



# Boreal forest soil CO<sub>2</sub> and CH<sub>4</sub> fluxes following fire and their responses to experimental warming and drying

Xiaoyan Song<sup>a,b</sup>, Genxu Wang<sup>a,\*</sup>, Zhaoyong Hu<sup>a</sup>, Fei Ran<sup>a</sup>, Xiaopeng Chen<sup>a,b</sup>

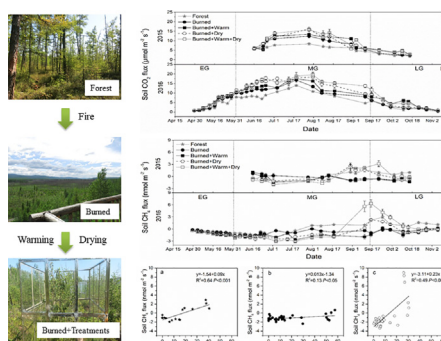
<sup>a</sup> Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu 610041, People's Republic of China

<sup>b</sup> University of Chinese Academy of Sciences, Beijing 100049, People's Republic of China

## HIGHLIGHTS

- Post-fire boreal forest had higher soil CO<sub>2</sub> flux than the mature forest.
- Fire changed the boreal forest soil from a weak source of CH<sub>4</sub> to a weak sink.
- Warming, drying and their combination made the post-fire soil a stronger C flux.

## GRAPHICAL ABSTRACT



## ARTICLE INFO

### Article history:

Received 21 April 2018

Received in revised form 1 July 2018

Accepted 1 July 2018

Available online xxxx

Editor: Jay Gan

### Keywords:

Soil carbon emissions

Simulated warming

Drying

Permafrost

Post-fire ecosystem

## ABSTRACT

Boreal forests store large amounts of organic carbon and are susceptible to climate changes, particularly rising temperature, changed soil water and increased fire frequency. The young post-fire ecosystems might occupy larger proportions of the boreal forests region with the expected increases in fire frequency in the future and change the carbon (C) balance of this region. However, it is unclear how soil C fluxes in the post-fire boreal forest response to the climate changes. Therefore, a two-year field experiment was conducted in a boreal forest to investigate the effects of fire on the soil C (CO<sub>2</sub> and CH<sub>4</sub>) fluxes and the responses of these fluxes to simulated warmer and drier climate conditions. The results showed that the boreal forest recovered from wildfire 7–8 years had higher soil CO<sub>2</sub> flux than the mature forest. Furthermore, the treatments of warming, drying and the combination of warming and drying increased growing season cumulative soil CO<sub>2</sub> flux in the post-fire forest by 15.8%, 20.4% and 34.2%, respectively. However, the boreal forest soil changed from a weak CH<sub>4</sub> source to a weak CH<sub>4</sub> sink after fire disturbance. Although CH<sub>4</sub> absorption increased by warming and drying treatments, the interaction of warming and drying led to a decrease in soil CH<sub>4</sub> uptake. The results indicated that the post-fire soil showed CO<sub>2</sub> and CH<sub>4</sub> fluxes with a greater global warming potential than before burning and that the global warming potential of the soil gas fluxes further increased by warming and drying. The predictive power of models of C cycle-climate feedbacks could be increased by incorporating the distinct ecosystem following fire with permafrost degradation and climate change across the boreal zone.

© 2018 Elsevier B.V. All rights reserved.

\* Corresponding author.

E-mail address: [wanggx@imde.ac.cn](mailto:wanggx@imde.ac.cn) (G. Wang).

## 1. Introduction

In the high-latitude regions of the earth, temperatures have risen 0.6 °C per decade over the last 30 years, which is twice as fast as the global average (IPCC, 2013), and this trend will likely continue in the future (Overland, 2014). Climate warming in these regions may have biogeochemical consequences because these regions contain large stocks of soil organic matter (Hugelius et al., 2014; Tarnocai et al., 2009), especially the boreal forests, which store 1095 Pg of C, representing more than one-third of global terrestrial C stocks (Bradshaw and Warkentin, 2015).

In boreal forest under a warmer climate, soil C releases are likely to increase due to stimulated soil microbial activities, particularly in association with soil warming and permafrost thawing (Jorgenson et al., 2001; O'Donnell et al., 2012; Kim, 2015; Schädel et al., 2016). The extent of permafrost is expected to continue to decline with future warming (Lawrence et al., 2012; Slater and Lawrence, 2013), which can release a large amount of thermally protected C (permafrost C) to the atmosphere (Lawrence et al., 2012; Schuur et al., 2008; Schuur et al., 2013; Slater and Lawrence, 2013), further amplifying climate change (Macdougall et al., 2012). Moreover, the potential loss of soil C to the atmosphere is also driven by the soil hydrological processes which associated with the local hydrological and topographical conditions (Morgenstern et al., 2013) and the changes in the precipitation patterns (Bintanja and Selten, 2014; Held and Soden, 2006). Although the increase in the soil CO<sub>2</sub> flux in response to a warmer climate may be limited by saturated soil conditions (Lawrence et al., 2015), such conditions are expected to decrease in some areas in the future because of permafrost degradation (Avis et al., 2011; Lawrence et al., 2015), forming stronger positive feedbacks on climate (Lawrence et al., 2015; Schädel et al., 2016). On the other hand, the production of CH<sub>4</sub>, a powerful greenhouse gas (IPCC, 2013), might be limited by the drainage of water following permafrost thaw, leading to negative feedbacks. Therefore, how the soil C flux responds to combined warming and drying is closely related to the form of C (CO<sub>2</sub> or CH<sub>4</sub>) released to the atmosphere, but few studies have focused on both CO<sub>2</sub> and CH<sub>4</sub> fluxes (Natali et al., 2015; Updegraff et al., 2001). Artificially drained or lowered water tables have been shown to result in a consistent increase in soil CO<sub>2</sub> release (Merbold et al., 2009) or a reduction in CH<sub>4</sub> fluxes during the growing season (Merbold et al., 2009; Kim, 2015; Kwon et al., 2017; Sturtevant et al., 2012) due to more oxic conditions and shifts in microbial activity and community structure. These results are the same for the predicted results of soil C fluxes with decreased soil water when permafrost thaws (Lawrence et al., 2015). However, how soil drying combined with warming affects soil CO<sub>2</sub> and CH<sub>4</sub> fluxes is still unclear due to the limited number of *in situ* experiments manipulated both moisture and temperature (Chivers et al., 2009; Natali et al., 2015; Turetsky et al., 2008; Updegraff et al., 2001).

Boreal forests are also strongly affected by wildfires, which instantaneously release large amounts of C to the atmosphere from combustion (Mack et al., 2011). Following fire, the ecosystem C balance was presumably altered due to the changes of surface reflectance, energy partitioning, and because the reducing of soil organic layer insulating permafrost led to thaw and destabilization of the ground surface (Mack et al., 2011). The boreal forests would act as C sources about 10 years following fire disturbance until a C compensation point where net ecosystem production (NEP) becomes positive is reached (Amiro et al., 2015; Kurz et al., 2013). Meanwhile, these young post-fire forests will occupy a larger fraction of the boreal regions due to the increased effects of fire under climate change (Abbott et al., 2016). Furthermore, the long-term recovery of C balance and organic carbon stocks in the burned forest are likely to be primarily driven by the warming climate (Jiang et al., 2016). Therefore, it is important to understand the post-fire soil C fluxes and their responses to climate changes (such as climate warming and dryer soil conditions) when predicting the C balance of boreal regions in the future. Although the young post-

fire boreal forest with changed vegetation and soil microbial communities, modified soil nutrient availability and induced permafrost degradation might be more sensitive to perturbations than mature systems based on the feature of ecosystem (Kröel-Dulay et al., 2015) and interact with climate changes (Allison et al., 2010; Brown et al., 2015; Jiang et al., 2016; Kim and Tanaka, 2003), the knowledge of how post-fire boreal forest soil CO<sub>2</sub> and CH<sub>4</sub> fluxes response to warming and drying is still limited.

Therefore, we examined the soil C fluxes of a young post-fire boreal forest and their responses to combined warming and drying, which are the key climate change processes in the boreal permafrost region. This work was conducted in a continuous permafrost region of the DaXing'anling Mountains, which plays an important role in the C budget of China (Fang et al., 2001). Because this region is at the southern boundary of the boreal forests, the study area is extremely sensitive to climate change (Peng et al., 2009). We hypothesized that 1) soil CO<sub>2</sub> flux in the post-fire boreal forest would be higher than that in the mature forest and further increased by warming and drying, but 2) soil CH<sub>4</sub> flux in the post-fire forest would be lower than that in the mature forest and further decreased by warming and drying.

## 2. Materials and methods

### 2.1. Study site

The experiment was located in the northern DaXing'anling Mountains (51.892° N, 121.912° E, 654 m a.s.l.), Northeast China. The study site is situated in the continuous permafrost zone. The annual average precipitation of the study area is approximately 500 mm, >60% of which occurs between June and August. The annual average temperature is −3.6 °C, with an average of −29.8 °C in the coldest month, January, and an average of 18.1 °C in the hottest month, August. Therefore, it has a terrestrial monsoon climate. The soil type is classified as Gelisols according to the USDA or as Crysols in the WRB scheme (Bockheim, 2015), and the details of the soil properties are shown in Supplementary Table A. The soil has an organic horizon that is 35 ± 2 cm thick above the mineral soil. The active layer, which thaws annually during the growing season, reaches a maximum depth of 44 ± 3 cm, below which is the perennially frozen permafrost layer. The vegetation of this area is classified as cool temperate coniferous forest in the southern extent of the eastern Siberian boreal forests (Wang et al., 2001).

In 2008, an extremely intense fire caused by lightning strikes burned approximately 478 ha of mature *Larix gmelinii* forest (117 ± 5 years) and resulted in most mortality of the overstory and ground cover and combustion of approximately 5 cm of the forest floor. Six years after the wildfire, many of the dead trees were still standing, and many shrubs <2 m (such as *Alnus hirsuta*, *Betula fruticosa*, *Ledum palustre* and *Vaccinium uliginosum*), grasses (such as *Calamagrostis* and *Carex*) and mosses (such as *Sphagnum* and *Polytrichum*) had recovered. The warming and drying experiment is situated in this fire scar (Supplementary Fig. A) in a relatively well-drained depression. To investigate the fire effects, we chose a comparable un-burned forest site (Supplementary Fig. B) that was adjacent to the burned site (<1 km) and that had a similar environmental conditions and similar vegetation composition to the burned site before the fire. The mature forest was located in a depression. The tree layer was dominated by *Larix gmelinii* with a canopy density of 0.6, density of 625 trees ha<sup>−1</sup>, mean height of 16.4 m and mean diameter at breast height of 17.1 cm. The shrub layer was dominated by *Ledum palustre*; and the ground cover was dominated by *Sphagnum*, *Calamagrostis* and *Carex*.

### 2.2. Experimental design

We had a total of five treatments (forest, burned, burned + warm, burned + dry and burned+warm+dry) with six replicates of each

Download English Version:

<https://daneshyari.com/en/article/8858669>

Download Persian Version:

<https://daneshyari.com/article/8858669>

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