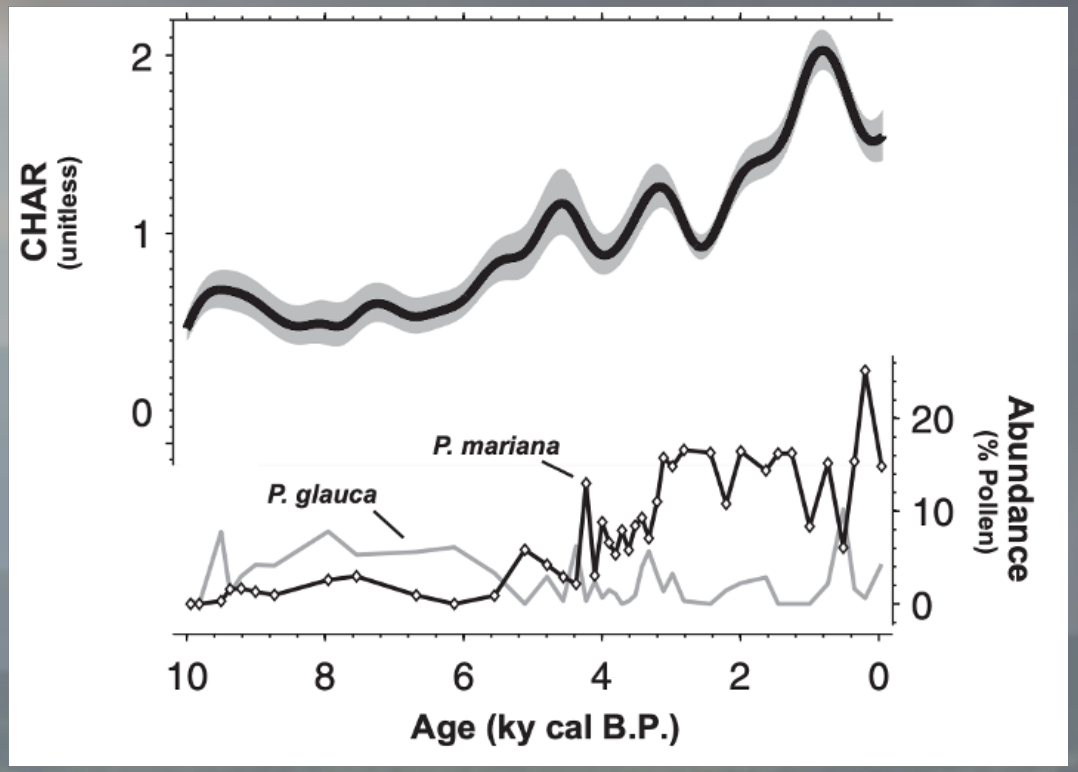
Wildfire as a catalyst of change in the boreal and arctic biomes

A landscape shaped by disturbance



Wildfire act to maintain and promote ecosystem structure and function across much of the boreal biome.

(Kelly et al. 2013)

A landscape shaped by disturbance

High moss NPP

Thick organic layer

Cool, moist soils

Slow decomp. & turnover

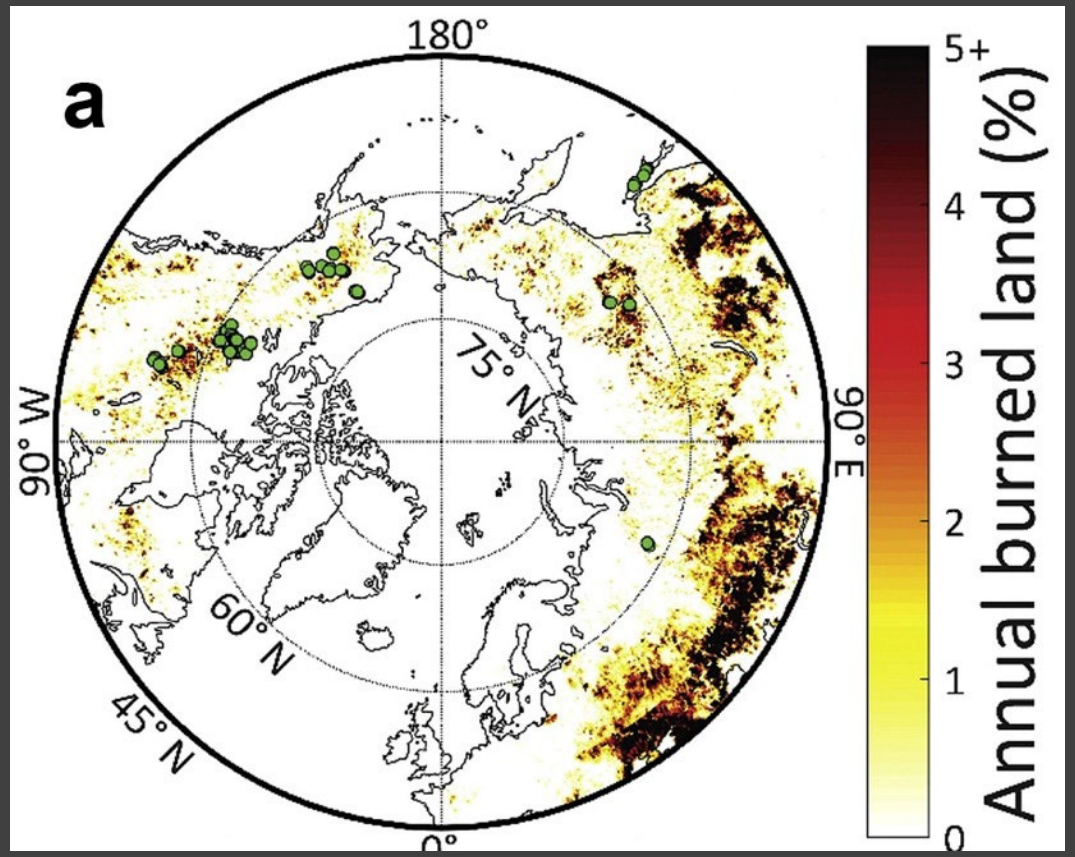
Wildfire act to maintain and promote ecosystem structure and function across much of the boreal biome.

Legacy lock on successional trajectory

- dominance of serotinous sp.
- species effects on local env.

(Johnstone et al.2011)

Direct carbon emissions

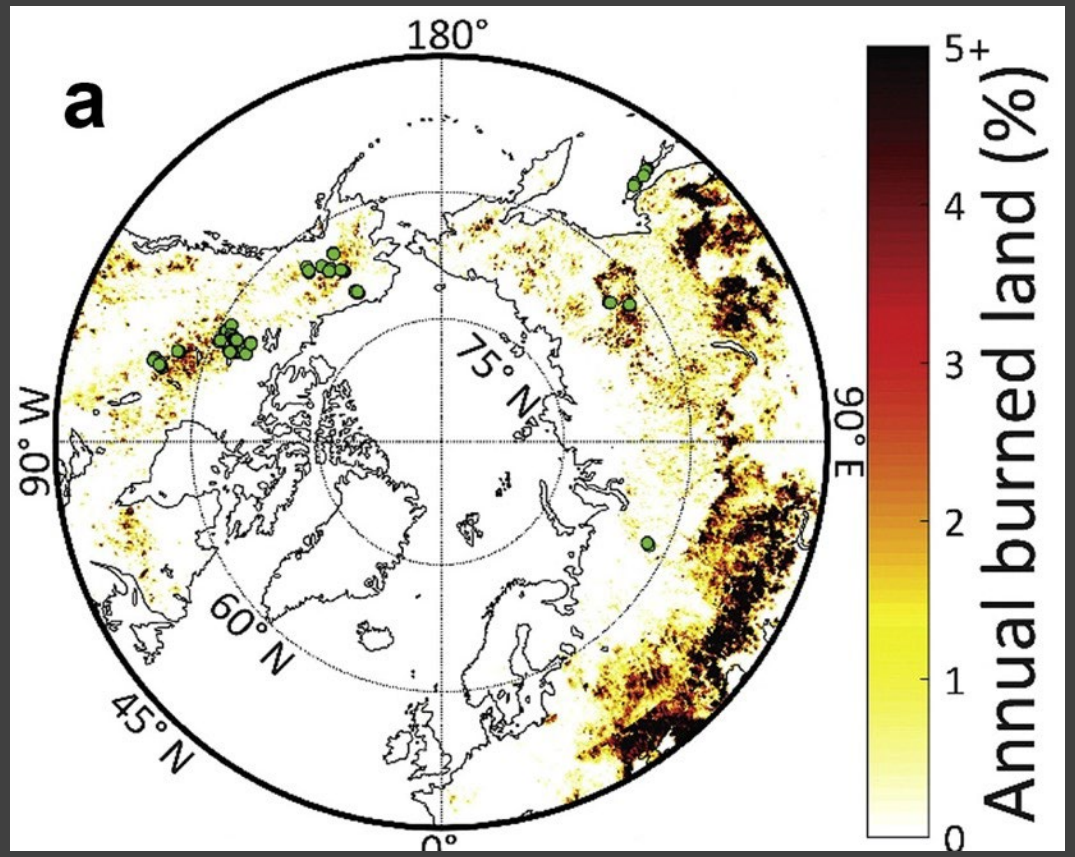


Veraverbeke et al. 2021

8.0 – 10.6 Mha/yr

~ 1.2 – 1.6% global area burned

Direct carbon emissions



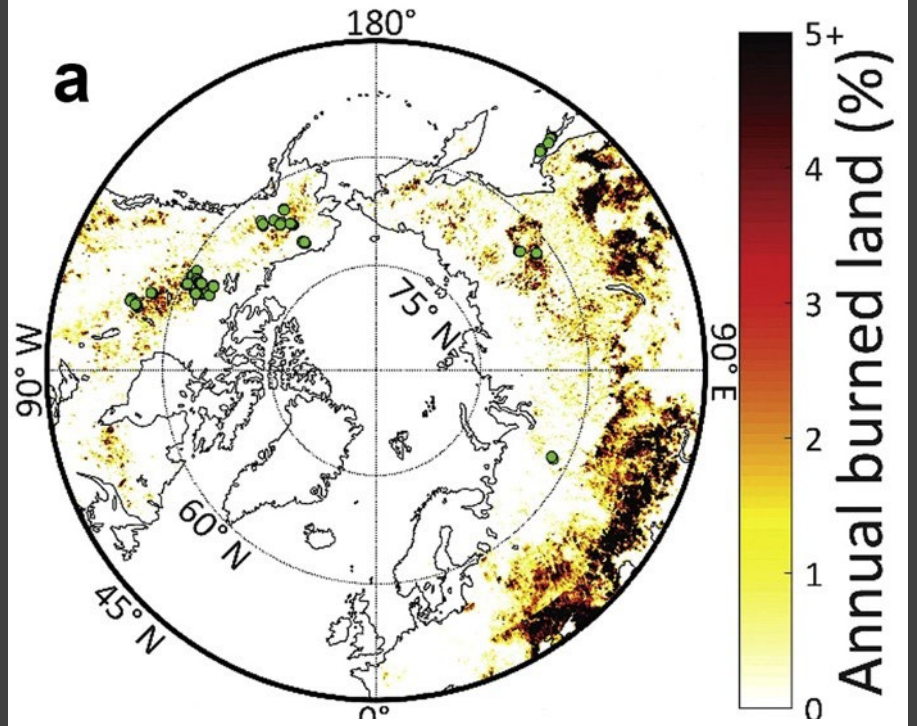
(Veraverbeke et al. 2021)

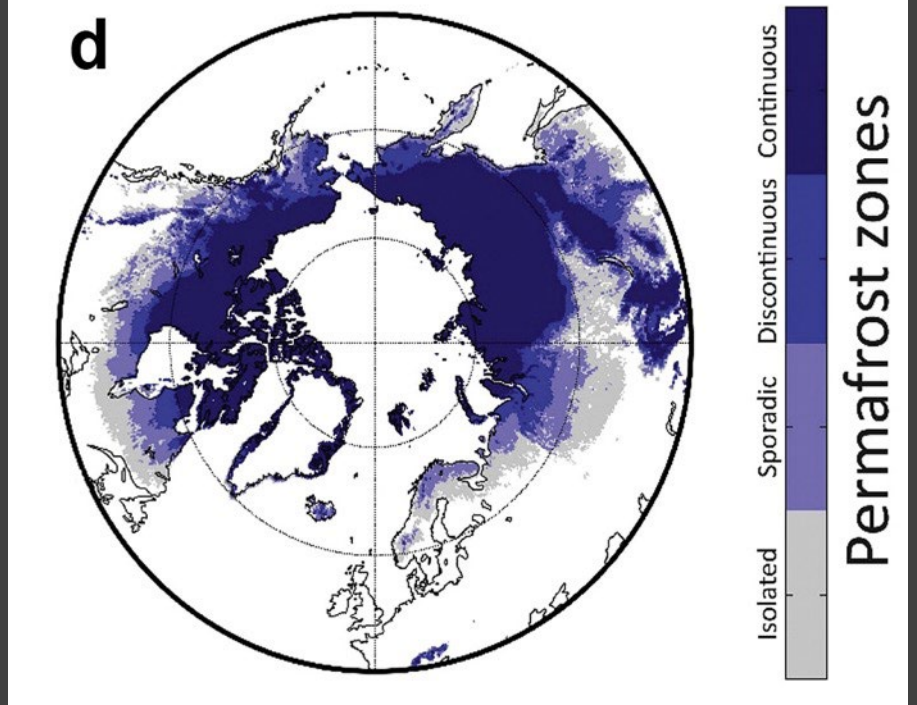
8.0 – 10.6 Mha/yr

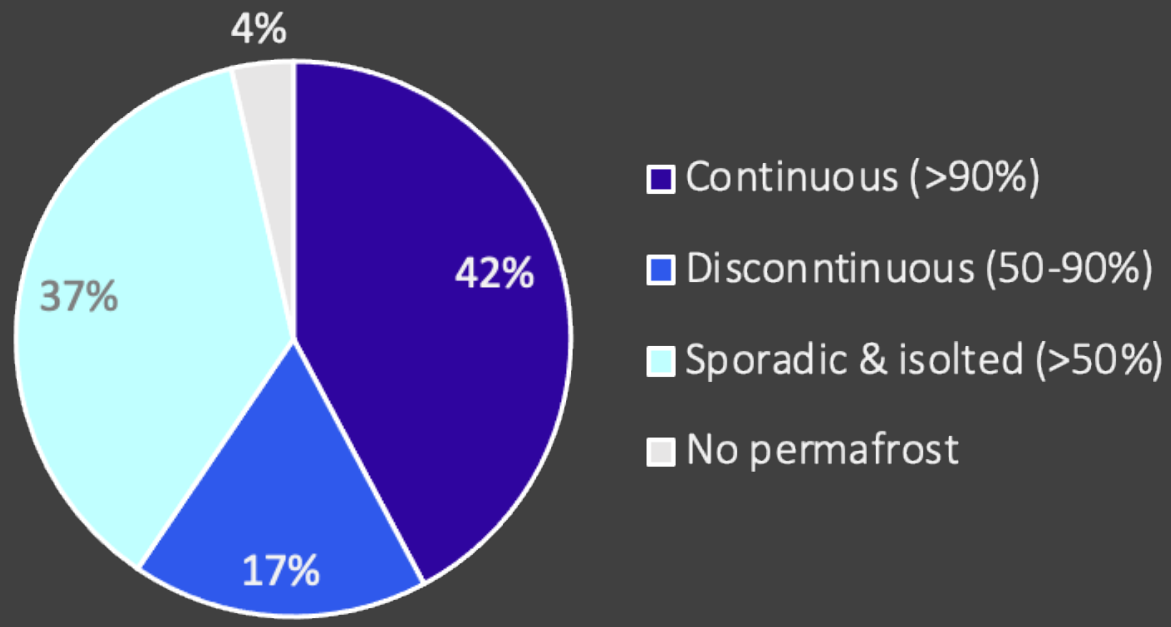
~ 1.2 – 1.6% global area burned

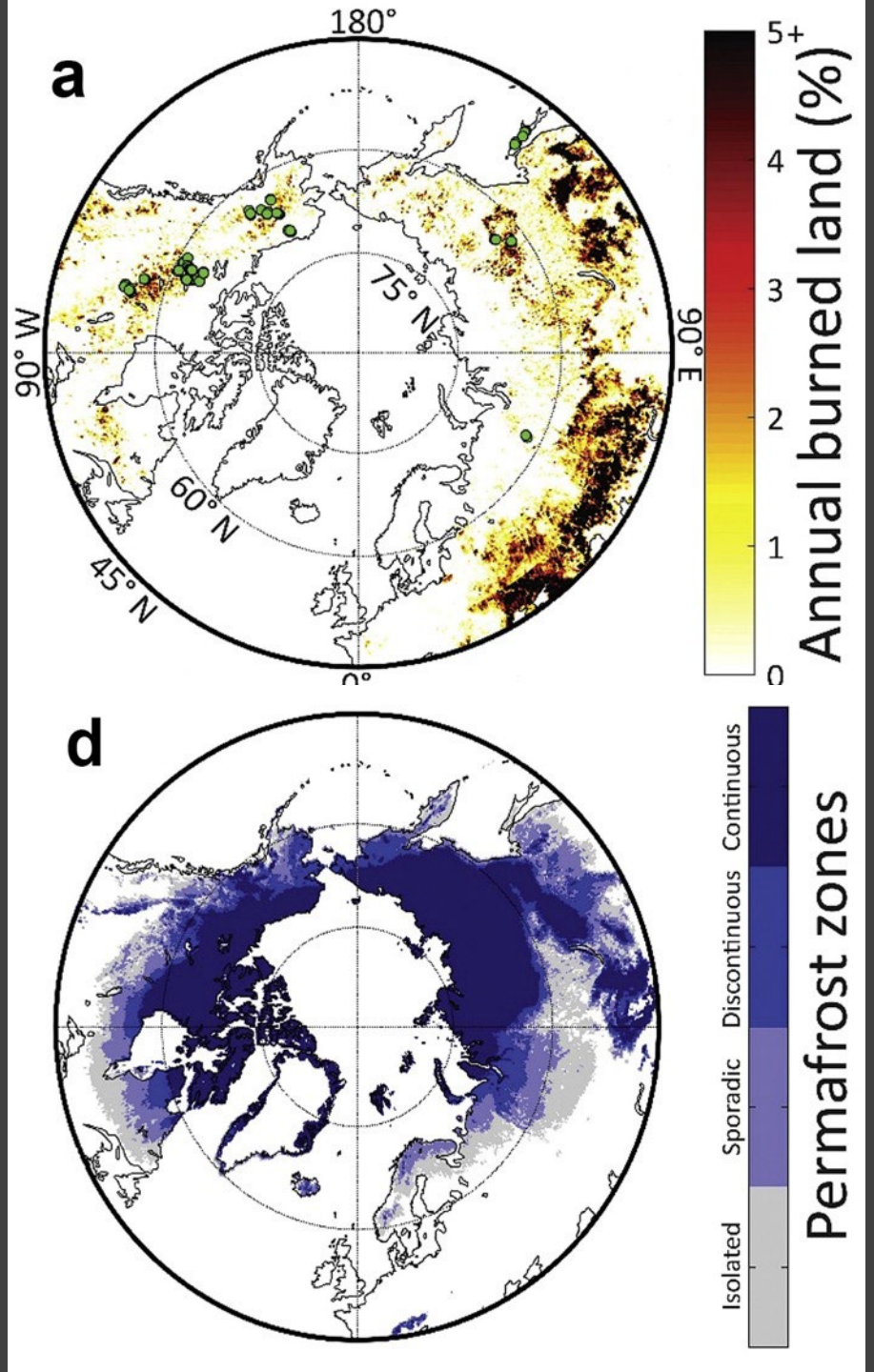
142 - 210 TgC/yr

~ 6.3 – 7.0% global C emissions


a
180°
90° W
90° E
75° N
60° N
45° N
0°
5+
4
3
2
1
0
Annual burned land (%)


d
Continuous
Discontinuous
Sporadic
Isolated
Permafrost zones


4%
42%
37%
17%
Continuous (>90%)
Disconntinuous (50-90%)
Sporadic & isolted (>50%)
No permafrost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Annual burned land (%)
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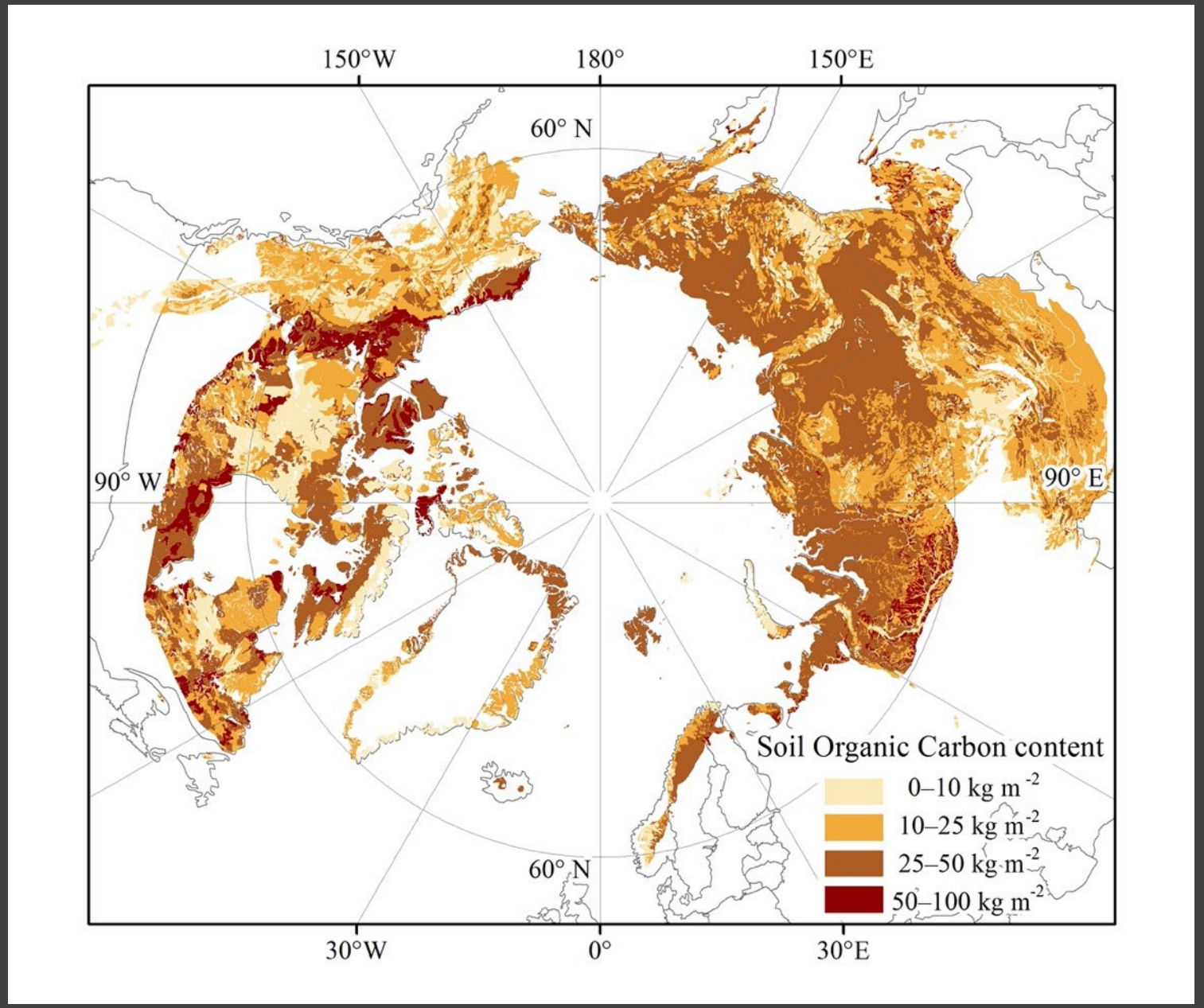
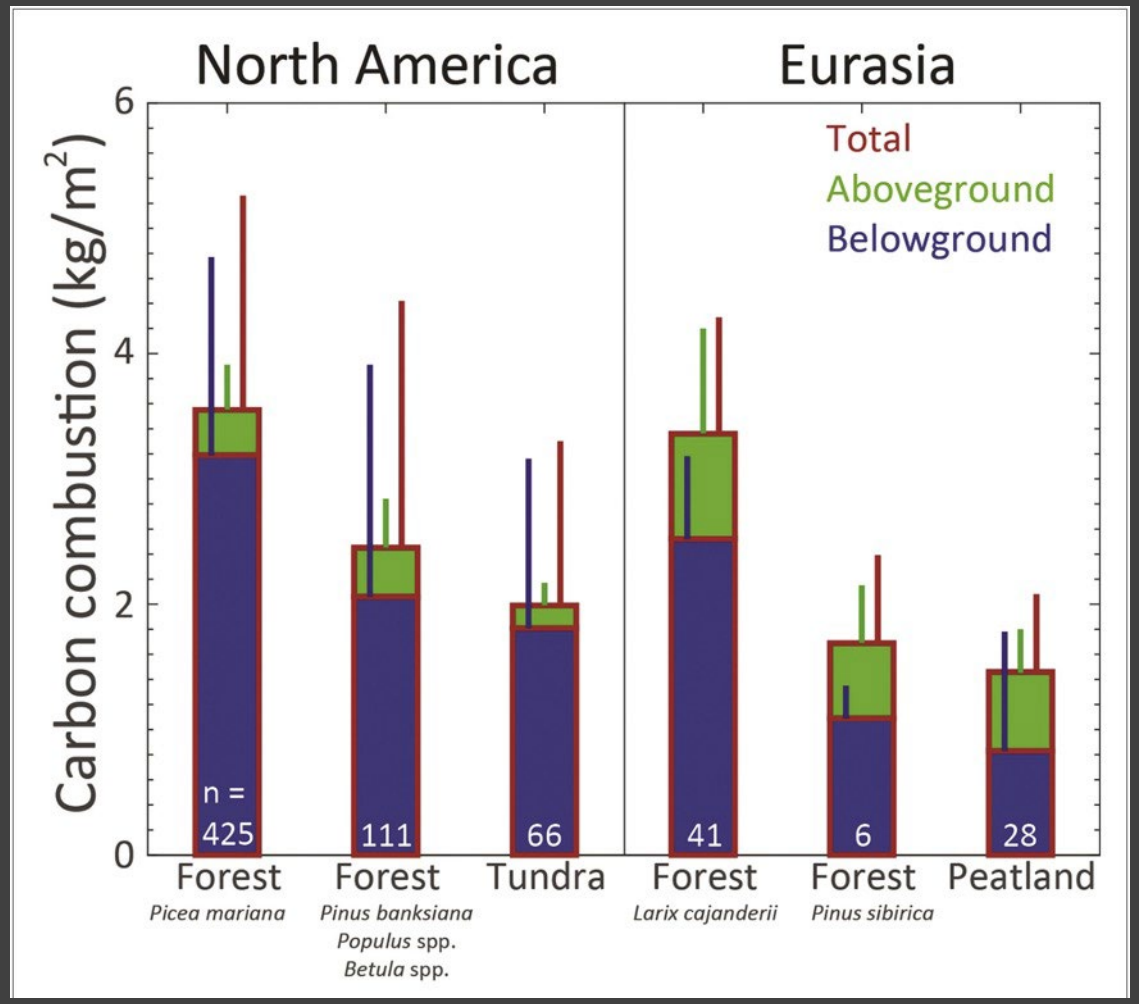

150°W
180°
150°E
60° N
90° W
90° E
60° N
30°W
0°
30°E
Soil Organic Carbon content
0–10 kg m -2
10–25 kg m -2
25–50 kg m -2
50–100 kg m -2

Direct carbon emissions

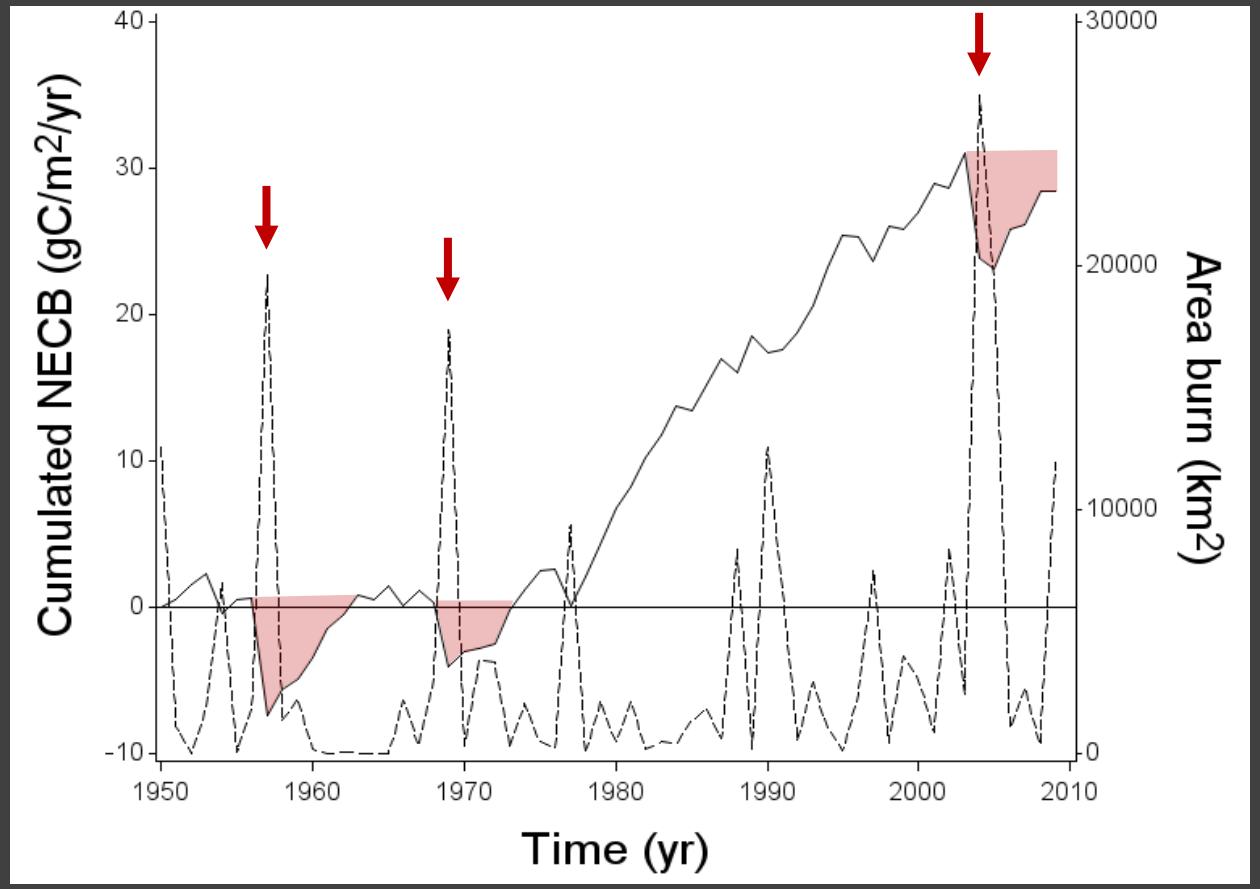


C combustion is dominated by combustion of belowground C.

Surface fires in Eurasia combust less belowground C than stand-replacing fires in North America.

(Veraverbeke et al. 2021)

Direct carbon emissions

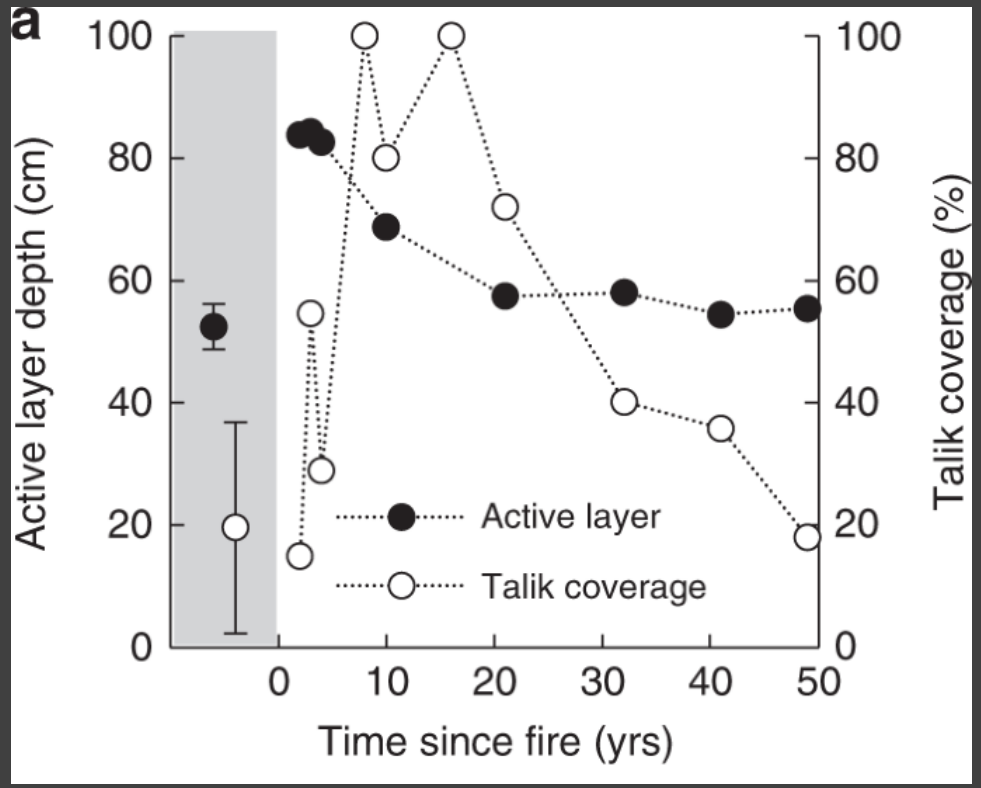


Carbon loss in a large fire year in Alaska represent ~ 10 yrs of C accumulation

(Genet et al. 2018)

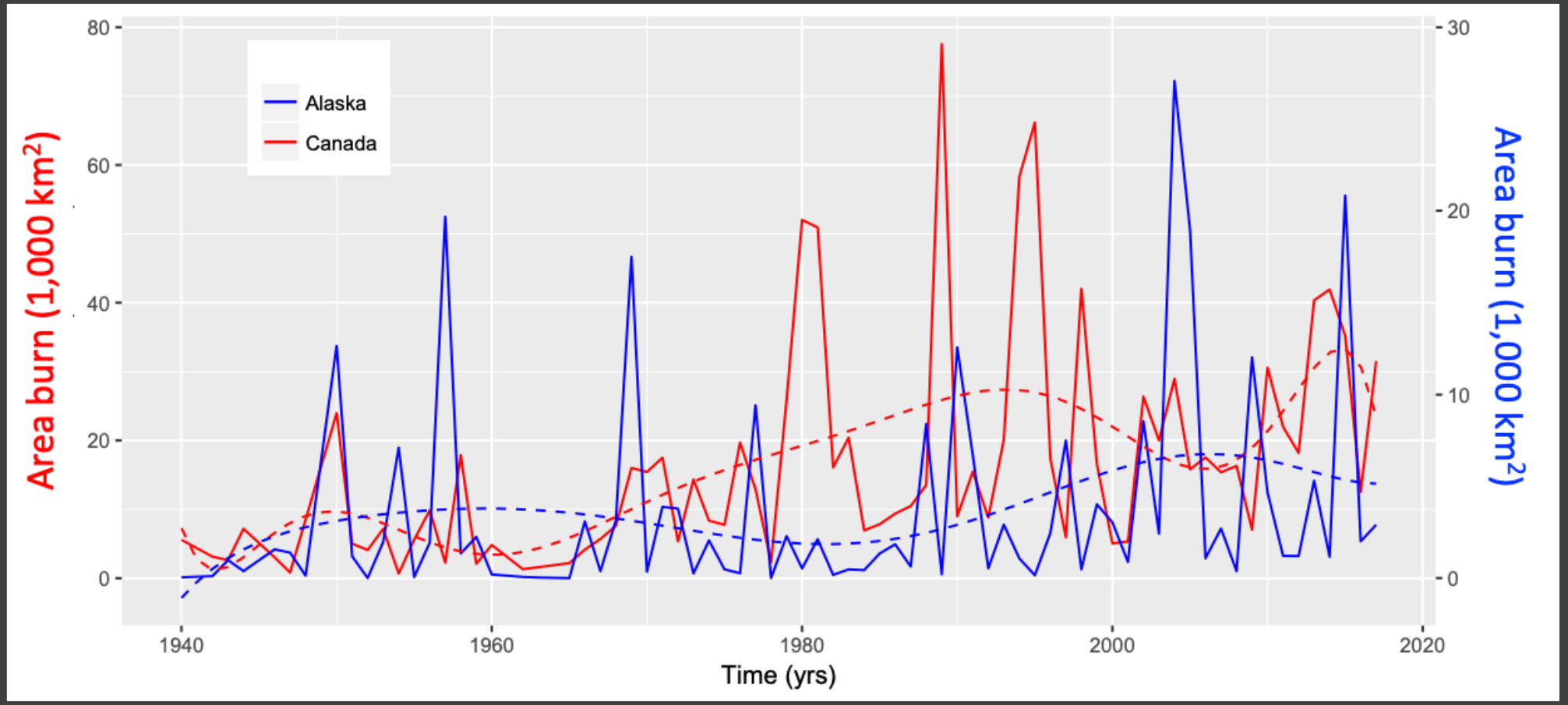
Post-fire trajectory

Permafrost thaw and talik formation

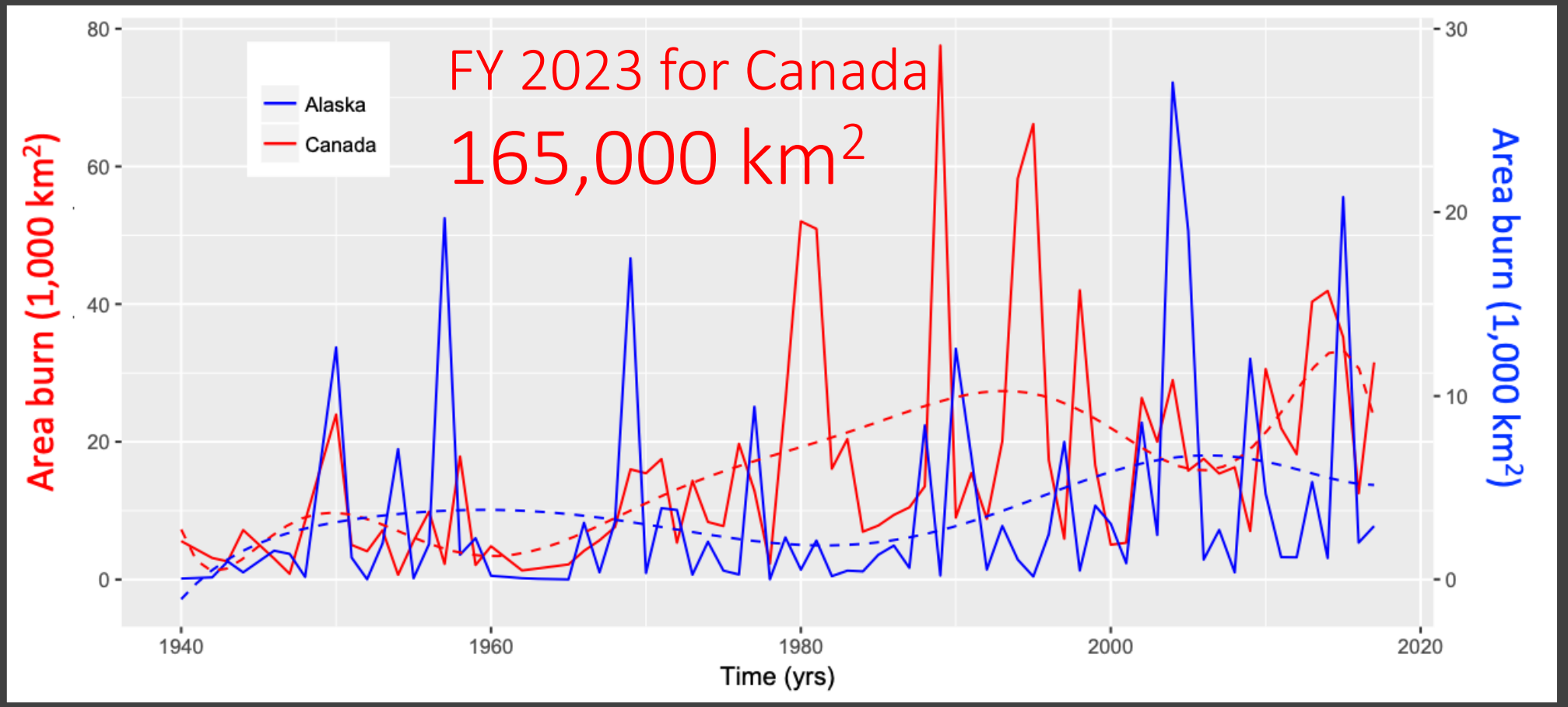


(Gibson et al. 2018)

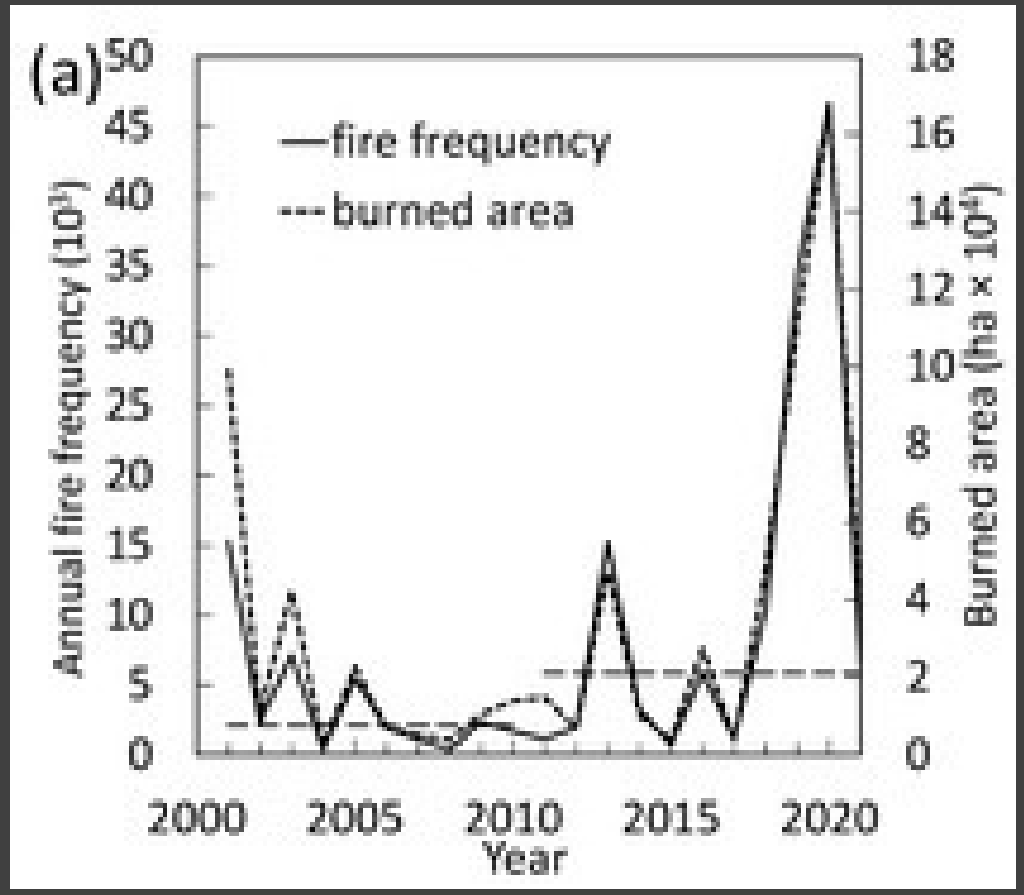
Increasing fire regime

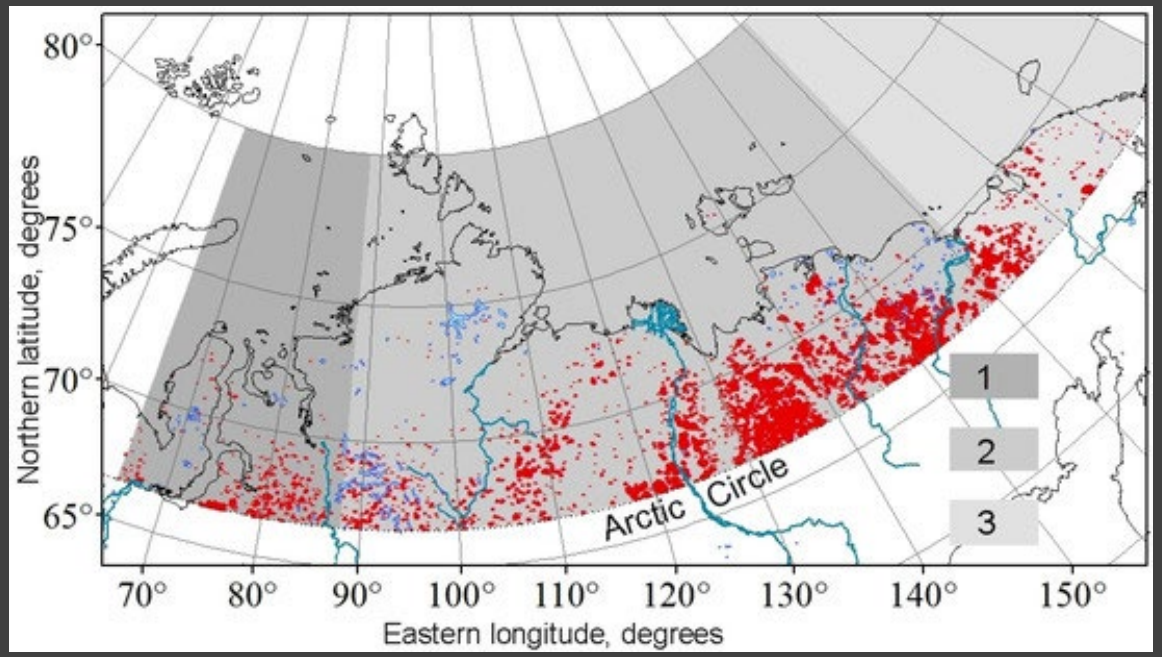


Increasing fire regime



Increasing fire regime





(Kharuk et al. 2022)

Increasing wildfire drives legacy loss

High moss NPP

Thick organic layer

Cool, moist soils

Slow decomp. & turnover

(Johnstone et al.2011)

Increasing wildfire drives loss of legacy

Increased severity

High moss NPP

Thick organic layer

Cool, moist soils

Slow decomp. & turnover

Low moss NPP

Thin organic layer

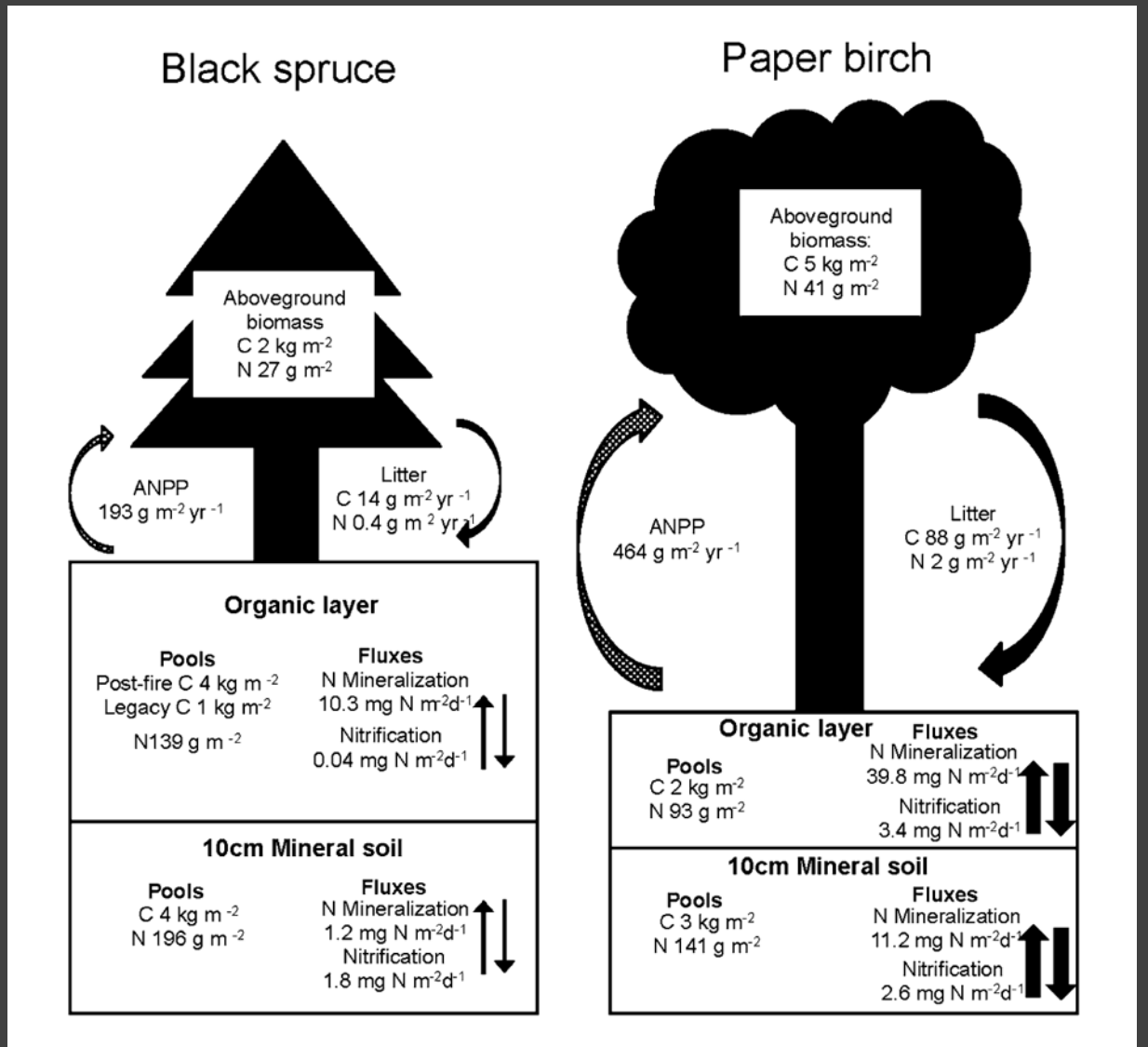
Warm soils

Fast decomp. & turnover

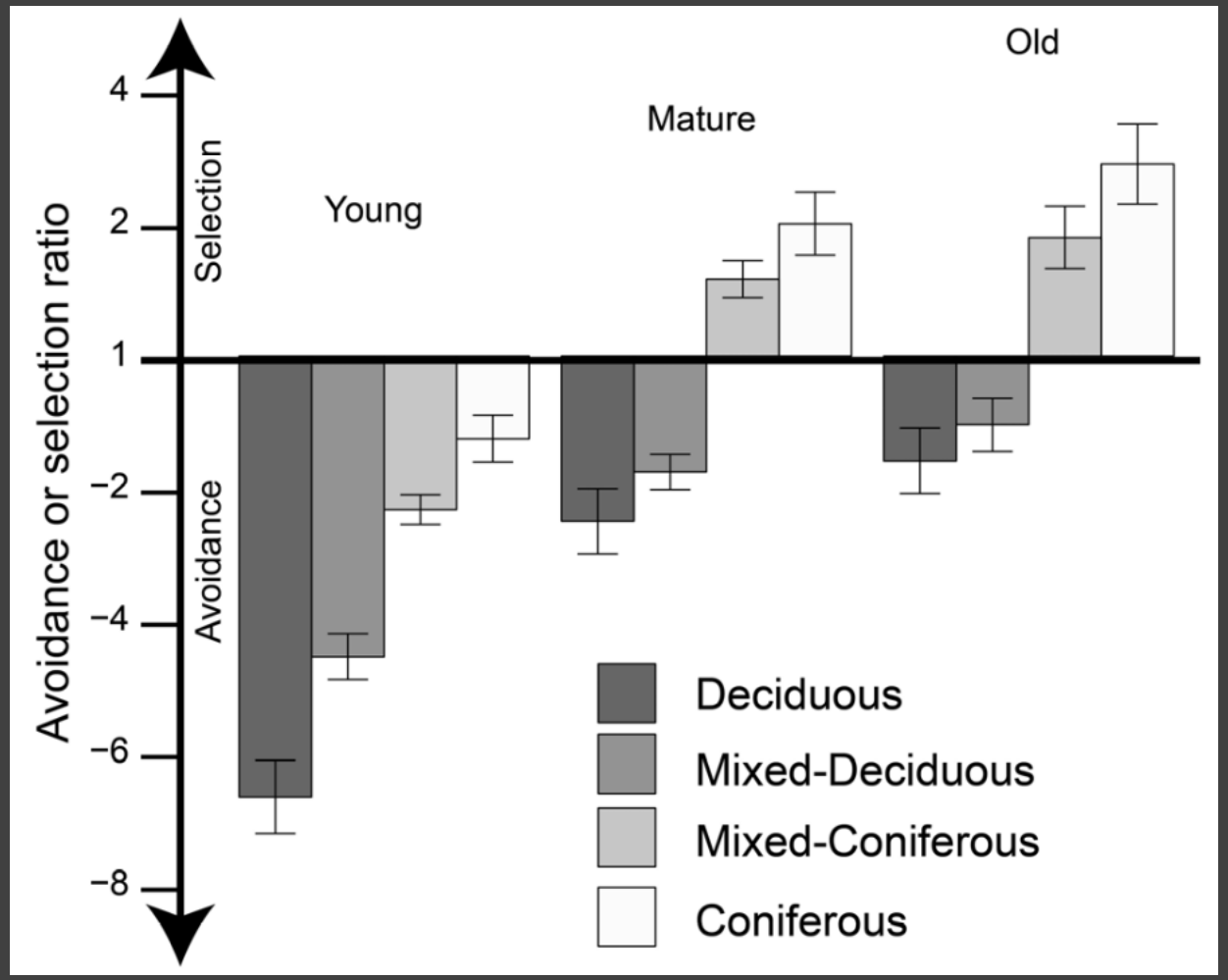
(Johnstone et al.2011)

Increasing wildfire drives loss of legacy

(Melvin et al. 2015)



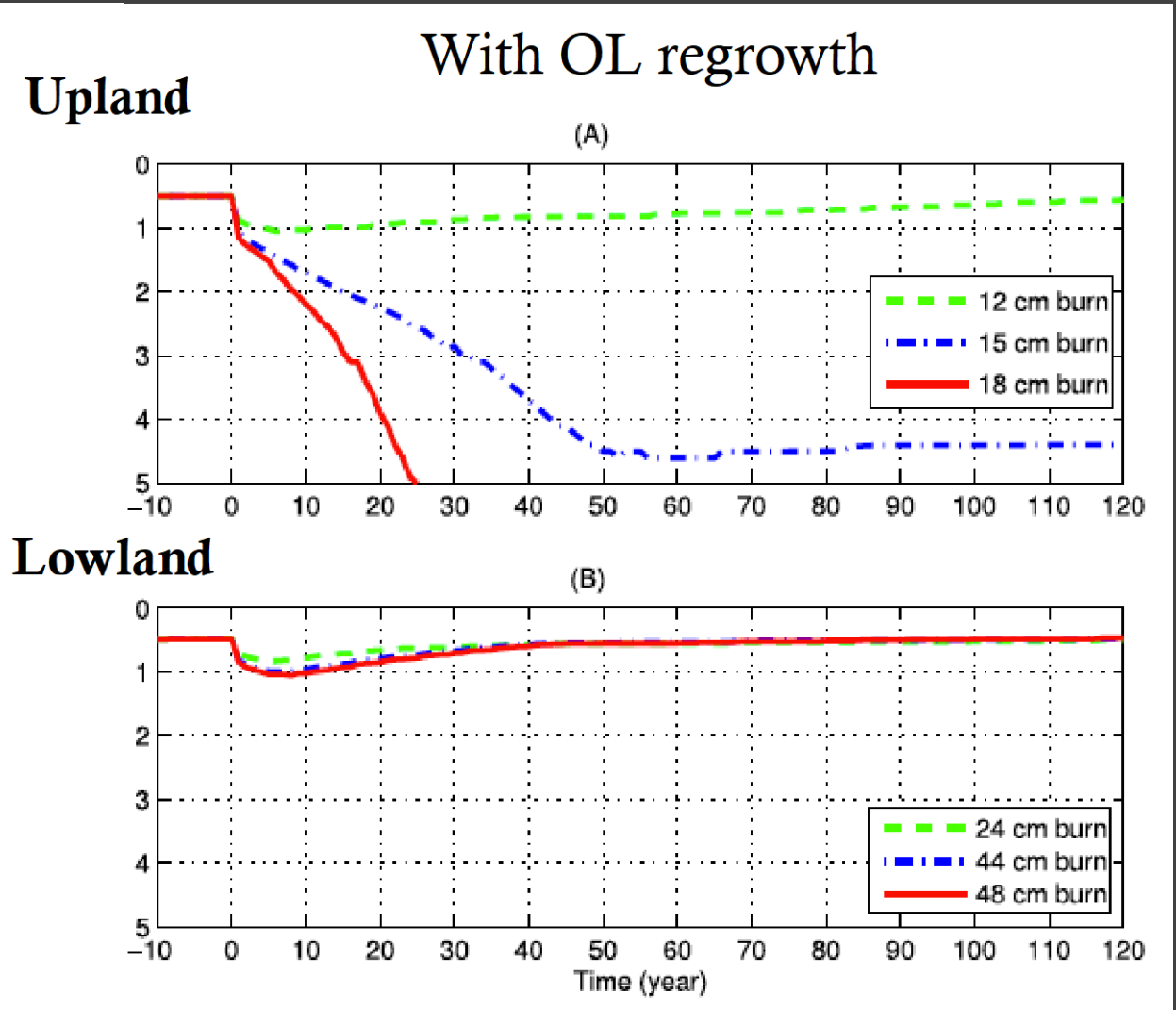
Increasing wildfire drives loss of legacy



Alternative post-fire trajectory may partially offset the effect of warming on increasing fire regime.

(Bernier et al. 2016)

Increasing wildfire drives loss of legacy



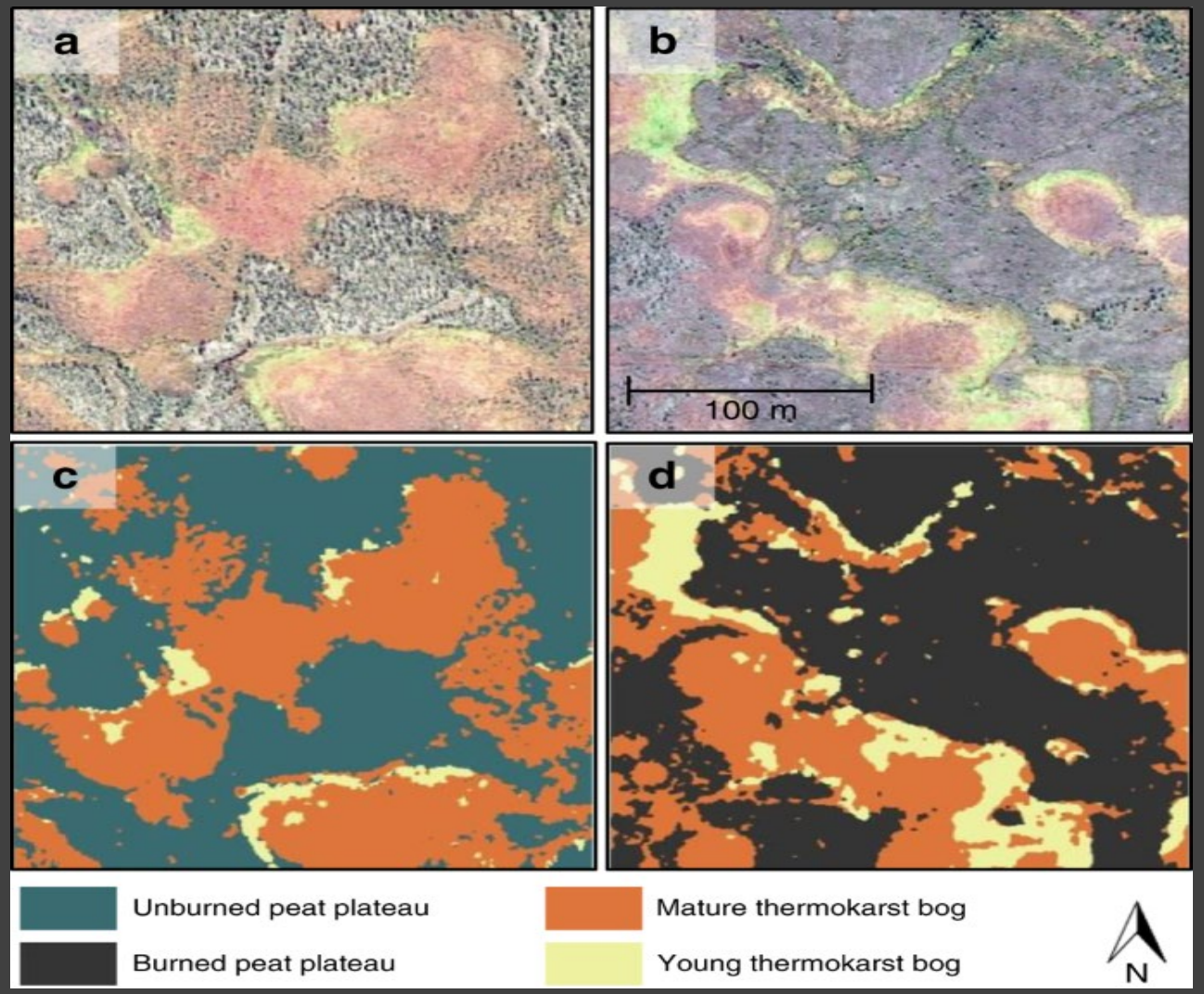
Increasing fire severity coupled with the effect of warming on soil temperature may in permanent permafrost loss after fire.

(Jafarov et al. 2013)

Increasing wildfire drives loss of legacy

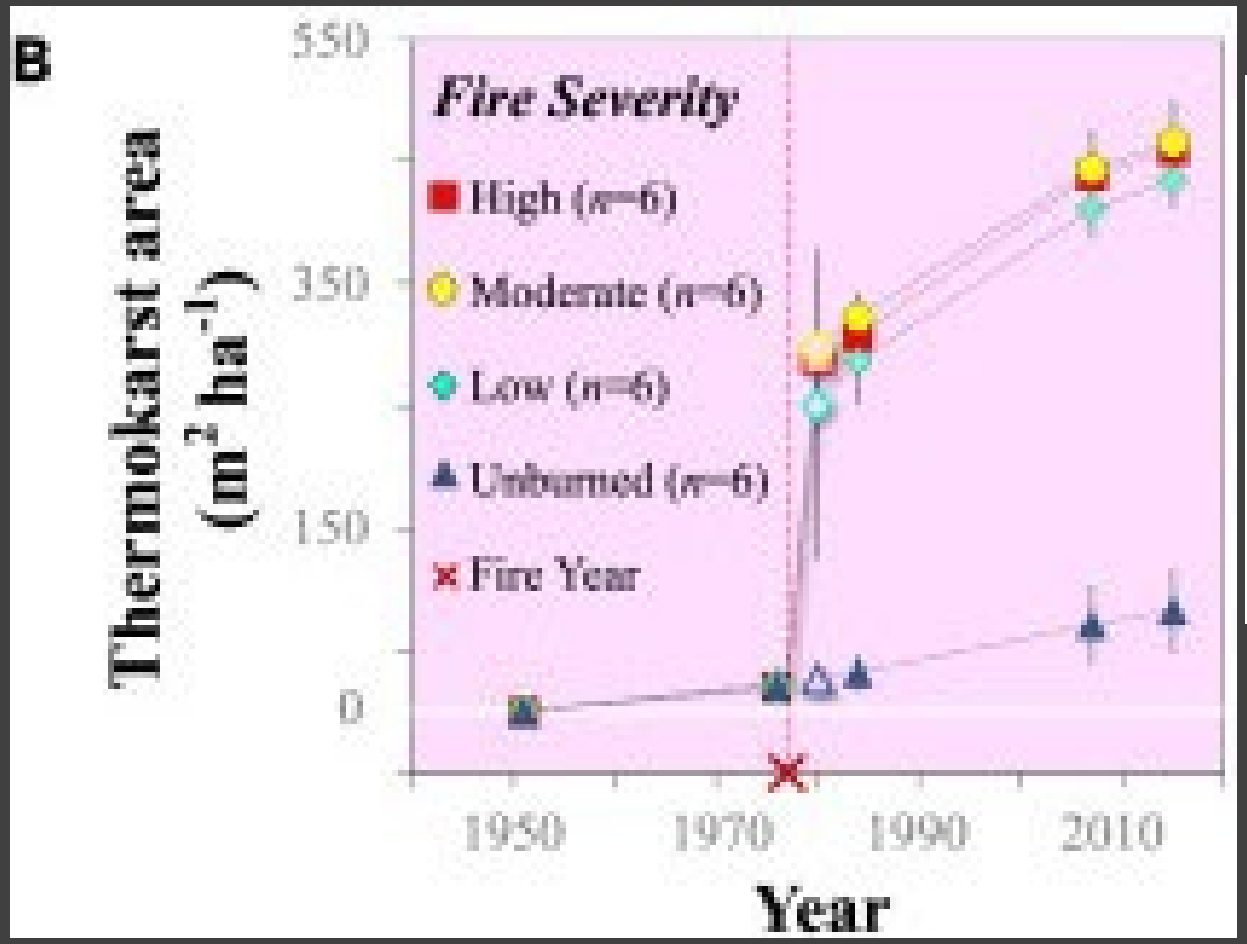
Severe wildfire in ice-rich permafrost can result in abrupt permafrost thaw

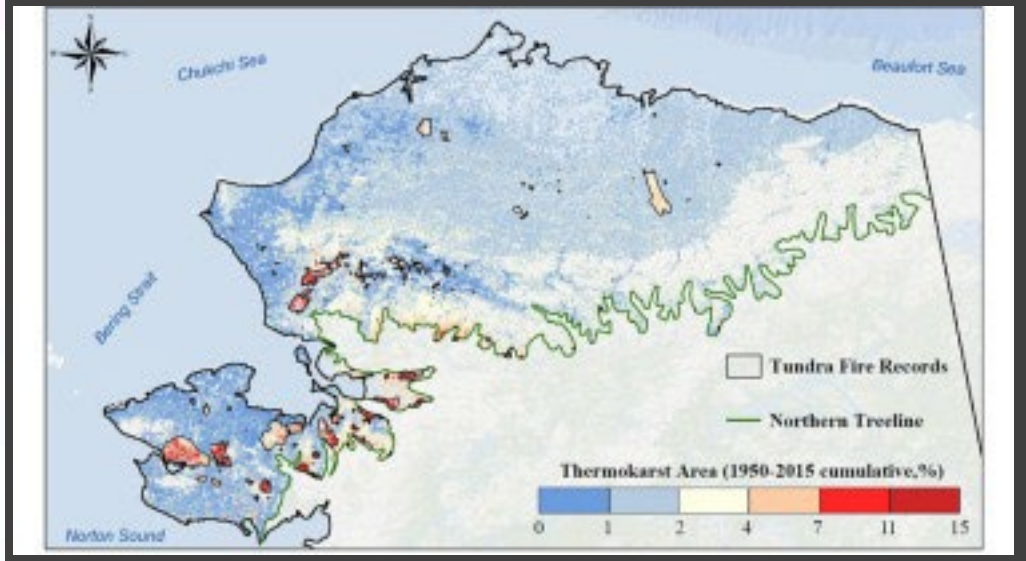
Increasing wildfire drives loss of legacy



(Gibson et al. 2018)

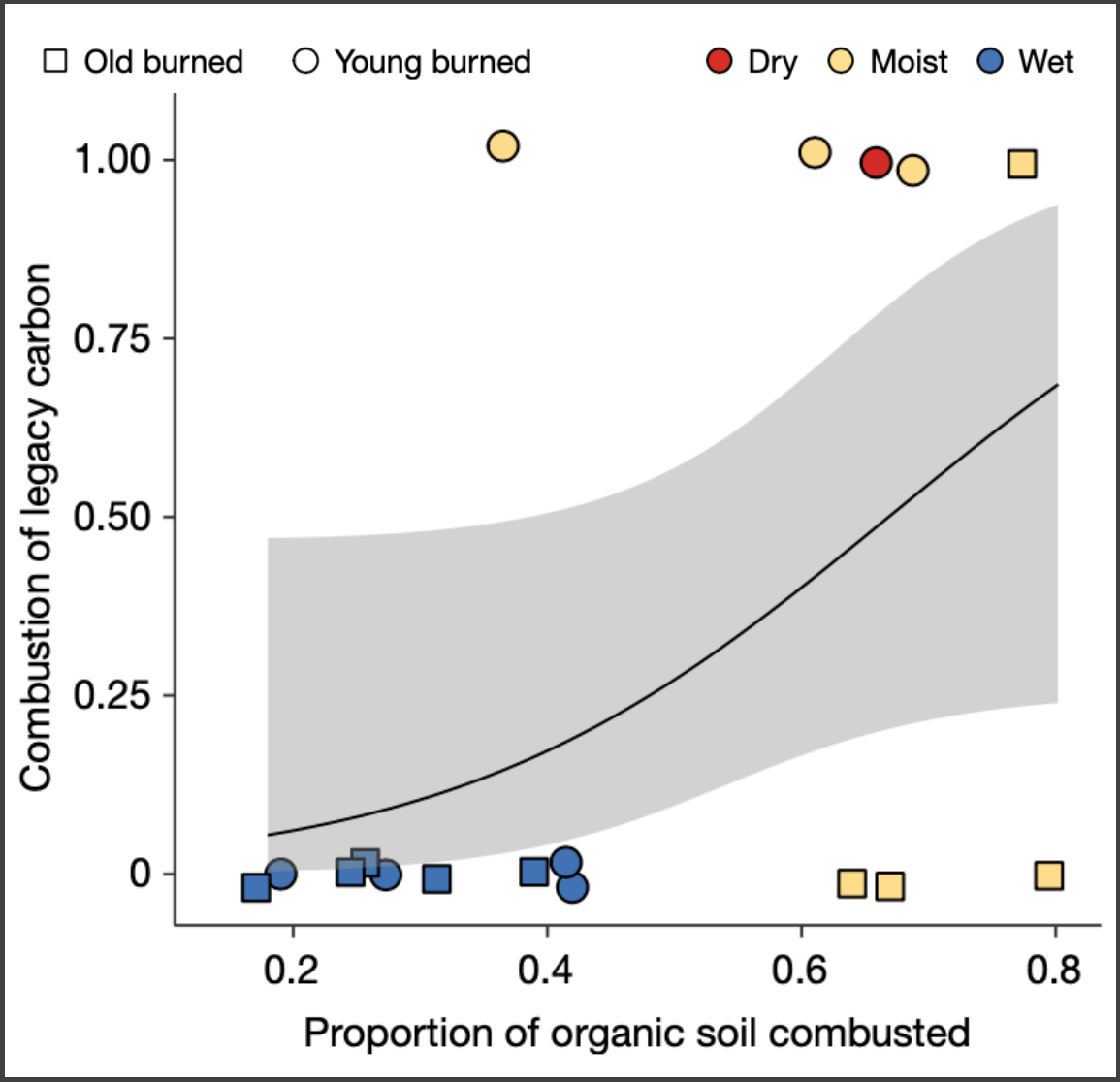
Increasing wildfire drives loss of legacy





(Chen et al. 2021)

Increasing wildfire drives loss of legacy



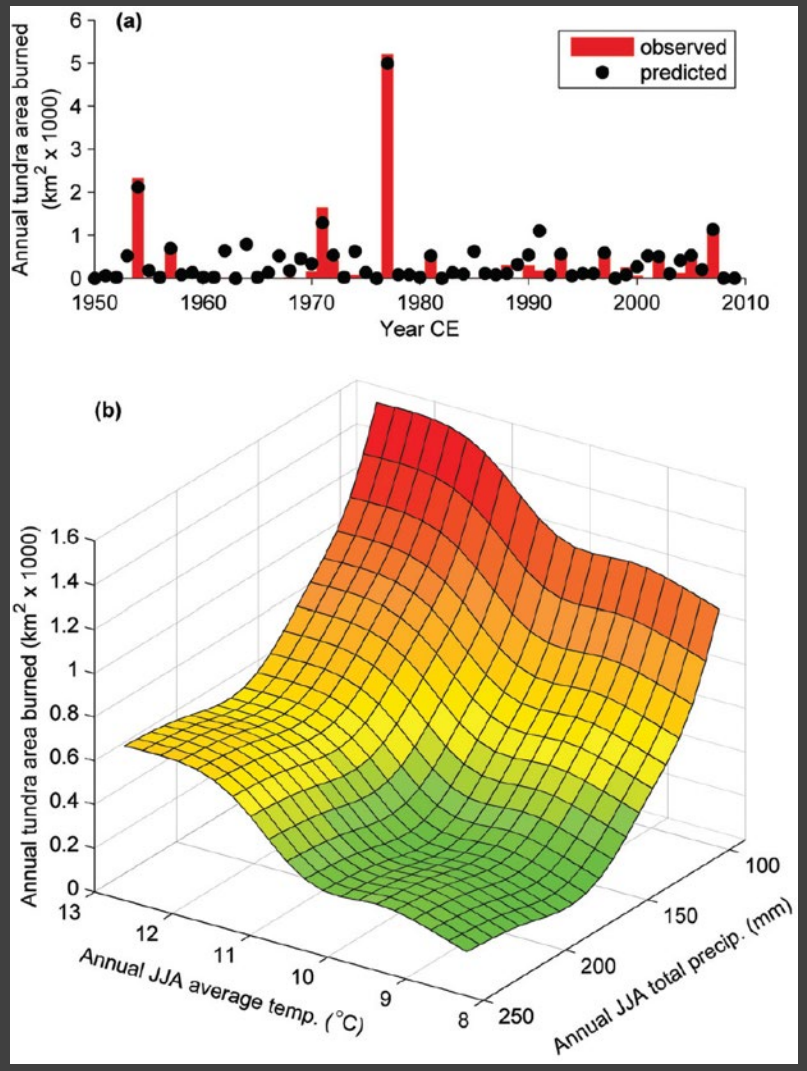
Carbon in permafrost soil has accumulated over millennia.

Increase in fire frequency and severity could lead to deeper burning of the organic layer.

This may result in a loss of “legacy carbon”, shifting the ecosystem from a net carbon sink to a source of the fire cycle.

(Walker et al. 2019)

Future fire regime

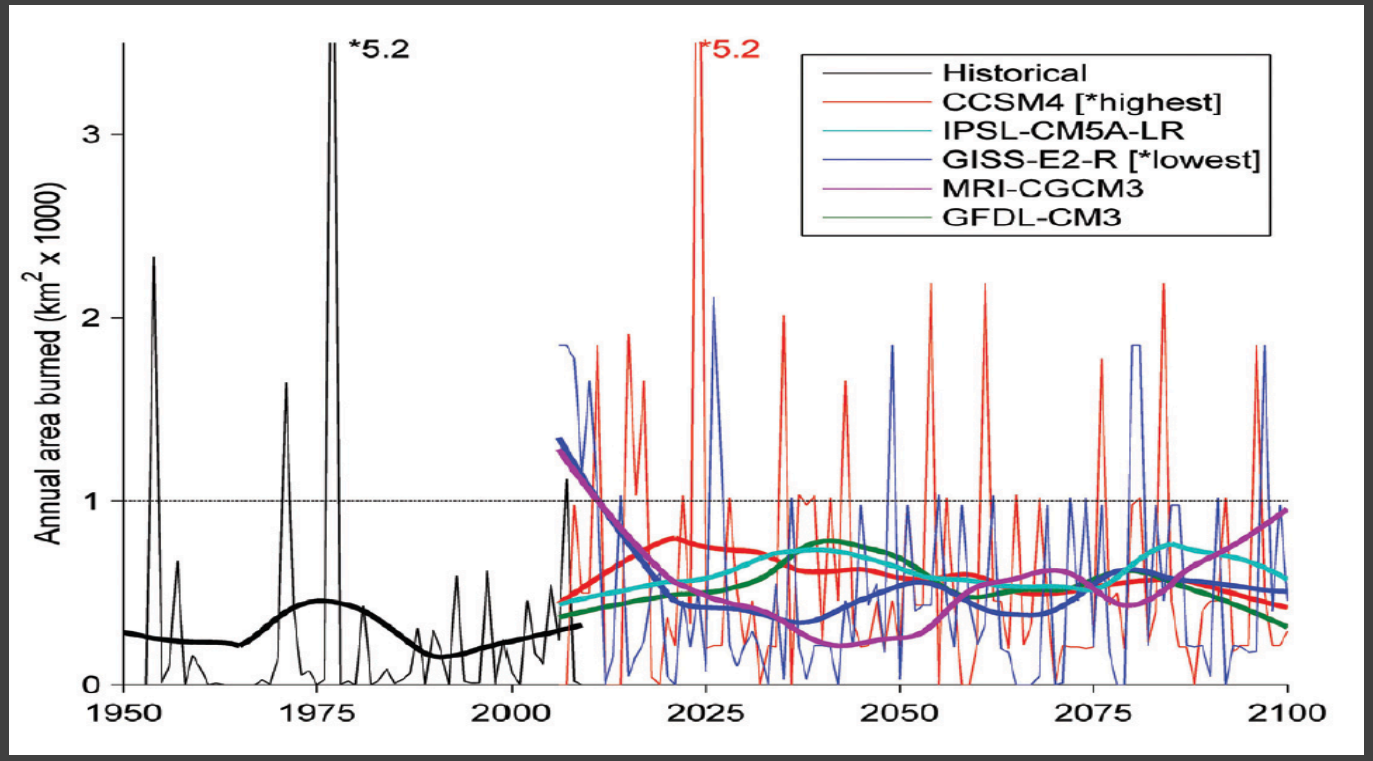


Analysis of historical data shows strong climate–fire relationships in arctic tundra , with threshold effects of summer temperature and precipitation.

(Hu et al. 2015)

Future fire regime

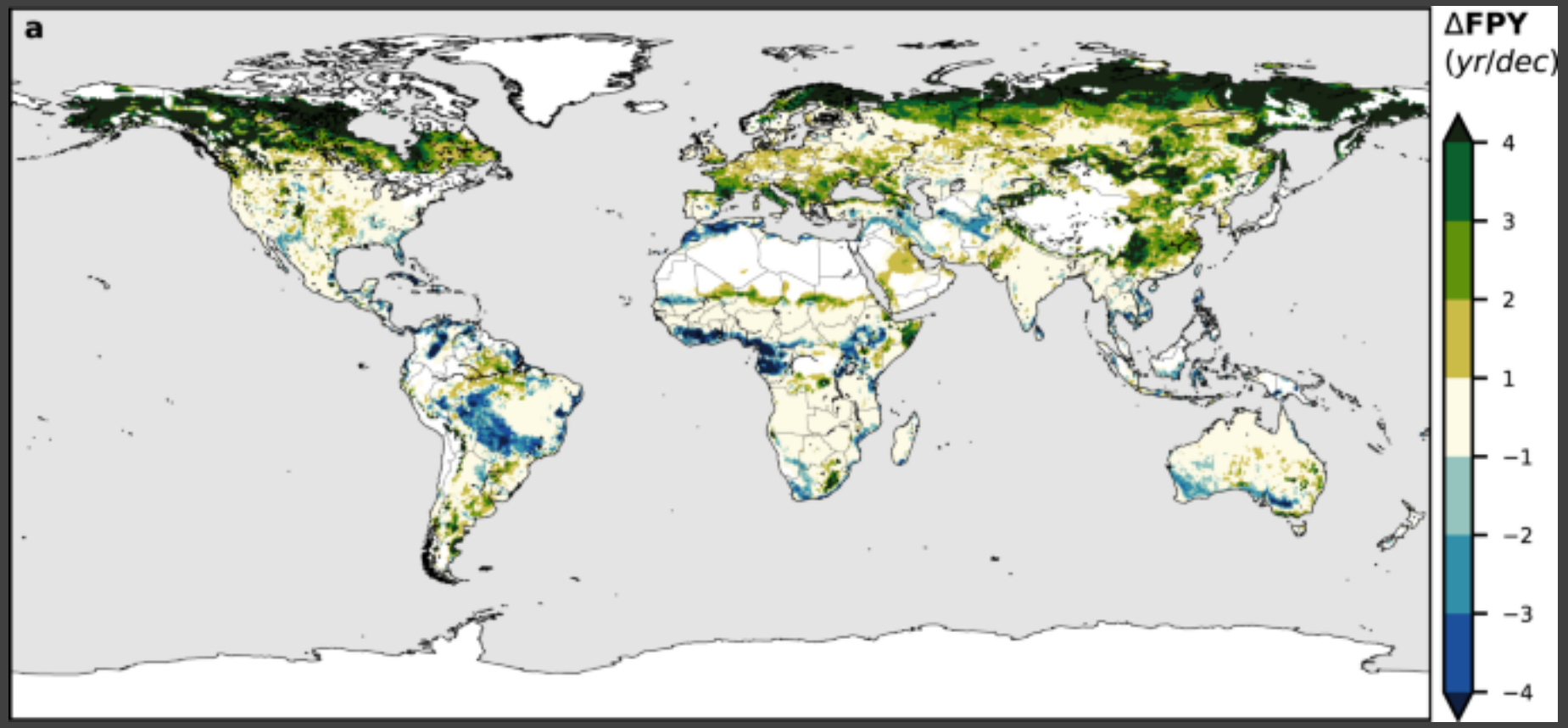
Projections based on 21st-century climate scenarios suggest that annual area burned will approximately double in Alaskan tundra by the end of the century.



(Hu et al. 2015)

Future projections

(Senande-Rivera et al. 2022)



ΔFPY = Future minus present number of years with at least one month classified as fire-prone per decade

The role of wildfire in Arctic and Boreal Biomes and the Associated Net GHG Emissions

- Over the past 6,000 yrs, wildfires helped maintain and promote ecosystem structure and function across much of the boreal biome.

The role of wildfire in Arctic and Boreal Biomes and the Associated Net GHG Emissions

- Warming and changes in precipitation regime are disrupting this dynamic equilibrium by increasing fire frequency, and severity across boreal and arctic biomes.

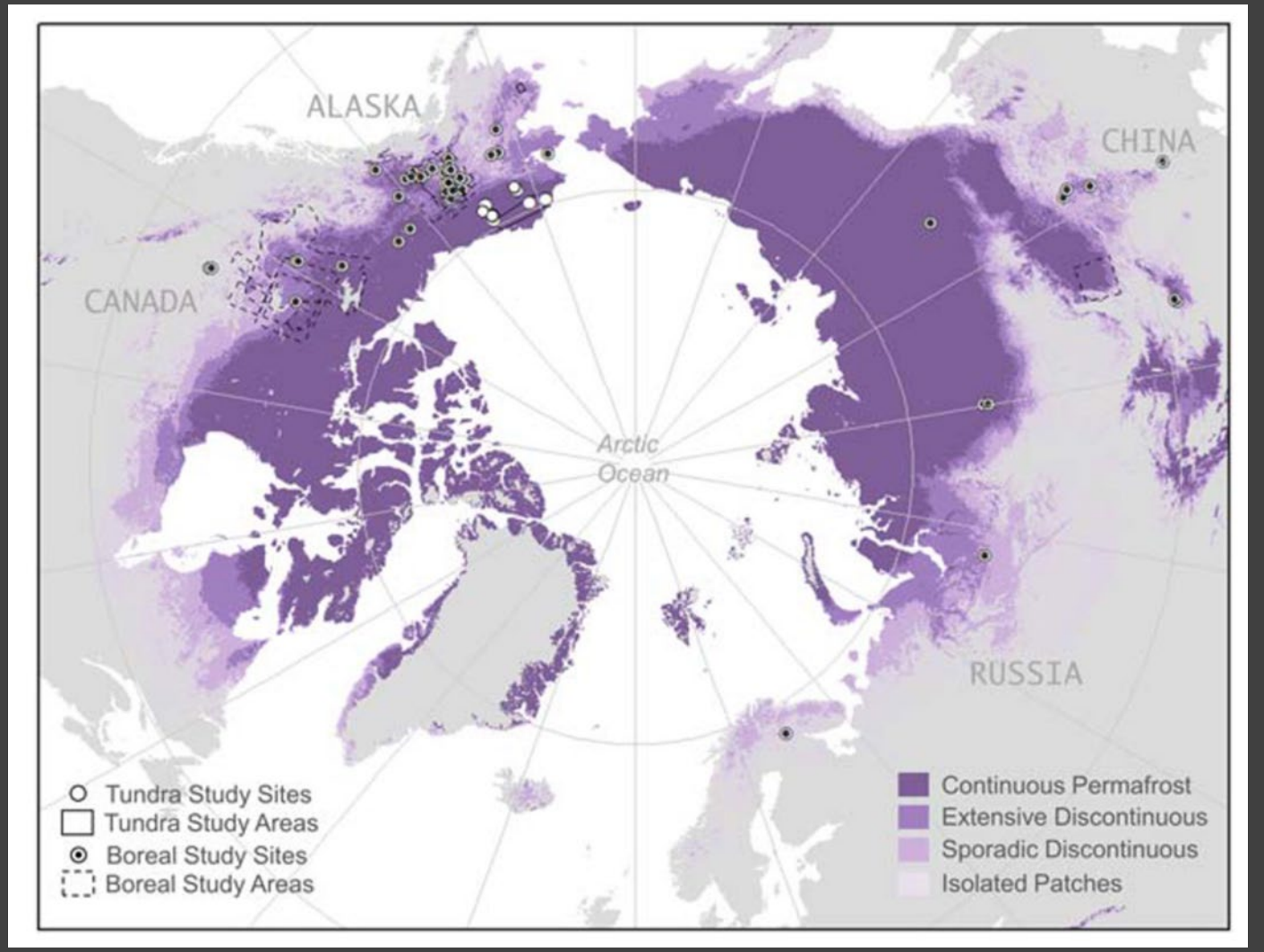
The role of wildfire in Arctic and Boreal Biomes and the Associated Net GHG Emissions

- As permafrost soils represent 30-40% of global terrestrial carbon stocks, accelerated loss of organic soil from increased fire regime can result in convert the arctic and boreal biomes to carbon sources.

Research needs and future directions

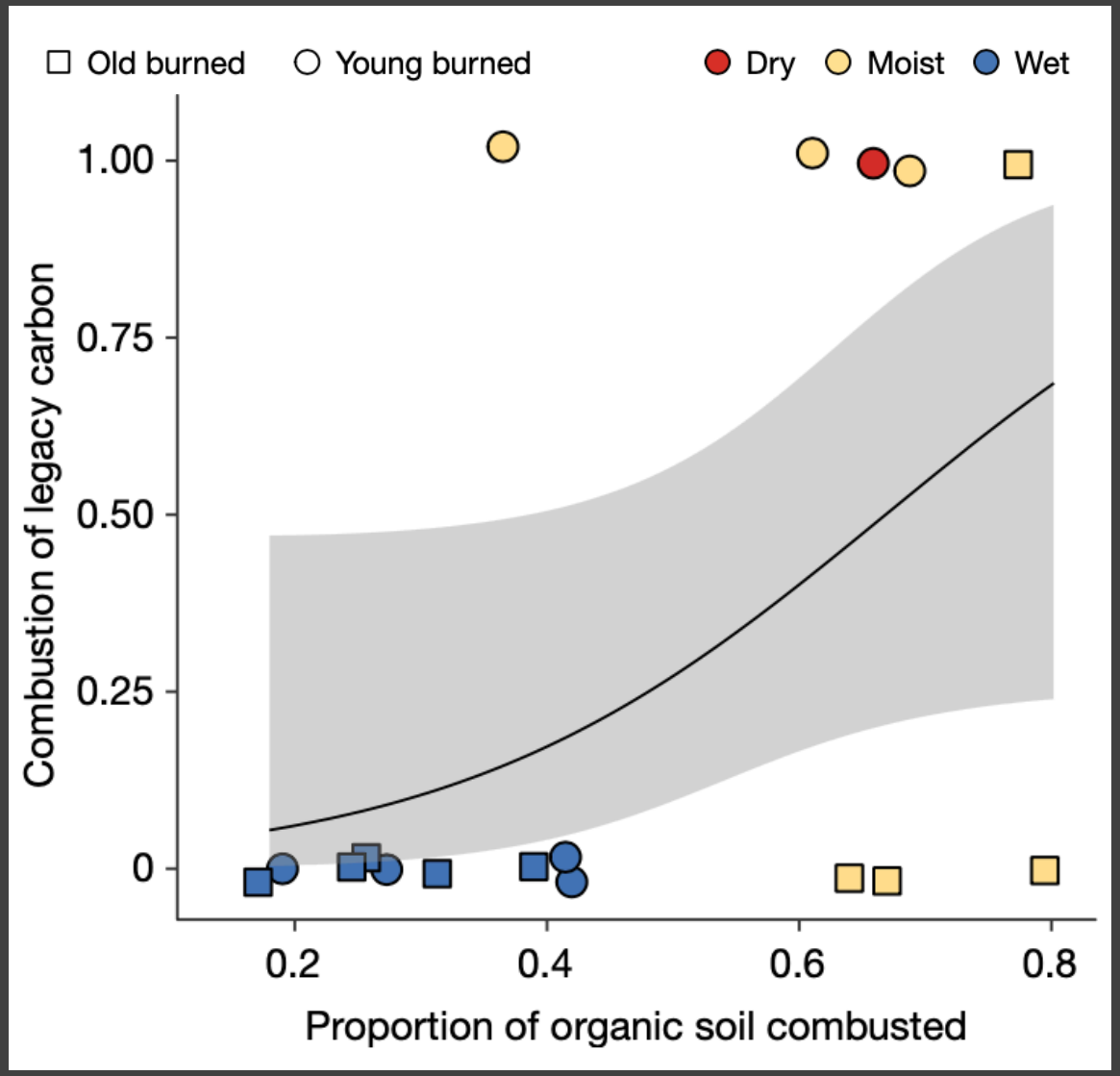
- Evaluation of long-term effects of wildfire on vegetation, permafrost and ecosystem carbon dynamics across the boreal and arctic biomes.

(Holloway et al. 2020)



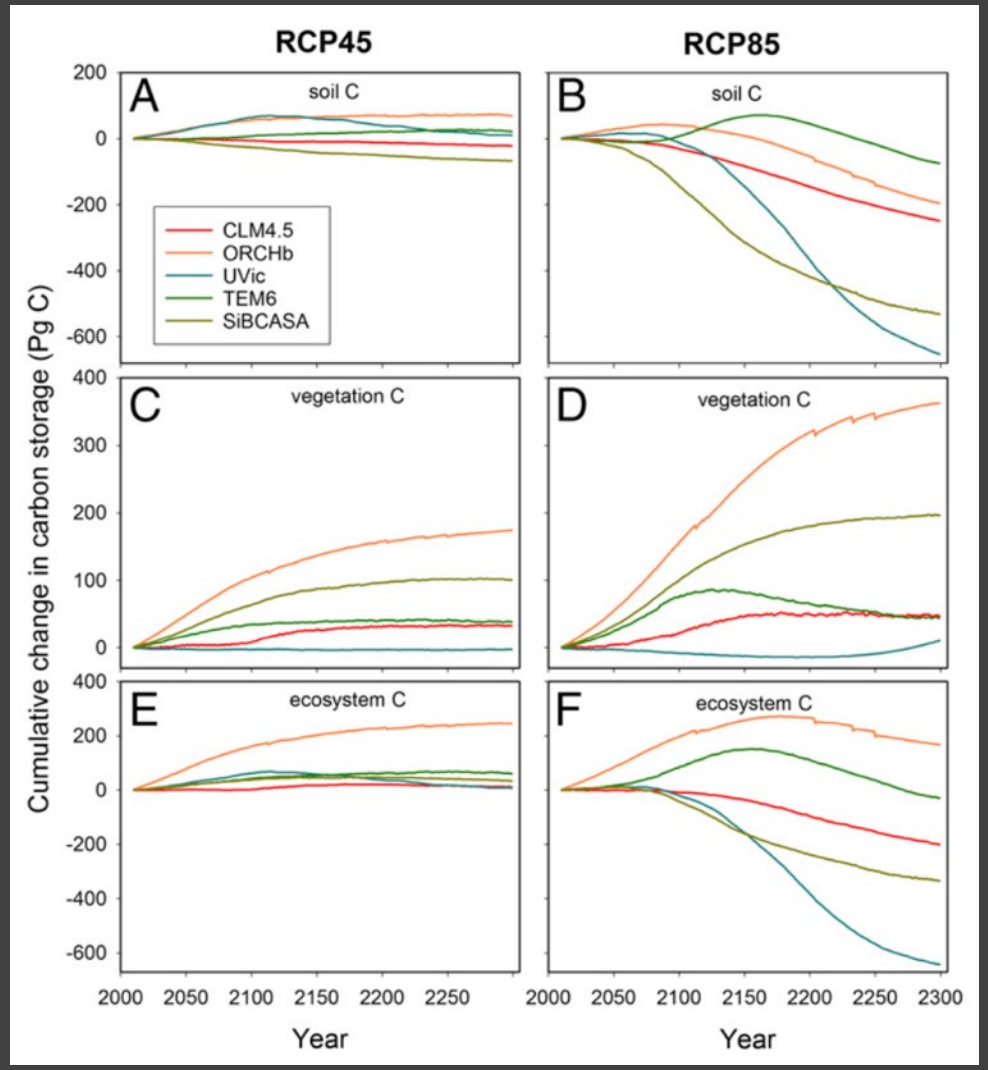
Research needs and future directions

- Better representation of drainage conditions and stand characteristics when estimating fire emissions.



Research needs and future directions

- Representation of ecological shifts associated with changes in wildfire regimes in process-based biogeochemical models.



(McGuire et al. 2018)

Research needs and future directions

- Possible synergistic interactions among disturbances are not well investigated, despite the recognition of the potential such interactions