Investigating Impacts of Seedling Removal on Soil and Ground-level Vegetation Respiration (CO2 and CH4) in a Restored Peatland Ecosystem

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Table of contents

# 1. Introduction

## 1.1 The Carbon Cycle in Peatlands

### 1.1.1 Land-atmosphere Exchanges of Carbon Fluxes

Chapin et al. (2006) proposed the term net ecosystem carbon balance (NECB) as the overall ecosystem C balance from all sources, including C pathways between terrestrial and atmosphere, terrestrial and aquatic and particulate transport, which represents the net rate of C accumulation in ecosystems. In most peatlands, NECB can be simplified as - NEE/FCO2 (net ecosystem exchange, the net CO2 flux between terrestrial ecosystems and atmosphere) + FCH4 (net CH4 flux between terrestrial ecosystems and atmosphere) + FDOC (net dissolved organic carbon) (Strack and Zuback 2013; D′Acunha et al. 2019). The land-atmosphere exchange of C fluxes include the two components of NECB, FCO2 and FCH4. The FCO2 (NEE) represents the difference between ecosystem respiration (Reco) and photosynthesis (Gross primary productivity, GPP) between the bog and atmosphere. Negative NEE values indicate a carbon sink peatland, which takes up more CO2 from the atmosphere and accumulates in terrestrial ecosystems.

The land-atmosphere exchanges of carbon fluxes in peatlands can be described using the acrotelm-catotelm model (Figure 1). The balance between photosynthesis, respiration and diffusion mainly represents the net FCO2 between the bog and the atmosphere. Autotrophic organisms convert CO2 from the atmosphere into chemical energy through photosynthesis. CO2 is released from ecosystems by Reco and diffusion. Reco including above- and below-ground autotrophic and heterotrophic respiration (Ra and Rh, respectively). Both Ra and Rh in bogs involve the consumption of organic matter and oxygen to produce energy, water, and carbon dioxide. The CO2 produced by aerobic decomposition and methanotrophy, the oxidation of CH4 by methanotrophs, diffused into the atmosphere (Bridgham et al. 2013). CH4 is made in the saturated zone of peat soils by methanogenic microbes. There are two primary pathways for methanogenesis in wetlands: acetoclastic and hydrogenotrophic methanogenesis (Bridgham et al. 2013). Acetoclastic methanogens utilize acetate as their primary electron acceptor during the methanogenesis process. Hydrogenotrophic methanogens rely on the utilization of hydrogen (H2) and CO2 as substrates for methanogenesis (Fenchel, King, and Blackburn 2012). Bogs tend to be generally dominated by hydrogenotrophic methanogenesis (Bridgham et al. 2013). CH4 flux is emitted to the atmosphere through three main pathways: diffusion (driven by CH4 concentration gradients from the peat to the atmosphere), ebullition (bubbles released from saturated peat), and plants-mediated transport (through aerenchyma, the plants’ internal gas-space ventilation system) (Holden 2005). CH4 fluxes from peatlands are the net balance of CH4 production (methanogenesis) in the saturated zones of the peat and CH4 oxidation in the oxic peat layers (methanotrophy) (Bridgham et al. 2013; White et al. 2008).

### 1.1.2 Biophysical Controls of Ecosystem Respiration and FCH4

Bridgham, Scott D., Hinsby Cadillo-Quiroz, Jason K. Keller, and Qianlai Zhuang. 2013. “Methane Emissions from Wetlands: Biogeochemical, Microbial, and Modeling Perspectives from Local to Global Scales.” *Global Change Biology* 19 (5): 1325–46. <https://doi.org/10.1111/gcb.12131>.

Chapin, F. S., G. M. Woodwell, J. T. Randerson, E. B. Rastetter, G. M. Lovett, D. D. Baldocchi, D. A. Clark, et al. 2006. “Reconciling Carbon-Cycle Concepts, Terminology, and Methods.” *Ecosystems* 9 (7): 1041–50. <https://doi.org/10.1007/s10021-005-0105-7>.

D′Acunha, Brenda, Laura Morillas, T. Andrew Black, Andreas Christen, and Mark S. Johnson. 2019. “Net Ecosystem Carbon Balance of a Peat Bog Undergoing Restoration: Integrating CO 2 and CH 4 Fluxes From Eddy Covariance and Aquatic Evasion With DOC Drainage Fluxes.” *Journal of Geophysical Research: Biogeosciences* 124 (4): 884–901. <https://doi.org/10.1029/2019JG005123>.

Fenchel, T, G.M. King, and T.H. Blackburn. 2012. *Bacterial Biogeochemistry*. Elsevier. <https://doi.org/10.1016/C2010-0-67238-5>.

Holden, Joseph. 2005. “Peatland Hydrology and Carbon Release: Why Small-Scale Process Matters.” *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 363 (1837): 2891–2913. <https://doi.org/10.1098/rsta.2005.1671>.

Strack, M., and Y. C. A. Zuback. 2013. “Annual carbon balance of a peatland 10 yr following restoration.” *Biogeosciences* 10 (5): 2885–96. <https://doi.org/10.5194/bg-10-2885-2013>.

White, Jeffrey R., Robert D. Shannon, Jake F. Weltzin, John Pastor, and Scott D. Bridgham. 2008. “Effects of Soil Warming and Drying on Methane Cycling in a Northern Peatland Mesocosm Study.” *Journal of Geophysical Research* 113 (July): G00A06. <https://doi.org/10.1029/2007JG000609>.