Effects of Fire on Ecosystem Carbon Exchange in Siberian Larch Forest

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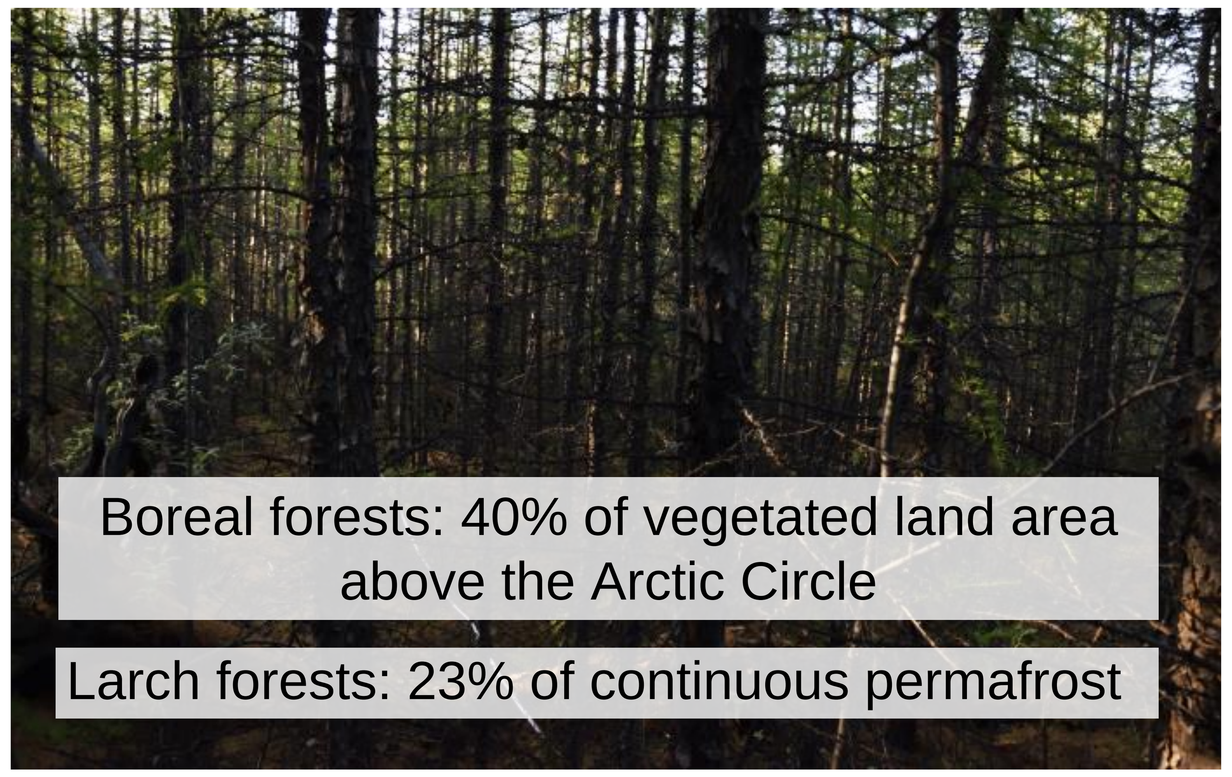
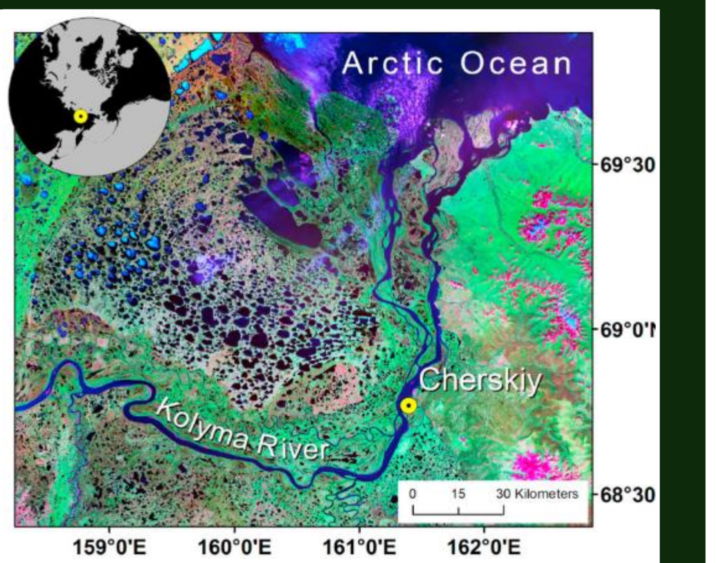
What are the effects of increased fire severity on carbon cycling in boreal forests underlain by permafrost ?

+ Fire severity
↓
- Soil organic layer
↓ ↓
+ Larch recruitment | - Soil insulation
↓ ↓
+ Stand density ⟶ Permafrost thaw
↓ ↓
+ Biomass C | Permafrost C



Study area

- Larch (*Larix cajanderi*) forest in NE Siberia
- Underlain by continuous permafrost and *yedoma* deposits

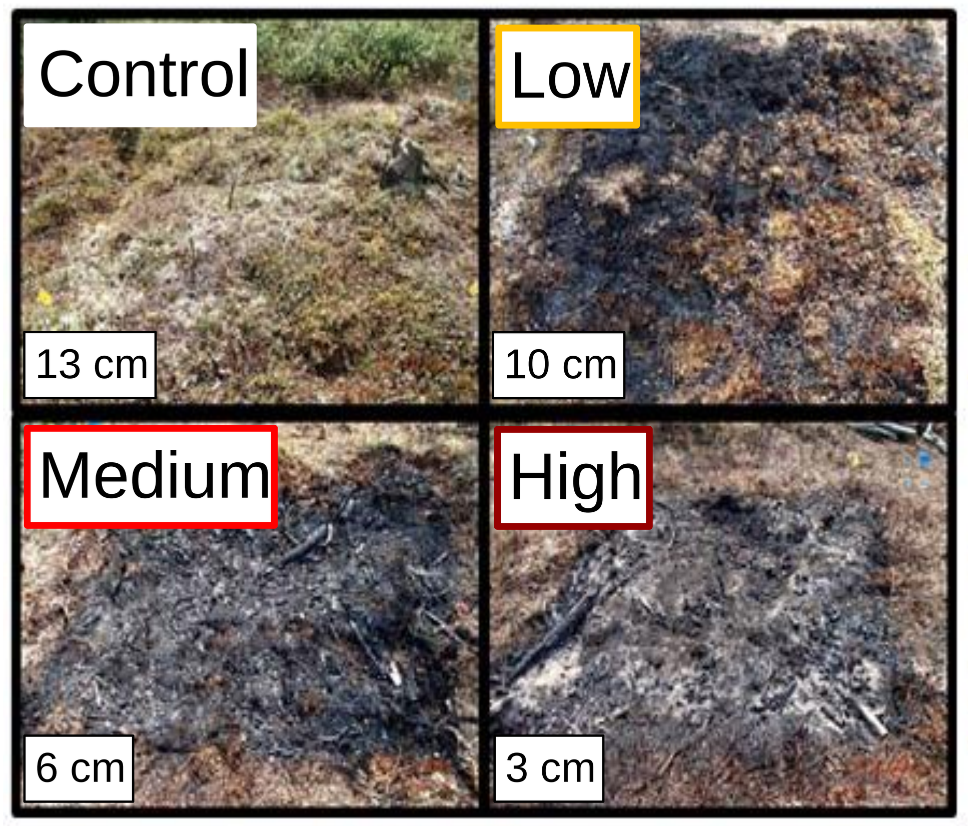


Methods

- Thaw depth, understory net ecosystem exchange (NEE), ecosystem respiration (R_{eco}) measured weekly
- Fluxes measured with Li-820 infrared gas analyzer
- Soils C pools from organic and top 10 cm mineral soils
- Larch and shrub biomass from DBH and allometry; understory from harvests

Acknowledgments: C. Connolly, S. Dunn, P. Ganzlin, P. Han, H. Pena, B. Petronio, E. Ramos, E. Webb for field assistance; NSF (# 1304040, 1304007)

Experimental Burn



Experimental burn:

- Plots (4m^2) were burned in July 2012
- Treatments (n=4): Control (clipped), Low, Medium, High severity burns
- Values represent post-burn organic layer depth.

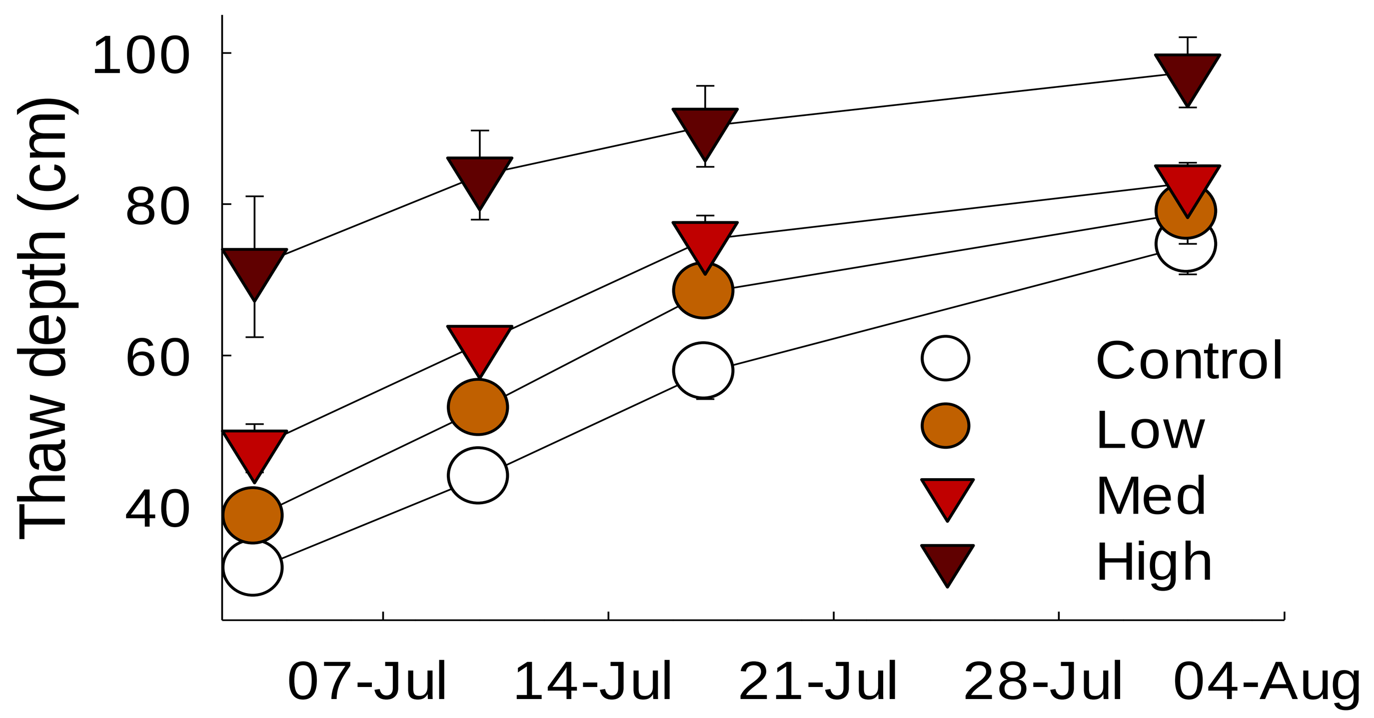


Fig 1. Burning significantly increased thaw depth in the months following the 2012 burn (not shown) and continuing through 2014 (shown here).

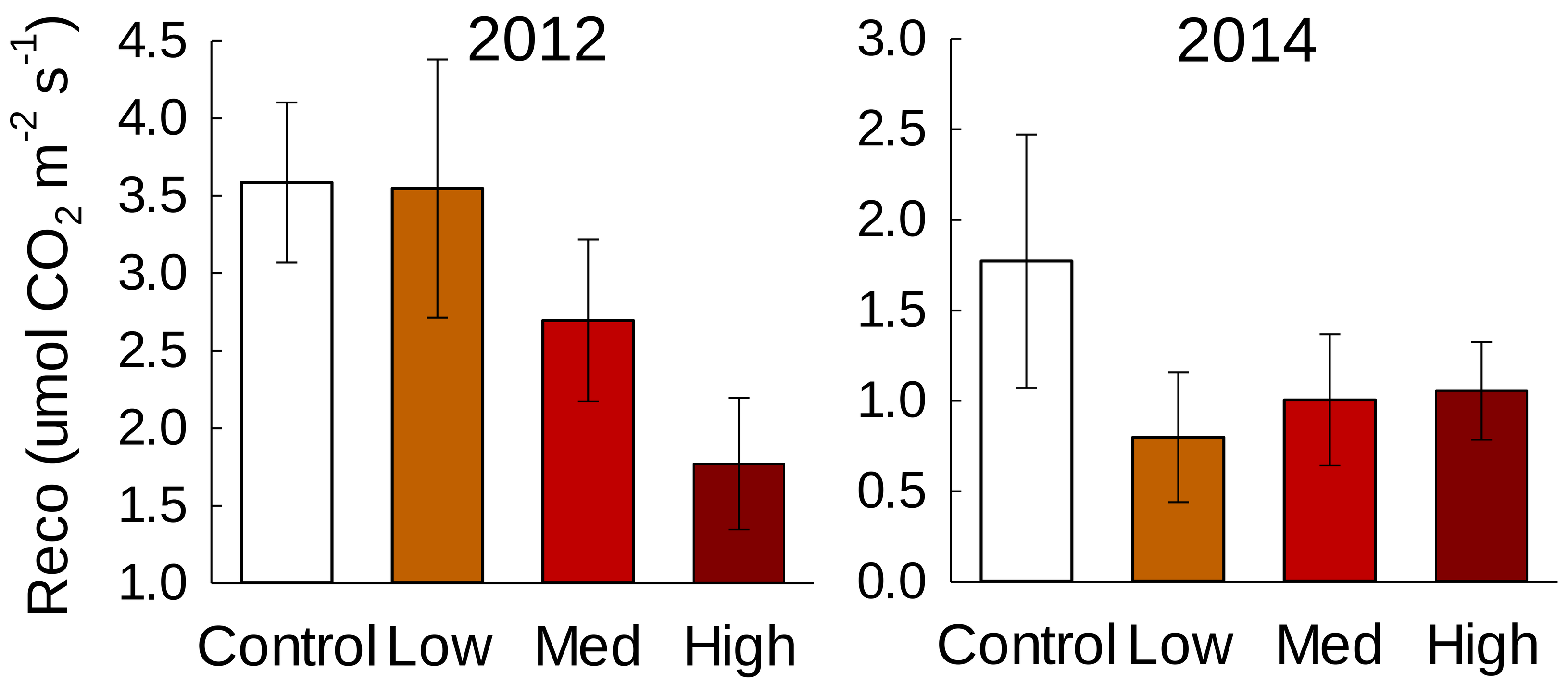
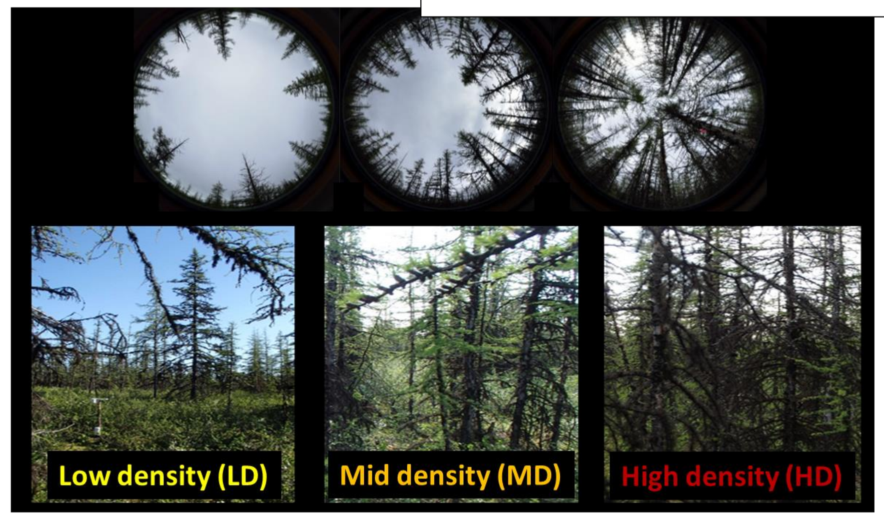
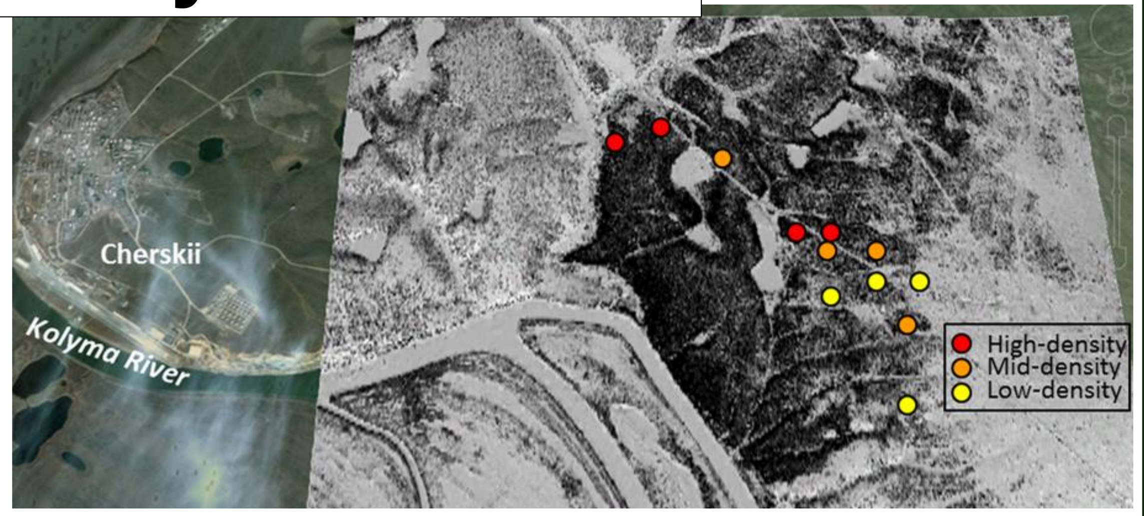


Fig 2. High intensity burning decreased R_{eco} following the 2012 fire, but by 2014 R_{eco} was similar across burn treatments. Higher R_{eco} in 2014 control plots likely reflects higher autotrophic contributions.

Stand Density Gradient





Stand Density Gradient: Low, mid, and high density stands in 75-yr-old burn scar

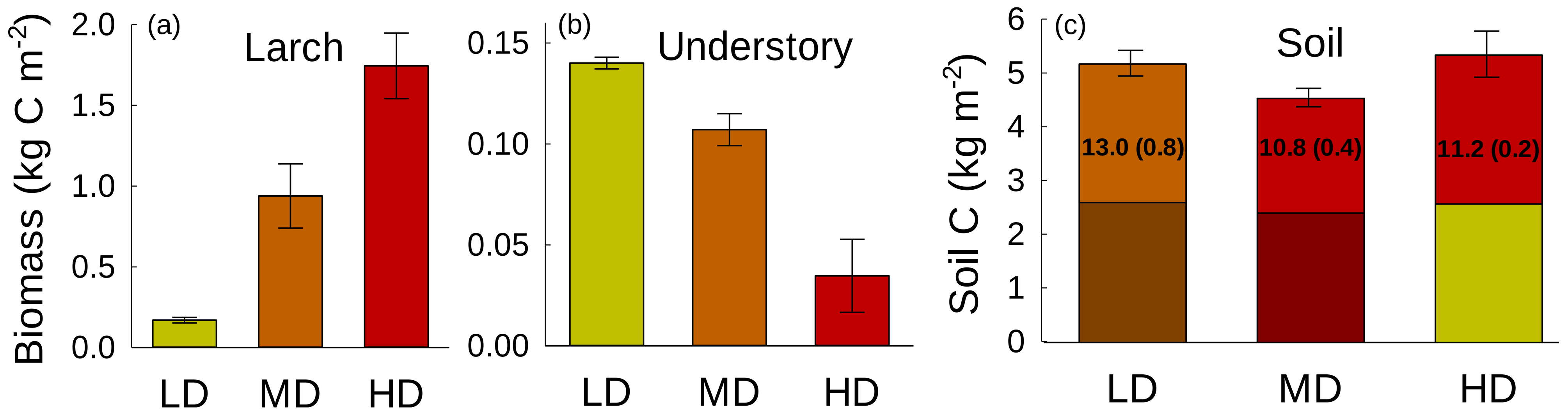


Fig. 3. Aboveground tree biomass positively related to density (a), while understory biomass decreased with density (b). Mineral soil C (c; dark shading) was similar across stands. Organic layer depth (c; numbers) and C pools (lighter shading) differences were likely due to variation in burn intensity and C accumulation rates across the density gradient.

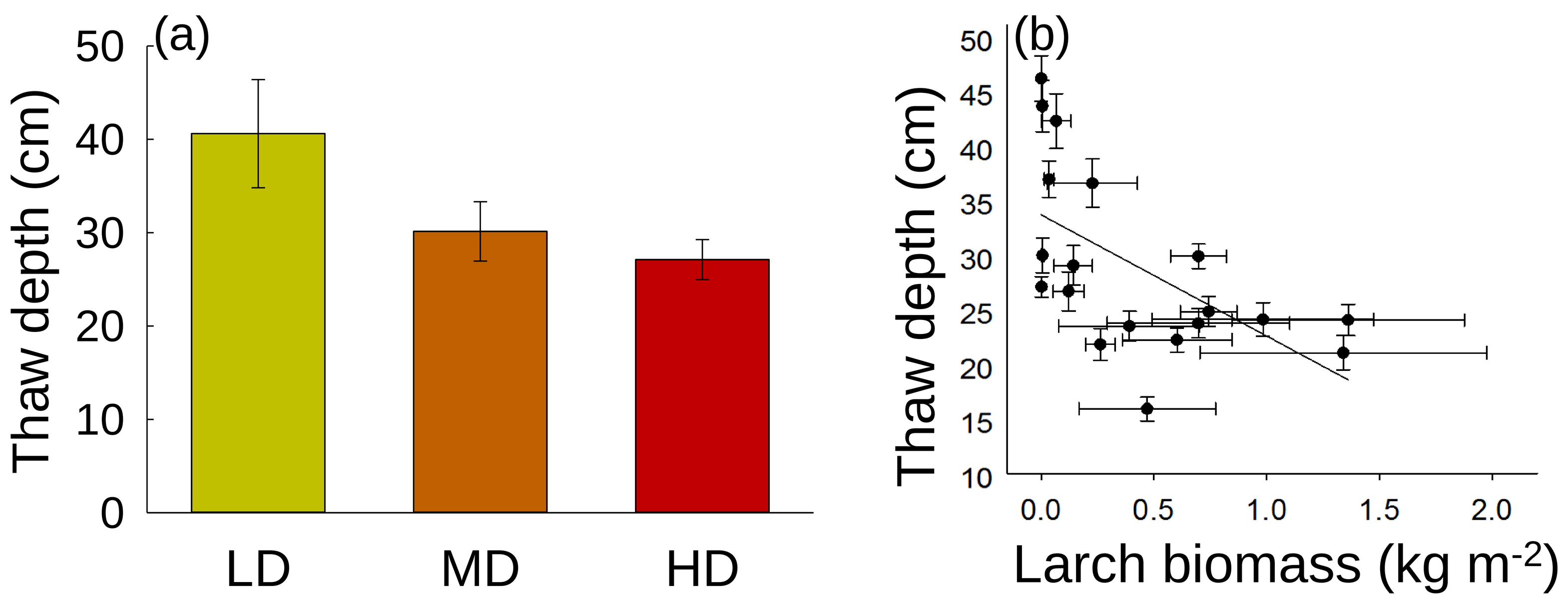


Fig 4. Thaw depth was negatively related to stand density in the 75-yr burn scar (a) and in stands across the watershed (b)

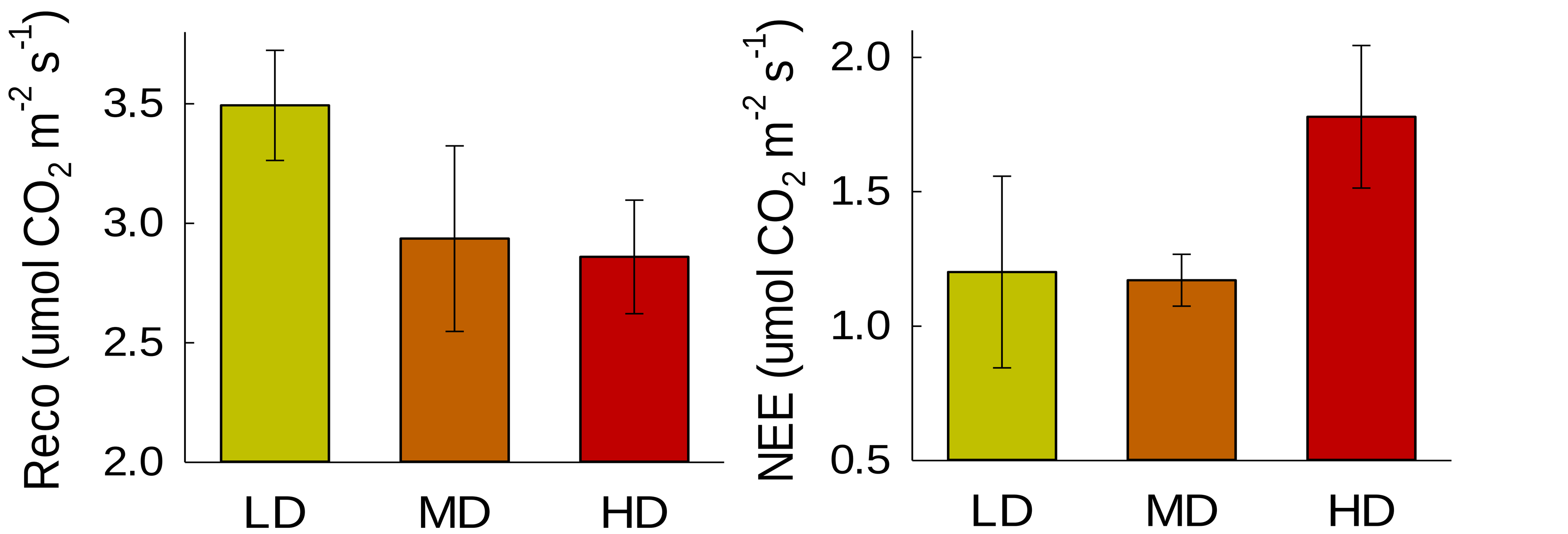


Figure 5. Understory R_{eco} was highest in LD, but net CO_2 loss (NEE) was highest in HD due to low understory biomass (Fig 3)/C uptake. Positive NEE represents CO_2 input to atmosphere.

Summary & Future Work

- Intensified fire regimes in larch forests will increase thaw and permafrost C vulnerability over short time scales (years)
- In the long-term, permafrost vulnerability and C accumulation will be driven by stand density and indirect effects of fire on permafrost thaw.
- **Future work**: 1. Stand-level annual C budgets; 2. Soil C accumulation rates; 3. Partitioning of respiration fluxes; 4. Parameterize NEE and R_{eco} models across stand densities