^{14}C and ^{13}C of emitted CO_2 and CH_4 and peat at SPRUCE

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Background

- Natural wetlands release approximately one-third of global CH_4 emissions to the atmosphere.
- Northern peatlands cover < 3% of the Earth's surface, but contain 550 Pg of carbon (> 20% of carbon stored on land)
- Changes in climate could result in favorable conditions for microbial decomposition and release of old peat carbon as CO_2 or CH_4.
- Predictions of future peatland carbon fluxes are challenged by inadequate understanding and data required for model development.

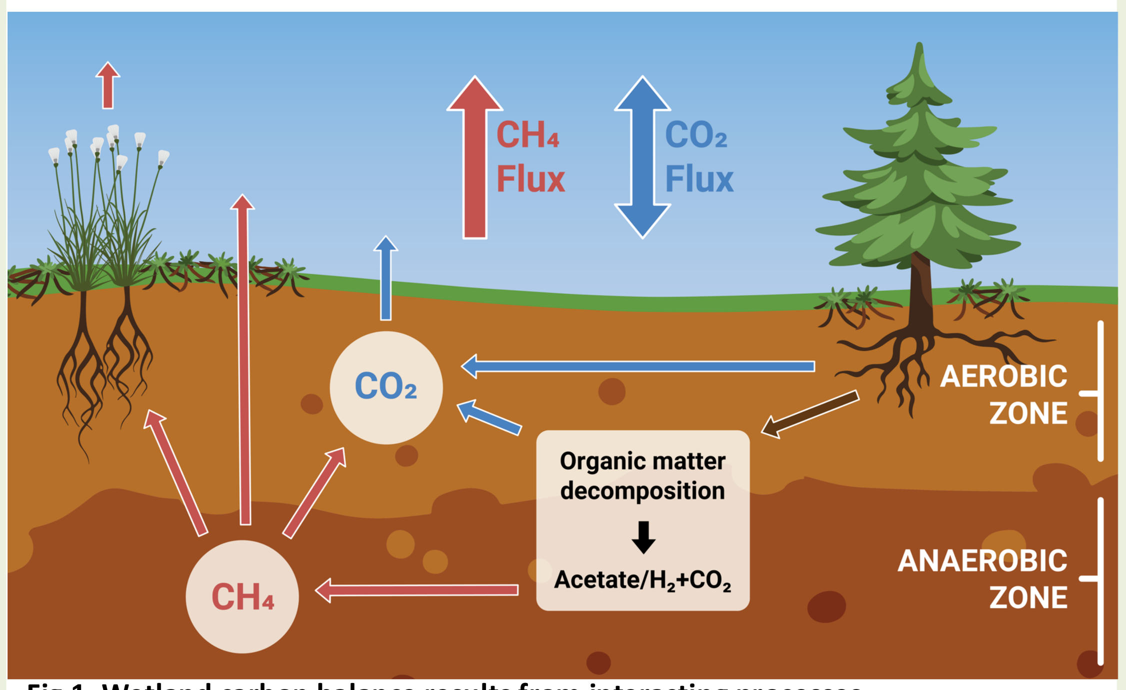

Fig 1. Wetland carbon balance results from interacting processes.

Will peatland response to a warmer climate include increased release of old carbon to the atmosphere???

SPRUCE Experiment

- Southern boreal, weakly ombrotrophic, *Picea mariana/Sphagnum* bog
- MAT = 3.4°C, MAP = 780 mm
- Whole ecosystem warming: + 0, 2.25, 4.5, 6.75, 9 °C
- eCO_2: 400, 900 ppm CO_2

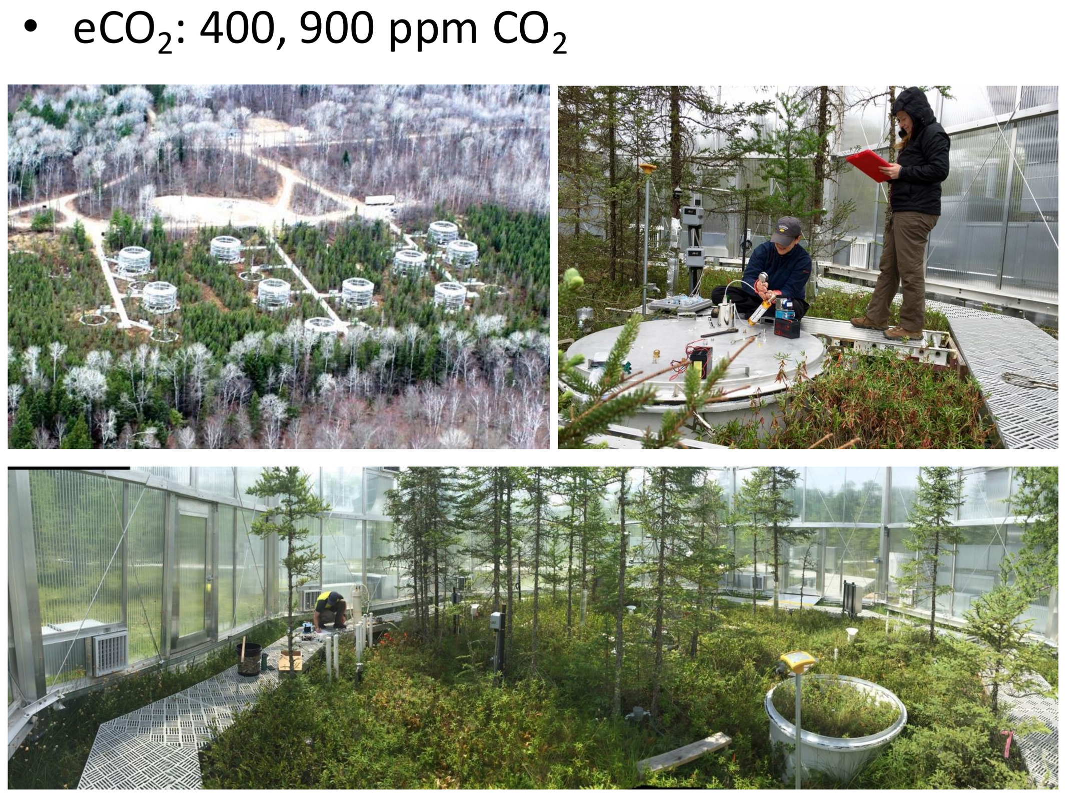

Fig 2. SPRUCE experimental infrastructure.

Approach

We seek to link subsurface processes to surface fluxes at SPRUCE with $\Delta^{14}C$ and $\delta^{13}C$ of:

1. Air collected from inside the experimental enclosures (plus 2 unchambered plots and a Met station at the bog outlet).
2. Surface-emitted CH_4 and CO_2 end-members derived with Keeling plots or isotopic mixing models correcting for background values (Table 1)
3. Bulk peat sampled in 2012 (pre-treatment) and 2020 (after 5 years of warming and 4 years of eCO_2)

Results: Treatment Enclosure Air Isotopes

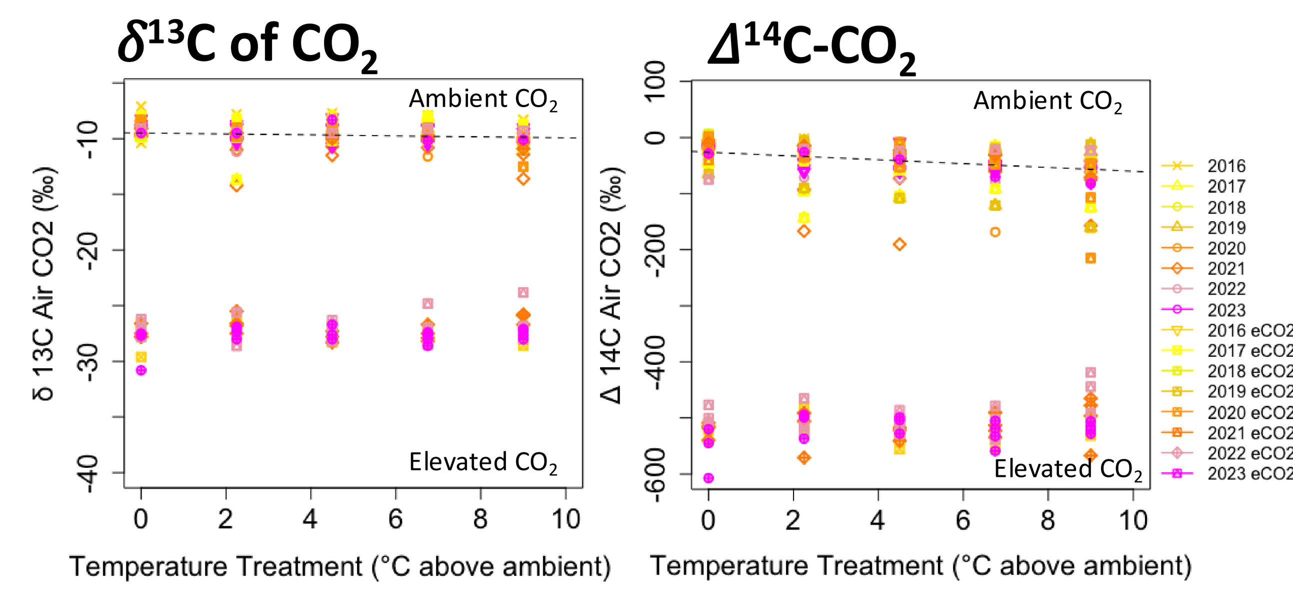

Fig 3. $\delta^{13}C$ and $\Delta^{14}C$ of CO_2 in air samples collected from ~2 m height at the center of the 10 treatment enclosures. Plots 7, 21, and met station not shown.

- Under ambient CO_2, $\delta^{13}C$ and $\Delta^{14}C$ of CO_2 decline with warming ($p = 0.01$)
- eCO_2 decreases both isotopes (eCO_2 is from fossil fuel)

Results: Surface Emitted Carbon Isotopes

- 2021 was a drought year, limiting CH_4 isotope data
- $\delta^{13}C$ of CO_2 shows no relationship with temperature under ambient CO_2

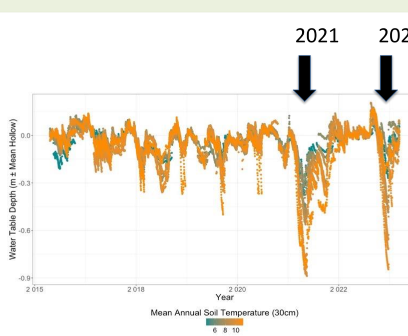

Fig 4. Water Table Depth

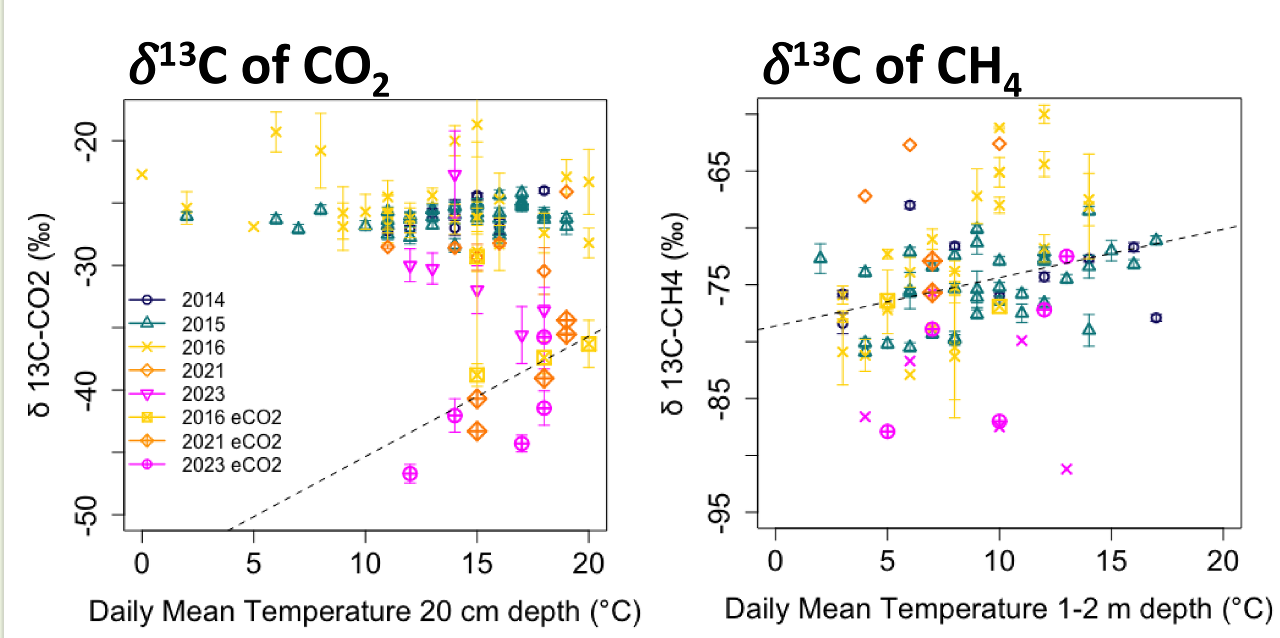

Fig 5. $\delta^{13}C$ of CO_2 and CH_4 from surface flux chambers

- $\delta^{13}C$ of CO_2 shows no relationship with temperature under ambient CO_2
- $\delta^{13}C$ of CO_2 may be increasing with increasing temperature under elevated CO_2 ($p = 0.08$, $R^2 = 0.2$)
- $\delta^{13}C$ of CH_4 increases with increasing temperature regardless of CO_2 treatment ($p = 0.01$, $R^2 = 0.1$)
- eCO_2 decreases $\delta^{13}C$, but less strongly for CH_4

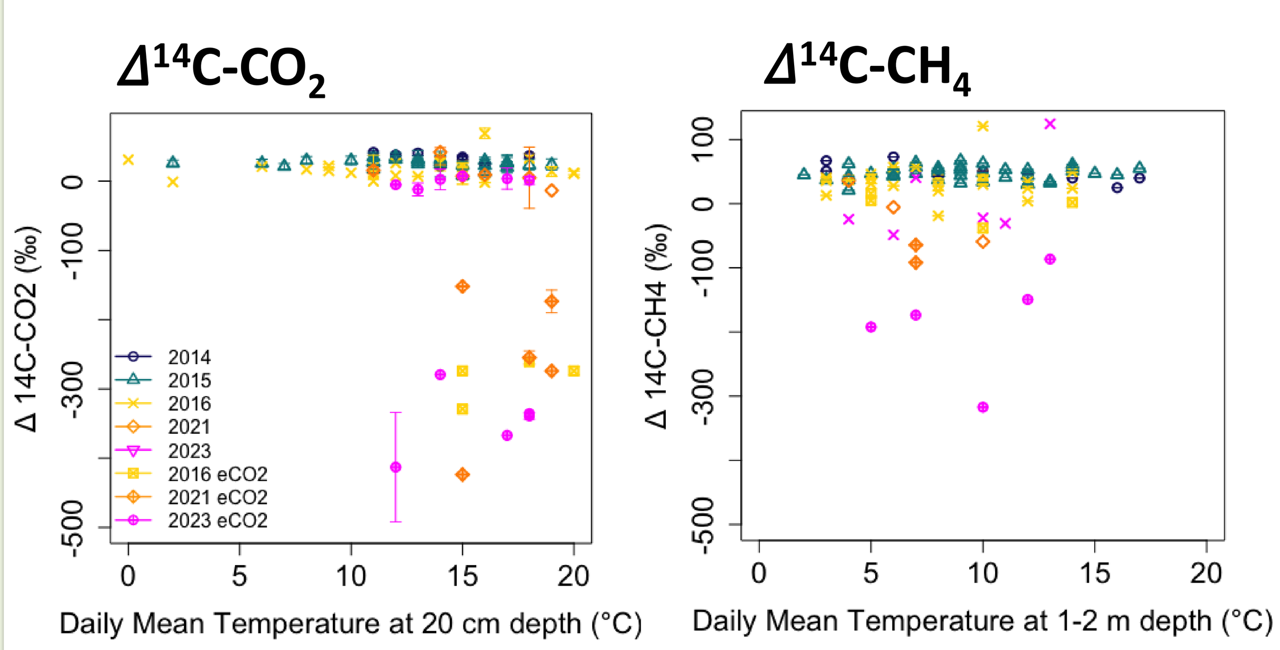

Fig 5. $\Delta^{14}C$ of CO_2 and CH_4 from surface flux chambers

- Emitted CH_4 and CO_2 is young, with little evidence of mobilization of old peat with warming
- eCO_2 decreases $\Delta^{14}C$ quickly for CO_2 than CH_4 and less strongly in warmer plots for CO_2

Results: Peat Elevation and Carbon Stocks

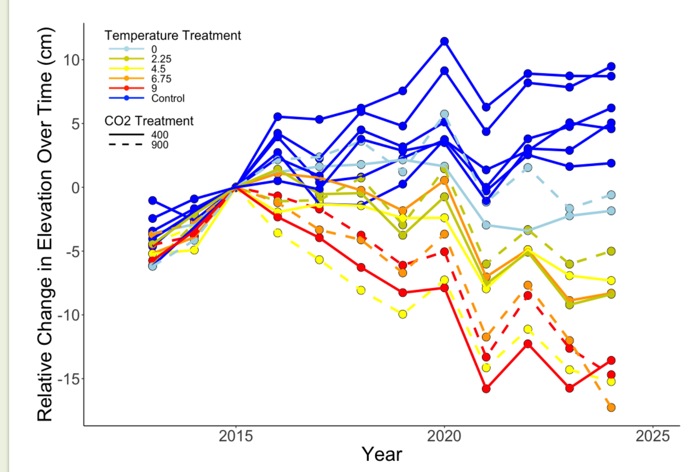

Fig 6. Elevation change relative to 2015

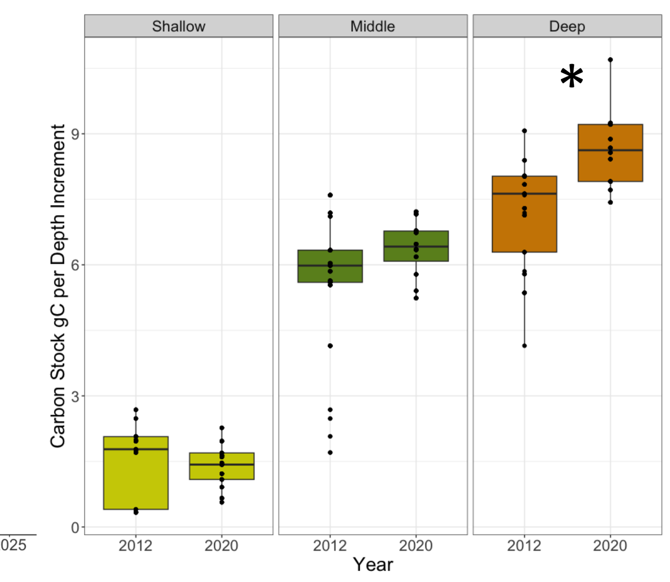

Fig 7. Peat SOC stocks in 2012 and 2020

- Elevation loss makes in warmed plots makes comparing peat characteristics challenging (Fig. 5), approaches to account for elevation changes are currently being evaluated.
- Here, we combine depth increments into shallow (0-40 cm), middle (40-100 cm), and deep (100-200 cm) depth (Fig 6). **Across treatments, peat carbon stock has increased in most plots from 2012 (pre-treatment) to 2020, with this increase mainly attributed to deep (100-200 cm) peat** ($p < 0.05$).

Results: ^{13}C and ^{14}C of peat

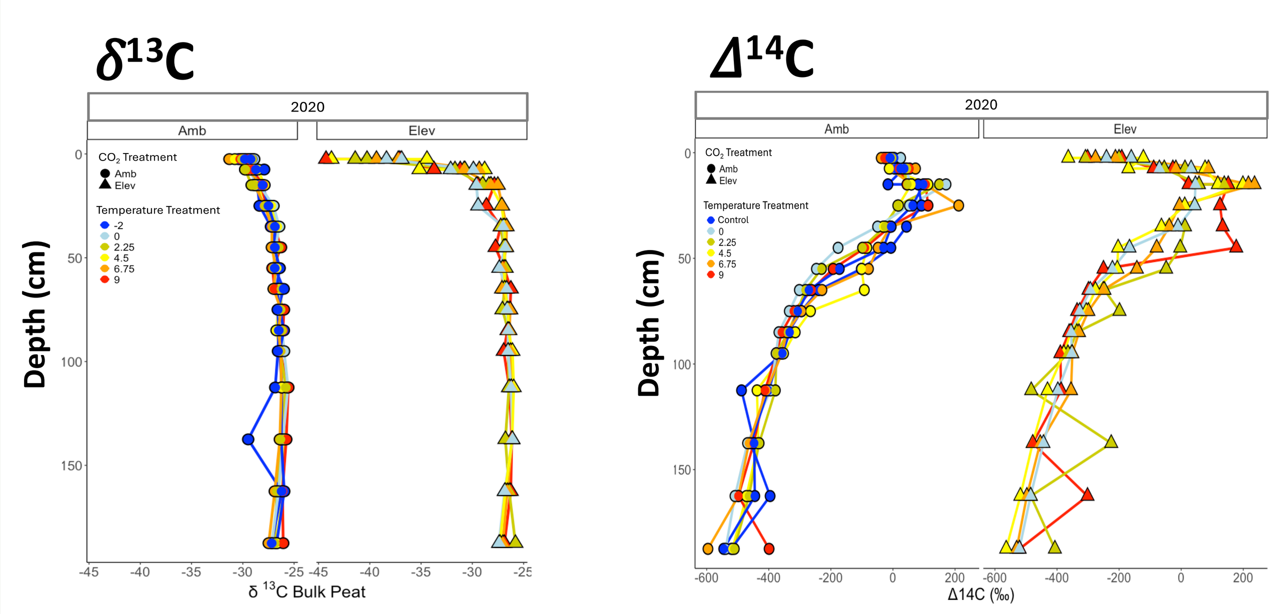

Fig 8. Bulk peat $\Delta^{14}C$ and $\delta^{13}C$ for ambient and elevated CO_2 plots in 2020.

Surface peat shows incorporation of eCO_2 signal

- Clear isotopic depletion after 4 years of eCO_2 fumigation in the top 20 cm of peat (Fig. 7), but heating effects are more subtle.

Summary and Implications

1. We found little evidence for increased use of old peat carbon after short-term warming, consistent with other research at SPRUCE.
2. Isotopically depleted eCO_2 treatments deplete $\Delta^{14}C$ and $\delta^{13}C$ of emitted CO_2 and CH_4 as well as in shallow peat.
3. Warming increases $\delta^{13}C$ of CH_4, possibly reflecting increased methane oxidation or shifts in methanogenesis pathways.

Increased carbon emissions with warming result from faster cycling of recently fixed carbon, not older peat (Scenario 1).

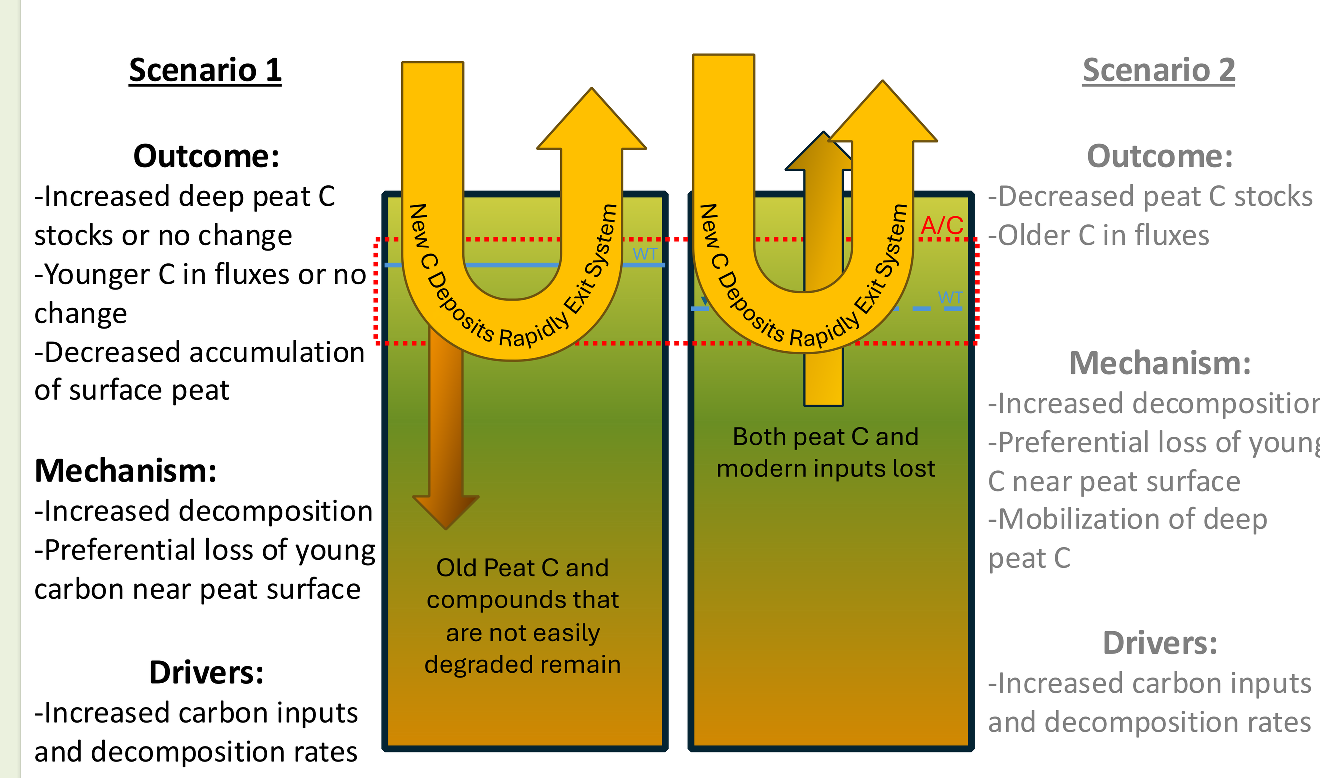

Fig 9. Conceptual model of hypothesized SPRUCE treatment effects on peat C storage and cycling

Table 1. Timelines for treatments and surface flux sampling

2014			2015					2016			2021	2023
PRE-TRT	DEEP PEAT HEATING ONLY						WHOLE ECOSYSTEM WARMING			eCO_2 + WARMING		
June	July	Aug	Apr	May	June	July	Aug	May	June	July	July	July
Plots 6, 13, and 17				All 10 treatment plots				All 10 treatment plots		All ambient plots plus 4, 10, 19	All 10 treatment plots plus plot 7	

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This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 LLNL-POST-2006056 and funded by DOE Office of Science, Office of Biological and Environmental Research, Climate and Environmental Science Division, Terrestrial Ecosystem Program and by LLNL ERD-14-038.

U.S. DEPARTMENT OF ENERGY Office of Science Biological and Environmental Research Program