years (Liu et al., 2006).

Wetlands play an important role in global carbon cycling (Davidson and Janssens, 2006; Fenner and Freeman, 2011). Although wetlands occupy only 4–6% of the terrestrial land surface, a substantial amount (~500 Pg) of soil organic carbon (SOC) is stored in these areas (Lal, 2008), corresponding to 20–25% of global SOC storage (Mitra et al., 2005; Mitsch et al., 2013). The critical function of wetlands serving as a sink for SOC is mainly attributed to their anoxic wet conditions with a generally low oxidation-reduction potential (Eh), which restricts SOC decomposition (Blodau, 2002). However, hydrological changes resulting from wetland drying can shift soil environment from anoxic to oxic conditions, leading to an increase in Eh (Picek et al., 2000; Davidson and Janssens, 2006; Peralta et al., 2014). It is widely reported that soil respiration in wetlands under oxic conditions (high Eh) is much faster than in anoxic environments (i.e. low Eh; Inglett et al., 2012; Szafranek-Nakonieczna and Stêpniewska, 2014). Moreover, due to the effects of Eh on microbial community structure and metabolic activity (Picek et al., 2000; Peralta et al., 2014), wetland drying may also affect the response of soil respiration or SOC decomposition to temperature change. However, little is known about the possible effects of Eh on the temperature sensitivity of soil respiration, which may bias our prediction of wetland SOC dynamics under global climate change.

Based on an assumption that the anoxic restriction on soil respiration is more significant at high temperature when soil microbes are more active than that at a lower temperature, we hypothesized that the temperature sensitivity of soil respiration increases with Eh in wetland soils. To test the generality of this hypothesis, soils with various backgrounds and characteristics were sampled from nine major types of wetlands in China, crossing temperate, subtropical and plateau-climate zones and with an annual temperature range of -2-18 °C and annual precipitation of 380–1300 mm (Table 1).

Since we did not intend to assess within-site variability, four sampling locations (four spatial replicates), at least 20 m apart from each other, were randomly chosen under dominant plants and typical hydrological conditions of each site. At each location, three soil cores

* Corresponding author. School of Life Sciences, Fudan University, 2005 Songhu Road, Shanghai 200438, China.
** Corresponding author. School of Life Sciences, Fudan University, 2005 Songhu Road, Shanghai 200438, China.
E-mail addresses: mnie@fudan.edu.cn (M. Nie), cmfang@fudan.edu.cn (C. Fang).

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Table 1
Characteristics of sampling sites used for the incubation study.

Site name	Type	Location	MAT (°C)	MAP (mm)	Total C (%)	Total N (%)	C:N ratio	pH	Silt (%)	Sand (%)
Tibetan Plateau (TPW)	Alpine Wetlands	37°36′N, 101°19′E	−2	380	21.31 ± 0.11	1.37 ± 0.002	15.59 ± 0.11	7.15 ± 0.02	58.67 ± 0.44	40.25 ± 0.56
Tibetan Plateau (TPM)	Alpine Meadow	37°36′N, 101°19′E	−2	380	22.70 ± 0.10	1.60 ± 0.008	14.23 ± 0.13	7.99 ± 0.10	49.69 ± 0.32	49.47 ± 0.54
Qinghai Lake (QHL)	Saltwater Lake	36°48′N, 100°45′E	−0.1	412	1.96 ± 0.05	0.10 ± 0.004	19.83 ± 0.36	9.66 ± 0.06	13.91 ± 0.31	85.47 ± 0.78
Jiamusi (JM)	Temperate Paddy	47°39′N, 133°35′E	2.5	644	2.64 ± 0.05	0.28 ± 0.007	9.28 ± 0.06	5.89 ± 0.09	91.42 ± 0.33	0.71 ± 0.24
Sanjiang Plain (SPF)	Temperate Fen	47°34′N, 133°29′E	2.1	619	11.93 ± 0.53	0.71 ± 0.012	16.86 ± 0.57	5.75 ± 0.15	84.71 ± 0.63	11.24 ± 0.72
Sanjiang Plain (SPM)	Temperate Wet Meadow	47°35′N, 133°28′E	2.1	619	7.90 ± 1.19	0.57 ± 0.076	13.67 ± 0.30	6.02 ± 0.12	92.26 ± 0.55	1.92 ± 0.30
Yancheng (YSM)	Salt Marsh	33°04′N, 120°52′E	14.5	984	1.52 ± 0.03	0.07 ± 0.005	22.42 ± 1.43	7.39 ± 0.07	86.98 ± 1.36	8.99 ± 1.58
Jiaxing (JX)	Subtropical Paddy	30°39′N, 120°50′E	15.9	1168	2.51 ± 0.02	0.30 ± 0.001	8.45 ± 0.01	6.60 ± 0.03	90.22 ± 0.40	6.40 ± 0.31
Poyang (PYL)	Freshwater Lake	28°57′N, 116°21′E	17.8	1301	1.32 ± 0.005	0.19 ± 0.001	7.07 ± 0.05	4.68 ± 0.07	90.00 ± 1.02	5.04 ± 0.55

MAT, mean annual air temperature; MAP, mean annual precipitation.

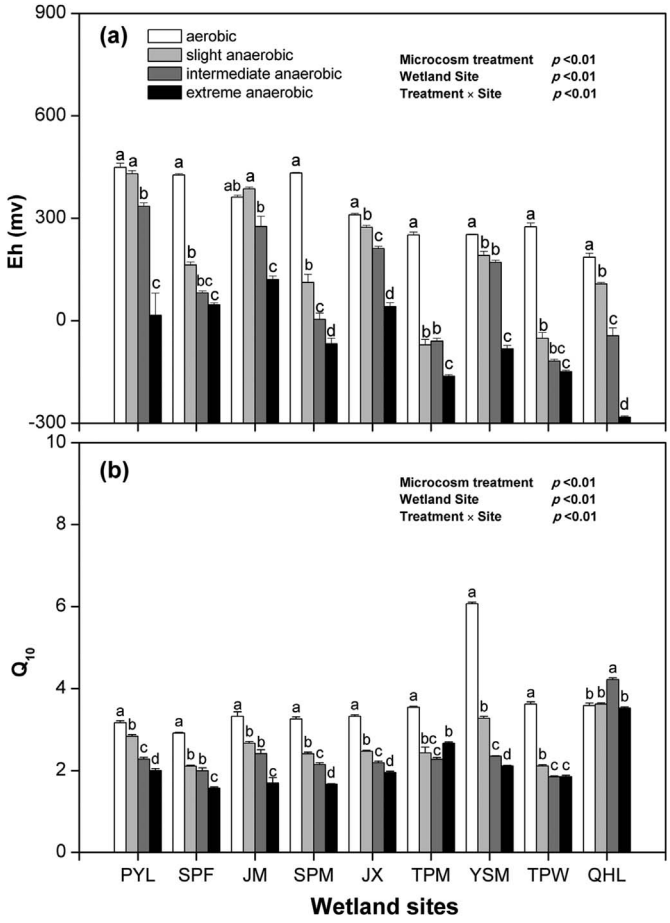

Fig. 1. The redox potential (Eh) (a) and Q_{10} values (b) under four microcosm treatments for nine wetland sites. Wetland site codes and associated properties are given in Table 1. Different letters denote a significant difference ($p < 0.05$) when comparing the variance among different microcosm treatments within each site according to Tukey HSD test. Data are the means ± SE (n = 4).

down to 0–20 cm depth were collected using an auger of 8 cm inner diameter. The three soil cores were thoroughly mixed and passed through a 2-mm sieve. Soil sample of each location, equivalent to 20 g dry weight, was then placed in a 250-mL glass serum bottle. Soil moisture content and headspace O_2 were strictly controlled to create different redox microenvironments (Fig. 1a): aerobic, slight anaerobic, intermediate anaerobic, and extreme anaerobic. Soil water contents were adjusted to 60% and 100% of water-holding capacity (WHC) for aerobic and slight anaerobic treatments, respectively. For intermediate anaerobic incubation, fresh soil and water were mixed in a 1:2 ratio to mimic flooded conditions. Extreme anaerobic microcosms were prepared in a manner similar to intermediate anaerobic treatment, except that deoxygenated water was added and the headspace of incubation microcosms was flushed with high purity N_2 gas. The deoxygenated water was made by flushing high purity N_2 gas through the water for 1 h. The extreme anaerobic microcosms were tightly capped with grey butyl stoppers throughout the experiment, whereas the microcosms for other treatments (aerobic, slight anaerobic and intermediate anaerobic) were regularly ventilated to maintain fresh air in the headspace.

All microcosms were incubated under changing temperatures manipulated by a cryogenic thermostatic bath (precision: ± 0.1 °C) following Fang et al. (2005) and Chen et al. (2010). Soils were pre-incubated at 20 °C for a week to minimize the initial disturbance. The incubation temperature was sequentially varied between 4 and 28 °C (changed from 4 °C to 28 °C and then back to 4 °C with a step length of 4 °C). Each temperature was held for *ca* 8 h for measuring soil respiration. The headspace CO_2 concentration in gas samples was