Cross-scale controls on boreal wildfire carbon emissions

Xanthe Walker

Baltzer, J. Barrett, K. Bourgeau-Chavez, L. Brown, C. Day, J. Cumming, S. de Groot. W.J. Dieleman, C. Goetz, S. Hoy, E. Jenkins, L. Johnstone, J. Kane, E. Natali, S. Parisien, M.A. Rogers, B. Schuur, T. Turetsky, M. Veraverbeke, S. Whitman, E. Mack, M.

Northern Arizona University

ECOS Center for Ecosystem Science and Society at Northern Arizona University

Photo credit: Matt Prokopchuk, CBC 2016

Boreal Forest Wildfires

Soil Organic Layer

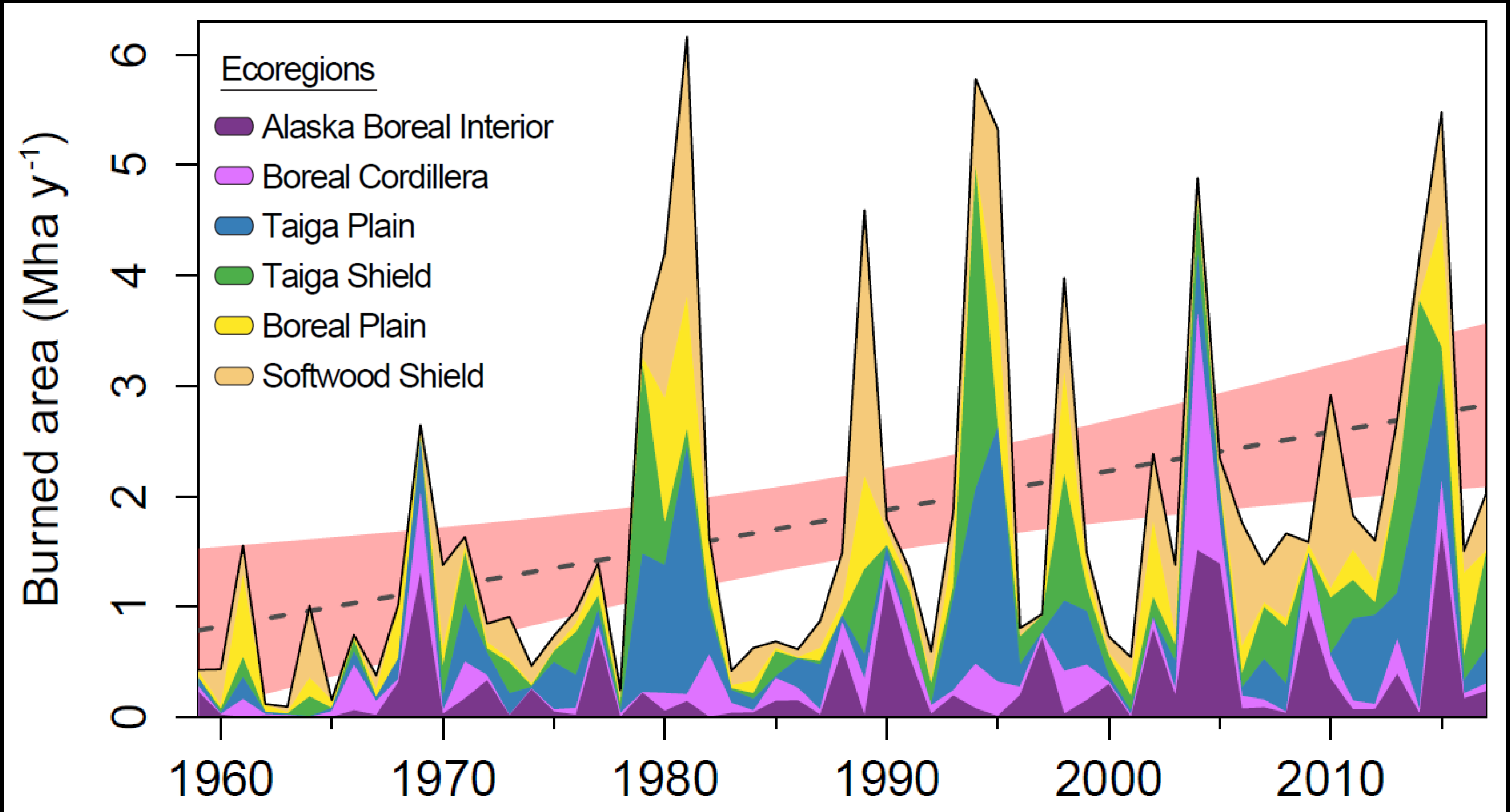
Soil Organic Layer

Legacy Carbon

Soil Organic Layer

- older than the stand age at the time of fire

Boreal Forest Wildfires



↑ Size, Frequency, Severity

↑ carbon emissions

- Models based on top-down controls of climate and fire weather

↑ carbon emissions

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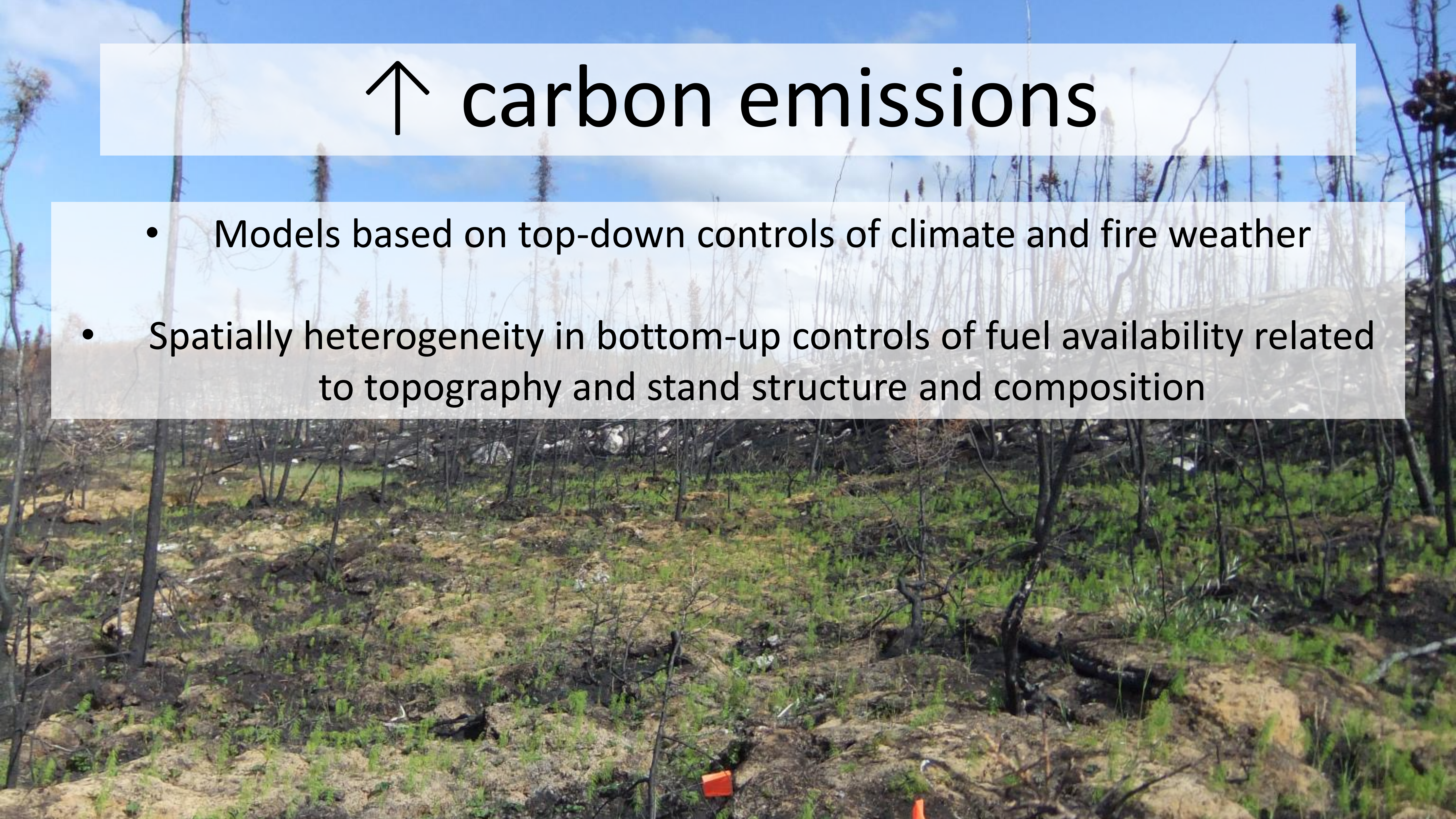
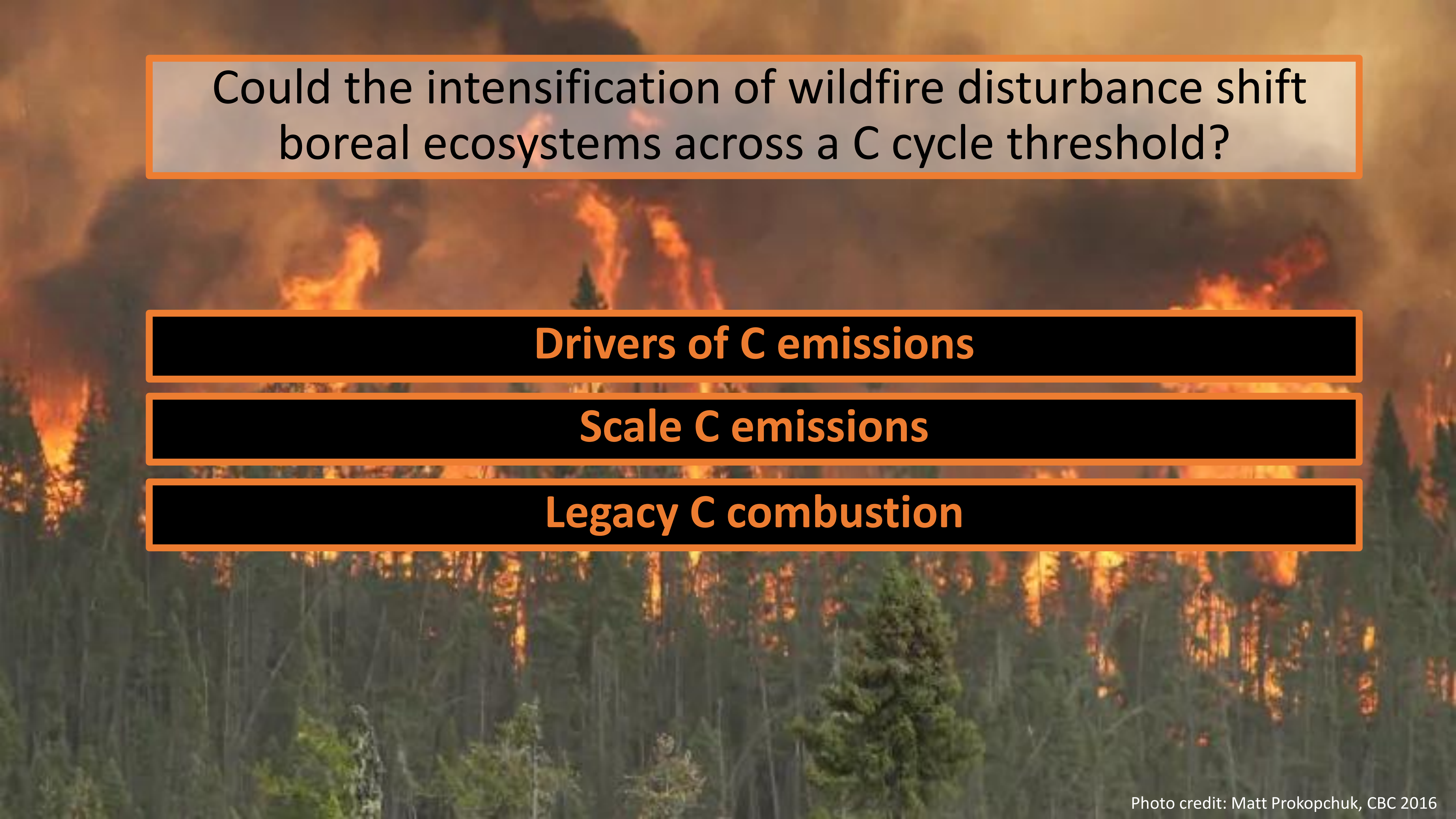
- Spatially heterogeneity in bottom-up controls of fuel availability related to topography and stand structure and composition



↑ carbon emissions

- Models based on top-down controls of climate and fire weather
- Spatially variability in bottom-up controls of fuel availability related to topography and stand structure and composition
- Scale C emissions to the entire area burned

Δ long-term net ecosystem carbon balance



Could the intensification of wildfire disturbance shift boreal ecosystems across a C cycle threshold?

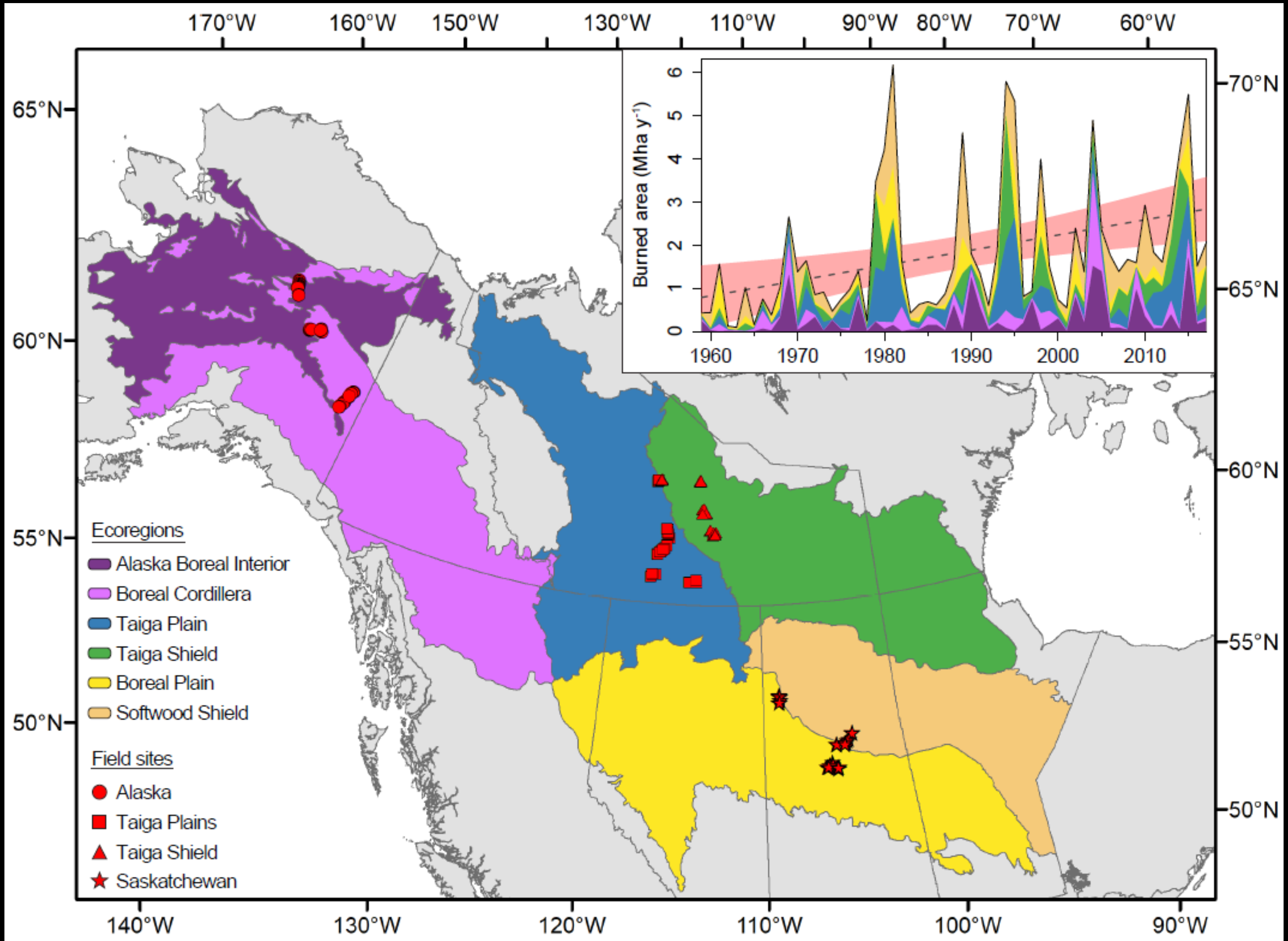
Drivers of C emissions

Scale C emissions

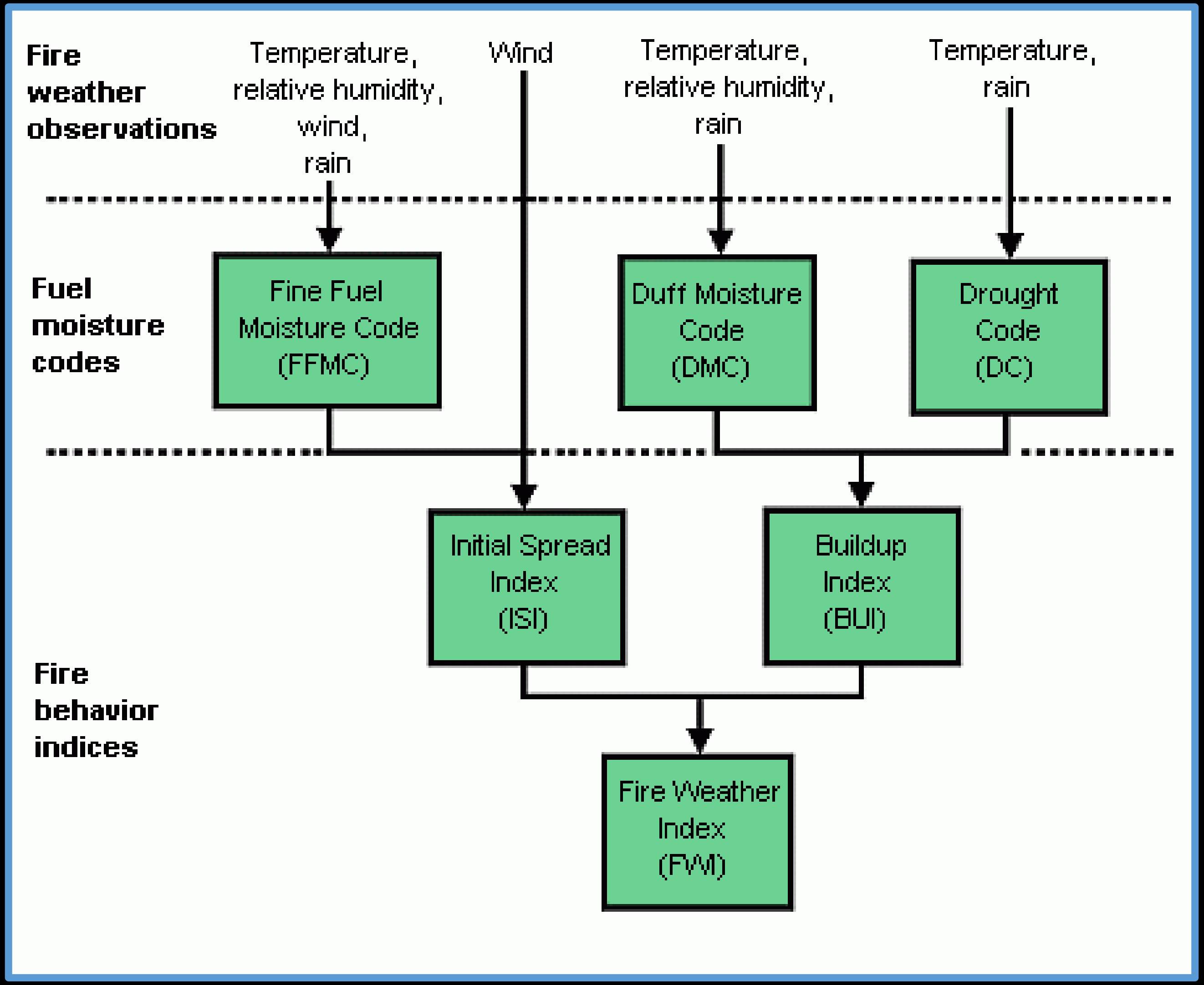
Legacy C combustion

Photo credit: Matt Prokopchuk, CBC 2016

Drivers of C emissions



- 417 burned plots in 6 ecoregions



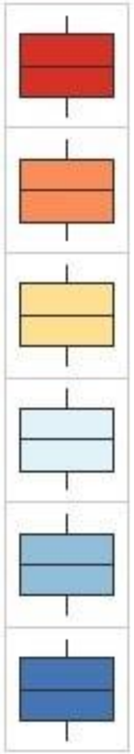
Day of Burn
Fine Fuel Moisture Code
Duff Moisture Code
Drought Code
Initial Spread Index
Buildup Index
Fire Weather Index
Daily Severity Rating

Stand Age

5 – 10 trees of the dominant species

Proportion of Black Spruce

Moisture



XERIC: Little surface moisture stabilized sand dunes and dry ridgetops

SUBXERIC: Some noticeable surface moisture; well drained slopes or ridgetops

SUBXERIC-MESIC: Very noticeable surface moisture; flat to gently sloping

MESIC: Moderate surface moisture; flat or shallow depressions including toe-slopes

MESIC-SUB-HYGRIC: Considerable surface moisture; depressions or concave toe-slopes

SUB-HYGRIC: Very considerable surface moisture; saturated with less than 5% standing water

Shallow Permafrost

Coarse Soil Texture

Modified from Johnstone et al. 2008

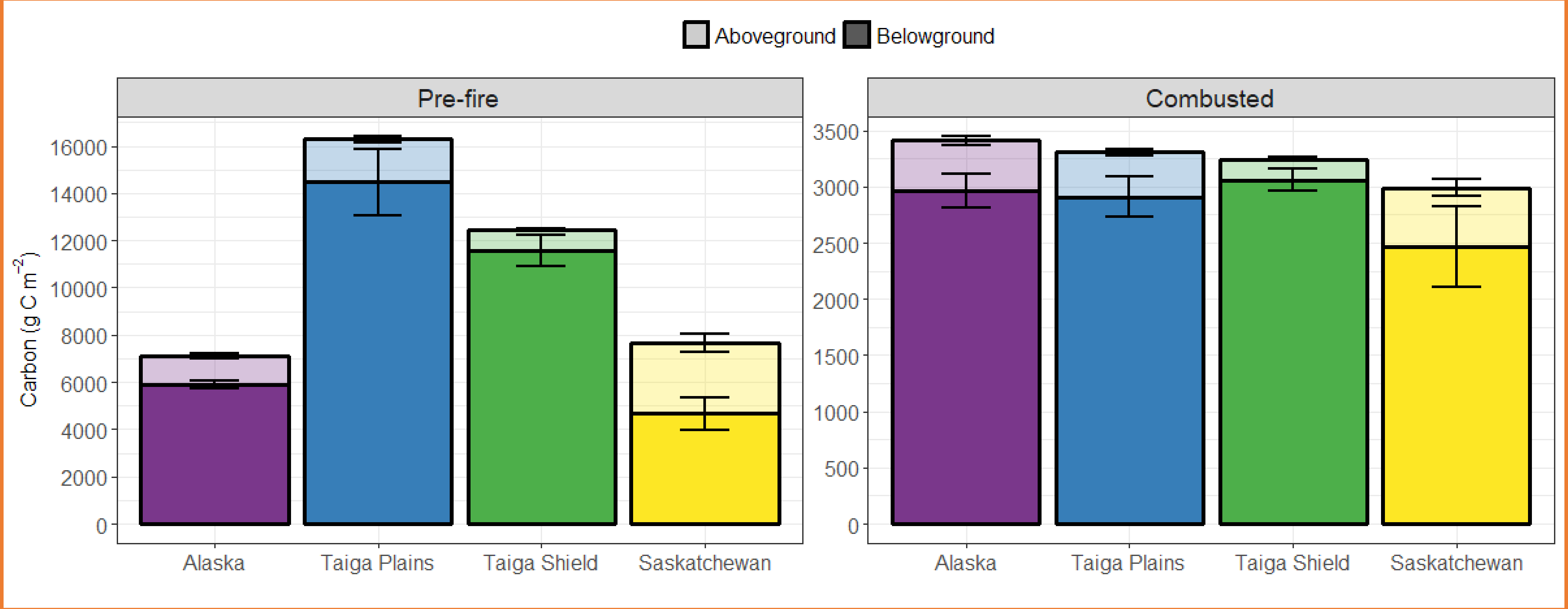
Aboveground

Each tree assigned score for combustion (0-3)
Allometric equations for biomass
Carbon component = 50% of biomass

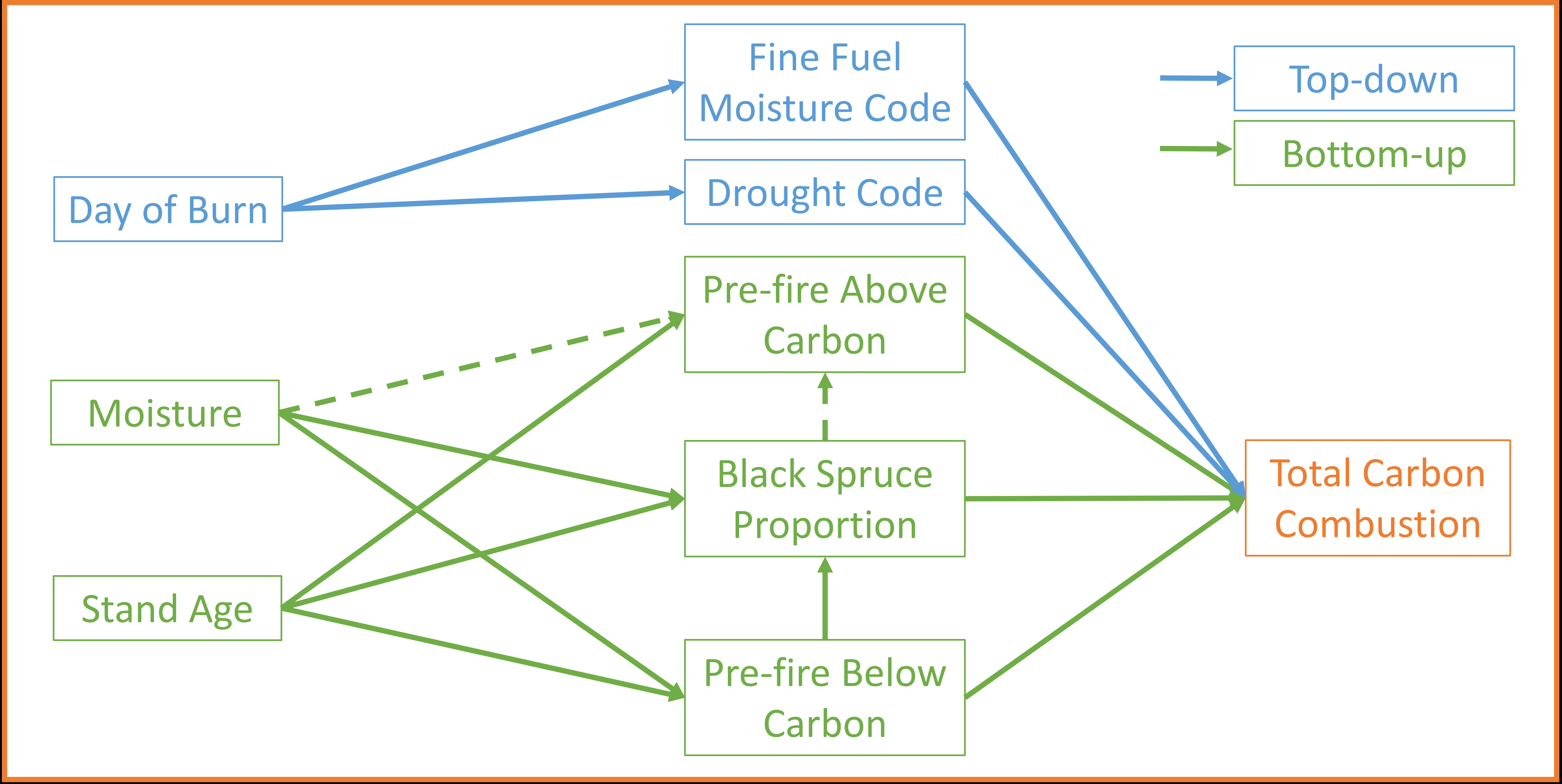
Belowground

Adventitious roots = burn depth
5 soil samples/site for C content and bulk density
Modelled carbon content ~ depth

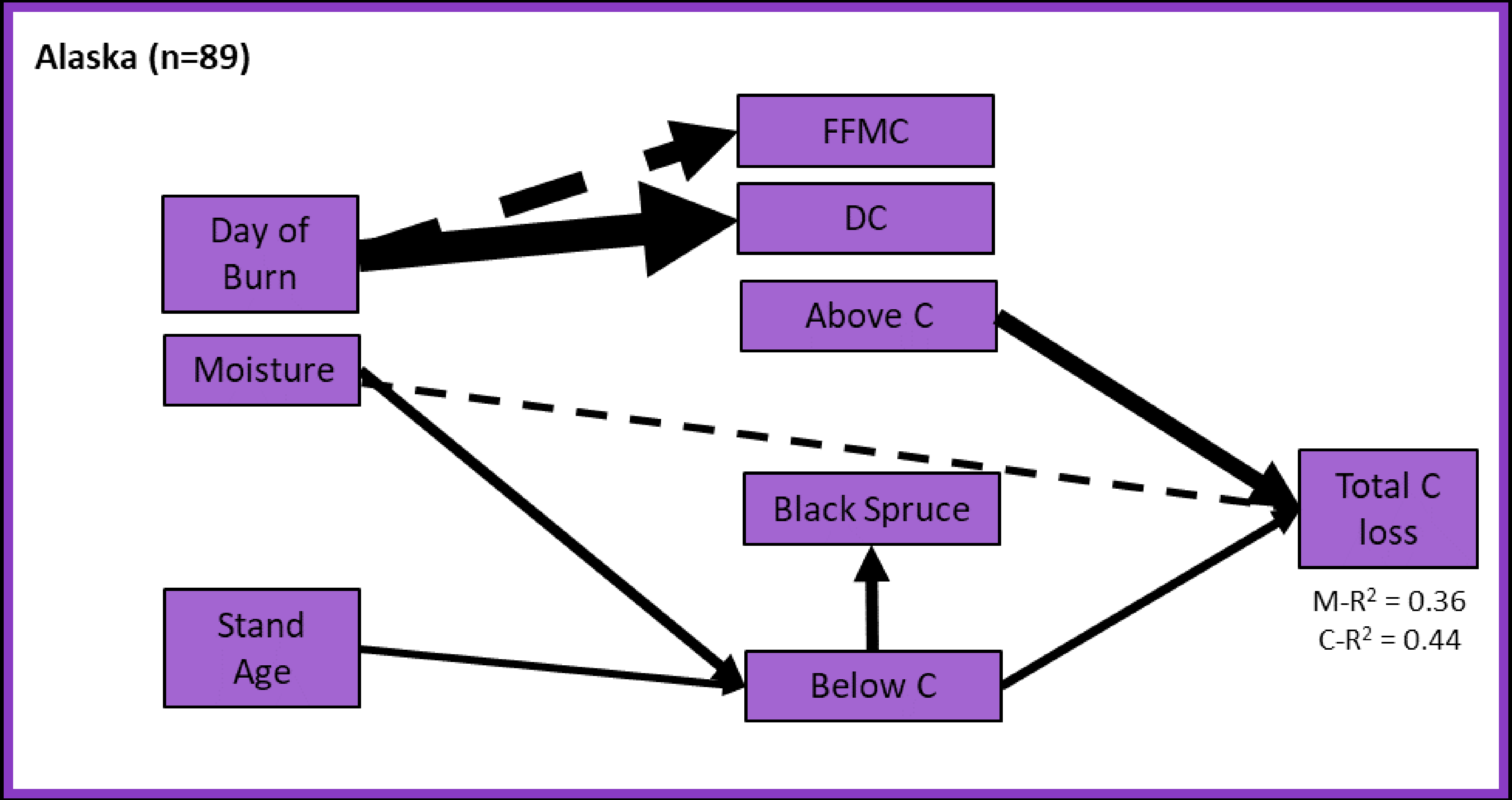
Pre-fire C pools and C combusted



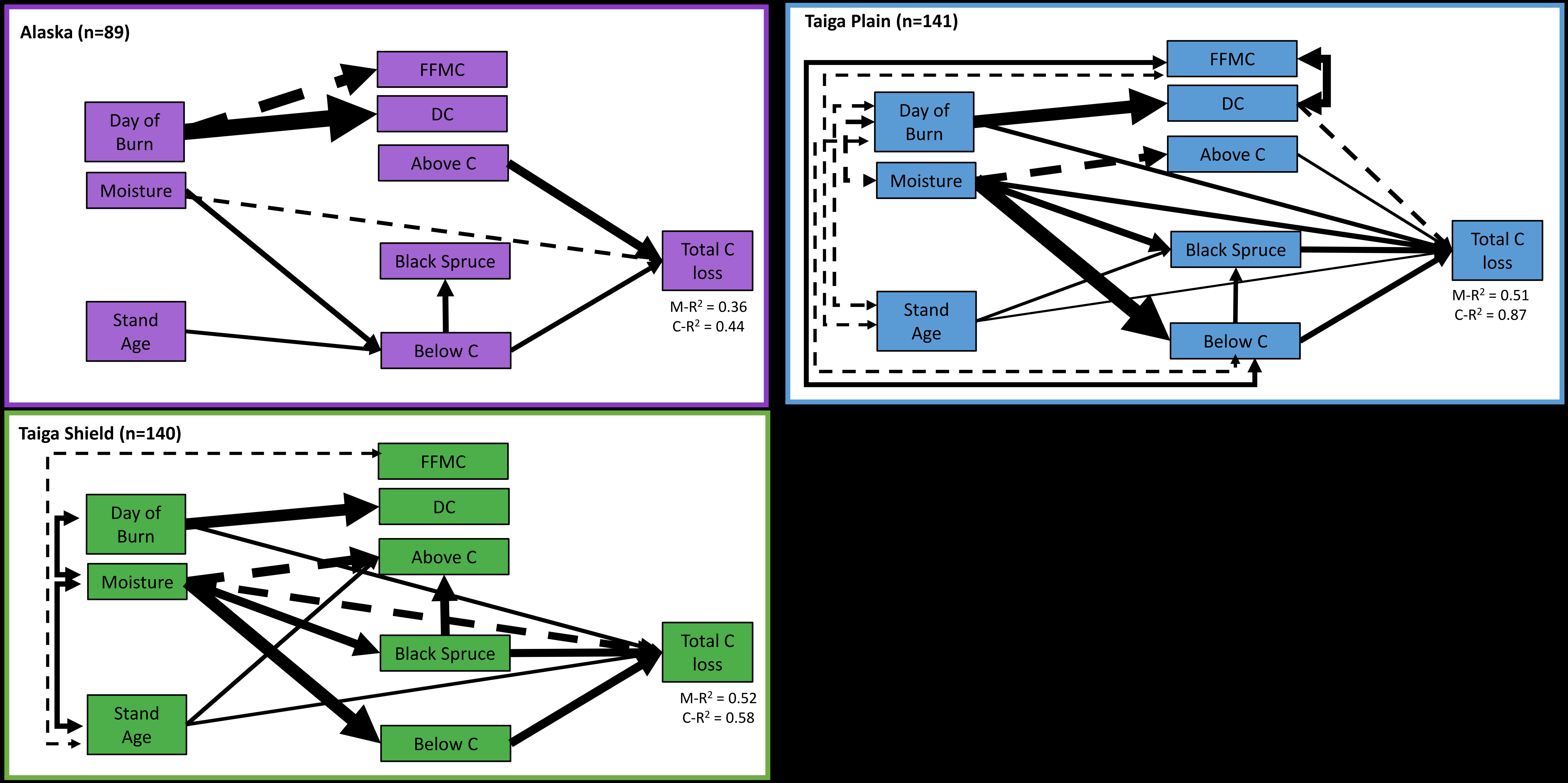
Drivers of C emissions



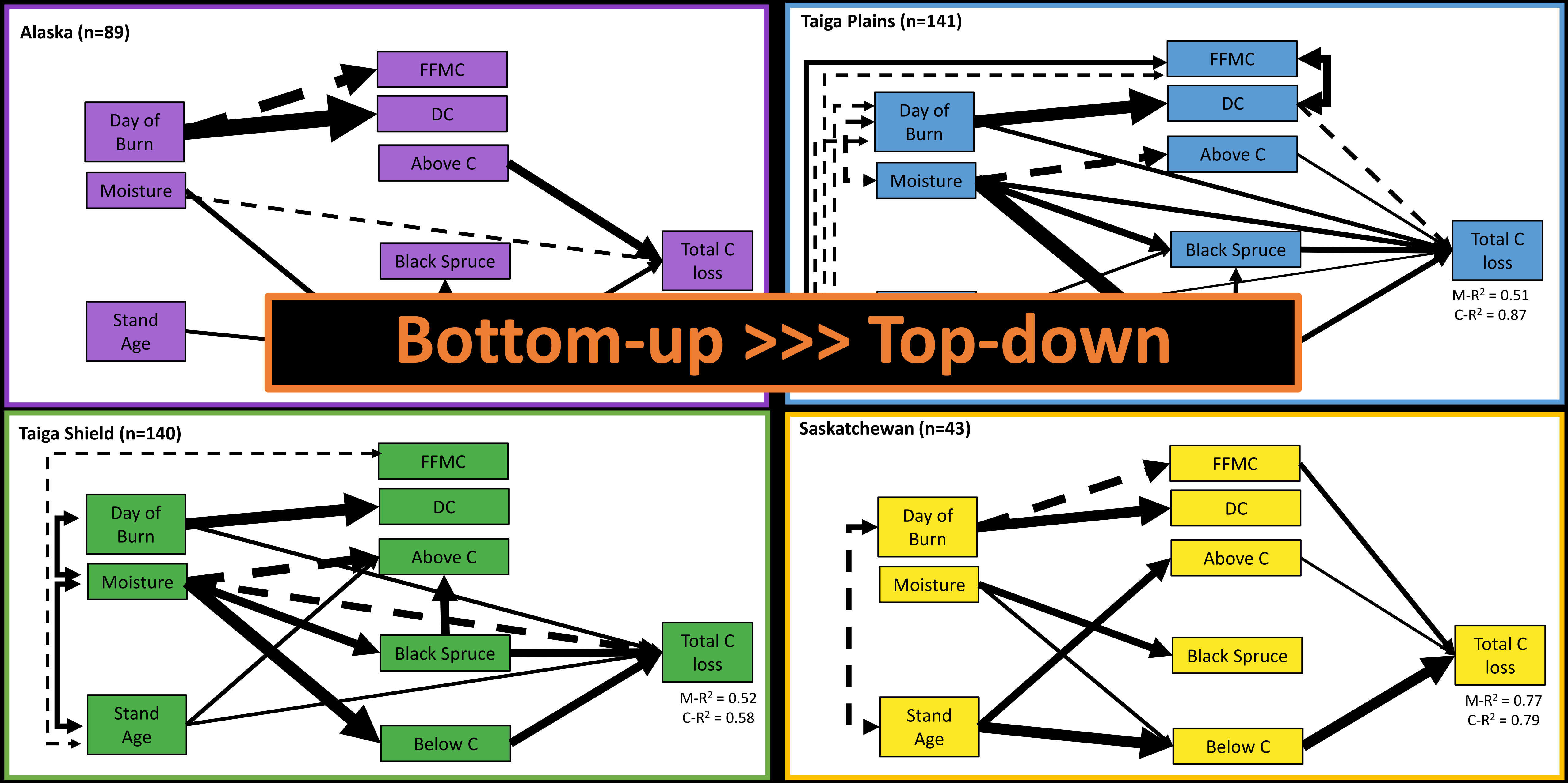
Drivers of C combustion



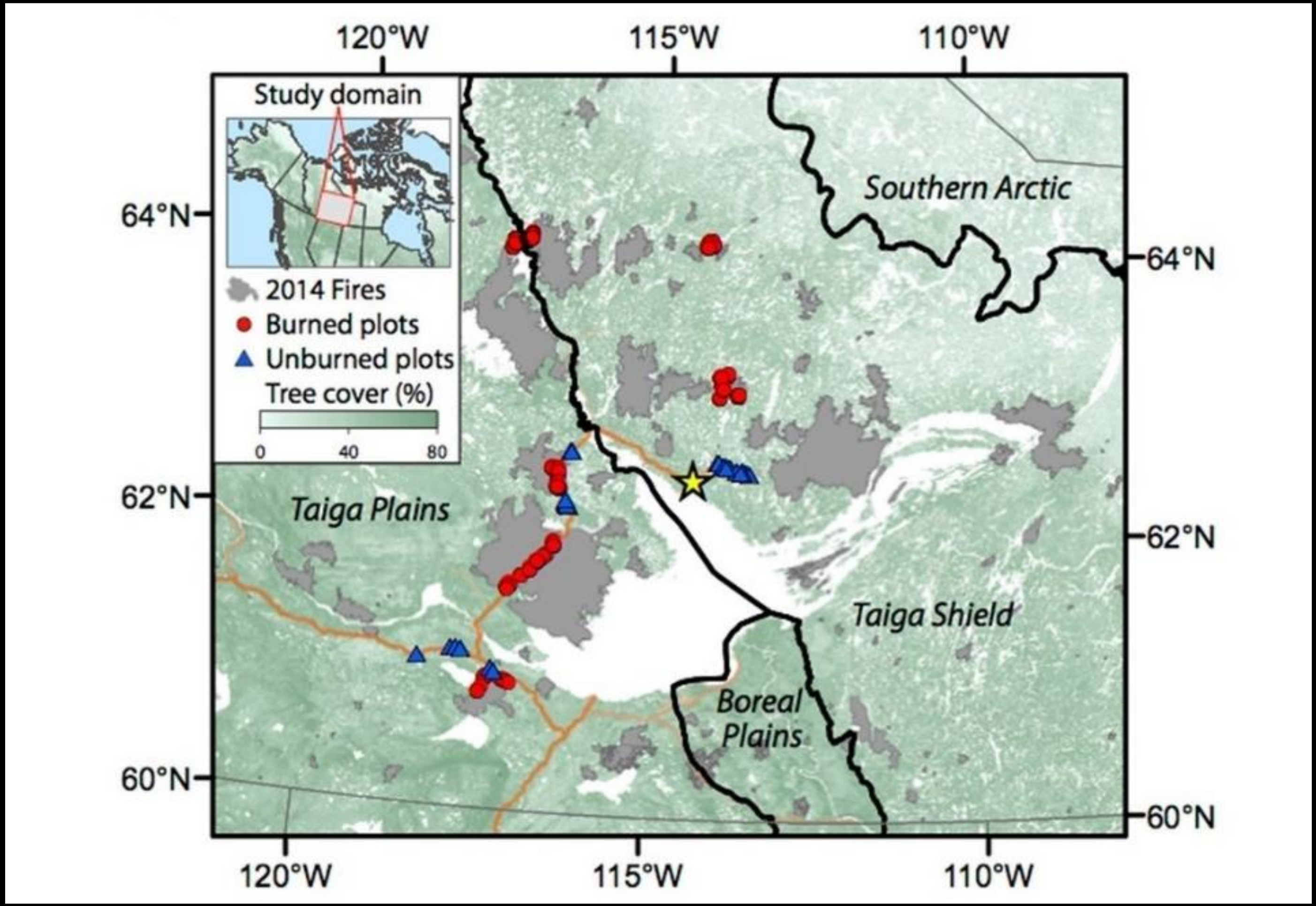
Drivers of C combustion



Drivers of C combustion



Scale C emissions

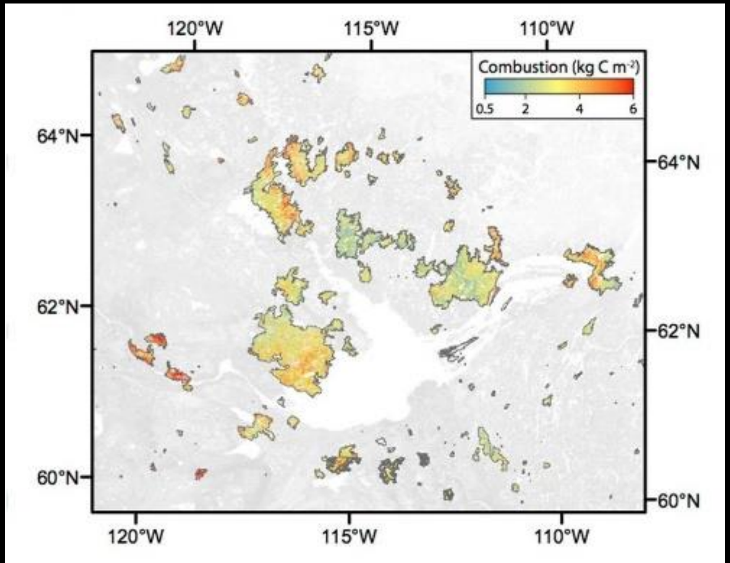


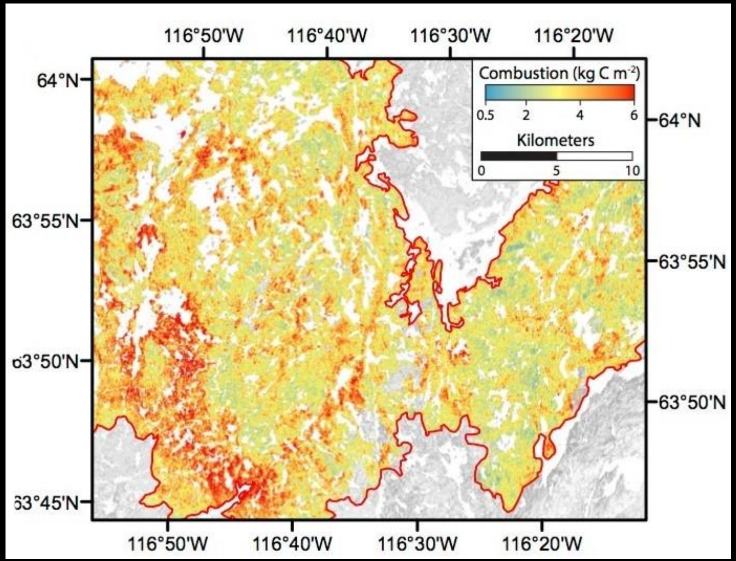
211 burned plots in 7 burn scars and 36 unburned plots in 3 regions

Total carbon combustion = 3.4 ± 2.0 Kg C m^{-2}

Scale C emissions

Full Model: topographic wetness index, terrain ruggedness, dNBR, relative change in tree cover, % black spruce, and % sand in the top 15 cm of soil

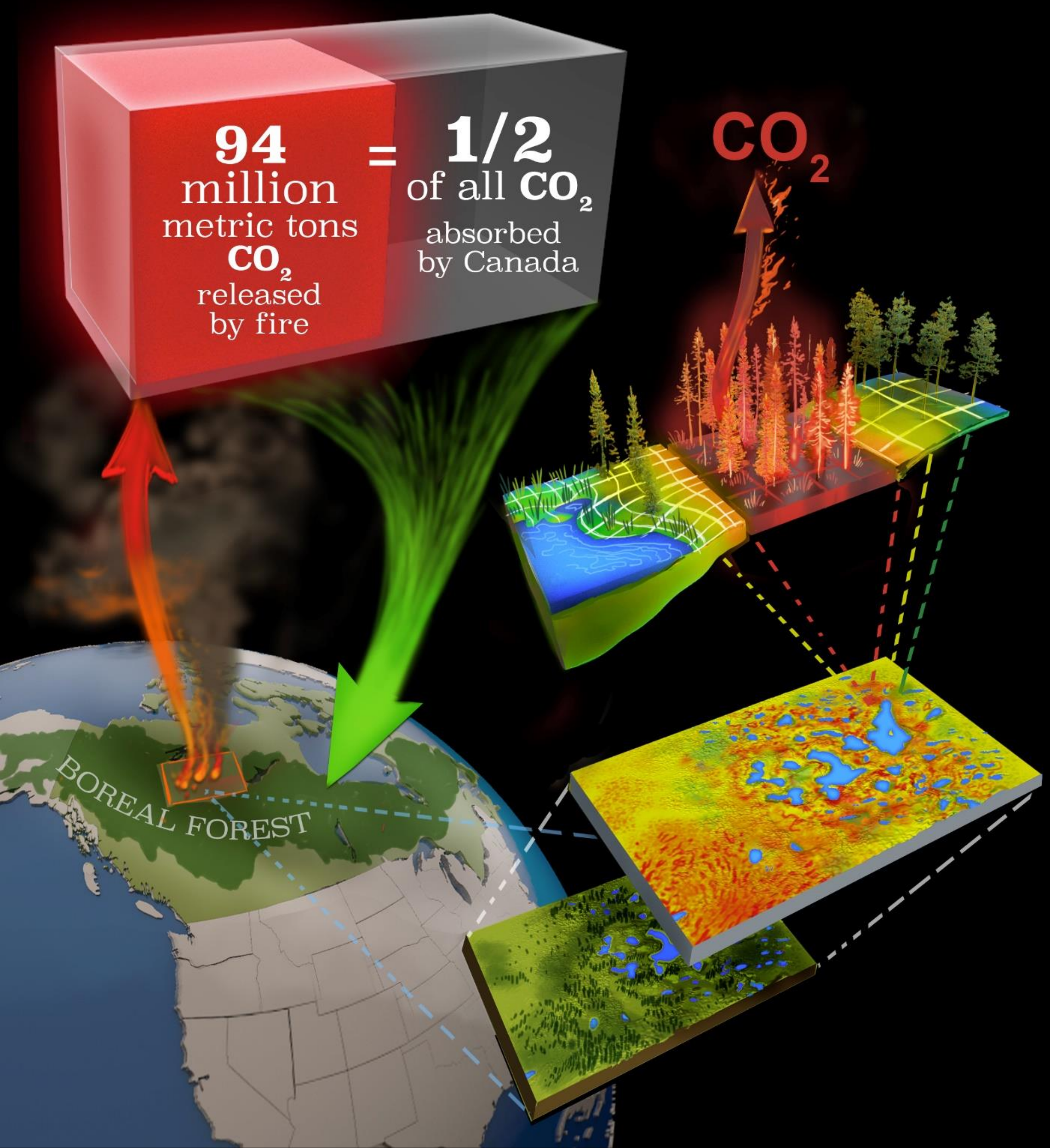




Study	Area Burned(Mha)	Total C emissions (Tg C)
Walker et al. 2018 (this study)	2.85	94.3
Veraverbeke et al. 2017	3.41	164

Differences due to:

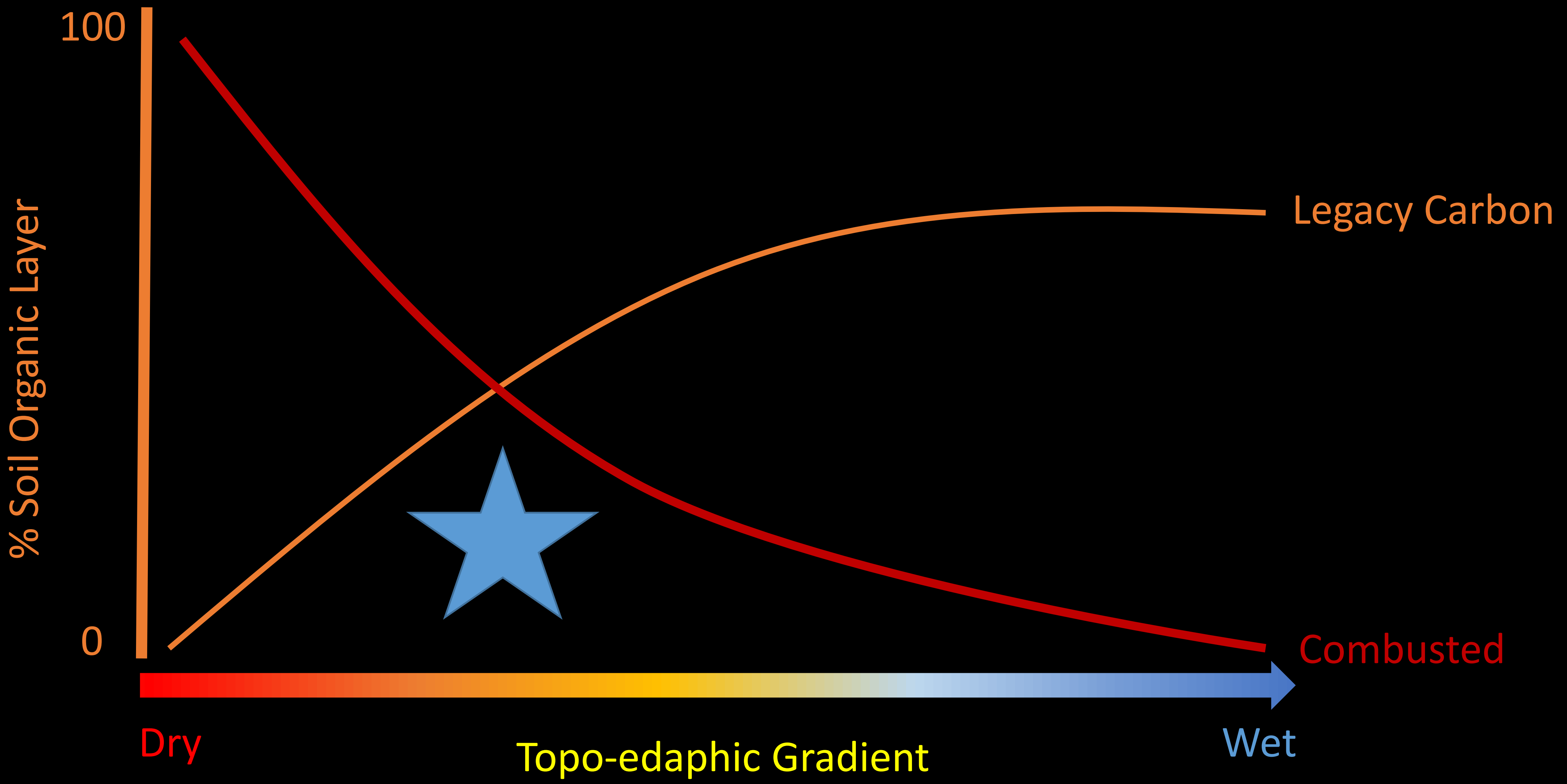
1) Spatial resolution (30m vs 500m) and ability to capture small water bodies and unburned areas
2) Regionally specific field training data vs. training data from Alaskan black spruce sites



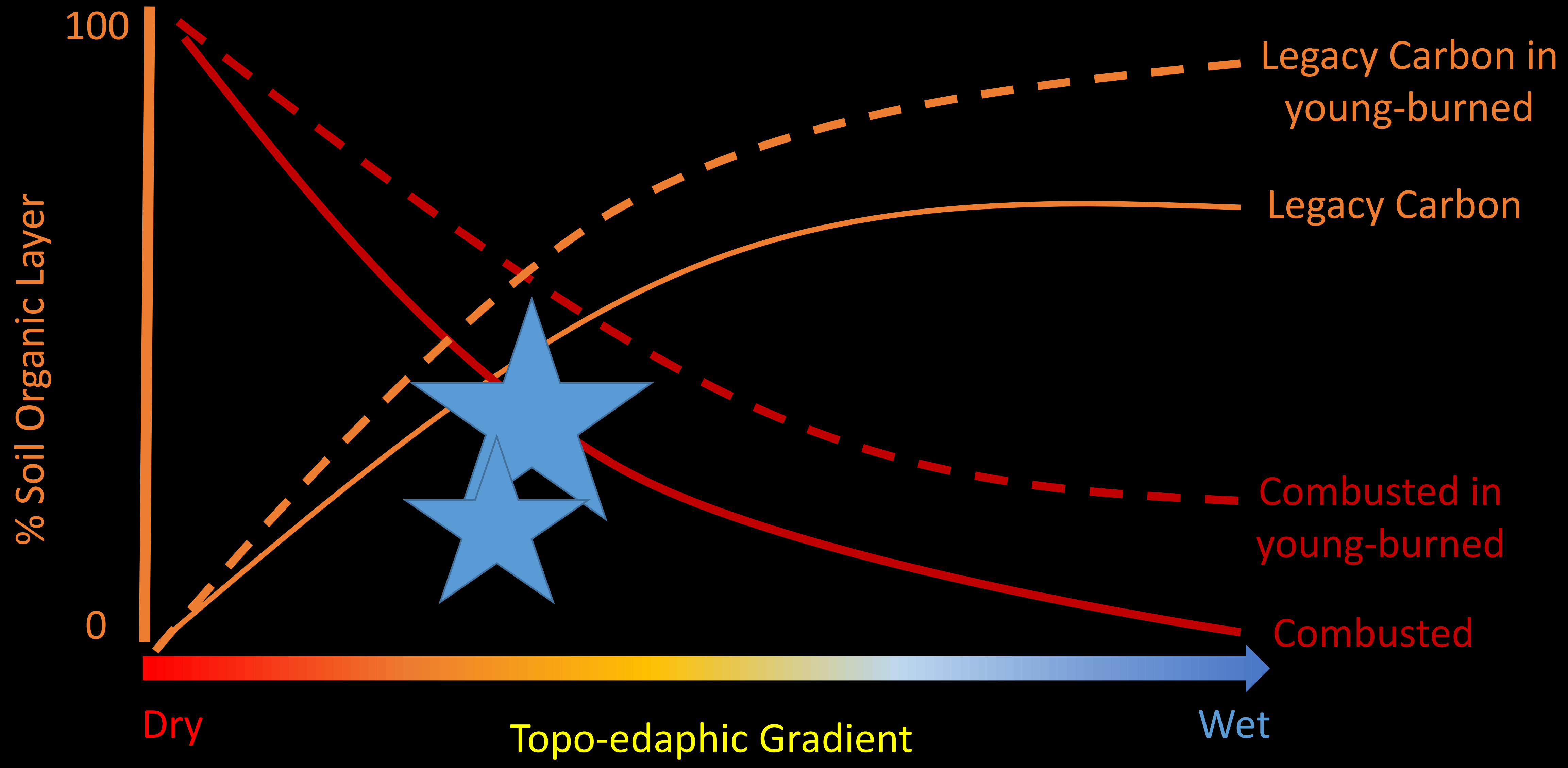
94.3 Tg C

= 50% annual C uptake in terrestrial ecosystems of Canada

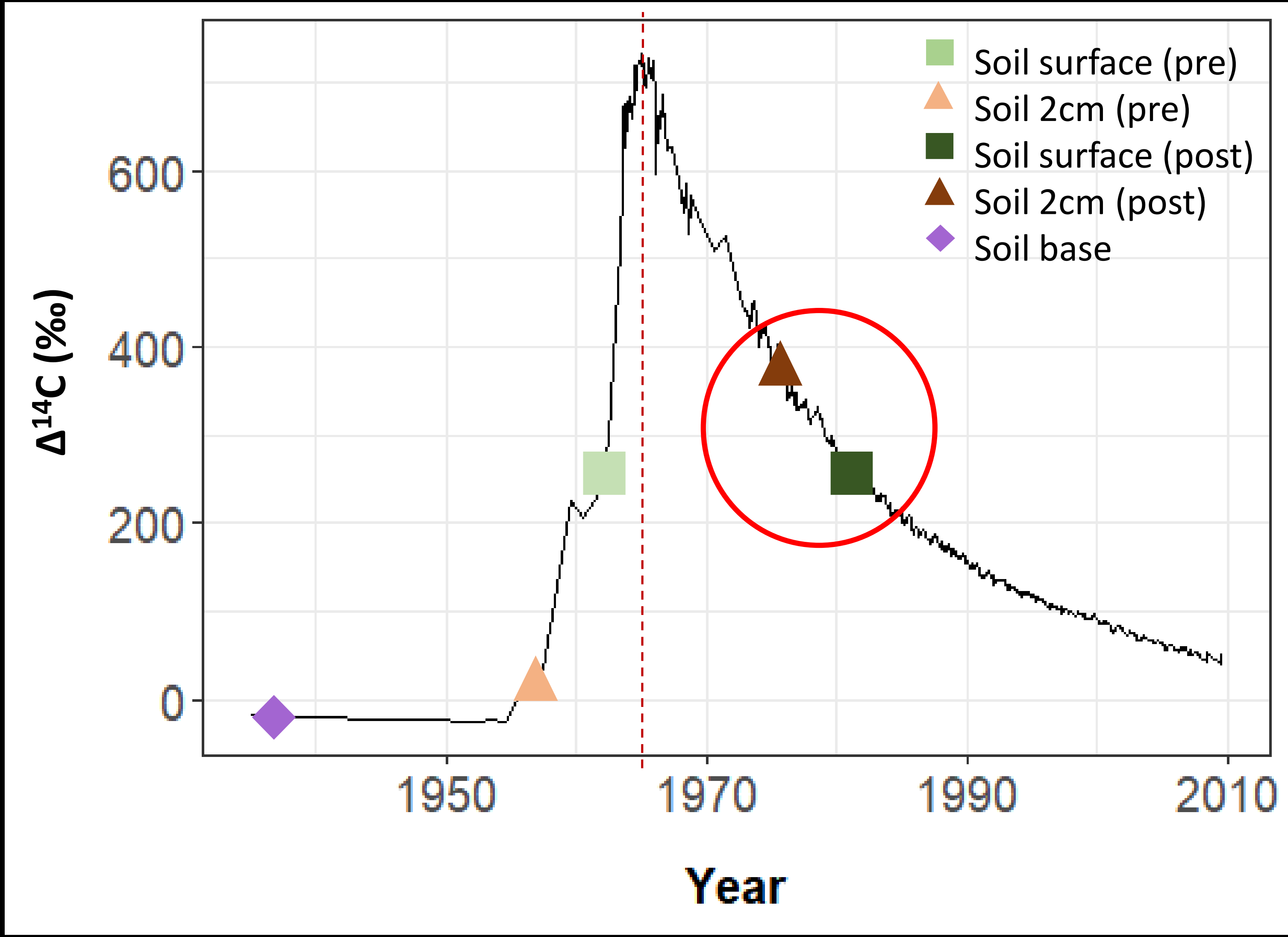
Legacy carbon combustion



Legacy carbon combustion

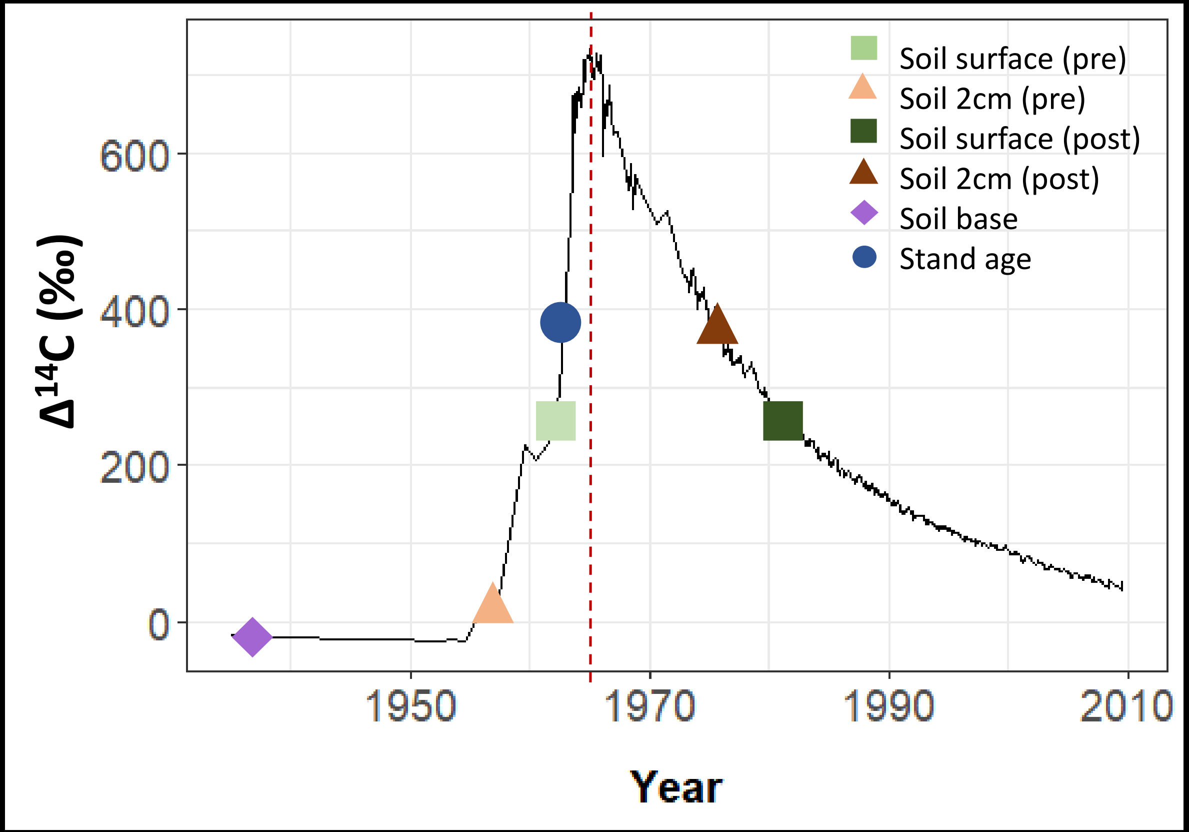


- Black spruce dominated sites
  - 28 old-burned & 9 young-burned plots
- Sectioned the SOL profile
  - 0-1cm
  - 1-2 cm
  - 1cm above mineral soil
- Removed roots and filtered soil
- $\Delta^{14}C$ values



Soil surface (pre)
Soil 2cm (pre)
Soil surface (post)
Soil 2cm (post)
Soil base
600
400
200
0
1950
1970
1990
2010
$\Delta^{14}C$ (‰)
Year

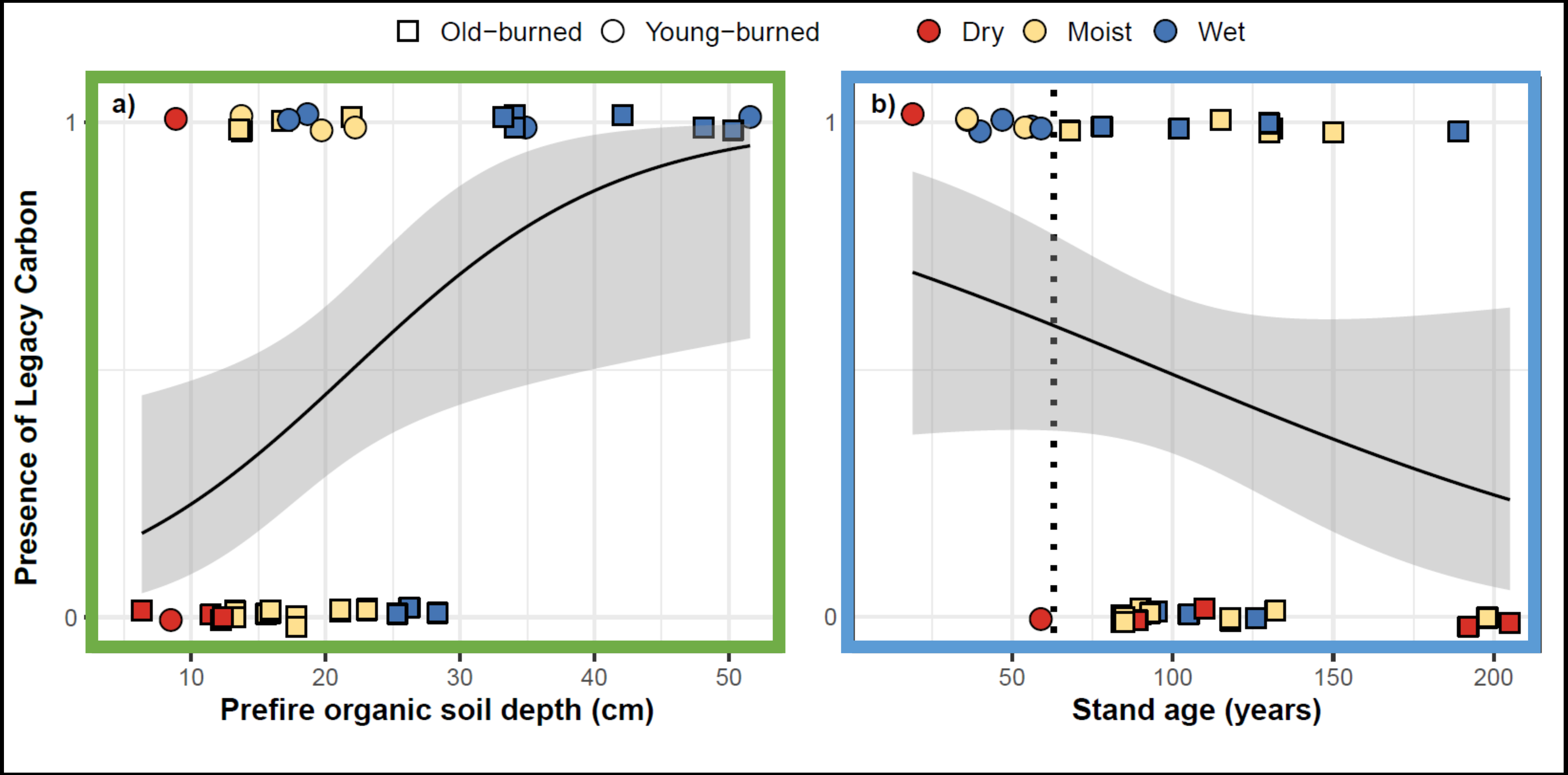
Stand age at time of fire



Legacy C is present if stand age is younger than soil base

Legacy C is combusted if stand age is younger than soil surface

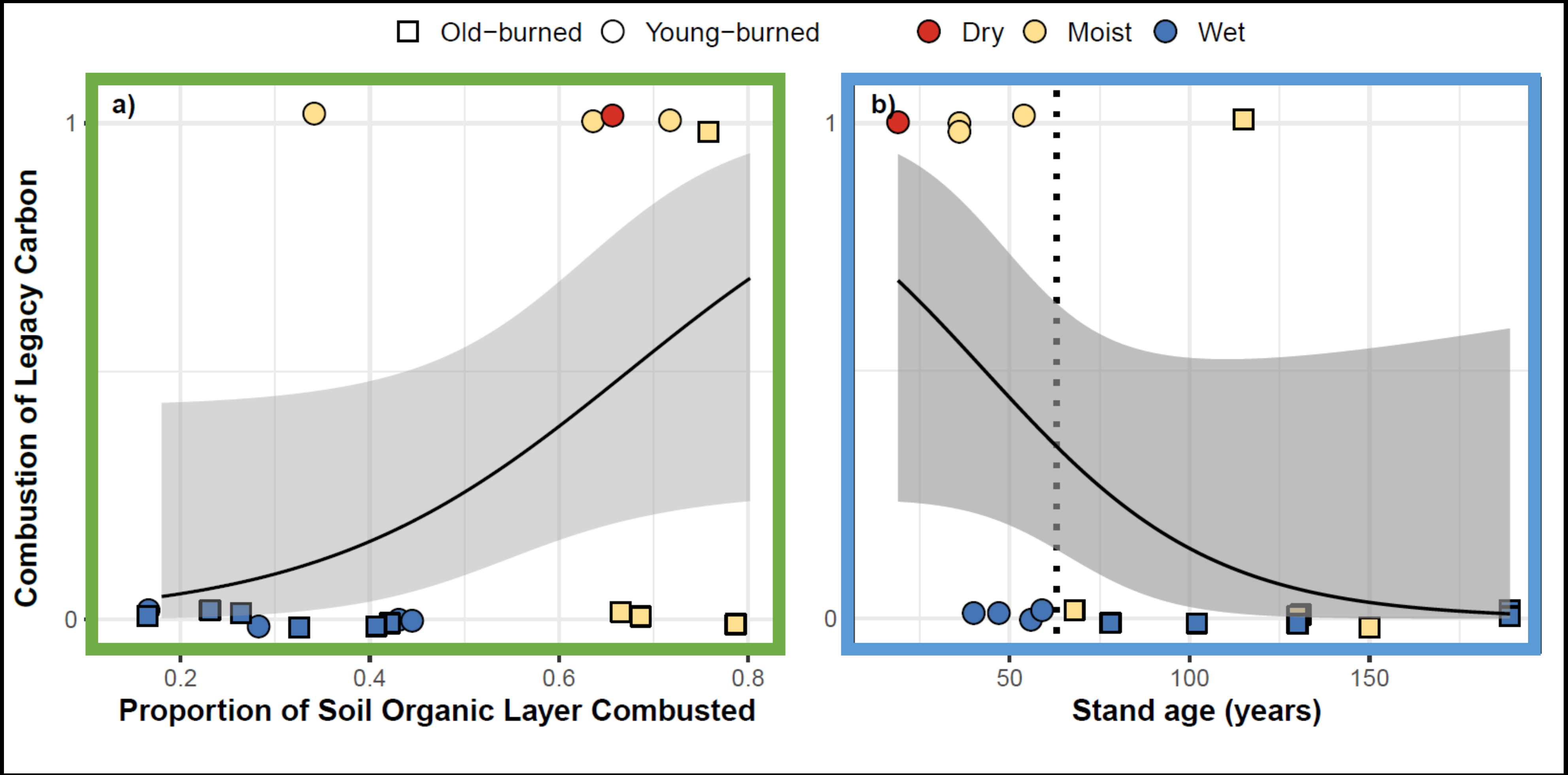
Legacy Carbon Presence



organic soil > 30cm

stand age <60 years

Legacy Carbon Combustion



proportion soil combusted > 50%

stand age <60 years

Legacy C Combustion

45% of young-burned plots = net C source

= 0.34 Mha of forests emitted 8.6 Tg C

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C emissions were NOT different between sites with legacy C combustion vs. NO legacy C combustion

Summary & Conclusions

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- C emissions controlled by bottom-up drivers
- Scaling emissions: account for spatial heterogeneity in fuel availability and fire severity & use regionally calibrated models
- Predicting future emissions: assess how environmental change will impact these bottom-up controls
- Measuring C emissions alone is insufficient for assessing the long-term impacts of wildfire on boreal net ecosystem carbon balance

Thank you

NORTHERN ARIZONA UNIVERSITY

ECOS^s Center for Ecosystem Science and Society at Northern Arizona University

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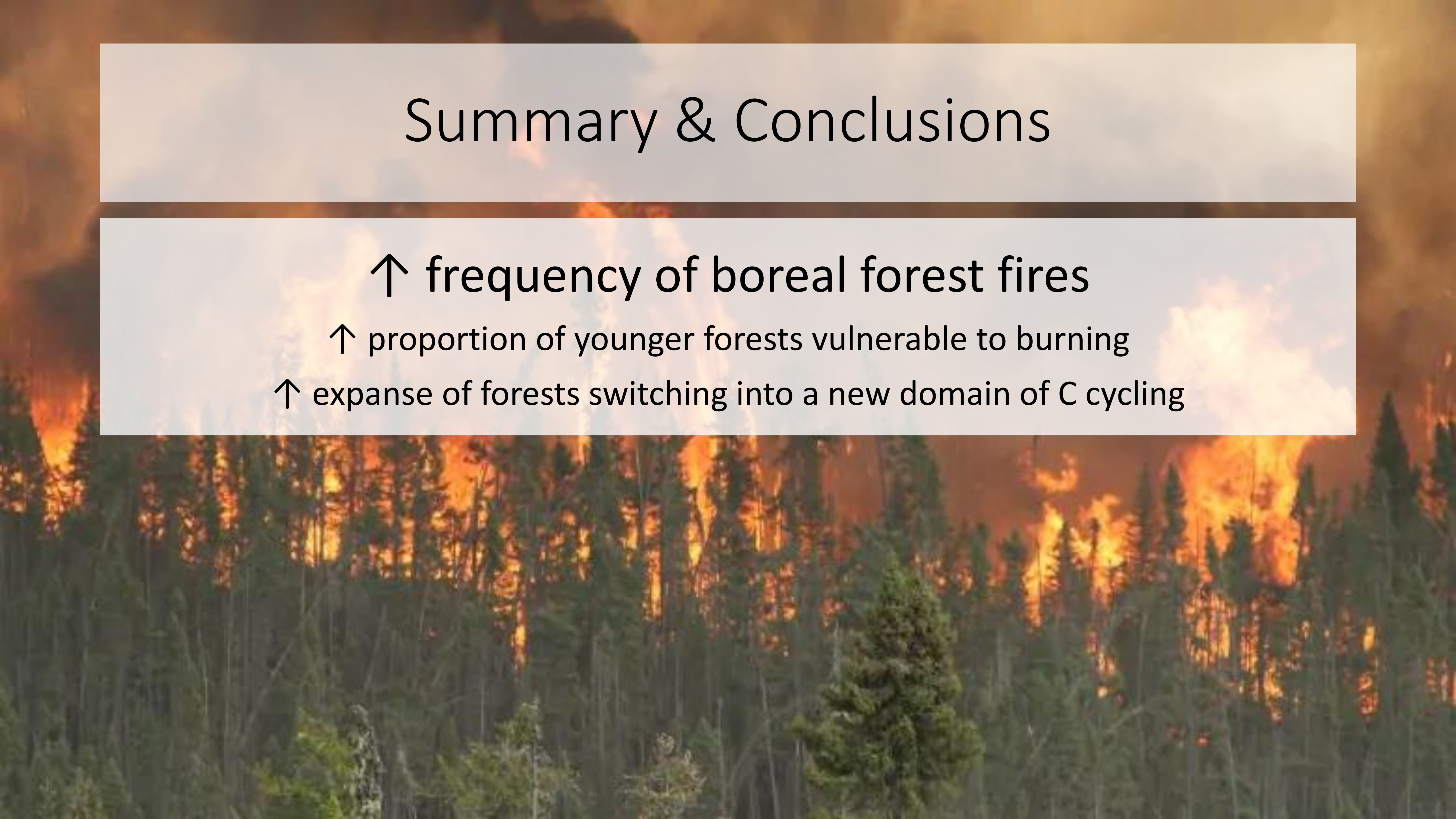


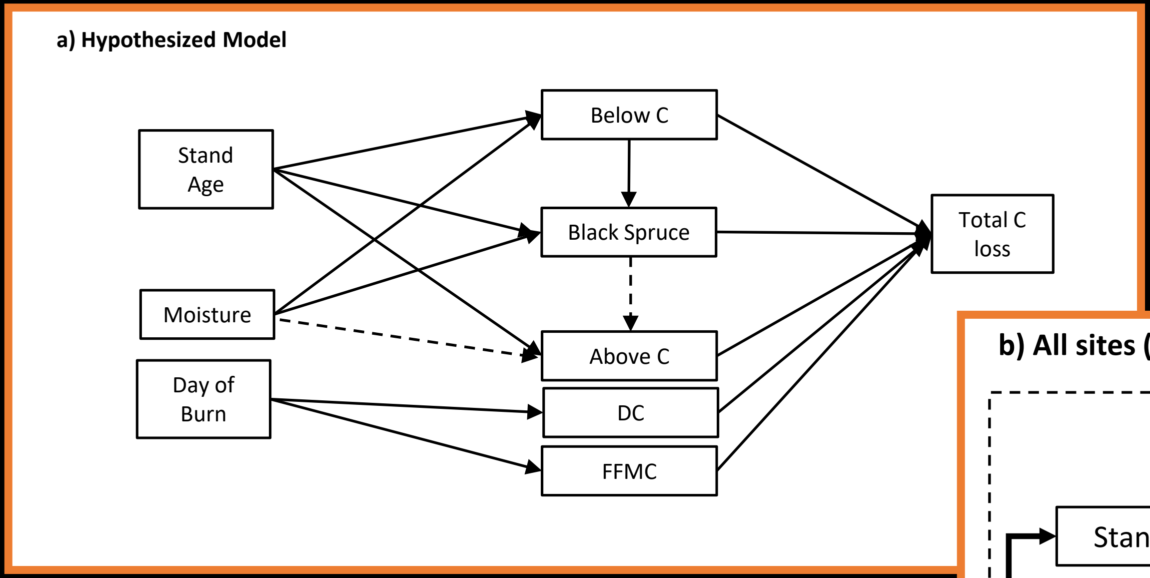
Summary & Conclusions

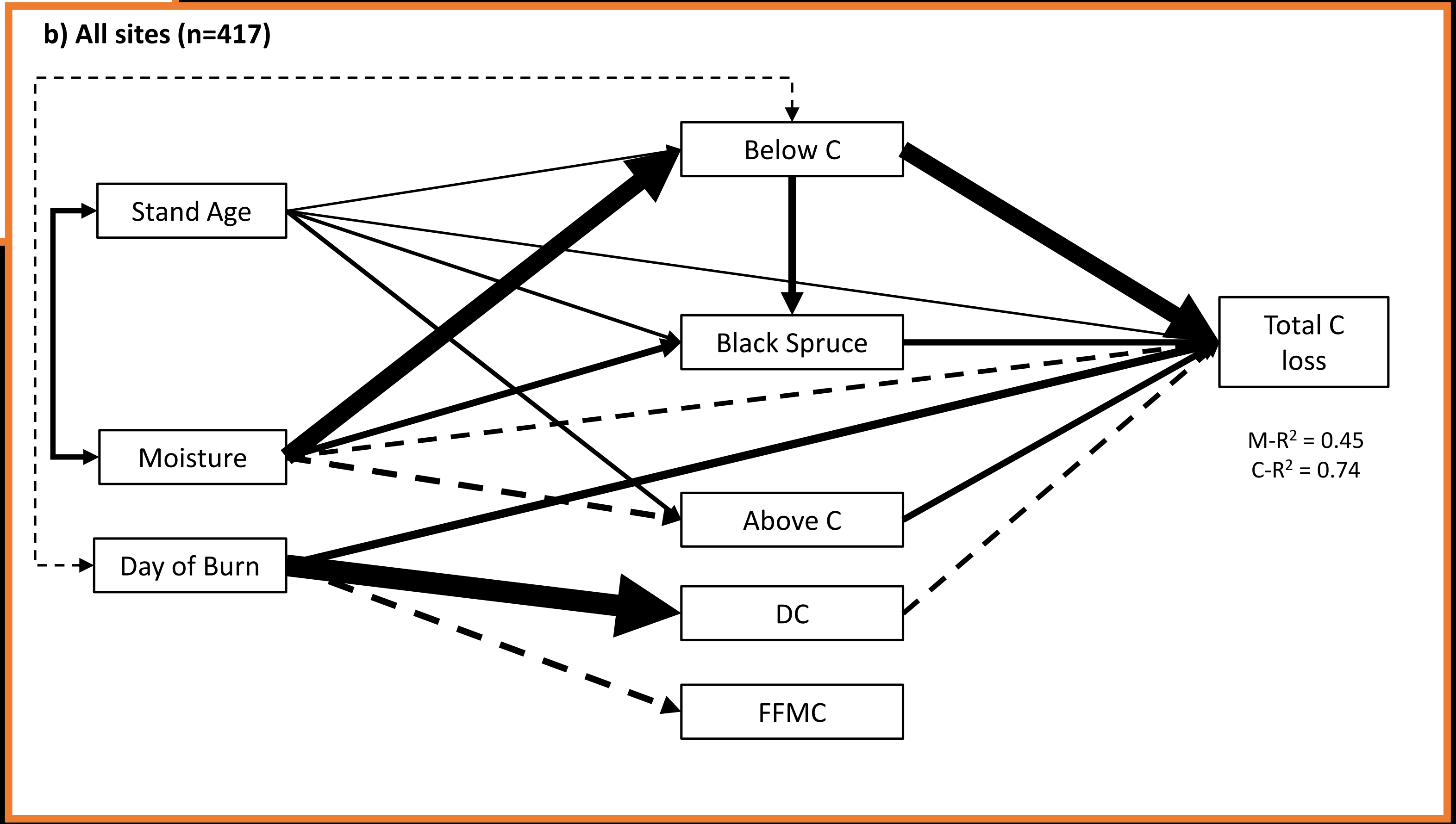
↑ frequency of boreal forest fires

↑ proportion of younger forests vulnerable to burning

↑ expanse of forests switching into a new domain of C cycling

Drivers of C emissions





Summary & Conclusions

↑ frequency of boreal forest fires

↑ proportion of younger forests vulnerable to burning

↑ expanse of forests switching into a new domain of C cycling

↑ exposure of legacy C to decomposition

Legacy C loss will impact:

future boreal net ecosystem carbon balance

global C cycle and climate