Global Change Biology

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RESEARCH ARTICLE

Permafrost Thaw Accelerates Old Soil Carbon Release, Outpacing New Plant Inputs During a 13-Year Tundra Warming Experiment

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Received: 12 June 2025 | **Revised:** 19 September 2025 | **Accepted:** 10 October 2025

Keywords: Arctic | deep soil organic carbon | permafrost | radiocarbon | shrubs | soil organic carbon | soil warming

ABSTRACT

Massive stores of ancient soil organic carbon (SOC) in permafrost can decompose with Arctic warming and accelerate global climate change. Declining SOC stocks are central to the permafrost carbon feedback, but direct measures of SOC loss are extremely rare due to methodological challenges related to subsidence in the Arctic. To fully capture changing SOC dynamics during thaw, we directly measured SOC stock and bulk soil radiocarbon (^{14}C) changes, while accounting for subsidence, during 13 years of permafrost thaw in a warming experiment in Interior Alaska. We found significant declines in SOC stocks: 14% (±6%) in ambient plots that experienced regional warming and 23% (±5%) in snow fence warmed plots, entirely in deep, mineral soil layers. Losses were largely driven by winter soil warming but were mediated by changing soil moisture and vegetation conditions. Plots with low shrub biomass had greater SOC losses, suggesting that vegetation community composition may play an important role in SOC storage. Surface soil ^{14}C measurements suggest that carbon inputs were three times greater in warming plots compared to ambient plots, but that decomposition increased proportionally leading to no detectable change in surface organic layers. We observed significant SOC losses of 5.2–8.1 kg C m^{-2} from deeper soil layers where carbon was sequestered ~2400 to ~4500 years ago. Our findings indicate that warmer soils in the winter will accelerate SOC losses, but that increasing density of shrub species through shrub expansion could help to mitigate SOC losses in deep soils. The significant loss of SOC from deep, mineral soils observed over just 13 years of ambient and experimental permafrost thaw highlights the vulnerability of this old C pool as it enters the active global carbon cycle.

1 | Introduction

Permafrost, perennially frozen ground and soil, covers only 15% of Earth's land surface area, but contains one-third of global soil organic carbon (SOC) stores (Schuur et al. 2015). As Arctic temperatures rise, these disproportionately large stores of SOC are thawing and becoming vulnerable to microbial decomposition, potentially resulting in massive emissions of greenhouse gases carbon dioxide (CO_2) and methane (CH_4). The release of permafrost SOC sets a global feedback into motion as greater atmospheric carbon (C) increases temperatures, further thawing permafrost soils (Schuur et al. 2008). By the end of the century,