



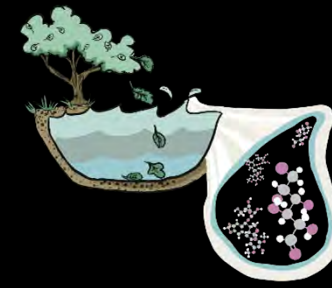
Intro-session A: Landscape Carbon 101

Andrew Tanentzap, Trent University & Elyn Humphreys, Carleton University



Photo: E Humphreys

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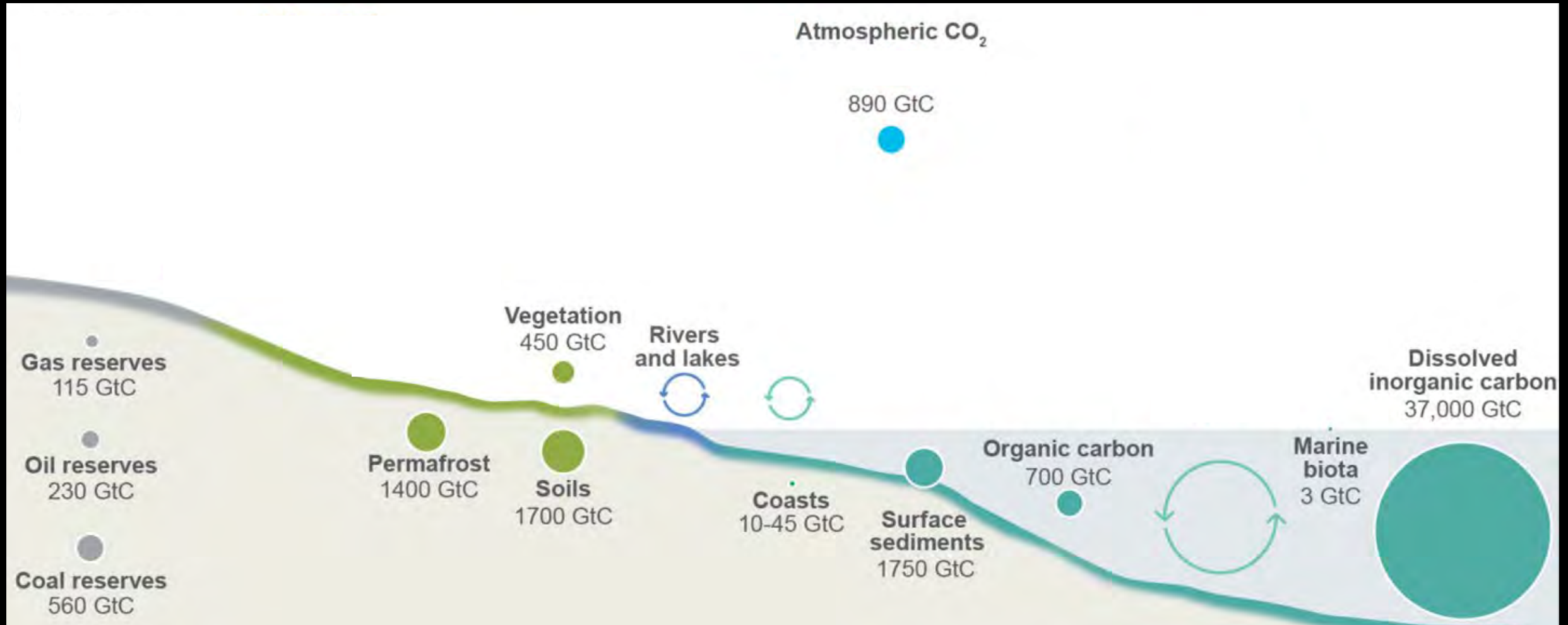


Carl von Ossietzky
Universität
Oldenburg

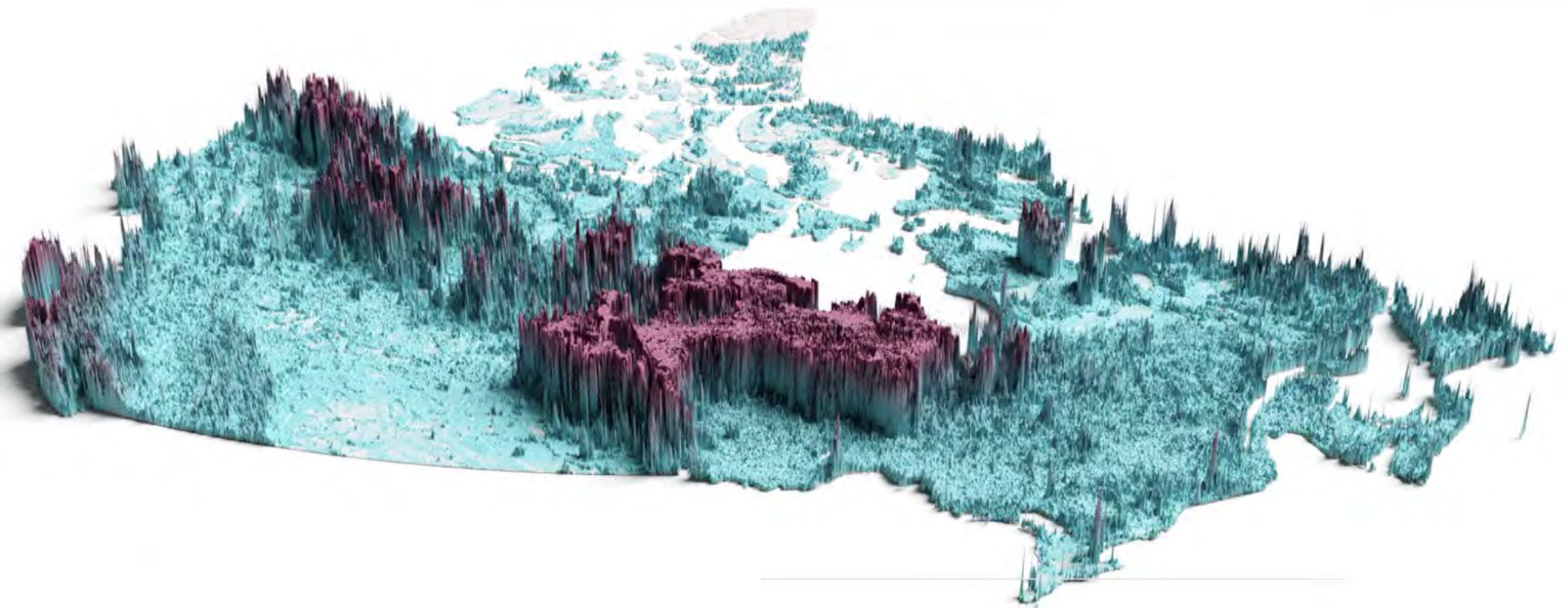
Carbon is everywhere



1) Small changes to carbon stored on land make a **big** difference to the climate



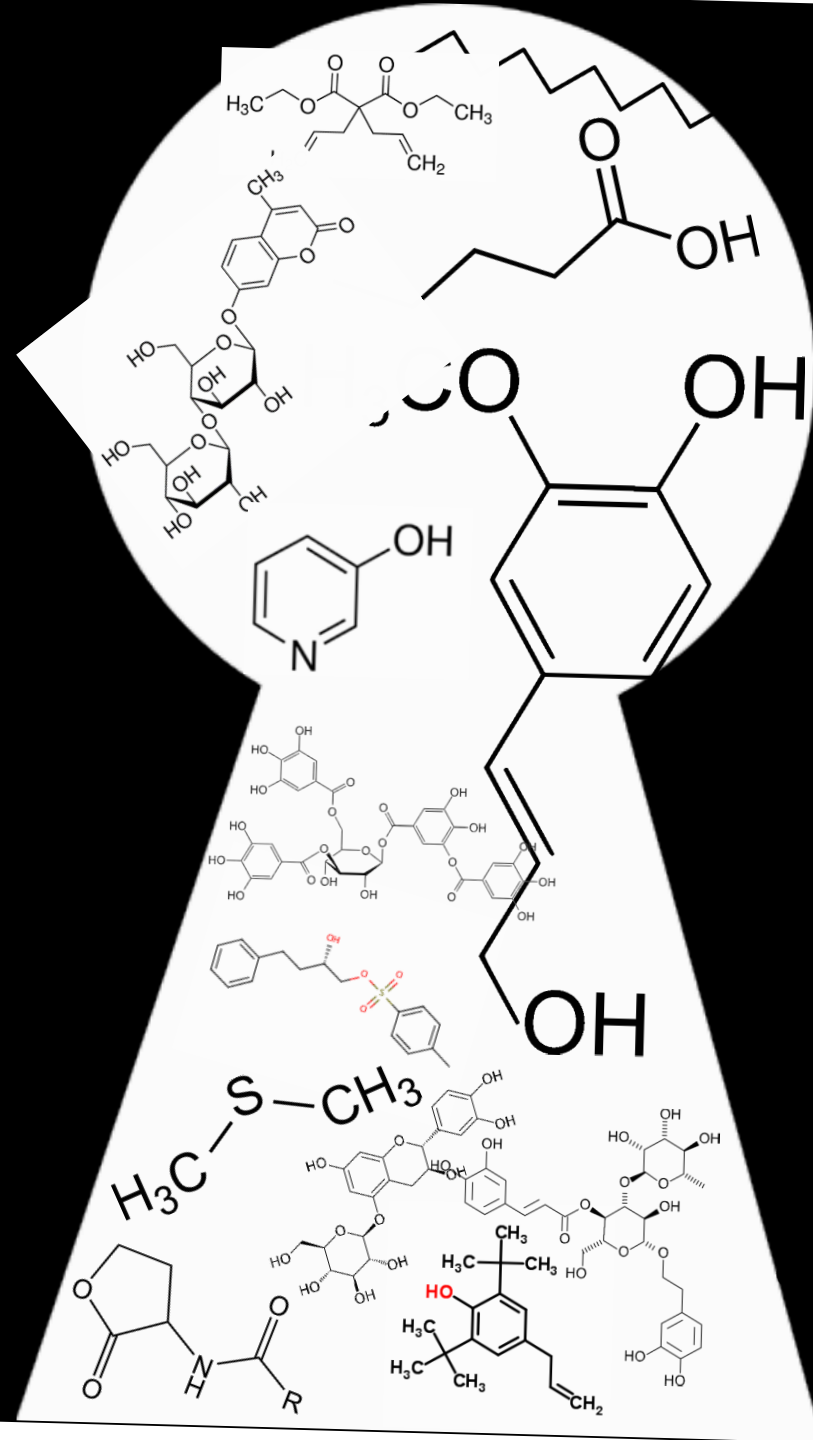
The NWT is carbon rich but how much is there?



Globe and Mail 2021 based on Sothe et al 2022 Global Biochemical Cycles



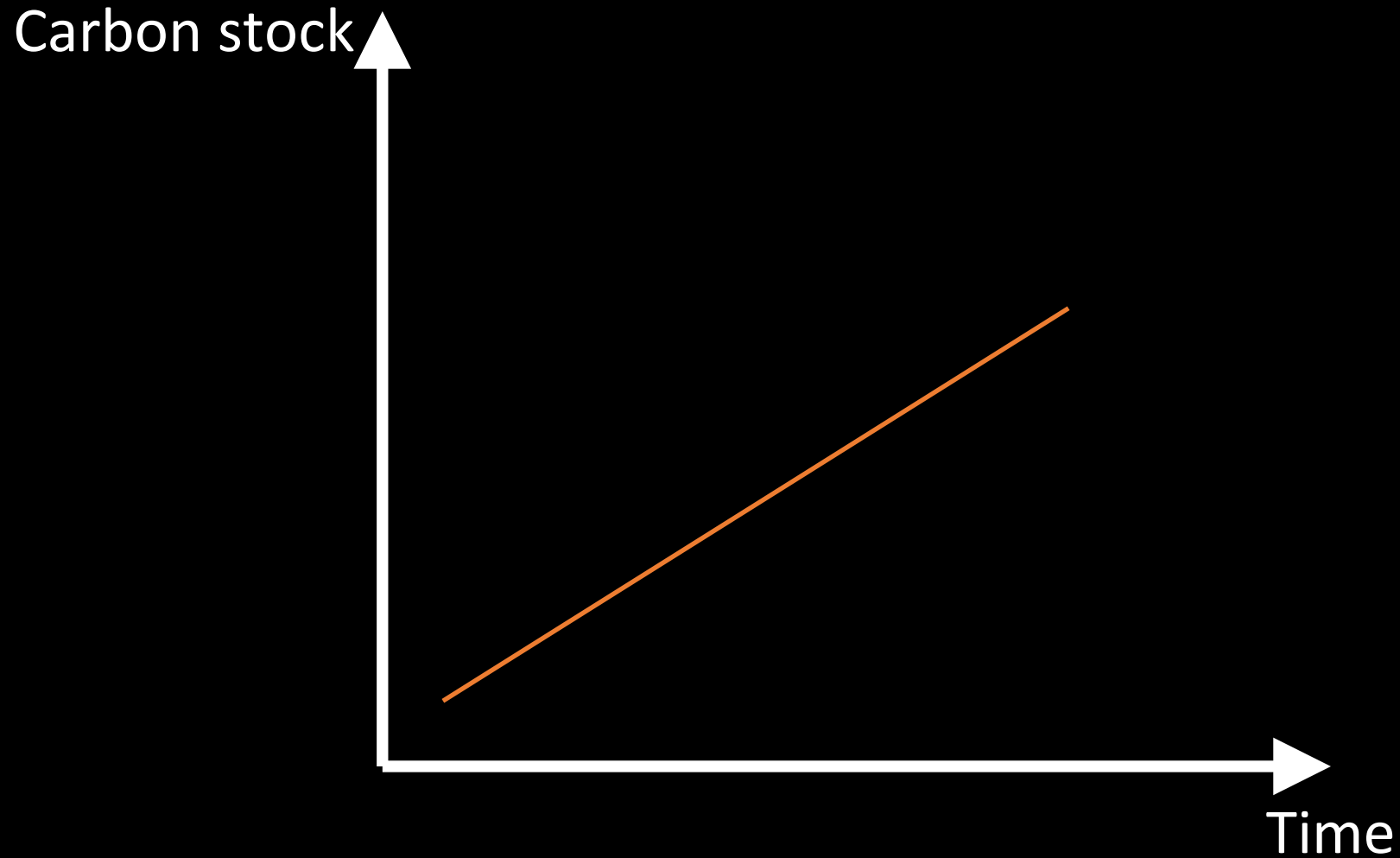




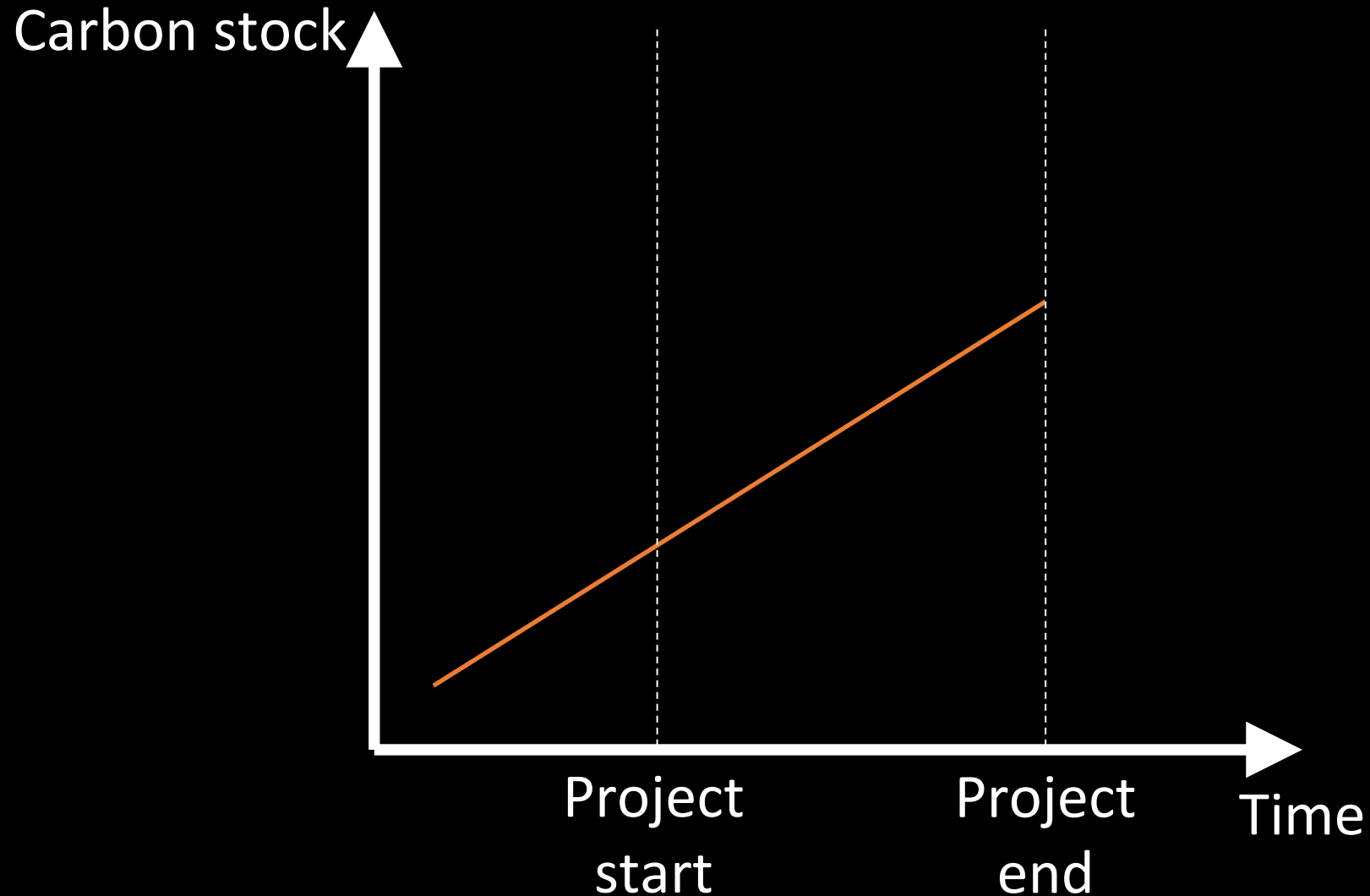
2) Carbon varies at a molecular level in ways that determine its role in the environment



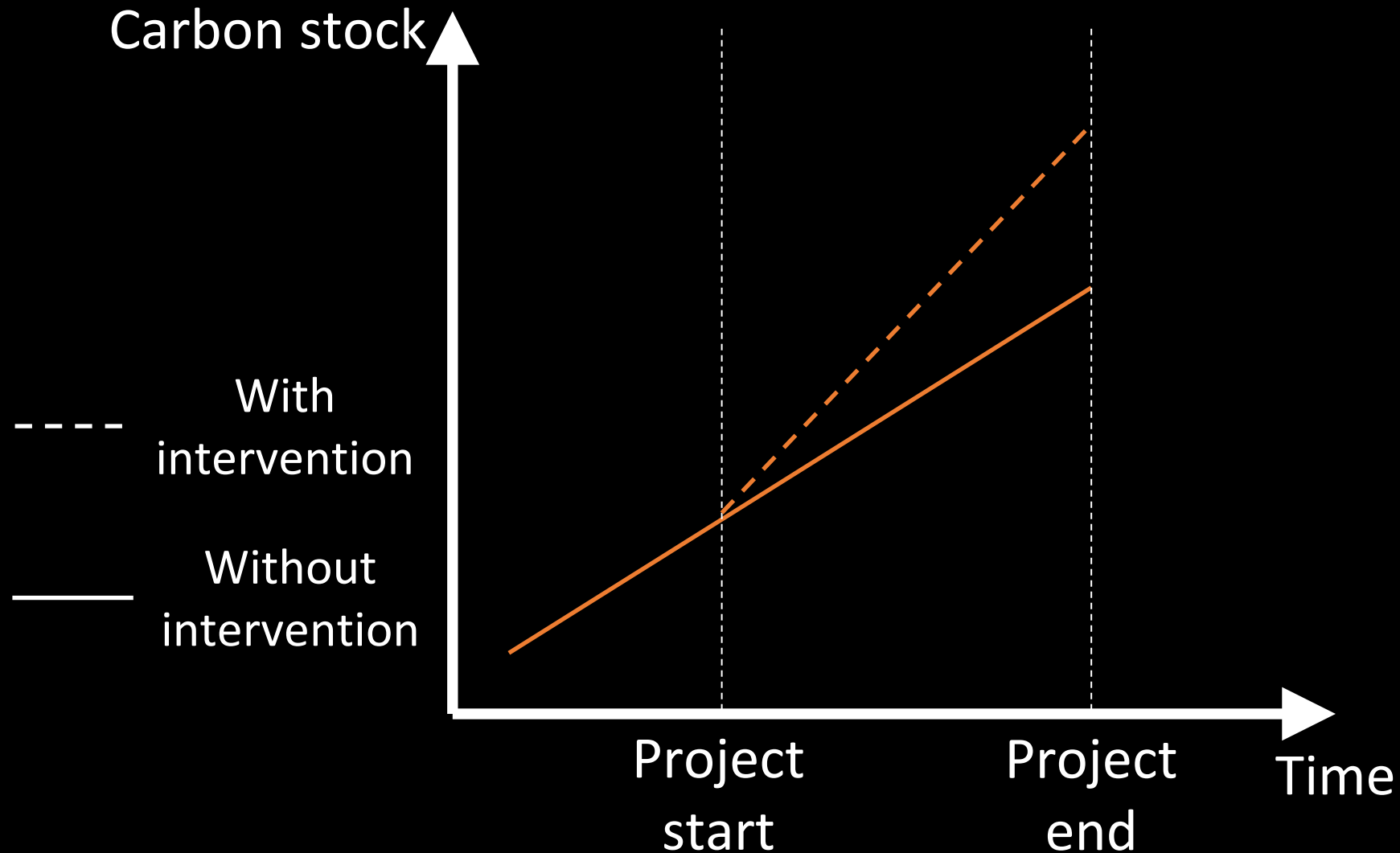
3) “What ifs” tell us how the land is *really* changing



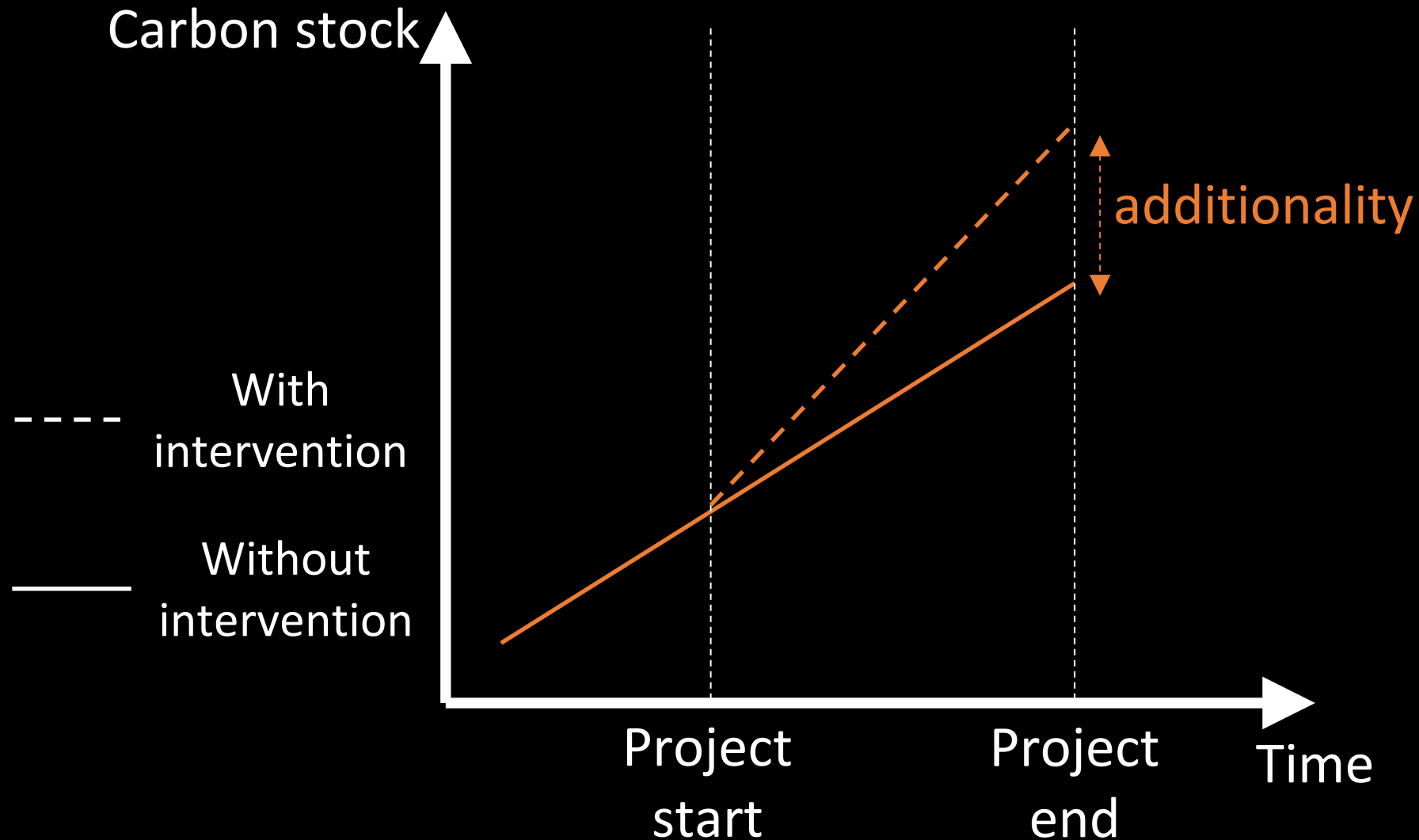
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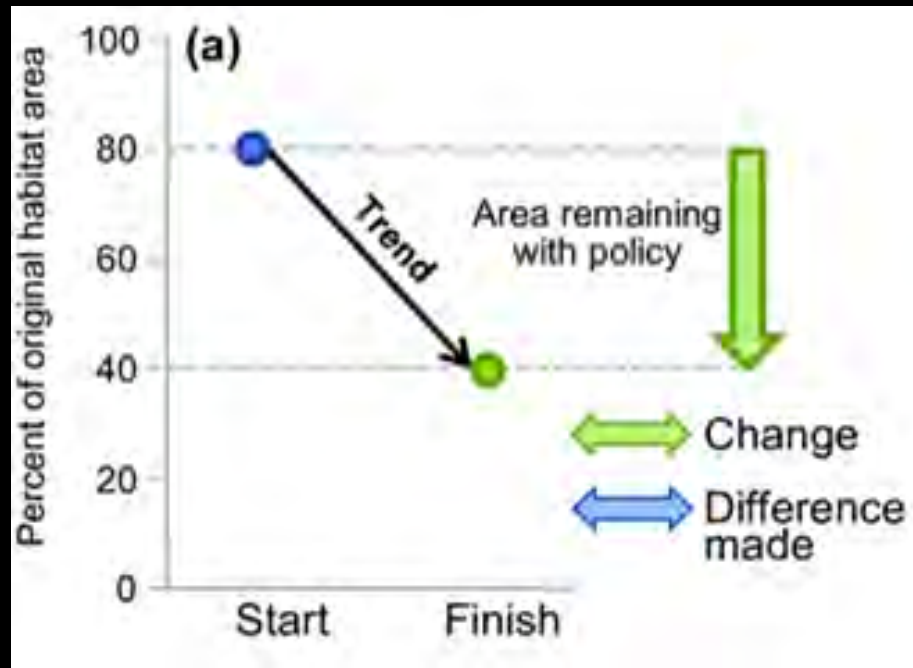
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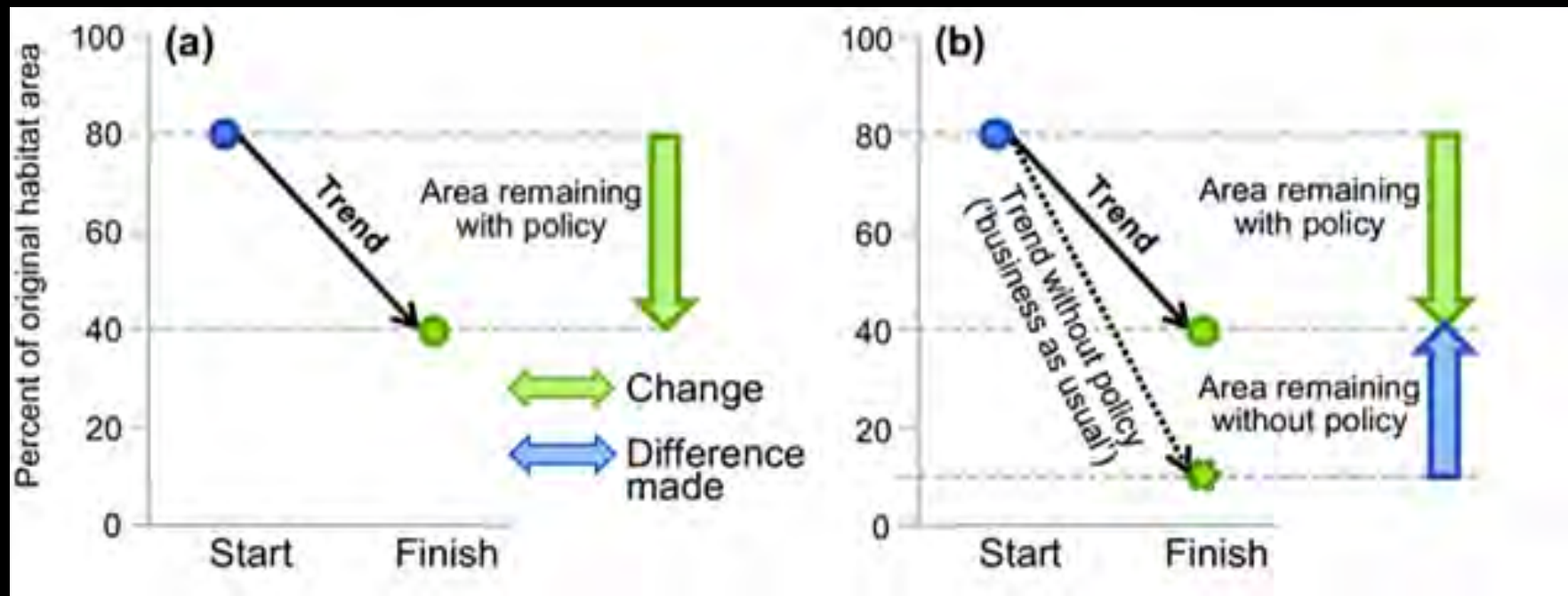
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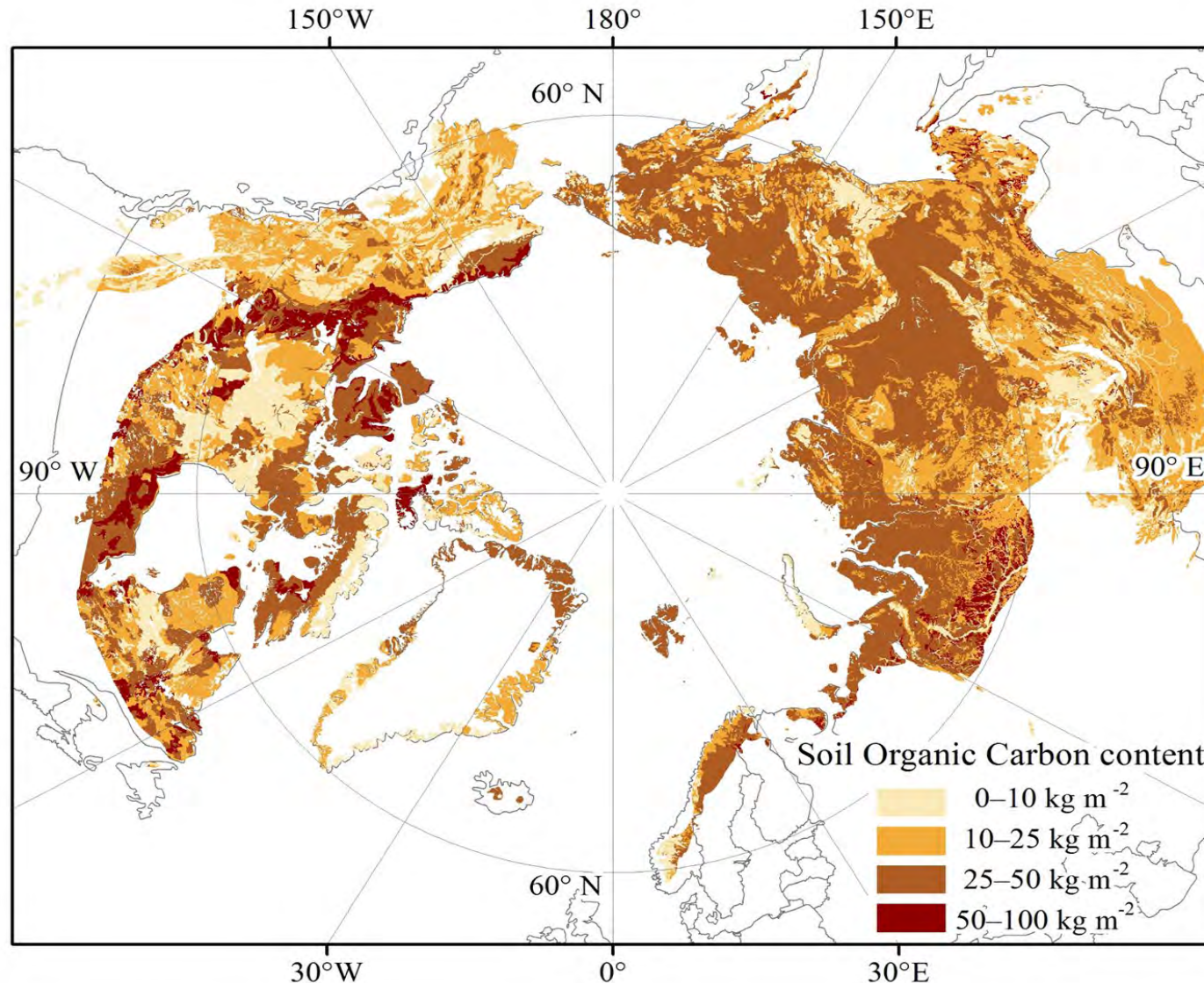
3) “What ifs” tell us if we are making a difference



3) “What ifs” tell us if we are making a difference



There are vast stocks of carbon in NWT soils including wetland and permafrost affected soils that are sensitive to climate change and other disturbances.



Terminology:

- Stocks
- Stores
- Reservoirs
- Pools

How are these carbon stocks estimated?



Photos: E Humphreys

Soil carbon stock estimates (kg carbon per square meter of ground)

- field measurements
- analysis in the lab
- calculate the carbon to different depths

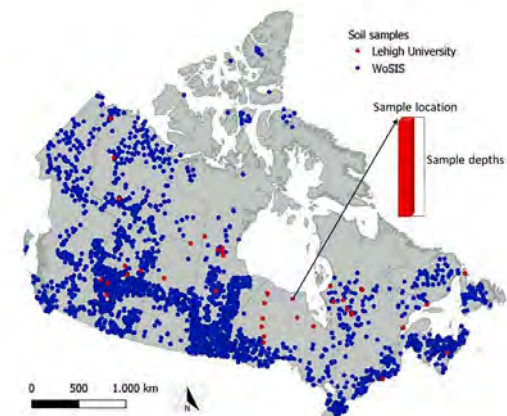
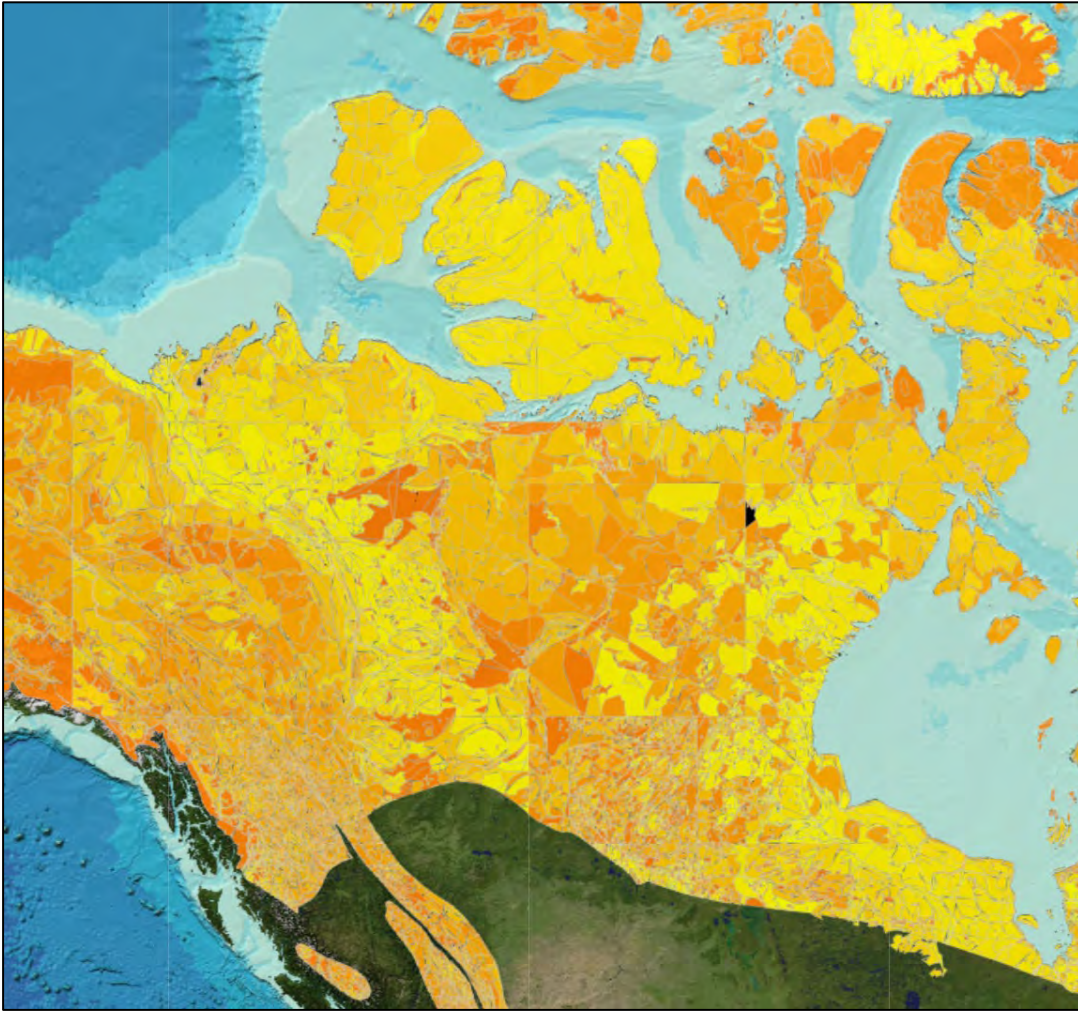


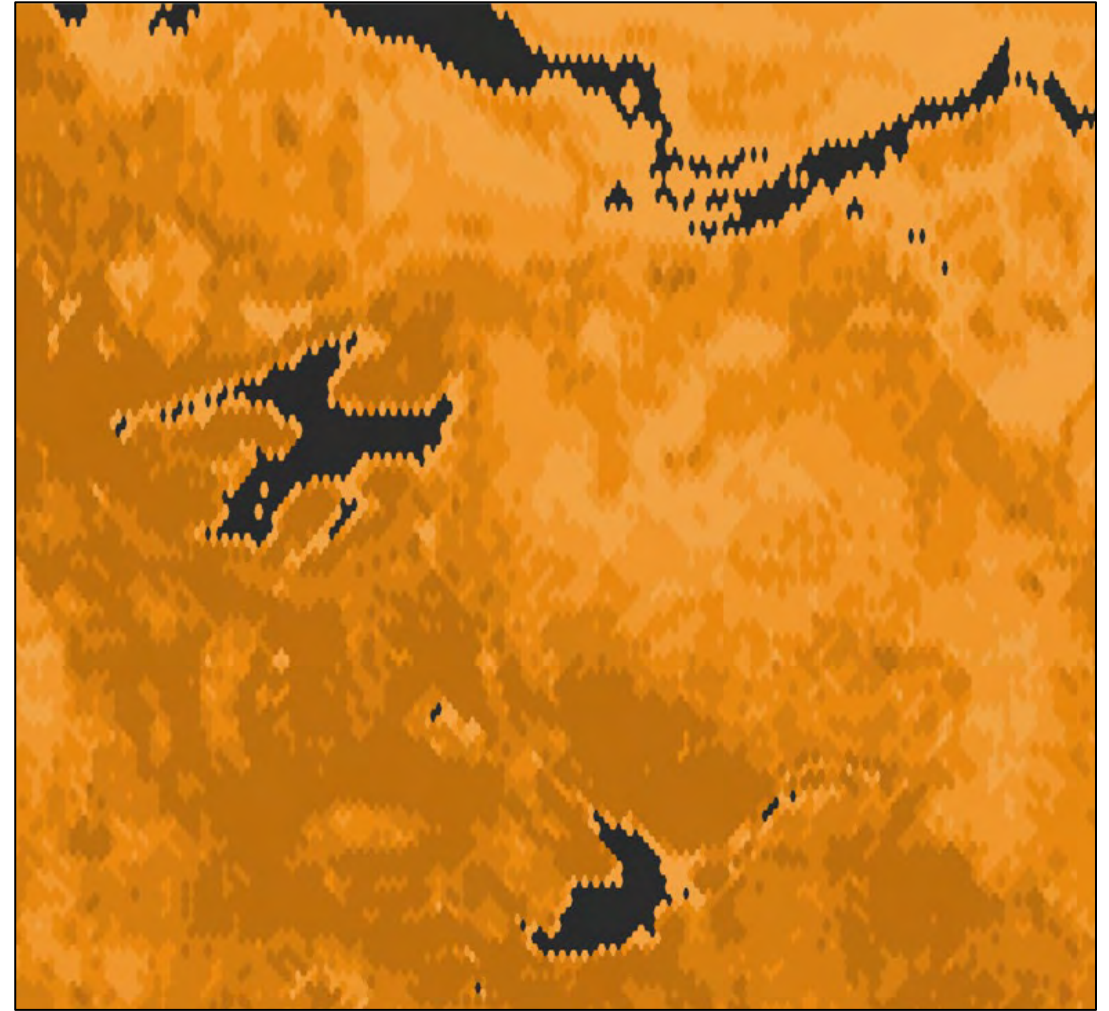
Fig. 2. Spatial distribution of the soil organic carbon (SOC) concentration ground measurements in Canada.

- Map the soil carbon over the landscape using different methods



- Classified soil polygons

<https://bolin.su.se/data/ncscd/map.html>



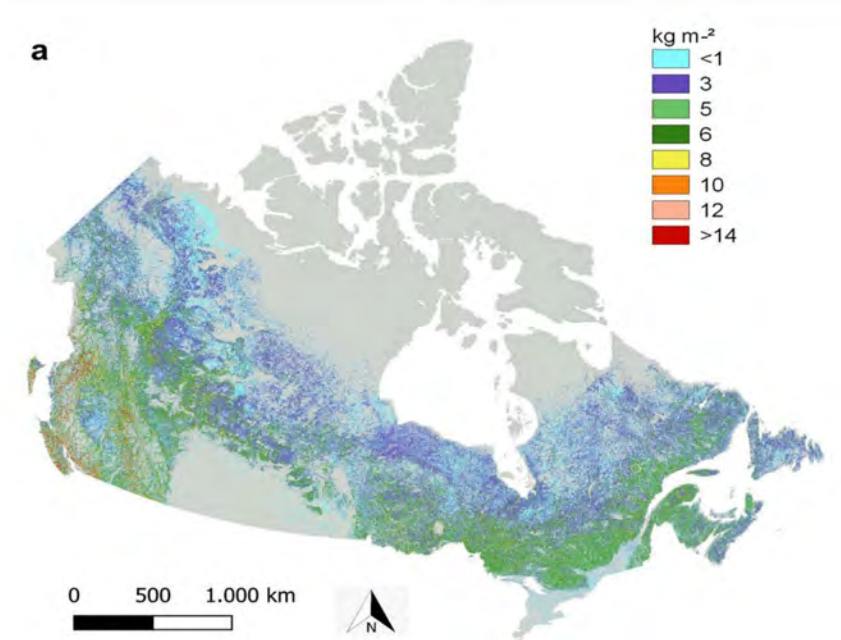
- Machine learning

<https://wwf.ca/carbon-stocks/>

Plant carbon stock estimates (above and belowground kg carbon per square meter of ground)



- field measurements: tree diameter, height (very little non-forest biomass data available)
- analysis in the lab
- map the plant carbon



Carbon flows into and out of reservoirs can change carbon stocks

Carbon stocks **increase** when carbon flows **in** are greater than carbon flows **out** to the **atmosphere** and **ocean**.

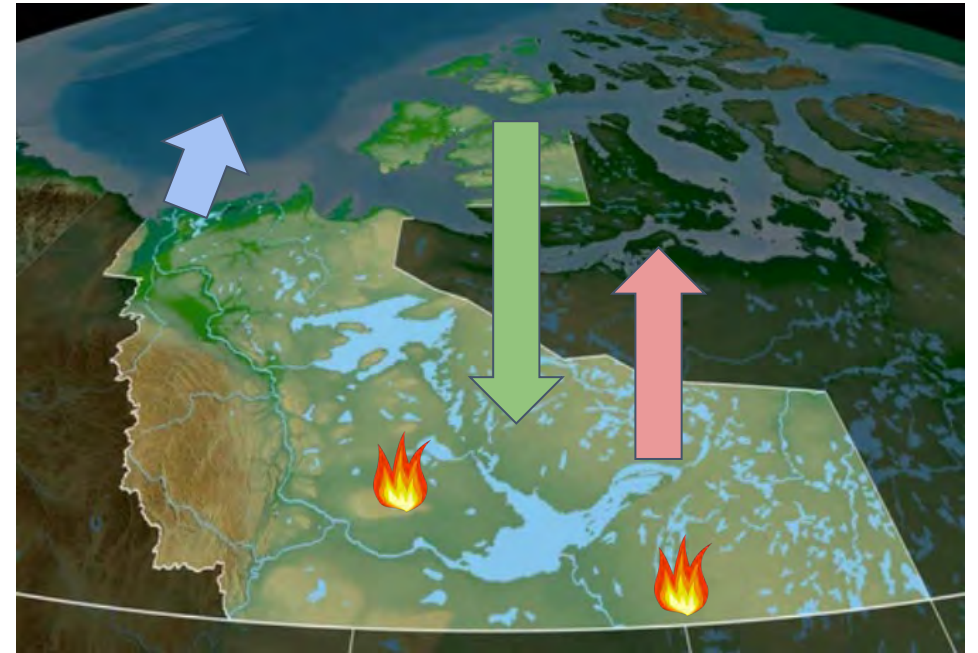
Natural flows of Carbon **IN**:

- Plant growth → photosynthesis

Natural flows of Carbon **OUT**:

- Respiration
- Decomposition
- Combustion

Methods to estimate carbon flows:
Bottom-up methods & **Top-down** methods



Terminology:

- Fluxes
- Flows
- Sinks
- Sources

“Bottom up” estimates of landscape carbon fluxes



Photos: E Humphreys

Observations in the field:

- Eddy Covariance
- Chambers
- Change in carbon stocks



“Bottom up” estimates of landscape carbon fluxes



Data-driven mapped products e.g. FLUXCOM

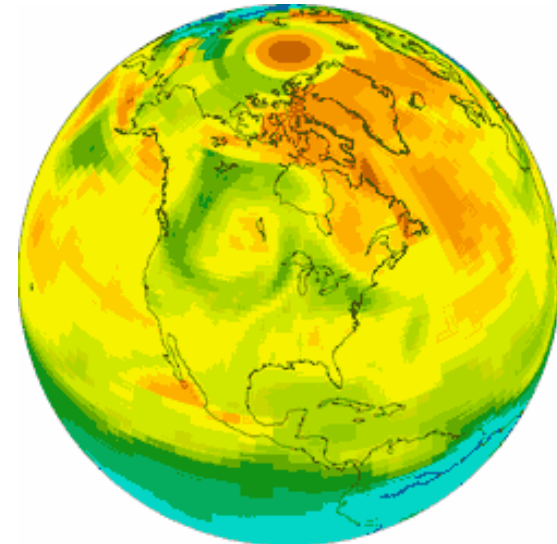


Process-based computer model simulations
e.g. global carbon models such as CLASSIC
→ *can be used to make predictions*

“Top-down” estimates of landscape carbon fluxes



Inversion models of atmospheric carbon measurements e.g. CarbonTracker



Summer months showing decrease in CO₂ in the atmosphere (cool colours) as plants grow and absorb CO₂.

Measuring and modelling carbon stocks and carbon flows IN & OUT of the landscape help us understand:



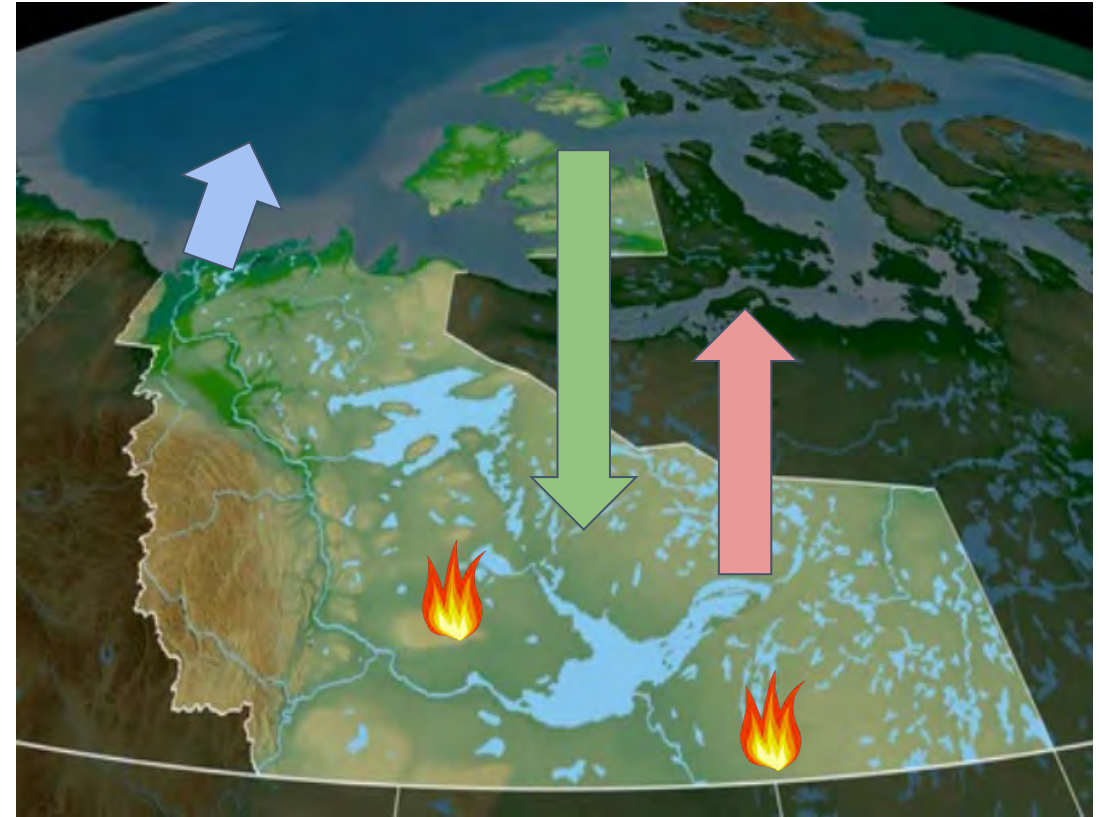
Factors that control carbon flows



How and why some carbon stocks are vulnerable to disturbances and climate change



Possibilities for enhancing carbon stocks



Questions?



Photo: Claire Elliott

Permafrost Carbon Feedbacks: What we need to learn about how thawing permafrost creates greenhouse gas emissions that can accelerate global climate change

GNWT Landscape Carbon Workshop, Yellowknife, 4 – 6 Feb. 2025

Peter Morse – Geological Survey of Canada

Scott Dallimore – Polar Knowledge Canada & Geological Survey of Canada



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Our diverse northern landscapes

Many different ecological, geological, and permafrost histories

19 different ecological regions in NWT

☒ Level IV EcoRegions

-  Boreal Cordillera, High Boreal
-  Boreal Cordillera, Mid-Boreal
-  Taiga Cordillera, High Subarctic
-  Taiga Cordillera, Low Subarctic
-  Tundra Cordillera, High Subarctic
-  Taiga Plains, High Boreal
-  Taiga Plains, High Subarctic
-  Taiga Plains, Low Subarctic
-  Taiga Plains, Mid-Boreal
-  Taiga Shield, High Boreal
-  Taiga Shield, High Subarctic
-  Taiga Shield, Low Subarctic
-  Taiga Shield, Mid-Boreal
-  Southern Arctic: Tundra Plains,

Low Arctic south

 Southern Arctic: Tundra Plains,

Low Arctic north

-  Northern Arctic, Low Arctic north
-  Northern Arctic, Mid-Arctic
-  Northern Arctic, High Arctic
-  Northern Arctic, High Arctic



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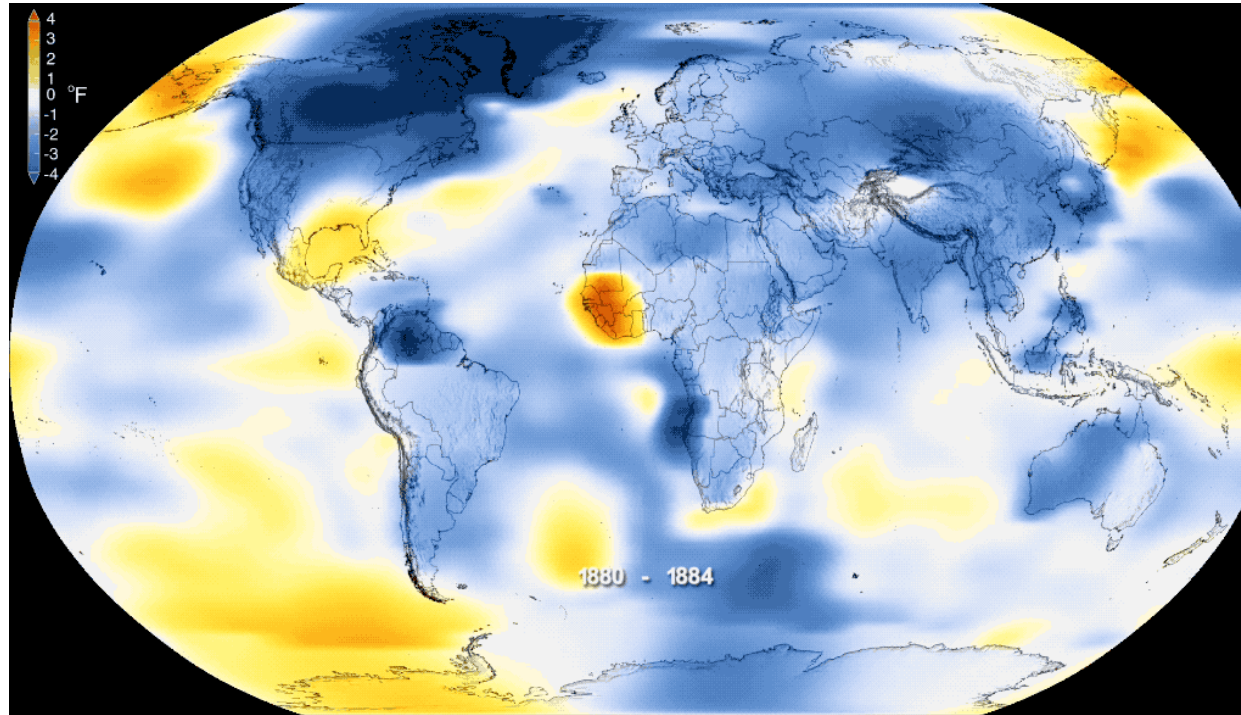
Our warming northern landscapes

Arctic warming is 2-4 times faster than the global average

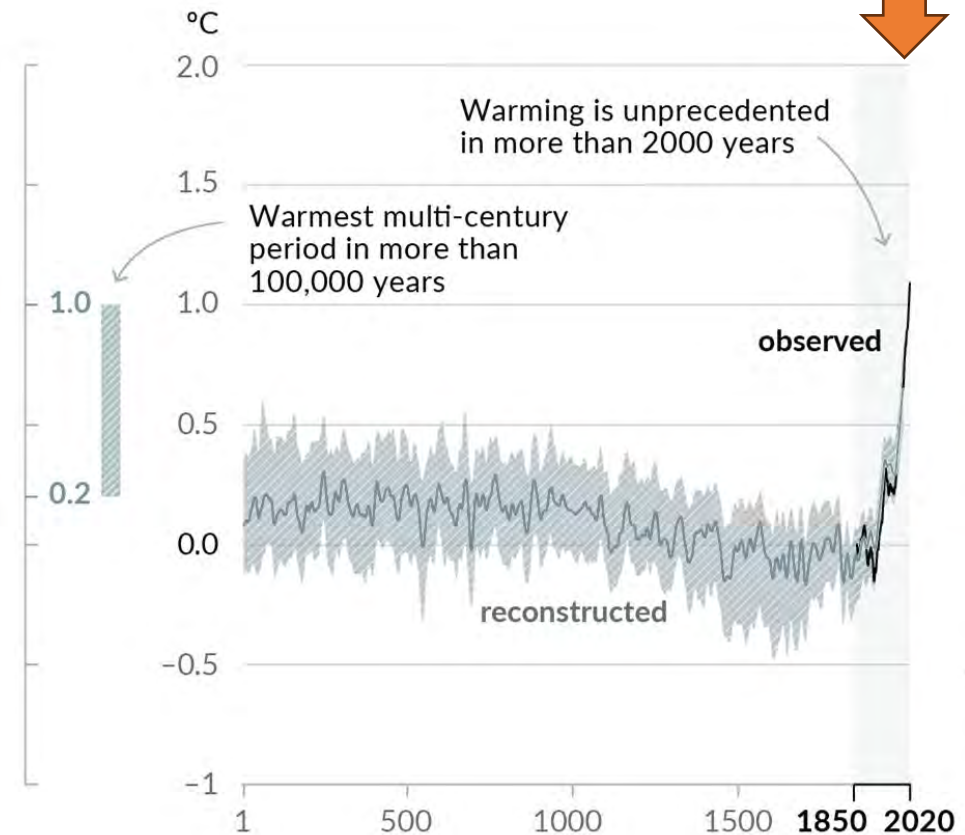
We are here



Earth's long-term warming trend: 1880 to 2018



NASA, 2019. <https://climate.nasa.gov/news/2876/new-studies-increase-confidence-in-nasas-measure-of-earths-temperature/>



IPCC, 2021. <https://www.ipcc.ch/report/ar6/wq1/figures/summary-for-policymakers/>



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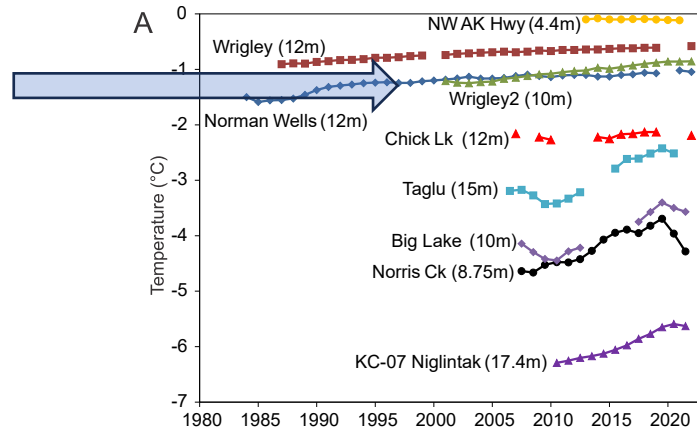
Our thawing northern landscapes

About half of Canada is underlain by permafrost that is changing

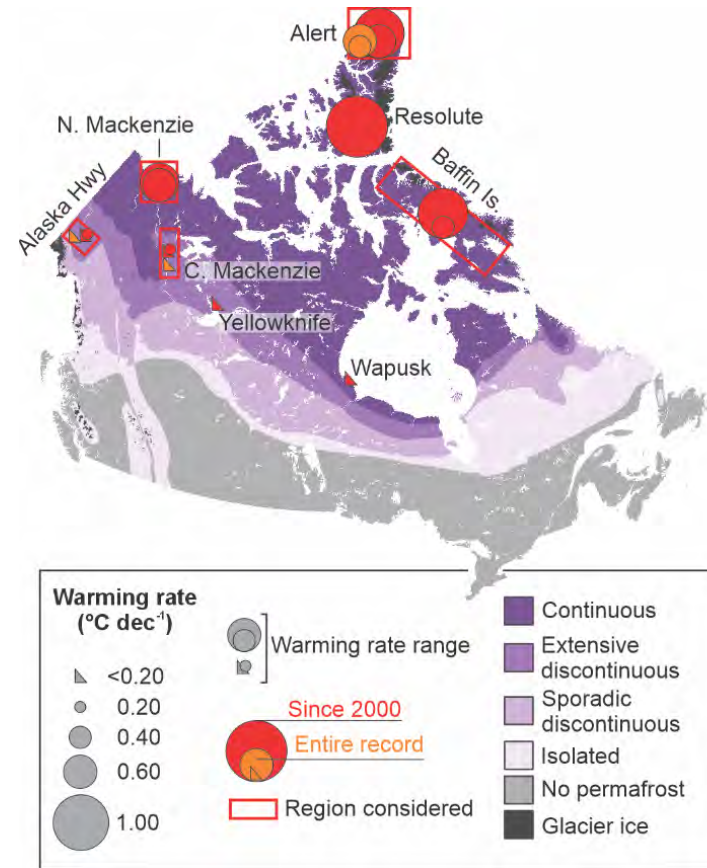
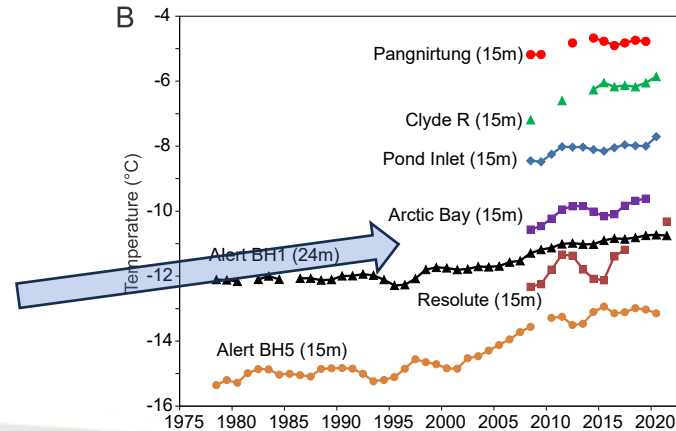
Permafrost temperatures are rising, and warm sites are thawing

Top-down thaw of permafrost is widespread

Thawing



Warming



Permafrost

- Layer of ground (rock, soil, ice, and organic matter) that remains frozen from year to year

Active layer

- Top layer of ground over permafrost that thaws each year



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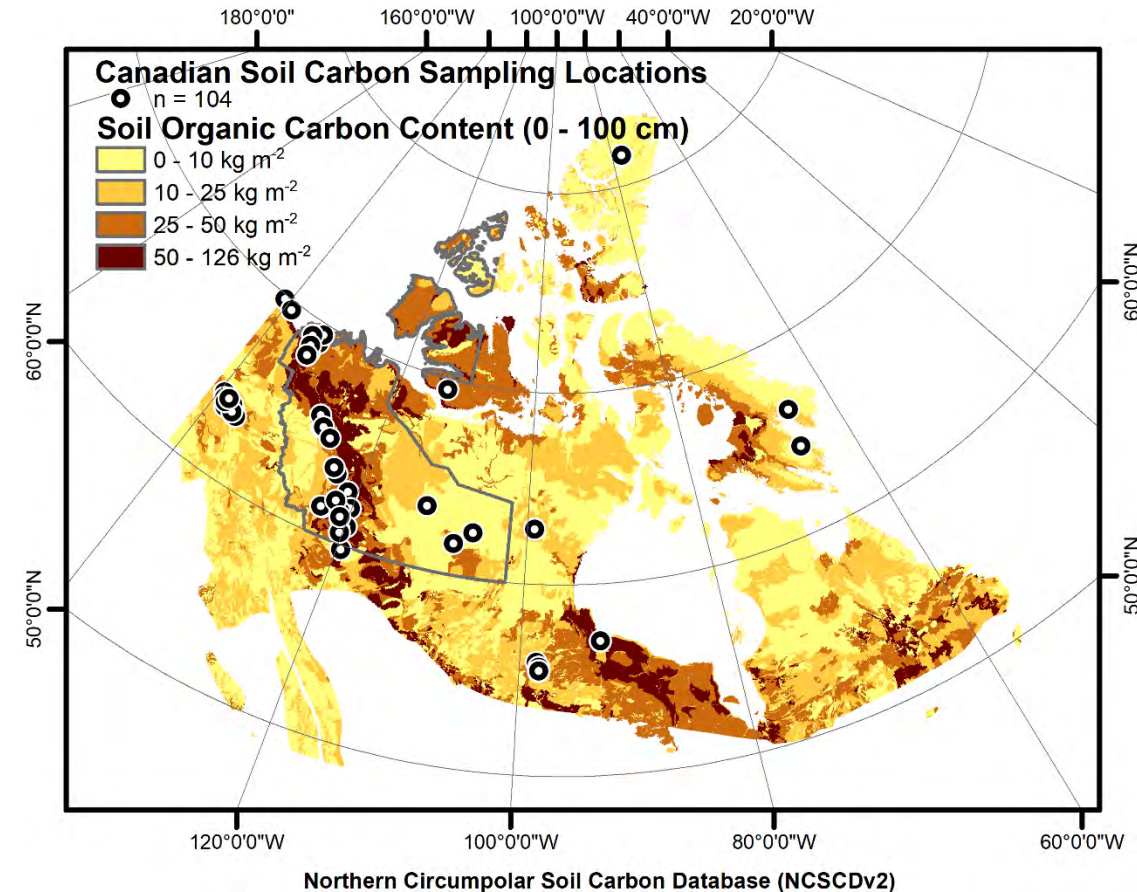
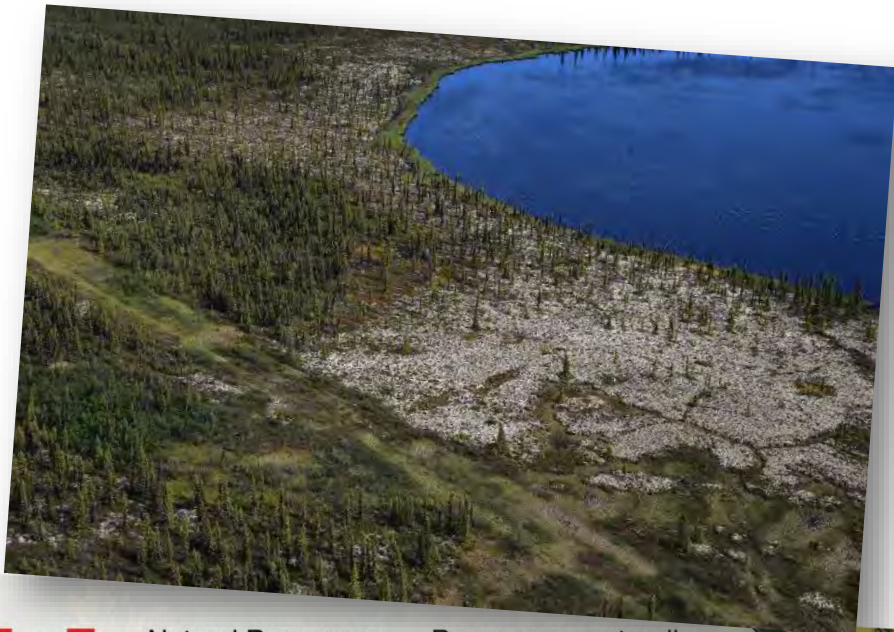
Source: Smith et al., 2024. <https://doi.org/10.52387/ICOP2024.84.1>

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Permafrost stores a lot of soil organic carbon (SOC)

Upper 3 m of permafrost contains about

- A third of the Earth's soil organic carbon
- Twice as much carbon as in Earth's atmosphere
- Four times the carbon from burning fossil fuels
- SOC estimates are 'rough' (only 104 sample sites)



Data source: Stockholm University, 2013. <https://dx.doi.org/10.5879/ECDS/00000002>

Soil Organic Carbon (SOC)

- Organic matter in the ground that came from vegetation.



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Threat: Permafrost carbon feedback loop

Thaw of SOC makes greenhouse gases (GHG)

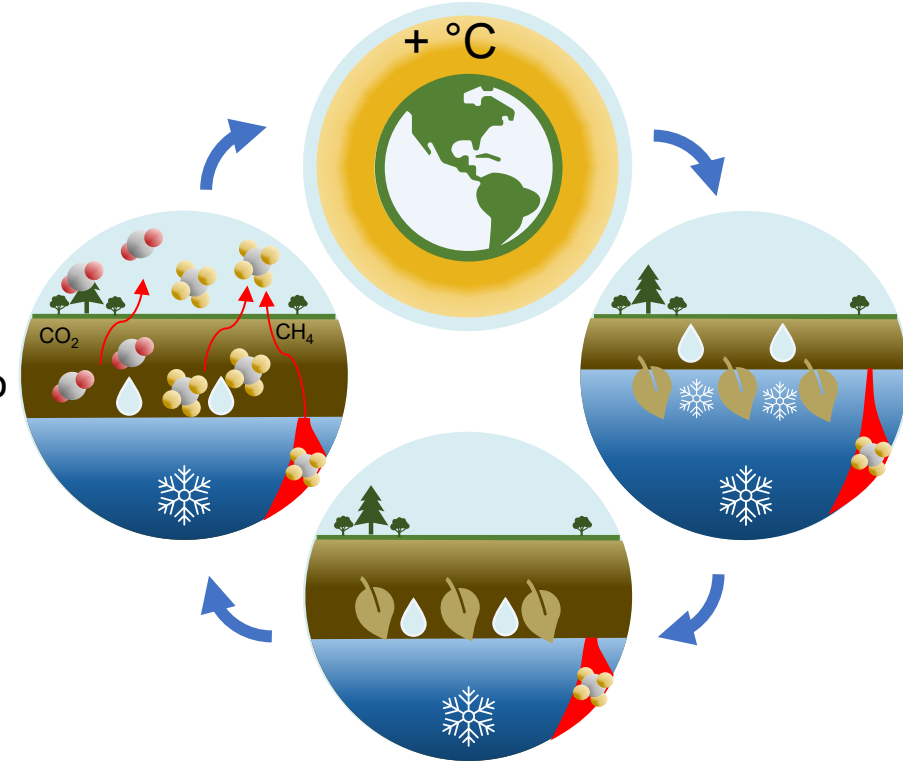
- Carbon dioxide (CO_2)
- Methane (CH_4), much more potent GHG

1. Rising greenhouse gas levels in the atmosphere cause global temperature to rise.

2. Rising air temperature causes permafrost thaw.

3. Thawing permafrost frees up previously frozen organic matter that then rots and decays.

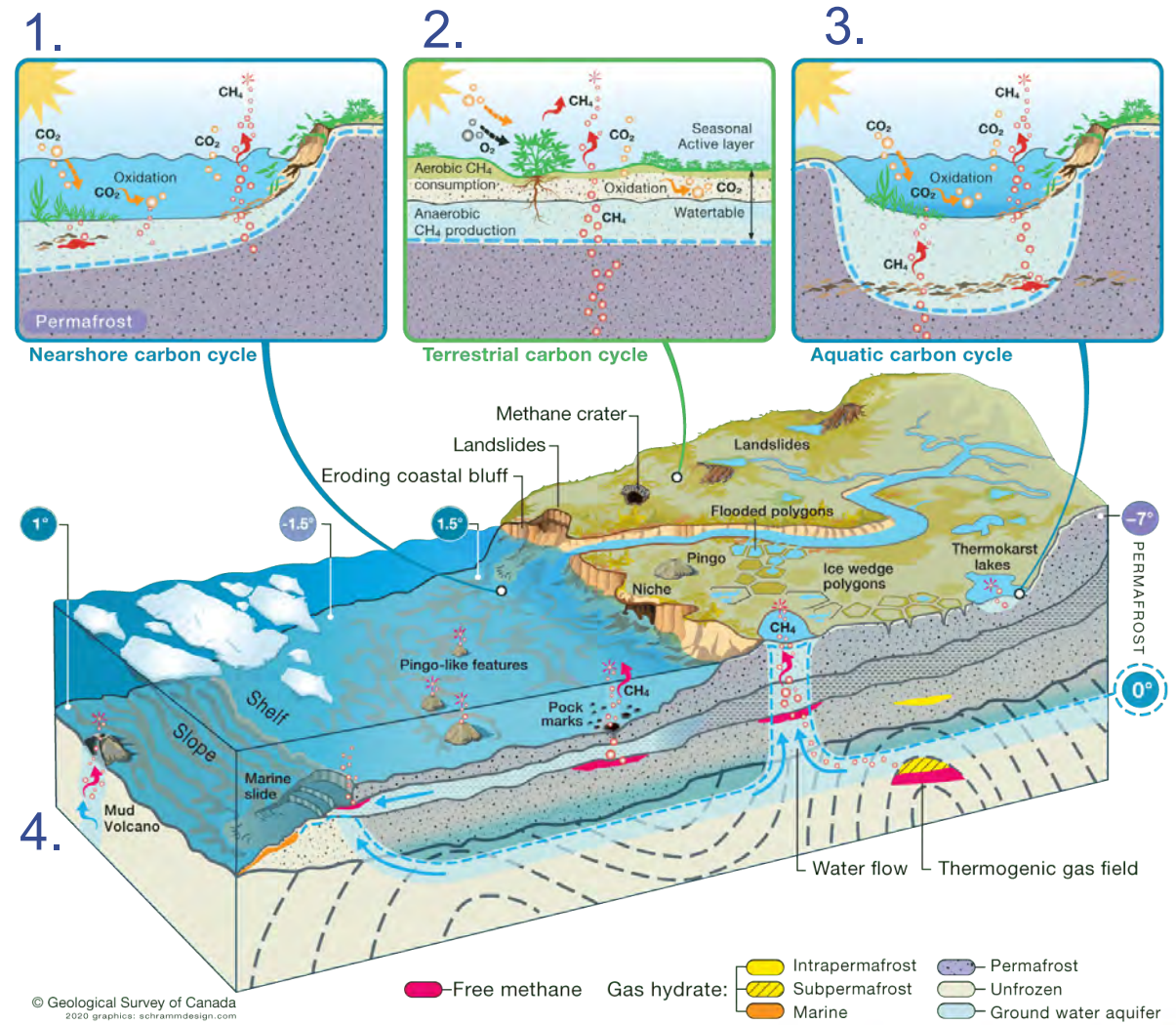
4. Decaying organic matter releases greenhouse gases to the atmosphere.



Soil organic carbon, methane, and carbon dioxide

Several complex biogeochemical processes involved

1. Nearshore carbon cycle
2. Terrestrial carbon cycle
3. Aquatic carbon cycle
4. Offshore carbon cycle
 - Cycles can interact together



Source: GRID-Arendal, 2020. <https://storymaps.arcgis.com/stories/c163de04de7849cdb917fee89015dd73>



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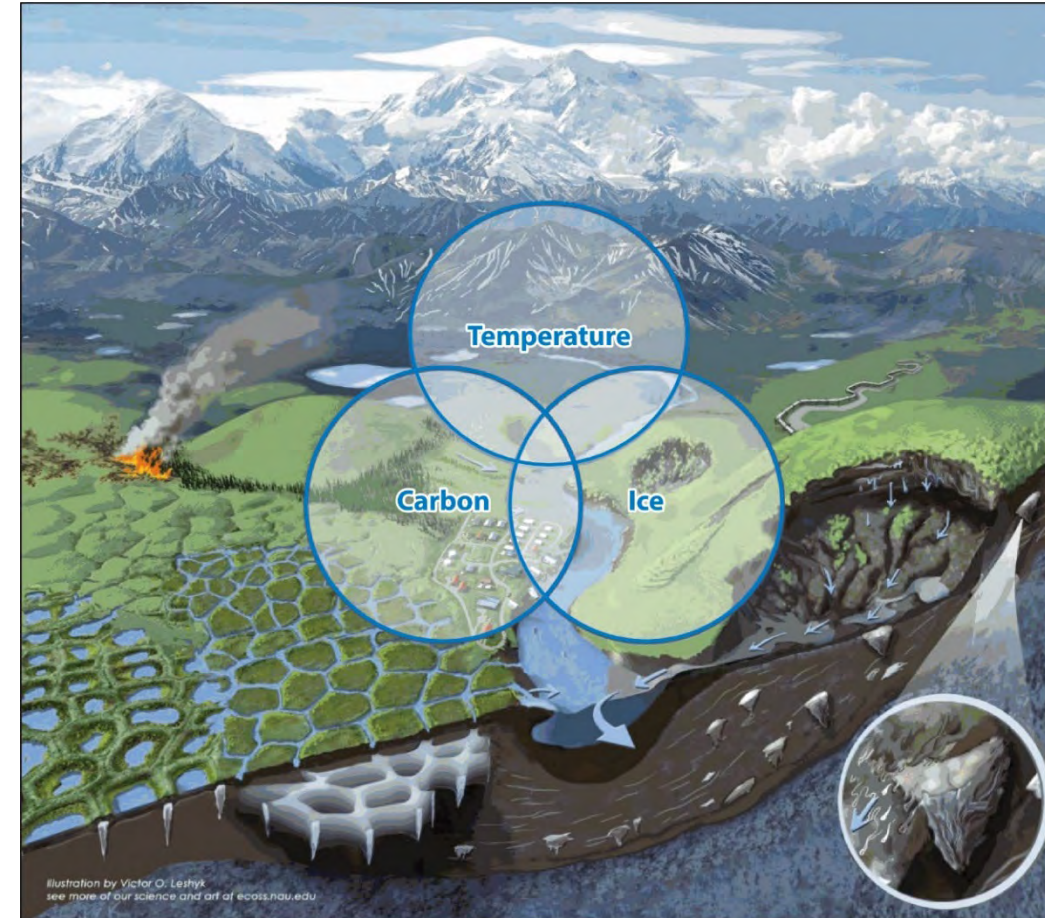
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Controls on permafrost soil carbon feedbacks

Interactions of temperature, ice, and carbon

- 1. Temperature:** permafrost integrity and rate of thaw
 - Affected by changing climate and surface conditions
- 2. Ice/moisture:** ground stability and soil wetness as permafrost thaws
 - Wetness influences methane (CH_4) vs. carbon dioxide (CO_2)
- 3. Organic carbon:** amount & 'lability' = GHG potential
 - Proportion that is "labile" influences rate of microbial decomposition

Labile carbon: breaks down quickly and is the major food for soil microbes



AR Schuur EAG, et al. 2022
Annu. Rev. Environ. Resour. 47:343–71



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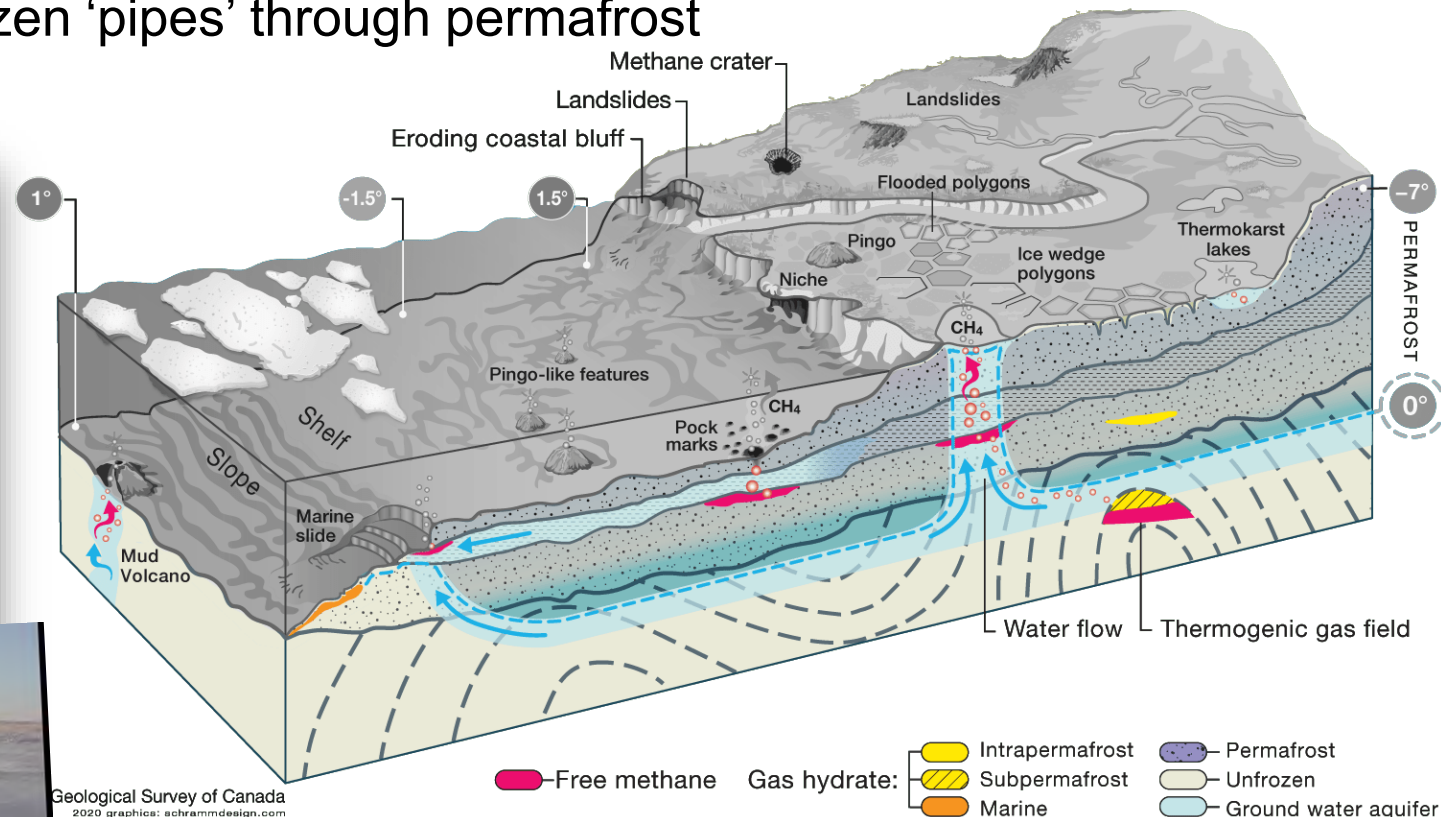
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Permafrost traps geologic methane

Free methane gas and solid methane hydrates can be present

- Warming permafrost may increase geologic methane emissions
- Methane seeps upward through unfrozen 'pipes' through permafrost



Methane hydrate

- A solid that forms in sediments.



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Controls on geologic methane feedbacks

Interactions of ground temperature and groundwater flow

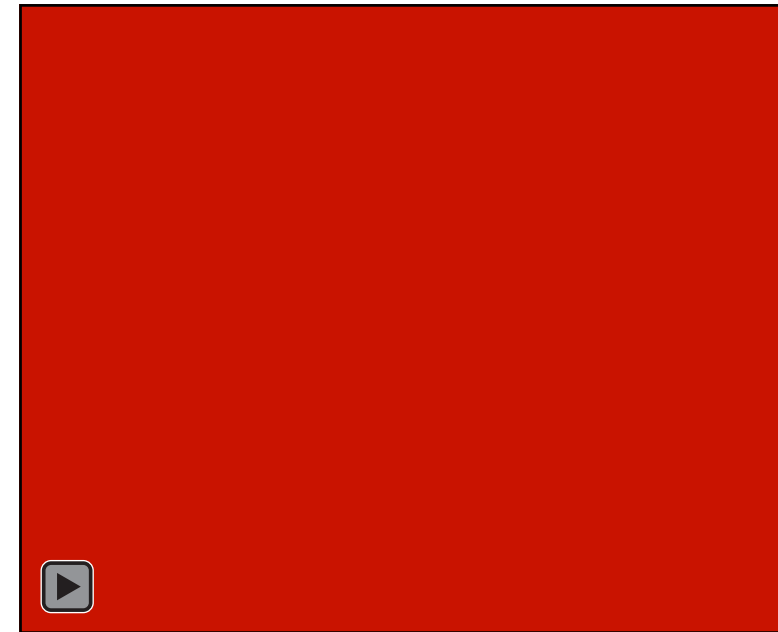
1. **Ground temperature:** stability of methane hydrate (solid vs. gas)

and size of unfrozen zones in permafrost

- Relates to **past climate** and **sea bottom** temperatures
- Unfrozen zones form under lakes and rivers

2. **Groundwater flow:** flow of methane gas through unfrozen zones

- Relates to geological history, hydrology, and 'ocean climate'



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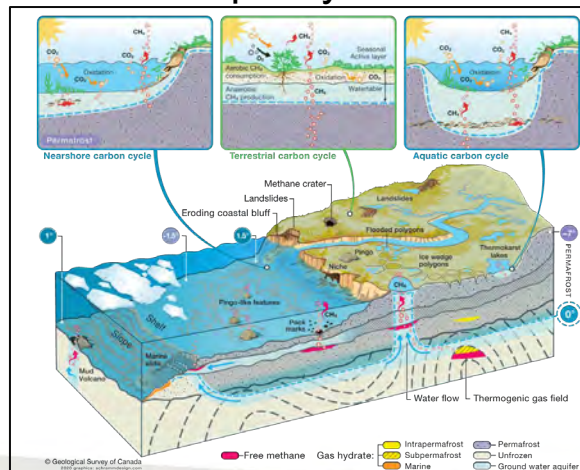
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How much will thawing permafrost carbon worsen climate change?

We don't really know yet

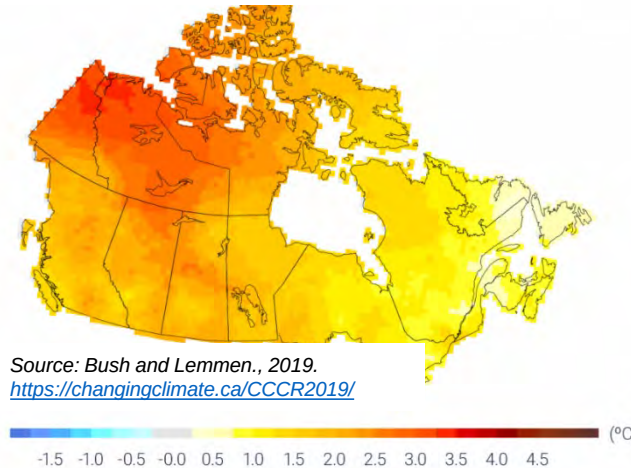
- There are a lot of unknowns
- Several cycles interacting together
- Some regions shifting from sinks to sources
- There is no consensus

Multiple systems



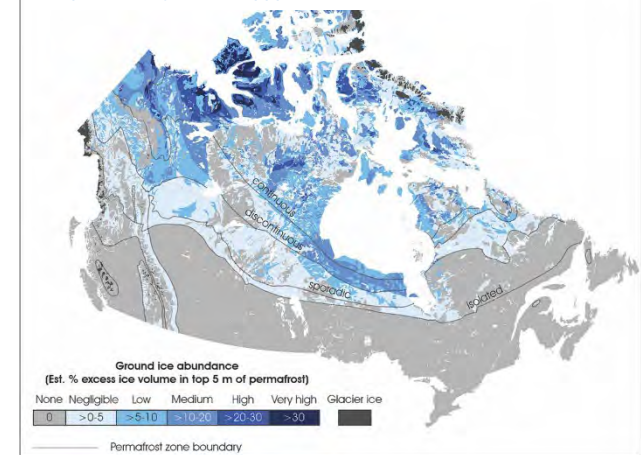
Source: GRID-Arendal, 2020.
<https://storymaps.arcgis.com/stories/c163de04de7849cdb917fee88015dd73>

Air temperature warming, 1848 - 2016

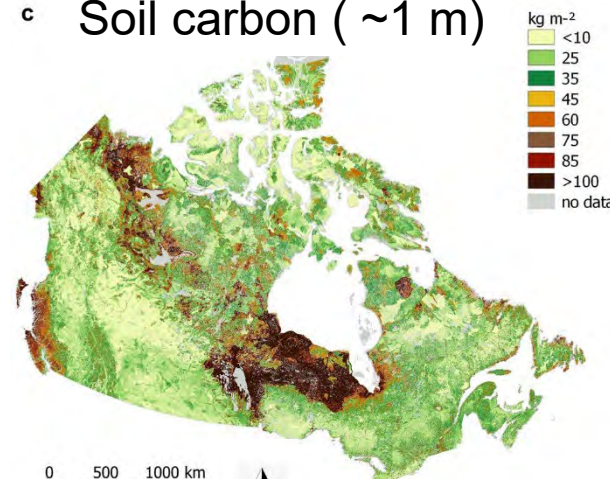


Permafrost and ground ice

Source: Burn et al., 2024.
<https://doi.org/10.1002/ppp.2261>

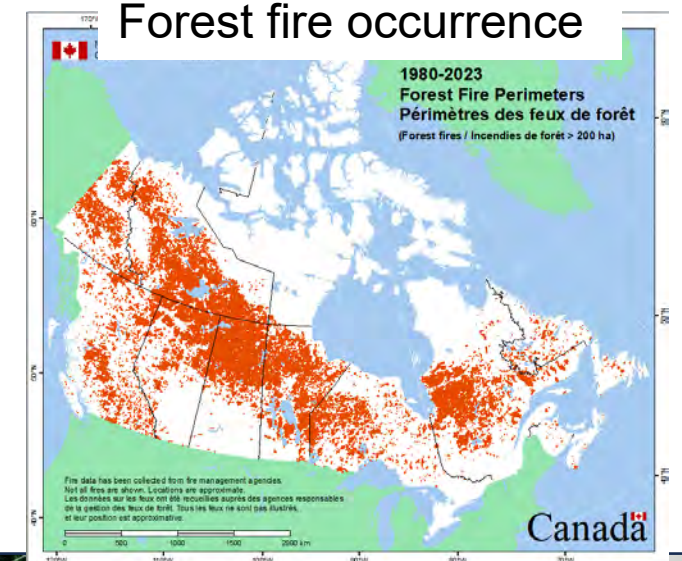


c Soil carbon (~1 m)



Source: Camille et al., 2022. <https://doi.org/10.1029/2021GB007213>

Forest fire occurrence



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Major information gaps in Global Carbon Budgets

Permafrost Carbon Feedbacks not included

- Thaw of icy, carbon-rich permafrost and links to GHG emissions poorly characterized
- Thaw of methane hydrates and links to GHG emissions are poorly characterized
- Few long-term records of GHG emissions and removals
- Few records of methane compared to carbon dioxide
- Atmospheric emissions estimates $\neq$ ground observations
- Need new, year-around sites in data poor Canadian Arctic

Example of permafrost carbon information gap:

ECCC Climate Indicator - Land-based greenhouse gas emissions and removals

- *Wildfire, insects, post-wildfire conditions*
- *Permafrost carbon dynamics are **not** included.*



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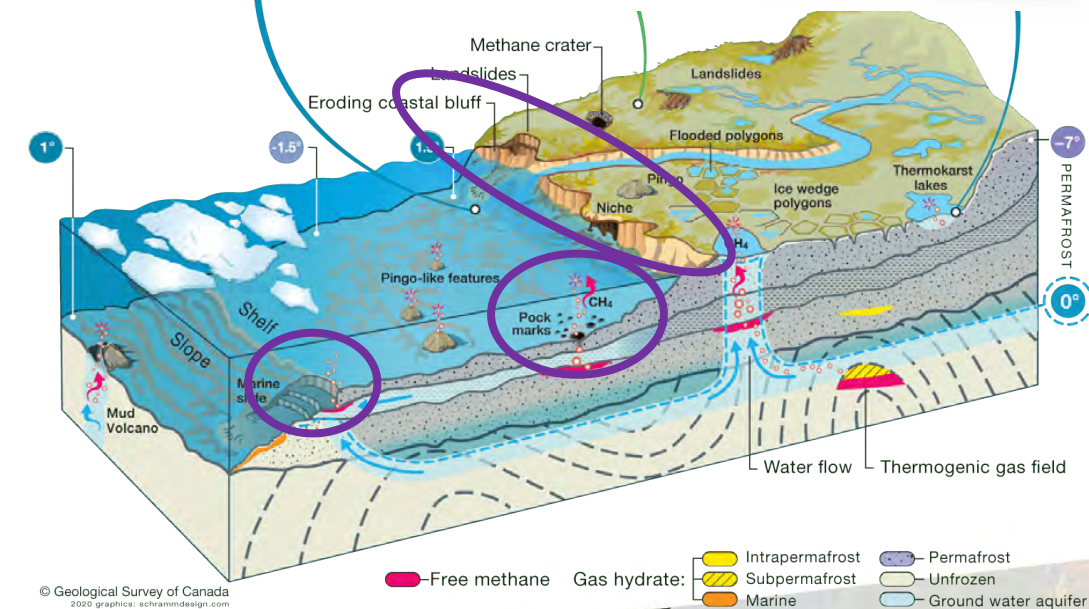
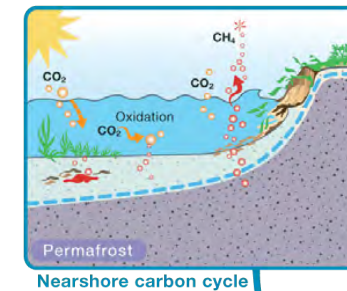
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Gaps: 1. Nearshore carbon cycle

How are changing coastal permafrost and processes affecting carbon dynamics?

- Impacts and rates of permafrost thaw?
- Impacts from sea-level rise and longer open water season, e.g., coastal erosion and flooding?
- Where exactly does the carbon go: ocean versus atmosphere?



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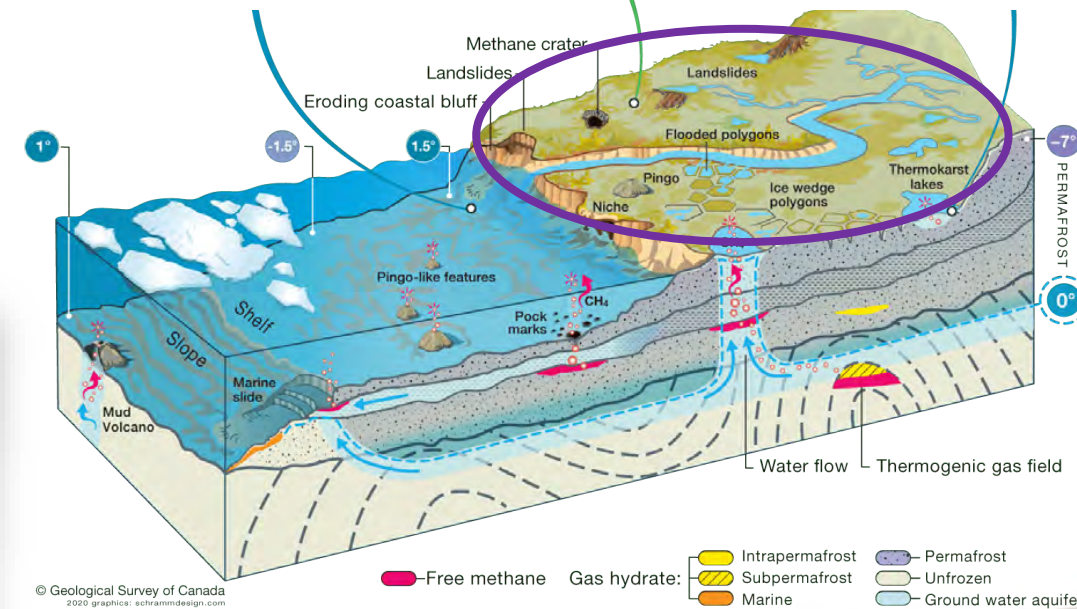
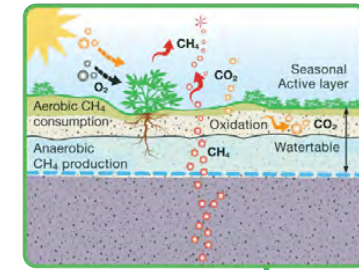
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Gaps: 2. Terrestrial carbon cycle

How does permafrost thaw in different environments translate to emissions?

- Quantity and lability of SOC in various environments?
- Balance of carbon (source/sink) in various environments?
- Quantity of non-growing season emissions?
- CH₄ versus CO₂ emissions/uptake?
- Wetting versus drying of soil?
- Active layer thickening versus landslides?
- Active microbiology of permafrost?



Source: N



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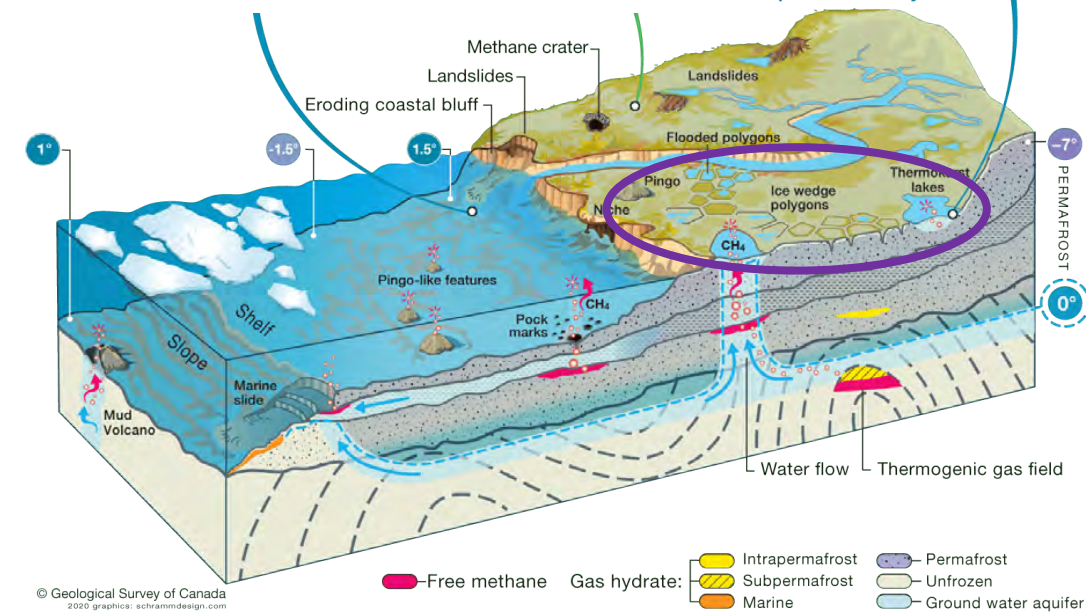
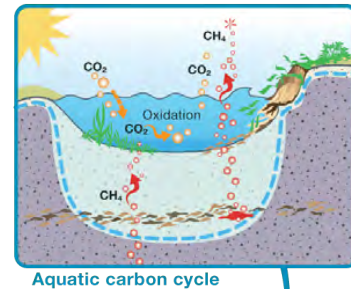
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CanadaSource: GRID-Arendal, 2020, <https://storymaps.arcgis.com/stories/c163de04de7849cbb917fe988015dd73>

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Gaps: 3. Aquatic carbon cycle

How do different, changing waterbodies translate to emissions?

- Emissions from inland waters versus wetlands or tundra?
- Effects of lake ice versus open water?
- Influence of different landscape histories?
- 'Thermokarst lakes' versus non-thermokarst lakes?
- Geological methane versus biological methane



Source: GRID-Arendal, 2020. <https://storymaps.arcgis.com/stories/c163de04de7849cdb917fee88015dd73>

Thermokarst lakes

- Lakes in permafrost regions that grow over time in area and/or depth due to thaw of ice-rich permafrost



Gaps: 4. Offshore carbon cycle

Geologic methane: occurrence, mobility and potential atmospheric release

10 years of active research

Satellite remote sensing

- GHGSat, NASA, CSA

Aerial remote sensing

- Alfred Wegener Institute, NASA, GSI

Drilling

- Geological Survey of Canada, JAPEx, International Continental Scientific Drilling Program, etc.

Multibeam sonar launch

- Aurora Research Institute

Marine ice breaker

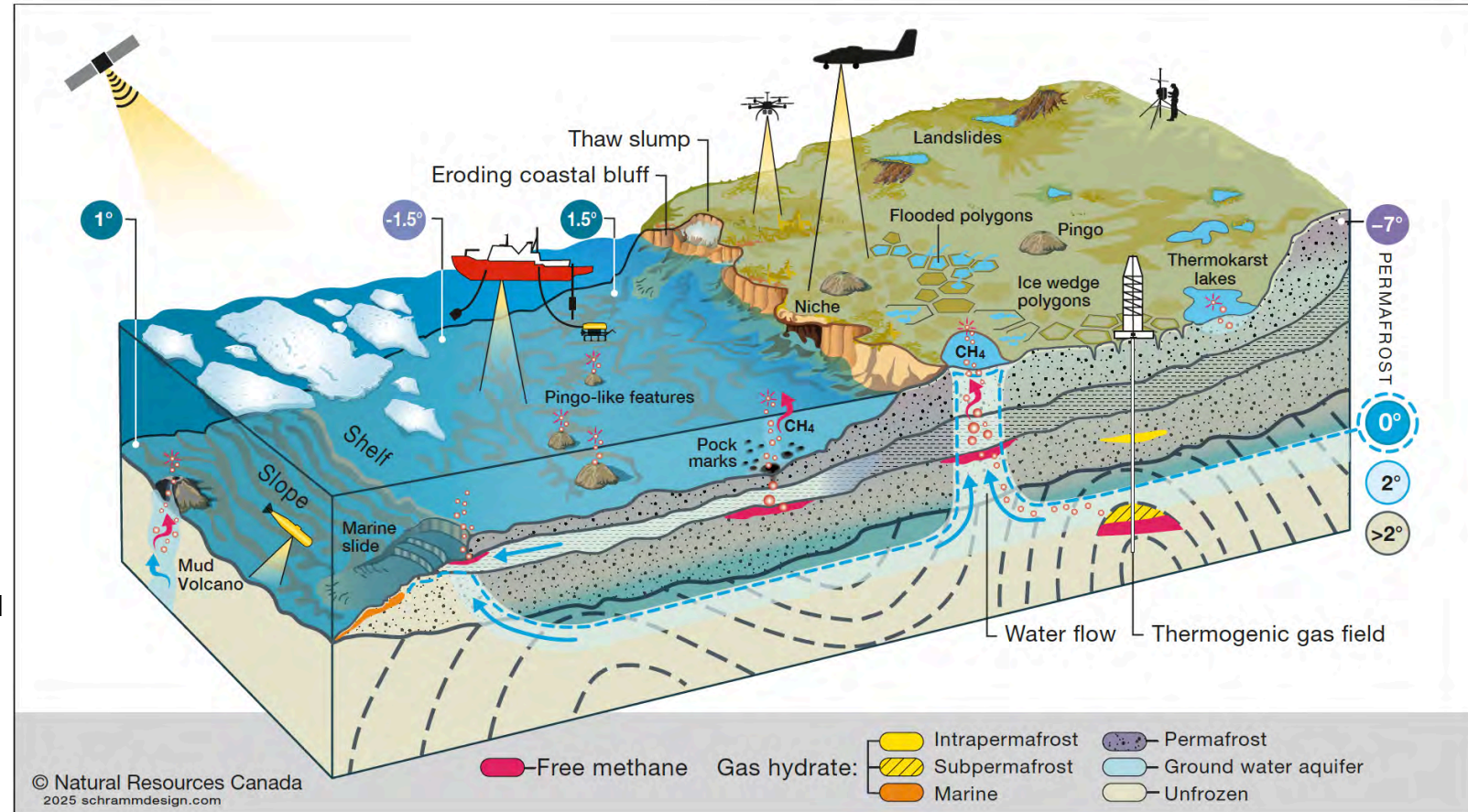
- Geological Survey of Canada, Department of Fisheries and Oceans, Korean Polar Research institute, US Naval Research Laboratory

Marine ROV AUV

- Monterey Bay Aquarium Research Institute

Sea floor moorings

- Department of Fisheries and Oceans, University of Maryland



Source: GRID-Arendal, 2020. <https://storymaps.arcgis.com/stories/c163de04de7849cdb917fee88015dd73>

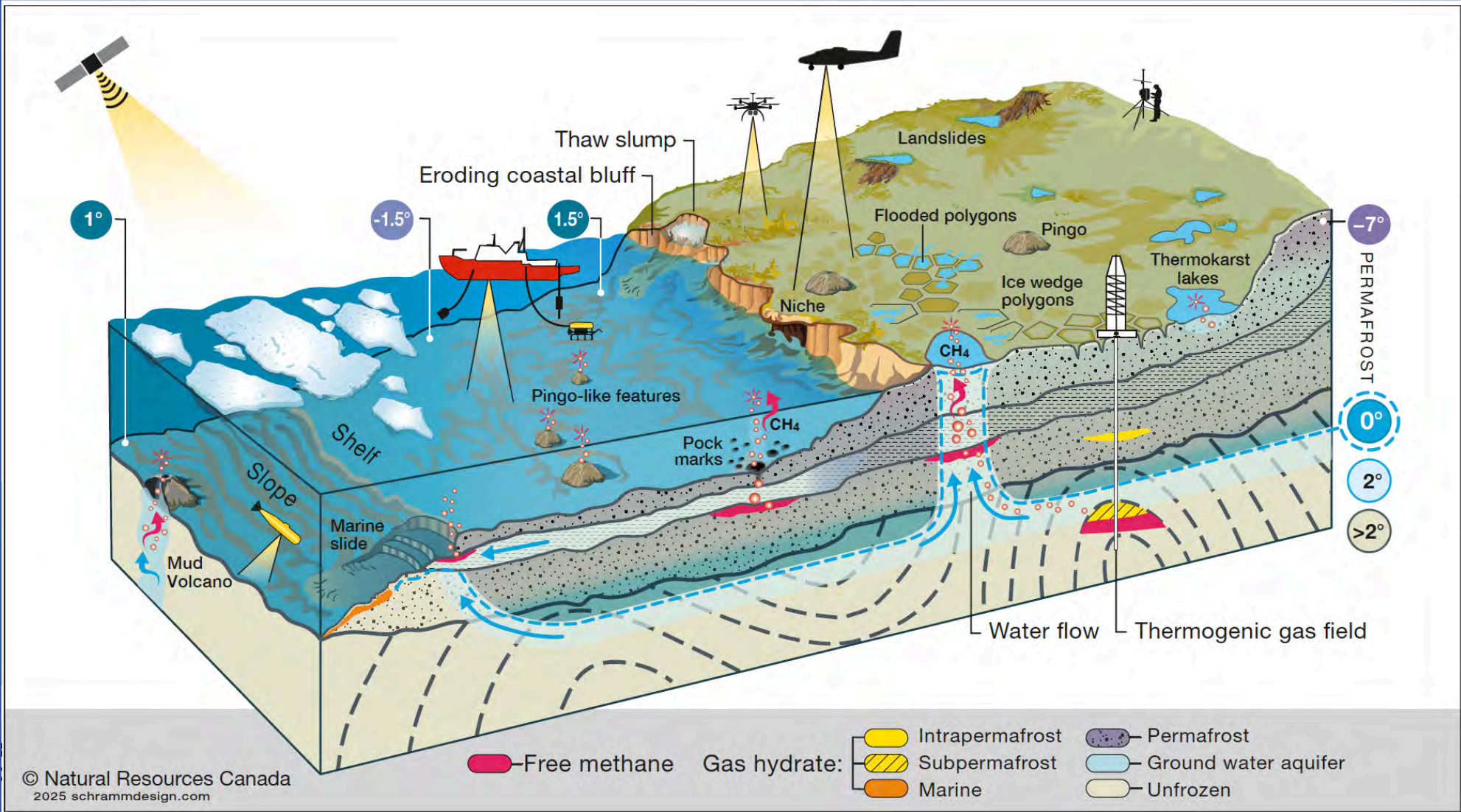
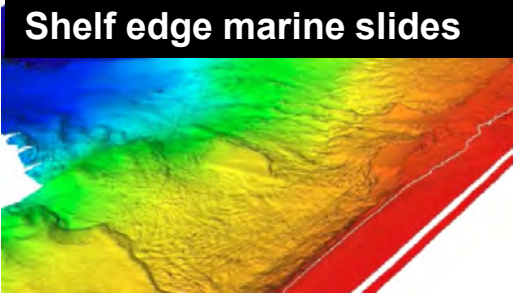
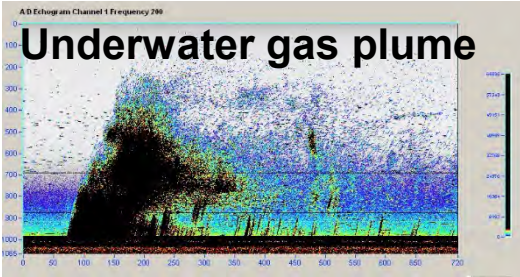
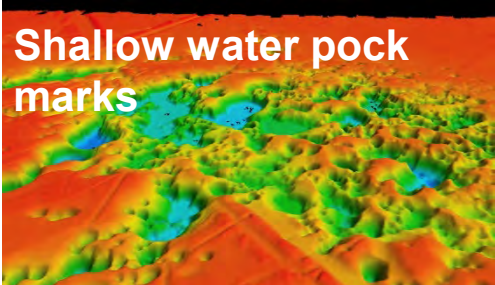


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Marine methane release



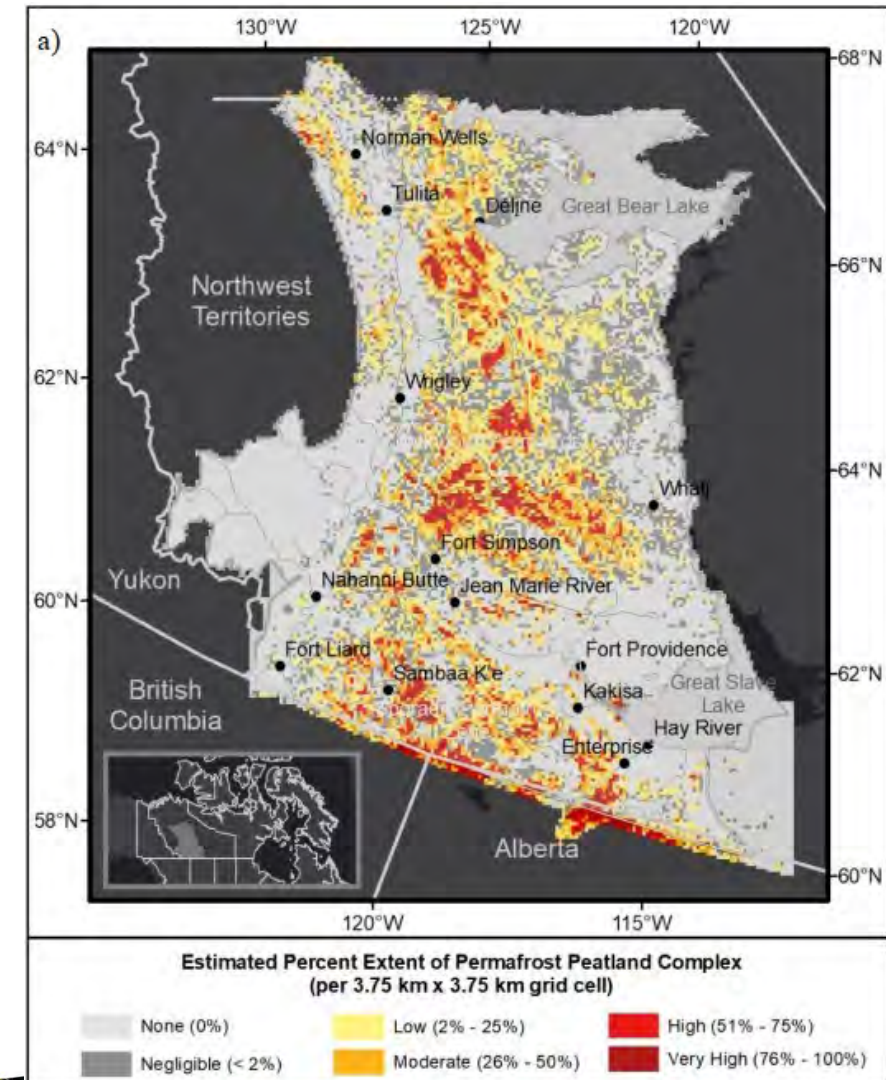
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Emerging priorities to close knowledge gaps

Combine process-based studies with mapping to improve models of landscape change

1. Focus on the four permafrost carbon cycles
 - Quantify processes and changes over time
2. Improve data on soil organic carbon stocks and lability
 - Intensify distribution of soil sampling sites across NWT
3. Establish observational benchmarks to test models
 - Territory wide monitoring network
4. Intensify GHG observation network to detect regional changes
 - Long-term, year around observations (CH_4 and CO_2) to establish trends
5. Link to understanding of 'Permafrost Land Systems'
 - Key to understanding landscape, ecosystem, and climate effects on future permafrost change
 - NWT Thermokarst Mapping Collective data sets

NWT Thermokarst Collective
Permafrost Peatland Mapping



Source: Gibson et al., 2020.
<https://doi.org/10.46887/2020-010>



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How to control permafrost carbon emissions?

Keep as much permafrost frozen as possible, as long as possible

Reality: Permafrost thaw will continue due to past human emissions

Impact: Less room in *Global Carbon Budget* as permafrost thaws

Goal: Minimize the amount that permafrost will eventually thaw

Actions:

- Support greenhouse gas removal strategies and cut human emissions
- Get permafrost carbon incorporated into the *Global Carbon Budget*

Global Carbon Budget

- The amount of greenhouse gas emissions humans can emit to limit global temperature increases to a certain amount, e.g., 1.5 °C.
- Balance of human emissions against storage in carbon sinks
- Permafrost carbon emissions not fully accounted for in Global Carbon Budget



Thank you!



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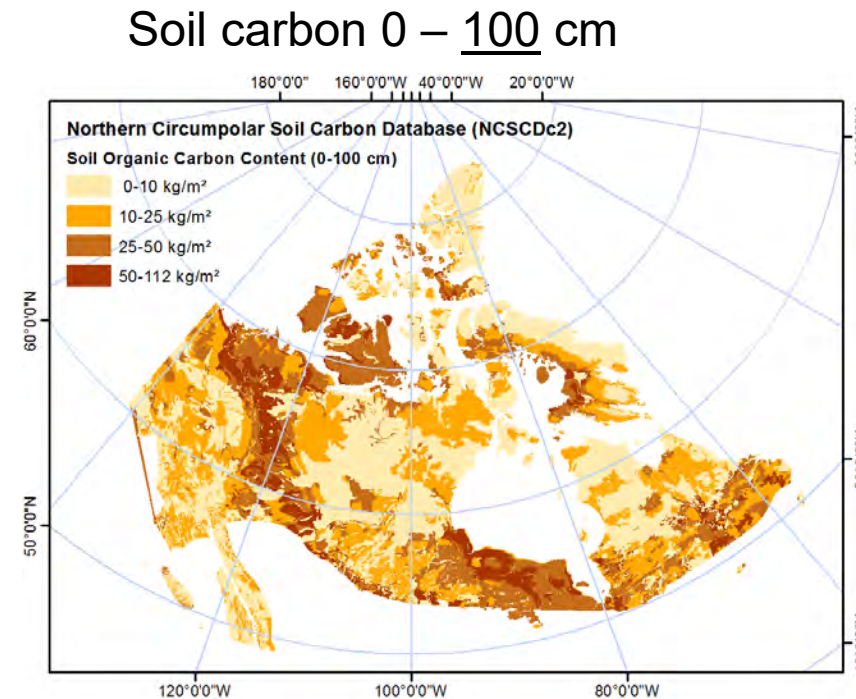
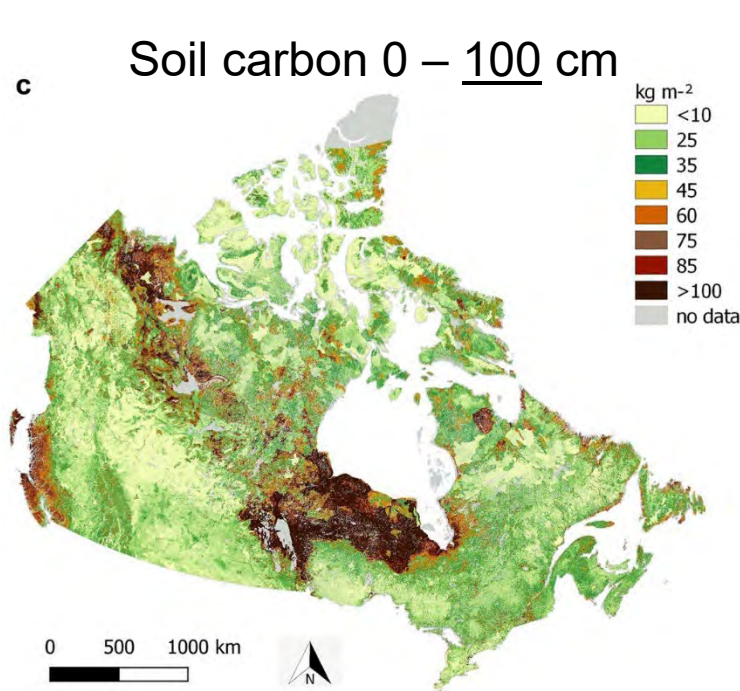
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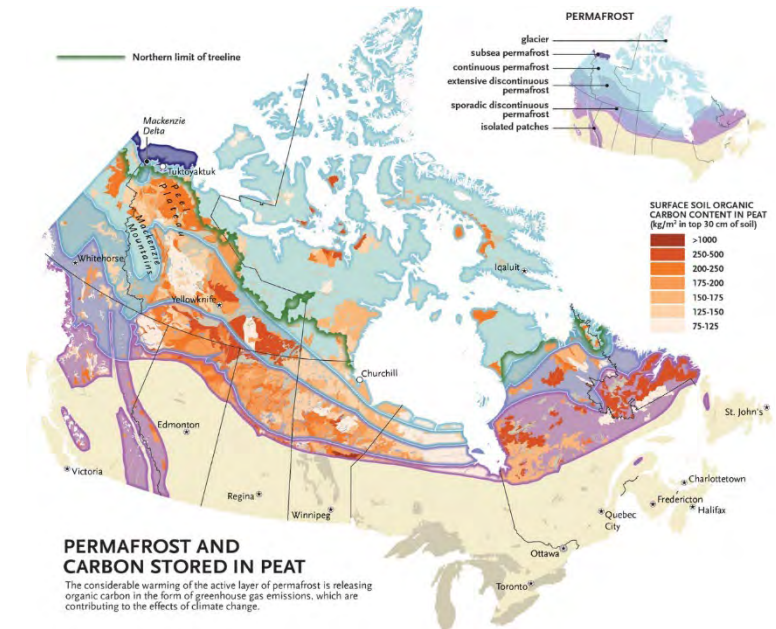
Gap Example: Soil organic carbon amount and quality?

Poorly understood or measured

- SOC outside of permafrost peatlands
- Lability of carbon not well known



Peatland soil carbon 0 – 30 cm



Source: Camille et al., 2022. <https://doi.org/10.1029/2021GB007213>

Source: Stockholm University, 2013. <https://dx.doi.org/10.5879/ECDS/00000002>

Source: Chris Brackley/Can Geo. <https://canadiangeographic.ca/articles/arctic-permafrost-is-thawing-heres-what-that-means-for-canadas-north-and-the-world/#&qid=1&pid=4>



Natural Resources
Canada

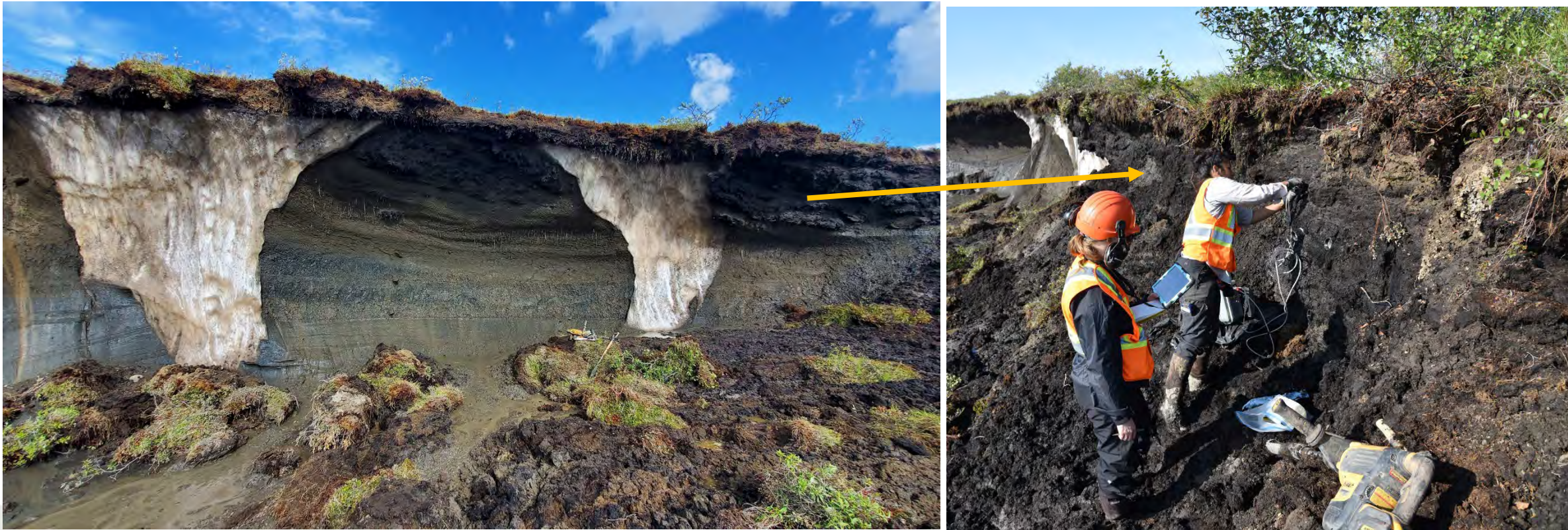
Ressources naturelles
Canada

Canada

E.g., Soil carbon accumulation at slopes

Several permafrost processes store carbon

- Slope movements accumulate carbon at top of permafrost
- Early Holocene thaw Earlier, deeper



Natural Resources
Canada

Ressources naturelles
Canada

Canada

Highlights of technology and geotechnique

Advancements in quantifying methane emissions

- Invented an ultra-lightweight laser spectroscopic sensor: deployed on a small UAV
- Coordinated ground- and helicopter-based methane surveys with airborne methane surveys (DLR CoMET 2.0 and NASA ABoVE) to develop atmospheric dispersion models (Fig. a)
- Flew low elevation aerial surveys to measure subregional variations in methane concentration and collect air samples (Fig.b)
- Developed chamber methods to determine methane fluxes from different cryostratigraphic units of permafrost (Fig. c)
- Incubated permafrost at subfreezing temperatures to assess microbial ecology and activity
- Analyzed gases from lake ice bubbles to relate them to bubble morphology and aqueous geochemistry and link these to satellite radar lake ice mapping (Fig. d).



Natural Resources
Canada

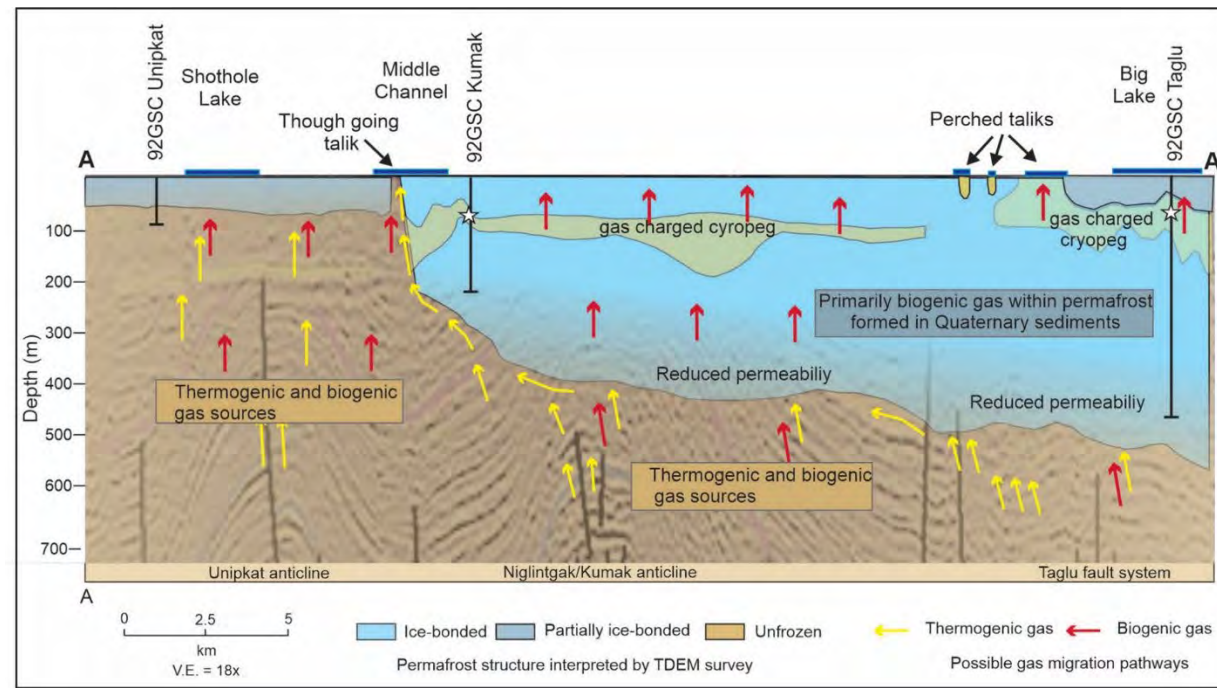
Ressources naturelles
Canada

Canada

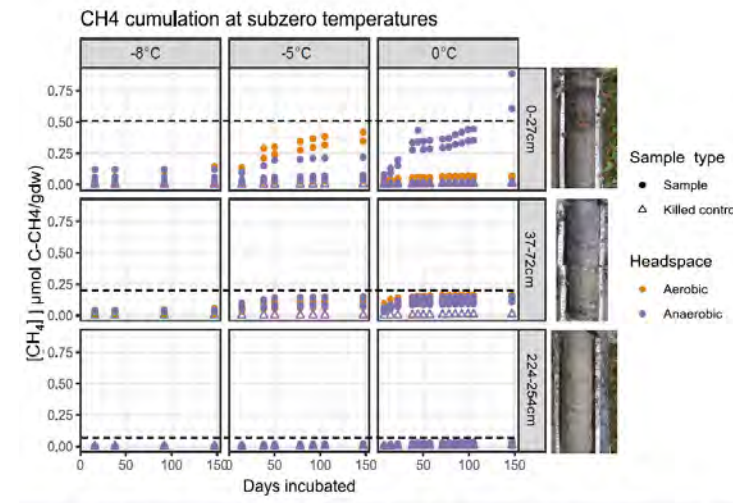
Initial findings

Key results from our work

- Geologic methane blocked by thick permafrost, passes through thin permafrost
 - Thin, warm permafrost = ancient biogenic + thermogenic + modern biogenic methane
 - Thick, cold permafrost = modern biogenic methane
- Emission locations may be “points” or diffuse
- Microbiota are active within permafrost
 - Methane producing bacteria associated with high *in situ* methane
 - Permafrost does not need to thaw to release methane



Dallimore et al., 2024.
<https://doi.org/10.1029/2023JF007515>



Mollica et al., ArcticNet, 2022



Natural Resources
Canada

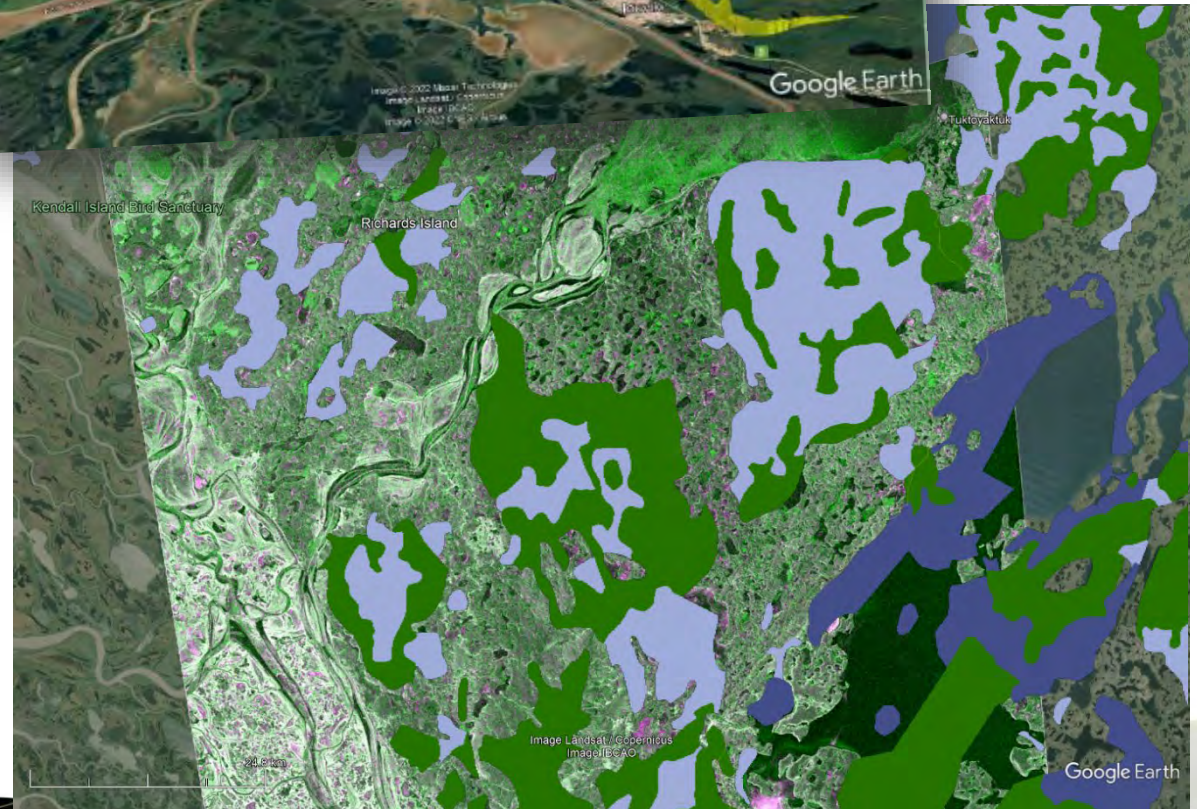
Ressources naturelles
Canada

Canada

Initial findings

Key results from our work

- In peak growth season, methane concentration increases with greater wetland extent and thinner permafrost.
- Gas bubbles in lake ice with higher bubble densities have elevated methane concentrations
- Higher bubble densities may relate to surficial deposits modified and resulting from the Holocene warm interval



Natural Resources
Canada

Ressources naturelles
Canada

Canada

Threats to land carbon in NWT – a focus on industry disturbances to peatlands



Peatlands in the Hudson Bay Lowland, Canada
Photo: Lorna Harris



Dr Lorna Harris

**Director – Forests, Peatlands, and Climate Change
Wildlife Conservation Society (WCS) Canada**

Landscape Carbon Workshop - Yellowknife, Northwest Territories – February 4, 2025

WCS Canada's Forests, Peatlands, and Climate Change Program

"Scientists in the service of conservation"

Using a combination of field-based, geospatial, and policy research and engagement to make change happen

- Generate scientific evidence through field-based and geospatial research to improve forest and peatland assessment and monitoring for biodiversity and climate-smart decision-making
- Identify and develop tools and actions to advance protected areas and to support climate-smart decisions for resource development across the carbon-rich boreal region of Canada
- Advance the protection and stewardship of peatlands and forests across Canada through policy research and direct engagement with decision-makers

Global, National, and Regional Science and Policy Projects and Partnerships



WCS Canada's Forests, Peatlands, and Climate Change Program

Our team



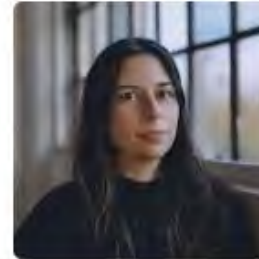
Lorna Harris
Director of Forests,
Peatlands and
Climate Change
Program



Victoria Goodday
Policy Lead -
Forests, Peatlands
and Climate
Change



Adam Kirkwood
Research Associate
- Peatland
Biogeochemistry



Laura Tanguay
Policy Analyst -
Forests, Peatlands
and Climate
Change



Caitlyn Lyons
Research Associate
- Peatland
Biogeochemistry



Meg Southee
Lead Geospatial
Analyst/Programmer

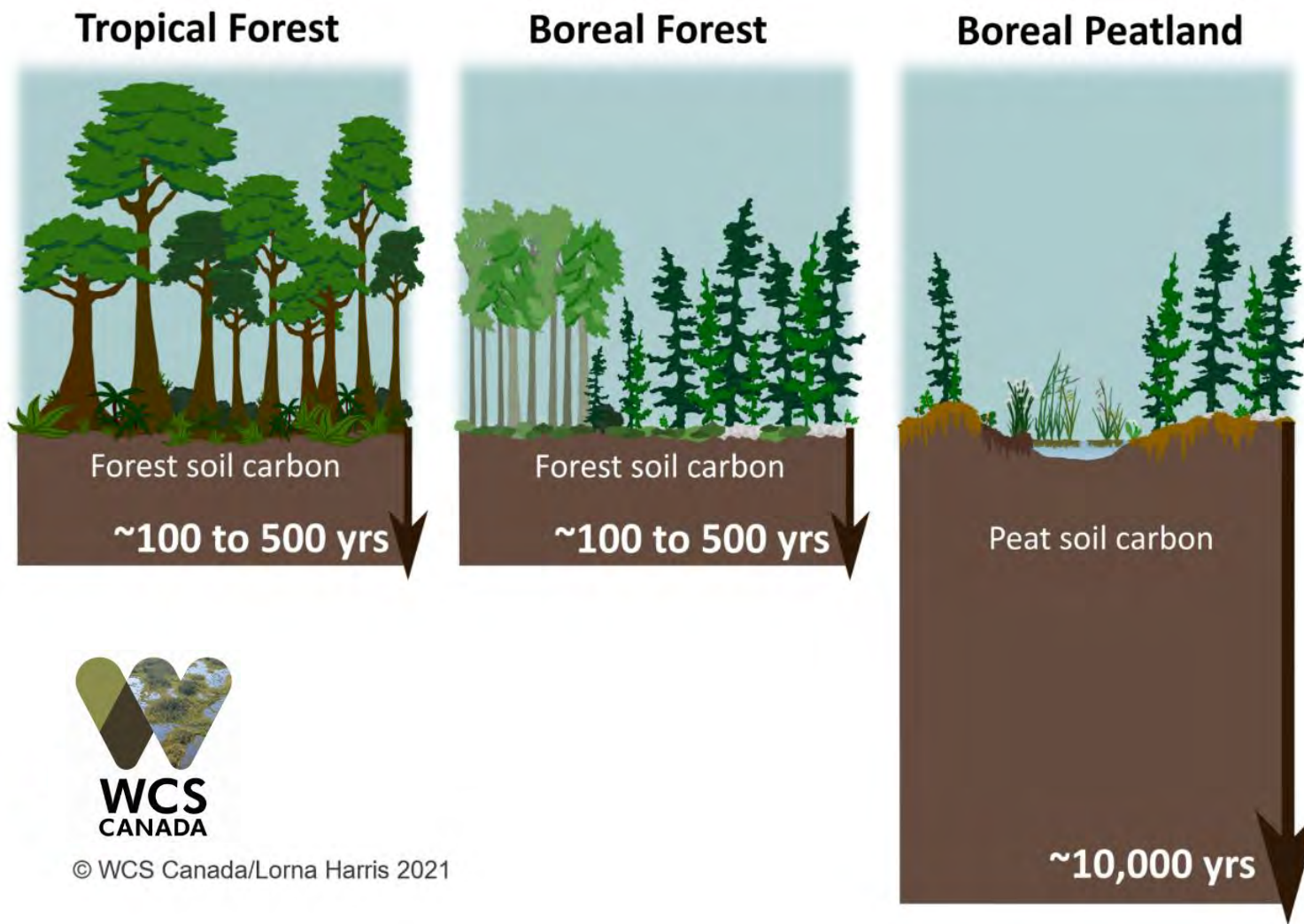
What is peat?



Examples of fen peat (sloppy!), permafrost peat (with ice!), and upper active layer *Sphagnum* peat from Yukon peatlands

Photos: Lorna Harris

Peatlands are enormous carbon stores



The power of peatlands is their ability to **capture and store carbon for a very long time**

Drained peatlands cover less than 0.5% of the world's land surface but **contribute 4% of global GHG emissions** each year (~1.5 billion tonnes of CO₂ per year)

Frolking and Roulet (2007). Holocene radiative forcing impact of northern peatland carbon accumulation and methane emissions. *Global Change Biology*, 13, 1079-1088.

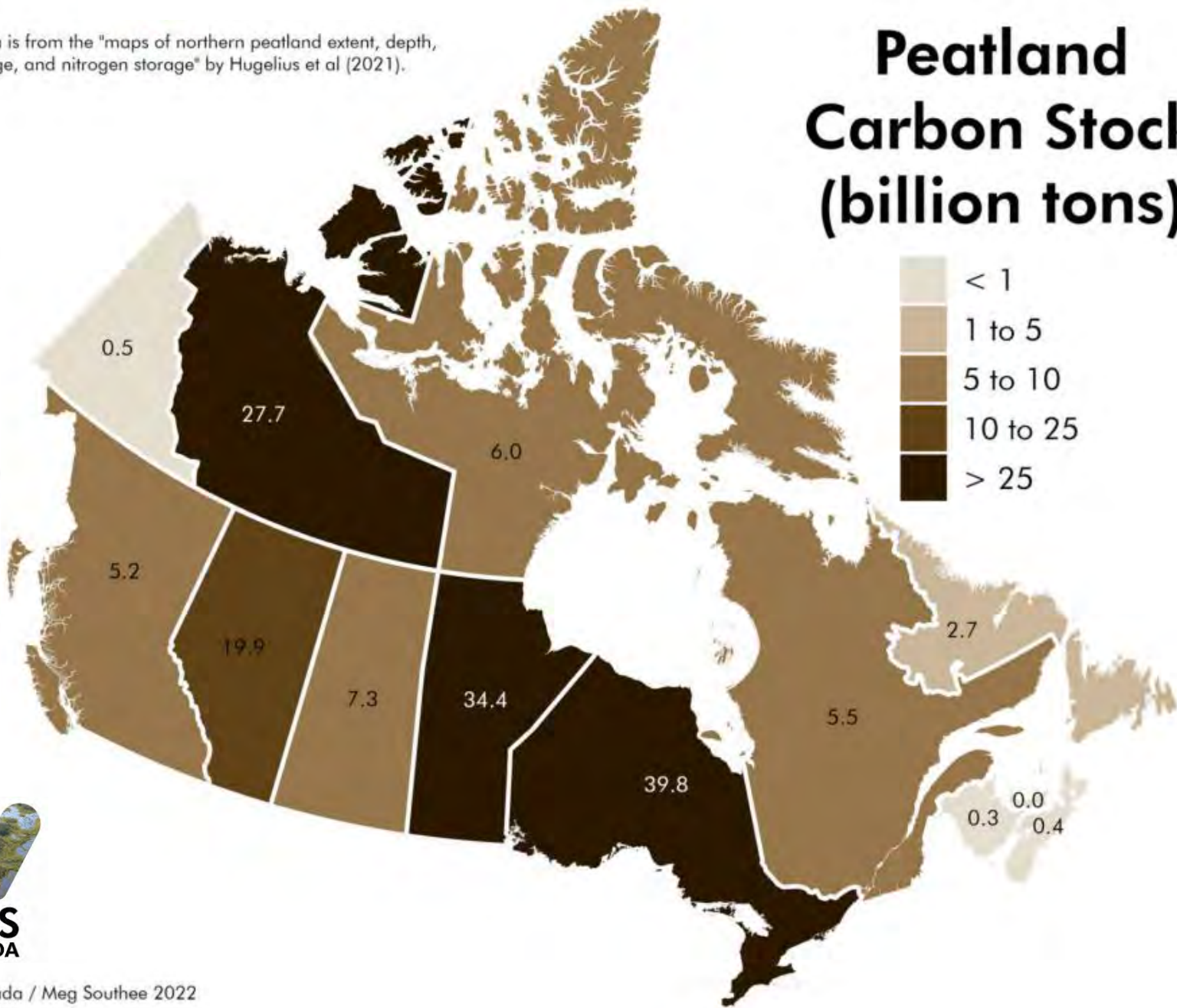
Leifeld and others (2019). Intact and managed peatland soils as a source and sink of GHGs from 1850 to 2100. *Nature Climate Change*, 9, 945-947.

Harris and others (2020). Drainage reduces the resilience of a boreal peatland. *Environmental Research Communications*, 2, 6.

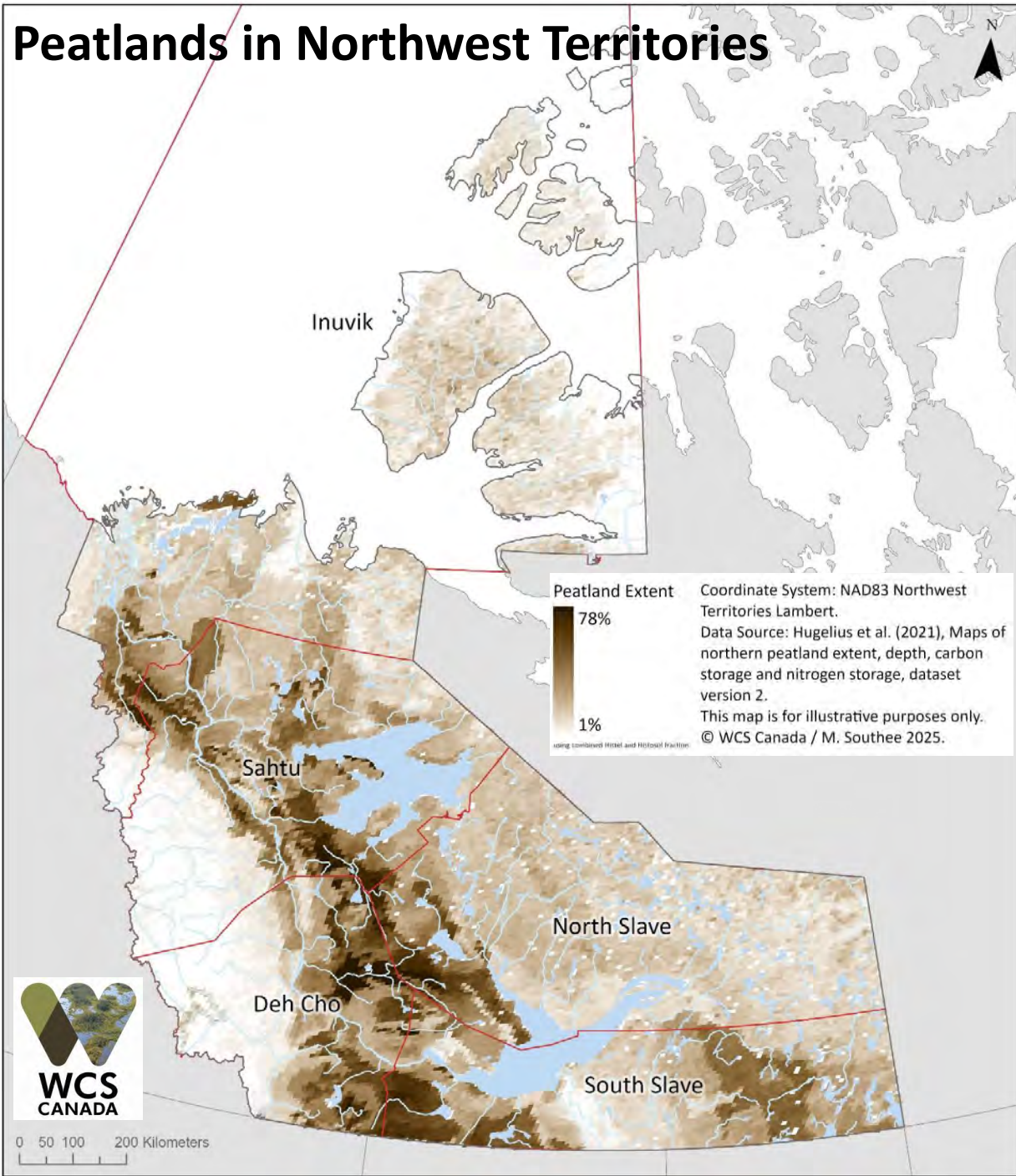
Peatlands in Canada

Peatland data is from the "maps of northern peatland extent, depth, carbon storage, and nitrogen storage" by Hugelius et al (2021).

Peatland Carbon Stock (billion tons)

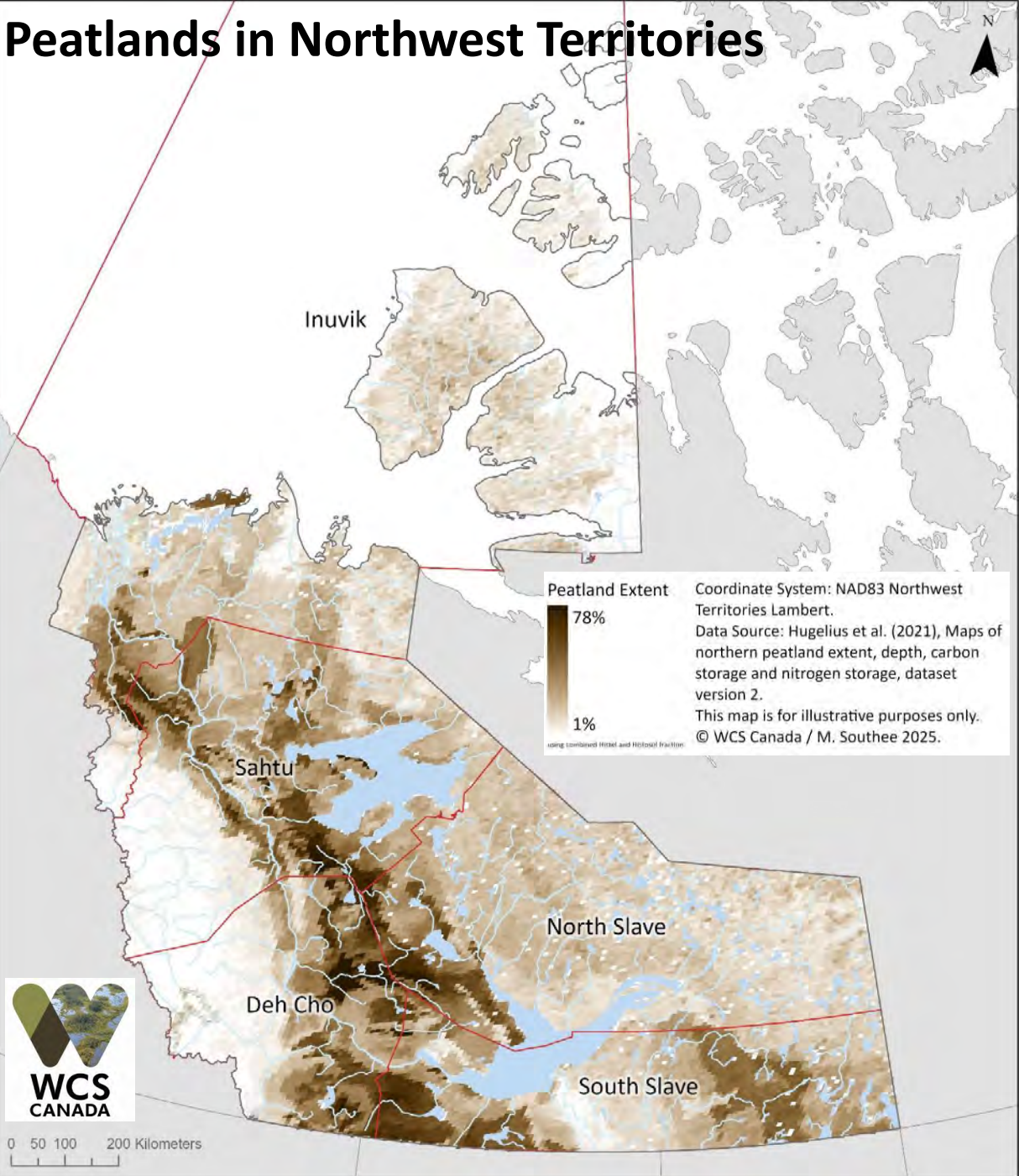


Peatlands in Northwest Territories



Around **27 billion tonnes** of carbon stored in
peatlands in NWT

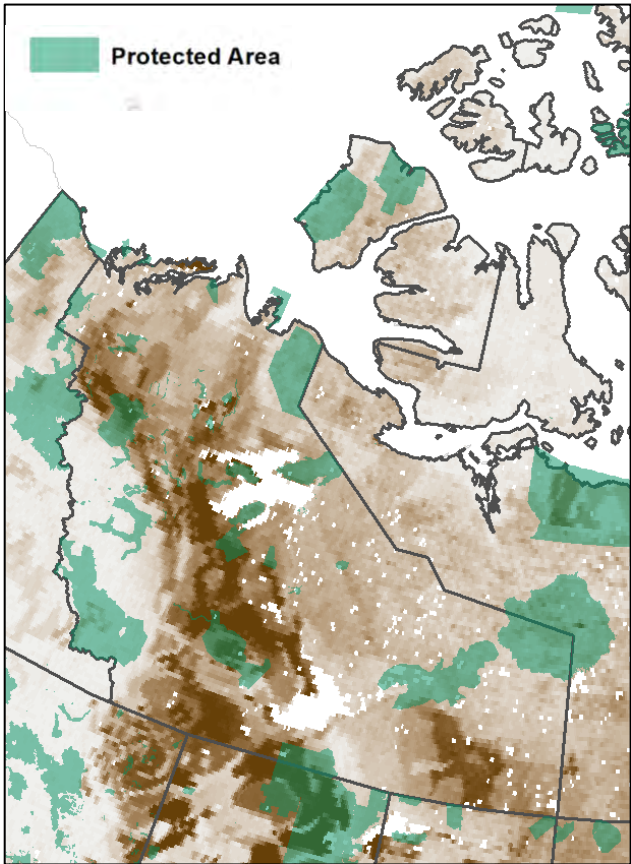
(estimated peatland area = 215,973 km²)



Around **27 billion tonnes** of carbon stored in peatlands in NWT

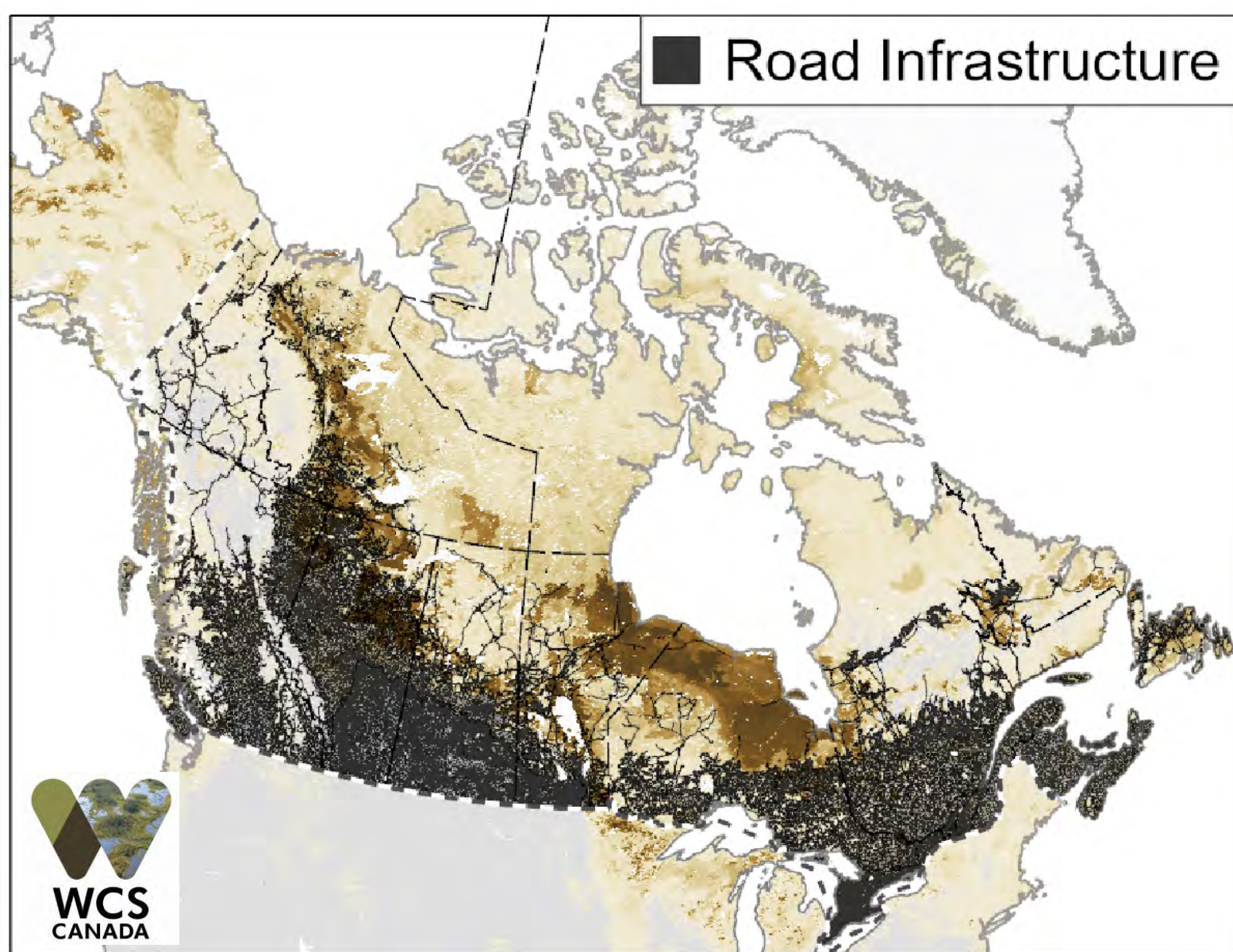
(estimated peatland area = 215,973 km²)

Just over **13%** of peatlands in NWT are within protected areas



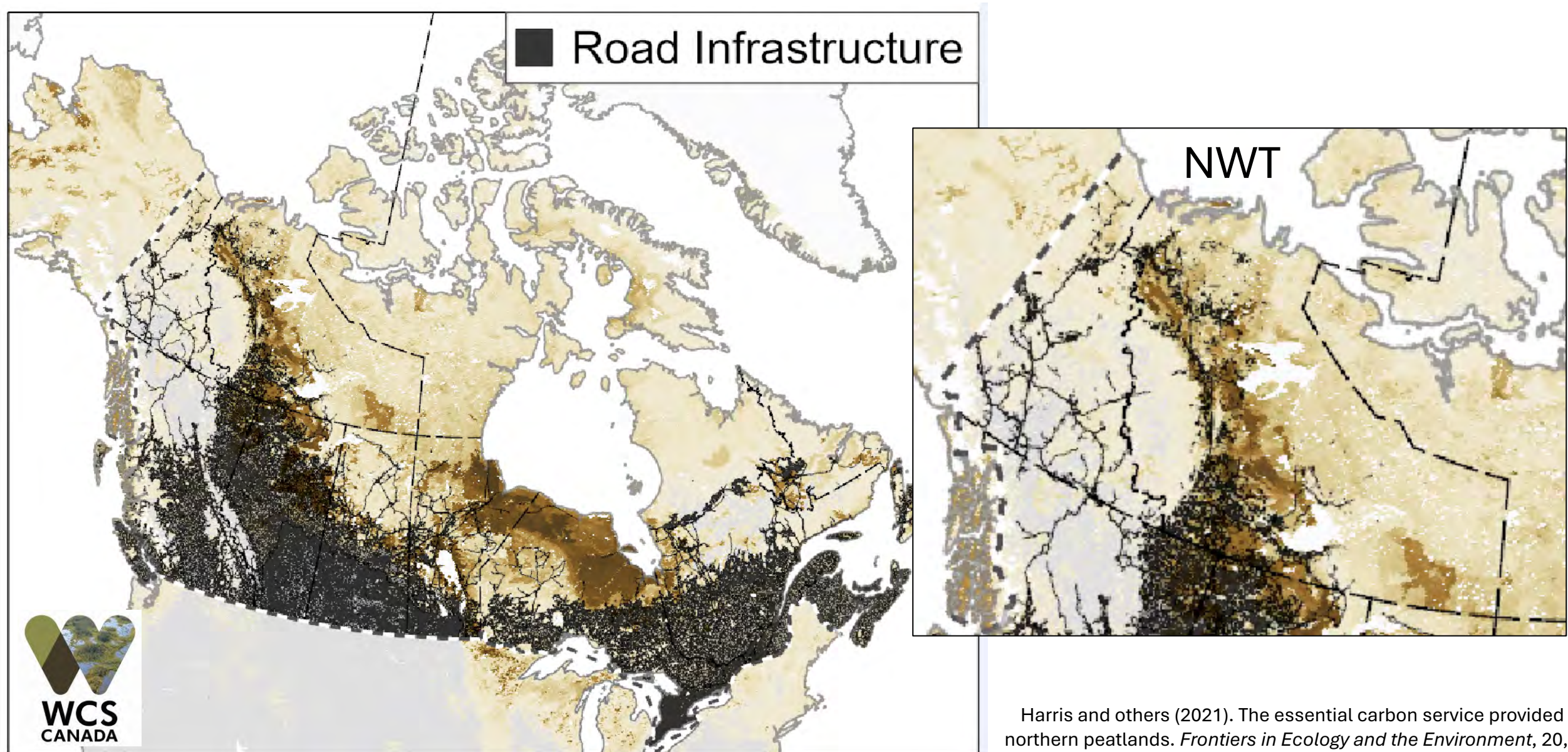
Province or territory	% peatland area within protected areas
Alberta	23.1
Yukon Territory	21.9
Quebec	19.5
Nova Scotia	15.5
British Columbia	14.2
Northwest Territories	13.3
Manitoba	13.2
Nunavut	10.7
Saskatchewan	9.8
New Brunswick	8.9
Ontario	8.8
Newfoundland and Labrador	6.1
Prince Edward Island	2.3
Canada total (this review)	13.1

Road infrastructure in Canada and NWT – impacts to peatlands



Harris and others (2021). The essential carbon service provided by northern peatlands. *Frontiers in Ecology and the Environment*, 20, 4.

Road infrastructure in Canada and NWT – impacts to peatlands



Mining claims in NWT

ALL CLAIMS

ACTIVE CLAIMS

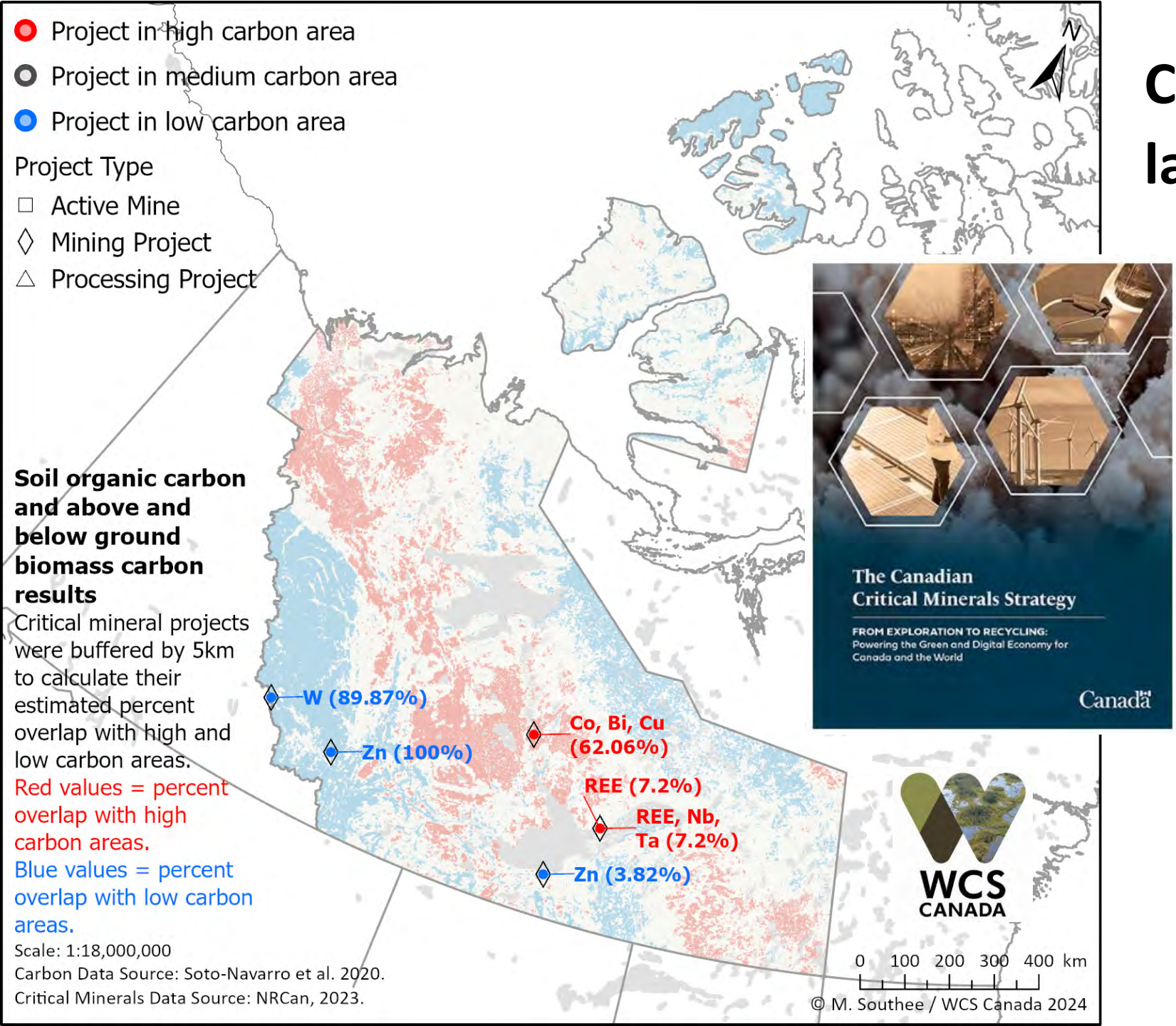
All claims includes active, leased, expired, refused, and withdrawn claims

All = 27,752,741 ha

Active = 745,442 ha

Ongoing analysis...

Critical minerals and land carbon risk in NWT



Not just peatlands! National analysis includes all soil and above and below ground biomass carbon

Critical minerals projects included on national database (NRCan)

Does not include other active mining claims that could be developed for 'critical minerals' in future

A close-up photograph of various mosses. The majority of the moss is a deep, vibrant red, forming dense, tufted clusters. Interspersed among the red moss are several stems of yellowish-green moss, which have a more elongated, segmented appearance. The lighting is bright, highlighting the intricate textures and colors of the moss.

Thank you!

Contact us:

peatlands@wcs.org

www.wcscanada.org

Photo: Lorna Harris





Wildfire – threats to landscape carbon stocks

Jenn Baltzer
Wilfrid Laurier University

Photo credit: GNWT ENR

Climate change is altering how fires impact the land

2014

Forest fires rage across the Northwest Territories

SAHAR FATIMA

PUBLISHED JULY 4, 2014

This article was published more than 9 years ago. Some information may no longer be current.

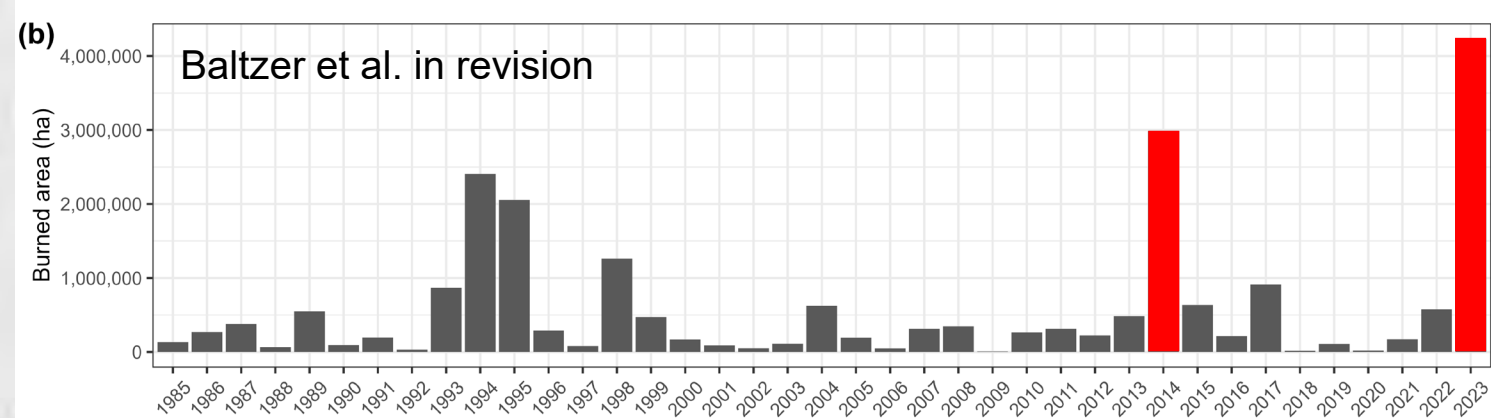
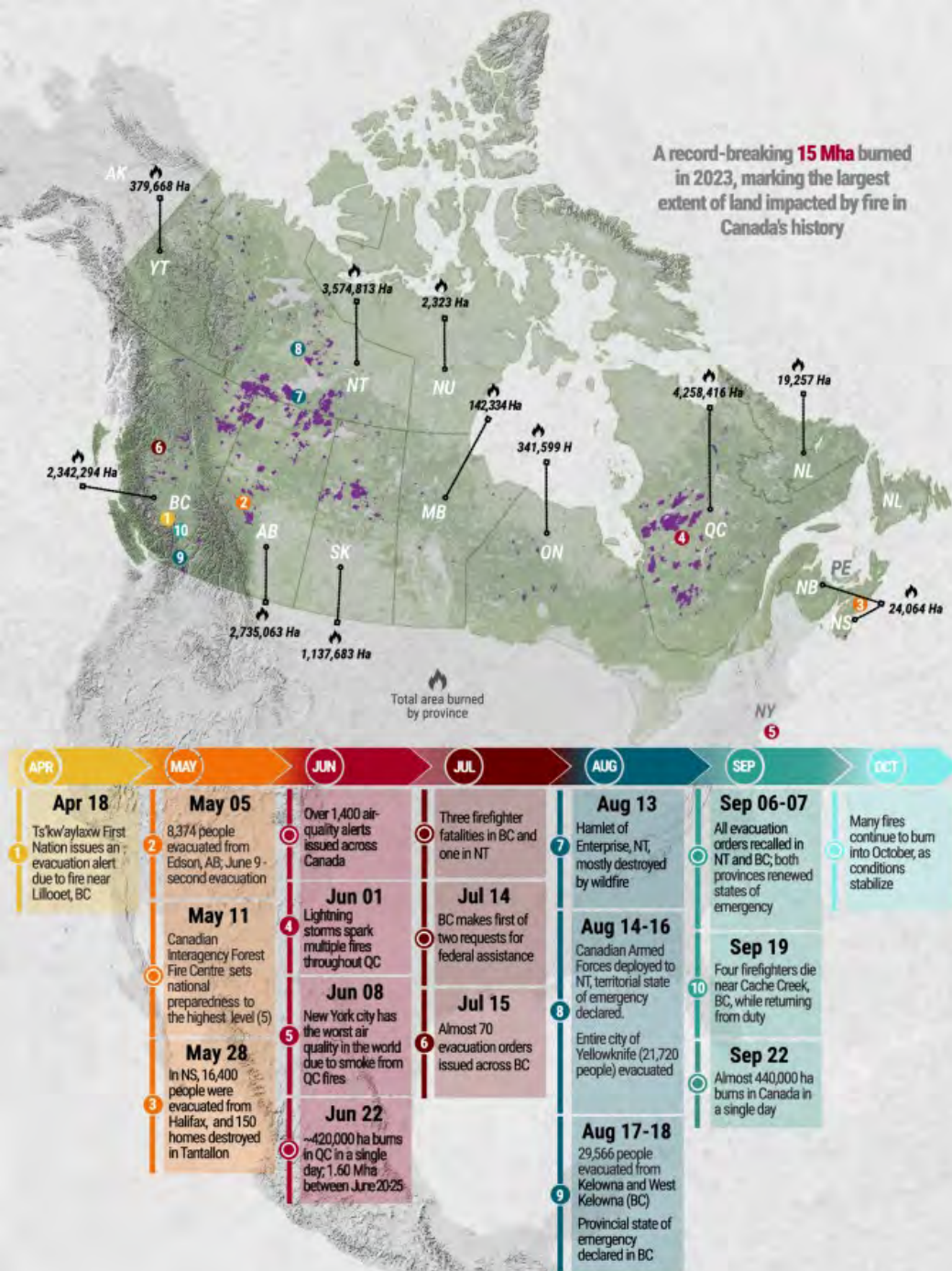


2023

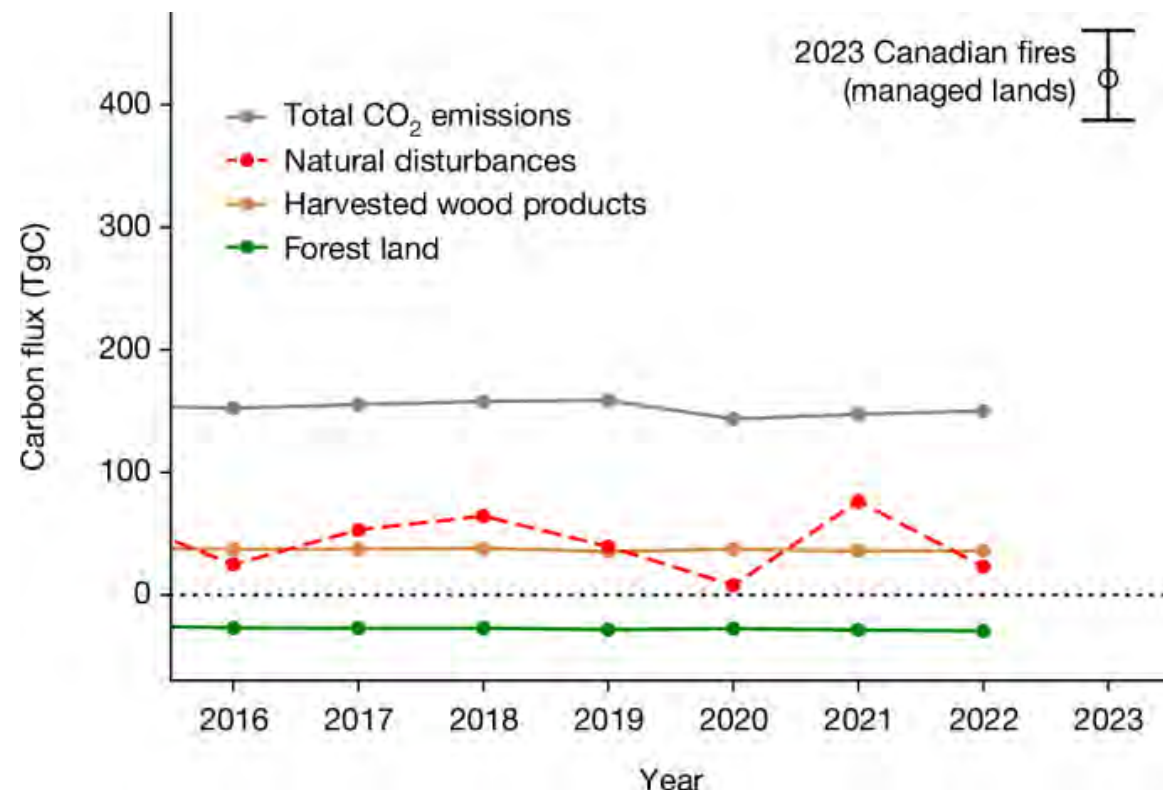
Area burned by wildfires surpasses NWT's 2014 record

Emily Blake · September 2, 2023





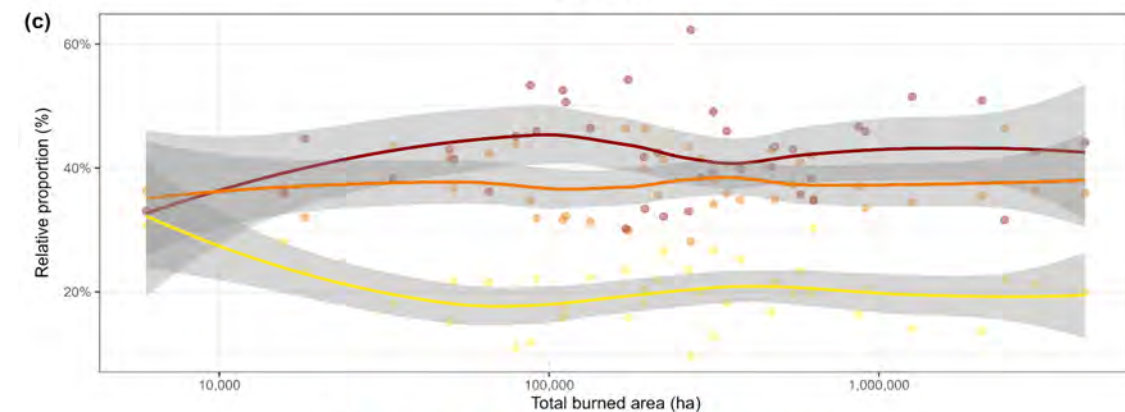
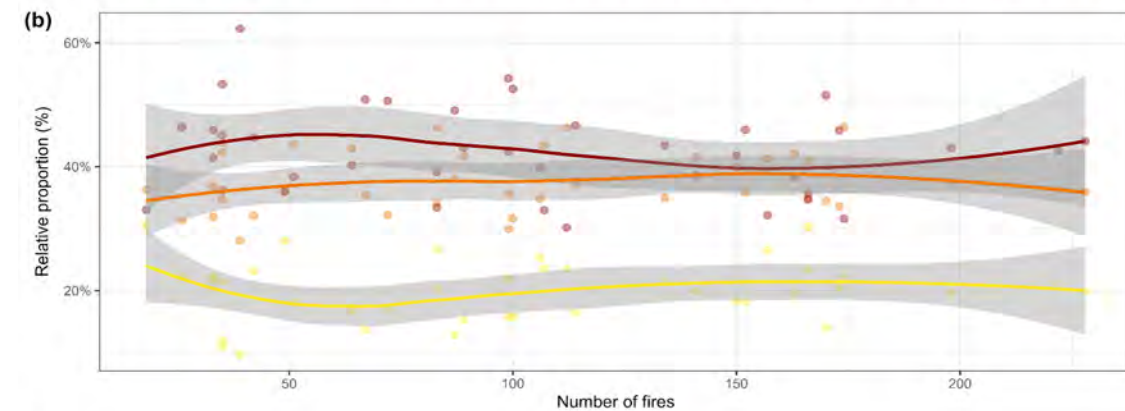
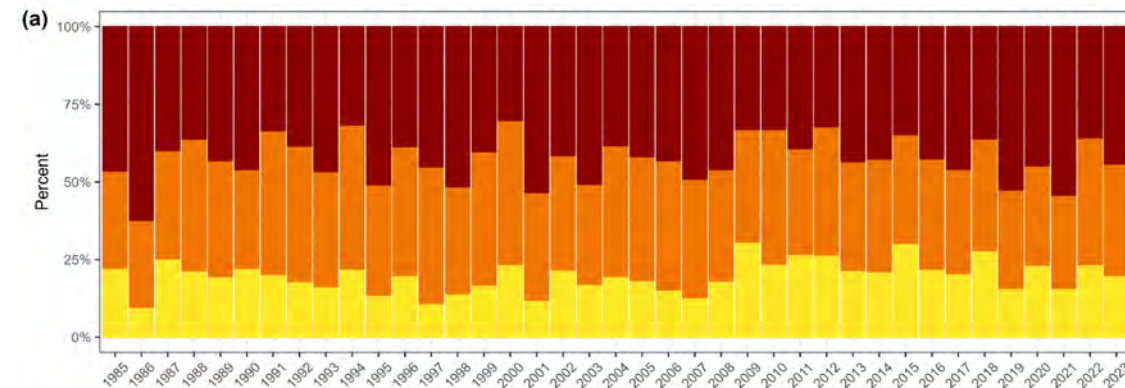
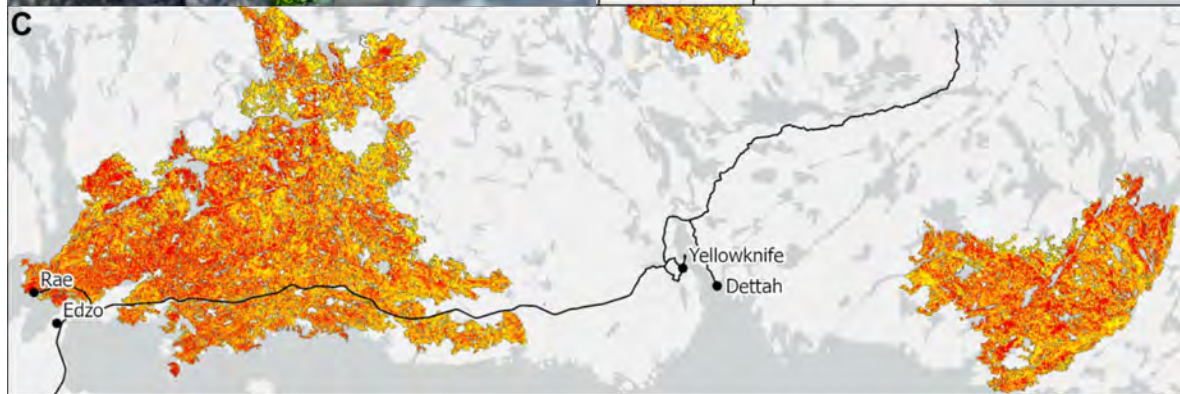
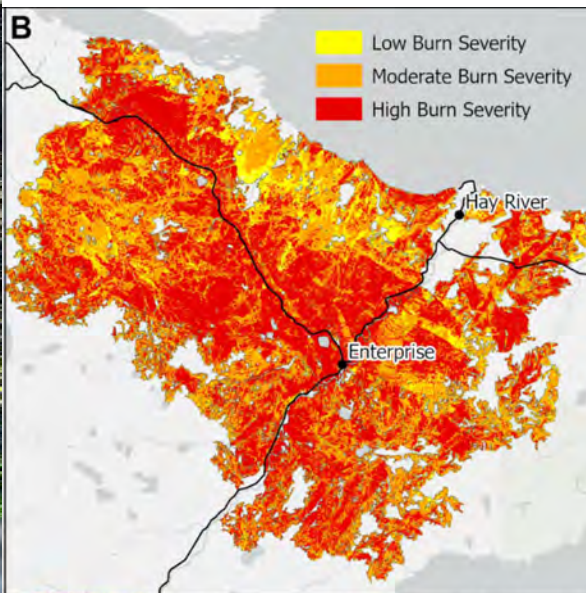
↑ Area burned = ↑ Emissions



Byrne et al.
2024.
Nature.

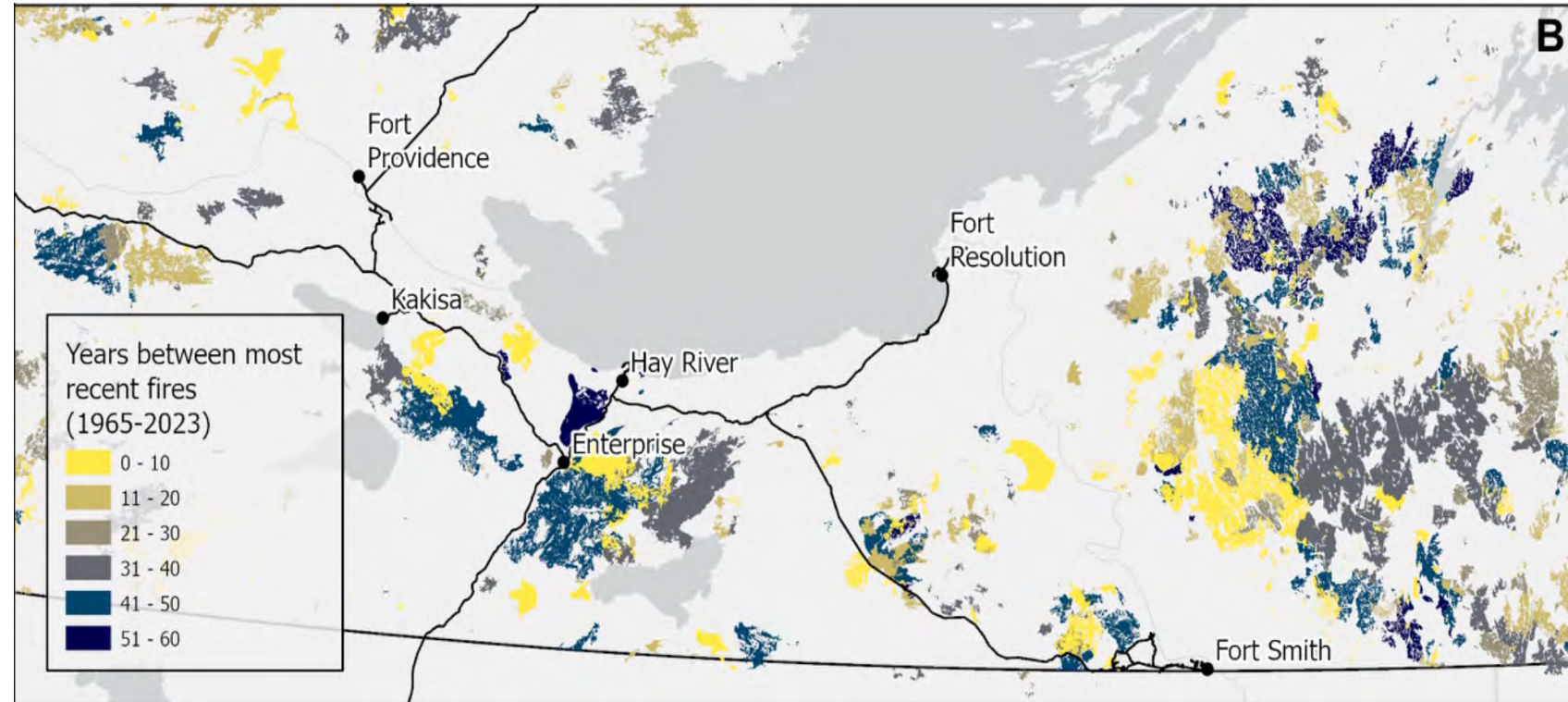


Fire severity

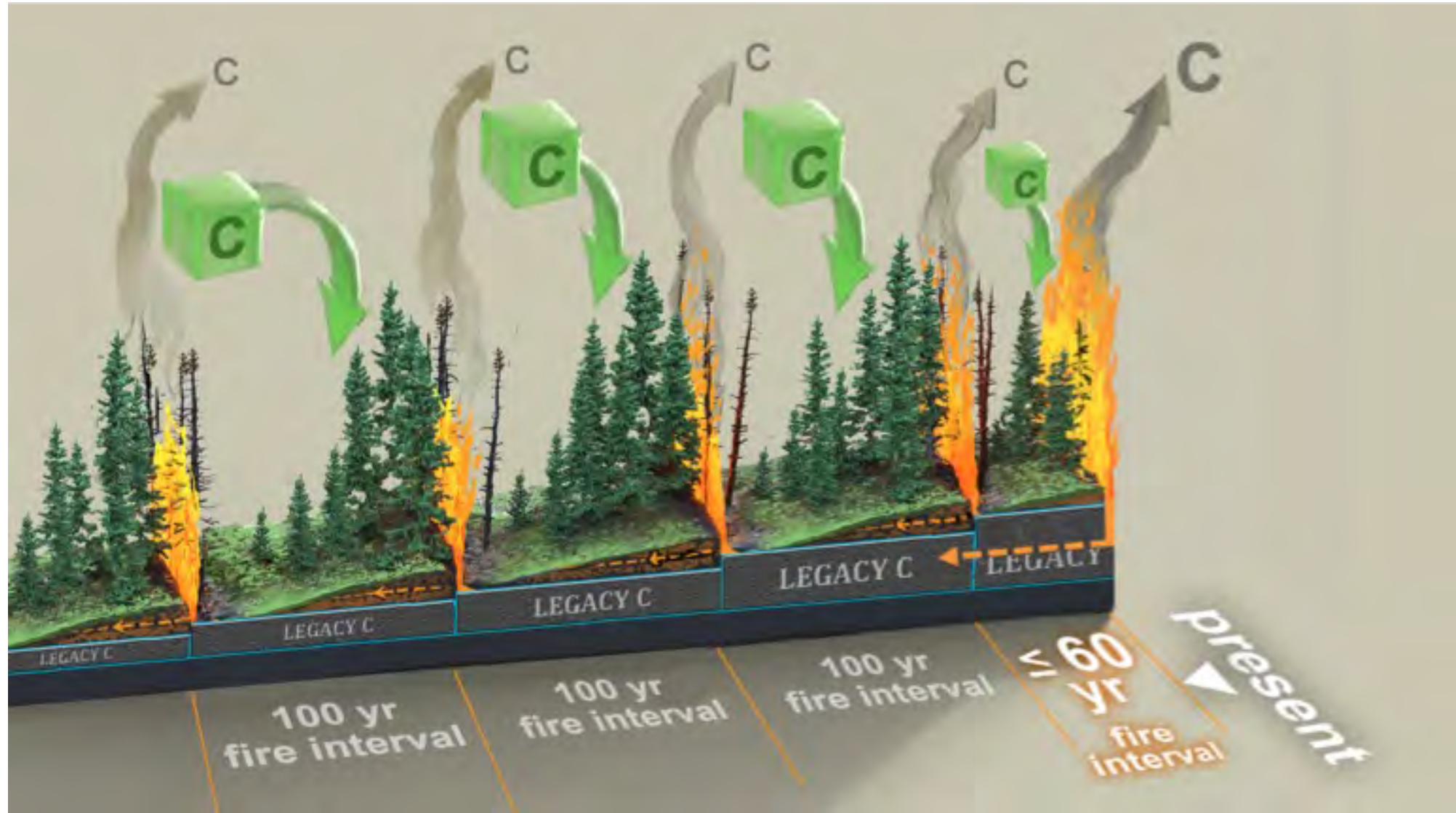


High Burn Severity Moderate Burn Severity Low Burn Severity

Short interval reburning



Short interval reburns: Legacy Carbon Loss



Short interval reburns: Failed recovery of forests



Overwintering fires

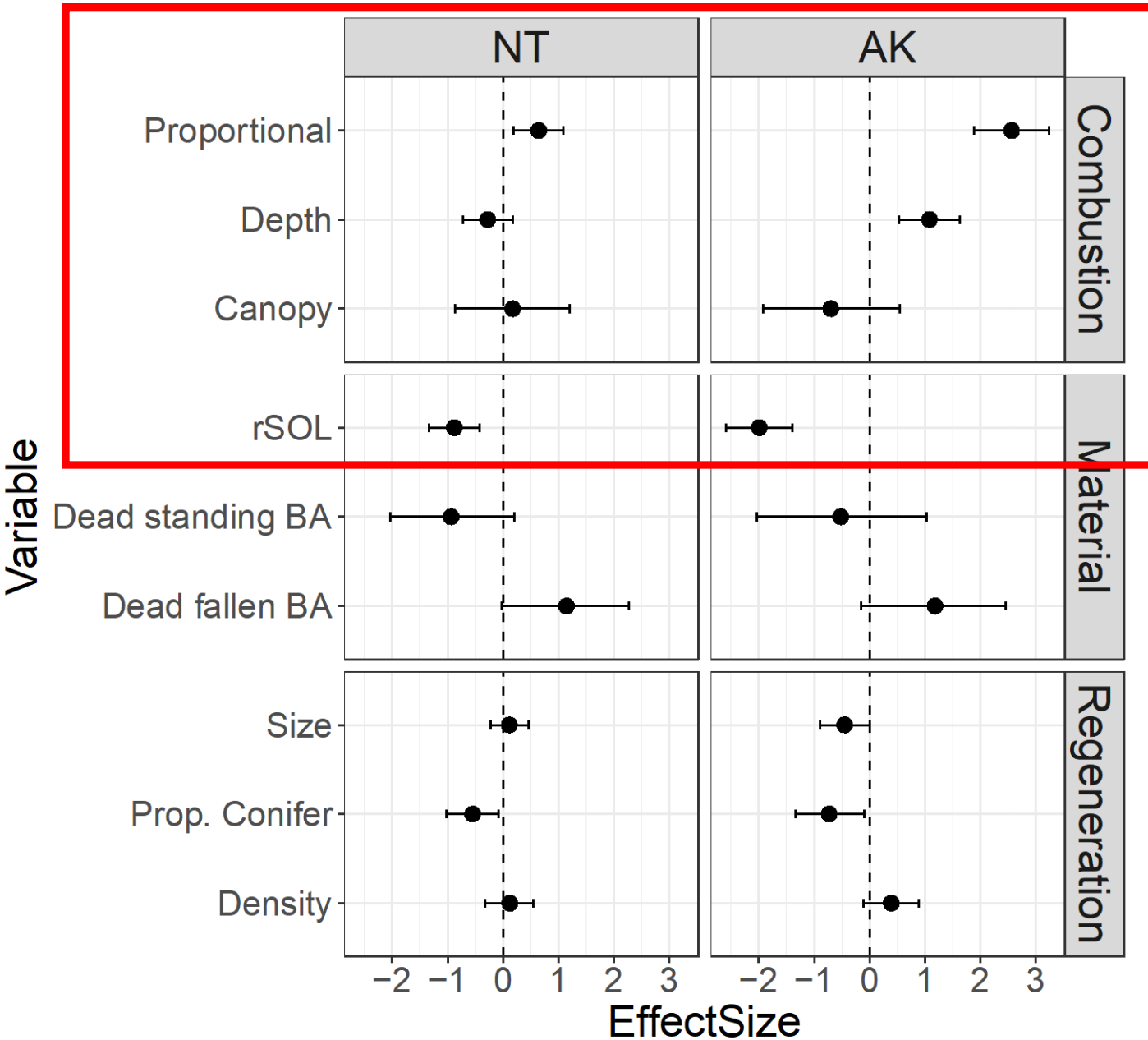
What exactly are 'zombie' fires?

'You think they're dead and then they're back': Fires that smouldered through the winter have re-emerged

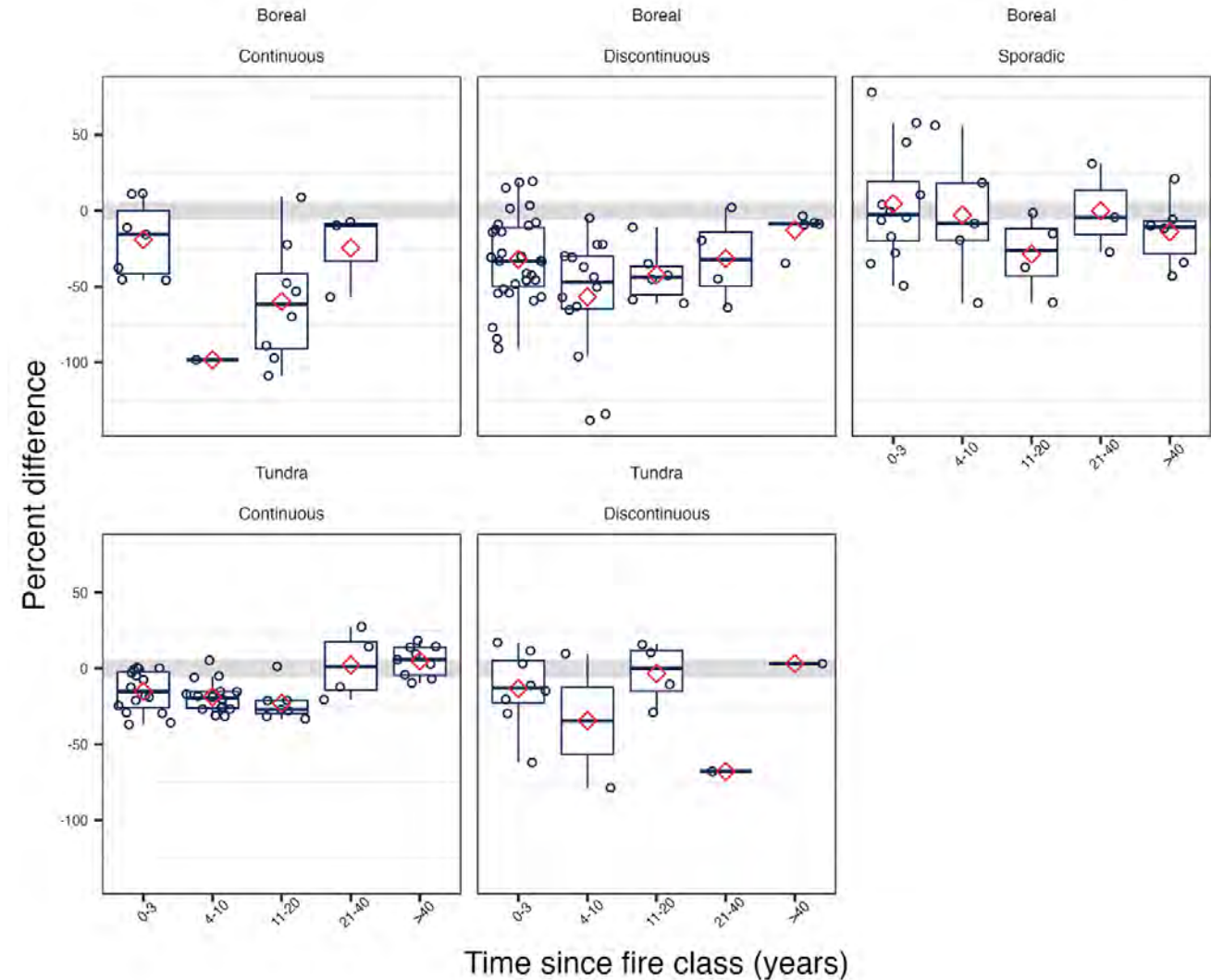
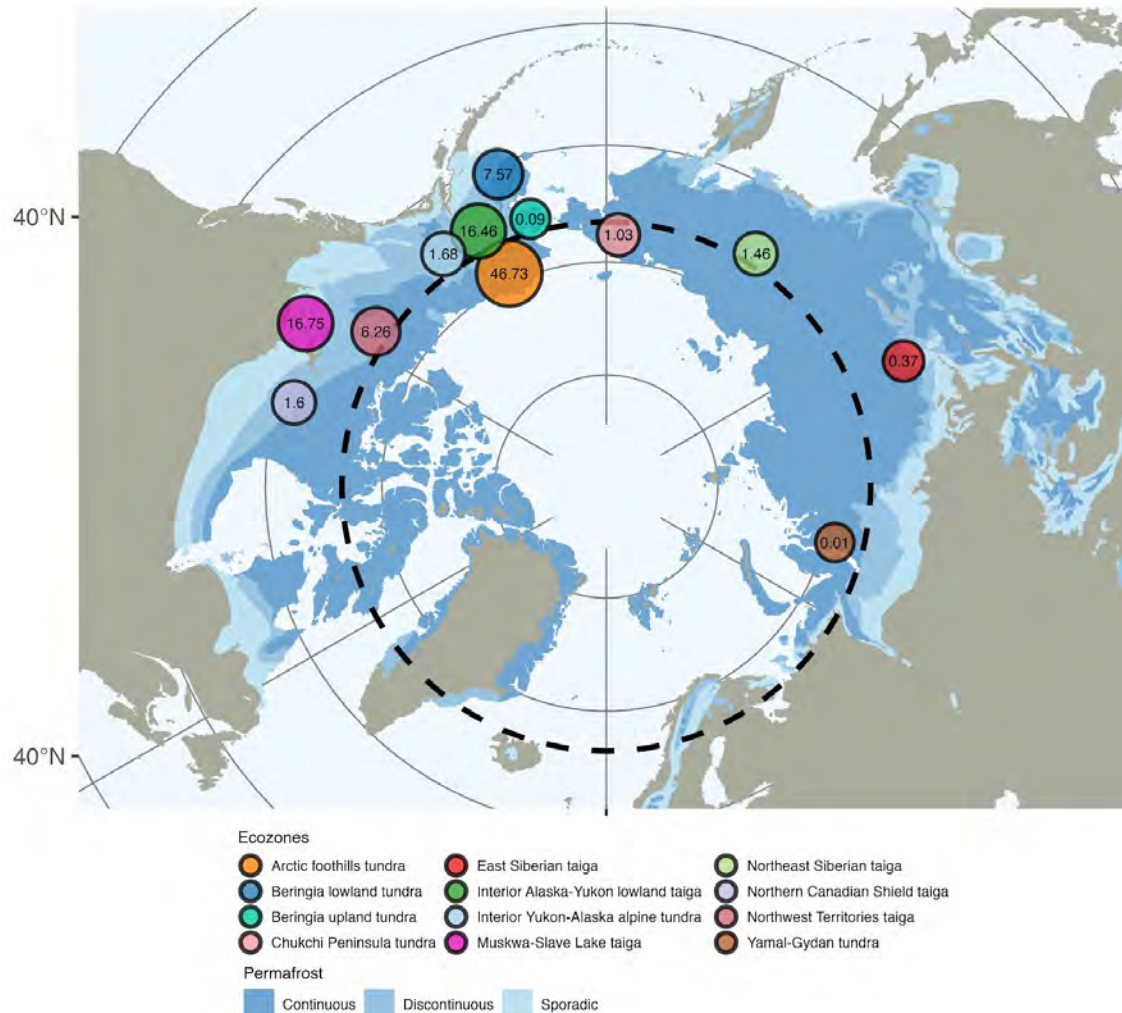
Benjamin Shingler · CBC News · Posted: May 18, 2024 2:00 AM MDT | Last Updated: May 21, 2024



A fire smoulders underground near Fort Nelson, B.C., this past winter. The region is now dealing with a wildfire that started from one of these 'zombie' or holdover fires. (Submitted by Sonja Leverkus)



Fire x Permafrost Interactions





Mahsi! Thank you!

Contact information:

Jenn Baltzer

jbaltzer@wlu.ca

www.forestecology.ca

Wildfire in the Boreal: The Role of Peatlands



**NSERC
CRSNG**



Canada Wildfire

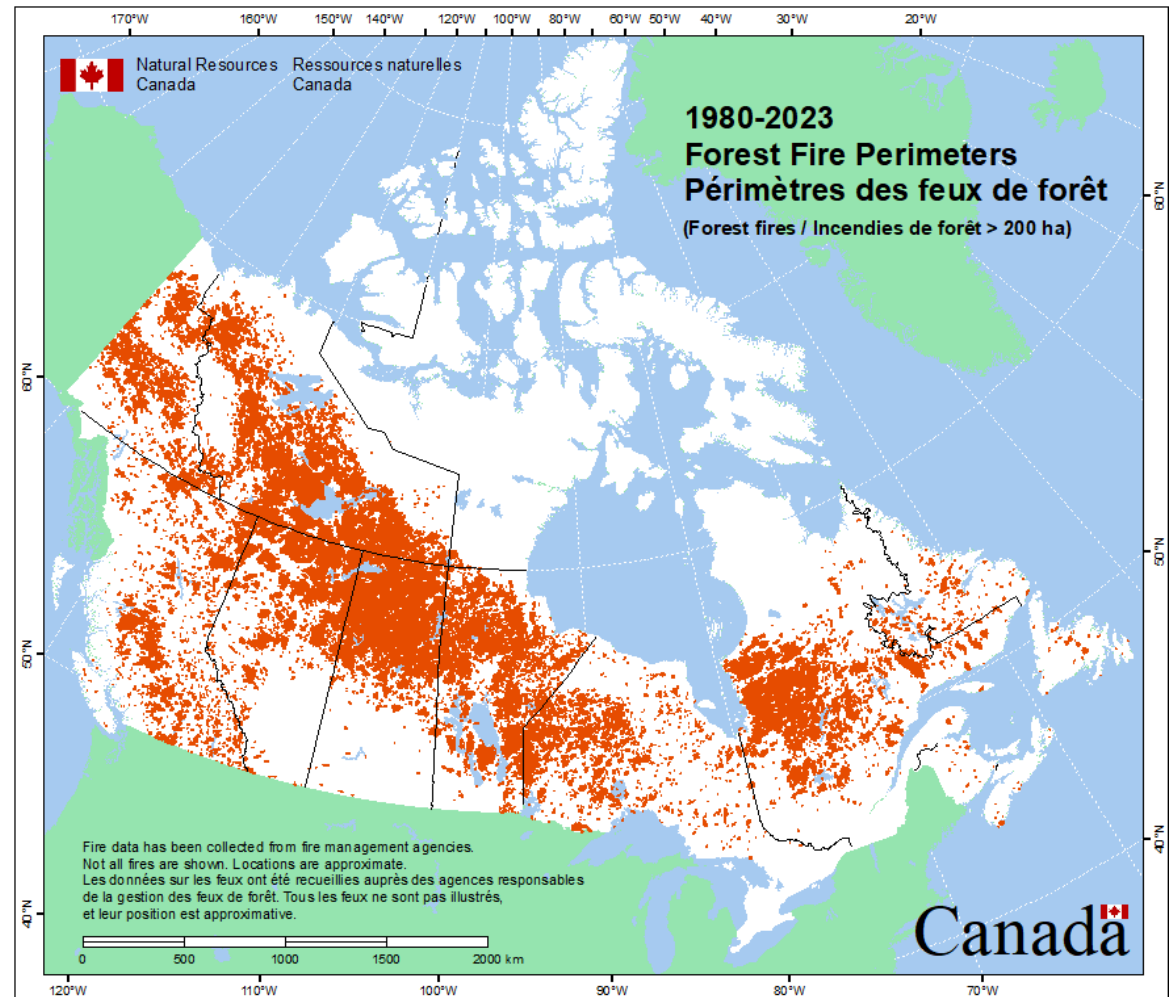


Sophie Wilkinson, Ph.D.
Simon Fraser University, BC, Canada
Landscape Carbon Workshop;
Yellowknife, NT



Fire in Canada

- Average annual area burned (1990-2020) = 2.1 Mha
- 2021 = 4.1 Mha
- 2023 = 15.1 Mha
- 2024 = 5.4 Mha
- Follows the boreal forest



Fire in the Boreal

- ~100-200 year fire return interval
- Lightning ignitions and human-ignitions
- Spring fire risk
- Many forests sit atop organic soil (peat)



Image: FPInnovations, 2015

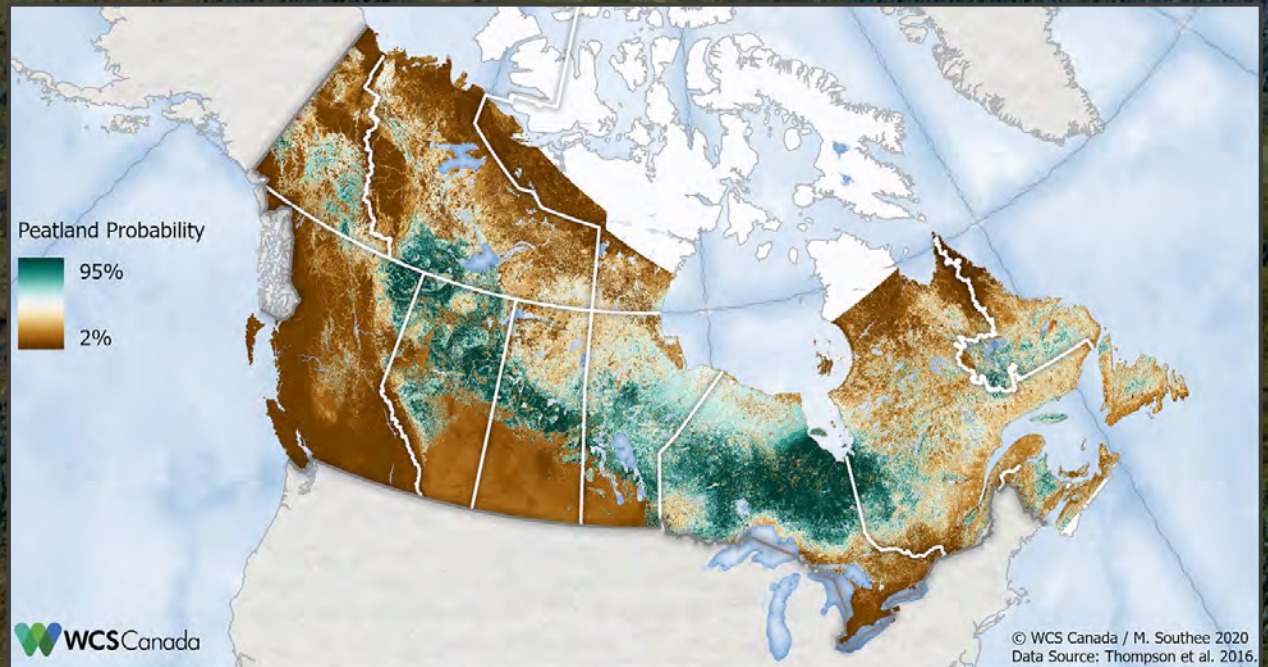
Northern Peatland Coverage

110 Mha

12% of Canada's
land area

Varied peatland
types

Dominated by slow-
growing mosses

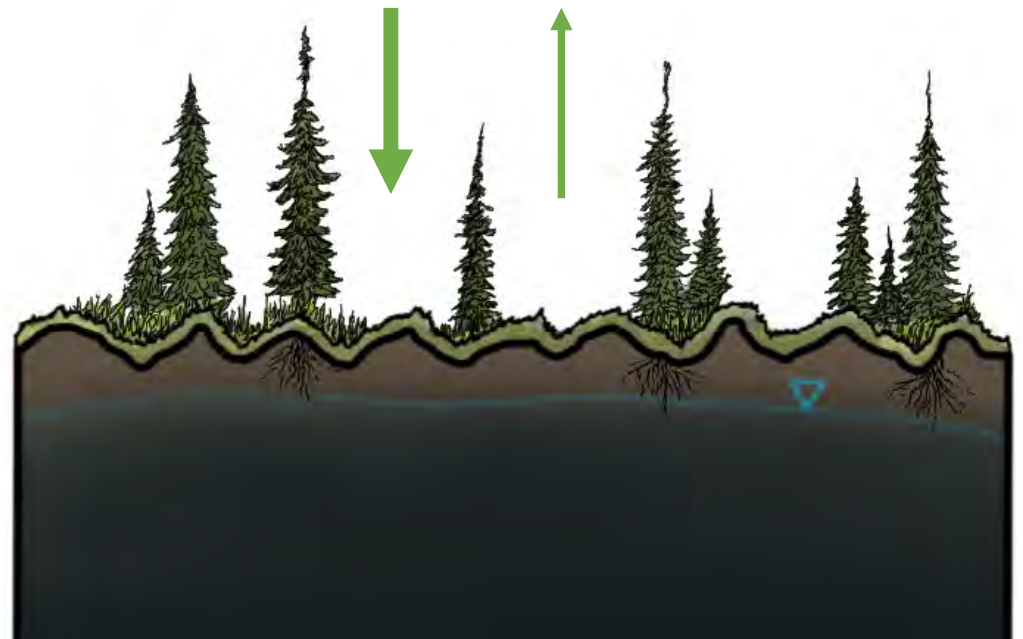


Landscape Carbon

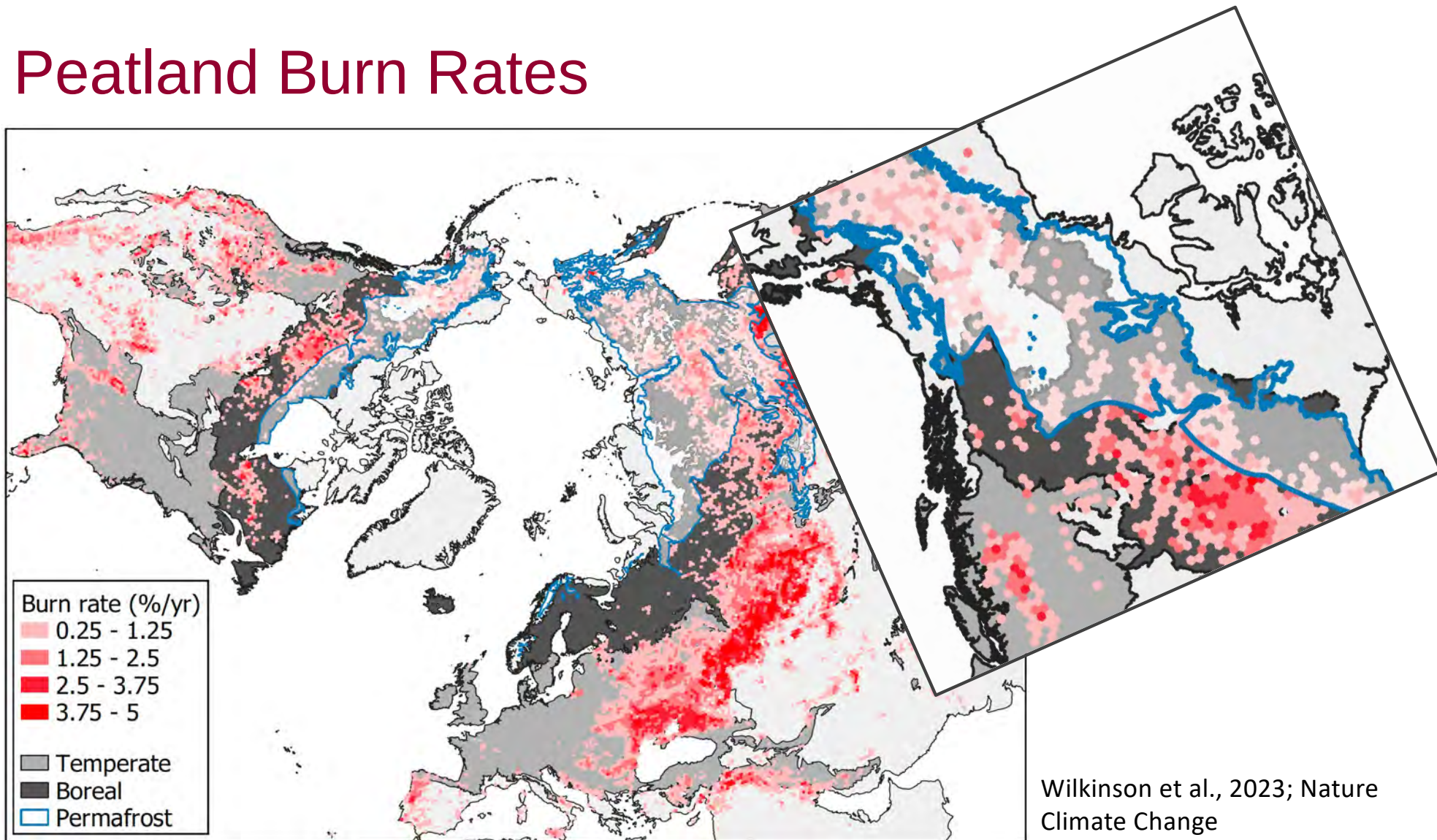
Peatlands are **dense** carbon stores

Over the last ~12,000 years northern peatlands have accumulated 500 Gt C

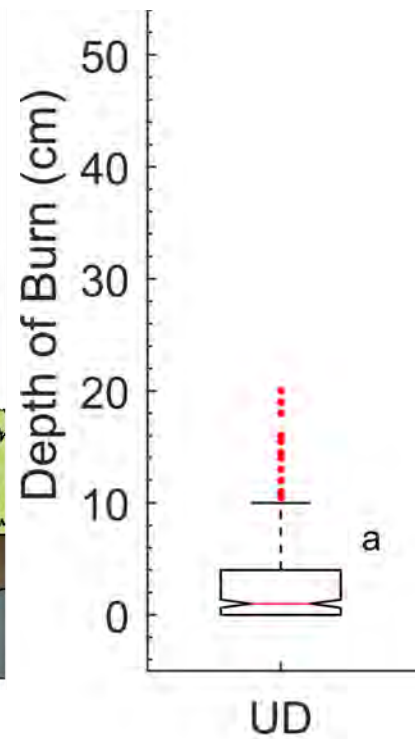
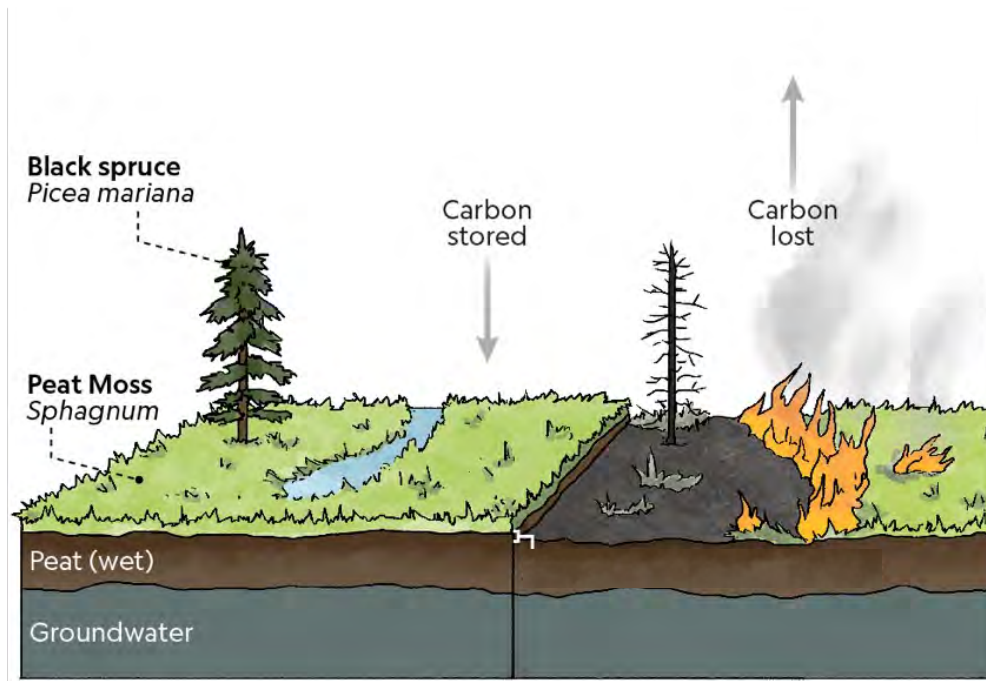
Key Takeaway 1:
Peatlands are great carbon stores



Peatland Burn Rates



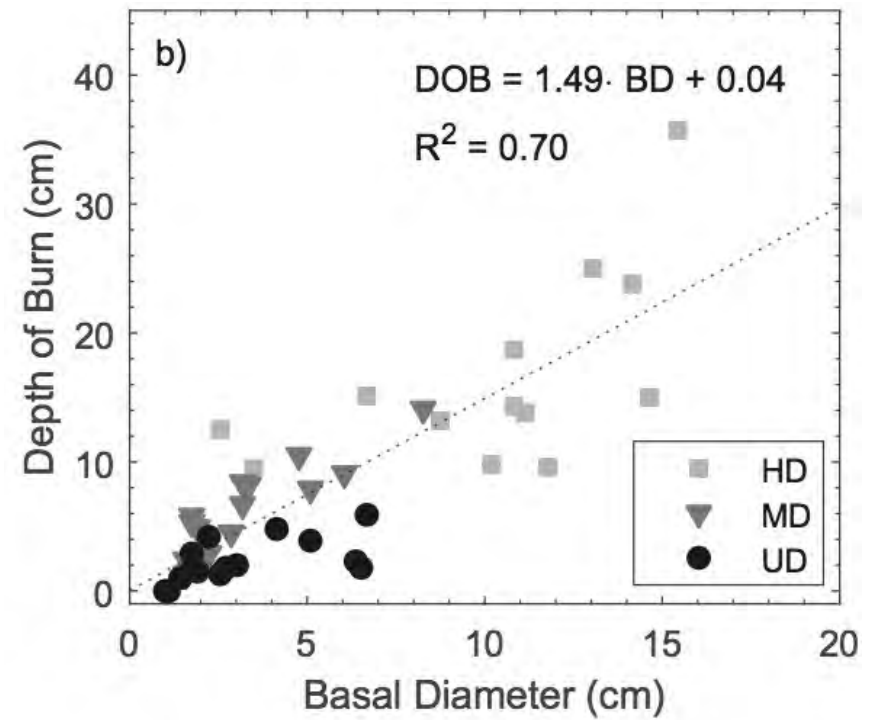
Burning Bogs



Wilkinson, S. & Champine, R. 2022; *Nat Geo*
Wilkinson et al., 2018; *ERL*



Wilkinson et al., 2018 *Environmental Research Letters*

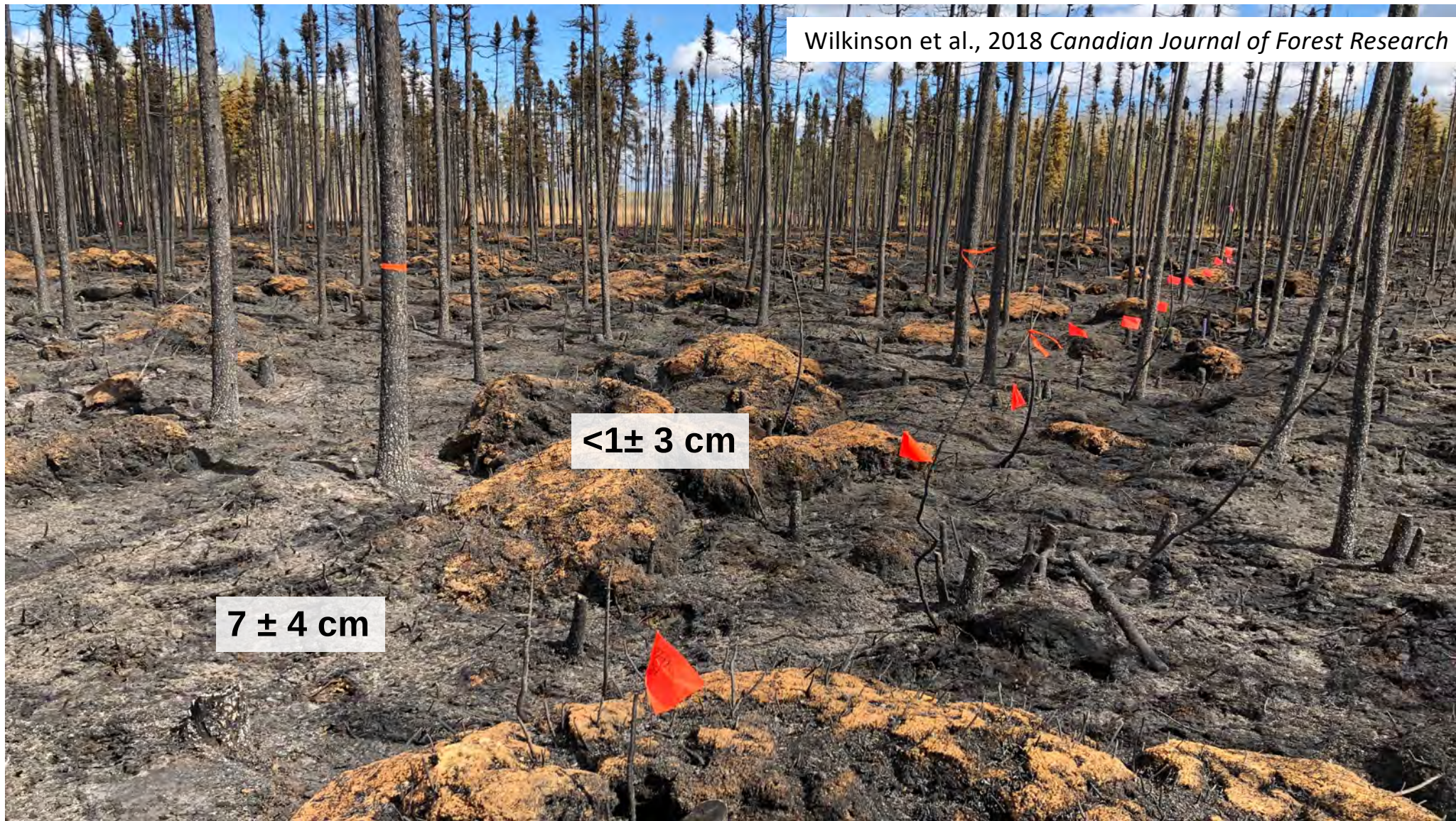


Key Takeaway 2: Bigger trees increase burn severity

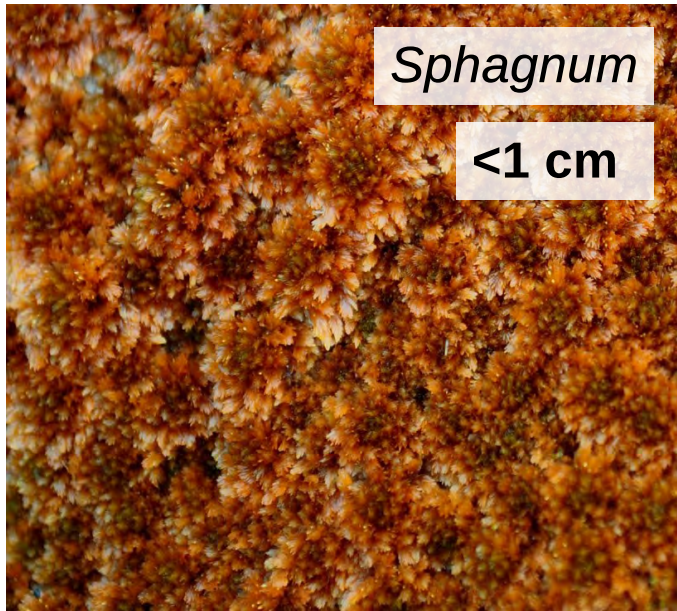


$<1 \pm 3$ cm

7 ± 4 cm

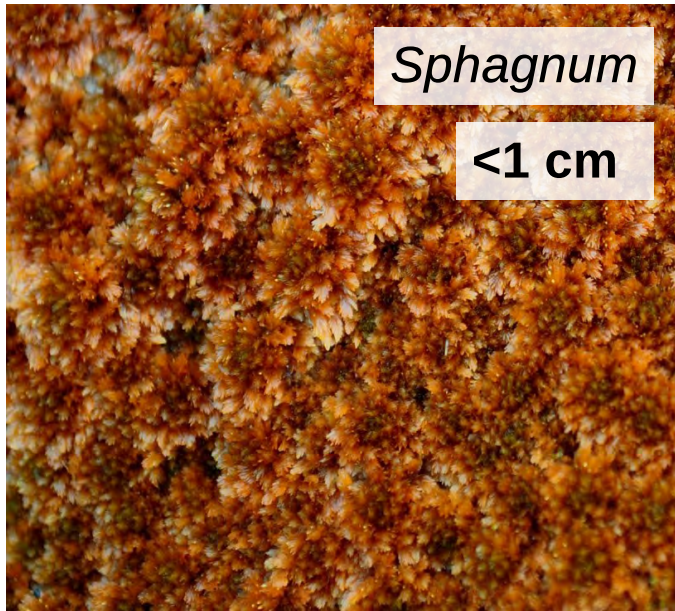


Groundcover Controls



Sphagnum is adapted for fire-resistance
Feathermoss is not

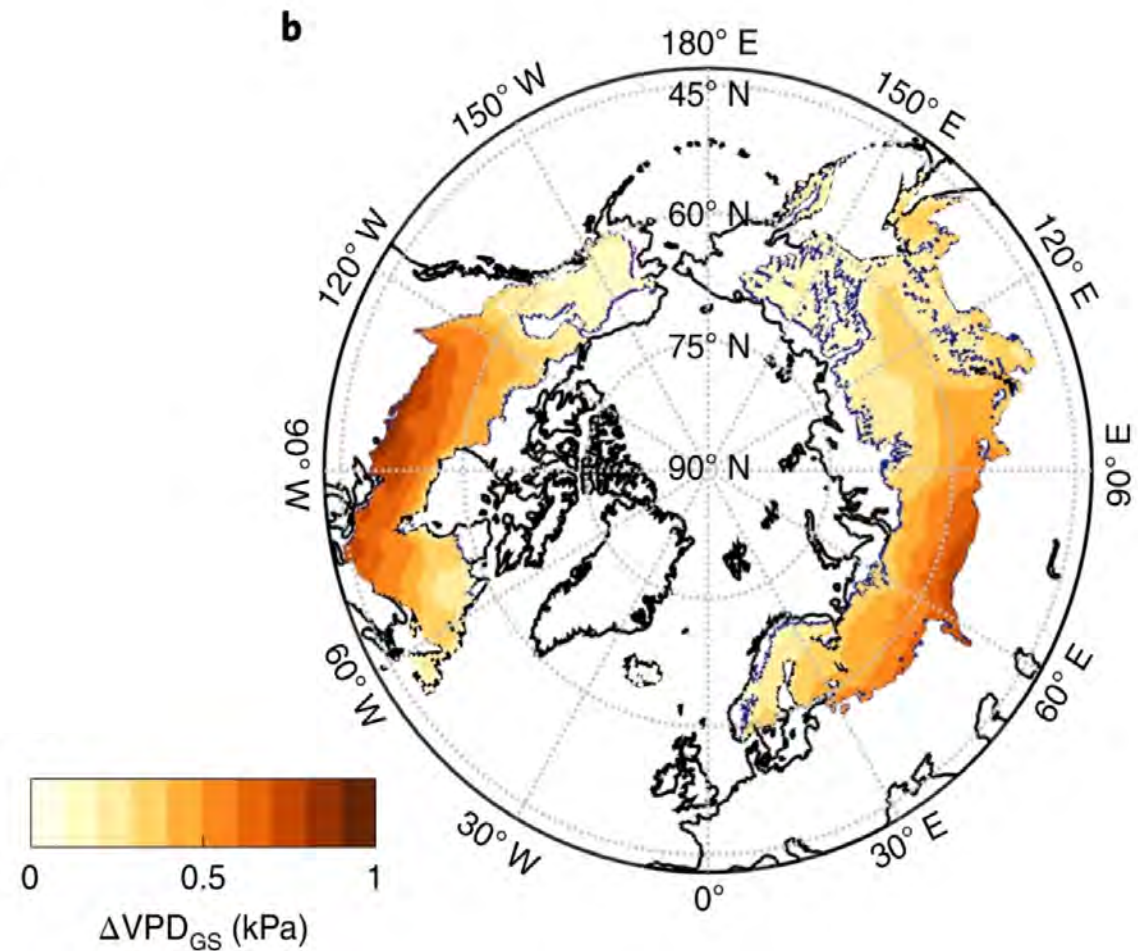
Groundcover Controls



Key Takeaway 3: Groundcover matters for burn severity and carbon loss

Climate Change

- Drying of northern regions
- Increased atmospheric demand
- More available fuels
- More severe fire weather



Key Takeaways

- Peatlands are great carbon stores
- Bigger trees increase peatland burn severity
- Groundcover moss type impacts burn severity and carbon loss



Key Questions

- How much fuel is there to burn?
(peat properties, trees, ice/permafrost depth)
- When is the surface fuel likely to ignite?
(groundcover, weather)
- How dry and dense is the peat profile?
(peat properties, weather)



Wildfires, Carbon, and Monitoring

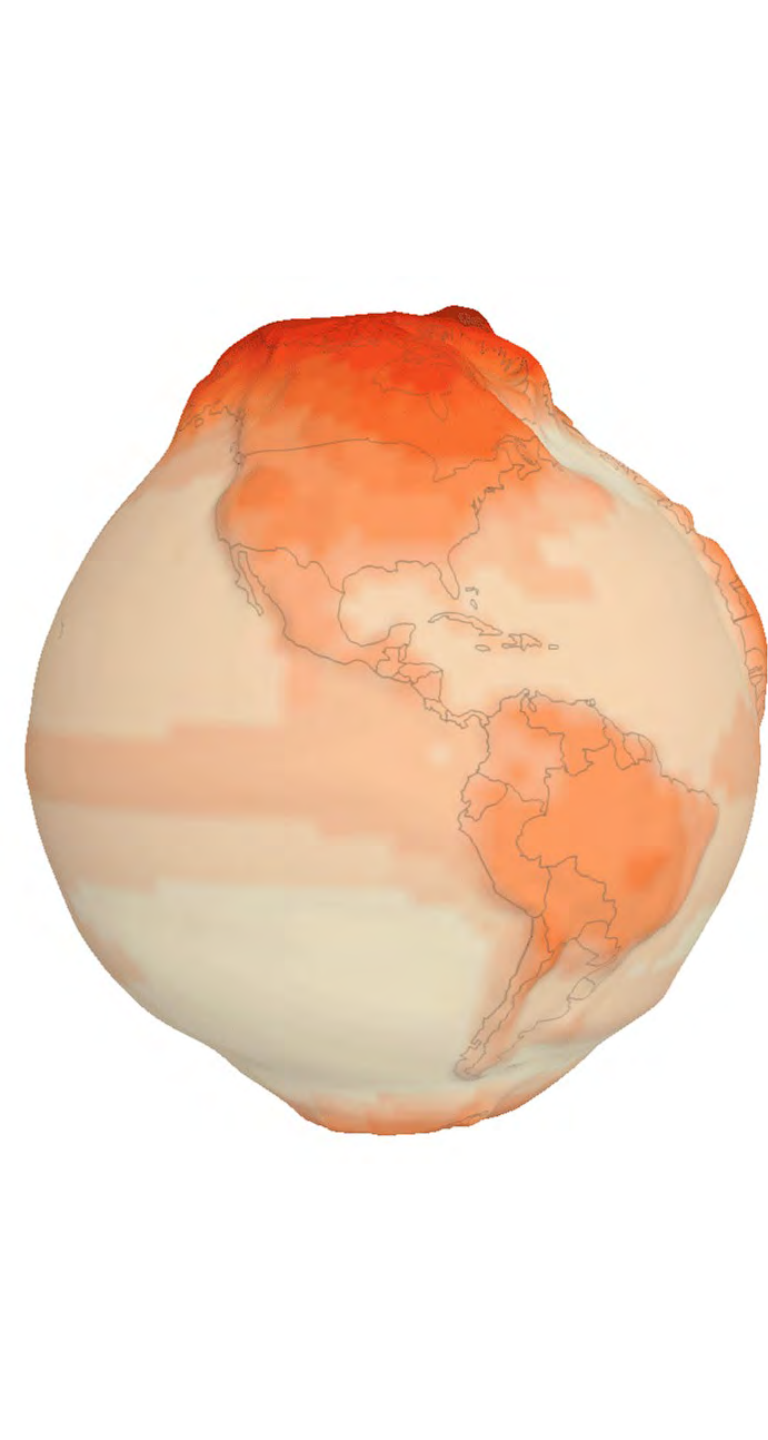
Brendan Rogers & Kyle Arndt
Landscape Carbon Workshop
February 4th, 2025

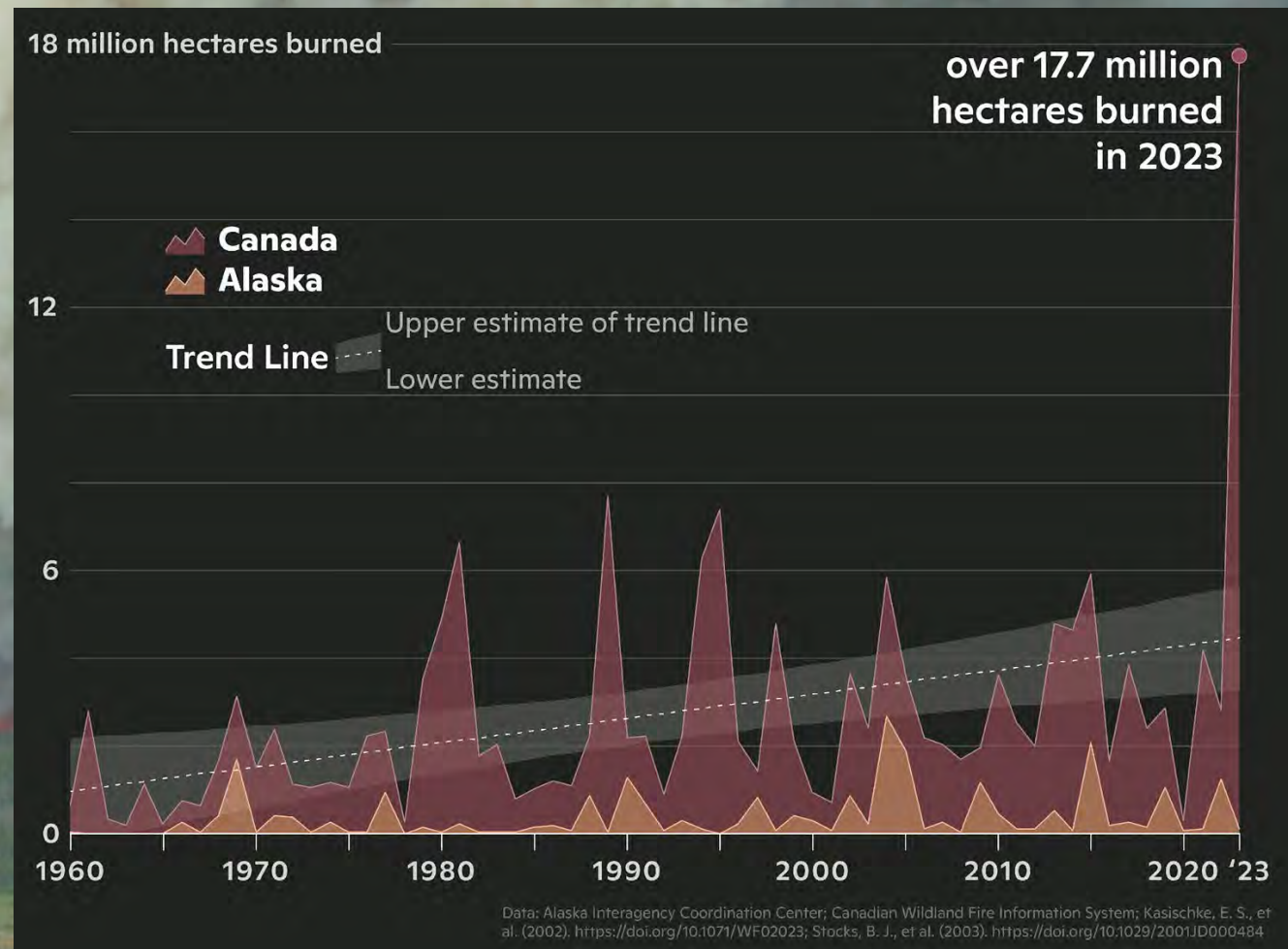
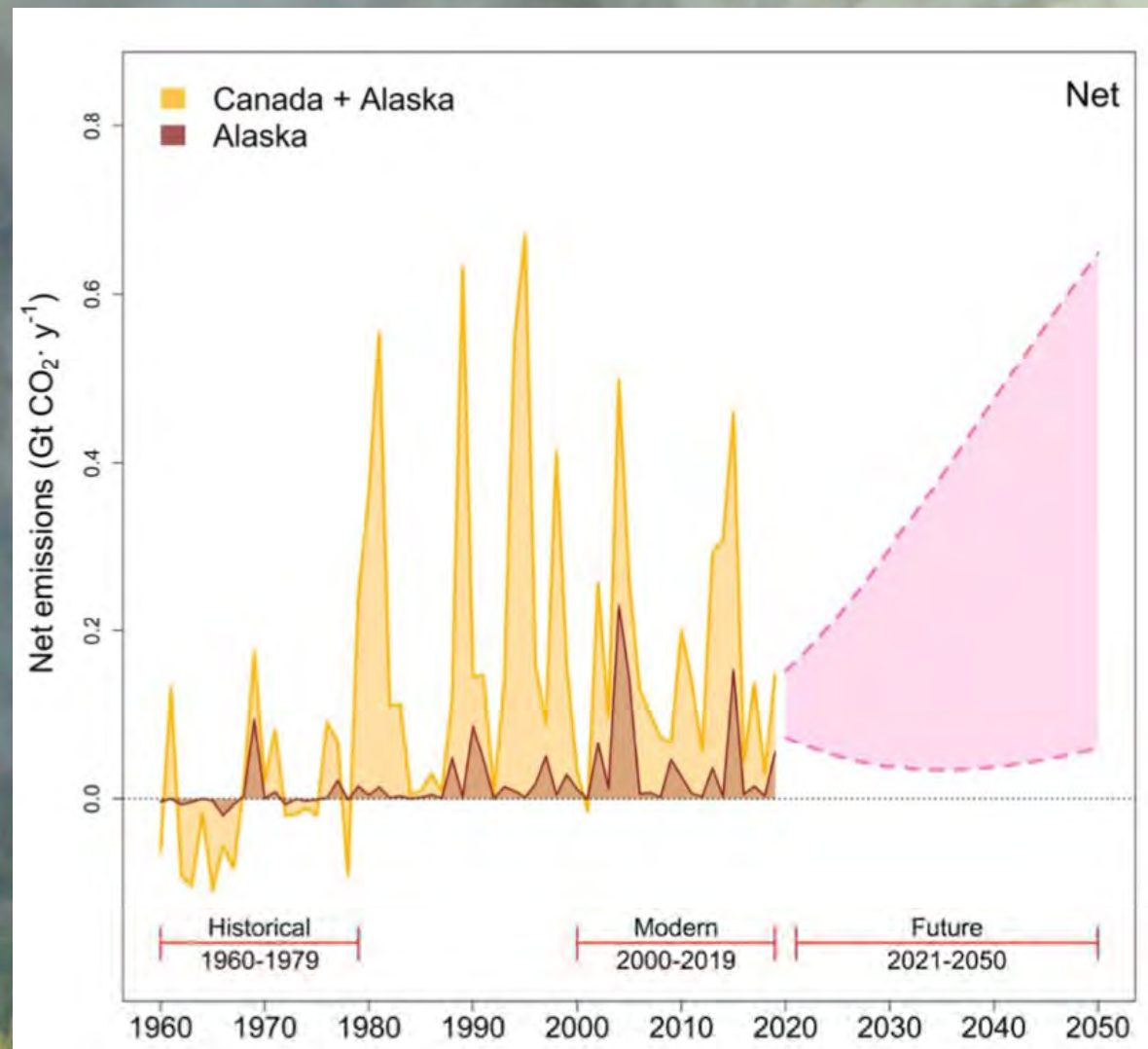


Woodwell
Climate
Research
Center

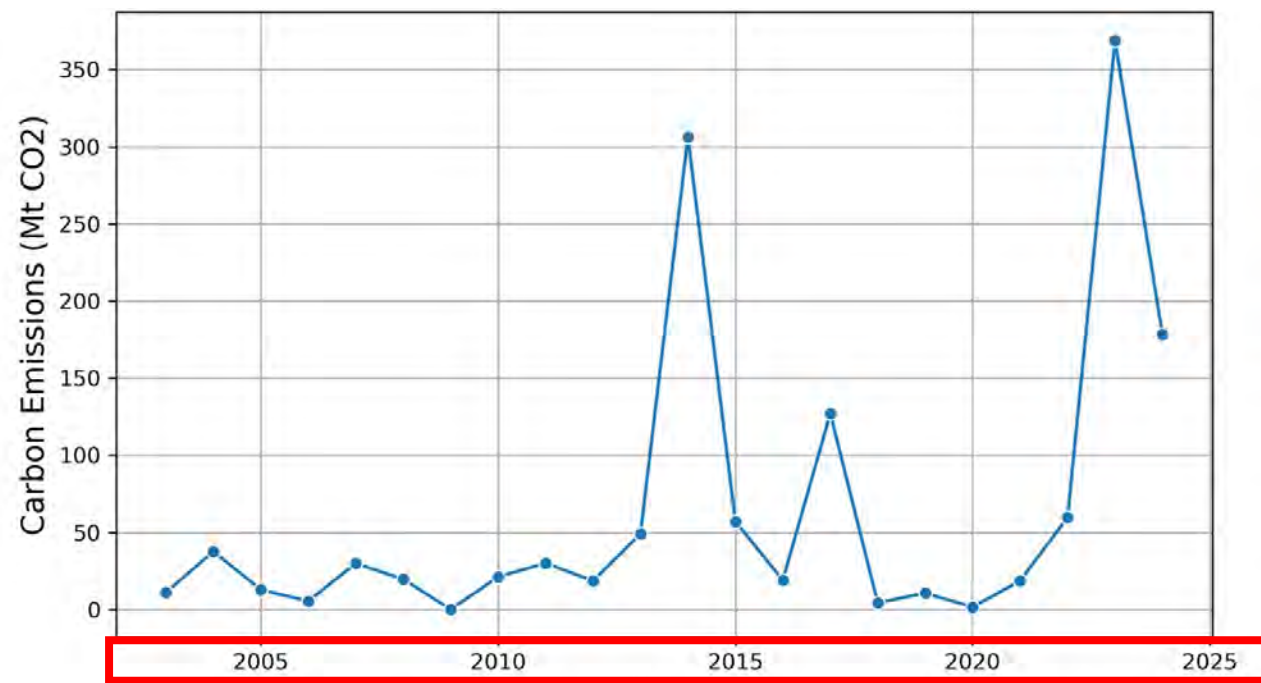
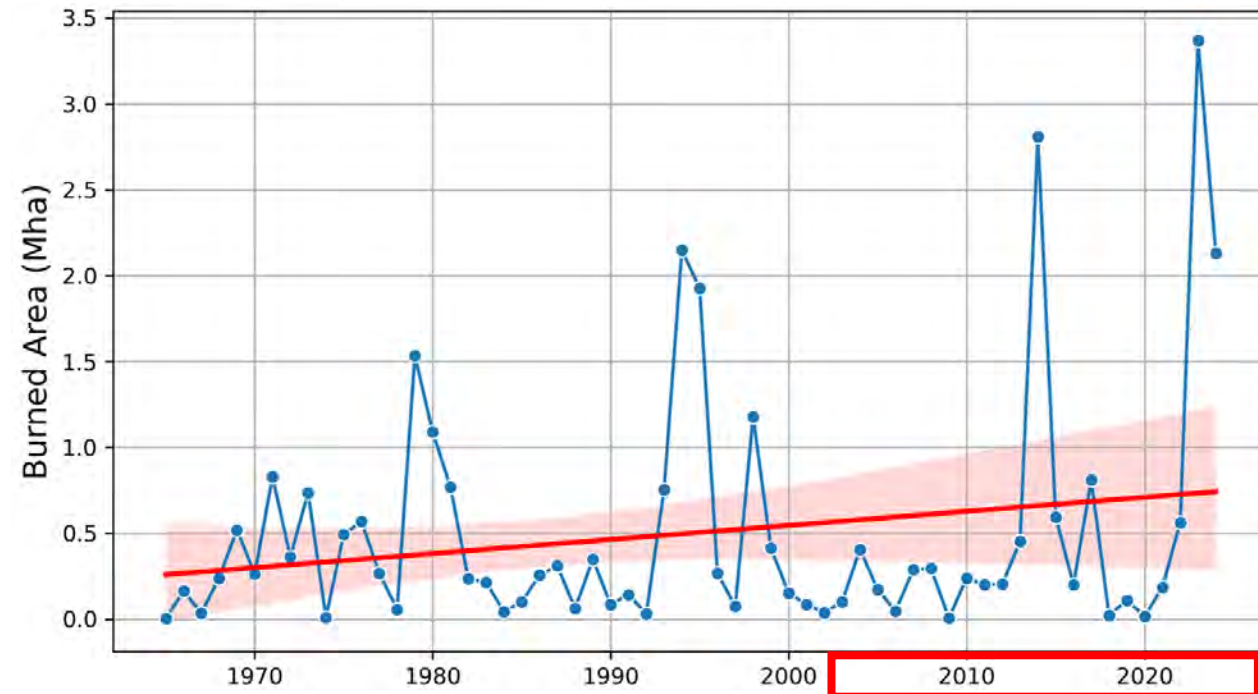
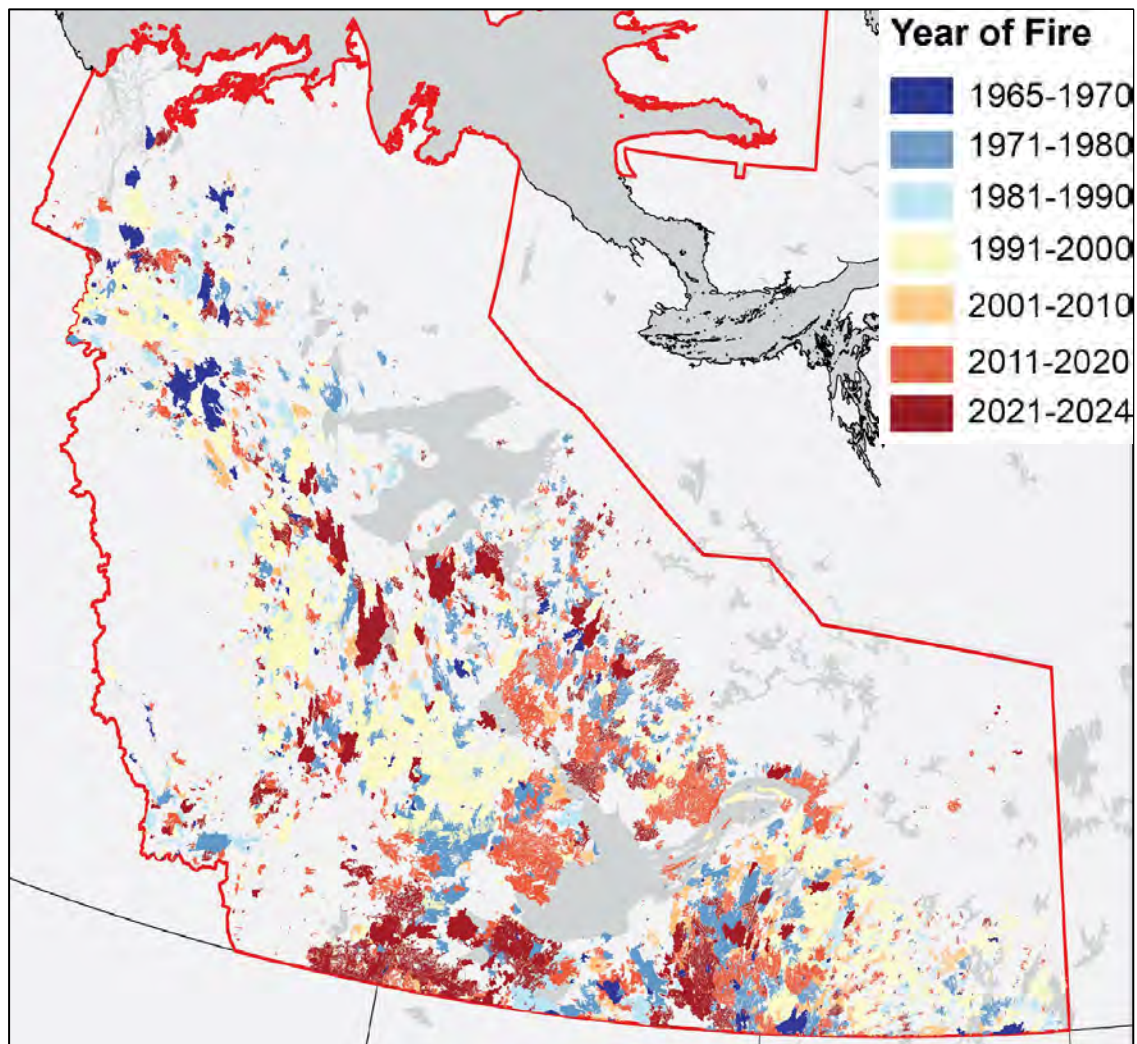
PERMAFROST
PATHWAYS

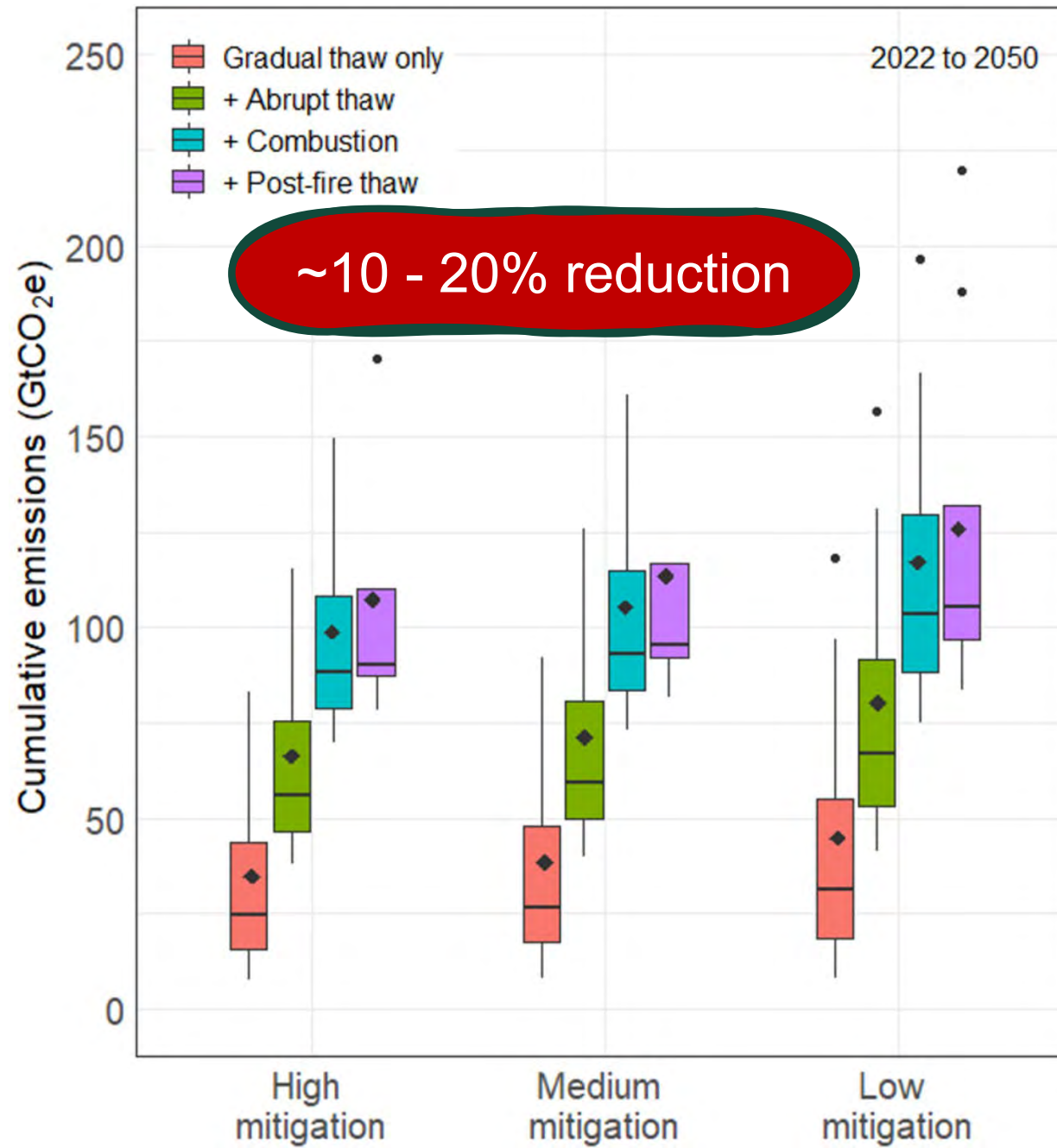
Photo: Joëlle Voglimacci-Stephanopoli



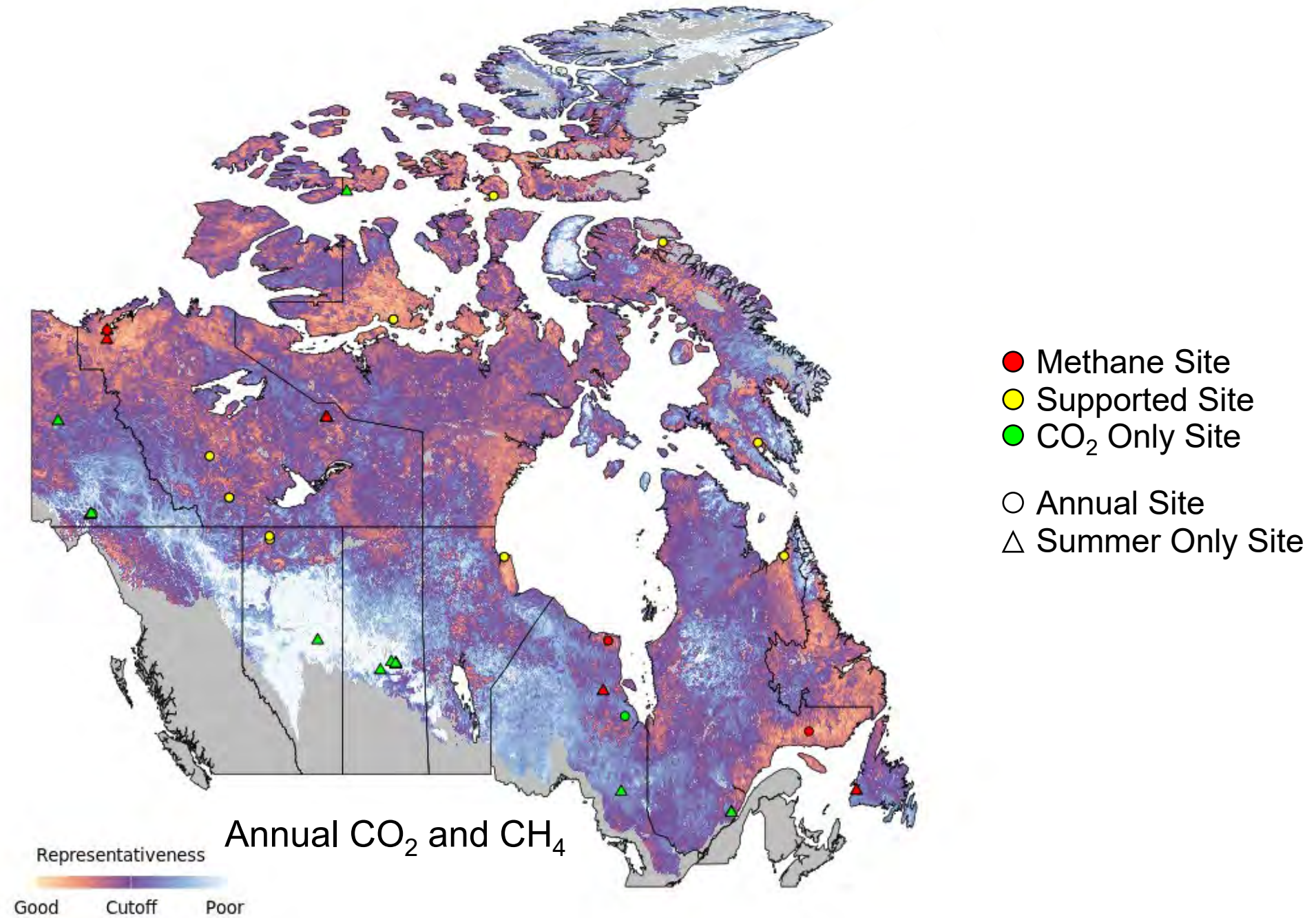


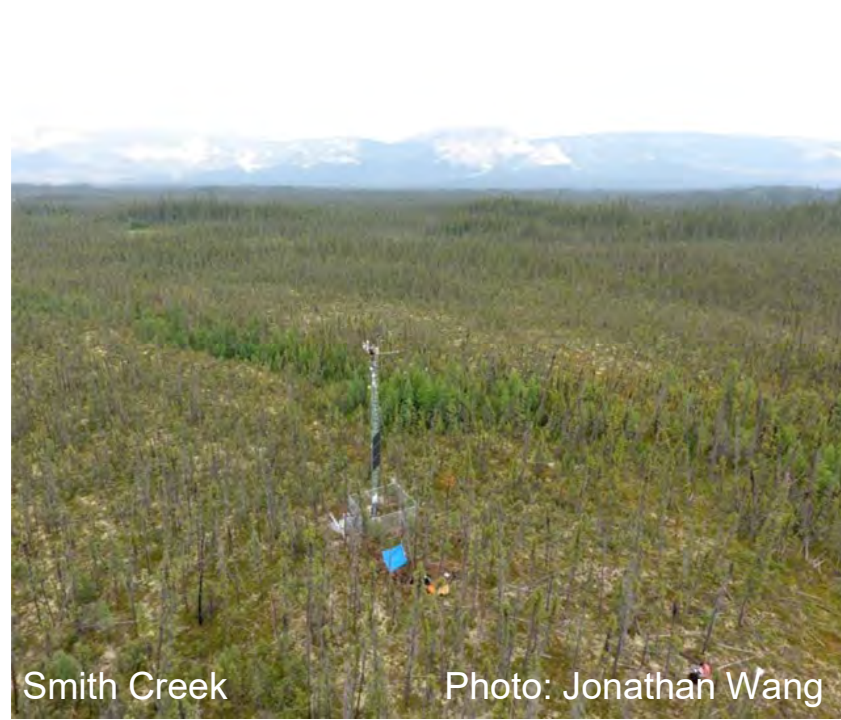
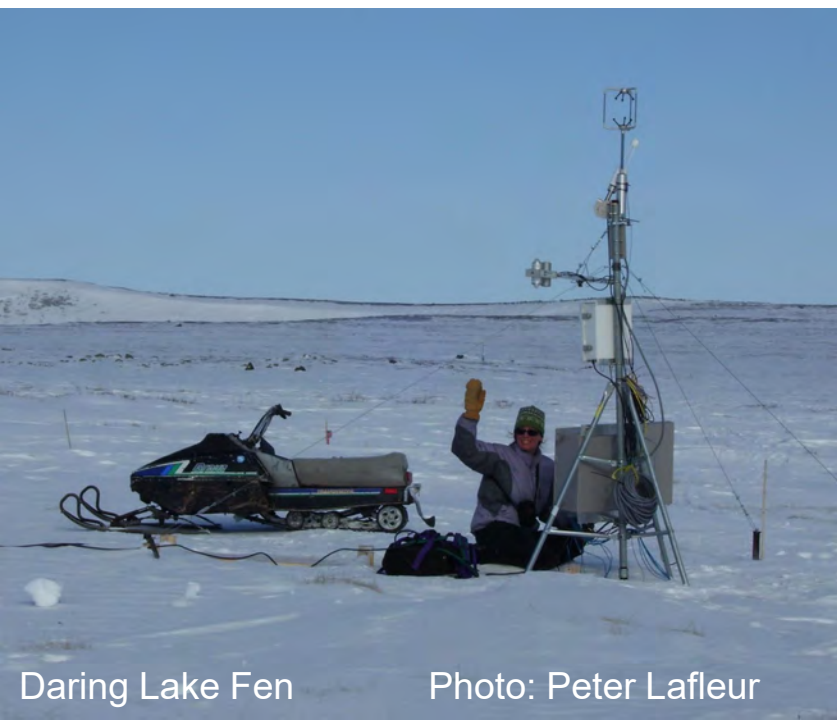
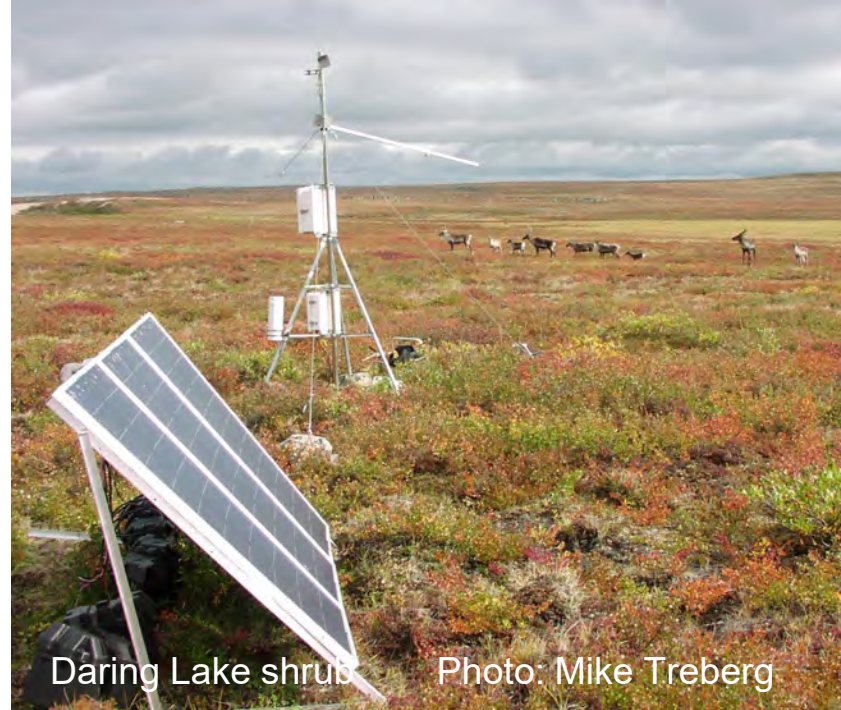
Phillips et al. (2022)



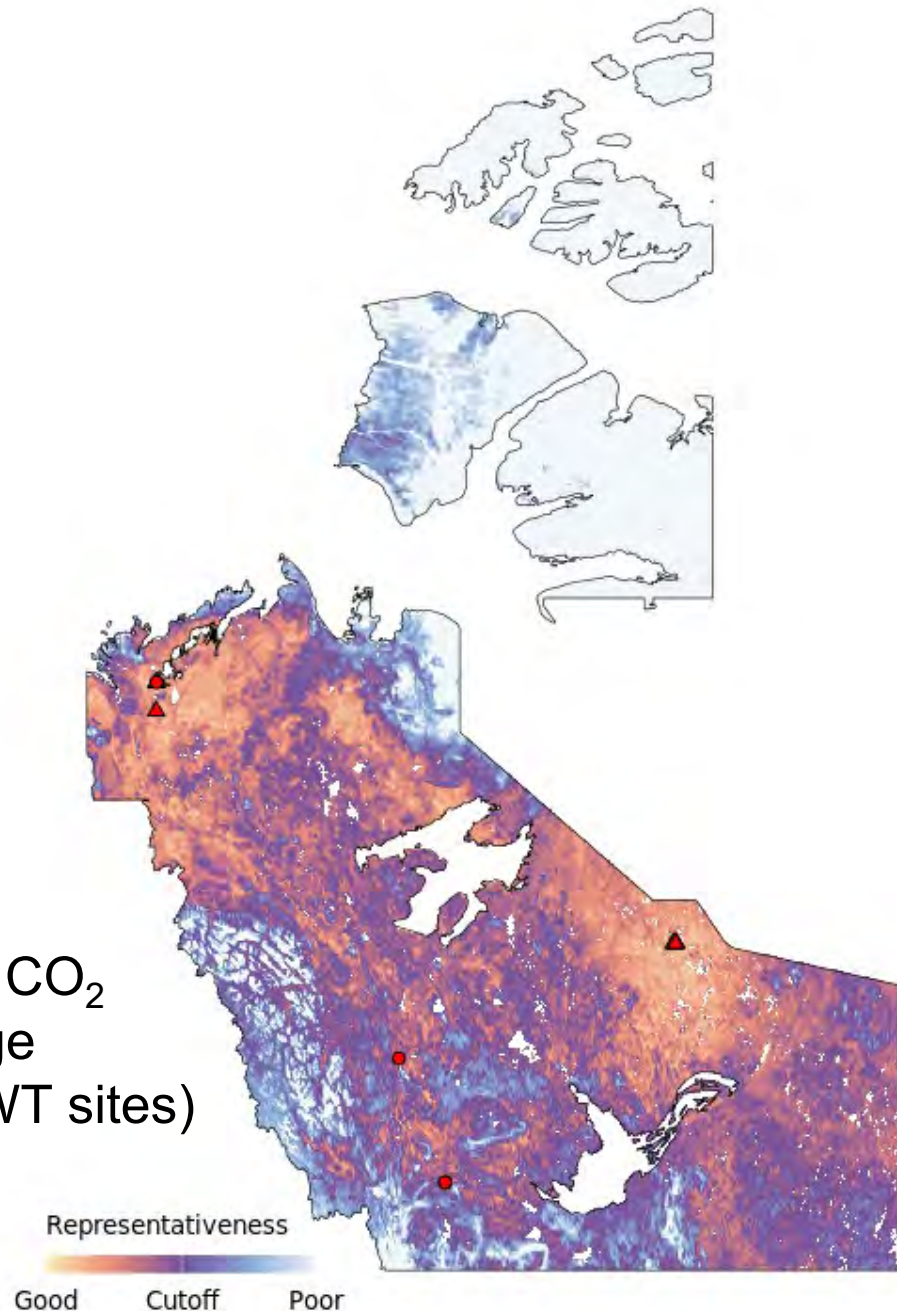


Canadian Carbon Exchange Monitoring Sites (Eddy Covariance)





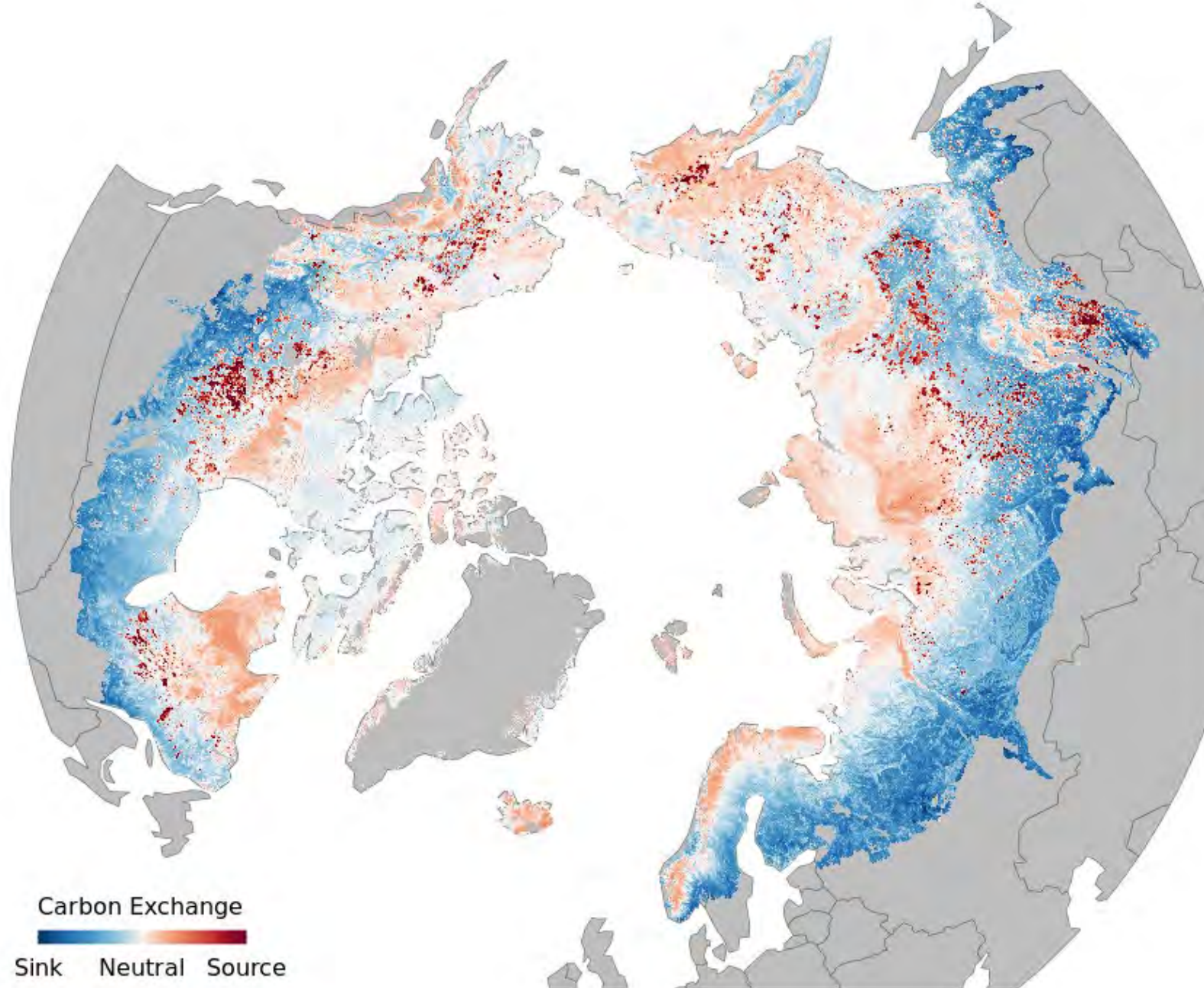
Summer CO₂
Coverage
(Only NWT sites)



Potential Improvements:

- Increased year-round coverage
- Dryland representation
 - Important for low flux representation in models
- Southern boreal and wetland sites
 - Larger fluxes and methane
- Tundra and shrubby sites well covered

Average CO₂ Exchange (2001-2020)



Adapted from Virkkala et al., 2024, Nature Climate Change

With Fire:

Arctic-boreal zone: $-319 \pm 140 \text{ Tg C yr}^{-1}$

Canada: $-69 \pm 35 \text{ Tg C yr}^{-1}$

Northwest Territories: $8 \pm 11 \text{ Tg C yr}^{-1}$

Without Fire:

Arctic-boreal zone: $-548 \pm 140 \text{ Tg C yr}^{-1}$

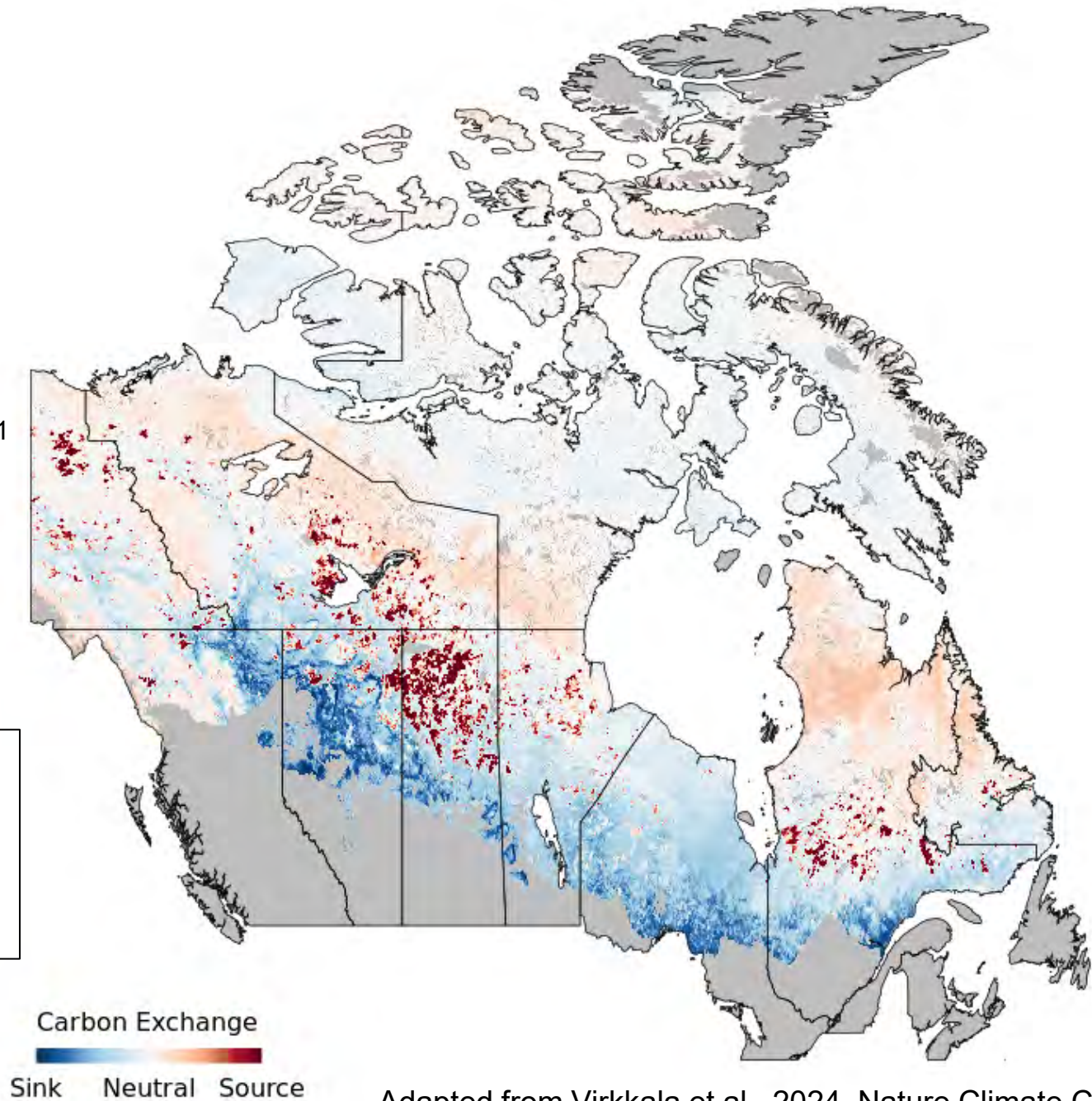
Canada: $-125 \pm 35 \text{ Tg C yr}^{-1}$

Northwest Territories: $-17 \pm 11 \text{ Tg C yr}^{-1}$

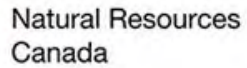
Negative are carbon uptake | **Positive** are carbon emissions

1.6 Mt CO₂e/y or approximately 0.44 Tg C yr⁻¹
Northwest Territories human emissions

With fire, natural ecosystems emit **~18x** human emissions in the Northwest Territories



Adapted from Virkkala et al., 2024, Nature Climate Change



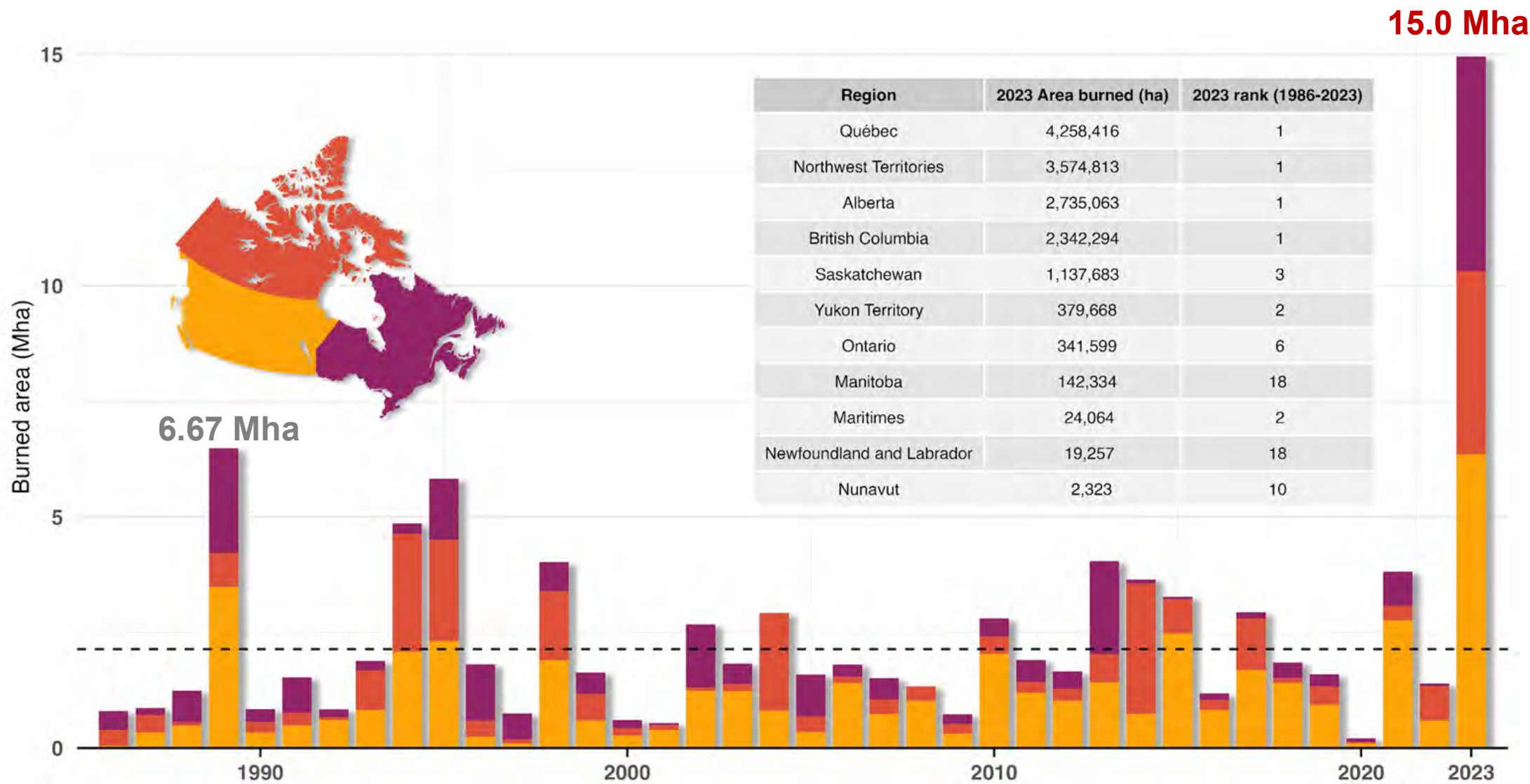
Ressources naturelles
Canada

A 2x4 grid of eight photographs showing various natural landscapes and seasons. The images include: a clear blue sky, a dense green forest with large trees, a lake reflecting a forest with autumn-colored trees, a misty lake with mountains in the background, a forest floor covered in fallen autumn leaves, a snowy forest of evergreen trees, a calm body of water, and a snowy landscape with evergreen trees.

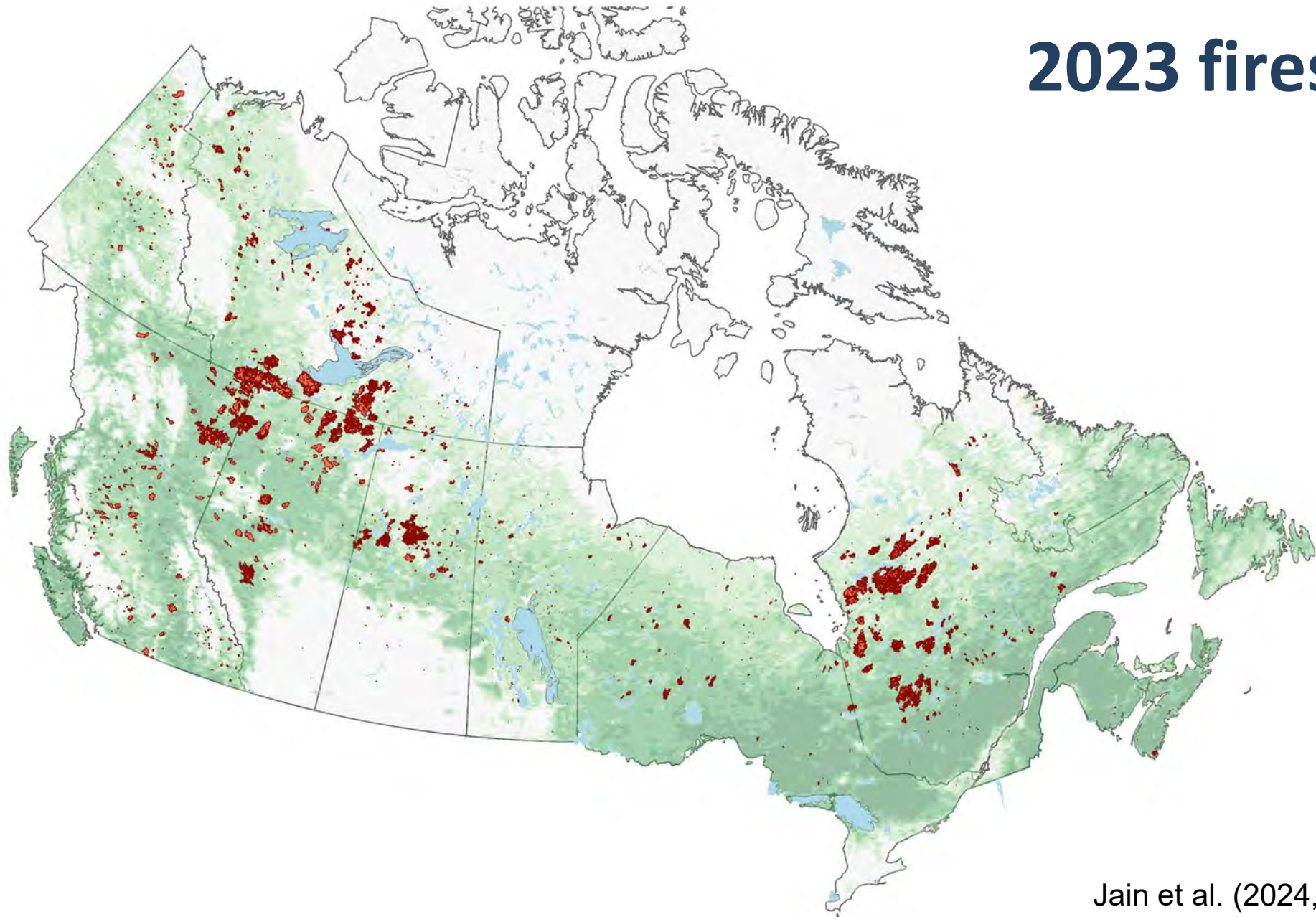
Treaty 6 Territory and Métis Homeland

diana.stralberg@nrca-nrcan.gc.ca

2023 - 15 million hectares burned



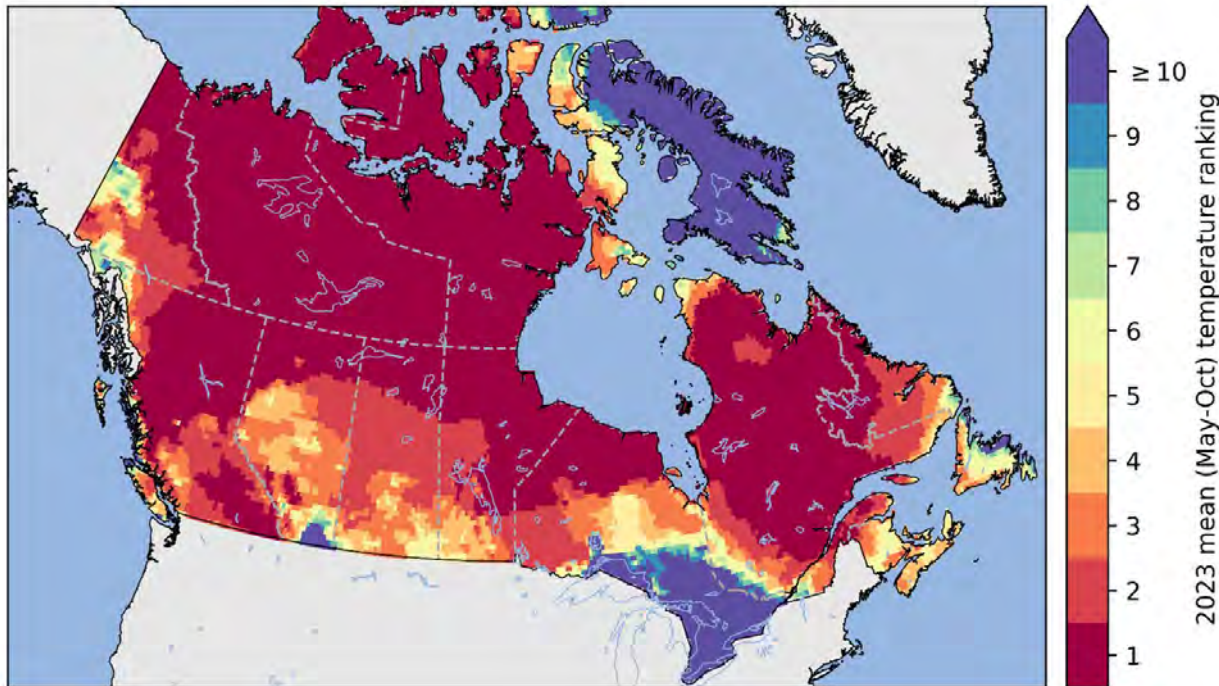
2023 fires



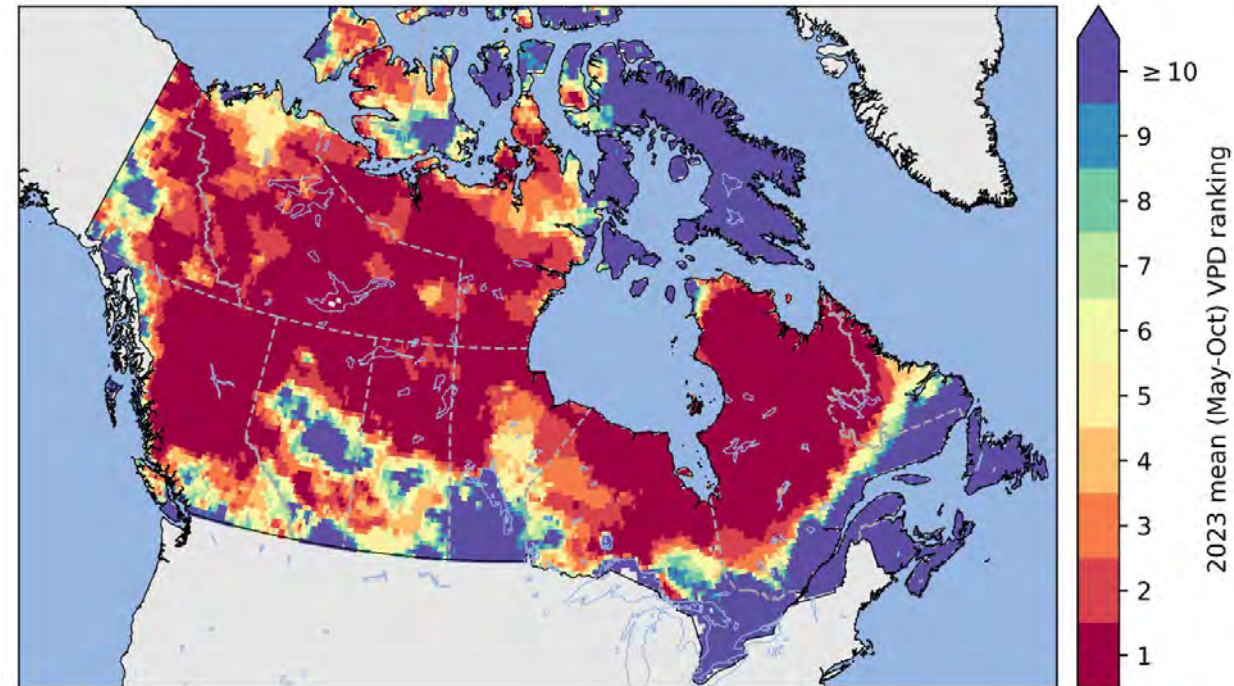
Jain et al. (2024, Nat. Comm.)

2023 was hot and dry!

Surface temperature (May-Oct)
ranking 1940-2023

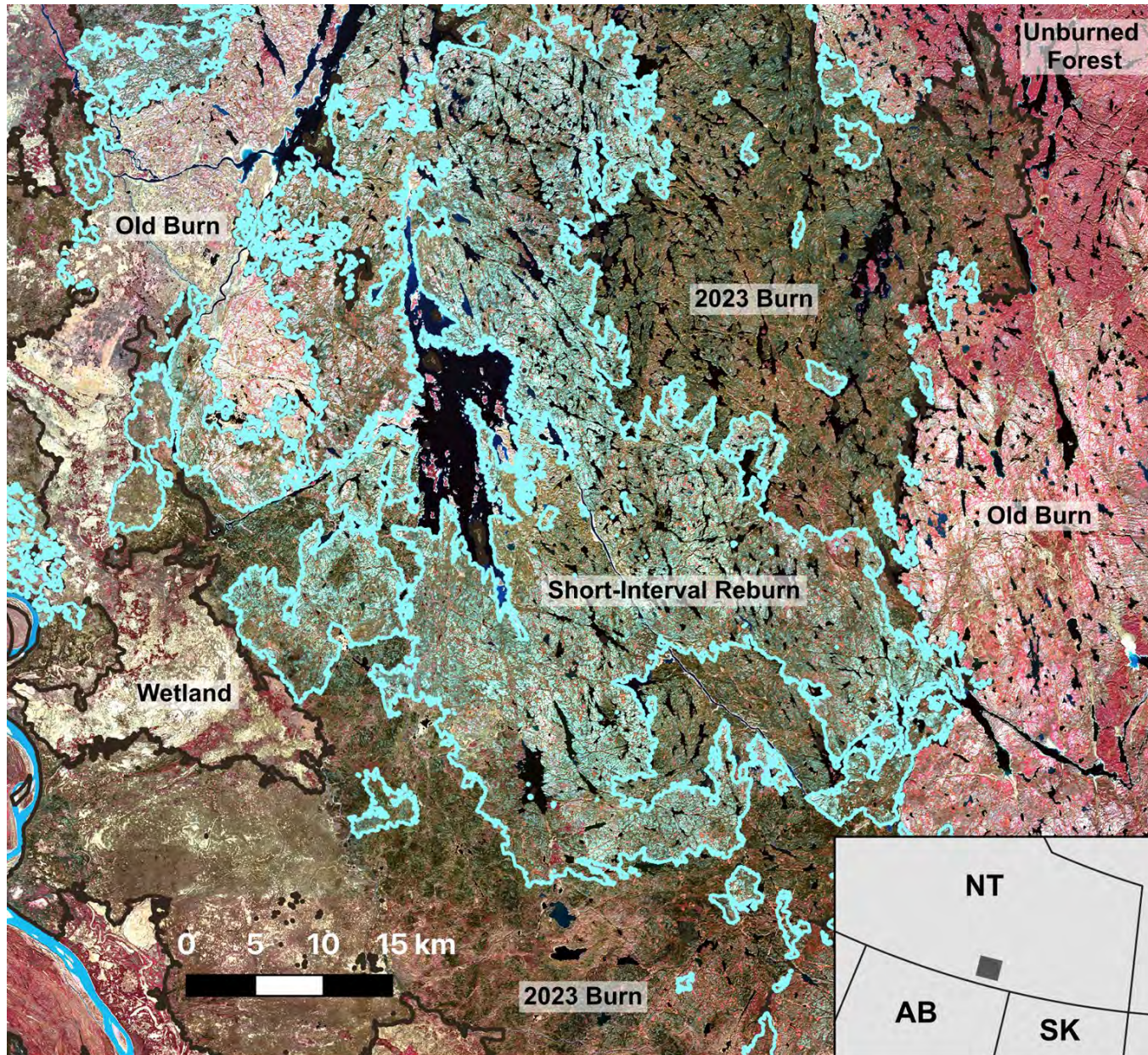


Vapour pressure deficit (May-Oct)
ranking 1940-2023



Derived from ERA5 reanalysis data

Jain et al. (2024, Nat. Comm.)



Short-interval reburn (<20 years between fires)

Total area in 2023: **415,911 ha**

Yearly average, 1986 – 2022: **13,699 ha**

Largest patch: **120,555 ha**

Fire severity

- Ecological impacts on vegetation and soils
- High severity fires can alter vegetation regeneration and carbon fluxes
- Measured in the field using Composite Burn Index (CBI): 0-3
- Measured with remote sensing using difference between pre- and post-fire satellite imagery: dNBR or RBR



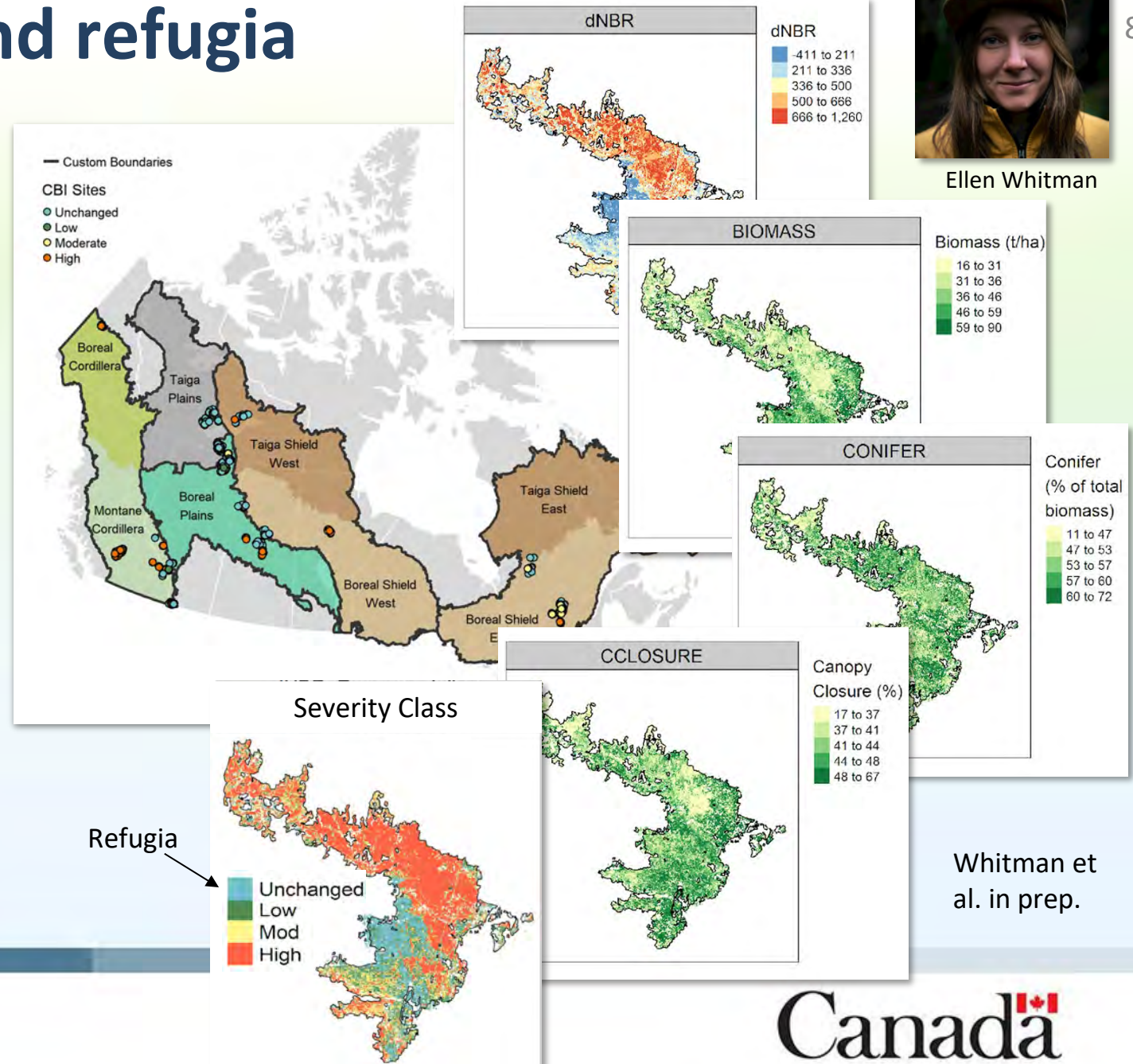
Fire refugia

- Patches of canopy within fire perimeters that survived burn^{1,2}
- CBI severity class = 0
- Important for post-fire recovery³
- May mitigate negative effects of increasing fire severity and decreasing re-burn intervals



Mapping fire severity and refugia using satellite imagery

- Field-collected Composite Burn Index (CBI) used to train models
- Fire severity class estimated from satellite imagery (dNBR index) and pre-fire forest structure and composition
- Annual national map product in development (anticipated release 2025)

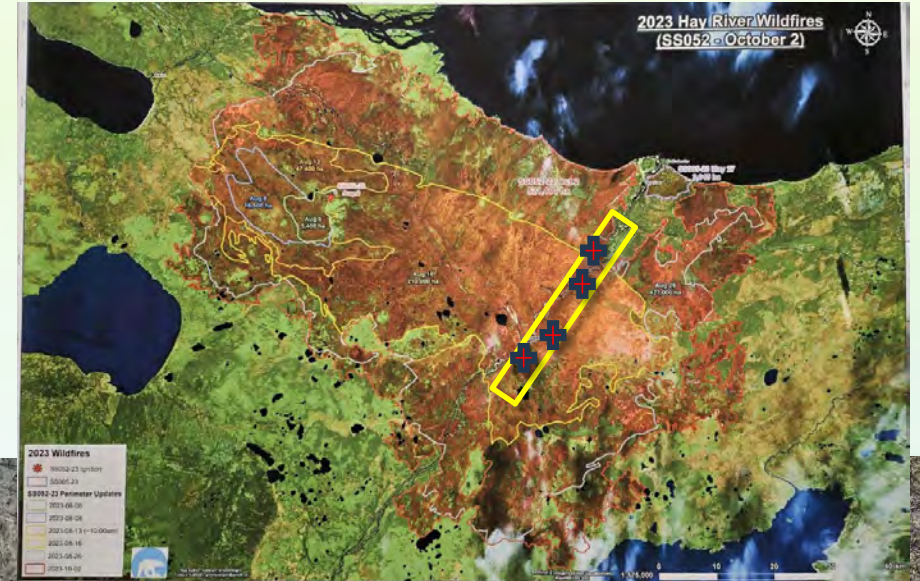


Improved fire severity mapping using drones



Guillermo Castilla

1. Evaluation of airborne and drone-based LiDAR to replace or augment the composite burn index (CBI)
2. Evaluation of multi-temporal drone-based data to map post-fire recovery



Drone acquisitions in May and August 2024 over four clusters of forest inventory plots burned in 2023 Hay River –Enterprise fires [planned for summer 2025]

Airborne LiDAR acquisition in July 2019, 2024 (30-km x 4-km block)



Drivers of fire refugia

Bottom-up

- **Terrain** features can promote fire skips
- **Peatlands** can reduce burn severity (standing water , moisture retention, fuel breaks)
- **Vegetation** type and pattern affects landscape flammability

Top-down

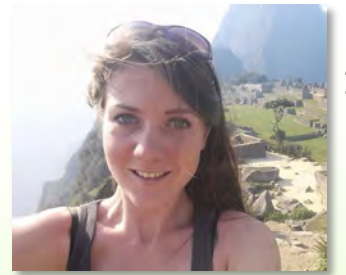
- **Climate and fire weather** affect fire ignition, intensity, and spread; fuel dryness



© Michelle Knaggs

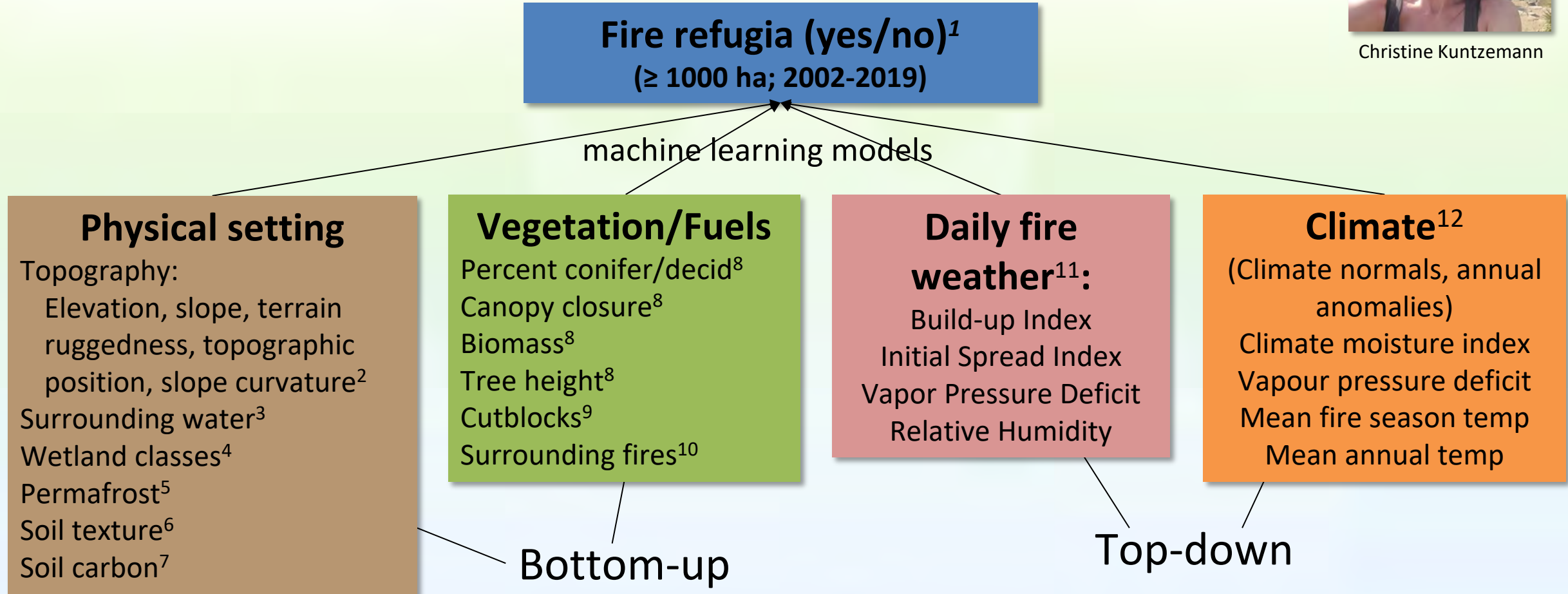


Modeling fire refugia probability



Christine Kuntzemann

11



Natural Resources
Canada

Ressources naturelles
Canada

National burned area composite/burn severity¹
Amatulli *et al.*, 2019²
Pekel *et al.*, 2016³
Pontone *et al.*, 2024⁴

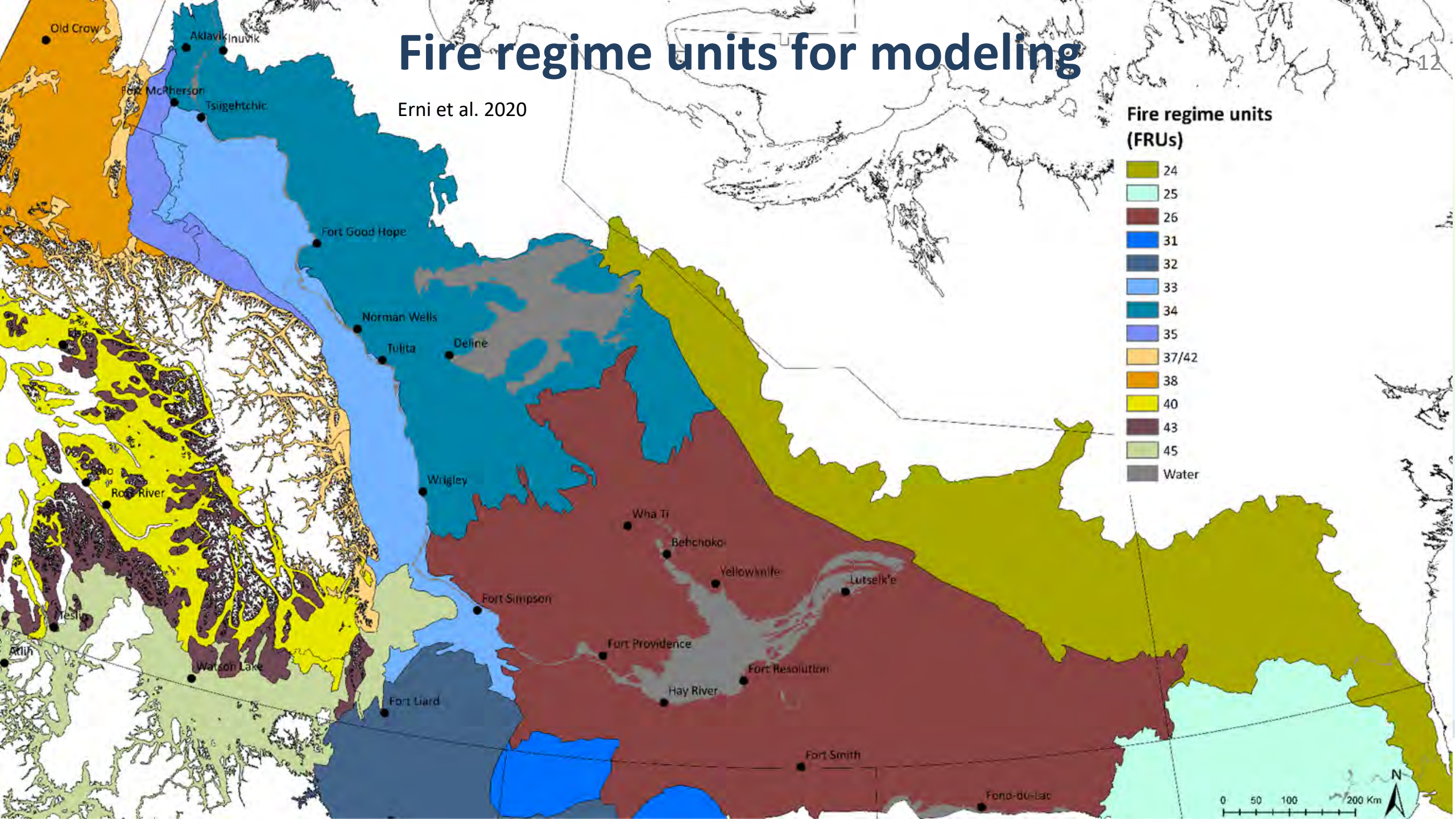
Obu *et al.*, 2018⁵
Poggio *et al.*, 2021⁶
Hugelius *et al.*, 2021⁷
Guindon *et al.*, 2024⁸

Hermosilla *et al.*, 2016⁹
Canadian Nation Fire Database¹⁰
Barber *et al.*, 2024¹¹
Munoz Sabater 2019¹²

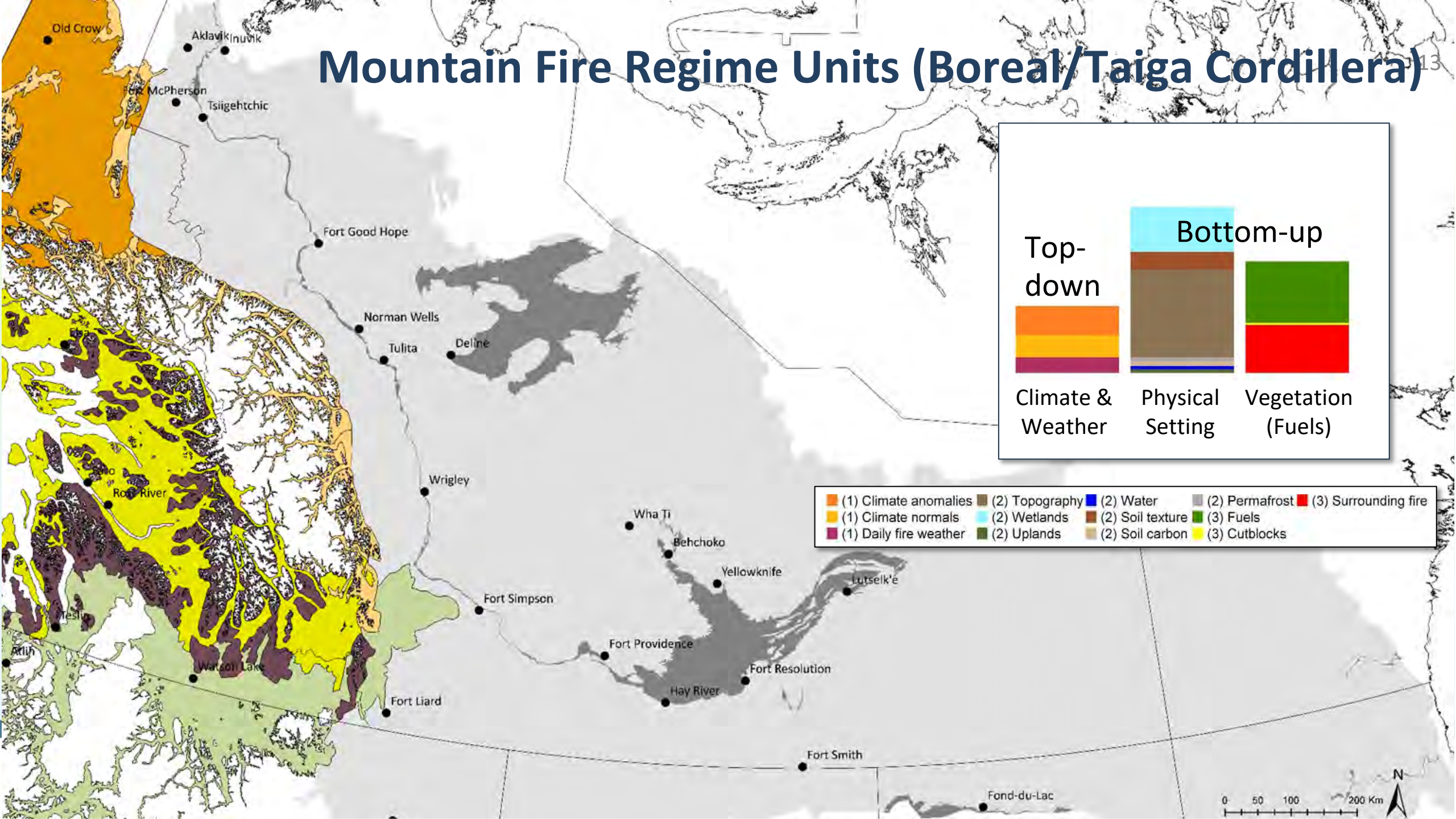
Canada

Fire regime units for modeling

Erni et al. 2020

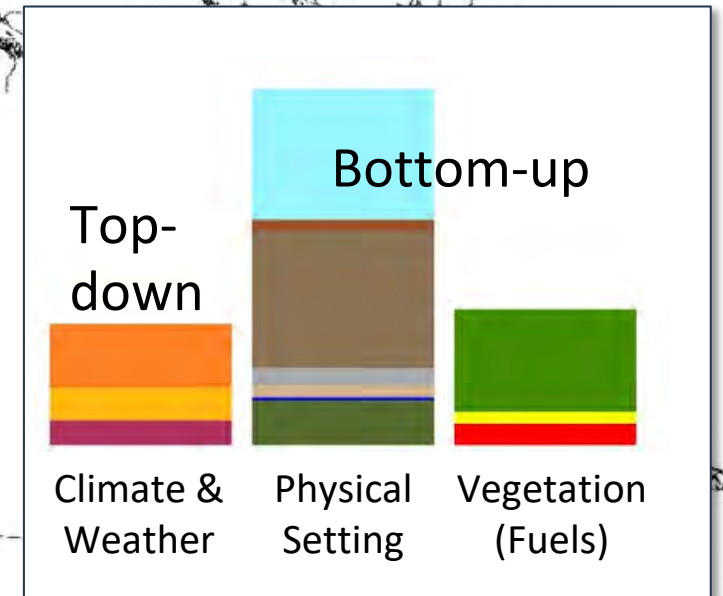


Mountain Fire Regime Units (Boreal/Taiga Cordillera)

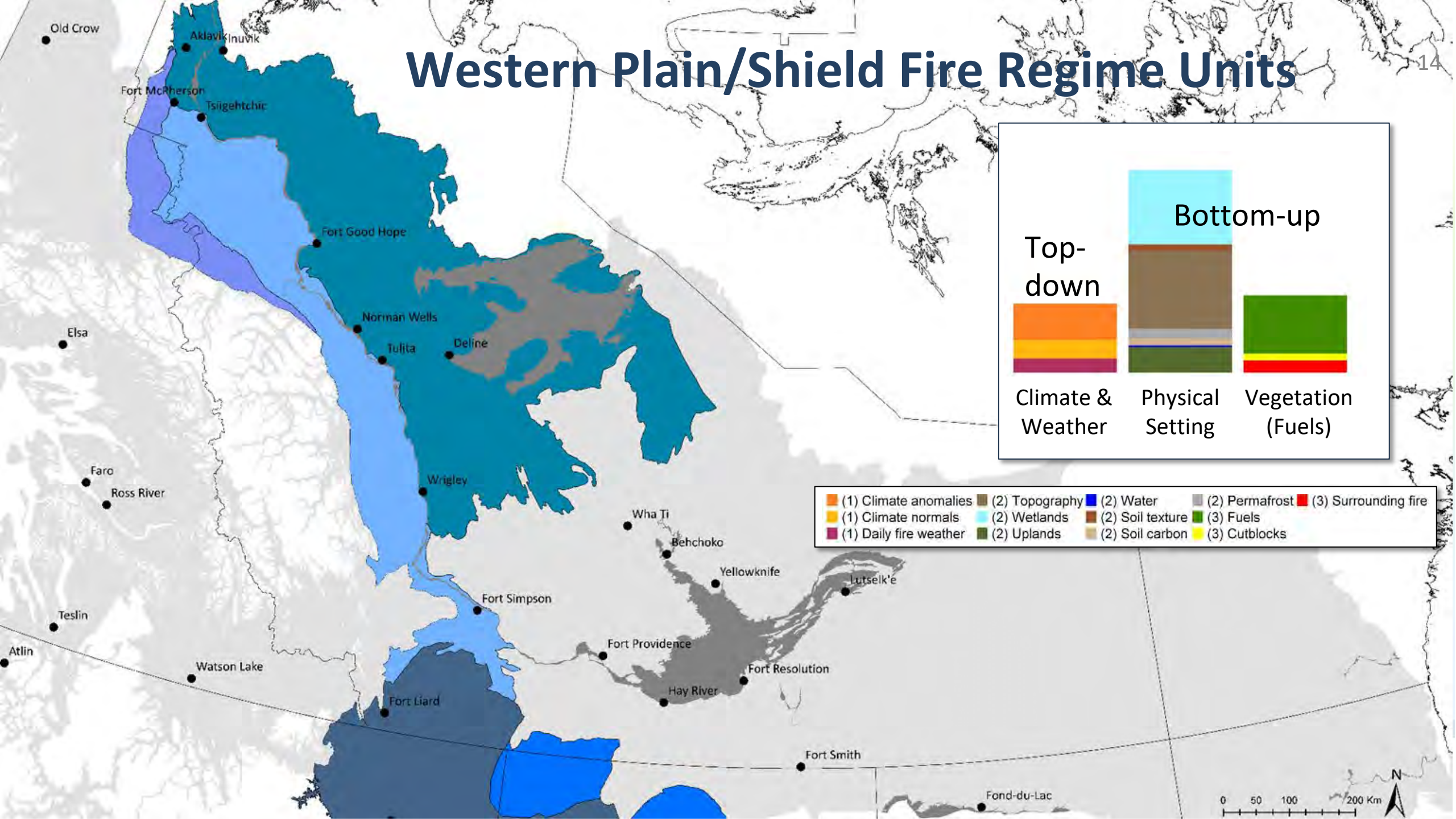


Western Plain/Shield Fire Regime Units

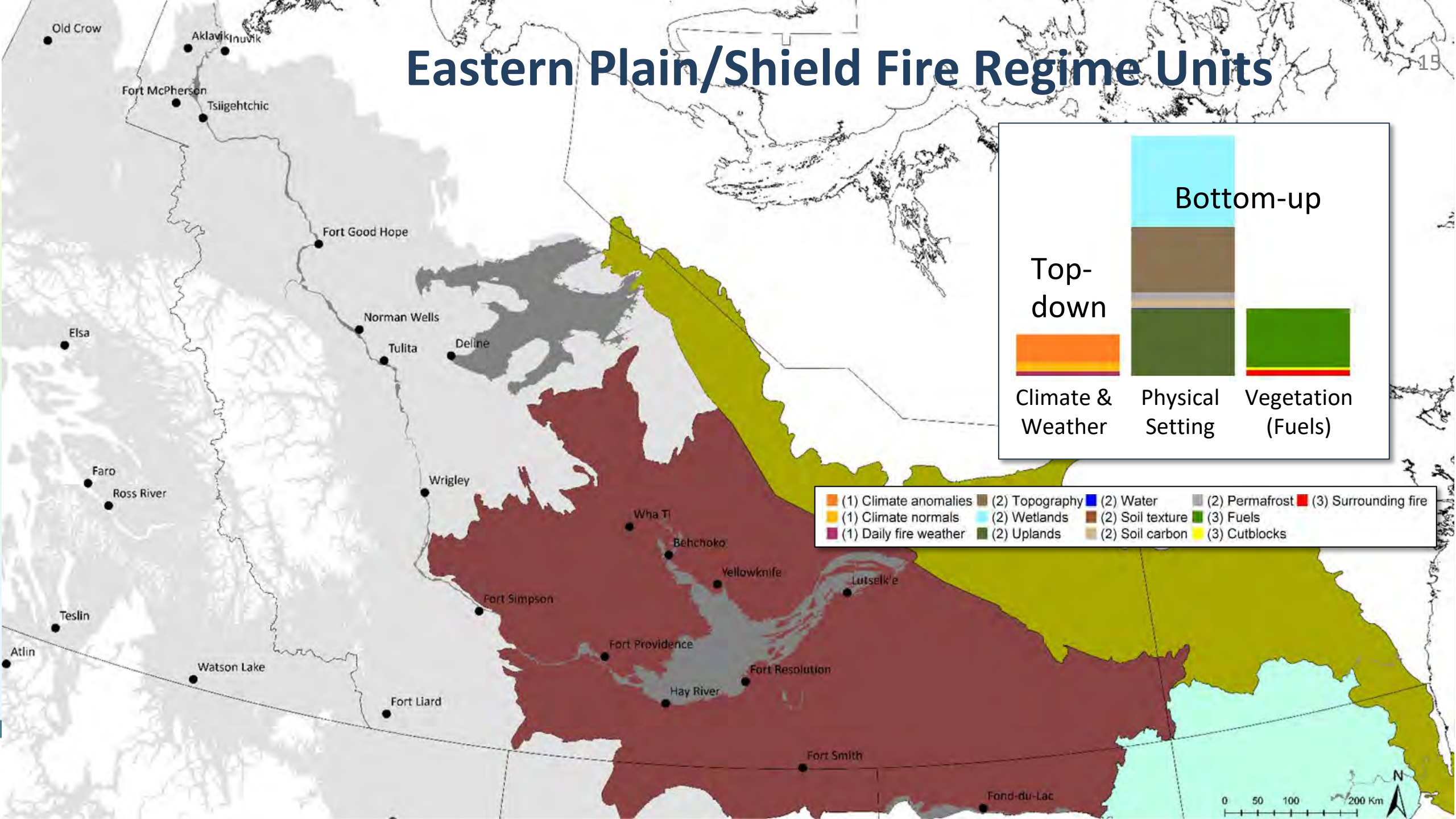
14



- | | | | | |
|------------------------|----------------|------------------|----------------|----------------------|
| (1) Climate anomalies | (2) Topography | (2) Water | (2) Permafrost | (3) Surrounding fire |
| (1) Climate normals | (2) Wetlands | (2) Soil texture | (3) Fuels | |
| (1) Daily fire weather | (2) Uplands | (2) Soil carbon | (3) Cutblocks | |

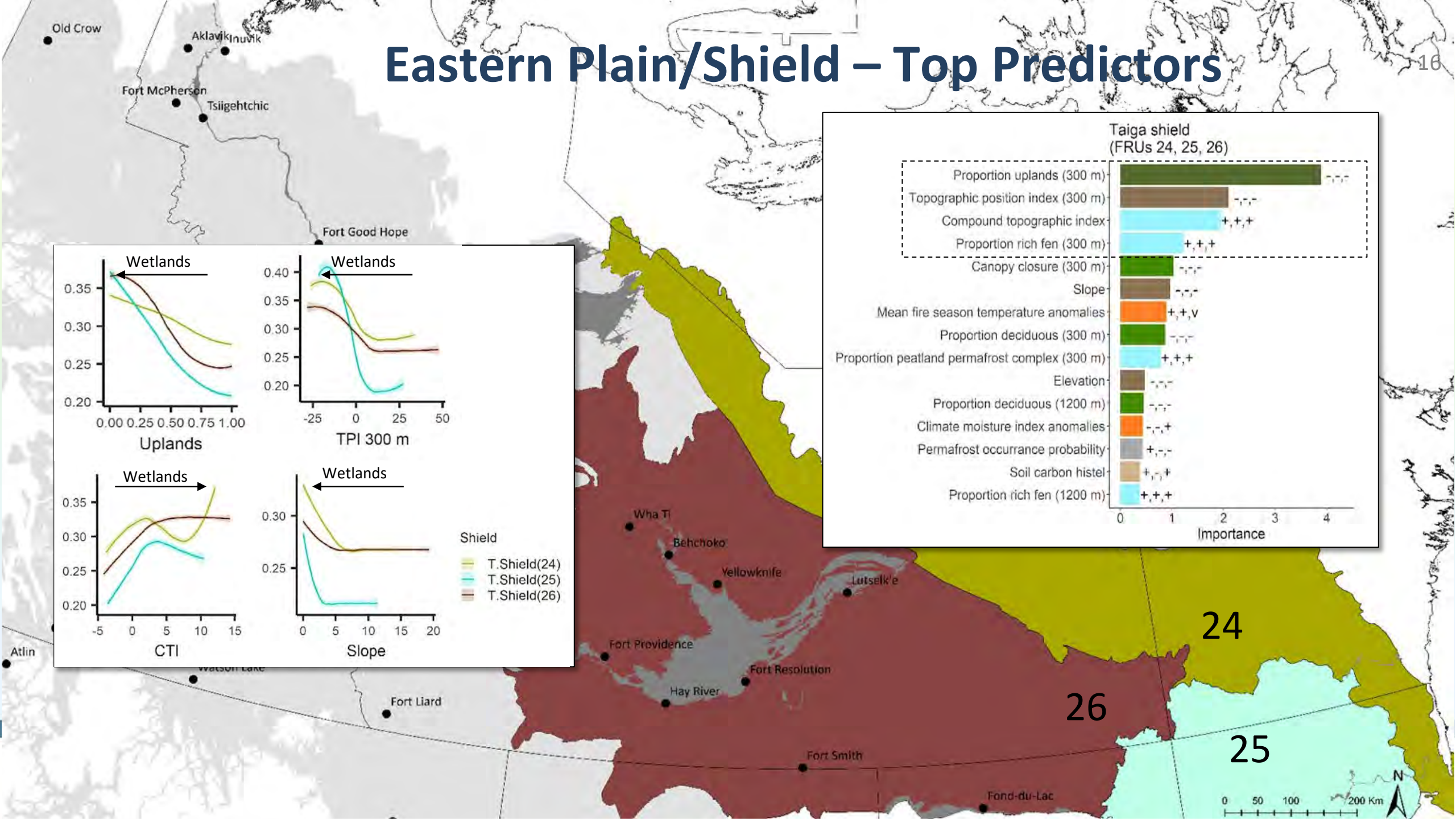
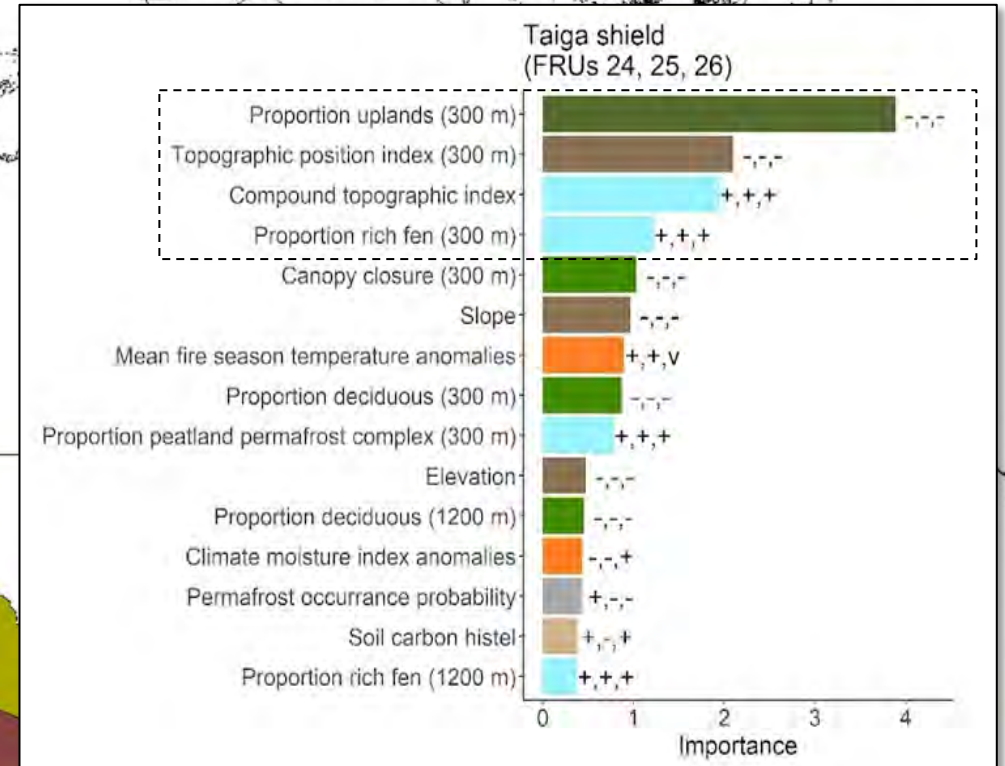
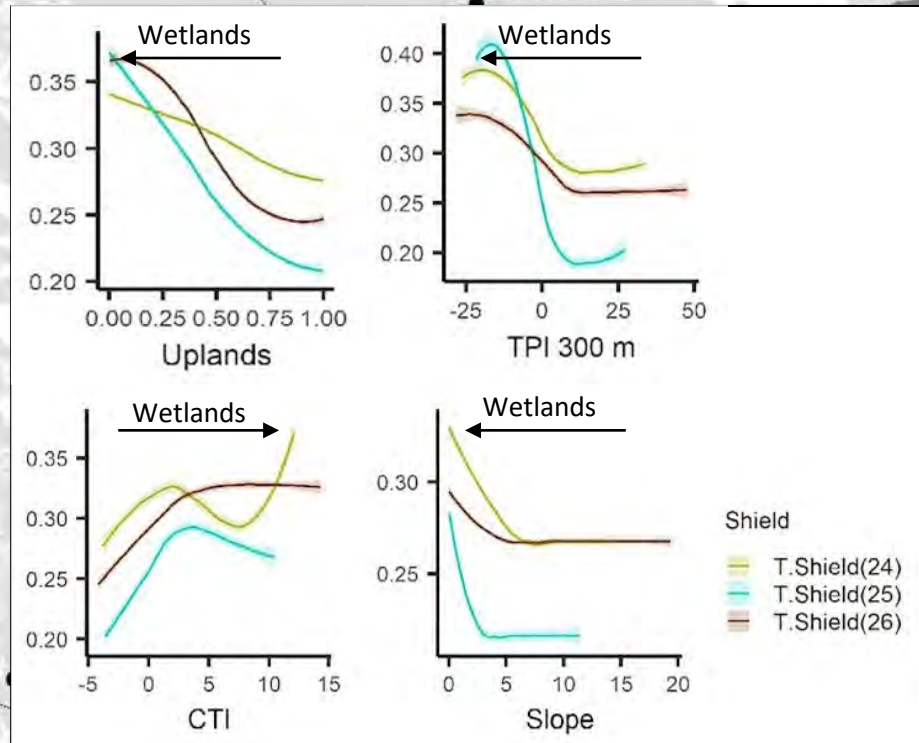


Eastern Plain/Shield Fire Regime Units



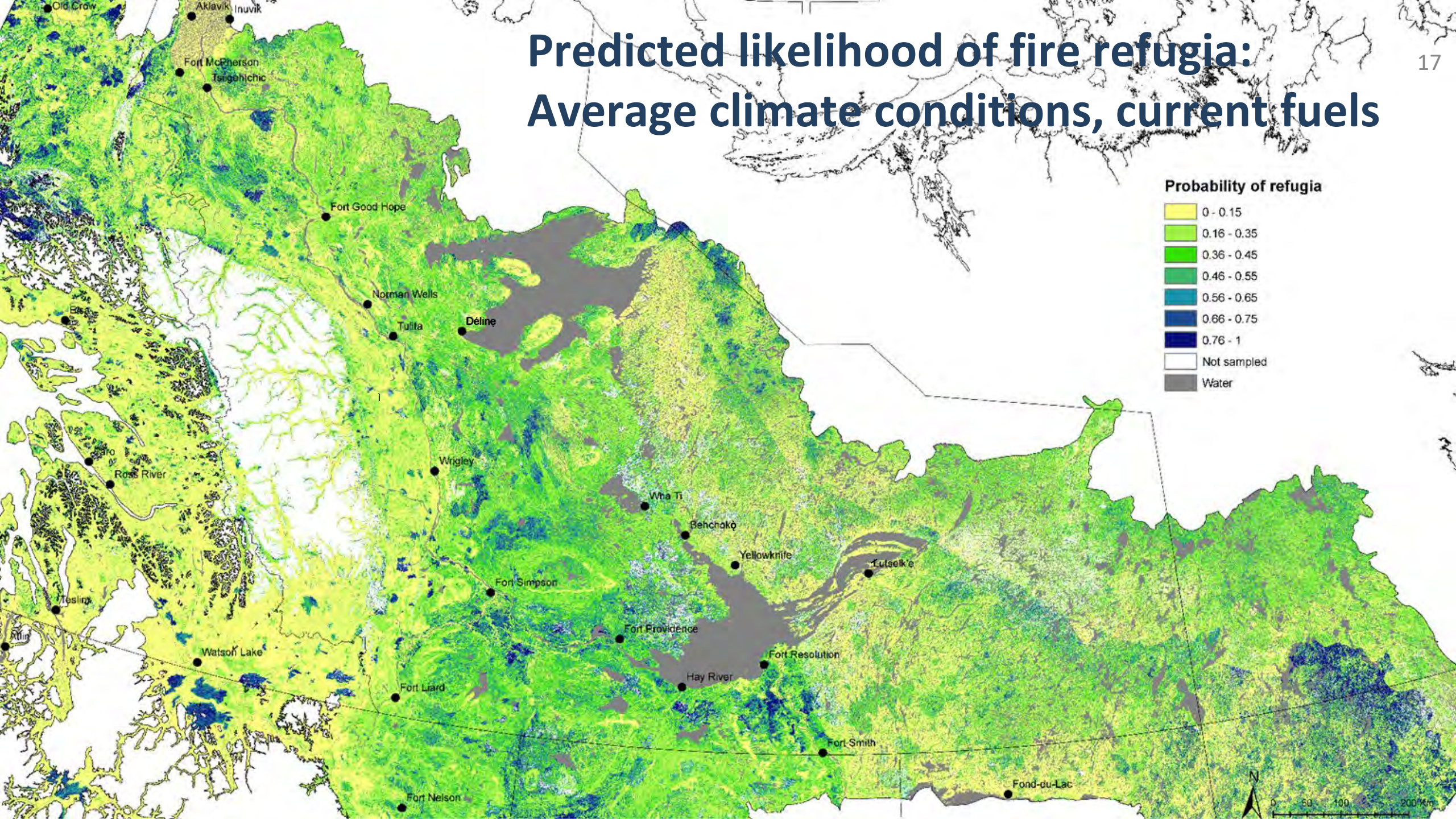
Eastern Plain/Shield – Top Predictors

16



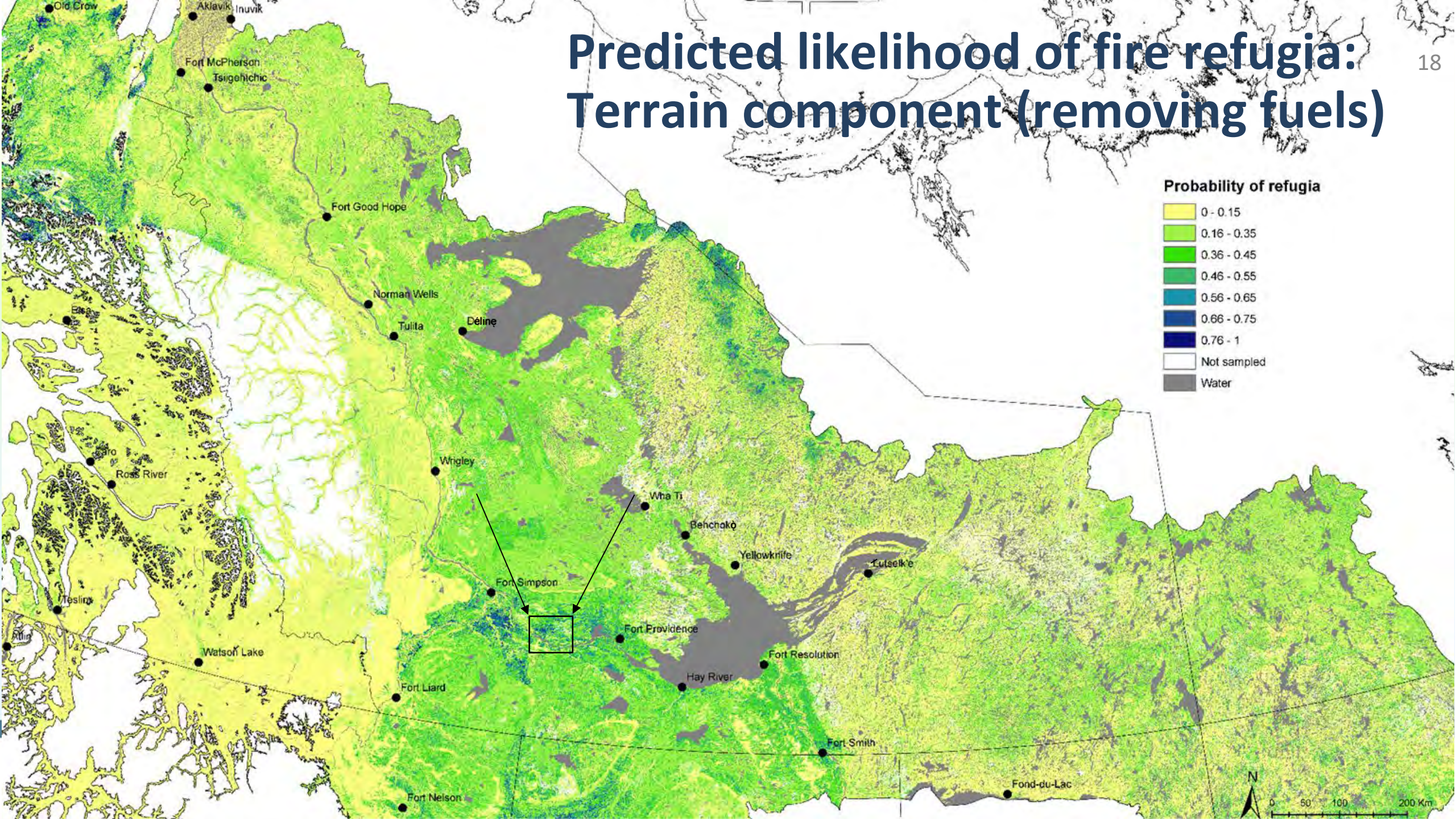
Predicted likelihood of fire refugia: Average climate conditions, current fuels

17



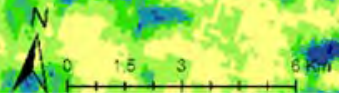
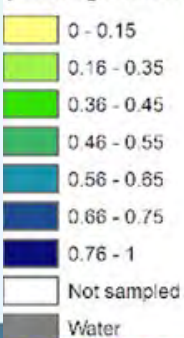
Predicted likelihood of fire refugia: Terrain component (removing fuels)

18

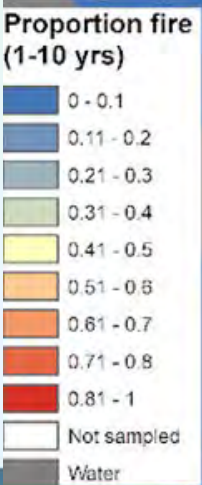


Predicted likelihood of fire refugia: Average climate conditions, current fuels

Probability of refugia
(average conditions)

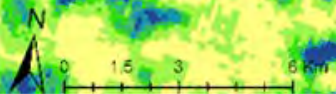
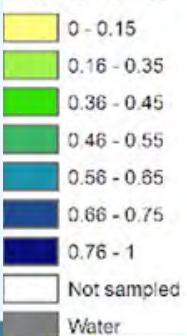


Surrounding fire proportion within 10 years



Predicted likelihood of fire refugia: Terrain component (removing fuels)

Probability of refugia
(topography)



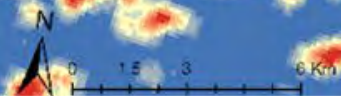
Surrounding peatland (poor fen) proportion

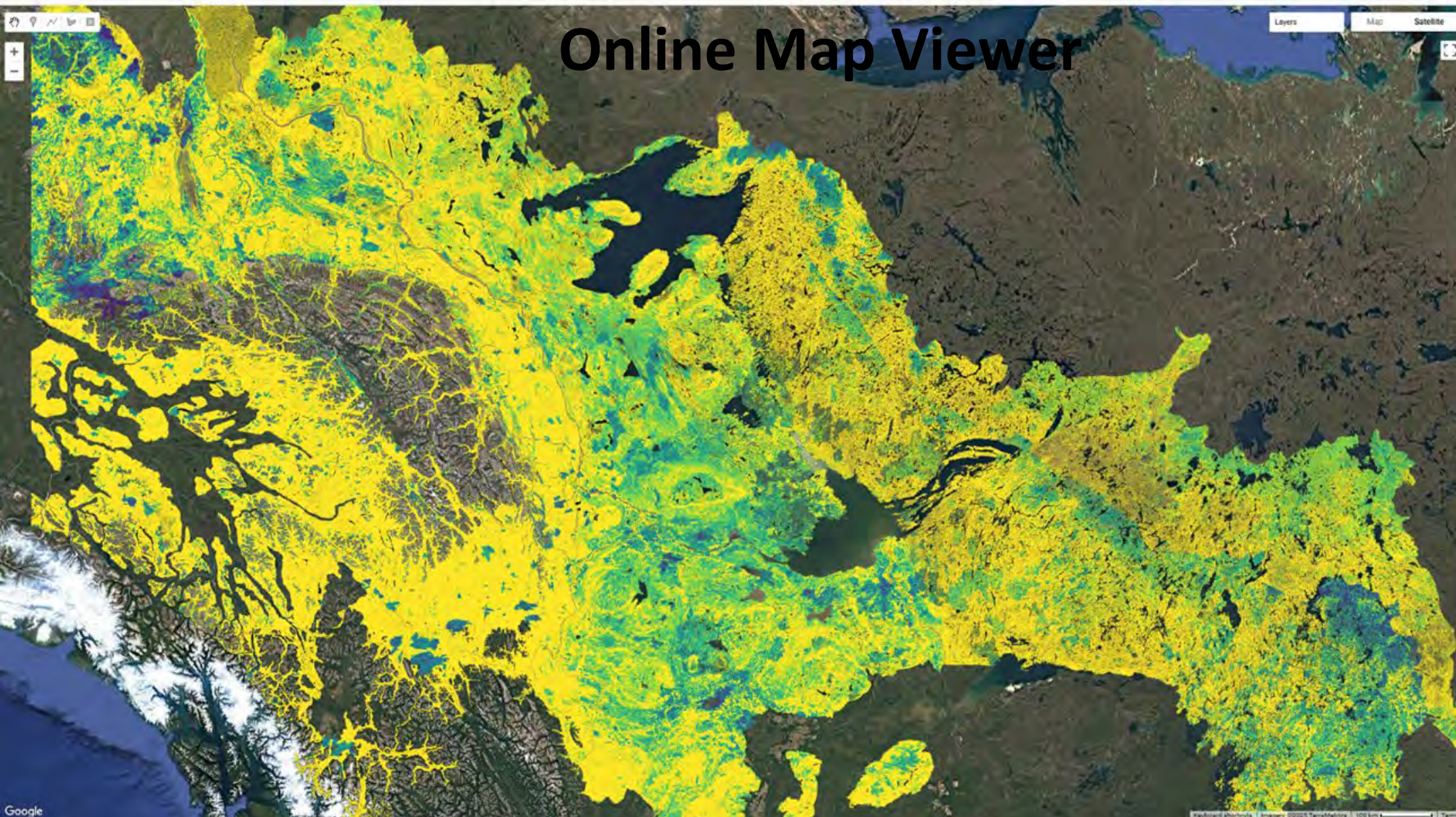
Proportion poor fen
(300 m)

0 - 0.1
0.11 - 0.2
0.21 - 0.3
0.31 - 0.4
0.41 - 0.5
0.51 - 0.6
0.61 - 0.7
0.71 - 0.8
0.81 - 1

Not sampled

Water





Predicted Fire Refugia Probability

This tool maps predicted fire refugia probability¹, generated from Boosted Regression Tree analyses, across a range of conditions for 14 Fire Regime Units² throughout the Northwest Territories, Canada, and surrounding areas. Our sample included all fires ≥ 1000 ha that burned in the study area from 2002-2019, with more recent fires withheld for validation purposes. Use the check boxes below to explore changes in predicted fire refugia probability based on physical setting and average climate conditions (more conditions to come).

Select layers to display

- ☒ Physical Setting
- ☒ Average Climate Conditions

0 1



Citations

Kuntzemann, C., E. Whitman, G. Castilla, S. Rodrigue, R. Skakun, B. Woodworth, R. Abernethy, D. Straiberg. IN PREPARATION¹

Erni, S., Wang, X., Taylor, S., Boulanger, Y., Swystun, T., Flannigan, M., Parisien, M.A. 2020. Developing a two-level fire regime zonation system for Canada. Canadian Journal of Forest Research. 50(3): 259-273. <https://doi.org/10.1139/cjfr-2019-0191>²



Natural Resources
Canada

Ressources naturelles
Canada

<https://ee-cek-nwt-fire-refugia.projects.earthengine.app/view/predicted-fire-refugia-probabilities-across-nwt-and-beyond>

Canada

Summary and Next Steps

- Fire refugia in NWT appear to be driven by bottom-up controls
 - Peatland-associated variables mostly determine long-term fire refugia
 - Previously burned areas also resist fire in the short term
- Top-down controls (climate and fire weather) have smaller and less consistent effects on fire refugia probability (through 2019!)
- Large areas of NWT have low refugia probability according to current models
- Next steps: Model improvement (additional understory variables + large lake effects) + Validation (2020-2023 fires)



Management & Conservation Implications

- Peatlands play an influential role in determining landscape-level fire refugia patterns; also responsible for majority of carbon storage
- Fire refugia maps can inform:
 - Long-term **conservation priorities** for carbon and biodiversity
 - Short-term fuel management priorities [**E.g., burning in strategic places to avoid high severity fires and short-interval reburns**]





Thank you!

For more info: Diana Stralberg
diana.stralberg@nrcan-rncan.gc.ca



Current funding:

- GNWT Department of Environment and Climate Change
- Canadian Forest Service Wildfire Risk Program
- Wilburforce Foundation

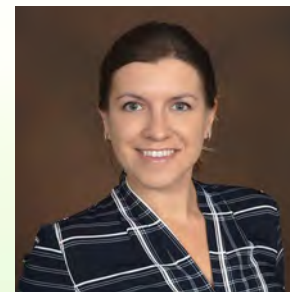
Historical funding for Alberta and BC fire refugia modeling:

- NSERC Advancing Climate Change Science in Canada grant
- Government of British Columbia Ministry of Water, Land, and Resource Stewardship

GNWT Collaborators: Brad Woodworth, Robin Abernethy, Brian Sieben, Amelia Cox, Liam Cowan, Dawn Andrews
CFS Contributors: Christine Kuntzemann, Ellen Whitman, Guillermo Castilla, Sebastien Rodrigue, Rob Skakun, Quinn Barber, Sasha Hararuk, Marc Parisien, Luc Guindon



Quantifying peat C stocks and fluxes in low-permafrost NWT managed forests



Sasha Hararuk

Peat C: 4.74 Pg C



NEP 1990-2019: 73.2 Mt C; Fire emissions: 24.5 Mt C



Climate
Land classification
Yield curves
Disturbance maps



Canadian Model for Peatlands



Natural Resources
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Parks
Canada

Parcs
Canada

Canada

Ecosystem Carbon in Forests of Canada's National Parks

February 4, 2025

Landscape Carbon Workshop
Yellowknife, NWT

Chelsea Chisholm
Ecosystem Scientist
Office of the Chief Ecosystem Scientist
Parks Canada





171 NATIONAL
HISTORIC
SITES

5 NATIONAL
MARINE
CONSERVATION AREAS

47 NATIONAL
PARKS

1 NATIONAL
URBAN PARK

7500 +
DEDICATED
EMPLOYEES



12 of 20
Canada's
WORLD
HERITAGE
SITES

3,800 +
designations
of people, places, and events
of importance

450 000 + km²
area protected

PARKS CANADA AT A GLANCE

more than
20 MILLION
visits per year

protection of
250 +
species at risk

8,000 + km
of trails

FREE
admission
for youth and new
Canadians

31 MILLION
archaeological and
historical objects

12,000
CAMPSITES

collaboration with
300 +
INDIGENOUS COMMUNITIES

\$27 +
BILLION
OF ASSETS

600 +
RED CHAIRS
#sharethechair





Ecosystem Carbon Management at Parks Canada

An increasingly important global conservation goal is to protect, manage, restore, and enhance ecosystem carbon to avoid emissions where possible.

Sound stewardship of ecosystem carbon involves:

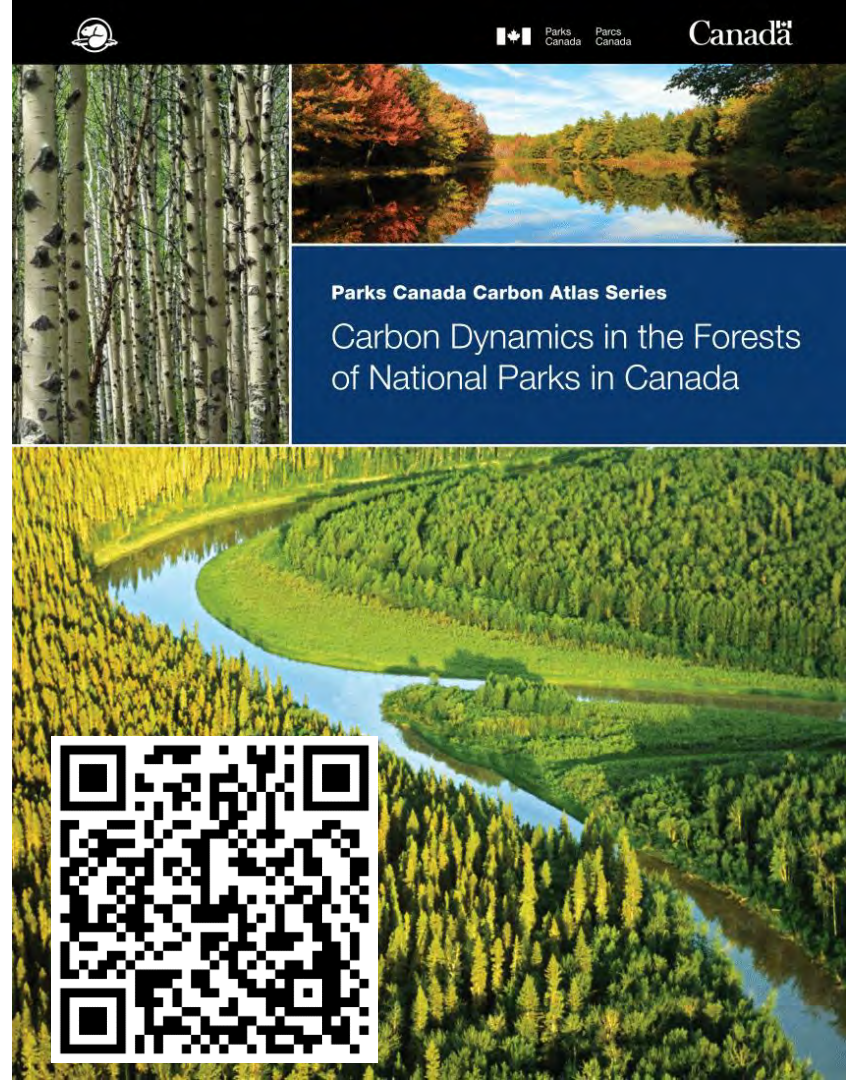
- Understanding the current distribution and dynamics of ecosystem carbon
- Understanding the status and trends of ecosystem carbon
- Developing guidance and beneficial practices to:
 - Plan development and operations to avoid impacts to stored carbon
 - Protect and restore ecosystems to better manage carbon over time





Forest Carbon Atlas

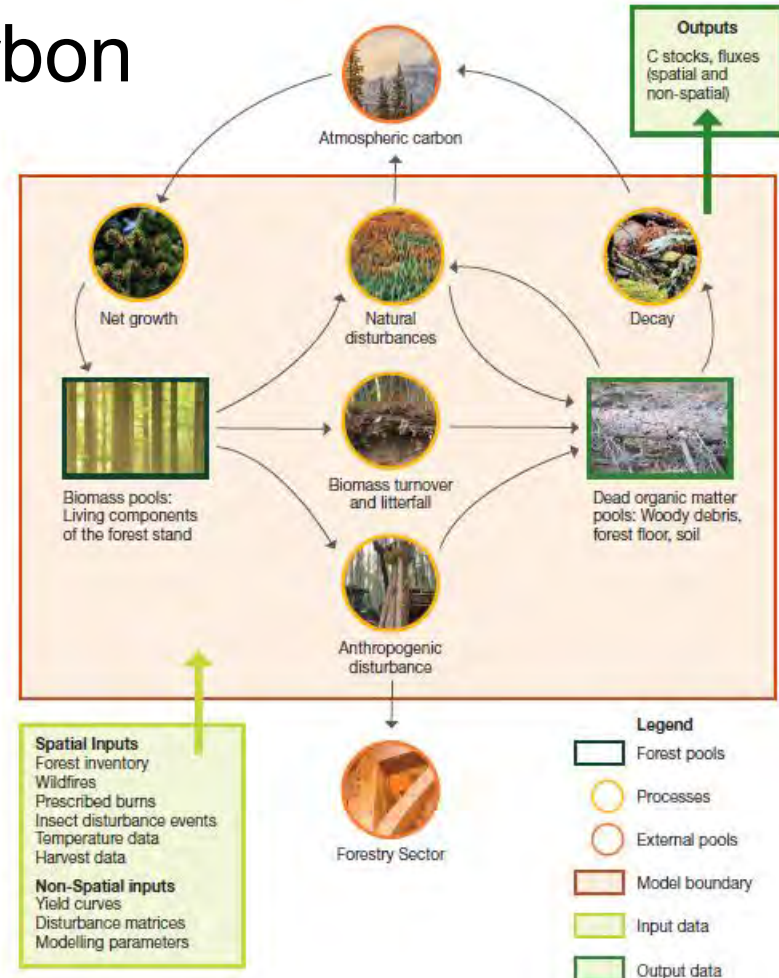
- Released publicly in October 2023 ([available here](#)).
- Modeled forest carbon stocks and fluxes for 31 national parks, for the period 1990-2020.
- Multi-year collaboration with Canadian Forest Service.
- National parks stored $1,452 \pm 11$ Mt C (average of 31 years), with a net gain (sink) of around 6.8 Mt C over the 31 years.





Modeling Forest Carbon

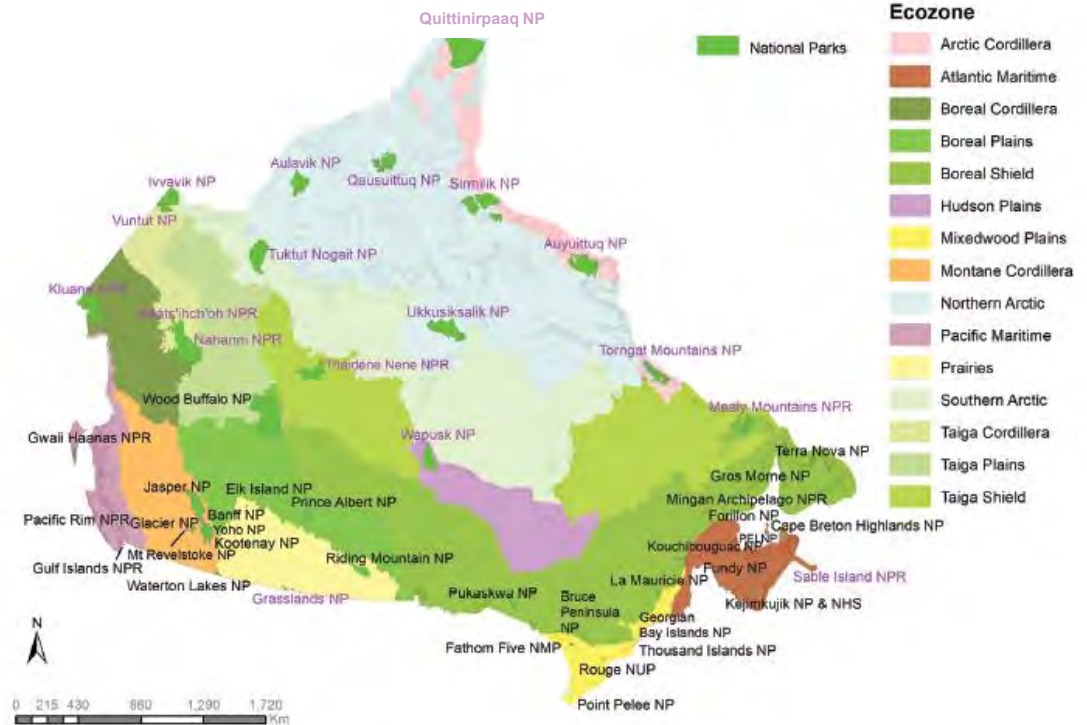
- The Generic Carbon Budget Model (GCBM) simulates the carbon dynamics in and amongst pools:
 - aboveground biomass
 - belowground biomass
 - litter
 - dead wood
 - soil organic carbon
- The model tracks carbon stocks, transfers between pools, and many other carbon flux metrics.





Selecting Sites

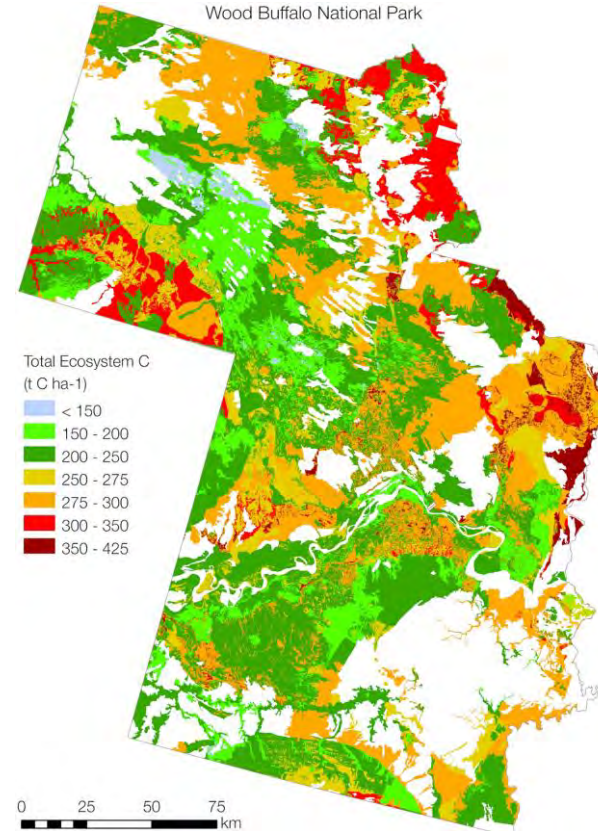
- Southern sites were selected due to availability of data for modeling.
- We assessed carbon in 31 national parks and national park reserves across southern Canada from 1990-2020.





Forest Carbon in WBNP

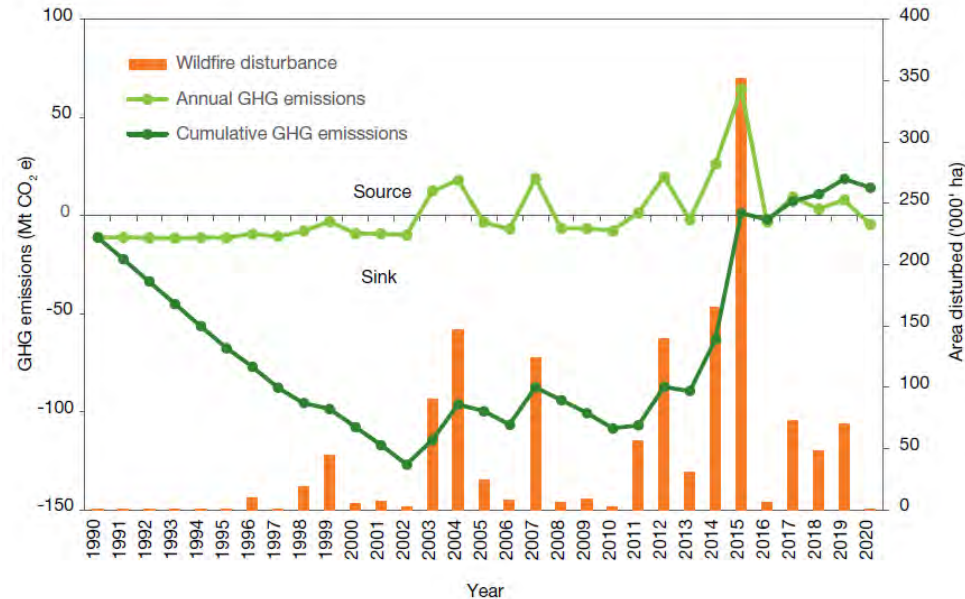
- Greatest carbon stocks of parks assessed.
- One of two parks that showed decreases in carbon stocks over time due to large-scale disturbances (over 1.3 million ha were burnt from 2002 to 2020, or 2% per year).
- Net total GHG emissions of 63.54 Mt CO₂e from 1990-2020.





Forest Carbon Emissions

- Large scale wildfire in a few parks (e.g., Wood Buffalo NP) dominated the carbon dynamics and greenhouse gas emissions at the national level.
- Disturbances from insect outbreaks and prescribed fire led to minor GHG emissions.
- Research is needed to assess how much ecological restoration and wildfire management can limit risk of the National Park system becoming a sustained source of GHG emissions.



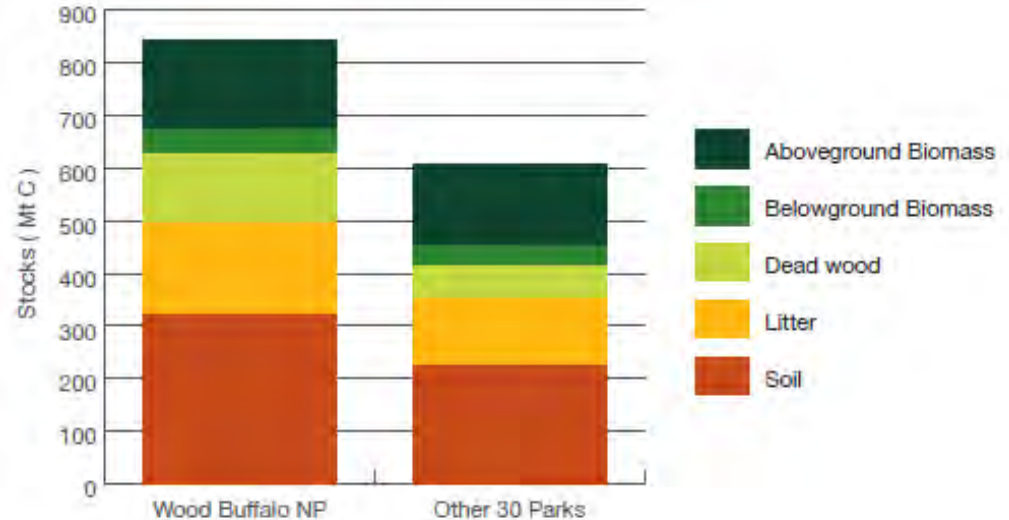
Large disturbances drove three parks to be net GHG sources and tipped the balance of overall GHG emissions



Forest Carbon in Northern Forests

Next steps include:

- Using northern-appropriate yield curves and park-scale inventory data
- Inclusion of climate change
- Managing for carbon in a future of increased frequency, severity, and size of wildfires





Carbon in Other Key Ecosystems



Grasslands



Blue Carbon



Peatlands



Peatland Carbon Sampling in Parks Canada

- In partnership with UQAM, a project is underway to quantify carbon stocks in peatlands in national parks.
- Peat depths and cores have been collected thus far from 6 national parks, including from permafrost peatlands in Wapusk NP.
- We are working with partners to quantify carbon fluxes using the Canadian Model for Peatlands (CaMP; including work on a permafrost peatland module).
- Additional parks for planned field work in 2025:
 - Wood Buffalo NP
 - Prince Albert NP
 - Riding Mountain NP



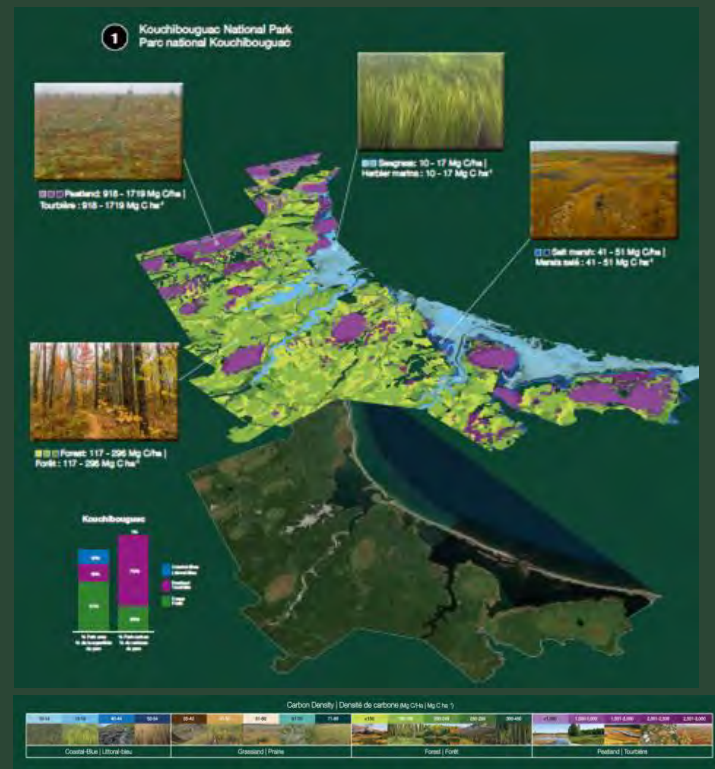


Next Steps: Site-level maps and guidance

In the near future, carbon information for each ecosystem will be overlain to tell the **‘site-level story’ of landscape carbon.**

This will provide evidence to inform management decisions, including with respect to:

- Park zoning (potentially);
- Asset or infrastructure development;
- Ecological restoration;
- Boundaries of new parks;
- Educational programing.



Forest, peatland and coastal salt marsh ecosystem carbon densities at Kouchibouguac NP



Thank you for your attention

Any questions, please contact:

chelsea.chisholm@pc.gc.ca



Spatio-Temporal Trends of Soil Organic Carbon in the Northwest Territories Under Future Climate Scenarios

Daorui Han, Alemu Gonsamo

School of Earth, Environment & Society, McMaster University



Environment and
Climate Change Canada
Environnement et
Changement climatique Canada



Digital Research
Alliance of Canada

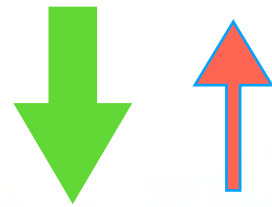


Chaires
de recherche
du Canada
Canada
Research
Chairs

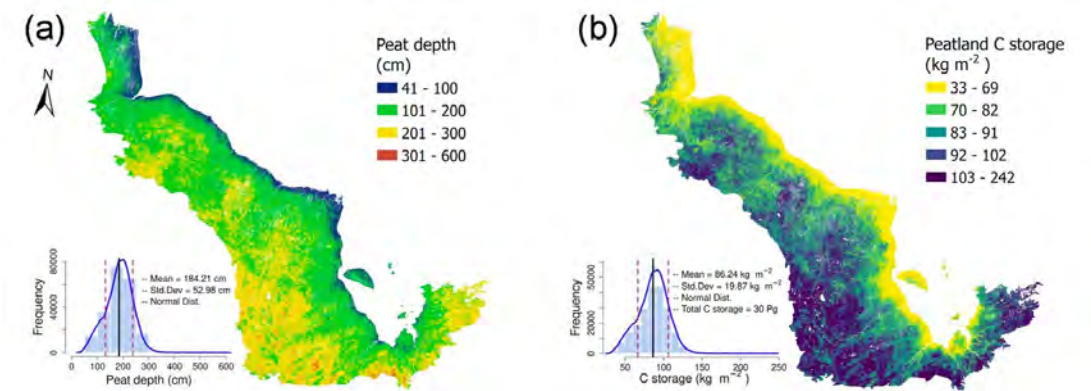
Canada

Background

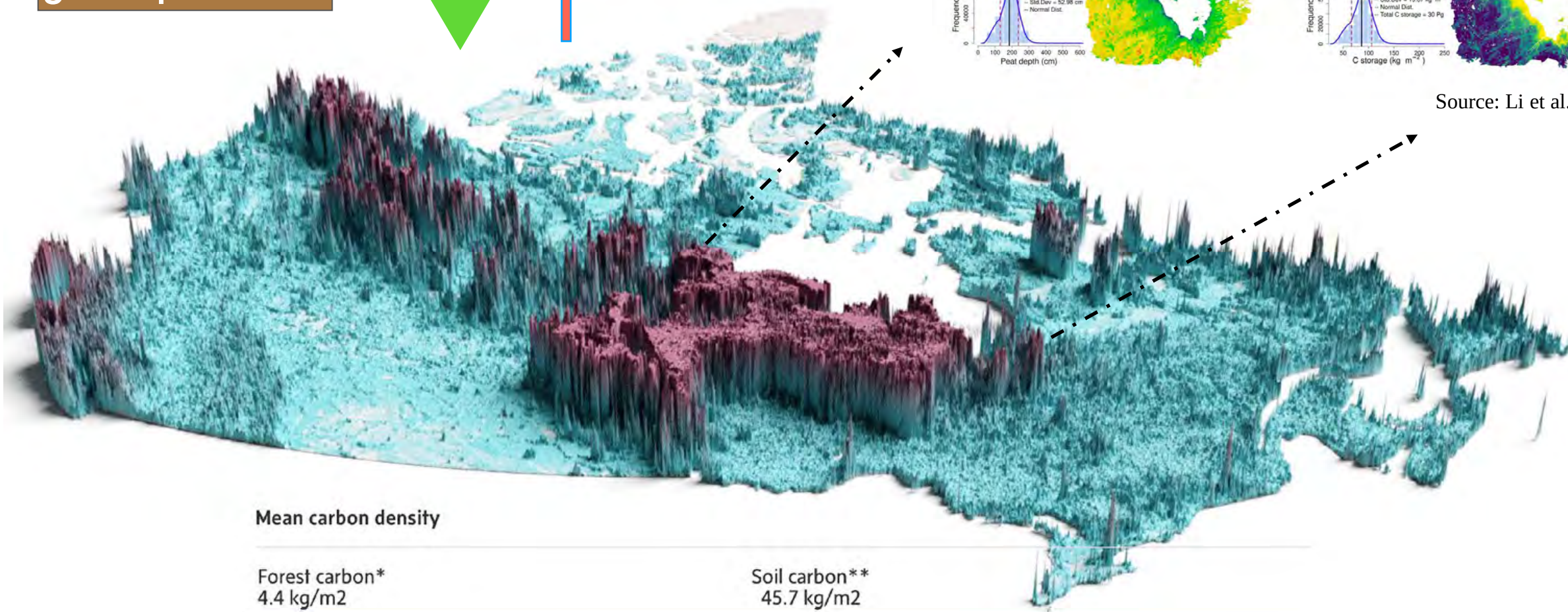
~ 1/3
global peatland



The Hudson Bay Lowlands



Source: Li et al. 2025



Mean carbon density

Forest carbon*
4.4 kg/m²

Soil carbon**
45.7 kg/m²



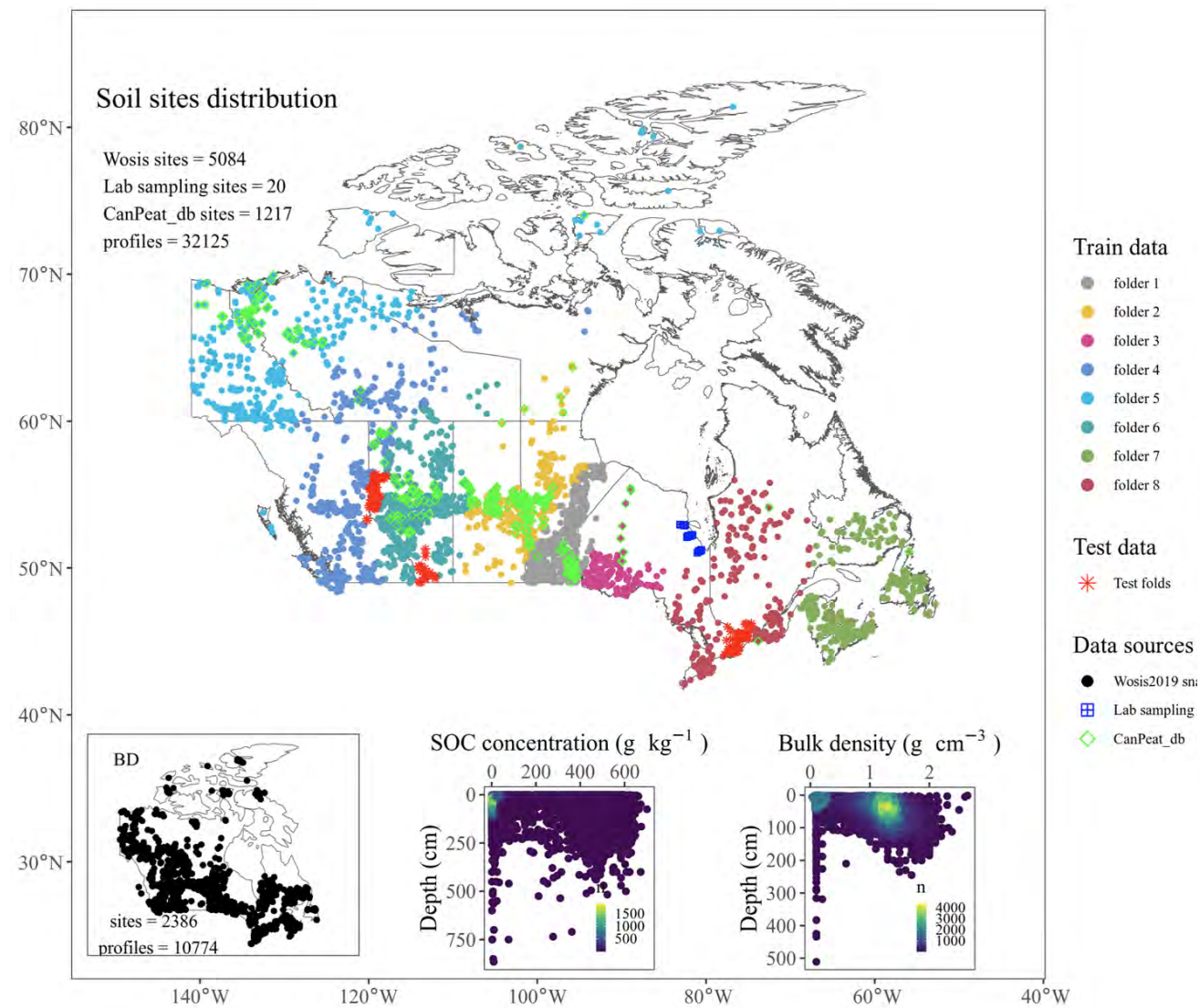
* Includes above ground biomass, below ground biomass (roots) and dead plant material.

** Soil to a depth of one metre.

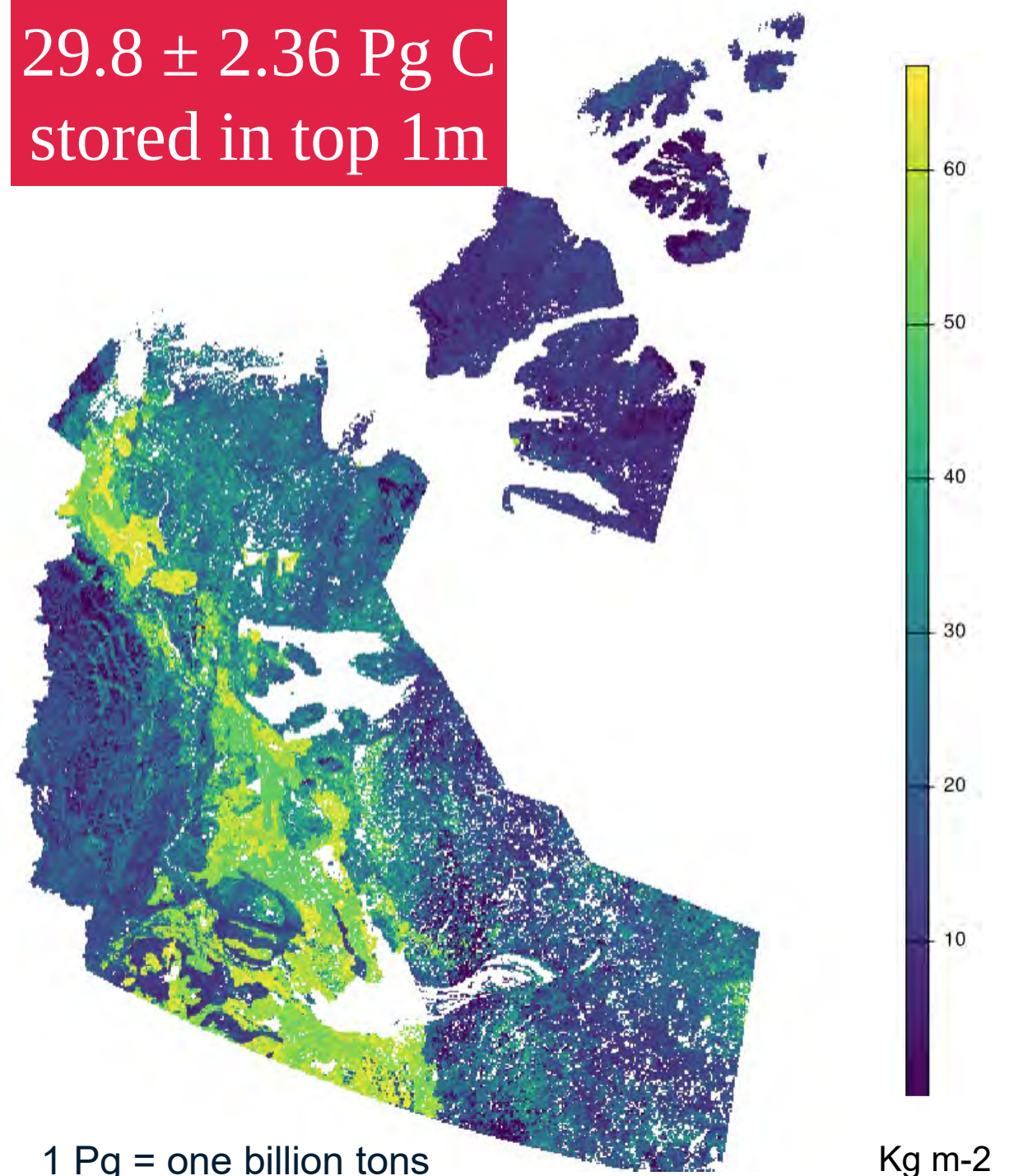
Source: Camille et al. 2022

Base SOC map in NWT

Model training

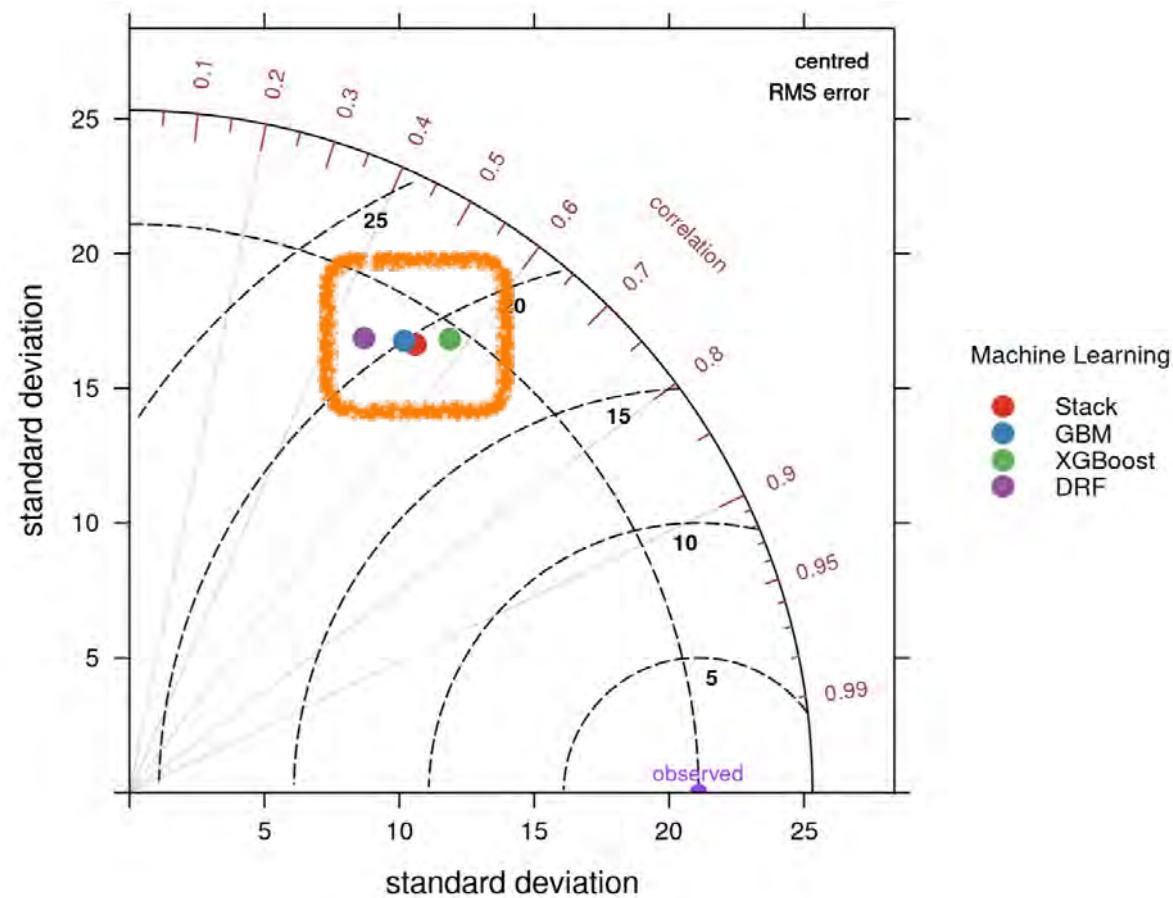


29.8 ± 2.36 Pg C
stored in top 1m

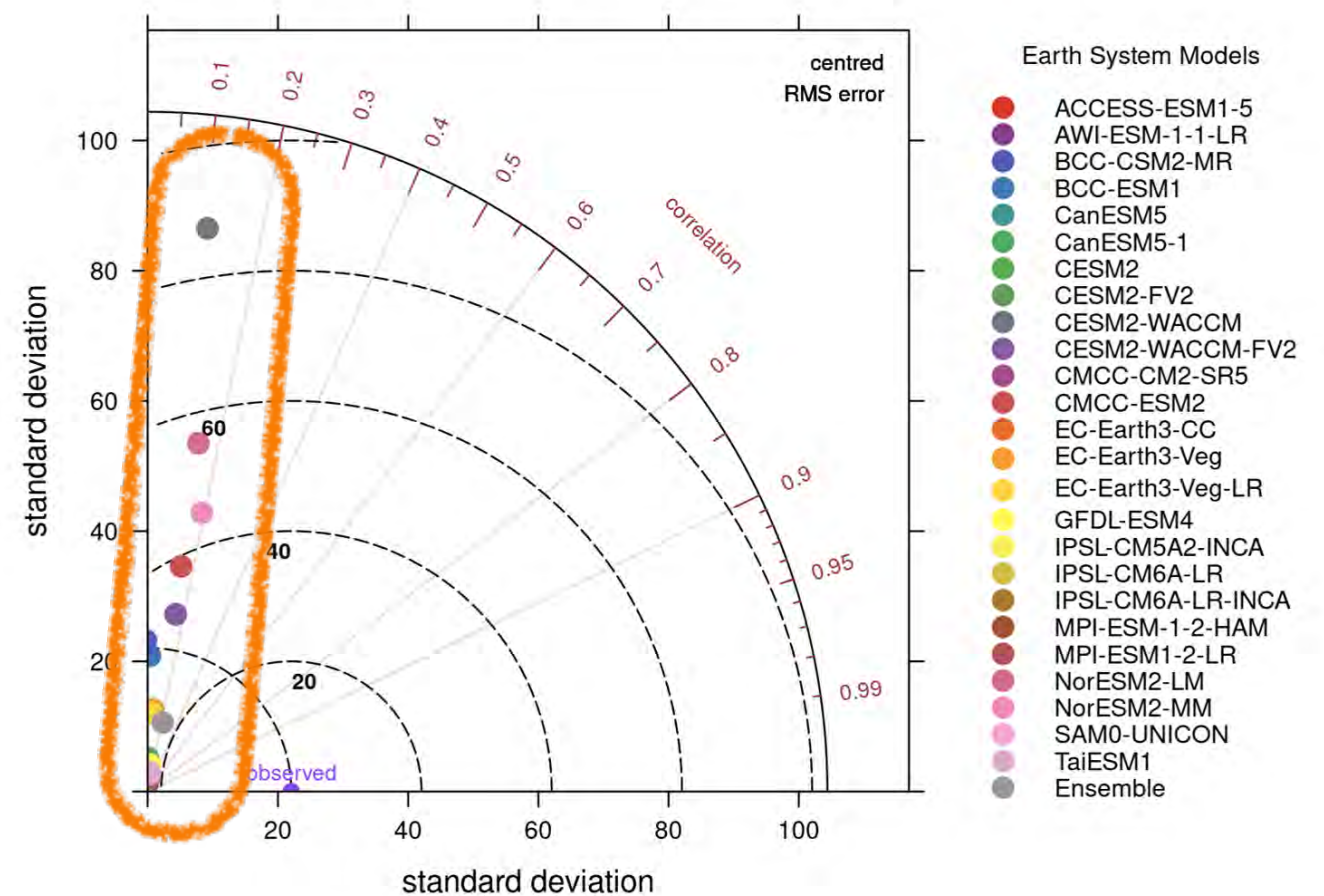


Model performance comparison

Our base map



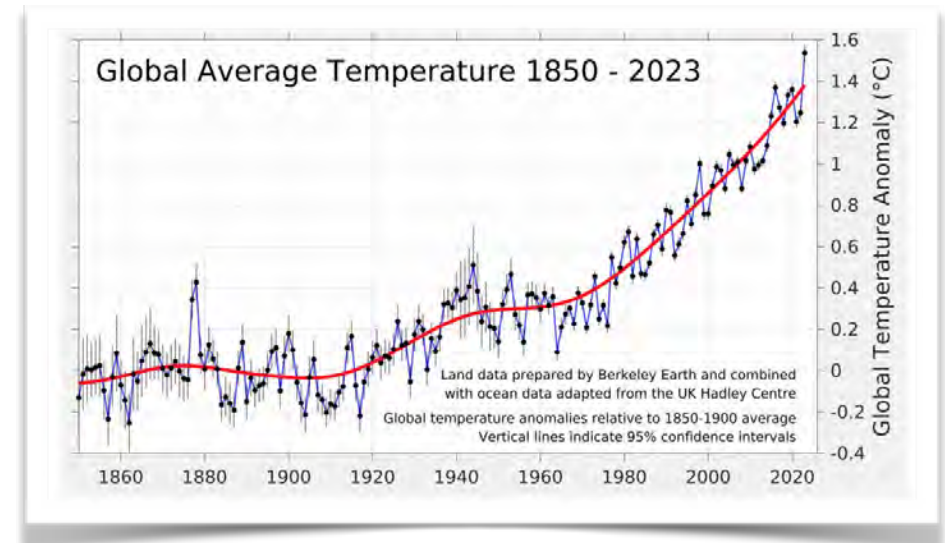
Earth System Models



Our predicted base map is better than the current CMIP6 ESM estimates.

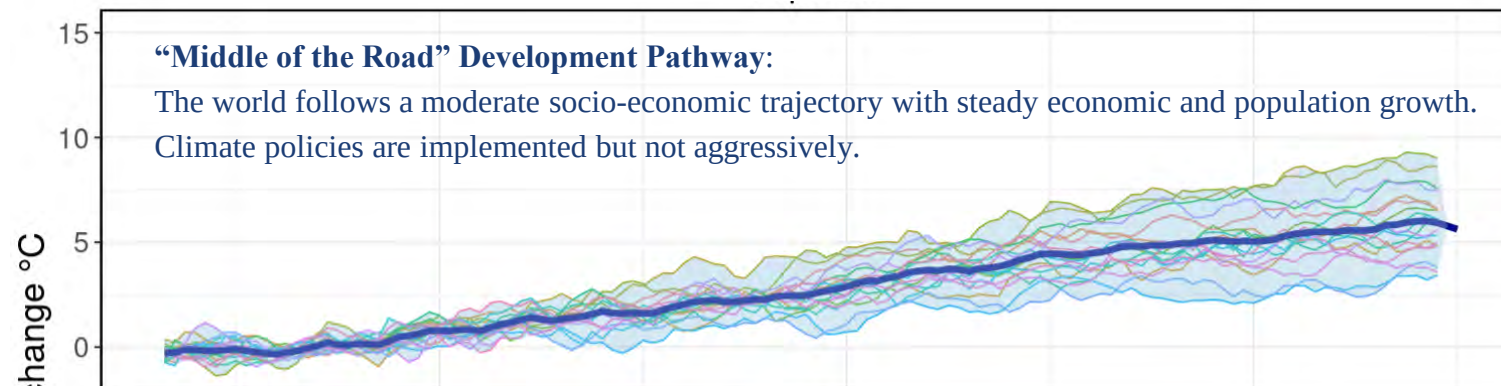
Climate trend to 2100

Global temperature has increased at an average rate **(0.06° Celsius) per decade since 1850**. The rate of warming **since 1982** is more than three times as fast: **(0.20° C) per decade**. (NOAA, 2023)

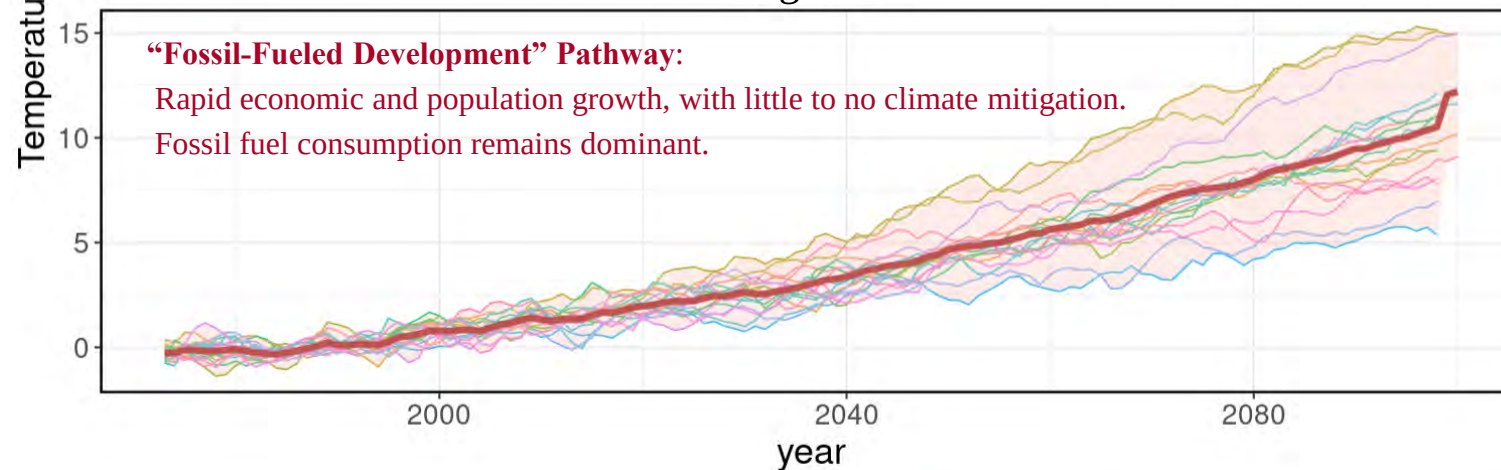


Northwest Territories

Under SSP2-4.5 Intermediate Emissions Scenario



Under SSP5-8.5 High Emissions Scenario

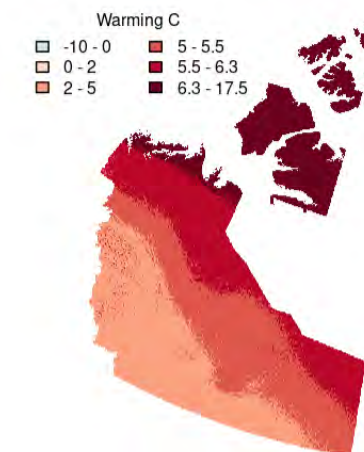


ESM models

ACCESS-CM2	CanESM5	CMCC-ESM2	EC-Earth3-Veg-LR	INM-CM5-0	MPI-ESM1-2-HR
ACCESS-ESM1-5	CanESM5-1	EC-Earth3-CC	FIO-ESM-2-0	IPSL-CM6A-LR	MPI-ESM1-2-LR
BCC-CSM2-MR	CAS-ESM2-0	EC-Earth3-Veg	INM-CM4-8	MIROC6	MRI-ESM2-0

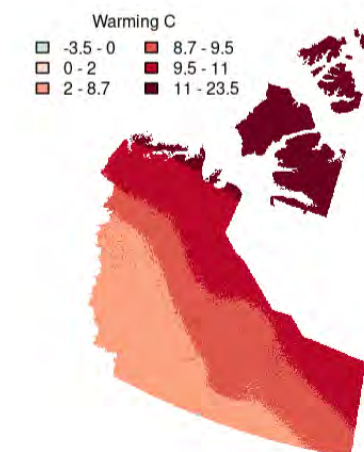
SSP: Shared Socioeconomic Pathways

Temperature change under SSP245



+ 0.56 °C/10yr

Temperature change under SSP585



+ 0.97°C/10yr

Methodology Outline

CMIP6

(Coupled Model Inter-comparison

Project Phase 6)

- A global climate modeling initiative by the **World Climate Research Programme (WCRP)**.
- Brings together multiple **Earth system models (ESMs)** from leading research institutions.
- Helps scientists and policymakers **understand past, present, and future climate change**.
- **Key Purpose:** Support **IPCC reports** and climate adaptation strategies.



Two scenarios included :

- **SSP2-4.5 : (Intermediate Emissions)**
Moderate policies
mix of fossil fuels & renewables
- **SSP5-8.5 : (High Emissions)**
Continued fossil fuel use
extreme climate impact

Future variables included:

- cLitter: carbon in litter
- cSoil: carbon in soil
- hurs: relative humidity
- mrso: total soil moisture
- miso: soil moisture in upper soil
- GPP: Gross Primary Production
- tas: Near-Surface Air Temperature
- sfcWind: Surface Wind Speed
- Srds: Surface Downward Radiation

Method 1

Direct use Earth System Model (ESM) output

Method 2

Ensemble machine learning

Method 3

C transient dynamic approach
Based on input and output balance

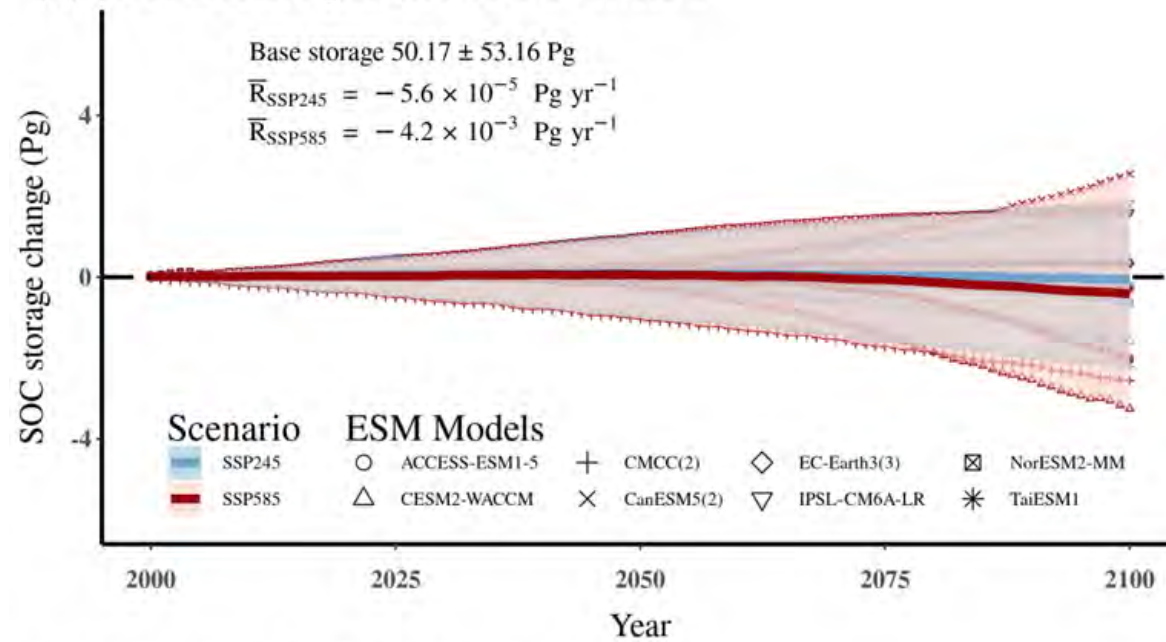
Method 4

Turnover time and Rh

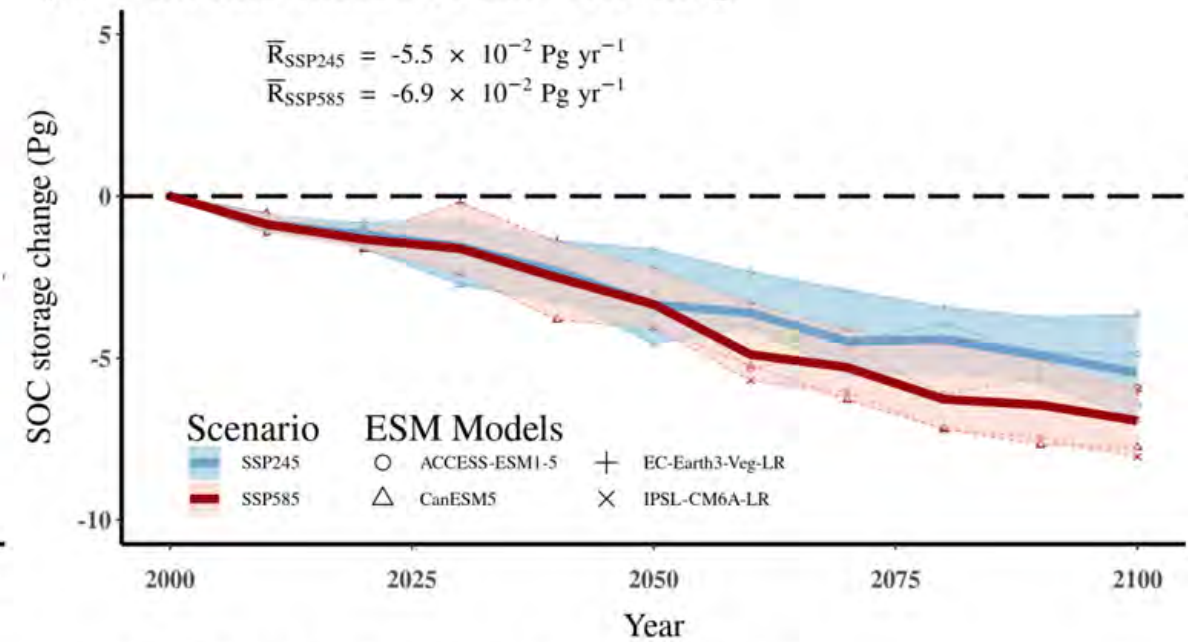
SOC dynamic in response to future climate

SOC temporal trend in NWT

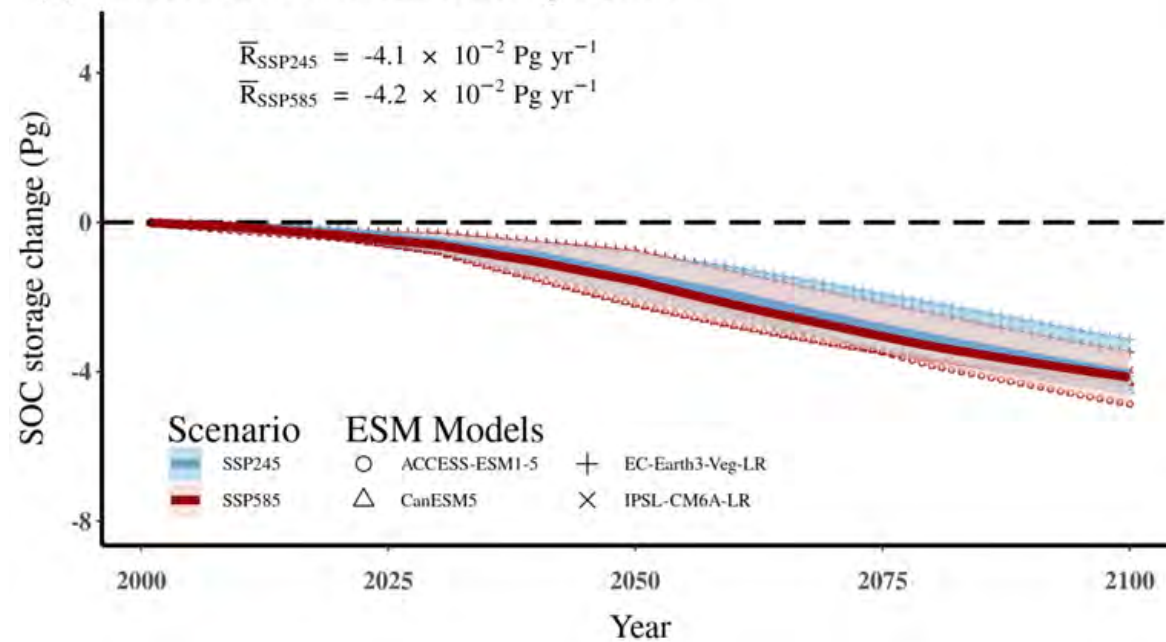
(a) M1: Earth System Model-CMIP6



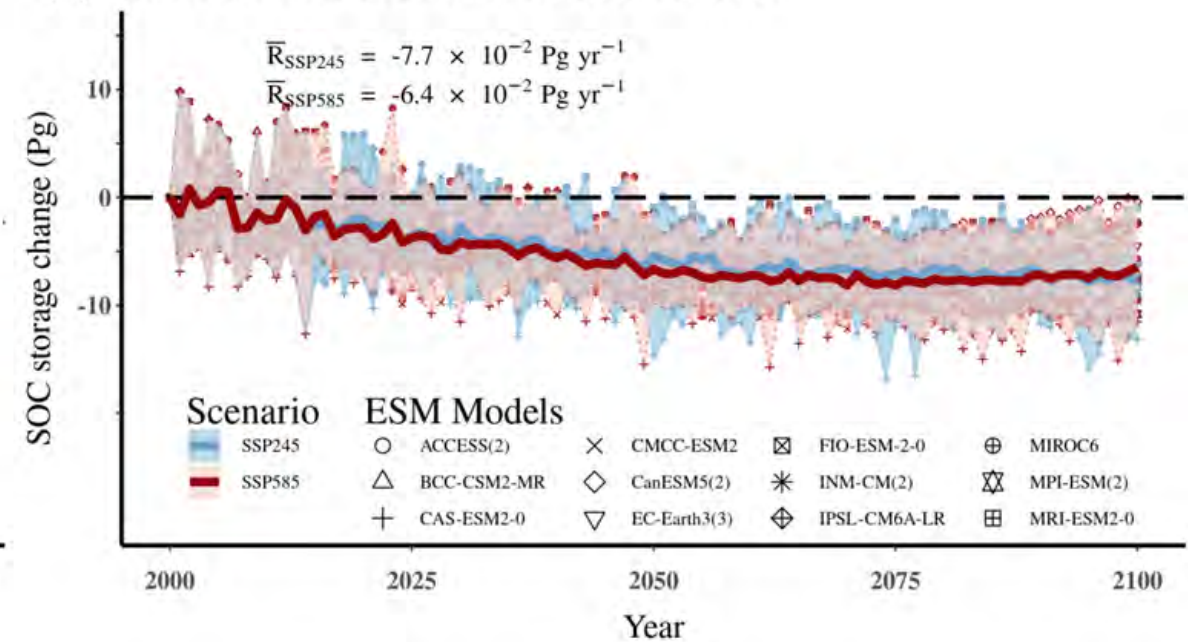
(b) M2: Ensemble Machine Learning



(c) M3: Carbon Transient Dynamic



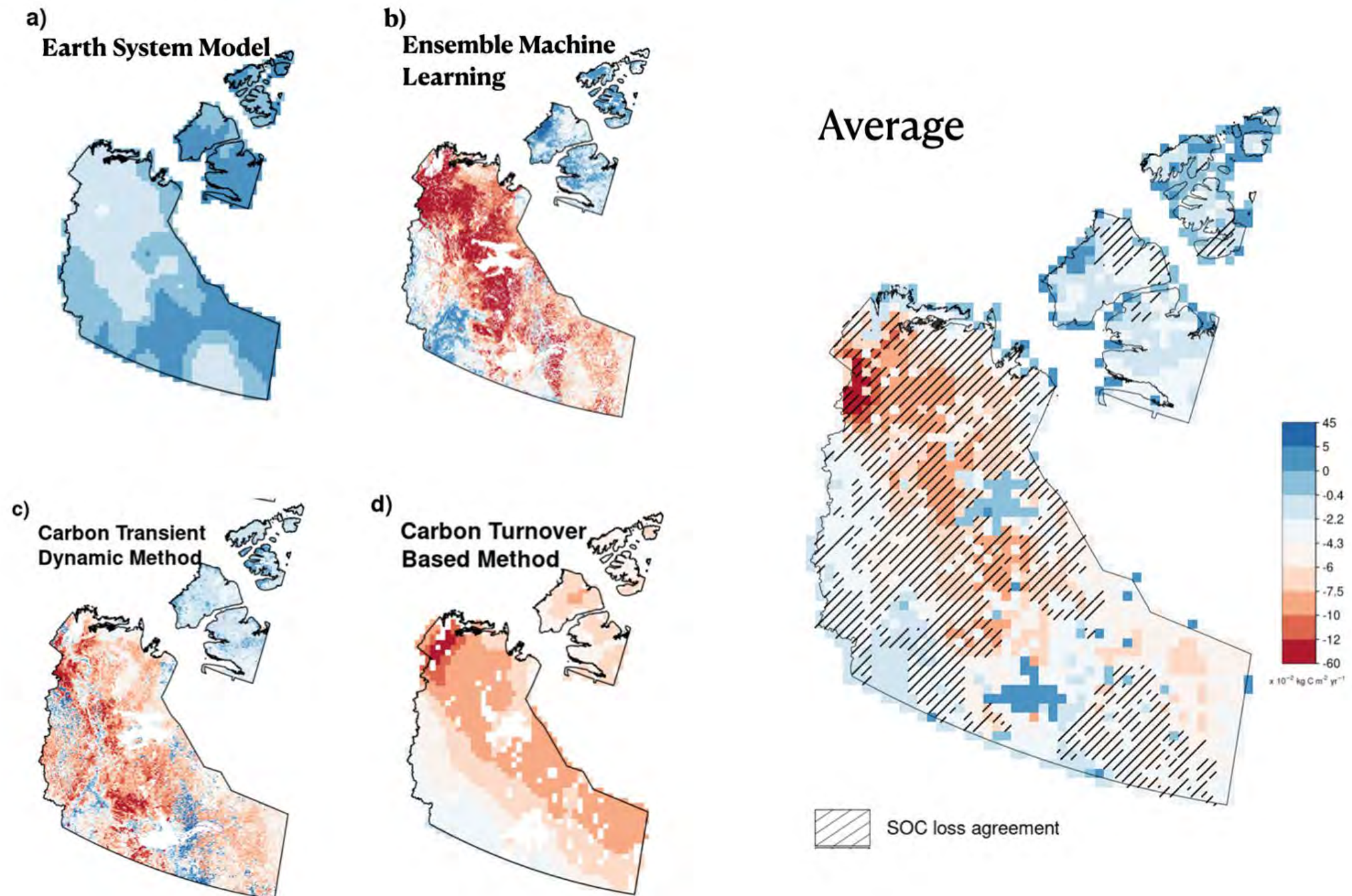
(d) M4: Carbon Turnover Based Method



SSP245 to -7.7 Pg
 SSP585 to -6.9 Pg

Uncertainty: M3 < M1 < M2 < M4

Spatial pattern of SOC change



Peatland contribute a large portion in C loss to 2100

Sensitivity of SOC to climatic variables

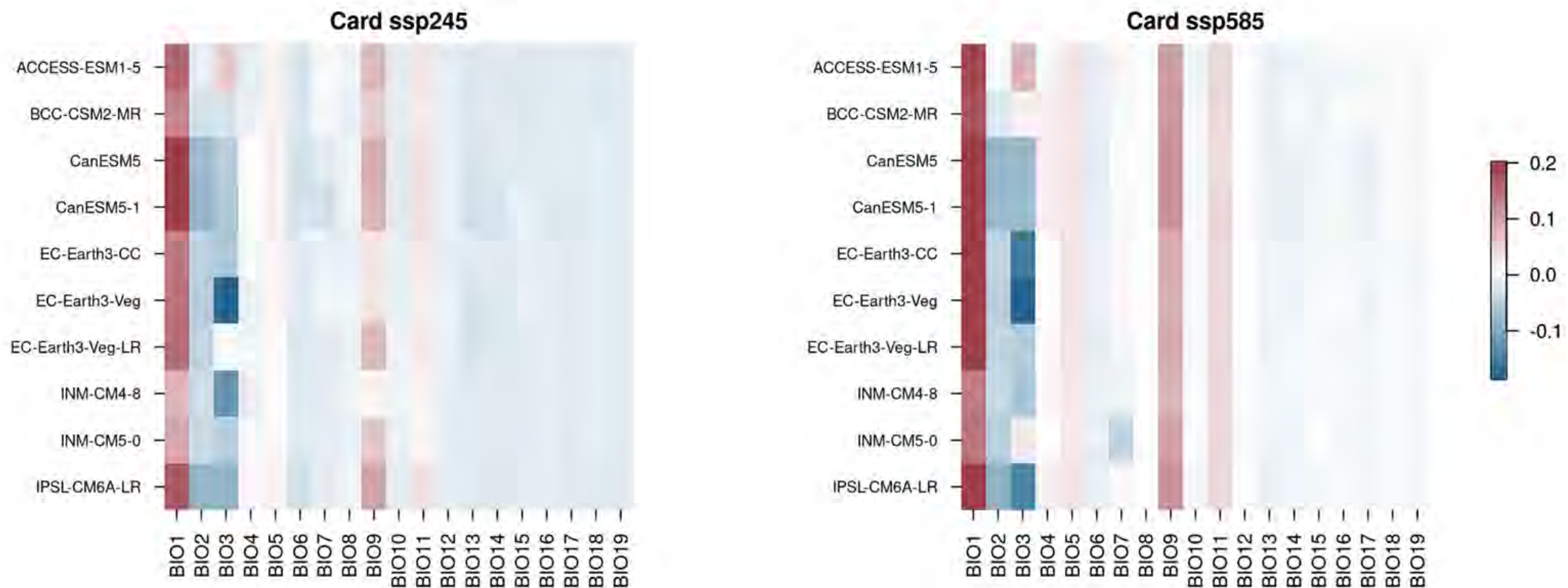


Fig. Sensitivity of SOC to the 19 bio-climatic variables for the two scenarios

BIO1 = Annual Mean Temperature
 BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
 BIO3 = Isothermality (BIO2/BIO7) ($\times 100$)
 BIO4 = Temperature Seasonality (standard deviation $\times 100$)
 BIO5 = Max Temperature of Warmest Month
 BIO6 = Min Temperature of Coldest Month
 BIO7 = Temperature Annual Range (BIO5-BIO6)
 BIO8 = Mean Temperature of Wettest Quarter
 BIO9 = Mean Temperature of Driest Quarter
 BIO10 = Mean Temperature of Warmest Quarter

BIO11 = Mean Temperature of Coldest Quarter
 BIO12 = Annual Precipitation
 BIO13 = Precipitation of Wettest Month
 BIO14 = Precipitation of Driest Month
 BIO15 = Precipitation Seasonality (Coefficient of Variation)
 BIO16 = Precipitation of Wettest Quarter
 BIO17 = Precipitation of Driest Quarter
 BIO18 = Precipitation of Warmest Quarter
 BIO19 = Precipitation of Coldest Quarter

Bio1-Bio11 temperature related vars
 Bio12-Bio19 precipitation related vars

Temperature especially driest/coldest season temperature

In sum

1) High Risk of SOC Decline:

- "By 2100, NWT faces a significant risk of SOC decline, especially under both SSP245 and SSP585 scenarios."
- "The most vulnerable regions are in the northern and central parts, where SOC losses are projected to be the highest."

2) Peatland Contributions to Carbon Loss:

- "Peatlands play an important role in SOC loss, contributing a large proportion to the total carbon decline."
- "Additionally, this contribution is expected to increase in the future, highlighting peatlands as a critical area of concern."

3) Temperature as the Dominant Factor:

- "Temperature-related variables, particularly winter warming, are identified as the dominant drivers of SOC decline."
- "This highlights the significant impact of seasonal changes on soil carbon dynamics."

What we should do next



To Enhance Accuracy of Regional Soil Organic Carbon (SOC) Estimates

Increase Regional Sampling Points

- Focus on key landscapes such as **peatlands and permafrost regions**.
- Prioritize **bulk density measurements**, as they are crucial for accurate carbon stock calculations but currently lacking.

Refine Landscape Distribution Mapping

- Develop **high-resolution peatland and permafrost maps**.
- Essential for future modeling and spatial carbon stock assessments.



To Better Understand Carbon Cycle Response to Climate Change

Establish Laboratory Experiments

- **Simulate soil responses from different landscape types** under controlled conditions.
- Focus on turnover rates, providing key parameters for improved model accuracy.



<https://kkgfradio.com/local-news/587162>



source: <https://sc-programs.llnl.gov/>



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OF MCMASTER UNIVERSITY

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a



 Environment and
Climate Change Canada
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du Canada
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Chairs
Canada

 **Digital Research
Alliance** of Canada



Personal website
[hand43@mcmaster.c](mailto:hand43@mcmaster.ca)
a

The Future of NWT Carbon Stocks: Winter Carbon Cycling

Fereidoun Rezanezhad

A. Rafat, E. Byun, S. Slowinski, K. Hettinga, S. Saraswati, B. Persaud,
W. L. Quinton, E. R. Humphreys, K. Webster, H. Liu, B. Lennartz, M. Strack, and P. Van Cappellen



Canada's Peatlands ➡ 32% of the Global Peatland Cover

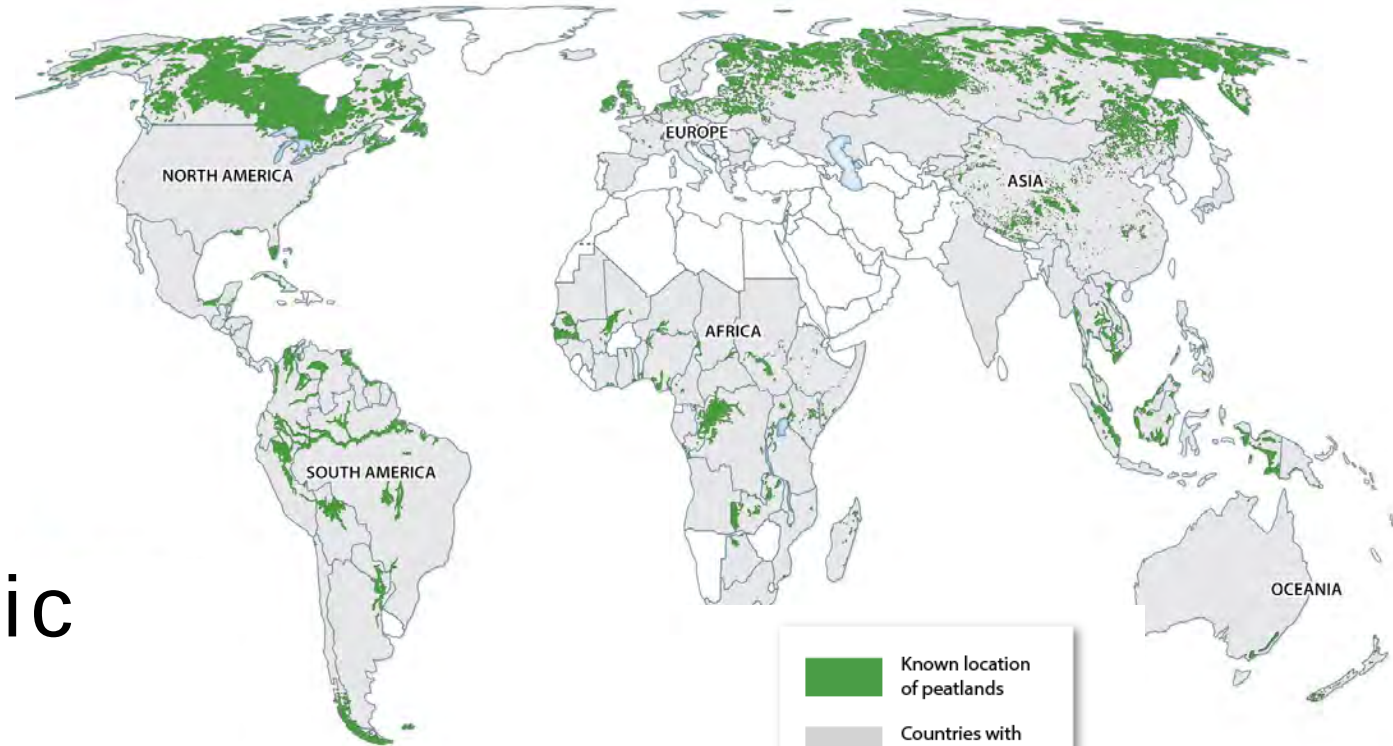
12% of Canadian land

56% of Organic Carbon
in all Canadian Soils

97% in Boreal & Subarctic

37% Frozen & Permafrost

~20% of Canadian Peatlands in N.W.T
➔ Store 24 Billion Tonnes of Carbon

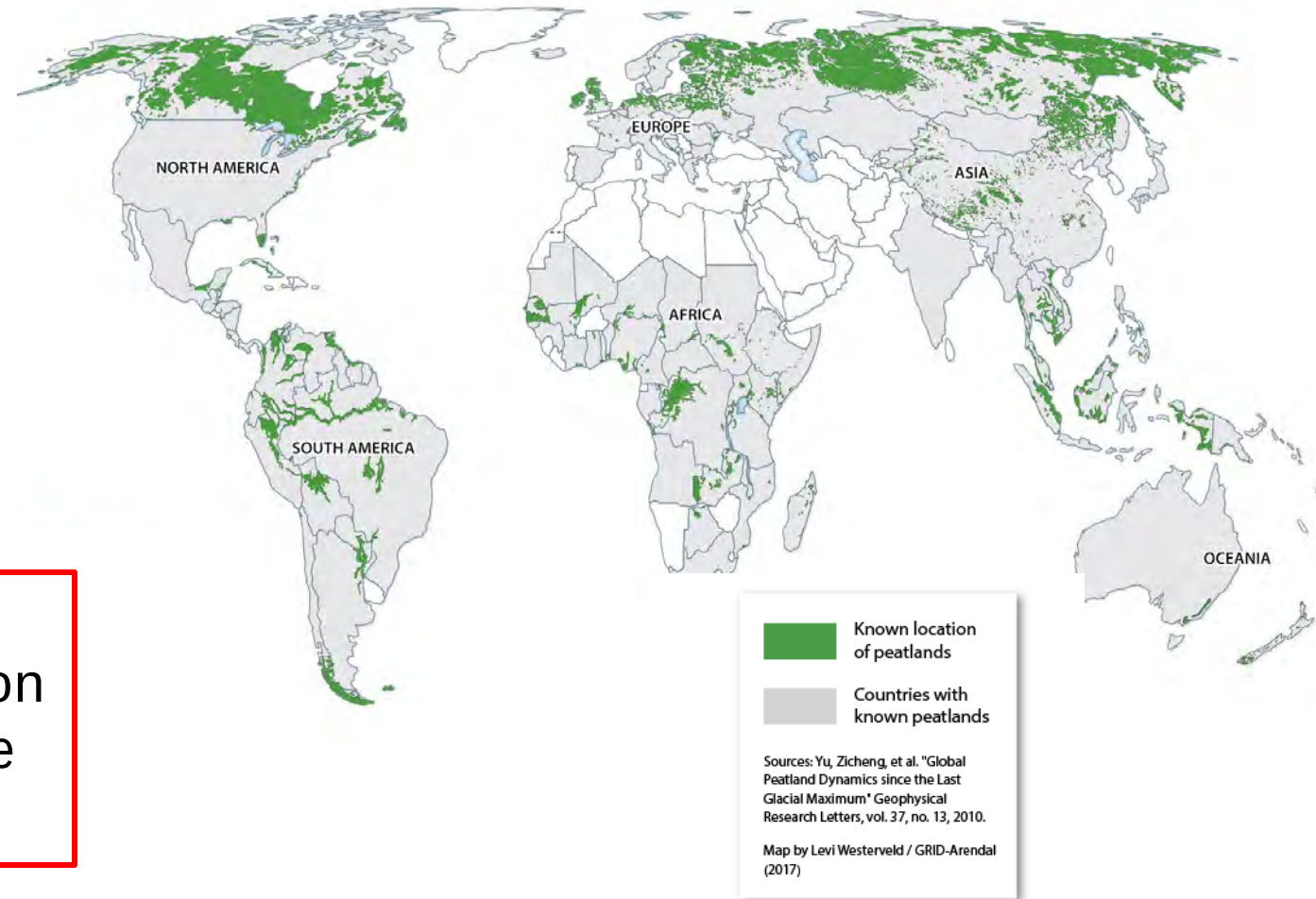


Canada's Peatlands ➡ 32% of the Global Peatland Cover

↓
Anthropogenic
Disturbances

↓
Land-use Changes &
Climate Warming

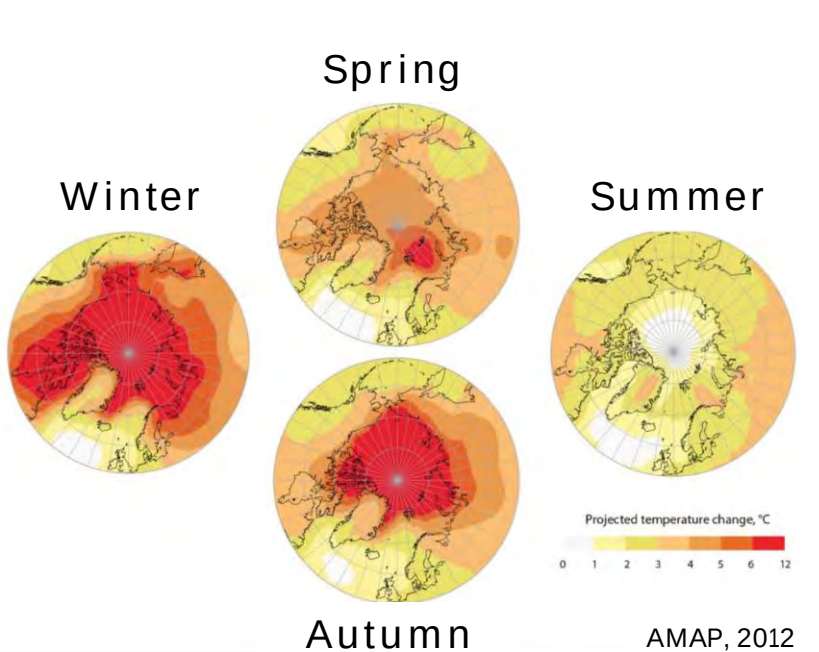
...the model predicts that ~60% of the peatlands and ~56% of the organic carbon mass will be severely affected by climate warming (Tarnocai *et al.*, 2013)



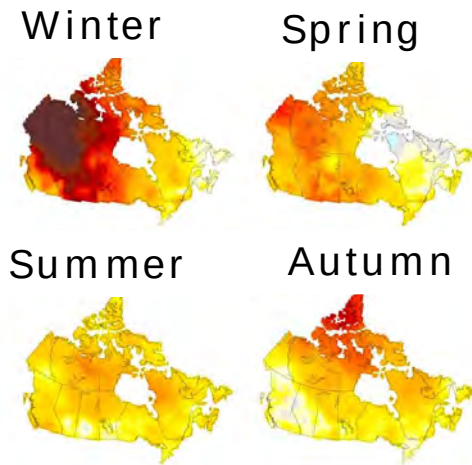
Winter Climate Warming

High latitude regions are warming faster than the global average

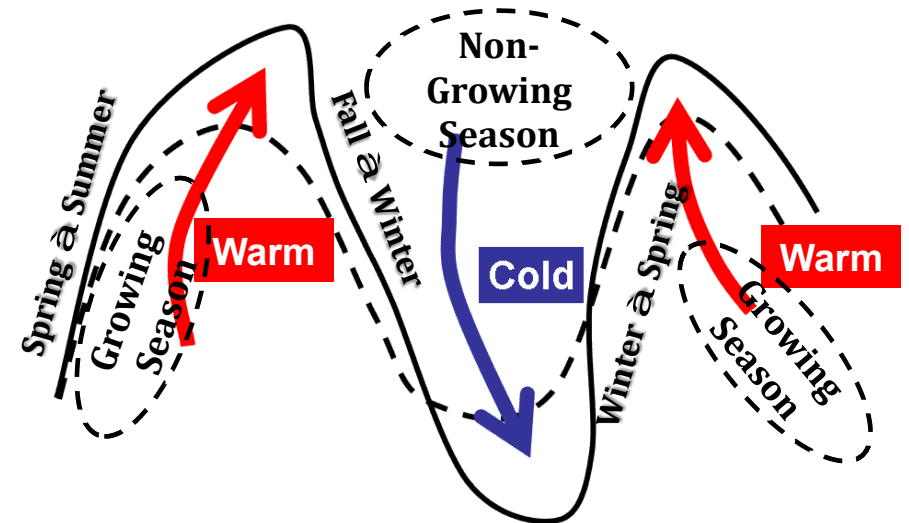
“Greatest Warming Occurring During the Winter”



Canadian peatlands are already warming



NRCan, 2019



Photos taken by Cameron Irvine

Non-Growing Season (NGS)

ENVIRONMENTAL RESEARCH
COMMUNICATIONS

The definition of the non-growing season matters:
a case study of net ecosystem carbon exchange
from a Canadian peatland



Northern Peatlands Winter Carbon Cycling

CO₂ and CH₄ flux studies during **winter** demonstrate active carbon cycling

→ important component of annual respiratory loss

Uncertainties in total peatlands carbon stock



Photo Credit: Elyn Humphreys



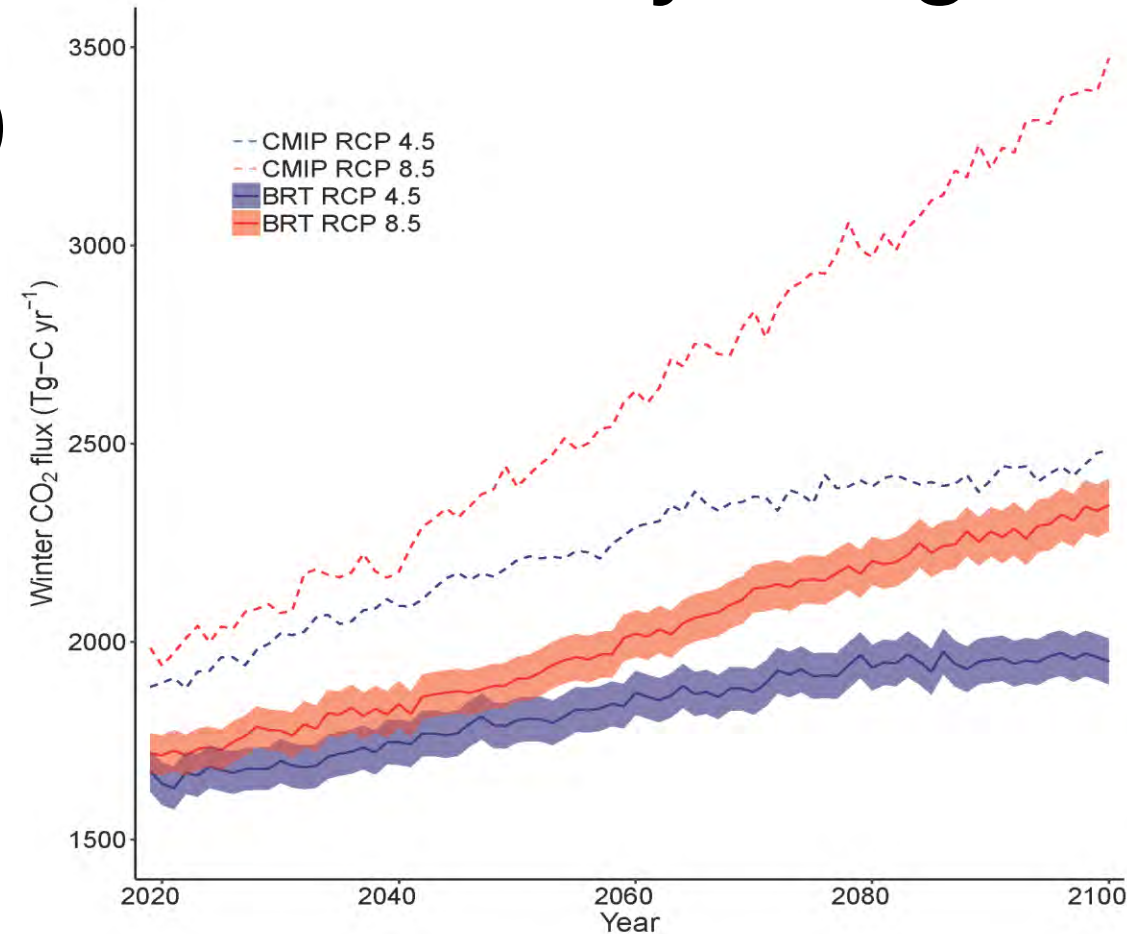
UNIVERSITY OF
WATERLOO

Northern Peatlands Winter Carbon Cycling

Large loss of CO₂ (1,662 Tg C yr⁻¹) during winter observed across northern peatland and permafrost regions

Winter emissions already shifting northern peatland/permafrost areas from an annual

Carbon Sink to a Source



LETTERS

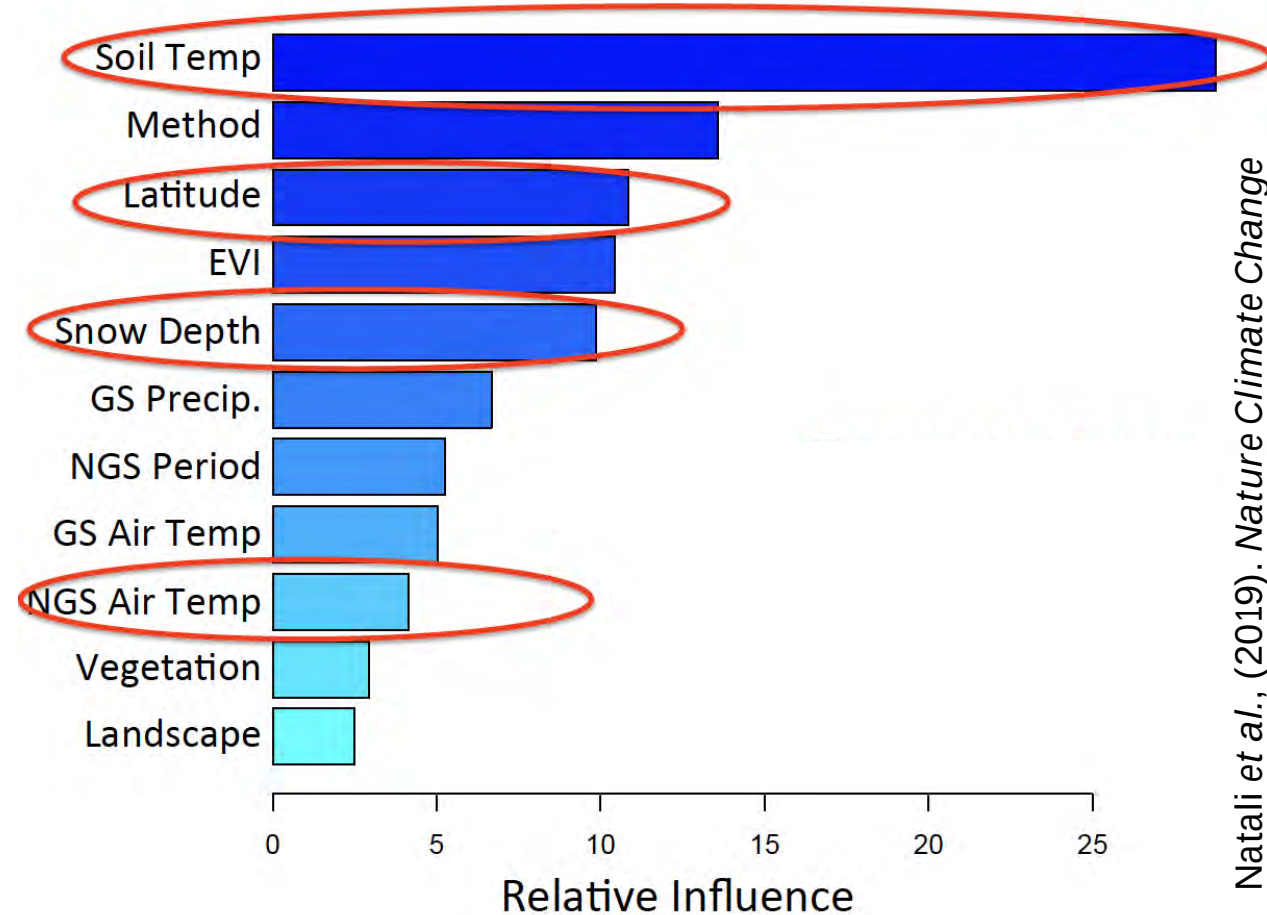
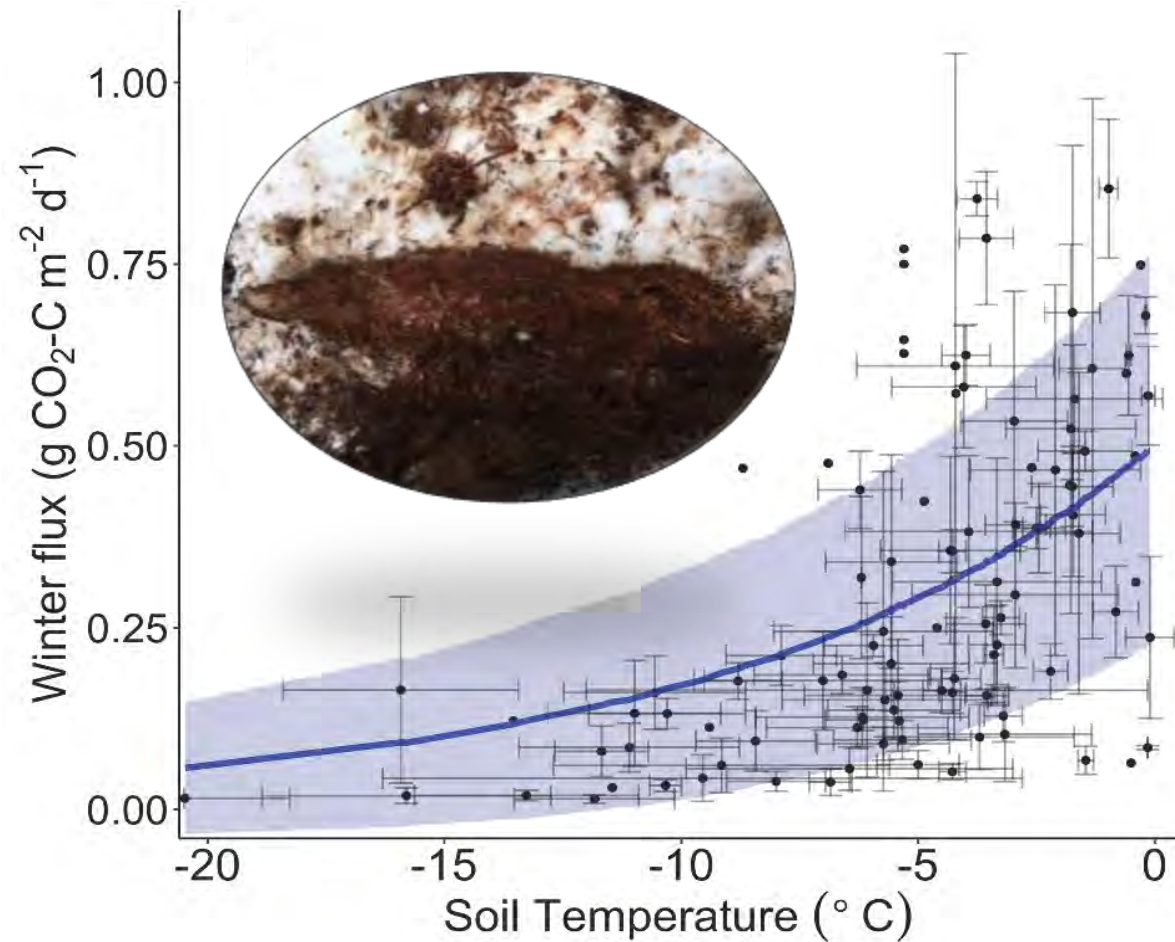
<https://doi.org/10.1038/s41558-019-0592-8>

nature
climate change

Large loss of CO₂ in winter observed across the northern permafrost region

Natali *et al.*, (2019). *Nature Climate Change*

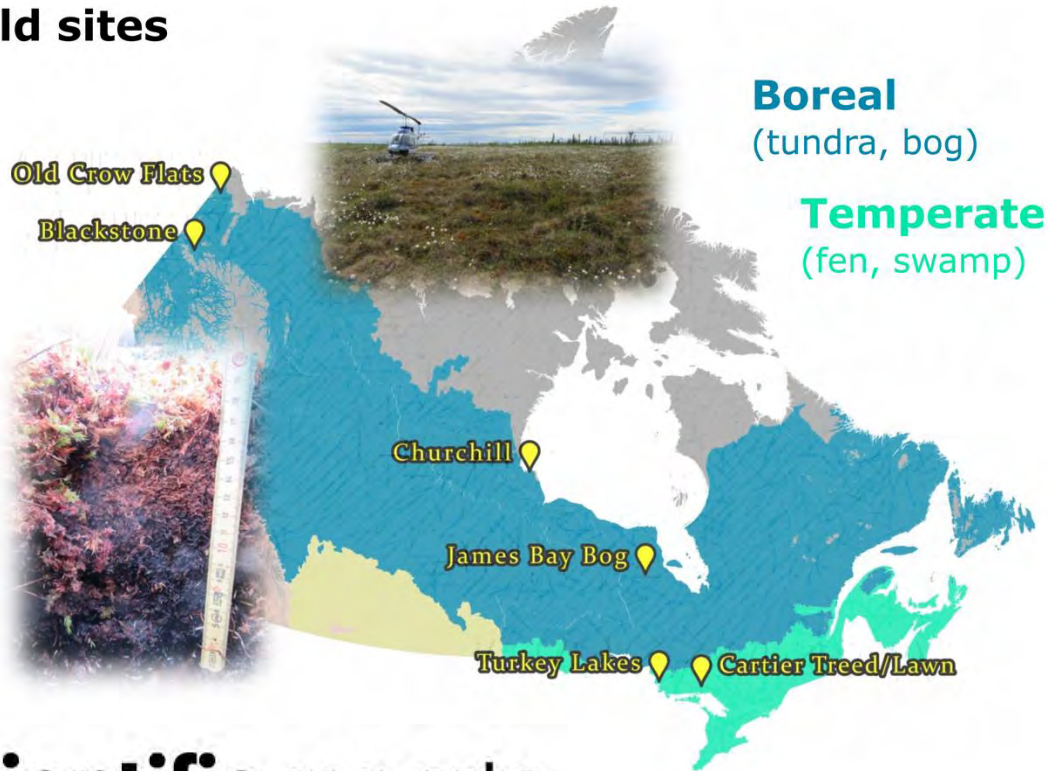
Northern Peatlands Winter Carbon Cycling



Natali et al., (2019). *Nature Climate Change*

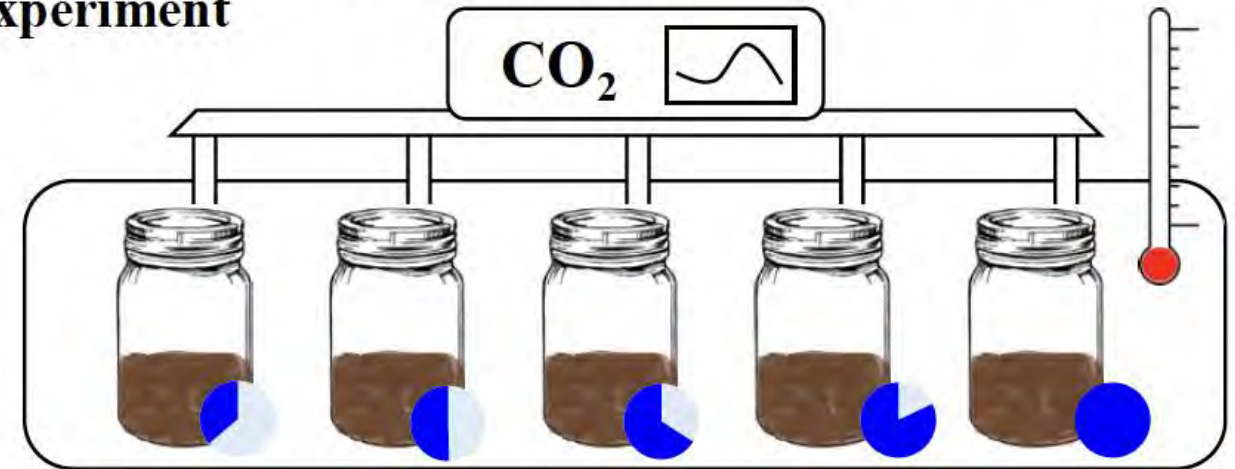
Temperature Controls on CO₂ Production

Field sites



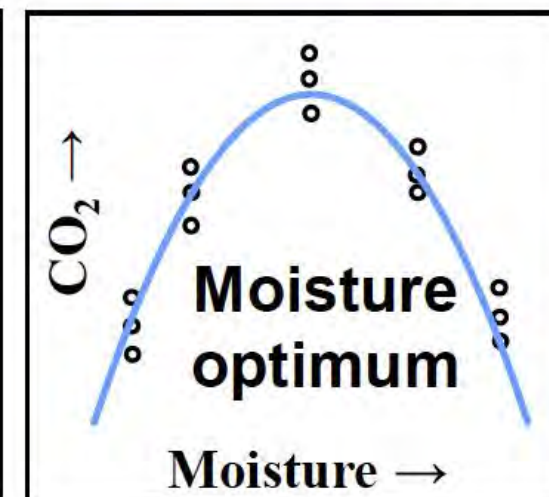
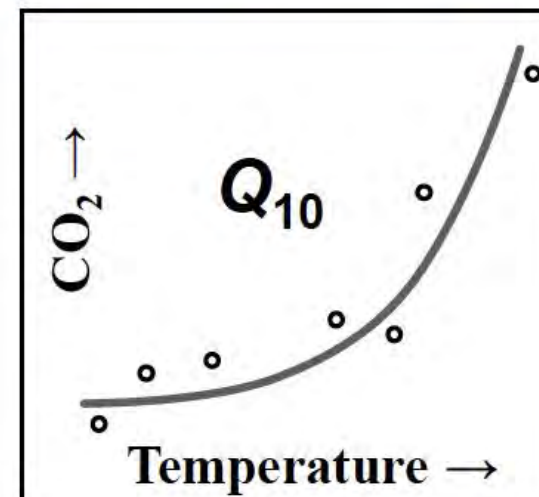
Lab incubation experiment

25°C → 35°C → 25°C → 15°C → 10°C → 1°C →
-2°C → -5°C → -10°C → -2°C → 5°C → 25°C



Data curve fitting

$$Q_{10} = \frac{R_{T+10}}{R_T}$$

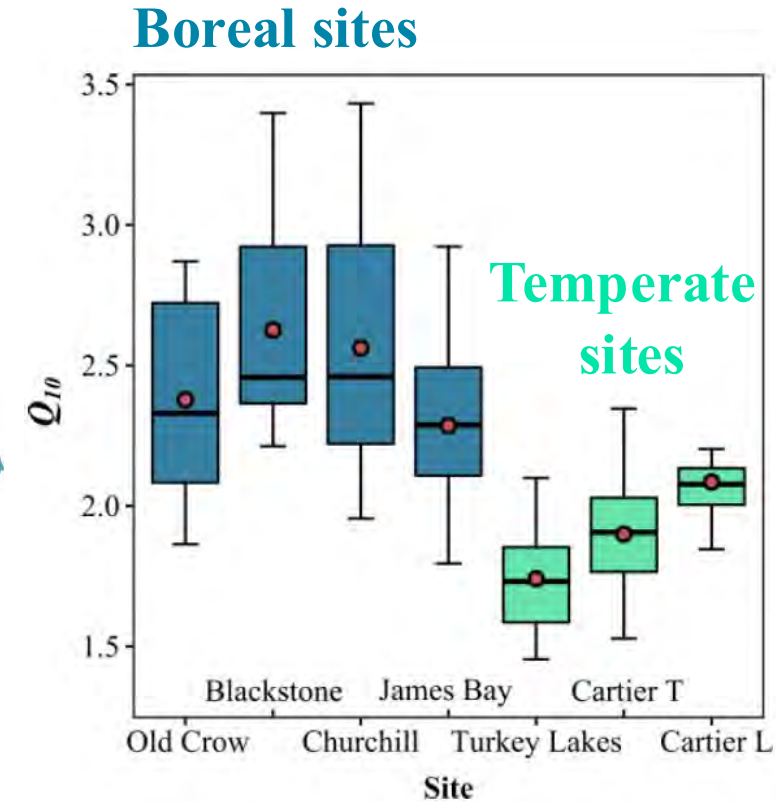
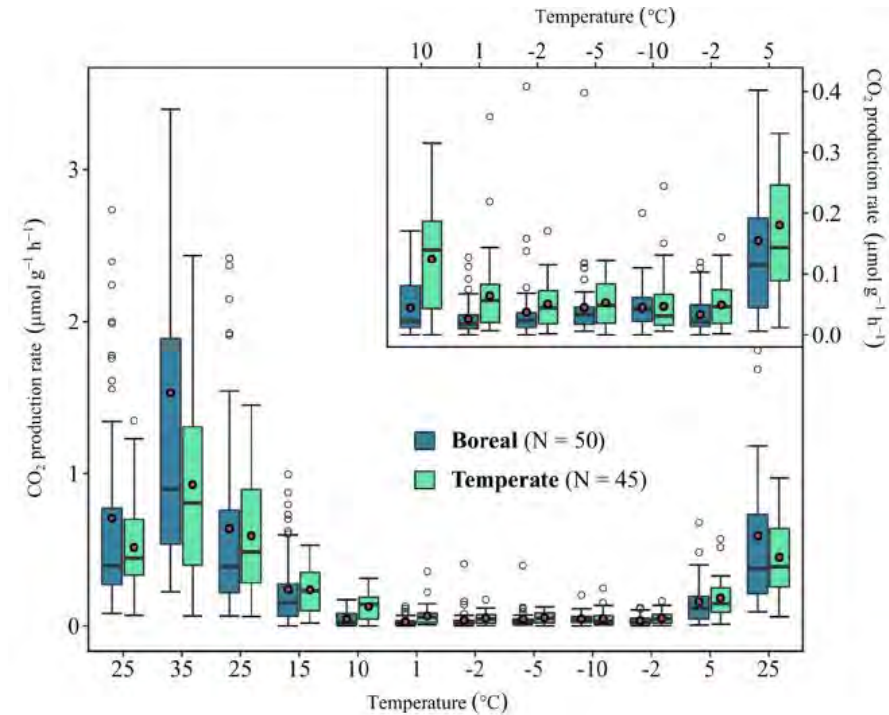


scientific reports

Temperature, moisture and freeze-thaw controls on CO₂ production in soil incubations from northern peatlands

Byun et al., (2021). *Scientific Reports*

Temperature Controls on CO₂ Production



scientific reports

Temperature, moisture and freeze–thaw controls on CO₂ production in soil incubations from northern peatlands

Byun et al., (2021). *Scientific Reports*

- ❑ CO₂ production rates were detectable even during the sub-zero conditions
- ❑ **Boreal peatlands** may increase future NGS CO₂ losses to a larger degree than **temperate peatlands**

Canada's Peatlands Winter Carbon Cycling



COMMUNICATIONS
EARTH&ENVIRONMENT

Non-growing season carbon emissions in a northern peatland are projected to increase under global warming

Rafat et al., (2021). Nature Communications Earth & Environment

- Key variables -NGS Net Ecosystem Exchanges (NEE)
- Develop Machine Learning model
- Sensitivity analysis → determine most/least sensitive variables in model
- Predict NGS NEE over 21st century, three climate scenario: RCP2.6, RCP4.5, RCP8.5

Mer Bleue Bog- Ottawa

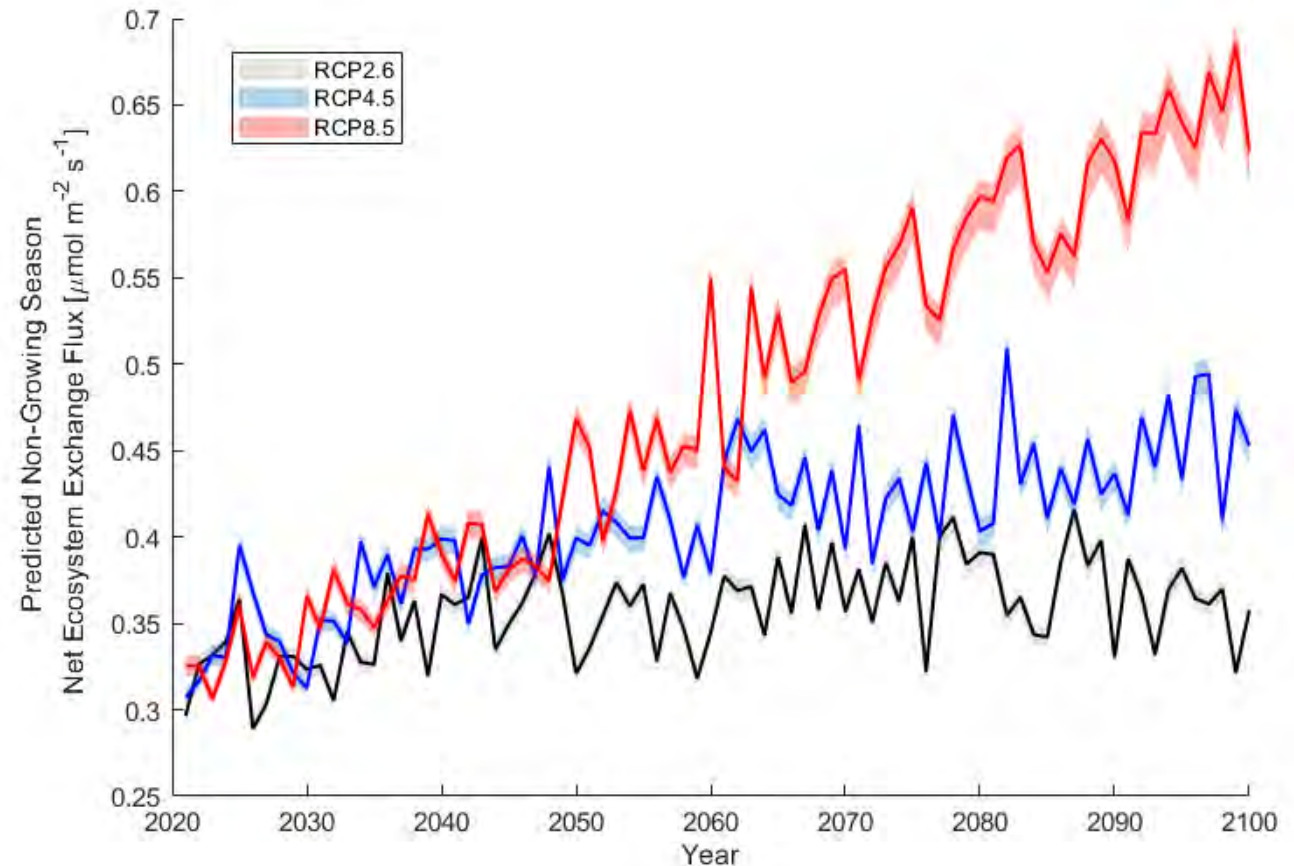
- ❑ Non-growing season (NGS):
defined by snow onset/offset



Canada's Peatlands Winter Carbon Cycling

Climate warming to increase winter carbon loss in Mer Bleue peatland by **103%**

→ projected for *Mer Bleue peatland* by 2100 under a high emission scenario



Winter is a Critical Period for Carbon Cycling in Northern Peatlands

Natural Climate Solution

- Nature-based climate change mitigation and adaption
- Reduce the uncertainty in estimating GHG emission reductions from peatland management actions



Acknowledgments

This project was undertaken with the financial support of the Government of Canada.

Ce projet a été réalisé avec l'appui financier du gouvernement du Canada.

Canada

CAN-PEAT



Universität
Rostock



Traditio et Innovatio

BALTIC
TRANSCOAST



Health
Canada



Canada
Natural Resources Canada
Canadian Forest Service



Environment and
Climate Change Canada
Environnement et
Changement climatique Canada

ecohydrology
research group



Questions?

CONTACT: frezanez@uwaterloo.ca



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- A. Rafat, A., Rezanezhad, F., Quinton, W. L., Humphreys, E. R., Webster, K., Van Cappellen, P. (2021). Non-growing season carbon emissions in a northern peatland are projected to increase under global warming. *Communications Earth & Environment*, 2:111
- E. Byun, F. Rezanezhad, L. Fairbairn, S. Slowinski, N. Basiliko, J. S. Price, W. L. Quinton, P. Roy-Léveillé, K. Webster, and P. Van Cappellen. (2021). Temperature, moisture and freeze–thaw controls on CO₂ production in soil incubations from northern peatlands. *Scientific Reports*, 11:23219,
- H. Liu, F. Rezanezhad, D. Zak, X. Li, B. Lennartz. (2022). Freeze-thaw cycles alter soil hydro-physical properties and dissolved organic carbon release from peat. *Frontiers in Environmental Science-Biogeochemical Dynamics*, 10:930052.
- A. Rafat, E. Byun, F. Rezanezhad, W. L. Quinton, E. R. Humphreys, K. Webster, P. Van Cappellen. (2022). The definition of the non-growing season matters: a case study of net ecosystem carbon exchange from a Canadian peatland. *Environmental Research Communications*, 4, 021003.
- F. Rezanezhad, M. Bieroza, A. Contosta, A., P. Van Cappellen (2023). Editorial: The Cold Regions in Transition: Impacts on Soil and Groundwater Biogeochemistry. *Frontiers in Environmental Science*, 11, 1143388.
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Introducing Nature based Solutions

Northwest Territories

February 5, 2025

Prepared by Climate Change Unit, GNWT

Nature based Solutions **Definition**

Protect



Manage

ECOSYSTEMS

Restore



Climate Change
Biodiversity Loss
Water Security
Well-being
Food Production
Disaster Risk



Nature based Solution Categories

Protect

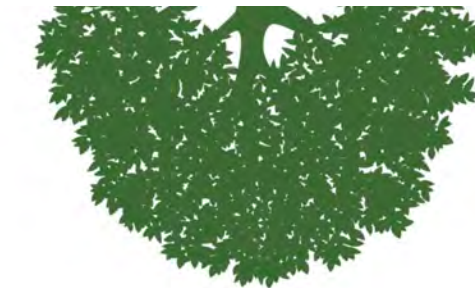
parks and protected areas



ECOSYSTEMS

Manage

prescribed fires or forest thinning



Restore

rewetting dried peatlands



Northwest Territories: Context

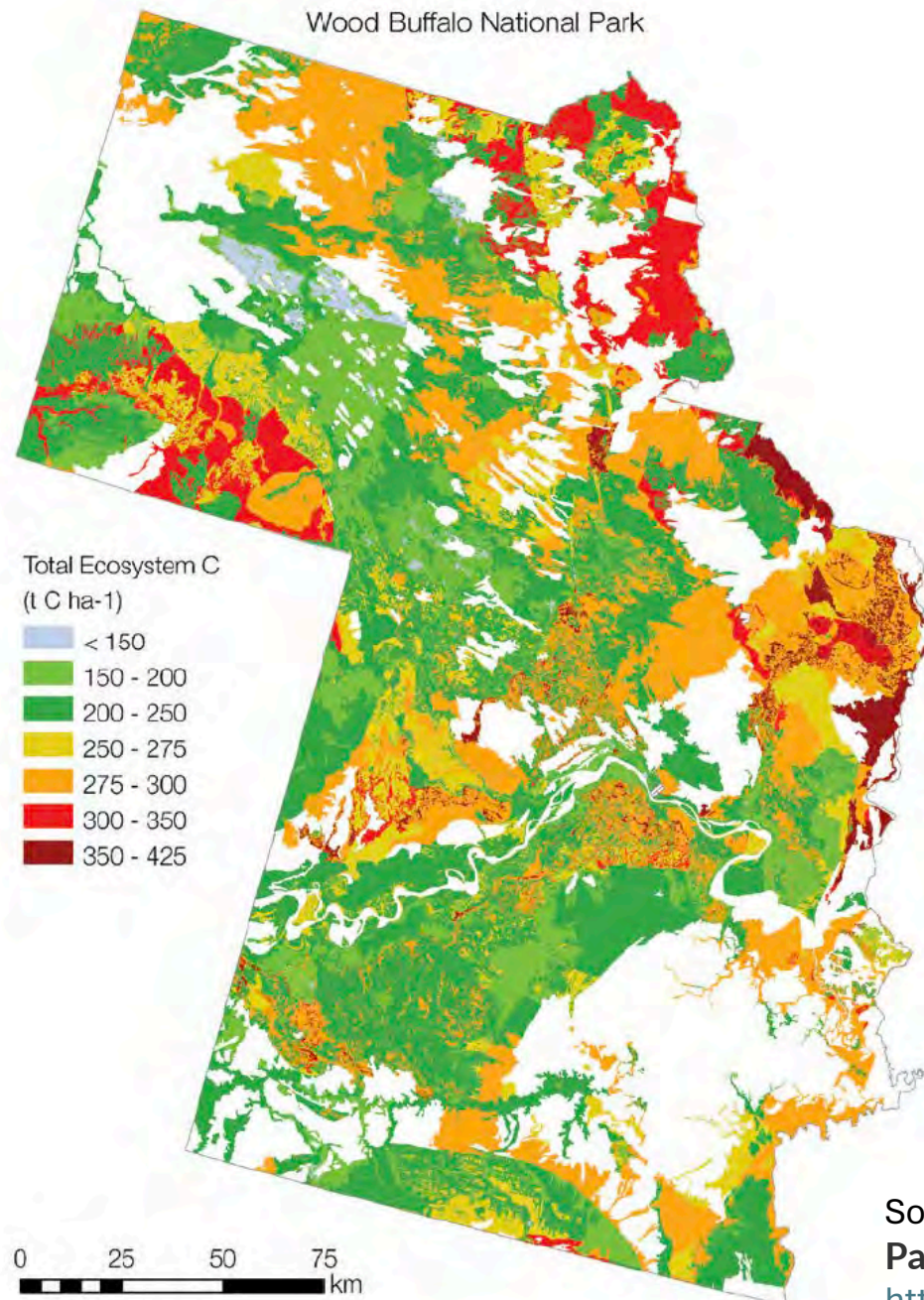
Wildfires 2023

356 Mt CO₂e

Peat Degradation, Permafrost Thaw

~ 24 Bt C





1990 - 2019

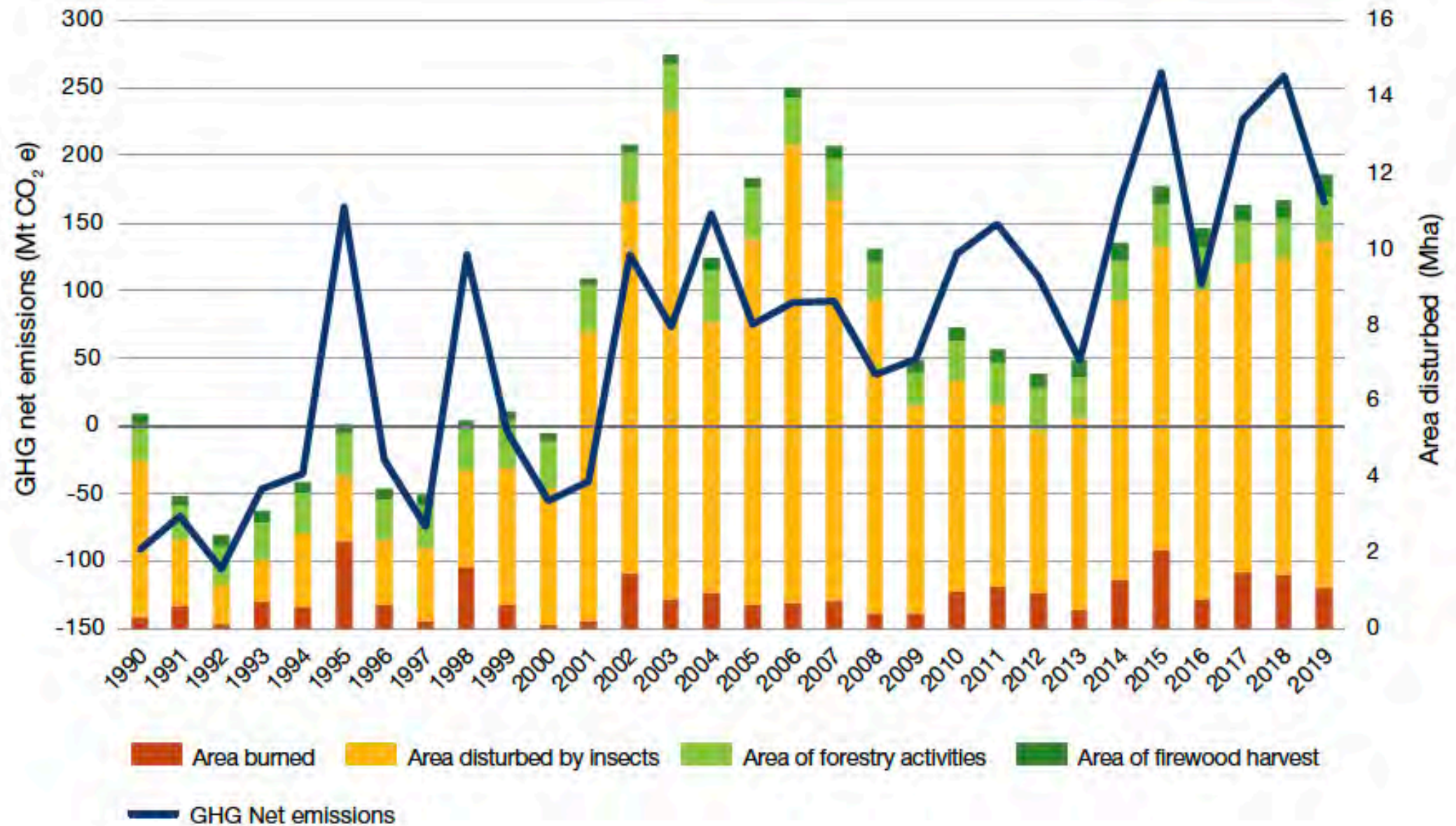
2 Mt CO₂e/ annum

NbS Management

Offset NWT emissions

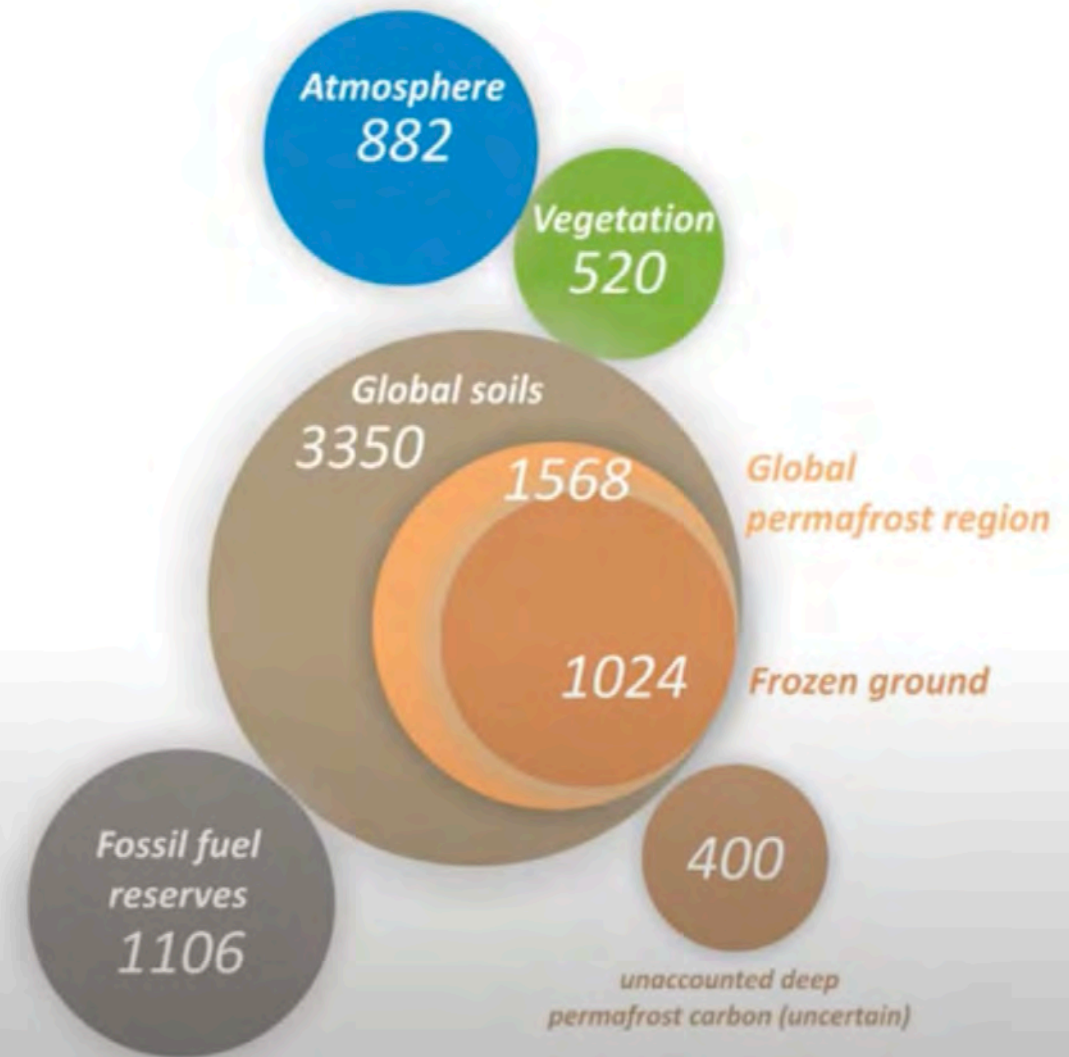
Source: Parks Canada Carbon Atlas Series: Carbon Dynamics in the Forests of National Parks in Canada

<https://open.canada.ca/data/en/dataset/4cc14294-b40d-40f2-bb27-201e40e1ded4>



Source: Parks Canada Carbon Atlas Series: Carbon Dynamics in the Forests of National Parks in Canada
<https://open.canada.ca/data/en/dataset/4cc14294-b40d-40f2-bb27-201e40e1ded4>

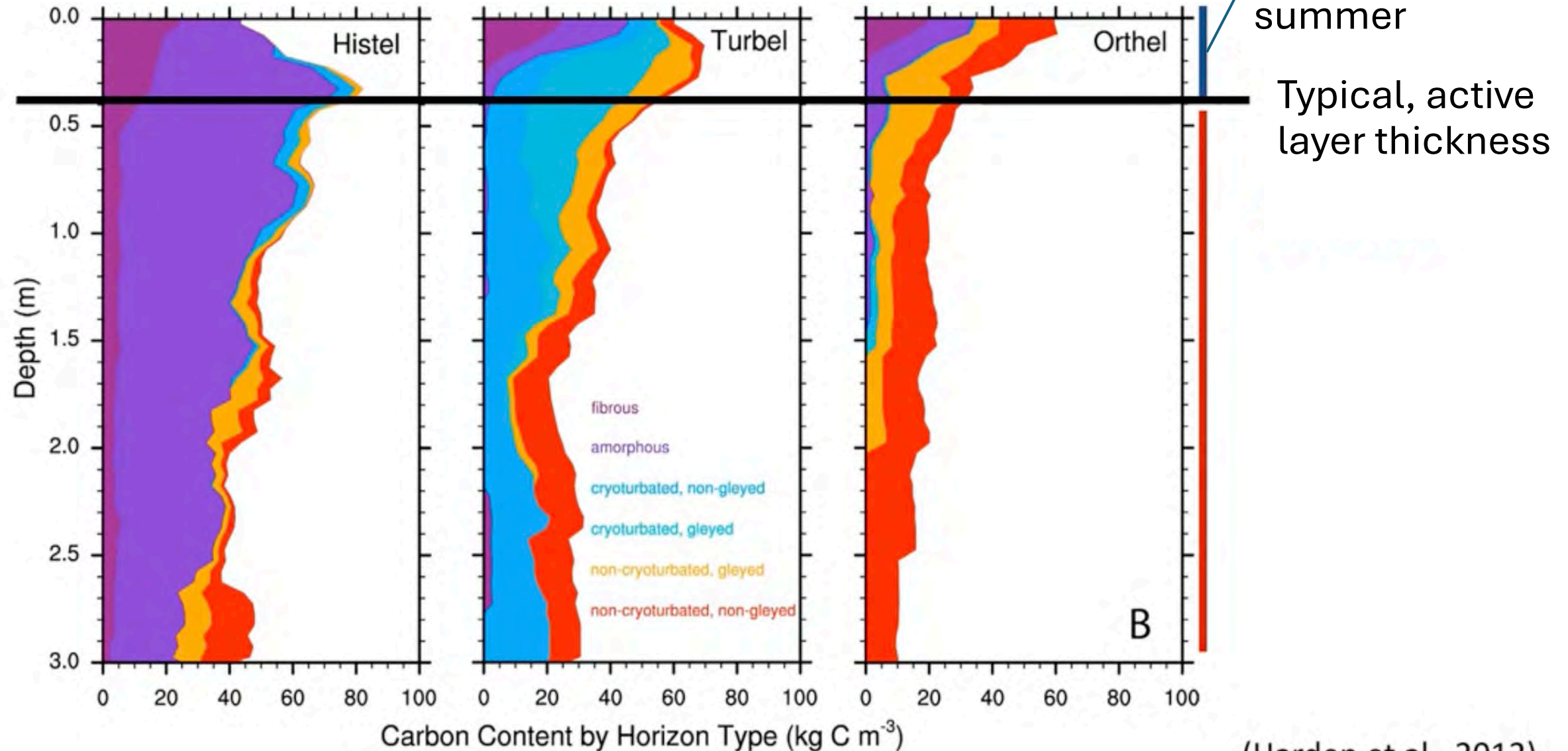
Landscape and Atmospheric Carbon



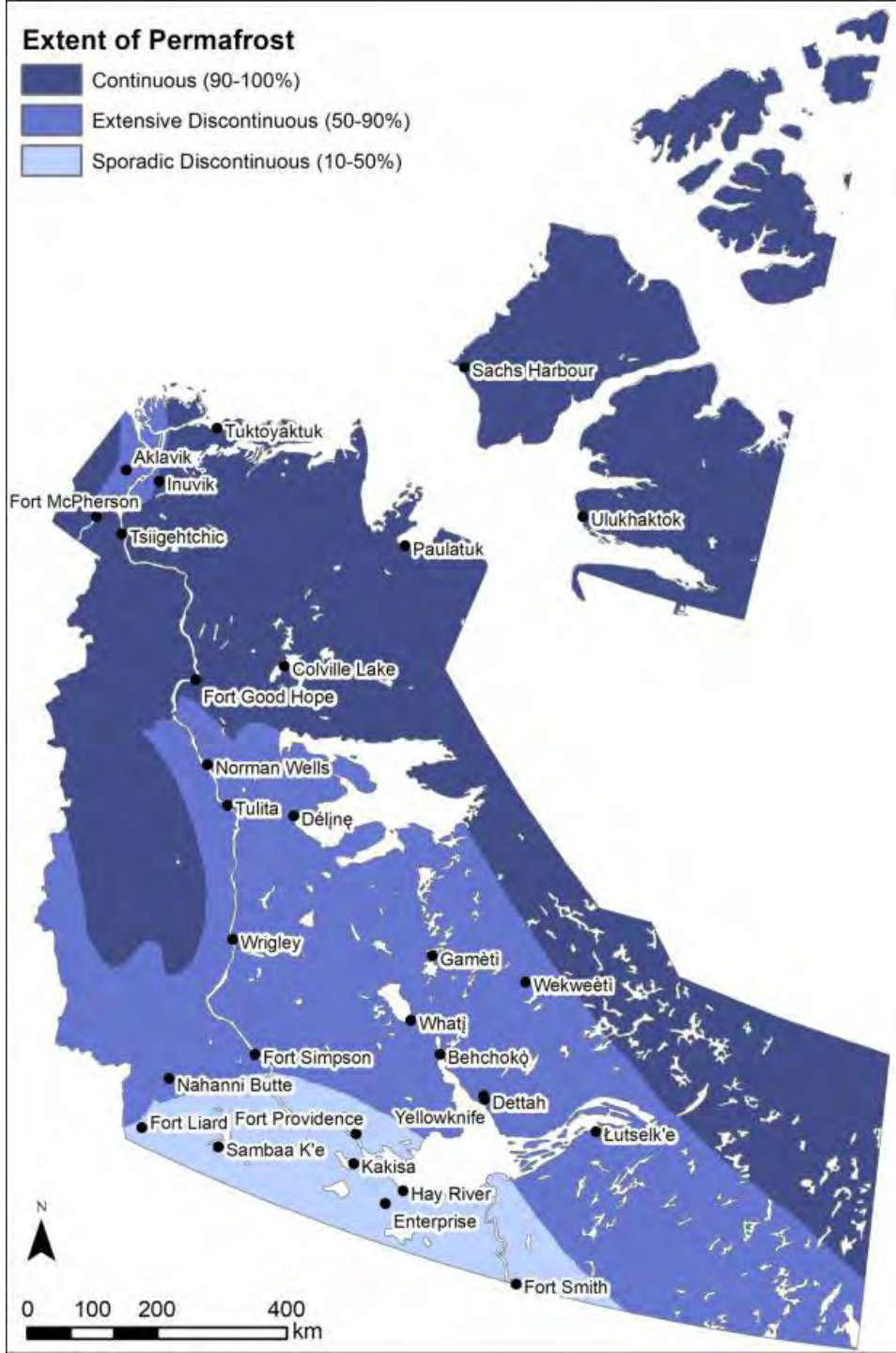
Source: Strauss et al. (2021), FAO



High C stocks in permafrost



(Harden et al., 2012)



Widespread Permafrost *Across NWT*

Question *Can NbS protect Permafrost?*

Source: <https://www.gov.nt.ca/ecc/en/services/nwt-state-environment-report/13-state-permafrost>

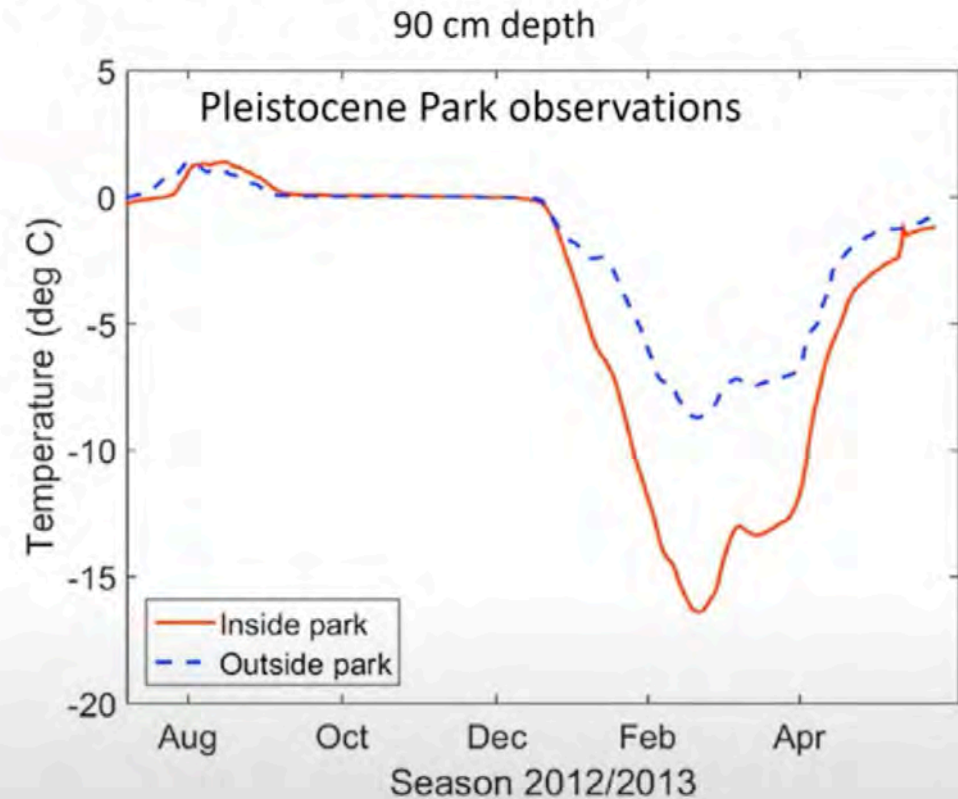
A photograph of a herd of bison in a snowy, open landscape. The bison are dark brown with thick, shaggy fur. They are standing in a line, facing towards the left. The ground is covered in snow, and the background is a hazy, snow-covered field. The overall tone is cold and wintry.

The Pleistocene Park

Animals save the permafrost

Source: <https://pleistocenepark.org>

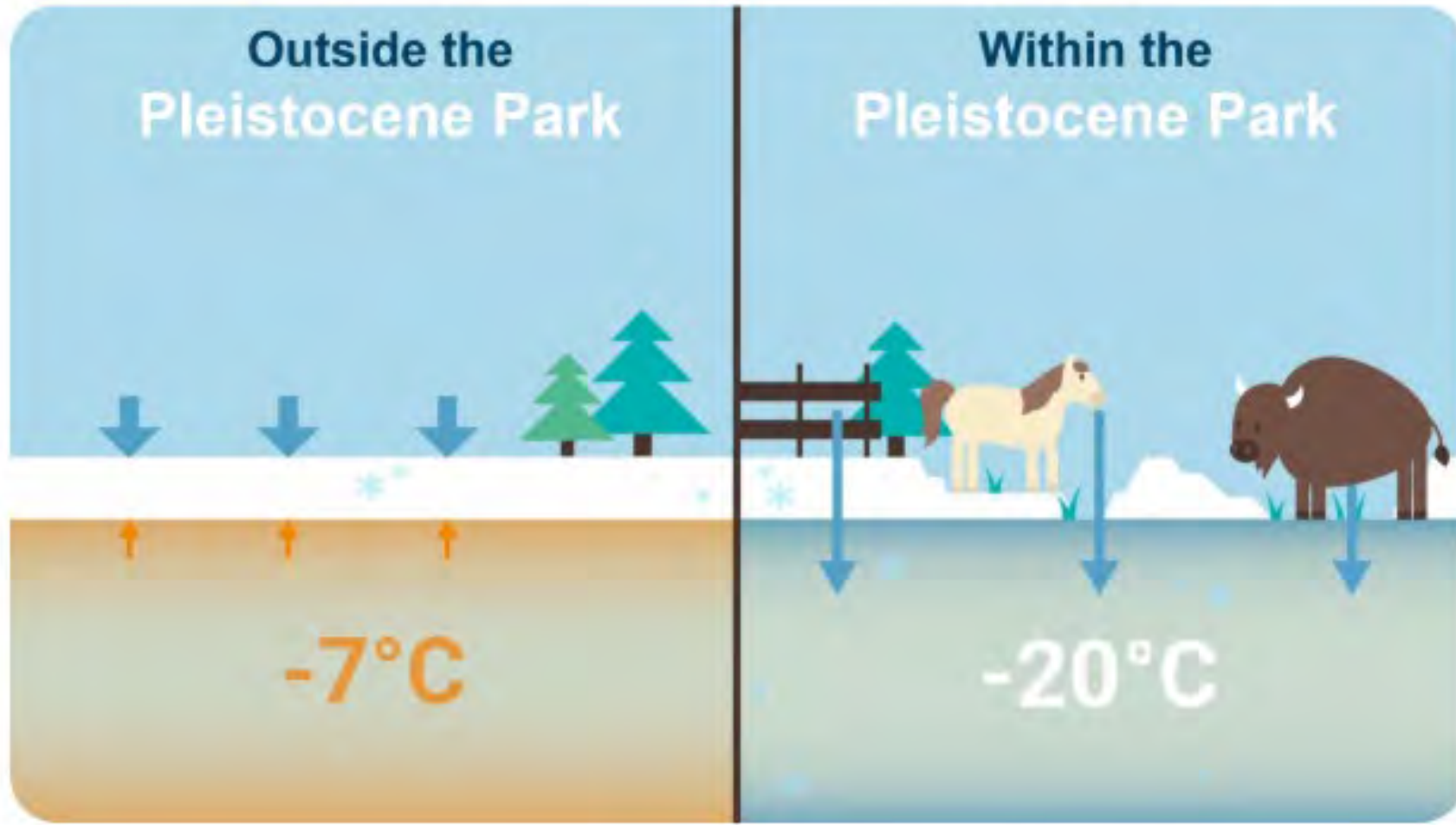
Idea by Sergey Zimov, Chersky, Russia: Herbivores trample down insulating layer snow → soil cooling



Source: Beer, C., Zimov, N., Olofsson, J., Porada, P., & Zimov, S. (2020). Protection of permafrost soils from thawing by increasing herbivore density. *Scientific reports*, 10(1), 4170.

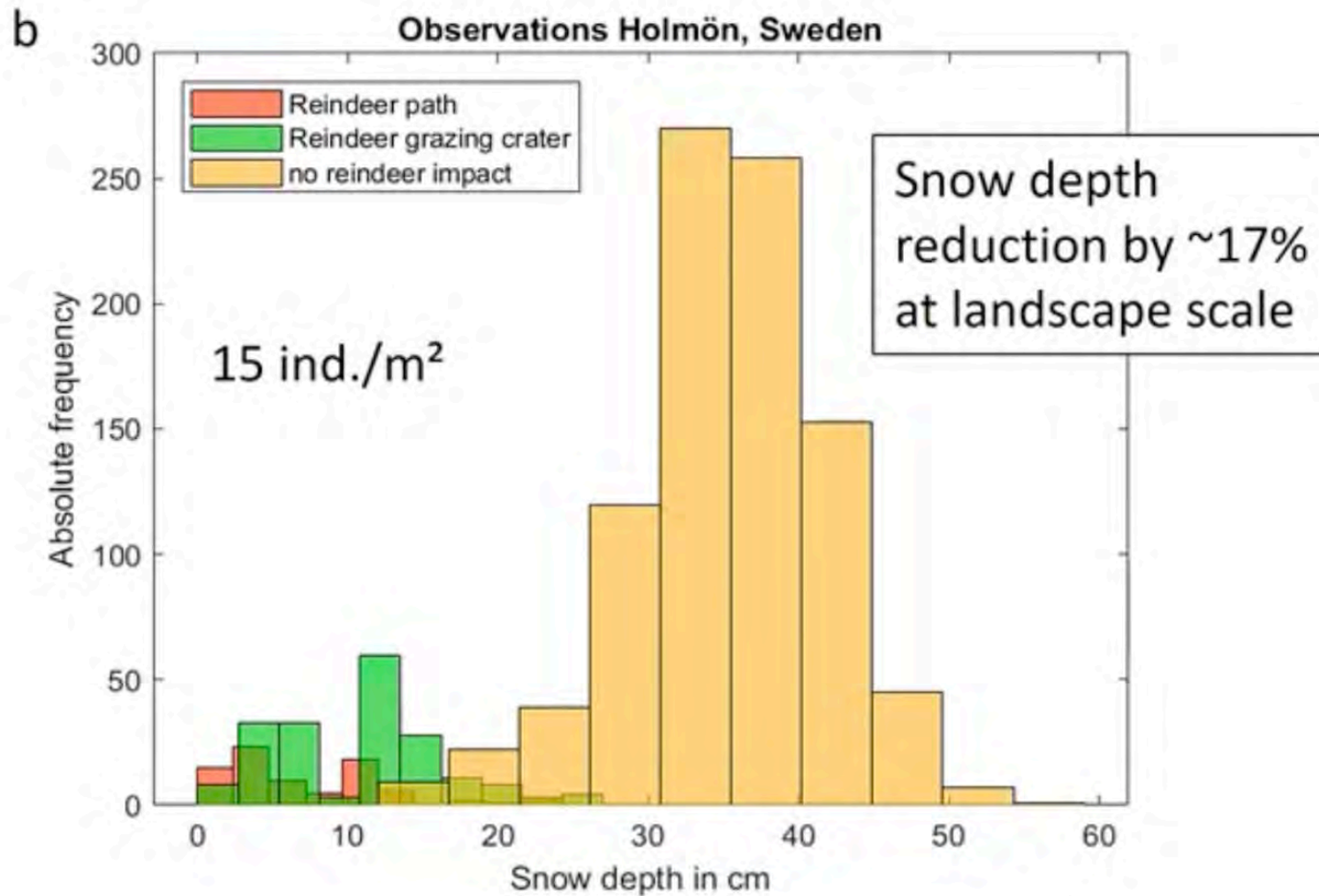
<https://www.youtube.com/watch?v=3fBx9mq6h7E>





Source: <https://pleistocenepark.org>

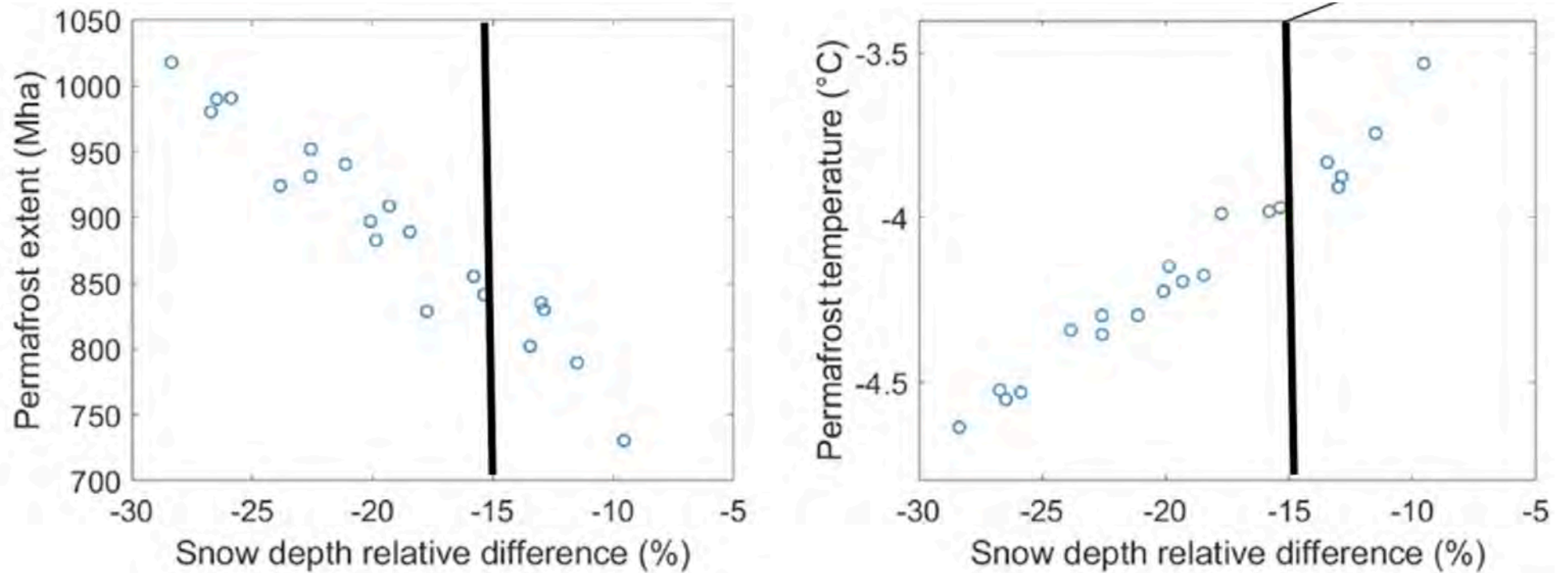




Source: Beer, C., Zimov, N., Olofsson, J., Porada, P., & Zimov, S. (2020). Protection of permafrost soils from thawing by increasing herbivore density. *Scientific reports*, 10(1), 4170.

<https://www.youtube.com/watch?v=3fBx9mq6h7E>





Source: Beer, C., Zimov, N., Olofsson, J., Porada, P., & Zimov, S. (2020). Protection of permafrost soils from thawing by increasing herbivore density. *Scientific reports*, 10(1), 4170.

<https://www.youtube.com/watch?v=3fBx9mq6h7E>



Additional Resources

<https://pleistocenepark.org>



Additional Resources

<https://www.nature.com/articles/s41598-020-60938-y>

<https://youtu.be/2ucmiJiEHJ4>



Nature based Solutions

Protect

parks and protected areas

Manage

prescribed fires or forest thinning

Restore

rewetting dried peatlands



ECOSYSTEMS





Thanks for listening!

Khizr Imran Tajammul
Climate Change Technical Specialist
ECC, GNWT

Khizr_Tajammul@gov.nt.ca



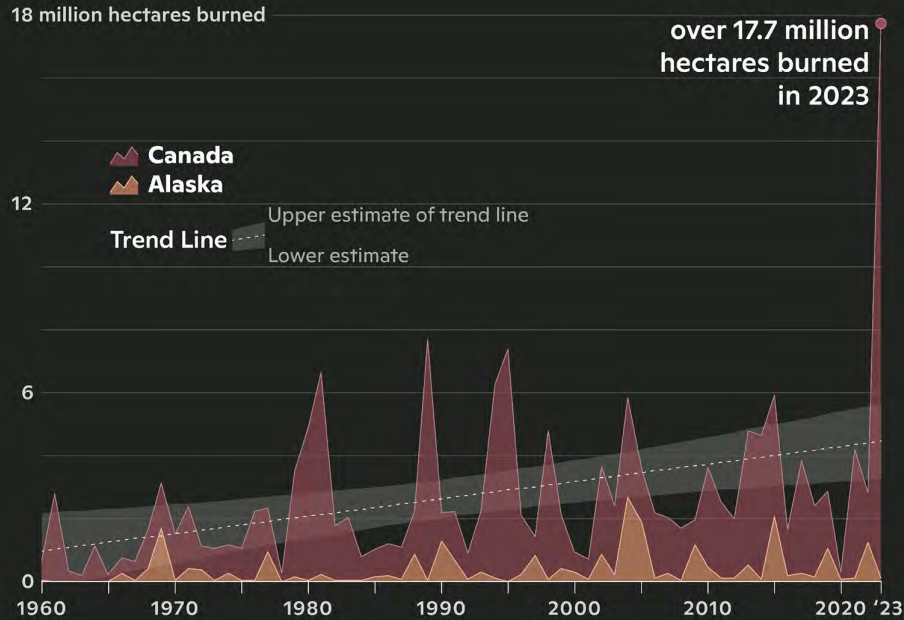
Protecting carbon and permafrost with boreal fire management

Kayla Mathes, Brendan Rogers
Woodwell Climate Research Center

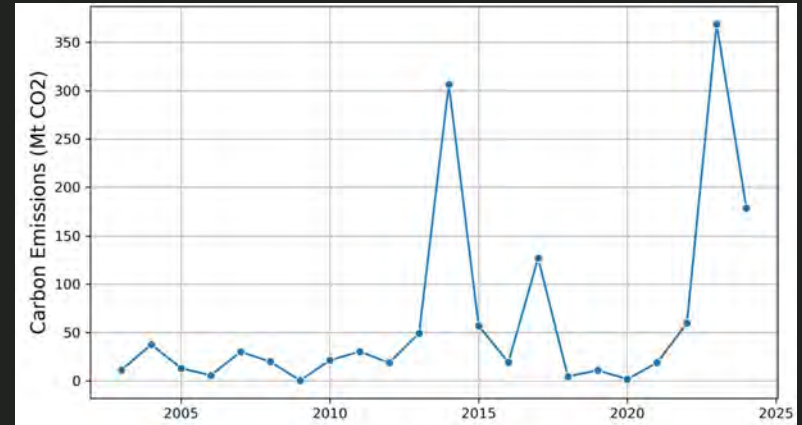
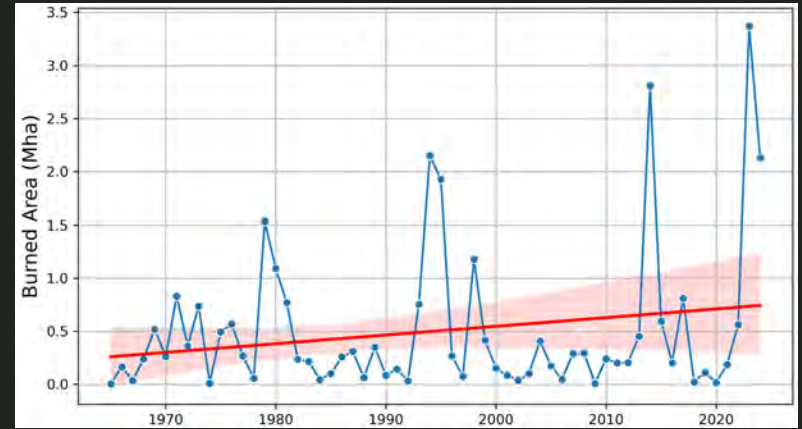


Landscape Carbon Workshop, Yellowknife NWT, February 5th, 2025

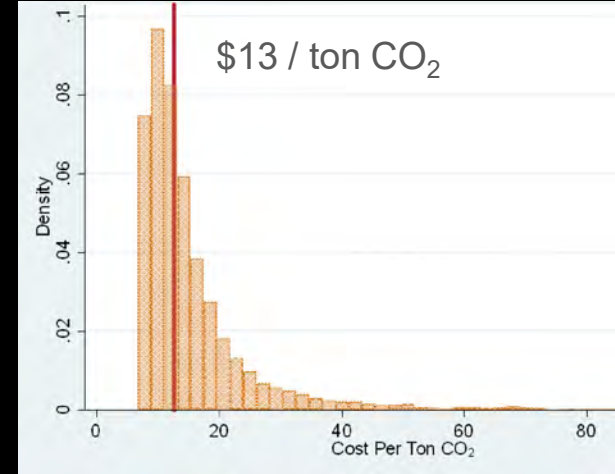
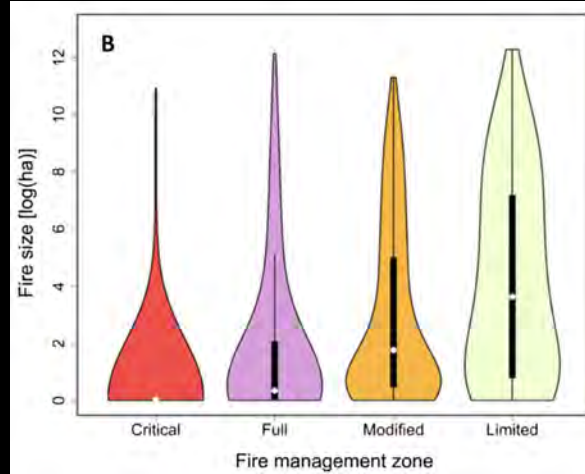
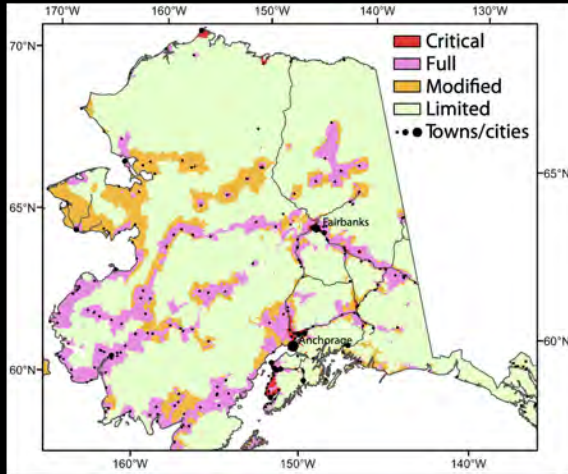
Increasing fire in Canada / Northwest Territories



Data: Alaska Interagency Coordination Center; Canadian Wildland Fire Information System; Kasoche, E. S., et al. (2002). <https://doi.org/10.1071/WF02023>; Stocks, B. J., et al. (2003). <https://doi.org/10.1029/2001JD000484>



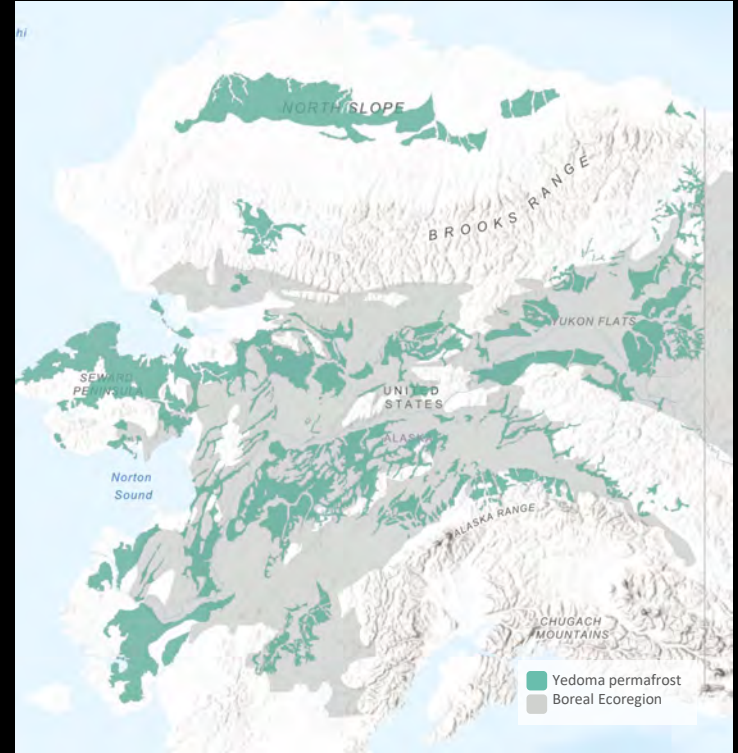
Fire management as a climate solution



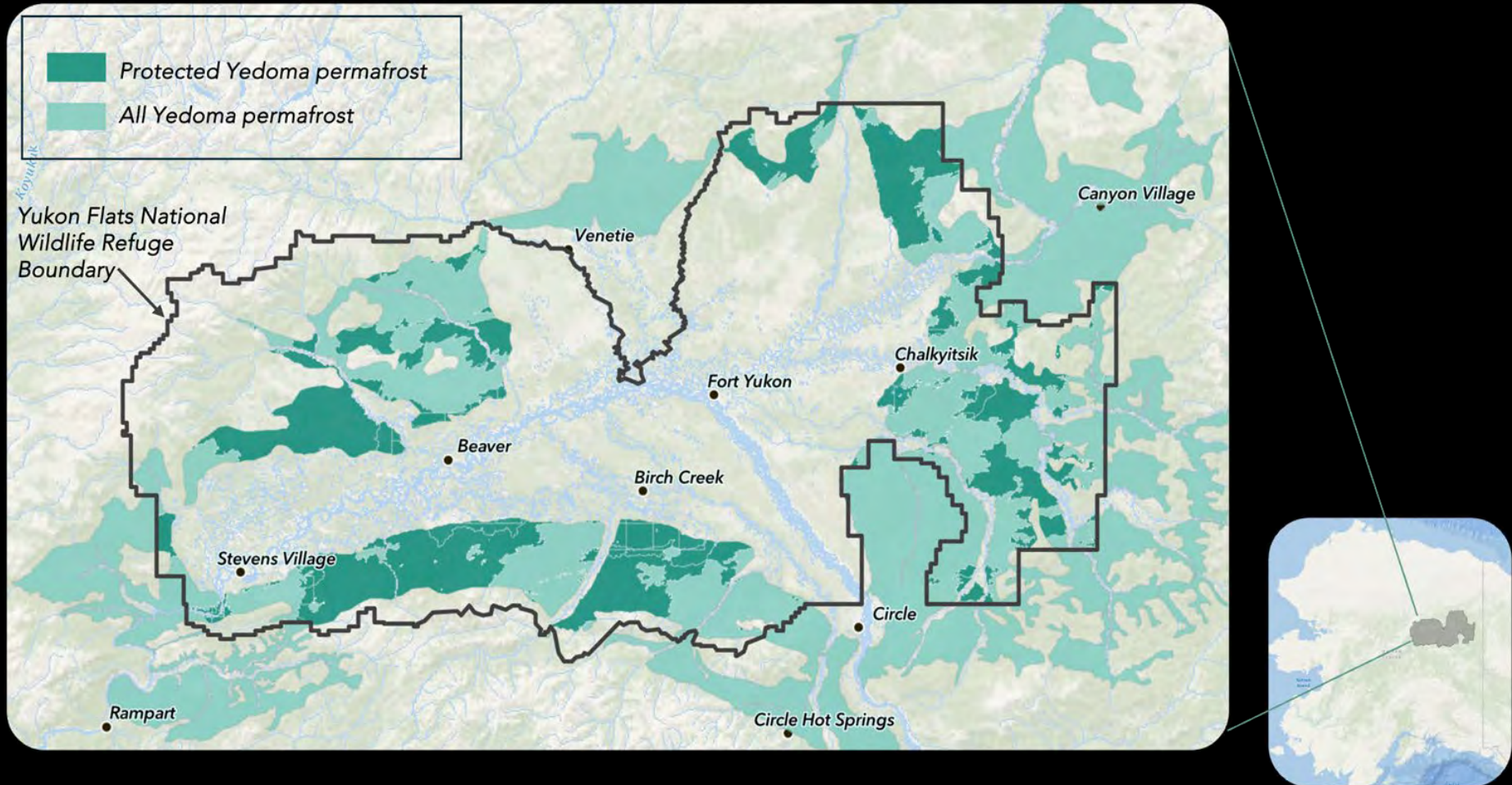
Fire - permafrost



Photo: Torre Jorgenson



Pilot Project: Yukon Flats National Wildlife Refuge, Alaska



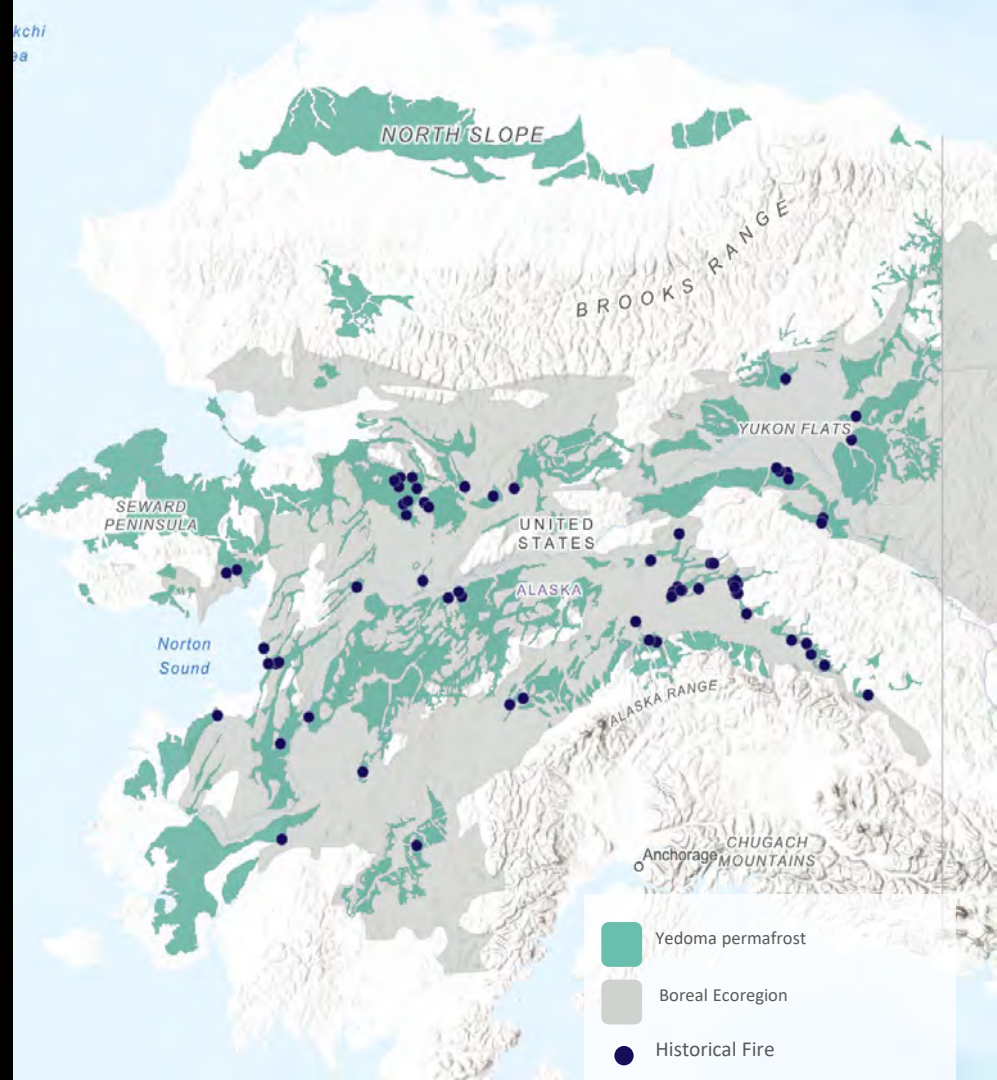


Research Objective

Estimate avoided carbon emissions from targeted fire suppression on the YFNWR and quantify its cost-effectiveness as a climate mitigation strategy.

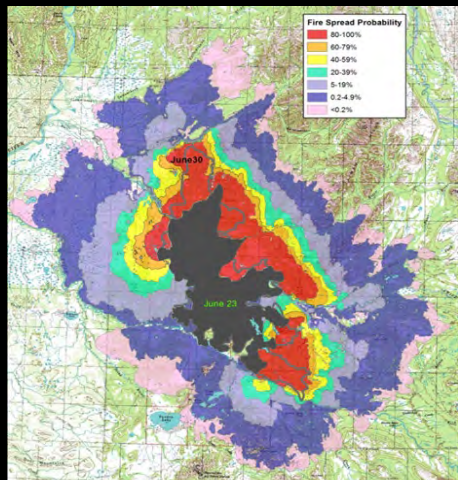
Historical fire dataset

Leveraging historical fire data
on yedoma permafrost land
across Alaska



Research Framework

1. *How big would these fires have been without suppression?*



Model counterfactual
fire spread

2. *How much carbon was protected?*



Avoided carbon emissions from
combustion and permafrost
thaw

3. *How much did it cost?*



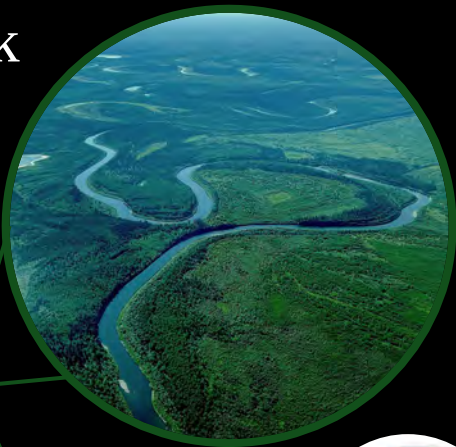
\$\$ per ton of avoided
CO₂ emissions

Estimate the cost of the fire
suppression efforts and compare to
other climate mitigation strategies

Expanding values-at-risk



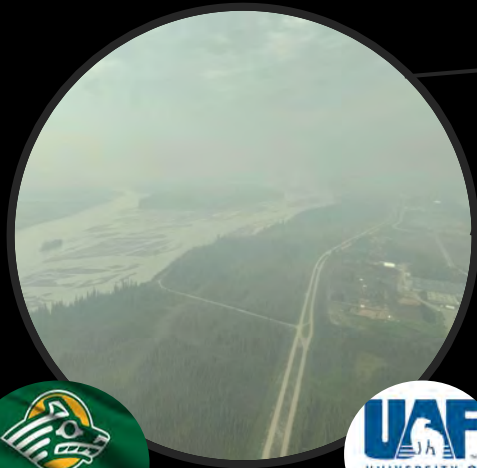
Carbon
Climate



Habitat
Ecosystems

Smoke
Health

Subsistence
Indigenous fire
stewardship

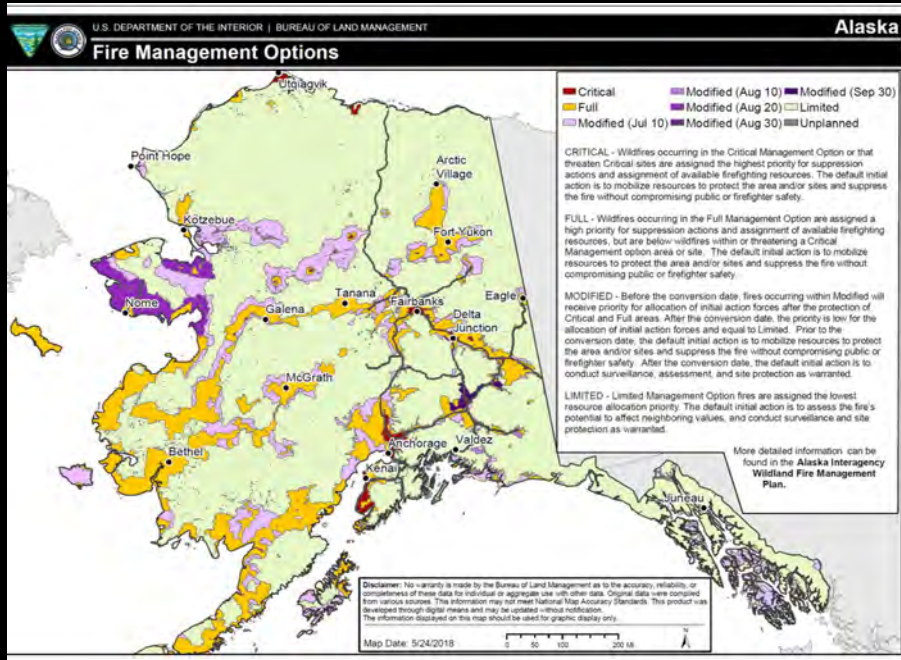


Advocating for complementary fire management strategies



Expanding this work & informing fire management policy

Carbon vulnerability to wildfire mapping project



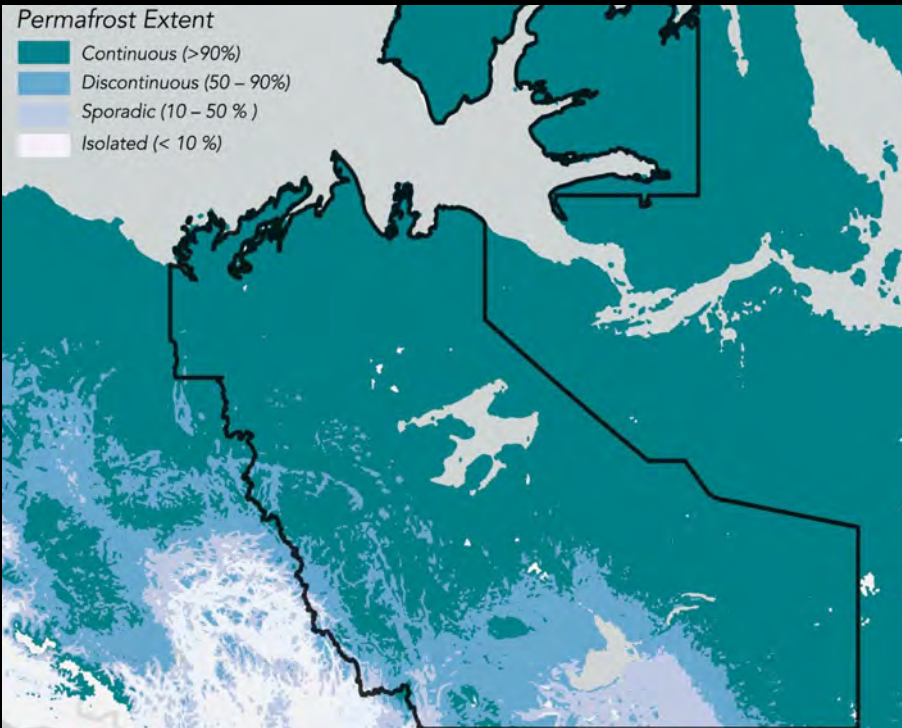
Contains information licensed under the Open Government Licence - Canada

Fig 1. A map of the area examined. The grey shaded regions represent the forested area within the provincial fire suppression zones.

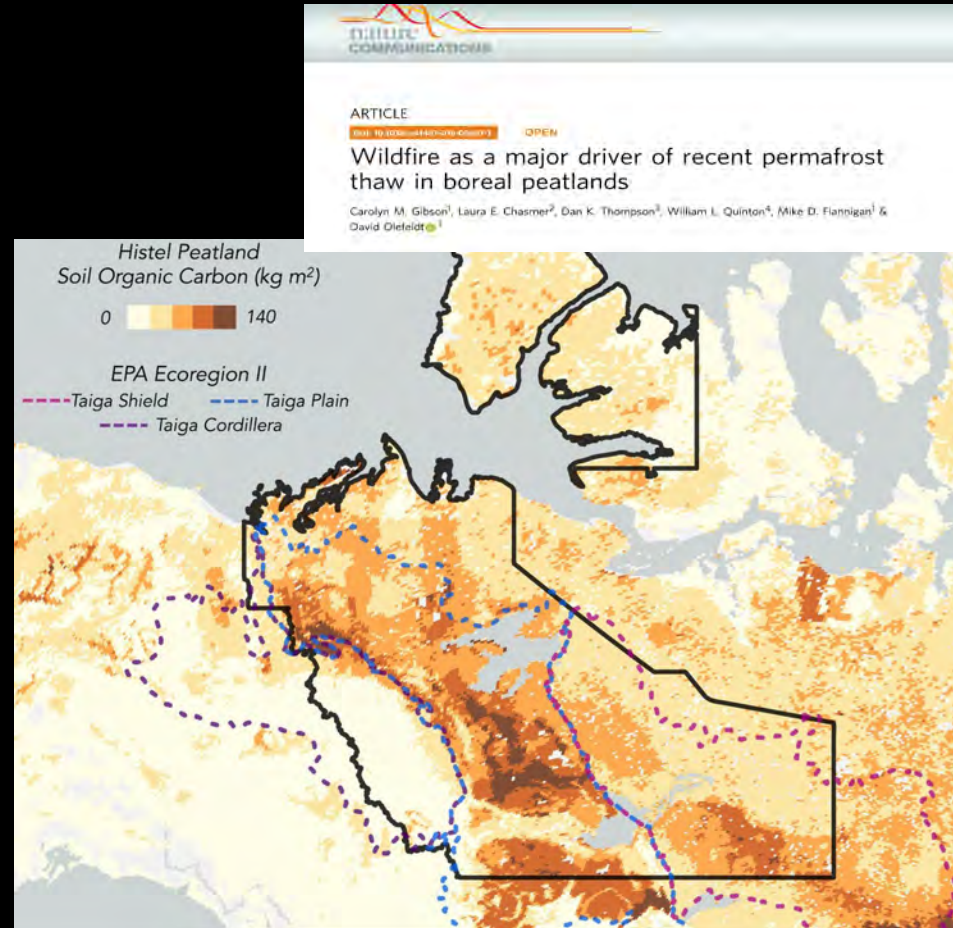
doi:10.1371/journal.pone.0157425.g001

Hope et al. 2016

Inform fire management across the boreal biome: *Northwest Territories*



Obu et al. 2019



Hugelius et al. 2020

Key considerations & concluding thoughts

- Boreal fire suppression for carbon protection appears to be a viable, cost-effective NCS
- Viable only in the context of deep reductions in fossil fuel emissions
- Likely more cost-effective than current analyses indicate
- Essential to maintain ecologically appropriate levels of fire
- Need to identify optimal mix of fire management practices
- Need to account for all ecosystem services, land-uses and Indigenous sovereignty
- Significant additional resources needed, multiple potential sources
- Carbon market viability should prioritize (i) robust accounting standards and (ii) companies committed to deep decarbonization
- Applicability to NWT:
 - Permafrost & peatlands in NWT large C stores and increasingly threatened by wildfires
 - Wildfire management could be a cost-effective approach for preserving C, with multiple co-benefits
 - We are seeking opportunities to collaborate!

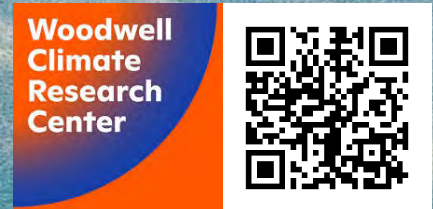
Thank you!!

Kayla Mathes kmathes@woodwellclimate.org

Brendan Rogers brogers@woodwellclimate.org



Woodwell Website





Landscape Carbon Workshop: Nature-Based Solutions for the NWT

FEBRUARY 2025



New long term finance models for
Indigenous-led enterprise based on healing
and stewarding land and sea.



Carbon

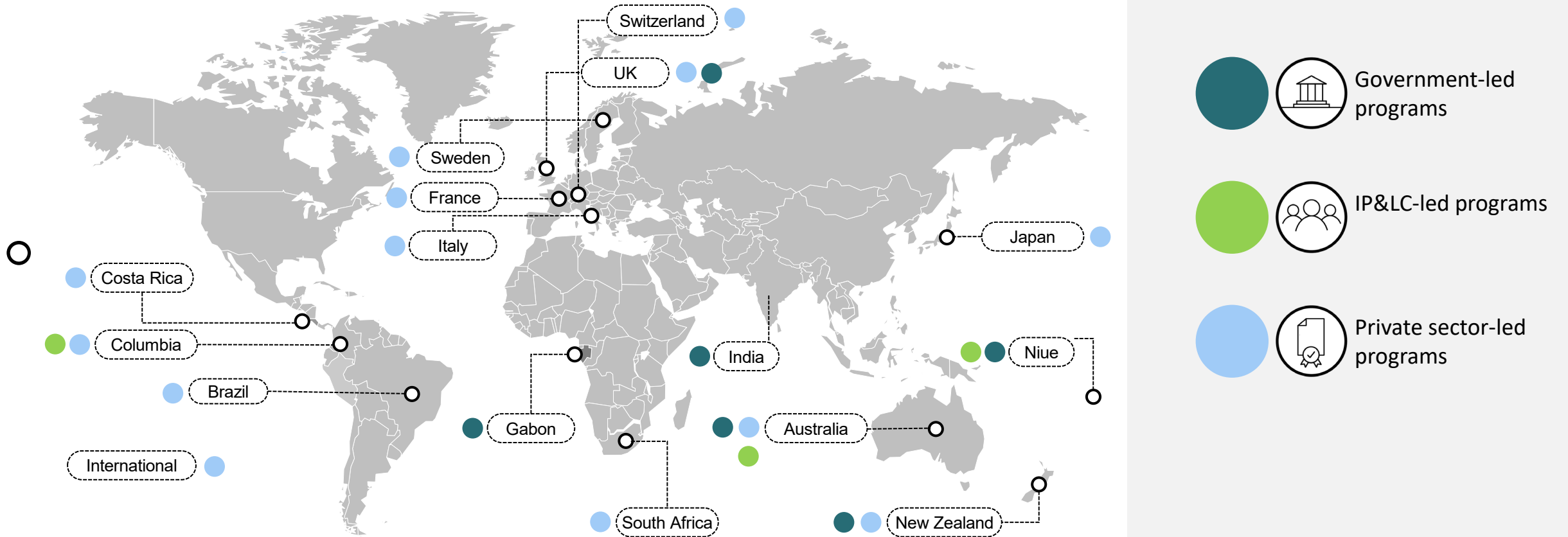


Nature

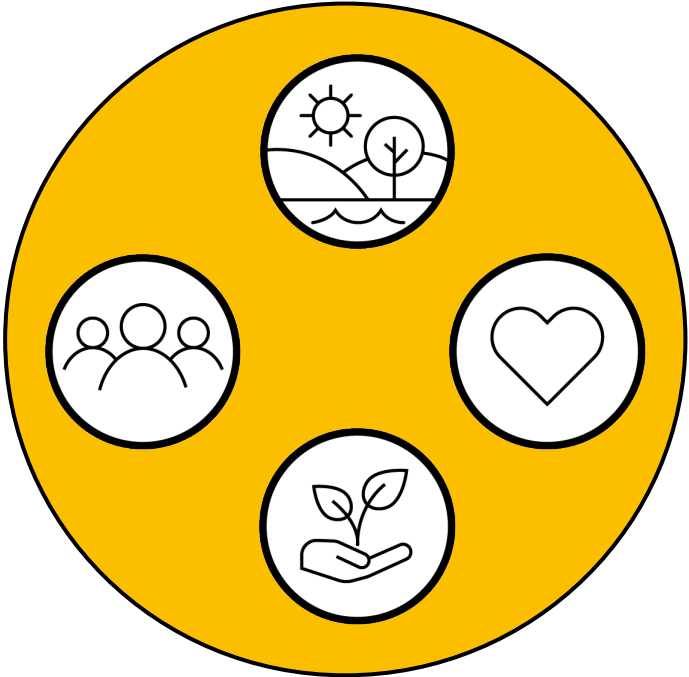
ICBA

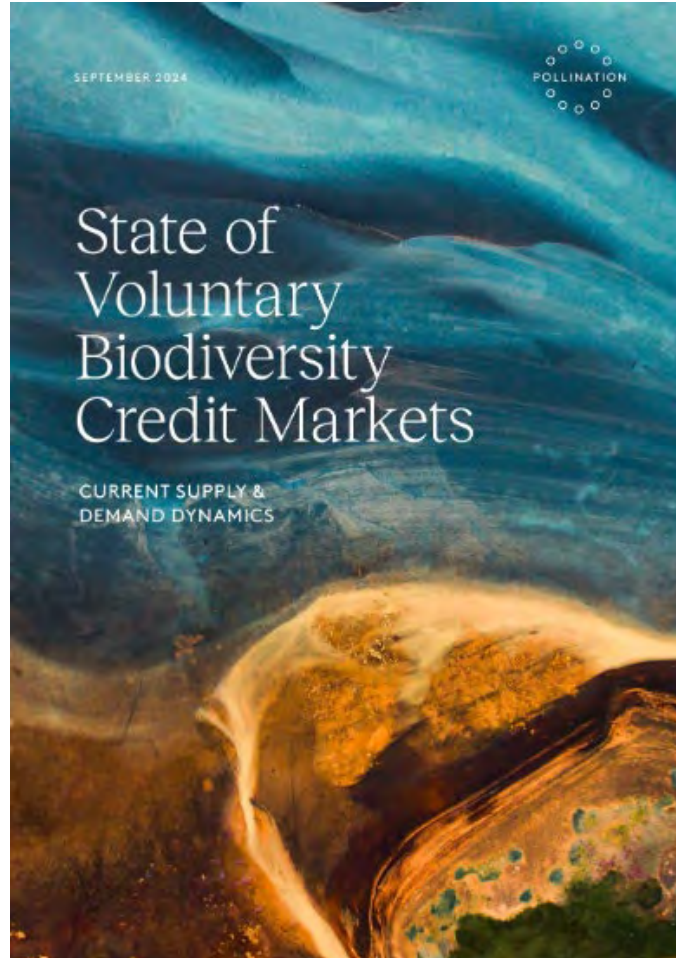


Biodiversity credit initiatives emerging globally



www.marketplacefornature.org





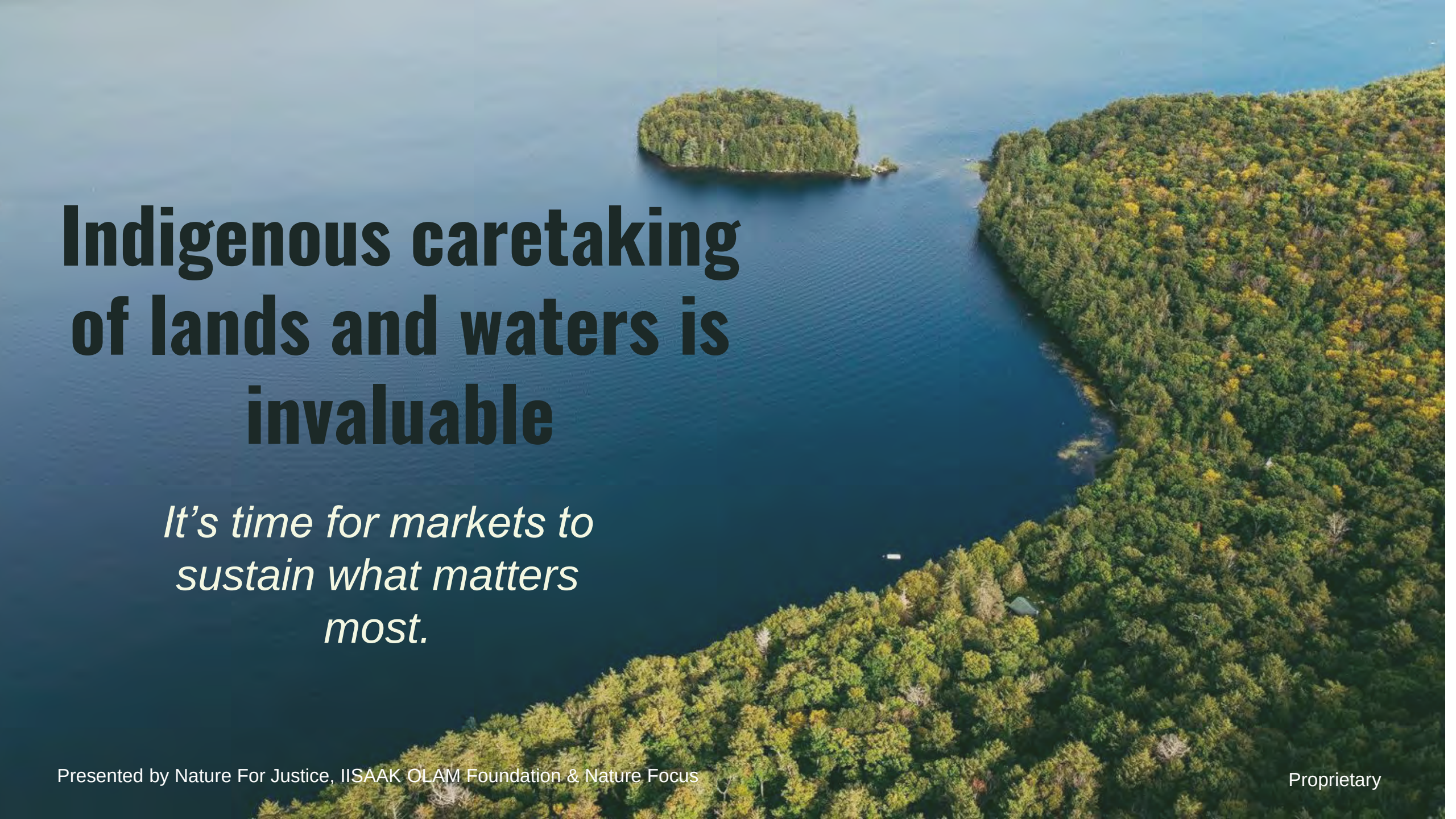
- o Who are the buyers?
- o What are they buying and why?
- o How much are they paying?

○ *Humanity at the heart* ○



FIRST 30X30 CANADA

Harnessing Nature-based Solutions as a Catalyst for Indigenous-Led Conservation

An aerial photograph of a deep blue lake surrounded by dense green and yellow forest. A small, forested island is visible in the upper center of the lake. The text is overlaid on the left side of the image.

Indigenous caretaking of lands and waters is invaluable

*It's time for markets to
sustain what matters
most.*

The Opportunity: Indigenous-Led Conservation in Canada

The Government of Canada has pledged to protect 30 percent of its land and waters by 2030, and recognize the leadership role that Indigenous governments play in identifying and caring for nature

Companies, governments and individuals are beginning to make climate and biodiversity goals and action plans.

For Indigenous Nations, this is an opportunity to secure funding for your leadership in caretaking for natural areas.

“Nature-based solutions” (NbS) markets are a key financial resource that can channel much-needed **finance for Indigenous-led conservation** and land stewardship.

This is the pathway to advance global climate and biodiversity goals while centering Indigenous rights and responsibilities.



Art by [Jennifer Adomeit](#)

Our Vision:

A network of Indigenous-led nature-based solutions projects with long term financing and Indigenous rights and responsibilities at their center.

What Are Nature-based Solutions (NbS)?



Nature-based Solutions are initiatives that protect, manage, and restore ecosystems to benefit nature and people.

Nature-based solutions markets are markets that pay for and invest in actions that restore, protect, and manage natural ecosystems.

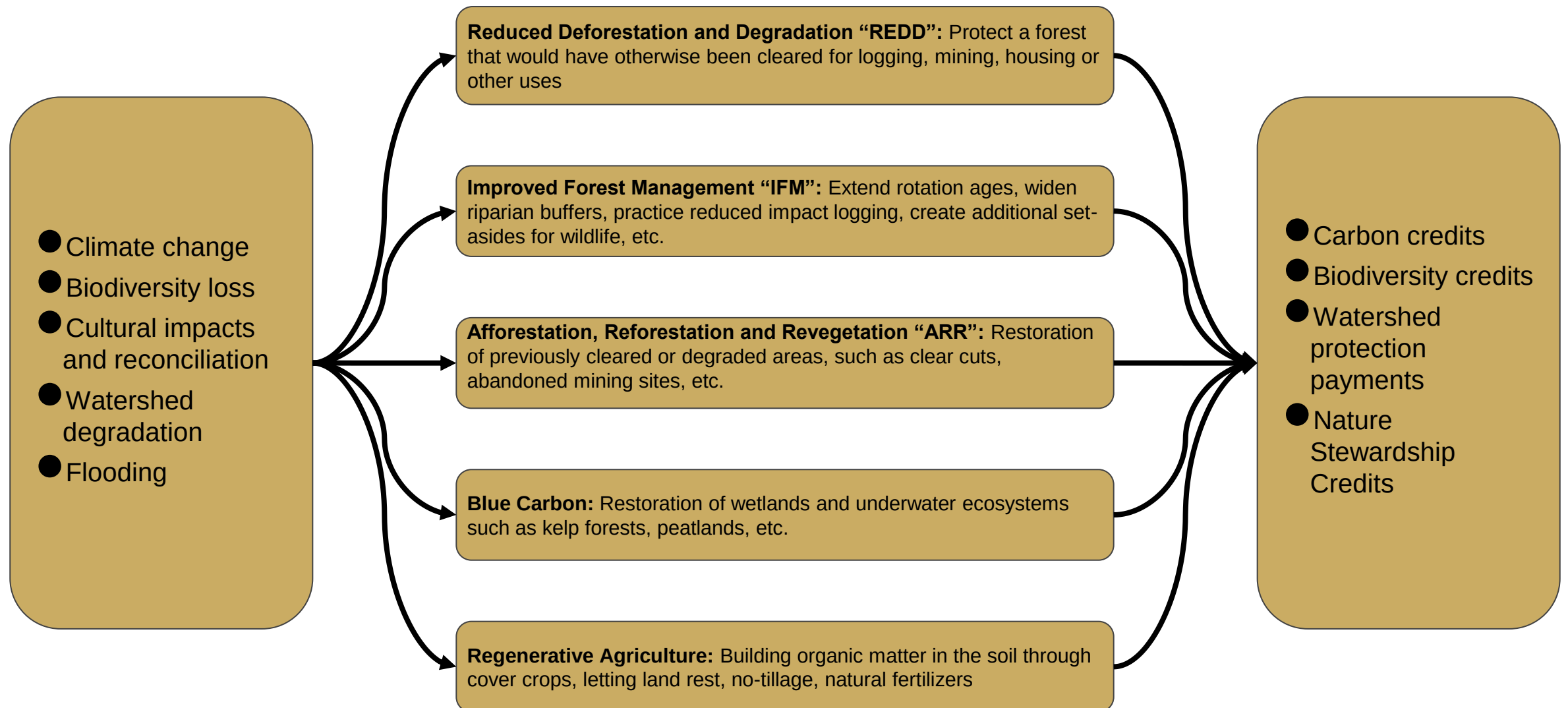
Examples:

Carbon Credits, Biodiversity Credits, Nature Stewardship Credits, Forest Resilience Impact Bonds, Payments for Ecosystem Services, etc.

The “Problems”

The “Nature-Based Solutions”

The Income Opportunities



Carbon Credits Example



To support climate goals, corporations & federal governments have set Net Zero Greenhouse Gas emission targets, that involve a mix of making changes to reduce their own emissions and buying “offsets” for their activities that they cannot yet reduce by paying for Carbon “Credits”.

- 1 Carbon credit = 1 ton of CO₂ eq that is reduced from the atmosphere, either from avoided emissions or additional sequestration
- When a tree grows, it takes in (or sequesters) carbon dioxide from the atmosphere
- When a tree that would otherwise be harvested is protected, that avoids release of carbon stored in the tree into the atmosphere
- A corporation that emits 1 ton of carbon can then purchase 1 carbon credit in order to “offset” their emissions to be “carbon neutral”.

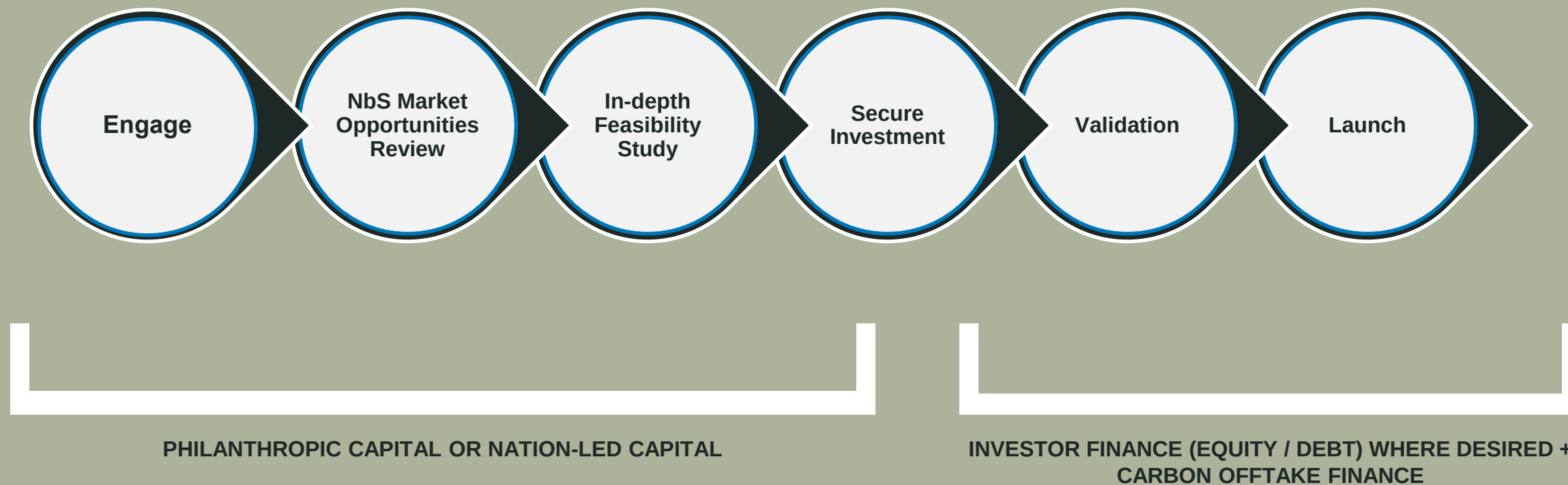
NbS markets are imperfect. We make them work for you.



We are a 'General Contractor' or 'Project Manager' for Indigenous governments interested in accessing 30 - 50 year funding for their Land and Water care-taking activities from NbS markets.

Unlike other carbon project developers, we're a not-for-profit program entirely focused on advancing Indigenous-led stewardship and Nation-building.

The First 30x30 Financial Stages



The Opportunity for Indigenous government in NWT



The Context



- While many barriers exist in NWT to accessing the carbon markets, Nature Stewardship Credits offer an opportunity to secure funding for the holistic stewardship and guardianship work taking place.
- A Nature Stewardship Credit (NSC) - a credit that values biodiversity, social impacts and inclusive governance alongside carbon is needed not only for NWT, but for many Indigenous Protected & Conserved Areas across Canada
- By piloting the new NSC framework, lessons and recommendations from Thaidene Nene can shape the future of the NSC standard to help ensure it is well suited to supporting Indigenous-led conservation
- We are looking to pilot Nature Stewardship Credits in the NWT and share lessons learned broadly

The Opportunity

FIRST
30X30
CANADA



The Overarching Goal

- 20-50 years of sustainable revenue
- Shape and influence the global marketplace
- Fund IPCA stewardship, operations, and growth
- Develop a tool for Indigenous Nations to benefit from - in the NWT and globally

First 30x30 Team



Steven Nitah
Nature For Justice



Eli Enns
IISAAK OLAM Foundation



Jeffrey Brown
Nature Focus



Robin Barr
Nature For Justice



Tess Zakaras
Nature For Justice



Monica Shore
IISAAK OLAM Foundation



Michael Weiss
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Isabel Ransom
Nature For Justice

Get in Touch!

Visit First30x30.earth to learn more.



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N4J Indigenous Funding Lead



Isabel Ransom
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IOF Engagement Coordinator

Thank you!

Disclaimer:

The material contained in this presentation is intended to be general background information on Nature For Justice, IISAAK OLAM Foundation, Nature Focus Development and their joint proposed program. The information is given in summary form and does not purport to be complete.

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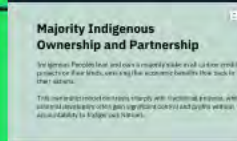
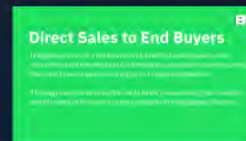
Indigenous Carbon Credits: Rare, Valuable, and Impactful

AJ Bird, Managing Partner of Bird & McCrimmon
aj@birdmccrimmon.com

NWT Carbon Landscape
Yellowknife, NWT Feb 4-6, 2025

Indigenous-Led Solution for the Carbon Market

Indigenous-led carbon projects empower Indigenous Nations
by ensuring majority ownership and control



Indigenous Carbon Credits:

Rare, Valuable, and Impactful

AJ Bird, Managing Partner of Bird & McCrimmon
aj@birdmccrimmon.com

NWT Carbon Landscape
Yellowknife, NWT Feb 4-6, 2025

The Problem of Traditional Carbon Projects

Traditional carbon projects often exploit Indigenous lands and waters while external parties profit

Exploitation of Indigenous Lands

External parties (including developers and financiers) utilize Indigenous lands and waters for carbon projects, extracting profits while leaving Indigenous Nations with minimal benefits.

The profit-driven motives marginalize the rights of Indigenous Peoples over their traditional territories.



Loss of Control for Indigenous Nations

The traditional carbon market model diminishes the control Indigenous Nations have over their resources.

This shift allows others to profit from their lands without equitable compensation or representation.

Indigenous voices are often sidelined in decisions that affect their futures.



Hudson's Bay Company Lib. - Winnipeg, Man.

Comparison to Historical Fur Trade

The current carbon market resembles the Fur Trade, where Indigenous lands were exploited for cheap goods — fur pelts became luxury goods in European markets.

This exploitation disrupted traditional Indigenous economies and transformed them into subsistence systems.



Lack of Transparency in Carbon Market Fees



The current carbon market lacks transparency, with intermediaries buying and reselling carbon credits, obscuring profits and fees involved.

This lack of clarity can lead to Indigenous Nations not receiving the financial benefits they rightfully deserve.

Speculative Nature of Current Carbon Markets

Current carbon markets operate in a speculative manner of: "buy cheap and resell high."

Like the Fur Trade economy, Indigenous Nations can be exploited from carbon projects on their lands and territories.



Indigenous-Led Solution for the Carbon Market

Indigenous-led carbon projects empower Indigenous Nations by ensuring majority ownership and control

Majority Indigenous Ownership and Partnership

Indigenous Peoples lead and own a majority stake in all carbon credit projects on their lands, ensuring that economic benefits flow back to their nations.

This ownership model contrasts sharply with traditional projects, where external developers often gain significant control and profits without accountability to Indigenous Nations.



Role of Project Developers and Financiers

Project developers work under the leadership of Indigenous Nations and must secure guidance and permission from Indigenous Nations at every stage.

Financiers can participate in these initiatives but only through debt financing, which allows Indigenous Nations to maintain control over their lands and resources.

Importance of Ethical Standards in Carbon Projects

Indigenous carbon credits are grounded in ethical practices, ensuring that projects do not exploit or harm Indigenous rights and territories.

These standards elevate the value of the credits, gaining them recognition as both valid and socially responsible in the marketplace.

Direct Sales to End Buyers

Indigenous carbon credits are sold directly to end buyers who retire the credits immediately, eliminating speculation and ensuring that profits are maximized and go to Indigenous Nations.

This approach eliminates the middlemen, maximizing the financial benefits and control over carbon projects for Indigenous Nations.

Benefits of Indigenous Carbon Credits

Indigenous carbon credits offer a transformative approach that promotes equity, transparency, and maximum value, benefiting Indigenous Nations while addressing the climate crisis.

Validity and Verification of Credits

Indigenous carbon credits are validated and verified through recognized standards, ensuring their credibility in the market.

This legitimacy supports broader acceptance and trust from buyers, amplifying the potential for successful project funding.

Ethical and Rare Value Comparison

The intrinsic value of Indigenous carbon credits is enhanced by their ethical sourcing and rarity.

Similar to Canadian mined diamonds, these credits attract premium market interest, distinguishing them from conflict-derived alternatives.





Opportunities for Reconciliation and Procurement

Indigenous carbon credits provide significant opportunities for companies to engage in Indigenous reconciliation.

Through direct procurement from Indigenous Nations, businesses can achieve corporate sustainability and Reconciliation in action.

Transparent Pricing Structure



The pricing of Indigenous carbon credits is the actual selling price, plus a transparent fee.

This clarity empowers Indigenous Nations, ensuring they retain the full value of their credits without hidden costs.

Own-source Revenue for Indigenous Nations



The Indigenous carbon credit model guarantees that the full selling price directly funds Indigenous-led projects.

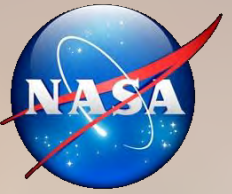
This approach ensures that profits stay in the Nations as own-source revenue.

Enhanced Transparency and Accountability



This model enhances transparency regarding fees and profits, unlike traditional carbon markets where costs remain concealed.

By establishing a clear framework, Indigenous Nations can eliminate profiteering intermediaries in traditional carbon markets.



What Did We Learn About Landscape Carbon from NASA ABoVE

Presenter: Dr. Laura Bourgeau-Chavez
Michigan Technological University
Michigan Tech Research Institute

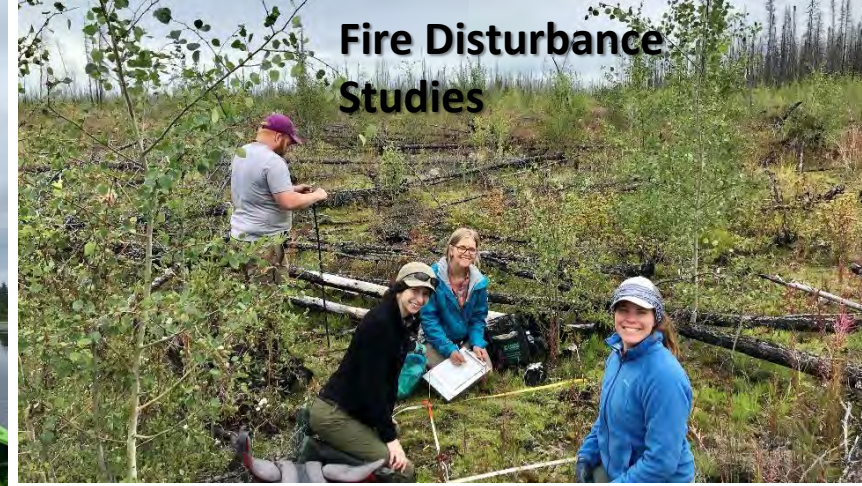
Landscape Carbon Workshop • NWT • Canada • 6 February 2025



Flux Towers



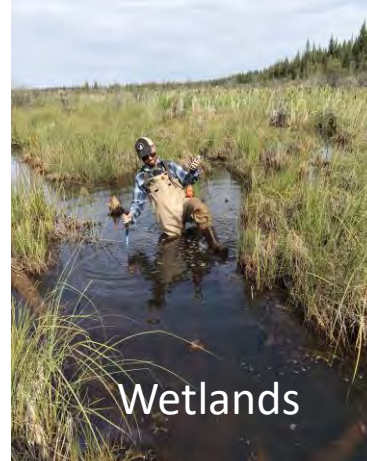
Flux Towers



Fire Disturbance Studies



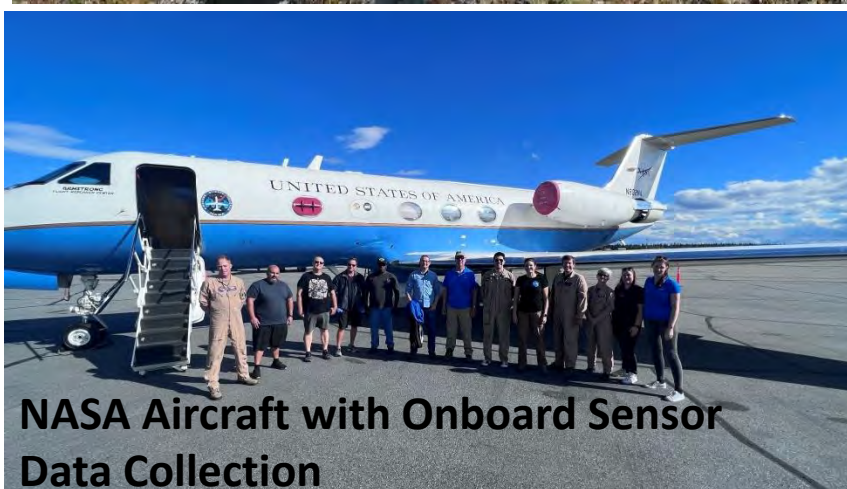
NASA ABoVE has been at the forefront of studying the changing Boreal Arctic with teams on the ground, in the air, using satellite imagery and modeling



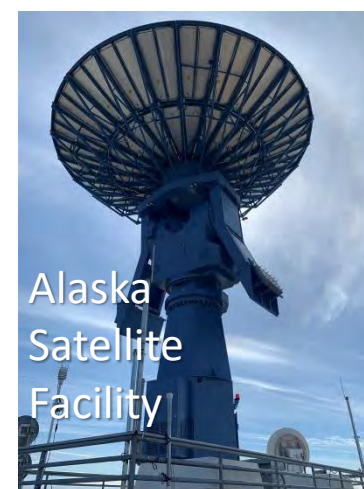
Wetlands



Bird and other Wildlife Studies



NASA Aircraft with Onboard Sensor Data Collection



Alaska Satellite Facility

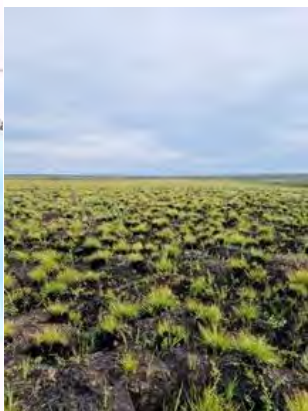
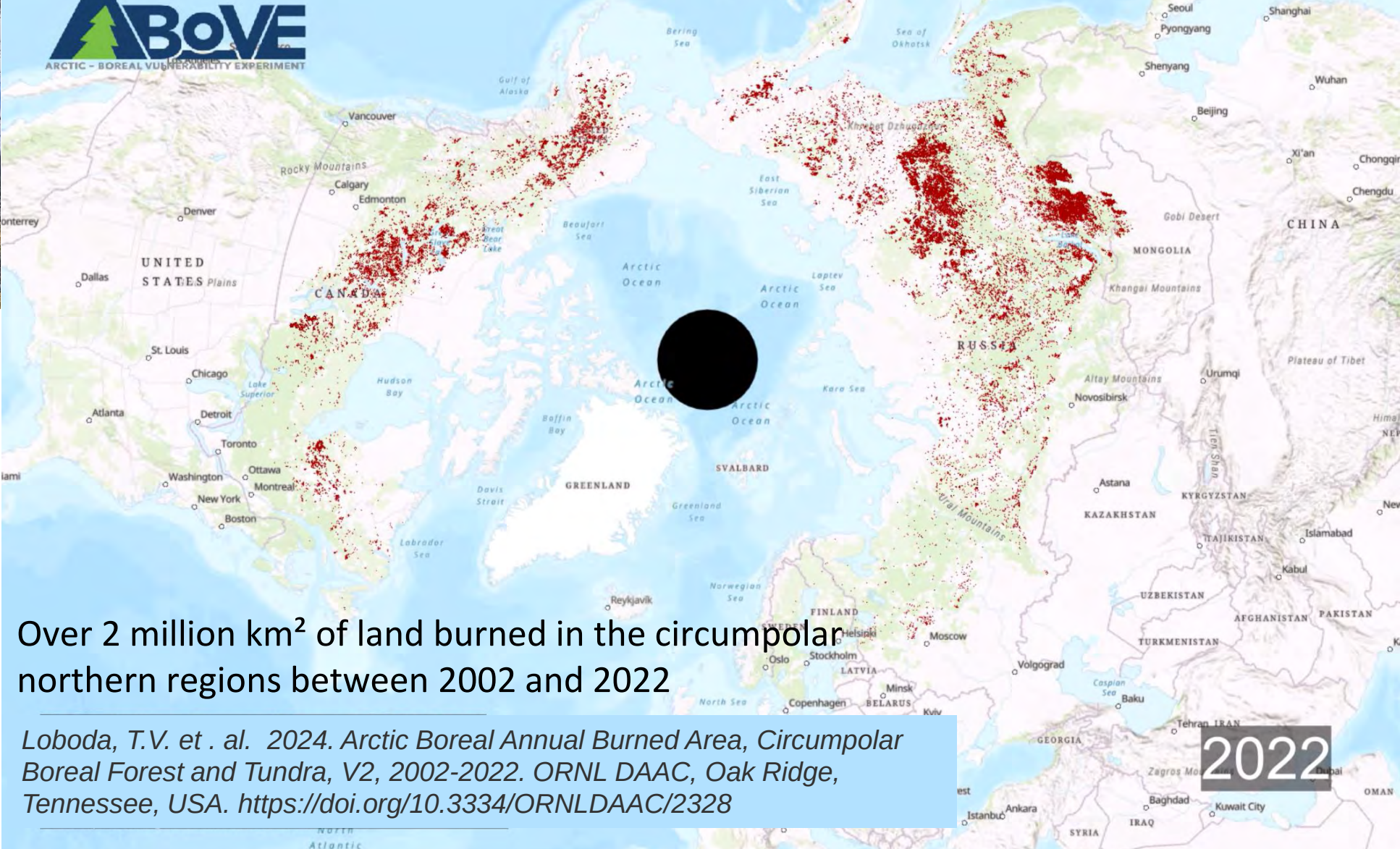
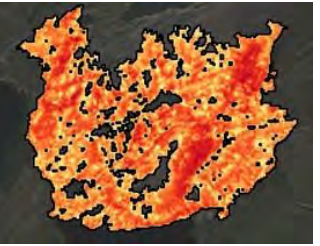


Satellites

Oct 27 2024 16:48



2002-2022 Cumulative Wildfire Boreal-Tundra Product

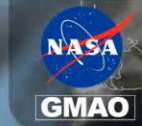


Over 2 million km² of land burned in the circumpolar
northern regions between 2002 and 2022

Loboda, T.V. et . al. 2024. Arctic Boreal Annual Burned Area, Circumpolar
Boreal Forest and Tundra, V2, 2002-2022. ORNL DAAC, Oak Ridge,
Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/2328>

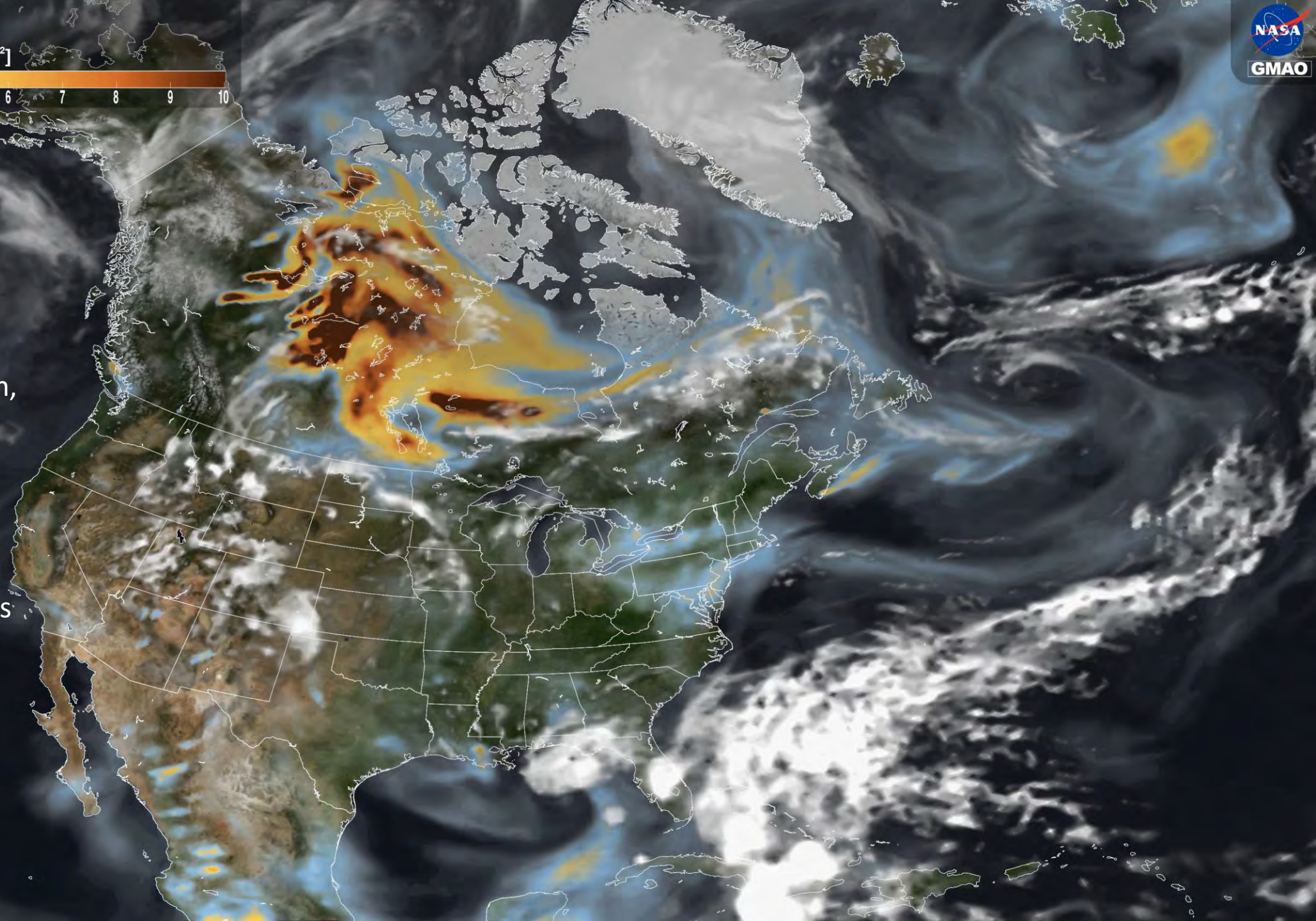
Canada Wildfires

Black Carbon Column Mass [mg/m^2]



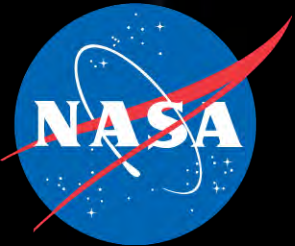
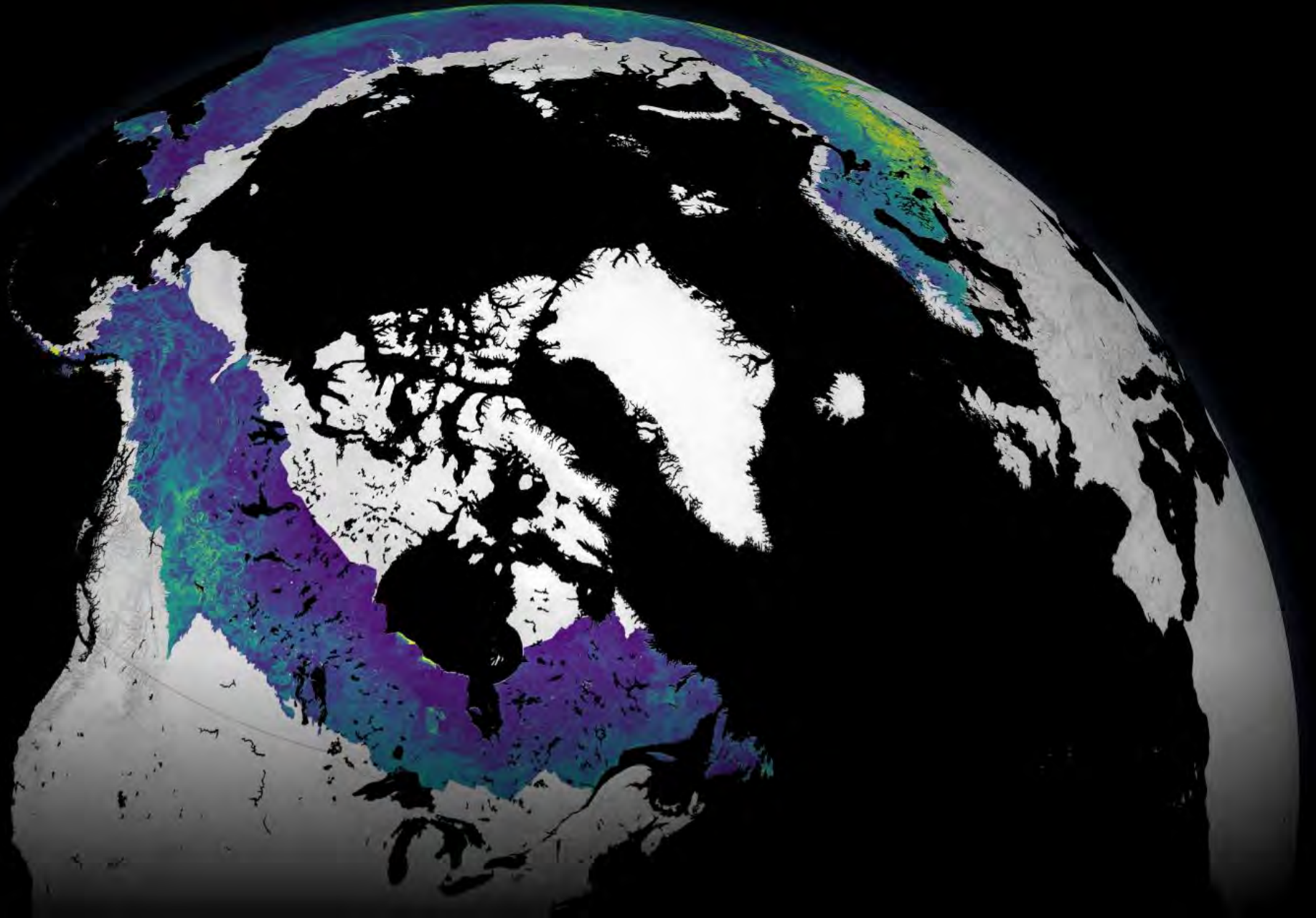
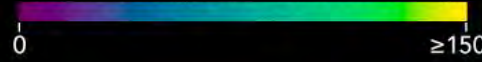
Byrne, B., Liu, J., Bowman,
K.W. *et al.* Carbon
emissions from the 2023
Canadian
wildfires. *Nature* **633**,
835–839 (2024).
<https://doi.org/10.1038/s41586-024-07878-z>

GEOS Analysis
01 Jun 2023 00:00 GMT



Forest Biomass from Satellite LiDAR (Mg/ha)

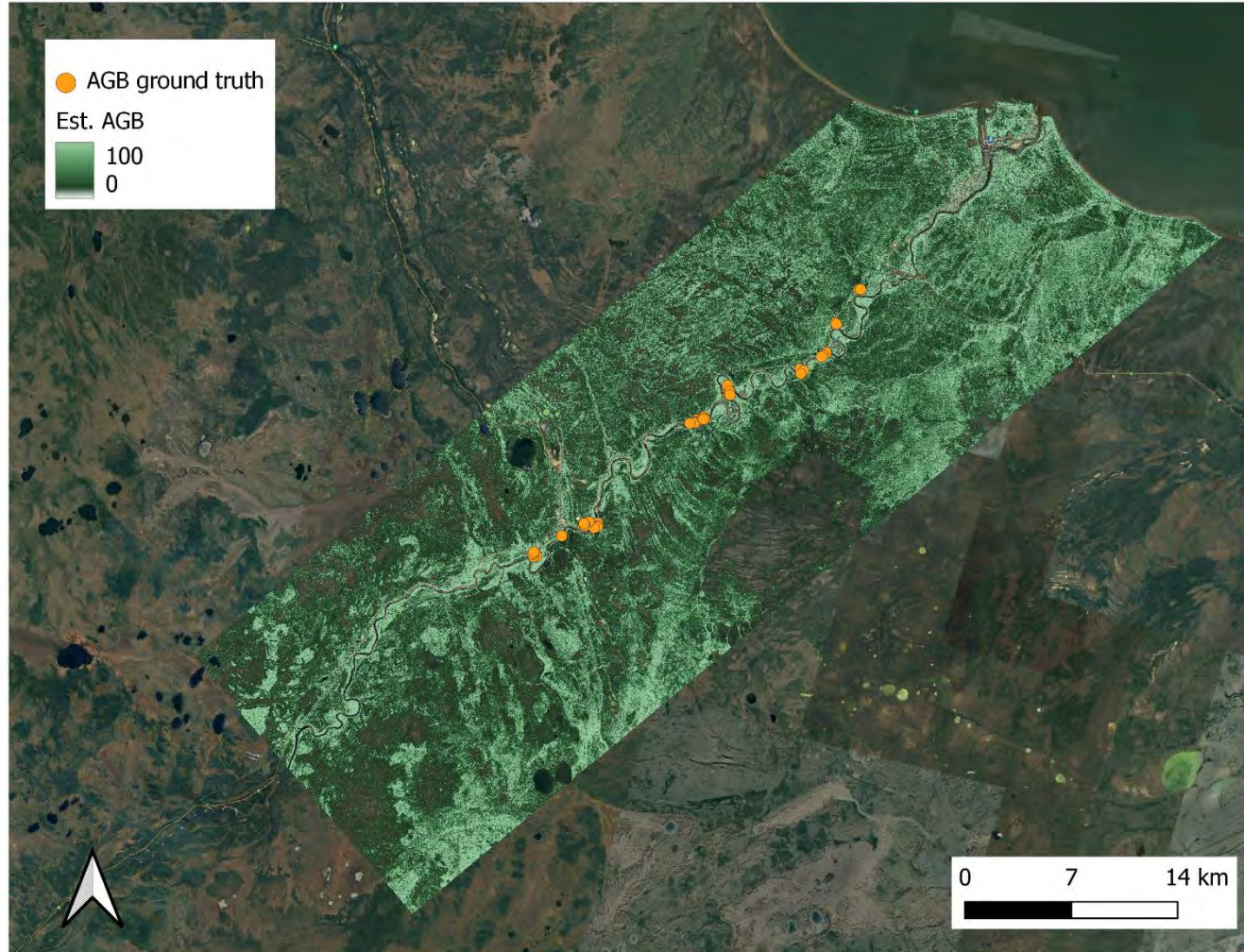
Duncanson, L., et al. 2023.
Aboveground Biomass
Density for High Latitude
Forests from ICESat-2,
2020. ORNL DAAC, Oak
Ridge, Tennessee,
USA. <https://doi.org/10.3334/ORNLDAAC/2186>



Forest Biomass from NASA Aircraft Radar UAVSAR



8/15/22: Hay River, Canada



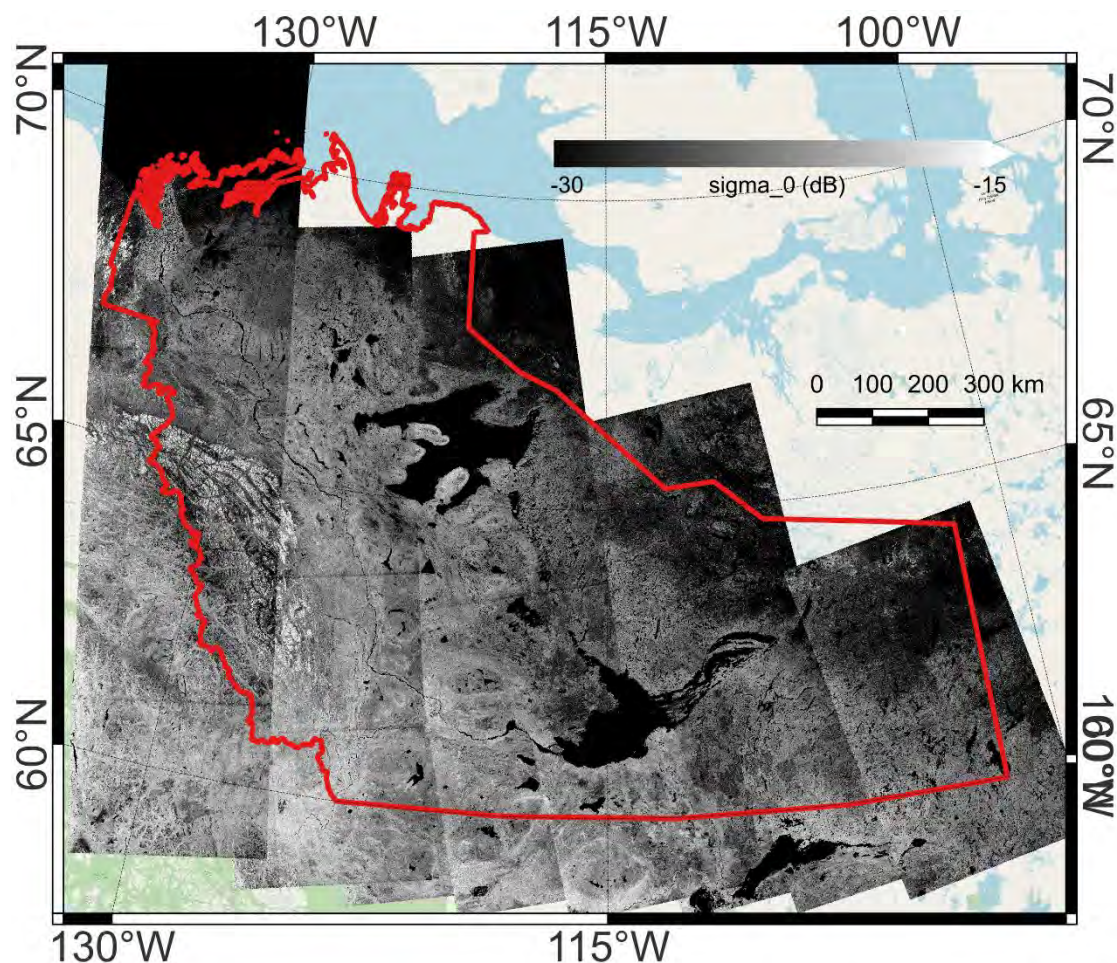
- Work in collaboration with GNWT
- Field data collected by GNWT in 3 years over Hay River
- Use radar sensor to scale field data across the scene
- MTU collected data around the Great Slave Lake – not shown

Product developed by Jessica Martinez, UMASS Amherst researcher

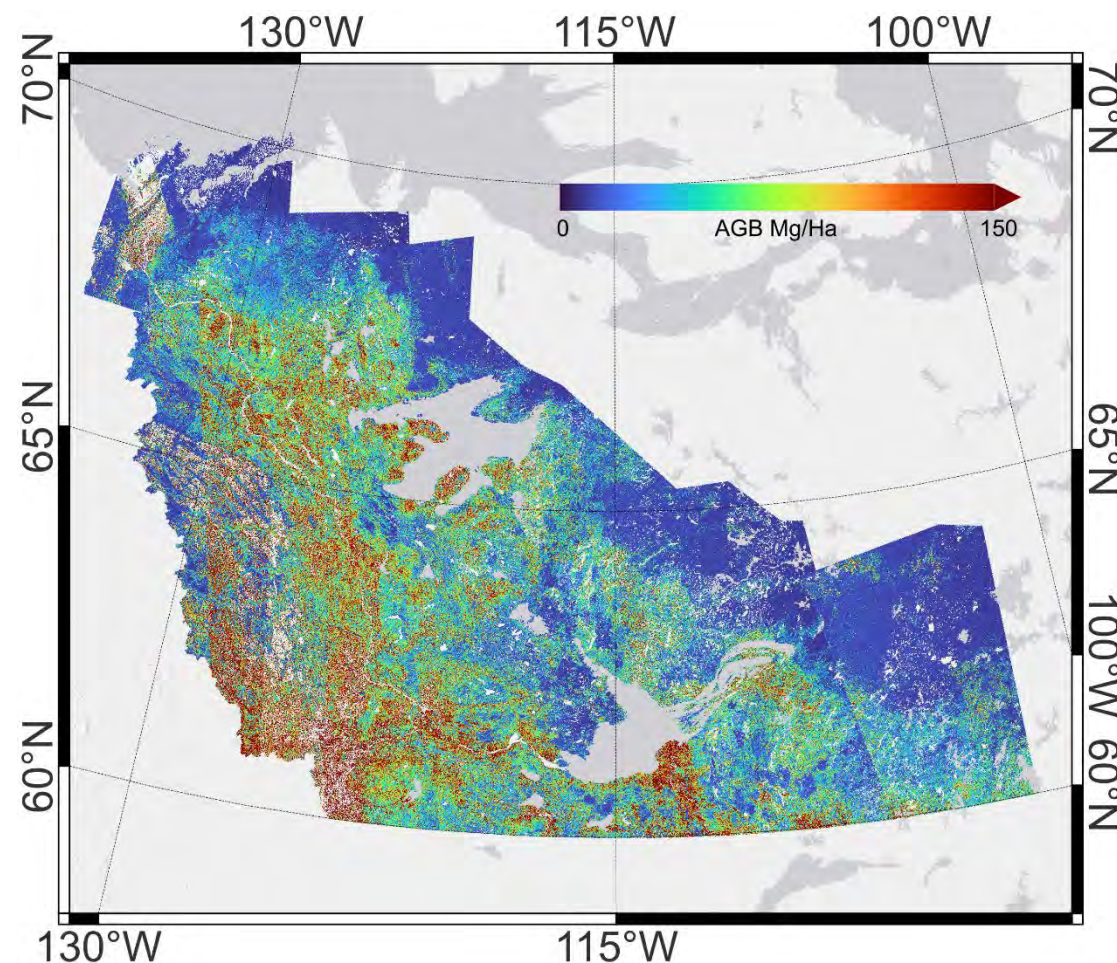


Forest Biomass from Satellite Radar Sensors

Japan's ALOS-2 PALSAR in Preparation for NISAR



Cross-pol (HV) Sigma₀



Estimated AGB

Above-ground biomass (AGB) estimated from 21 Satellite (ALOS-2/PALSAR-2 ScanSAR) scenes

Aug-Oct 2023 over Northwest Territories, Canada

Narayana Bhōgāpurapu, UMASS Postdoc (co-I Siqueira)

ABOVE Field Datasets Archived – Example



Field Data for Burned and Unburned Sites 2015-2024

90 burned (one ha) & 85 unburned (0.2 ha) field sites distributed in peatlands/uplands throughout study area.

Measurements include:

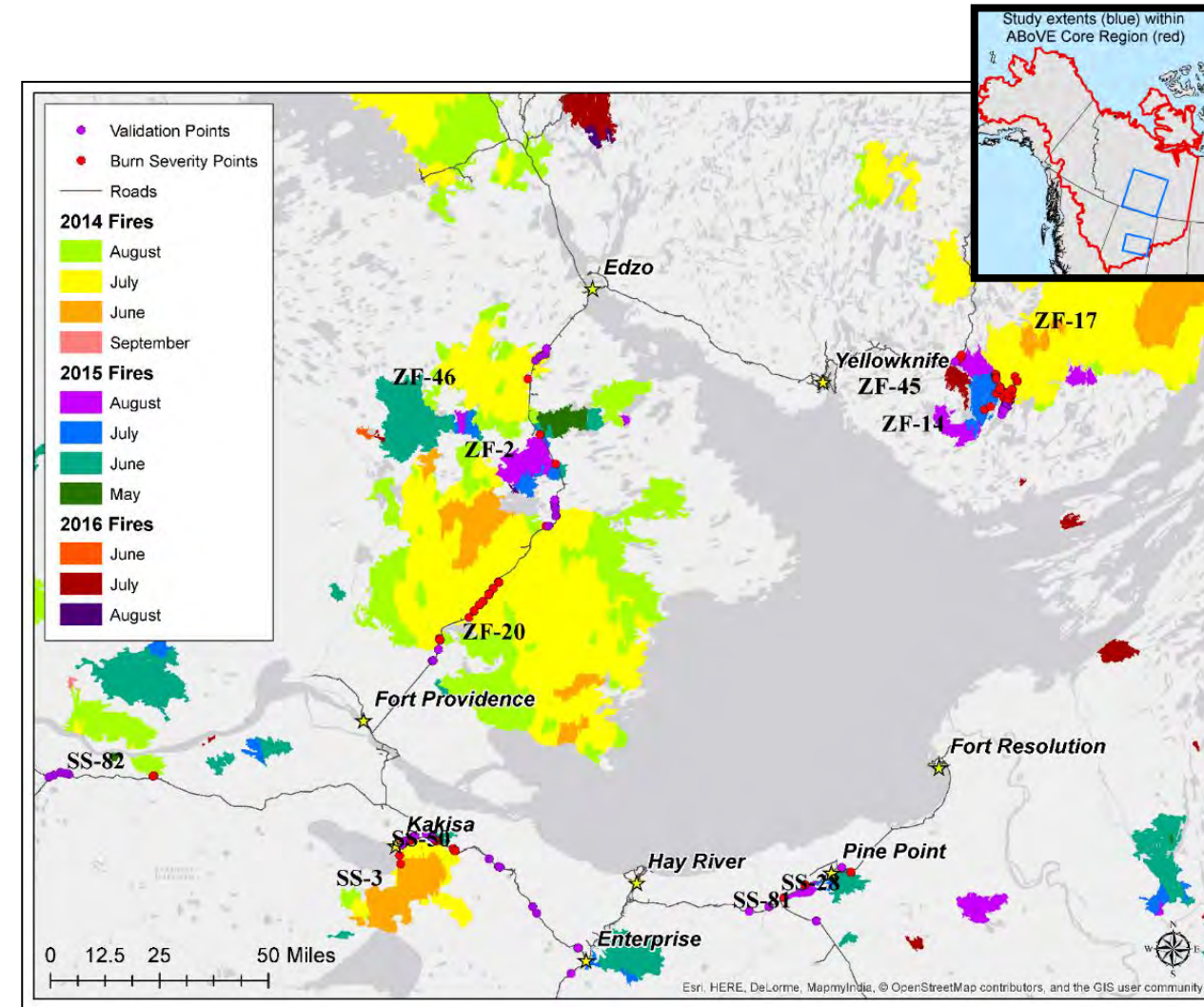
- Burn severity to tree canopy and peat/ground
- Revegetation/post-fire tree recruitment
- Soil moisture
- Active layer thickness
- Forest inventory (live and dead)
- Organic soil depth & fuel loading
- Spectral signatures for moss PFTs

NASA ORNL DAAC <https://daac.ornl.gov/Bourgeau-Chavez>

Field work in summer 2024:

- A first look at 2023 wildfire effects in peatlands including 2 2014-2023 reburns

2025-26 funding to sample 2023 wildfires





Two Current ABoVE Phase 3 Projects with Research Focus on NWT and Expanded Study Area

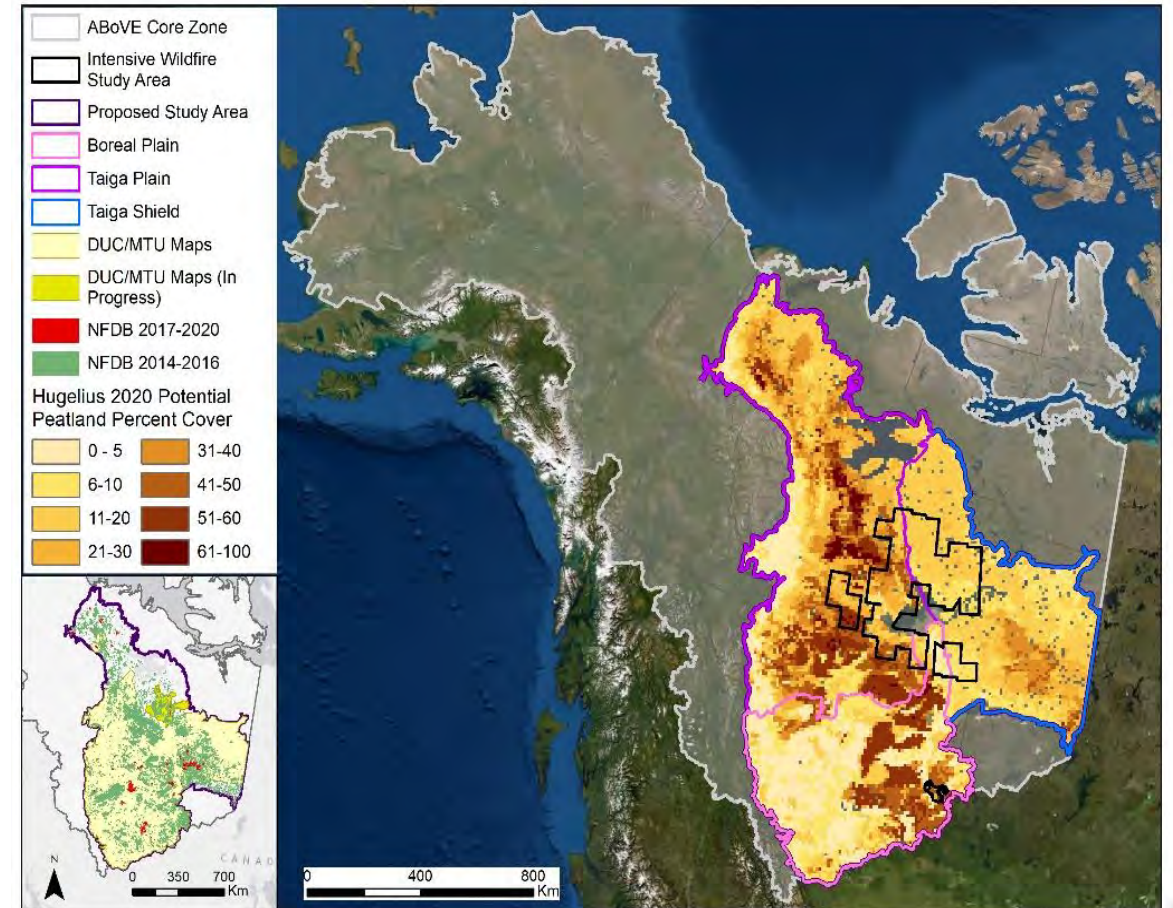


- **ASSESSING CLIMATE CHANGES TO WETLAND INUNDATION AND WILDFOWL HABITAT**

PI Nancy French (MTU) in collaboration with DUC

- **ASSESSING VULNERABILITY OF BOREAL PEATLANDS TO WILDFIRE**

PI Laura Bourgeau-Chavez in collaboration with University of Massachusetts and NCAR



Inset shows the area where peatland and upland ecotypes have been mapped by the co-Is and Ducks Unlimited Canada, as well as wildfires from 2014-16 (green) and 2017-2020 (red).

Wetland Mapping Product Example

Slave River Delta (SRD)



Summary & Accuracy:

12 wetland classes 5 upland classes

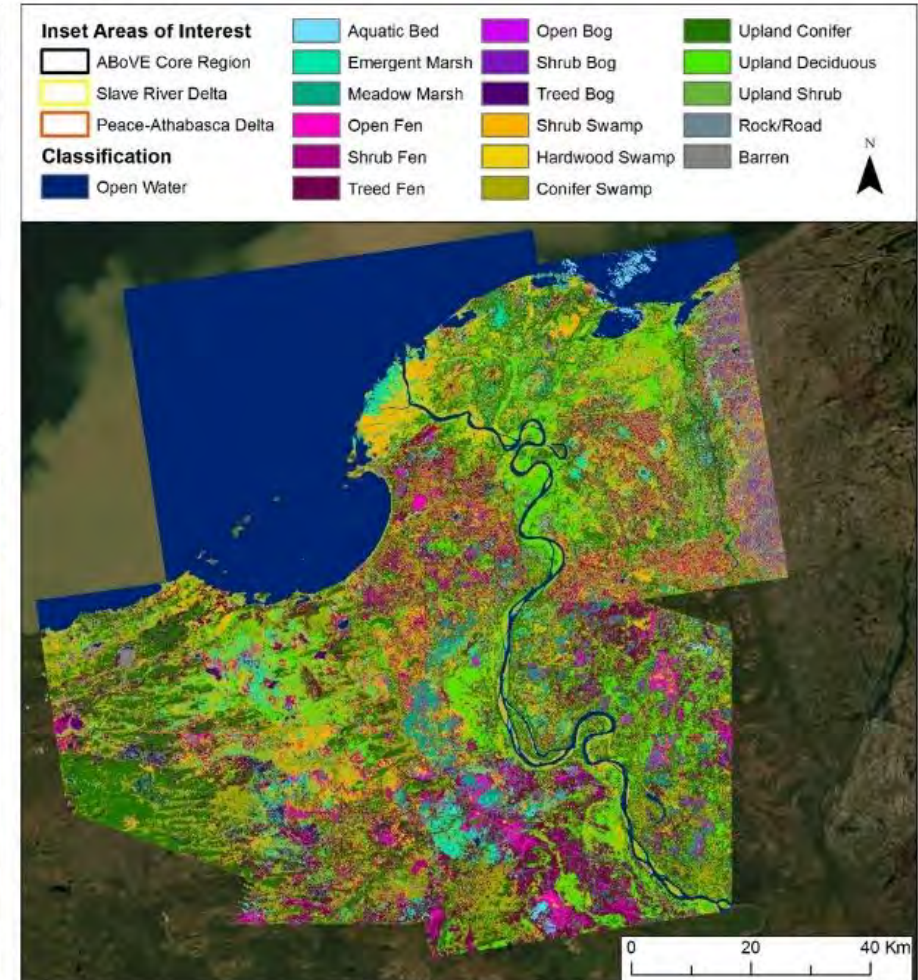
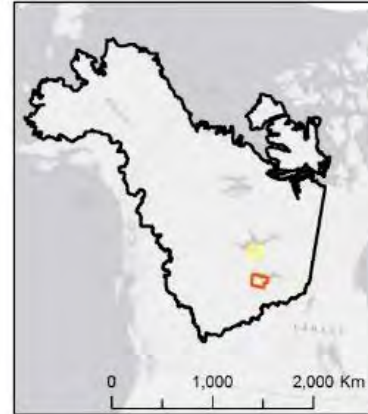
Uses multiple dates and types of satellite data (radar, optical)

High resolution, High accuracy maps

2007: 11,789 km², 83.4% accuracy

2017: 4,762 km², 86.5% accuracy

2007 SRD

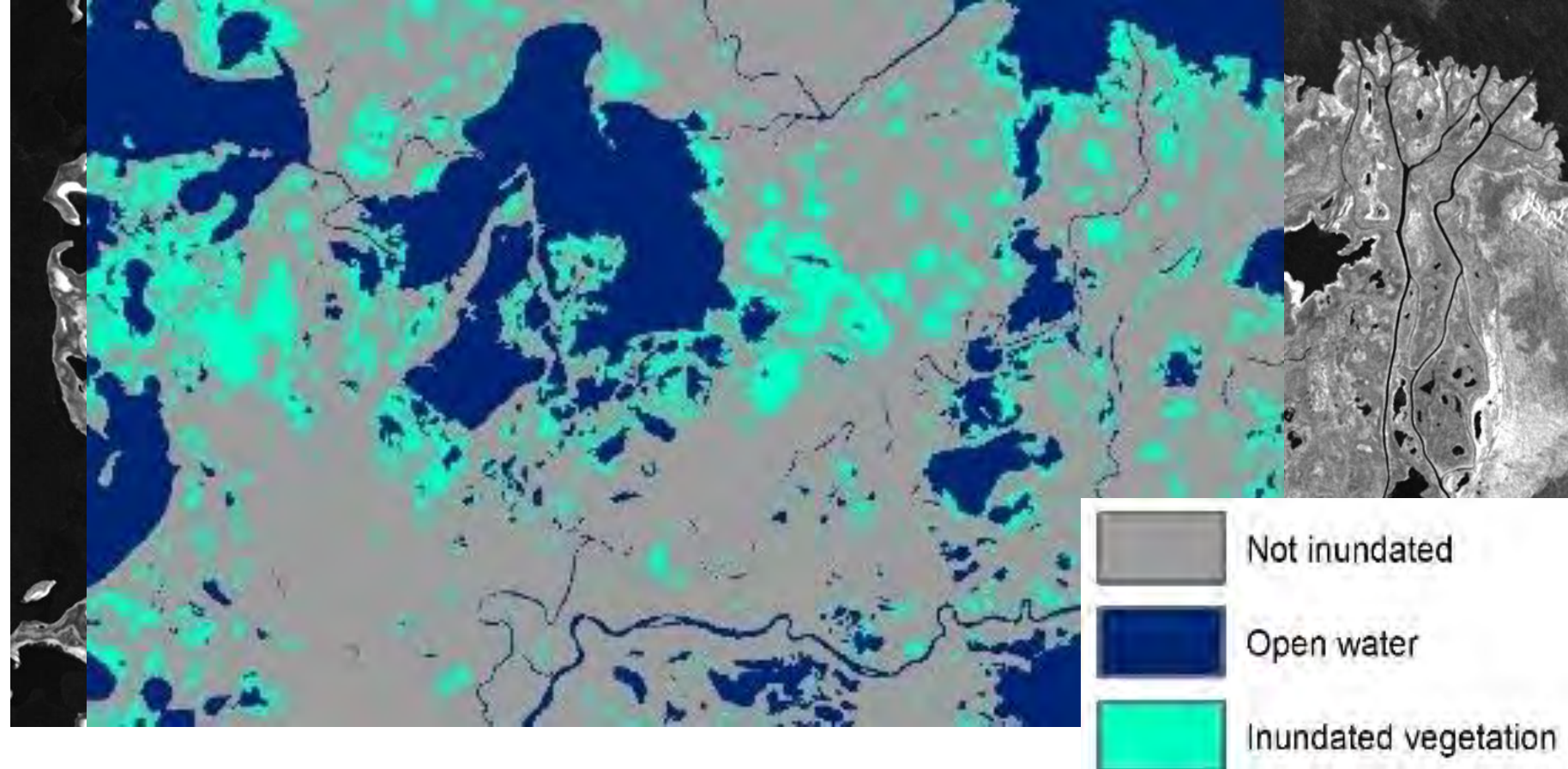


Where is the Water on the Landscape?

Surface Water and Vegetation Flood Mapping



- Can be used for determining whether or not specific areas are flooded on specific days that satellite flies over
- Implications for C storage and flux



This is a product French's team is creating for the expanded Great Slave Lake study region from 2016-2024.

Working to engage Land Guardians through DUC to collect more validation field data

Collaboration and Engagement:

Wetland Monitoring with Satellites



- MTU/DUC team worked with Ecology North and Northern Youth Leadership to conduct an On-The-Land Camp in Hidden Lake Territorial Park, from August 11th - 19th, 2024
- Products created through our ABoVE project were used as an educational tool
- to teach high-school-aged NWT youth about remote sensing and environmental science



Assessing the Vulnerability of Peatlands to Wildfire



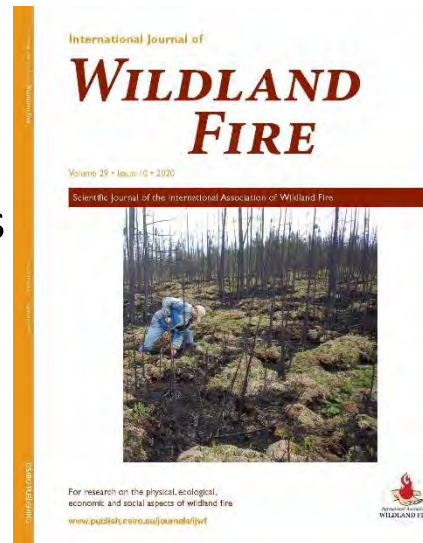
Required Producing Maps of:

1. Peatland and upland ecosystem types
(after Bourgeau-Chavez et al. CJRS 2017)
2. Burn severity to the organic surface-peat layers (French et al. 2020 IJWF)
3. Seasonal Fire progression (after Loboda and Csiszar 2007)

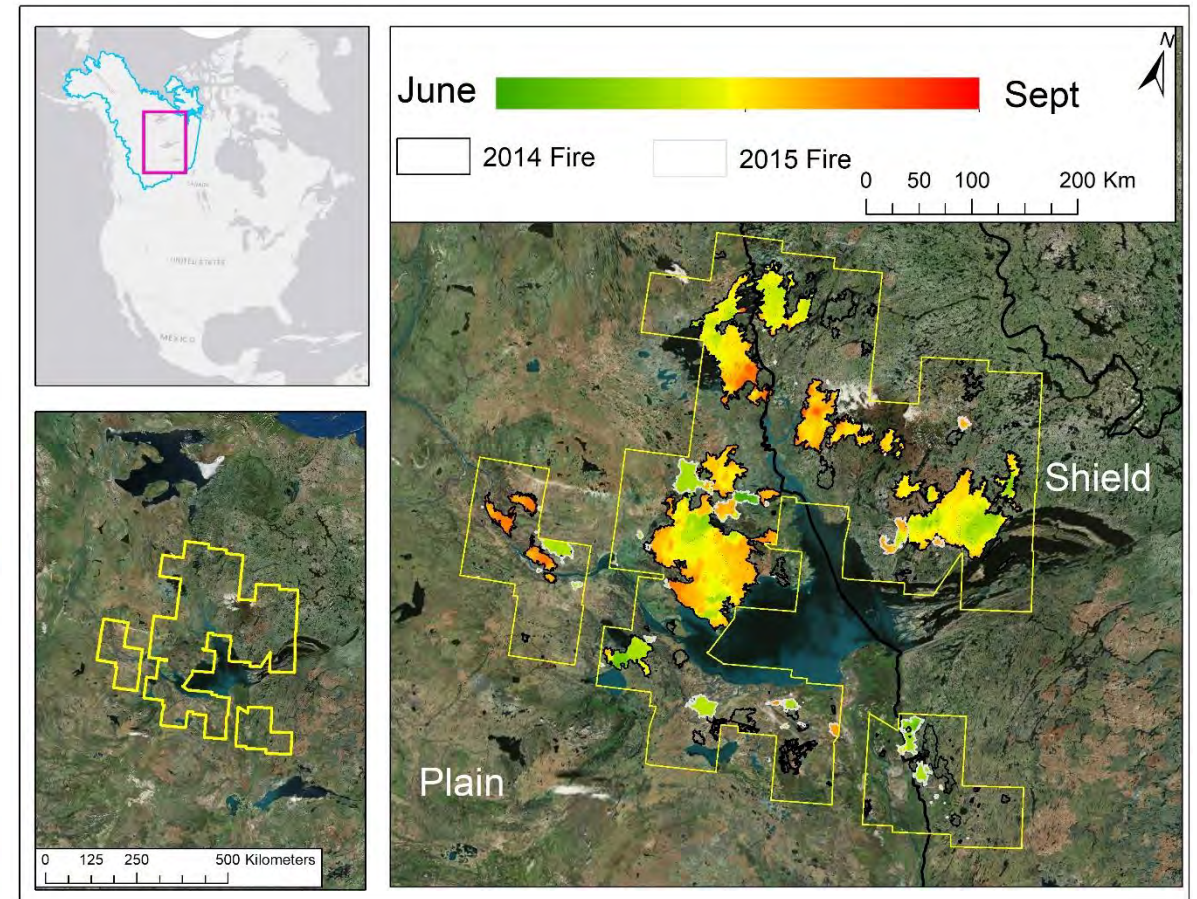
all archived on the ORNL DAAC

These were used with field data:

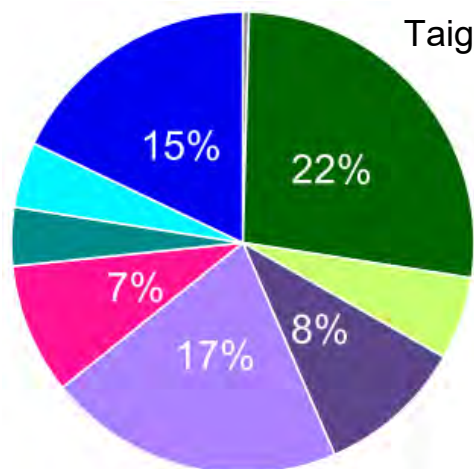
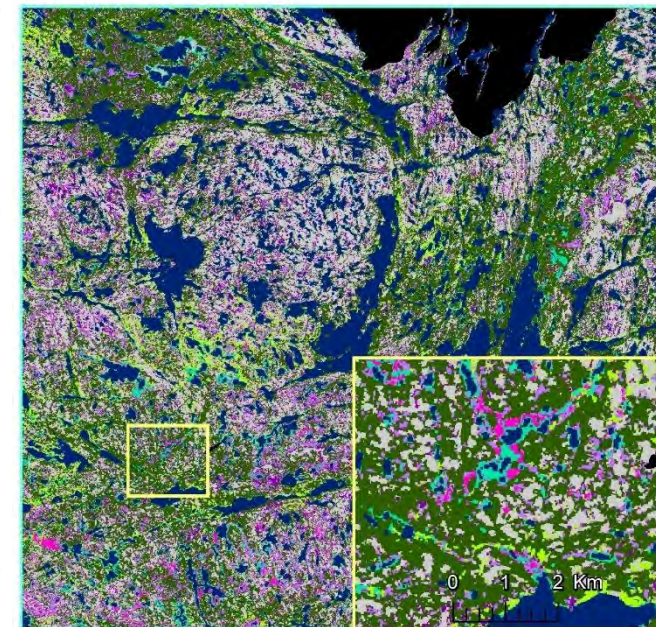
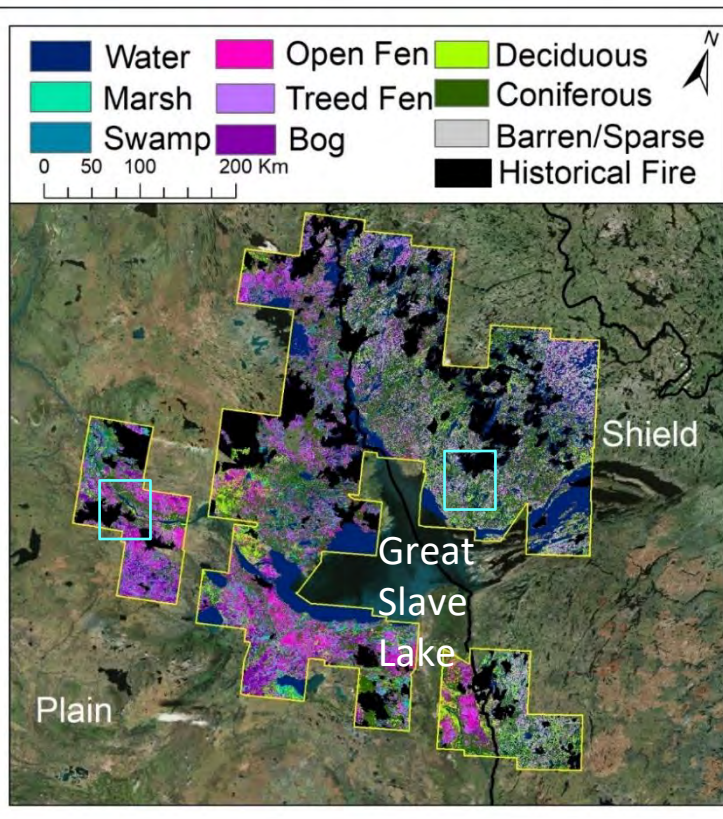
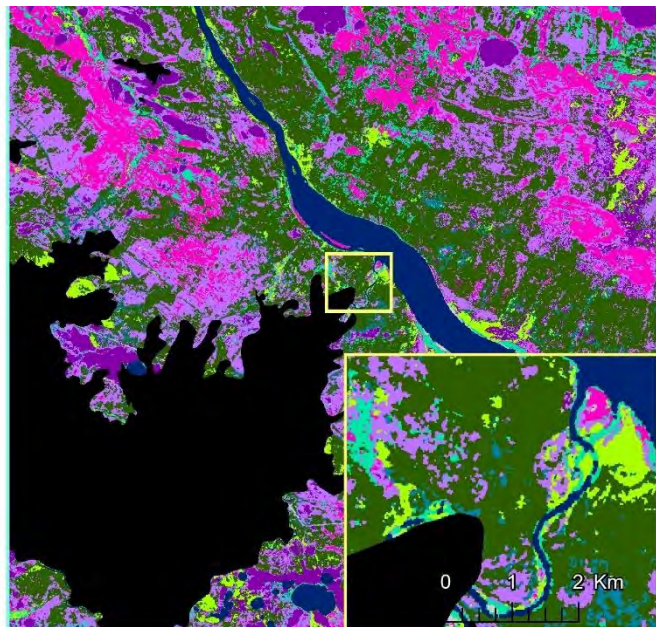
- To assess fire effects on peatlands compared to uplands
- To estimate Carbon stocks and emissions from 136 fires across the Taiga shield/plains study region



Fire Progression Maps from MODIS (Loboda & Csiszar algorithm)

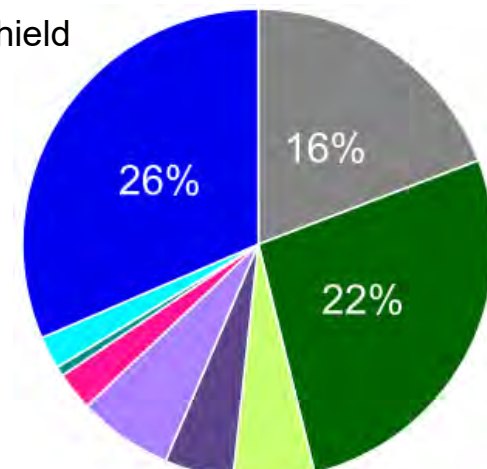


Boreal Peatland Mapping for Drought and Wildfire Affected Area



Taiga Plains

3 season satellite radar and optical data with 4 years of field data
1.34 million Ha mapped with 94% overall accuracy.
90% peatland user's acc., 92% peatland producer's acc.

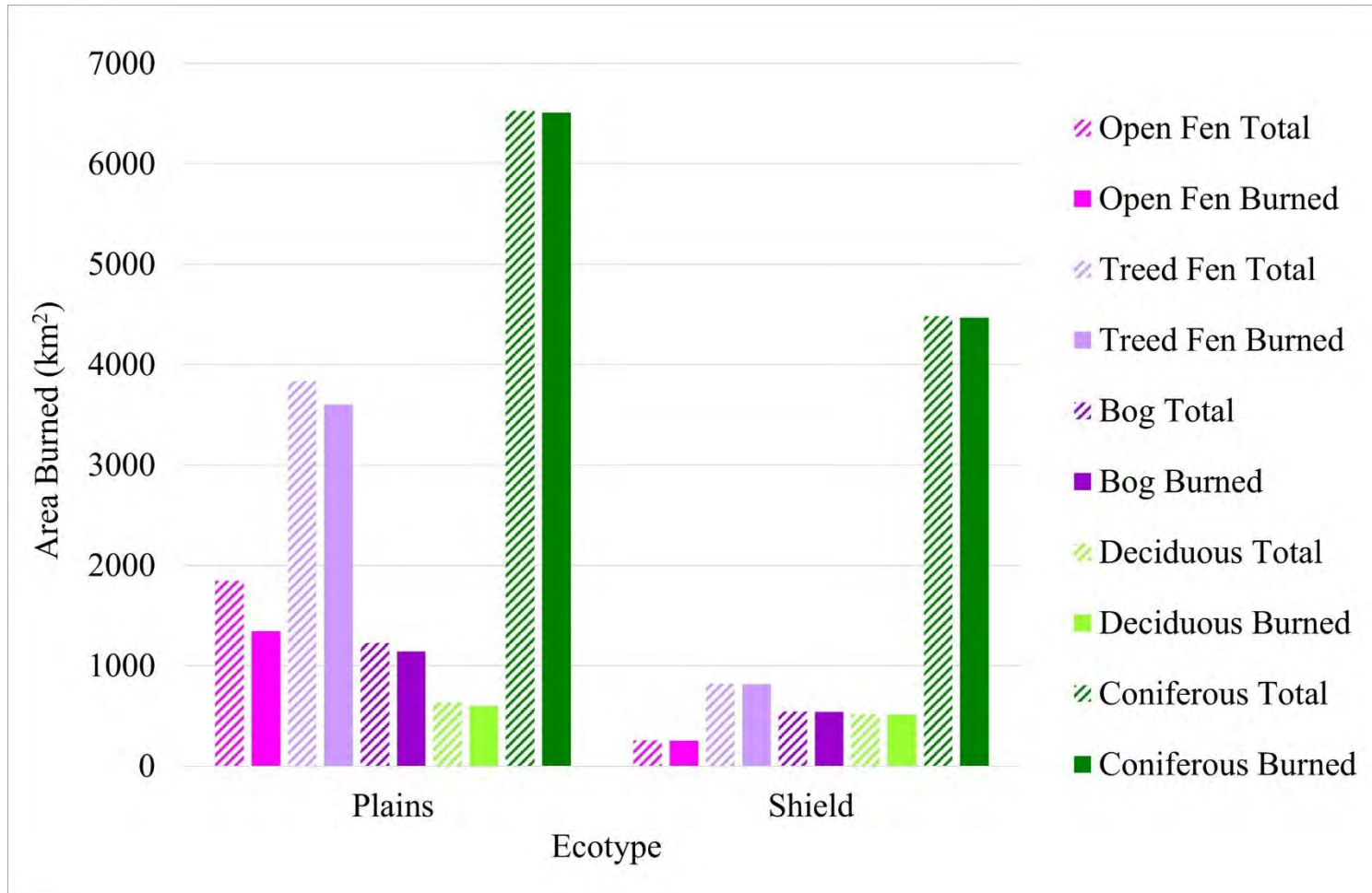


Taiga Shield

Bourgeau-Chavez et al. 2017 CJFR. Maps available on NASA ORNL DAAC:
Bourgeau-Chavez et al. 2019. <https://doi.org/10.3334/ORNLDAAAC/1695>



How Much Peatland Burned in 136 of the 2014 Wildfires?

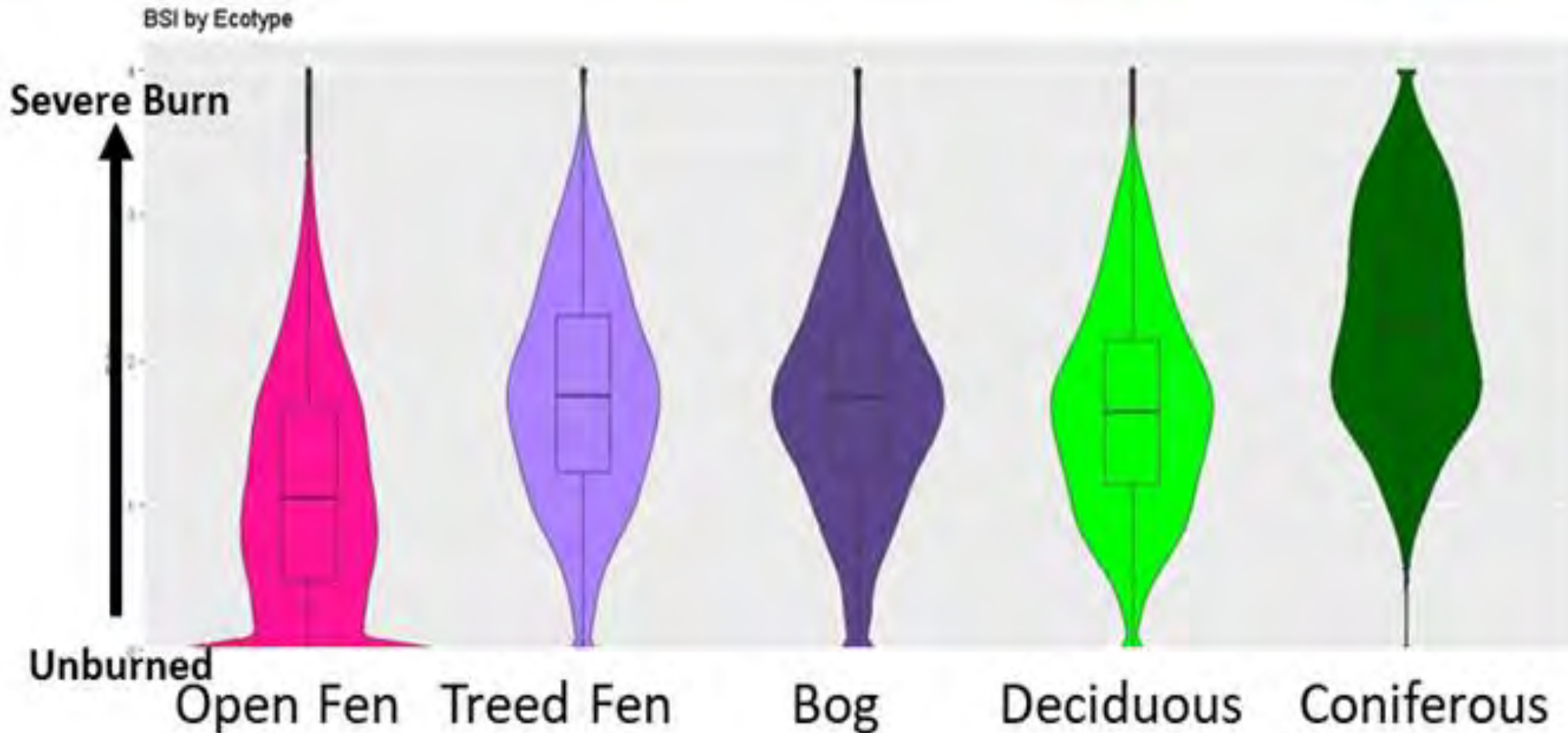


- Hashed bars are total area within fire perimeters
- Solid bars are area burned
- Nearly all of the upland conifer forest burned within all the fires on Shield and Plains
- More areas left unburned on the Plains

Bourgeau-Chavez et al. 2023 Frontiers in Forests and Global Change

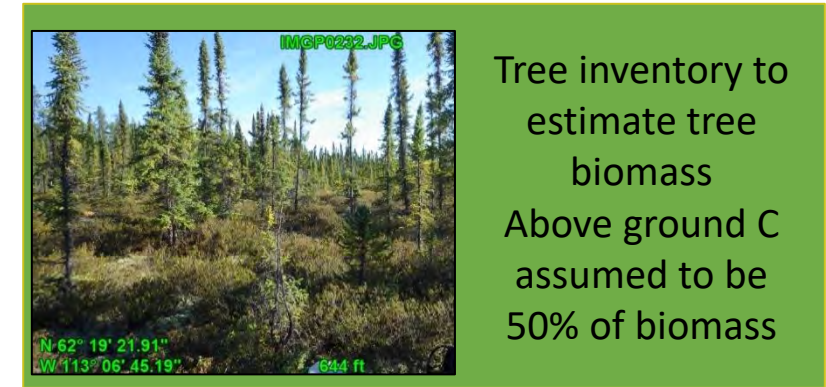
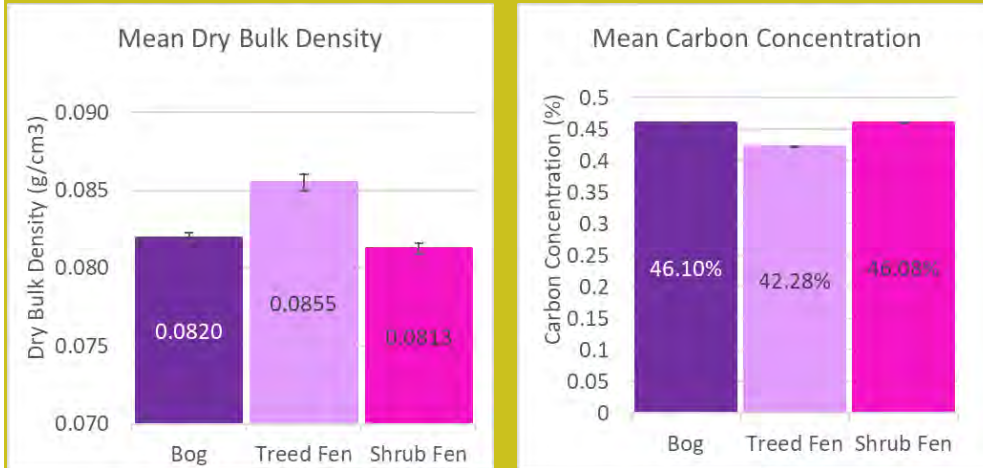
How Deep Did the Ground Burn?

Distribution of Burn Severity in 136 of the 2014 wildfires



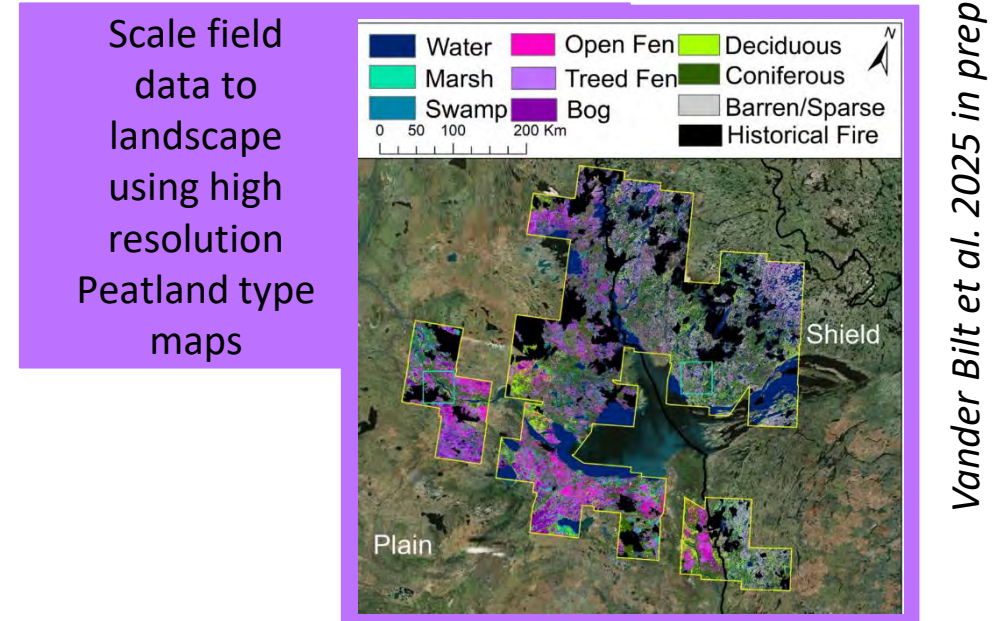
How Much Carbon is Stored in the Peatlands?

Field data on peat depths, peat bulk density and carbon concentration by Peatland type



- Total carbon storage 900 ± 19 Tg for peatlands in study area
- 97% of the C is stored belowground
- More data collected in August will allow separating estimates between shield and plains

*C calculations based on equation from Page et al 2011 Global Change Biology

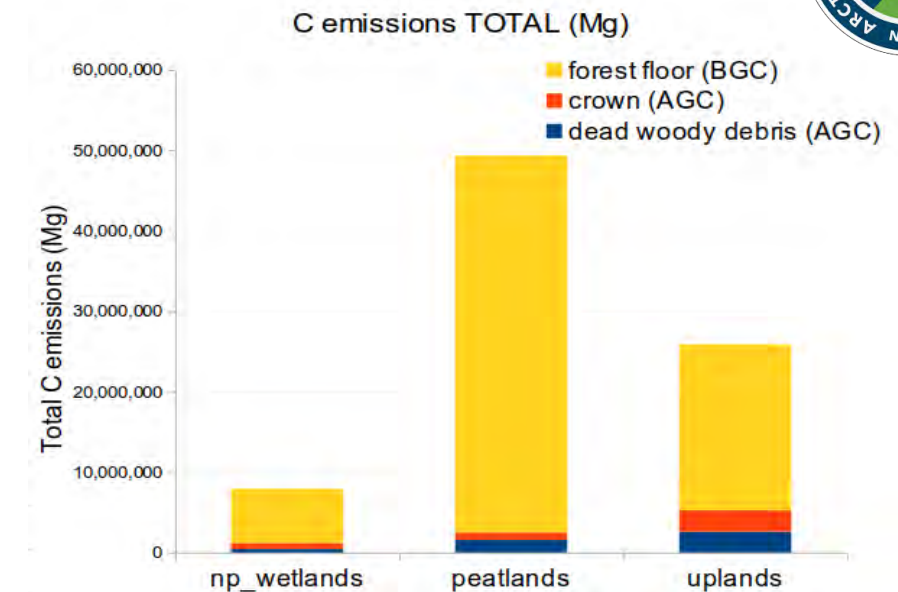
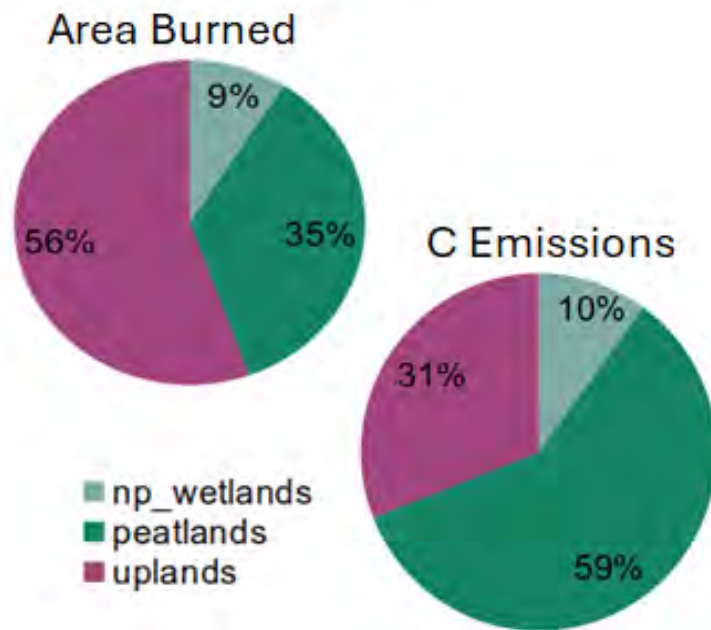


Vander Bilt et al. 2025 in prep

How Much Carbon was Emitted from the Peatlands in Comparison to the Uplands in 2014?



- The fire effects and emissions model, CanFIRE, was parameterized for peatlands for this study using field data on peat characteristics, fuel loading and forest biomass and run on the 11 largest fires



- Most of the emissions are from belowground consumption
- peatlands emit over 3x as much carbon as uplands

Peatlands account for 59% of total C emissions despite making up only 35% of the area burned

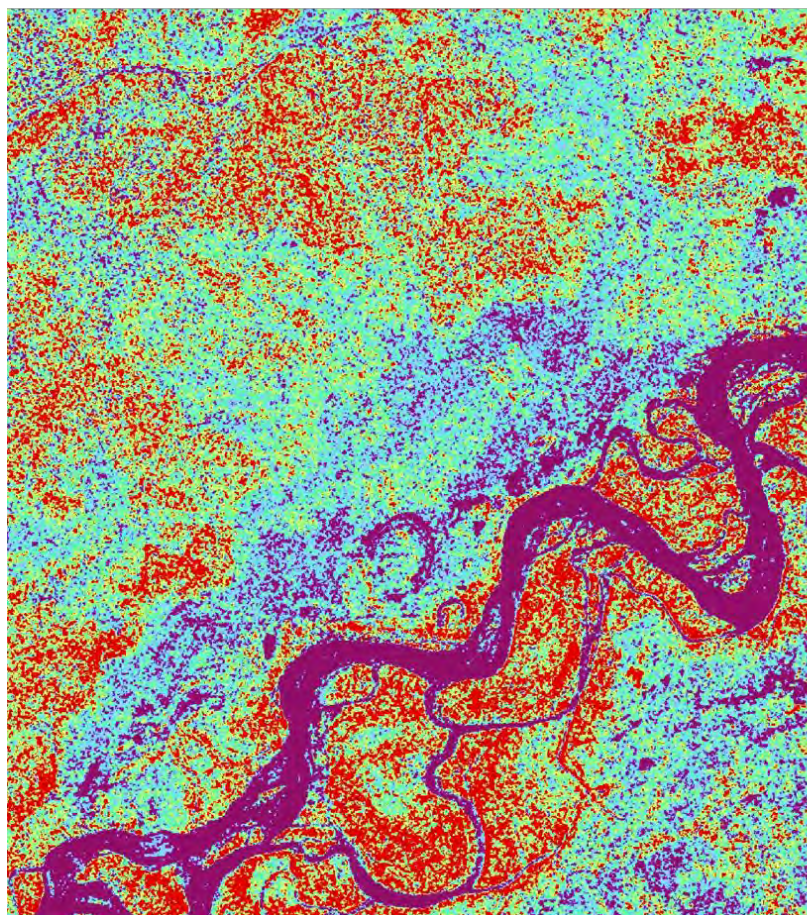


Soil Moisture and Relative Soil Drainage Maps from Satellite Radar

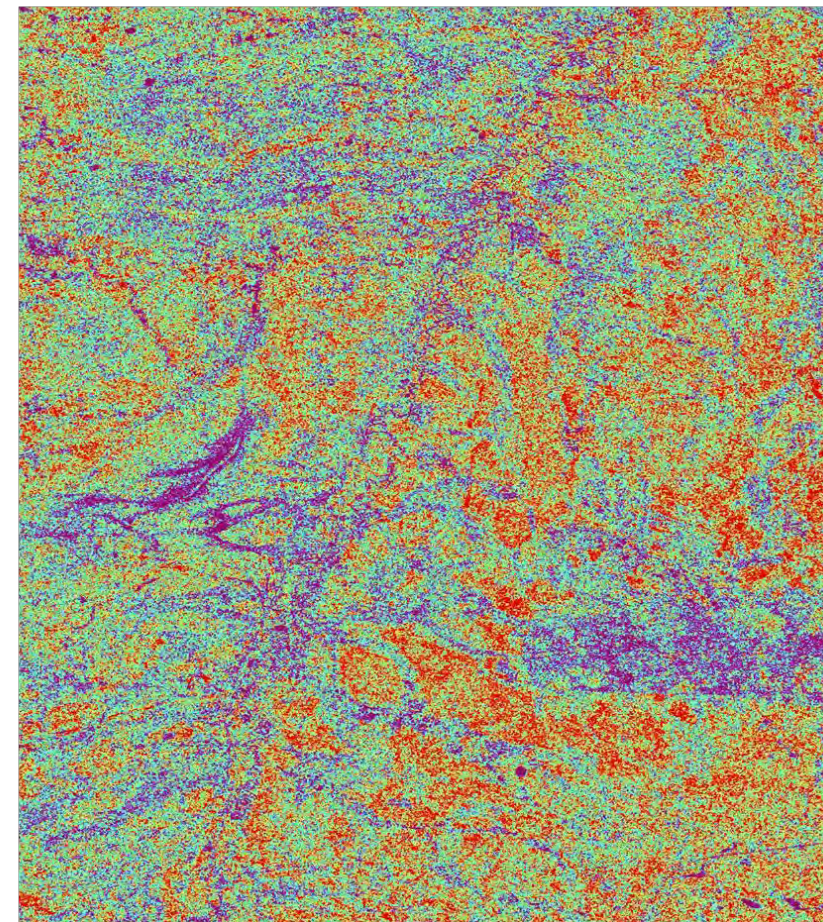
- Soil drainage maps were generated from many dates (time series) of radar images
- Compared each drainage map with field data of soil moisture showed strong correlations (80-90%)
- Products of soil drainage will be made for whole expanded NWT study area
- Need more field data for validation

Poorly Drained

Well Drained



Bonanza Creek Alaska



Red Earth Creek Alberta



Special thank you to the First Nations for allowing us to study your lands and for providing traditional knowledge:

Akaiitcho Territory Government
ARI - South Slave Research Centre
Dehcho First Nations
Denendeh Resource Committee
Deninu K'ue First Nation Environment and Conservation Committee
Fort Providence Resource Management Board
Ka'a'gee Tu Hunters and Trappers Association
North Slave Métis Alliance
Northwest Territory Métis Nation
Tlicho Government
Wek'èezhìi Renewable Resources Board
Yellowknives Dene First Nation - Lands & Environment

And to all the Collaborators and field crews:





ABOVE Successes

Ongoing Engagement with the GNWT Since 2013



*Slide from
Brian Sieben*

- The 2014 NWT Fires— developing a research framework, Yellowknife, NWT, January 2015
- Joint Polar Knowledge Canada/NASA ABoVE/GNWT Workshop Yellowknife, NWT, May 10th to 12th, 2016
- NASA Earth to SKY, Climate Change Education workshop in Yellowknife in April 2017
- Community and Youth Engagement
- Impacts of Forest Wildfire Research Results and Planning Workshop March 2019, Yellowknife
- 2024 Forest and Fire Ecology Workshop, Hay River NWT April 2024
- GNWT Participation in the ABoVE Science Meetings
- Seeking GNWT input on flight paths aircraft undertaking remote sensing
- ABoVE newsletters/ ABoVE NWT webinar series



Joanne Speakman is an emerging Indigenous Leader from Délı̨nę on a NASA flight.

Joanne Speakman and Mandy Bayha being involved in the NASA remote sensing and having the opportunity to present at the ABoVE Science Meeting in San Diego, in 2019



Jacki, North Slave Métis Alliance youth, with MTRI handheld field spectrometer NWT in 2022



ABOVE Open House at the Yellowknife Airport Thursday August 15, 2024



*Slide from
Brian Sieben*





All are welcome to attend the next ABoVE Science team meeting in Fairbanks in person or via remote participation

https://above.nasa.gov/meeting_2025/index.html

- marine mammals
- raptors
- seabirds
- shorebirds
- terrestrial mammals
- waterbirds



Thank you
Questions?

Ichavez@mtu.edu

Jan 01

Davidson SC, et al. 2020. Ecological insights from three decades of animal movement tracking across a changing Arctic. Science.





Aurora Research Institute's Carbon Emission Project: Methane Detection

Garfield Giff Ph.D.
**Research Chair: Climate Change
Adaptation**





Project's Aim

- To support methane data collection and analysis from natural and man-made features across the NWT
- Build methane data collection capacity at the community level





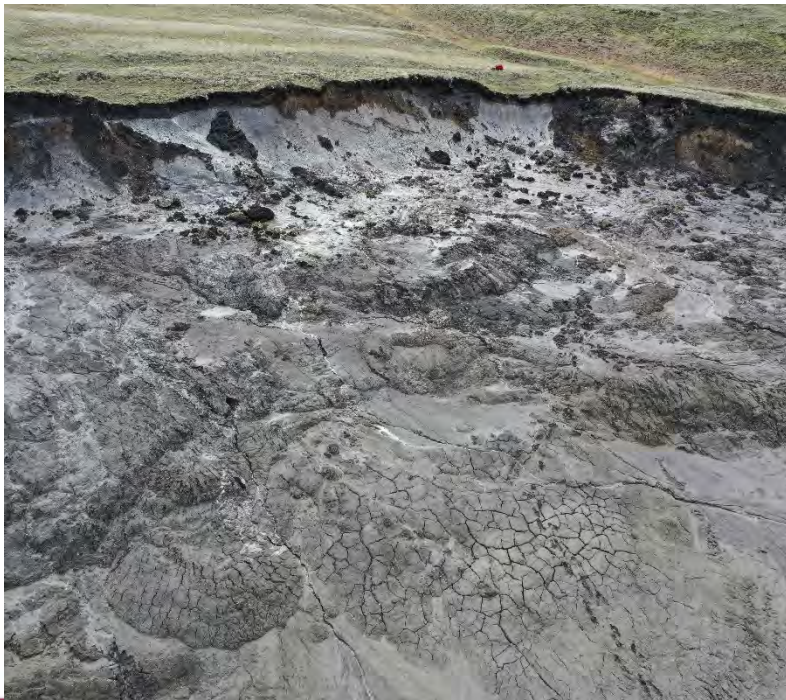
Two Phases Over Five Years

- Phase 1 2024-26: Data collection and training
- Phase 2 2026-29: Data collection, analysis and training



Phase 1 Activities

- Methane Data Collection From Natural Features



Phase 1 Activities Cont'd

- Methane Data Collection From Man-made Features

Waste Site



Capped Wells and Sumps



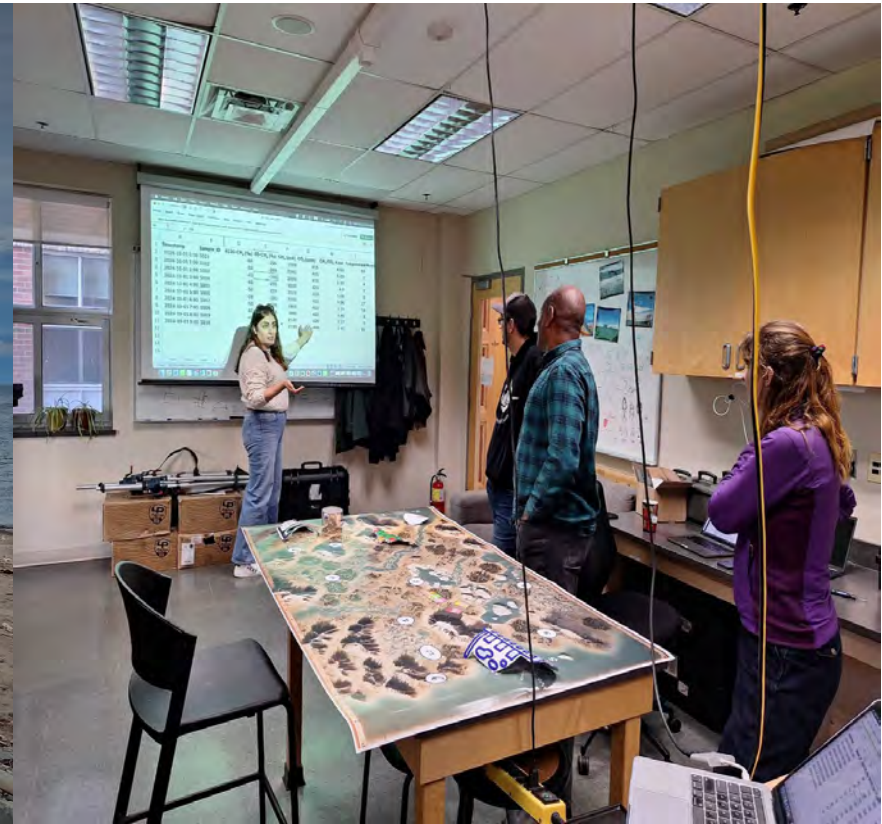
Phase 1 Activities Cont'd

- Methane Data Collection Training for Community-based Researchers
- Training on at least 3 different types of sensors
 - ☐ Drone Based
 - ☐ Vehicle Based
 - ☐ Hand held



Phase 1 Activities To-Date

- ARI Team trained in methane data collection using different sensors



Phase 1 Activities To-Date Cont'd

- Equipment Acquired:
 - ❑ Drone-based sensor: MIRA Strato LDS
 - ❑ Drone: Matrice 350

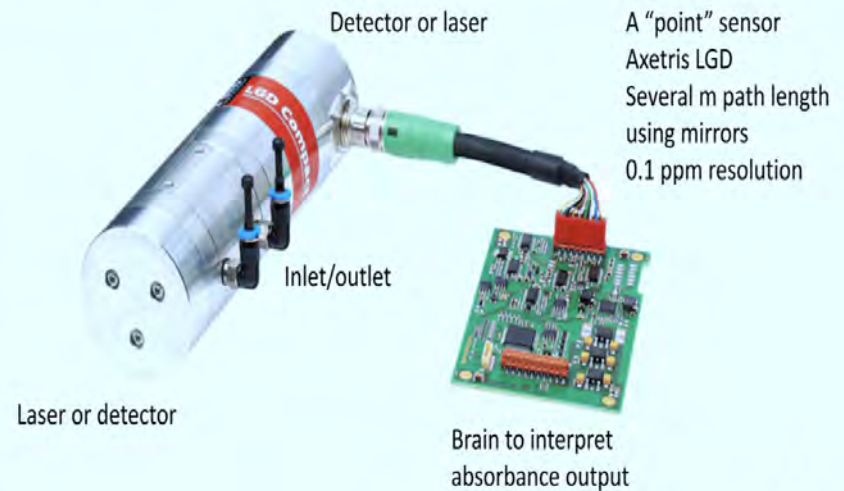


Phase 1 Activities To-Date Cont'd

- Vehicle- based Sensor: Tunable Diode Laser Absorption Spectroscopy (TDLAS)



Traditional TDLAS



Phase 1 Activities To-Date Cont'd

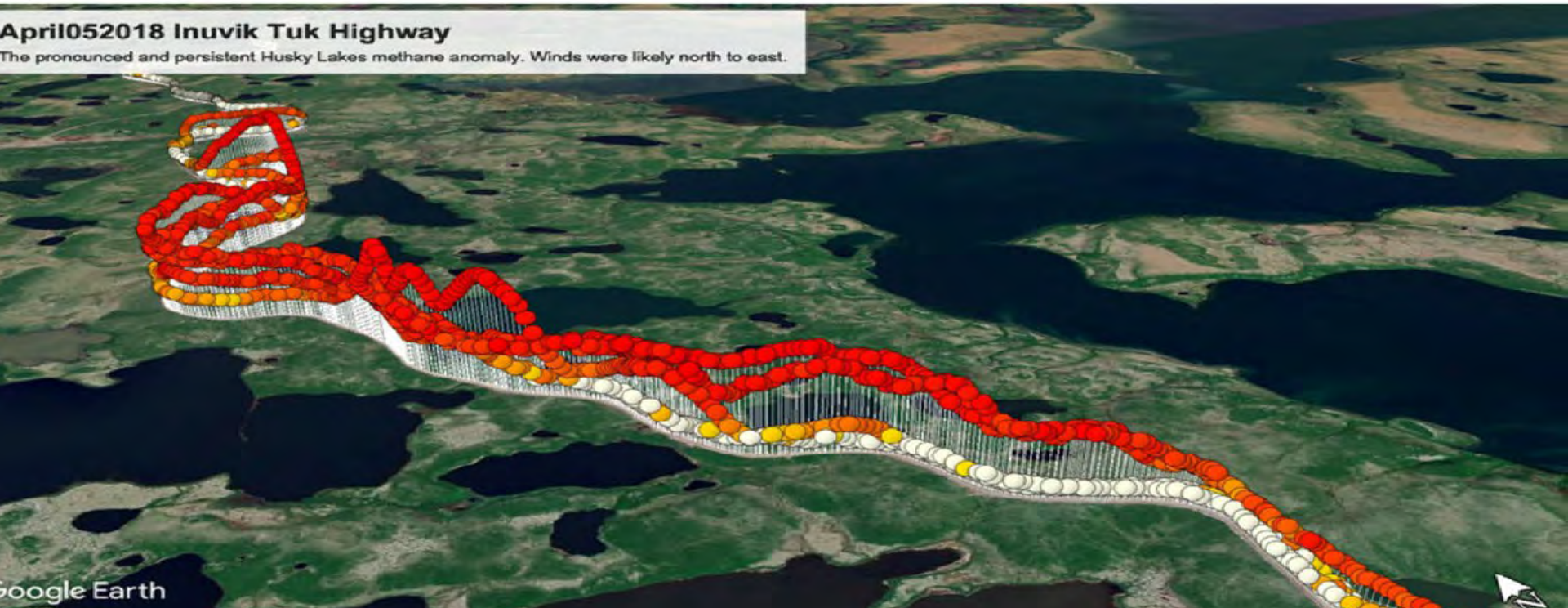
- Hand-held sensor: Gazoscan BT



Upcoming Projects

Collect methane emission data along the Dempster Highway from the Yukon border to Tuk. A follow-up on work previously done by FluxLab and ARI. Partners: C-CORE and FluxLab

April 05 2018 Inuvik Tuk Highway
The pronounced and persistent Husky Lakes methane anomaly. Winds were likely north to east.





Upcoming Projects Cont'd

- Collect Methane Data From:
 - Wetlands
 - Lakes
 - Landslides
 - Slumps
 - Burnt Areas and
 - Other natural features identified by partners



Upcoming Projects Cont'd

- Monitoring of selected oil and gas wells and sumps in the ISR for possible methane emission. Partners ILA



Kokelj and GeoNorth 2002



Kokelj and GeoNorth 2002



Upcoming Projects Cont'd

- Provide support for C-CORE's projects on "Quantifying Landscape Emissions" in the NWT
- Provide Training of community-based researchers in methane data collection





Other Planned Projects in Phase 1

- Partner with selected local community governments to measure methane emission from community dumps
- Partner with Indigenous organizations to grow capacity in measuring methane emission.





Reach out if you are interested

Garfield Giff

Garfield.Giff@auroracollege.ca

867-777-3298 x209





Multiple Platforms for Quantifying Landscape Emissions

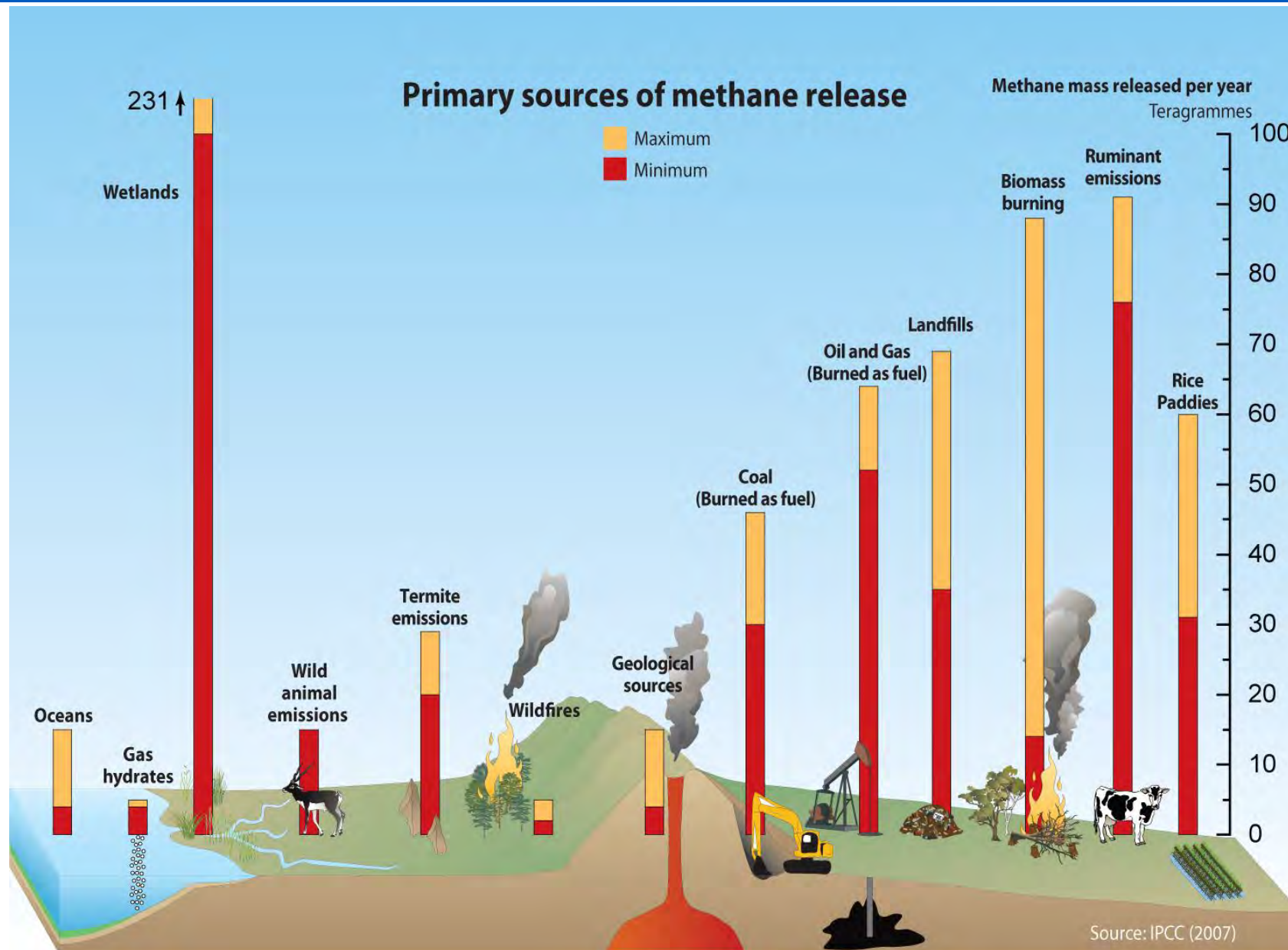
Landscape Carbon Workshop, Yellowknife, NT
6th February 2025



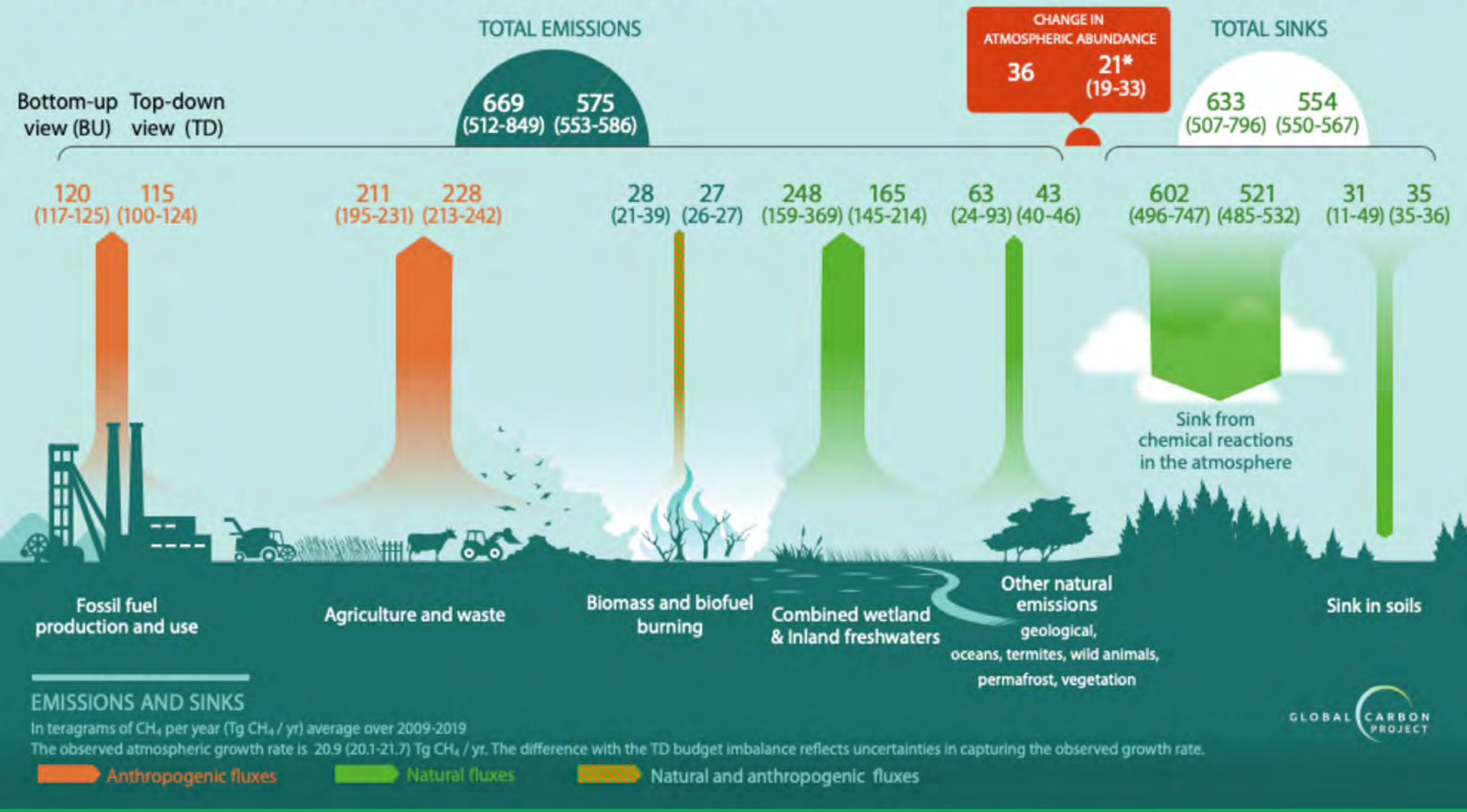
Overview

- Methane emissions from human/site activity and landscapes
 - Landscape emissions is 'next frontier'
- Use of AI needed for efficient scaling globally
 - Facility based emissions work progressing
- Multi-platform approaches to methane emissions
 - Satellites, drones, aircraft, field campaigns, in-situ platforms
- Multi-collaborator approaches to projects
 - ARI, GHGSat, FluxLab, TerraMotion
 - U of Montreal, Wilfrid Laurier University, Memorial, GSC

Overview

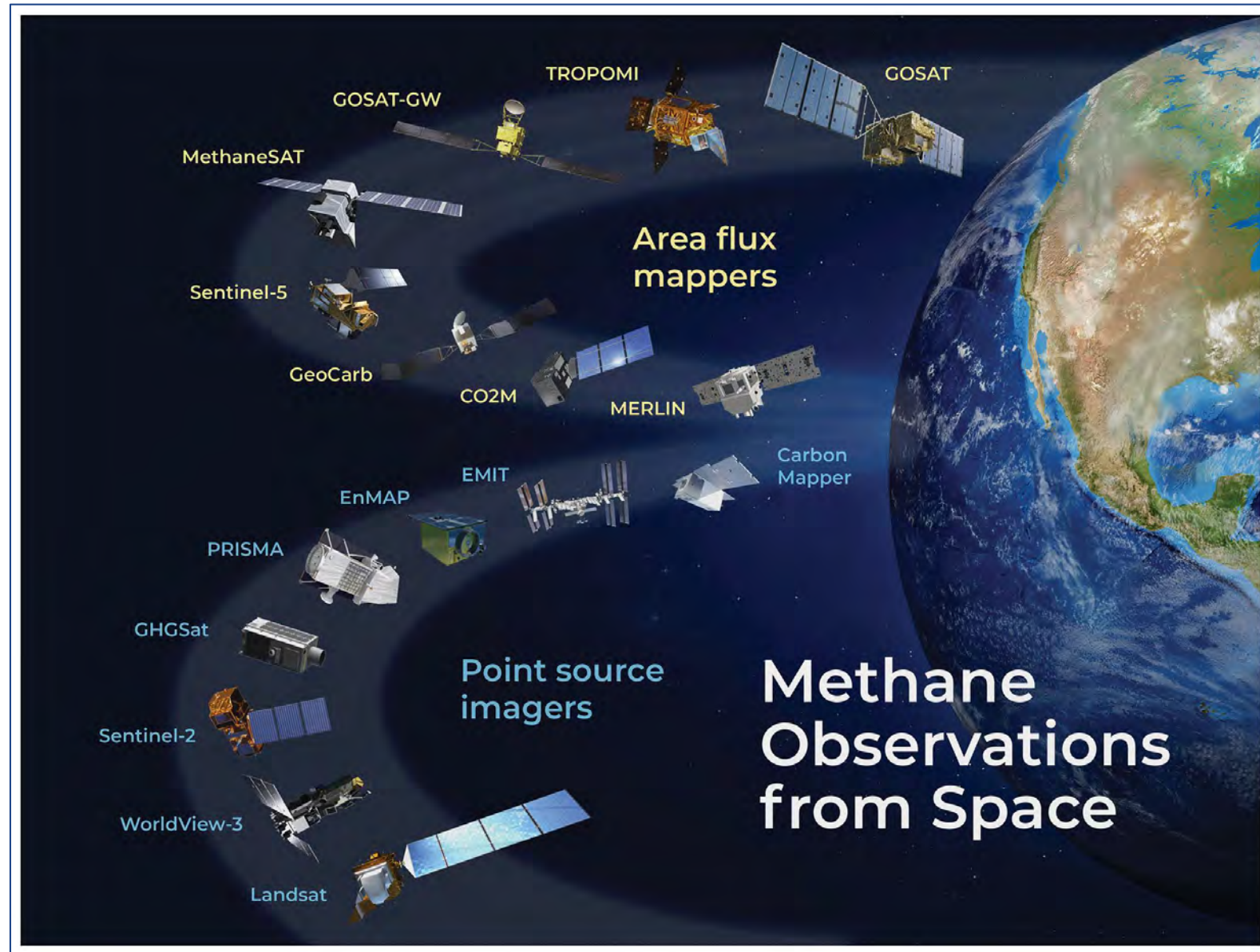
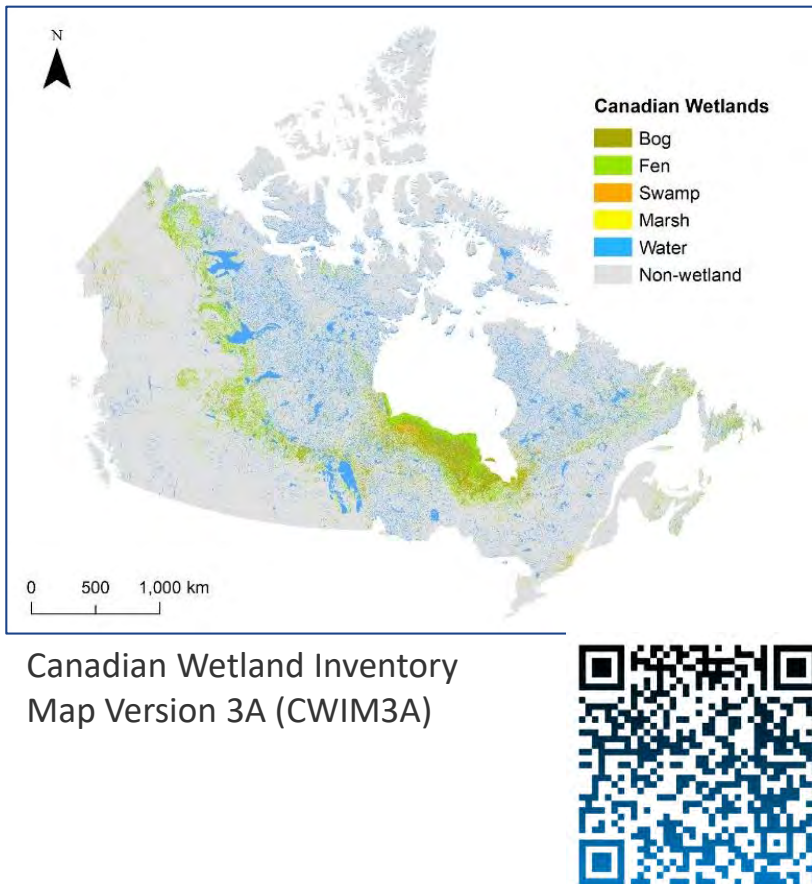


GLOBAL METHANE BUDGET 2010-2019



Overview

- C-CORE – satellites
- Landscape feature map – Wetlands



Jacob, D. J., et al. (2021). *Satellite observations of atmospheric methane and their value for quantifying methane emissions*. Atmospheric Chemistry and Physics, 21, 14351–14378.

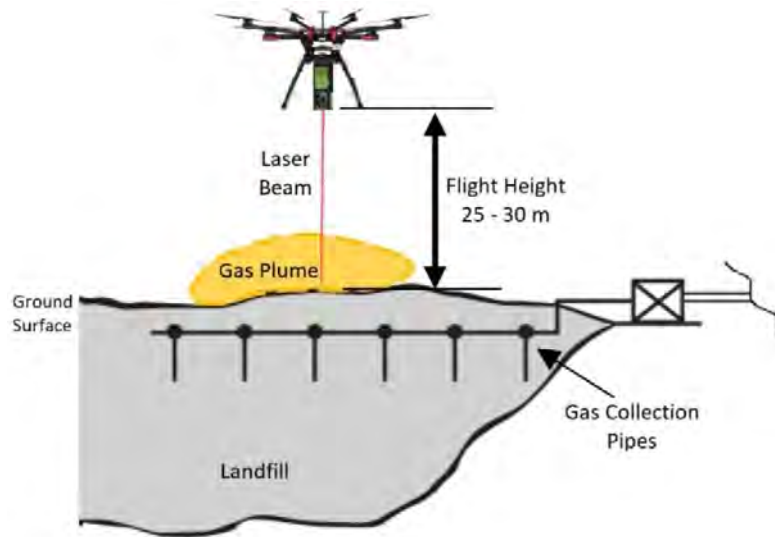
Overview

- University of Montreal
 - Eddy covariance towers



Overview

- Aurora Research Institute
 - Drone and vehicle measurements





Environment and
Climate Change Canada

Environnement et
Changement climatique Canada

CANADA'S GREENHOUSE GAS OFFSET CREDIT SYSTEM AND PROTOCOLS

Landscape Carbon Workshop
February 6th, 2025



Negha Dágøht'e

Negha Dágøndih

Haluuqqagin

Bienvenue

Aatituu / Aaqana tānisi

Ainngai

Édlánet'é

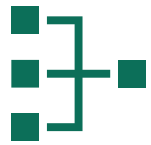
Dànch'ùh

Welcome

Edànet'e / Dànet'e



PRESENTATION OVERVIEW



Canada's GHG Offset Credit System



Implementing an Offset Project



Improved Forest Management Federal Offset
Protocols



Additional Resources



CANADA'S GHG OFFSET CREDIT SYSTEM

Canada's GHG Offset Credit System

Incentive for activities that reduce GHGs and:

- go beyond business-as-usual practices and legal requirements
- are not already covered by other carbon pollution pricing measures.



New opportunities to earn **revenues**



Can be sold to facilities regulated under the **federal pricing system** for industrial emitters



No restrictions as to who can purchase federal offset credits



Sale of federal offset credits occurs outside the system

FEDERAL OFFSET PROTOCOLS - STATUS

Landfill Methane Recovery and Destruction



Status: Final Protocol Published
Applicable: Everywhere but BC, AB, QC

Reducing GHG Emissions from Refrigeration Systems



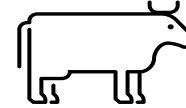
Status: Final Protocol Published
Applicable: Everywhere

Improved Forest Management on Private Land



Status: Final Protocol Published
Applicable: Everywhere but BC

Reducing Enteric Methane Emissions from Beef Cattle



Status: Expected Publication of Final Protocol Winter/Spring 2025

Other Protocols Under Development



Reducing Manure Methane Emissions



Enhanced Soil Organic Carbon



Direct Air Carbon Dioxide Capture and Geological Storage



Improved Forest Management Public Land

Project Types in Consideration for Future Protocol Development



Bioenergy carbon dioxide capture and geological storage

KEY ELEMENTS OF CANADA'S GHG OFFSET CREDIT SYSTEM



Offset Credit System Regulations

Contains **rules to establish and operationalize the system**, and the general requirements applicable to all project types



Federal Offset Protocols

Sets out **requirements and the approach for quantifying** GHG reductions for a given project type



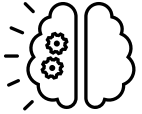
Credit and Tracking System (CATS)

Enables **registration of offset projects, issuance and tracking** of offset credits, and sharing of key information through a public registry

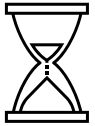


IMPLEMENTING AN OFFSET PROJECT

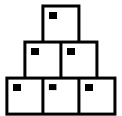
CONSIDERATIONS WHEN PLANNING A PROJECT



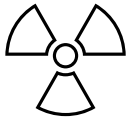
Understand the **rules of the system** and **project feasibility**



Commitment to **project lifecycle** (usually 10 – 125 years)

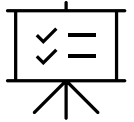


Build up required capacity and resources



Understand **risks** and **uncertainties** involved

CONSIDERATIONS WHEN PLANNING A PROJECT



Find ways to achieve **multiple objectives**



Build relationships with **trusted partners**

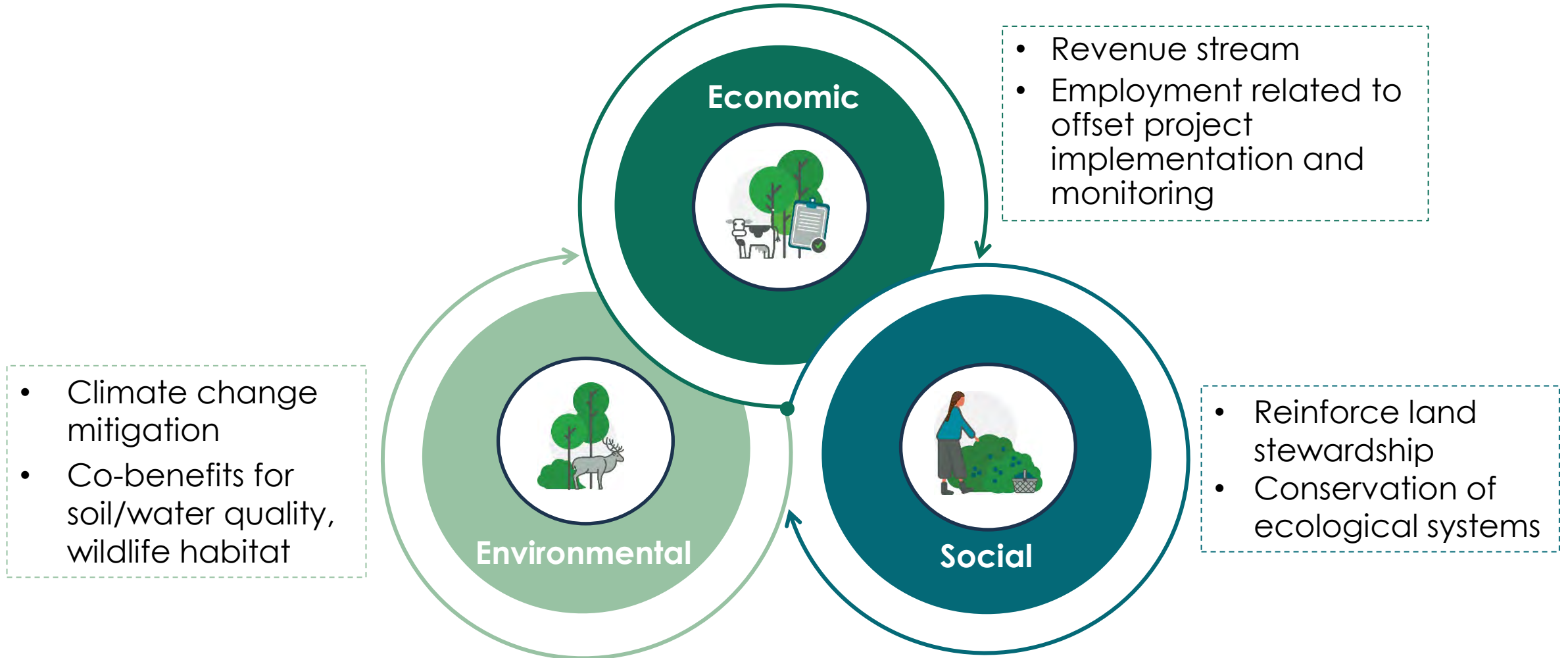


Learn from the **experience of others**



Find a **buyer** for credits, in advance if possible

BENEFITS OF OFFSET PROJECTS

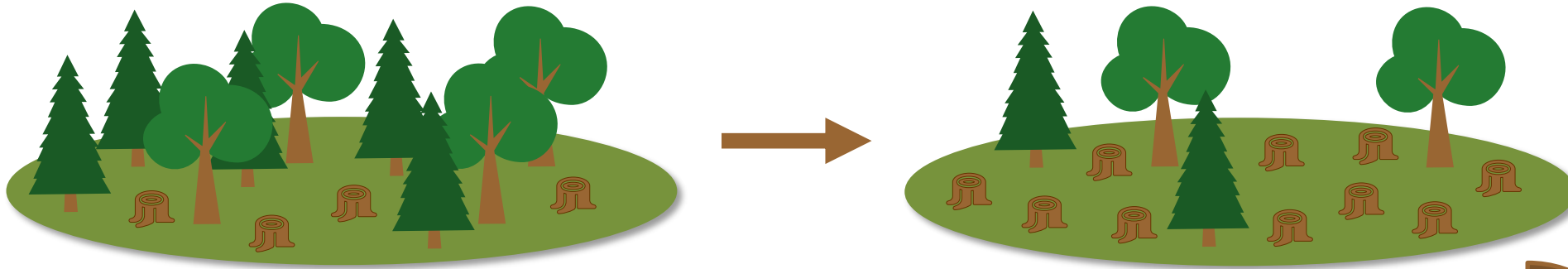




FEDERAL OFFSET PROTOCOLS: IMPROVED FOREST MANAGEMENT

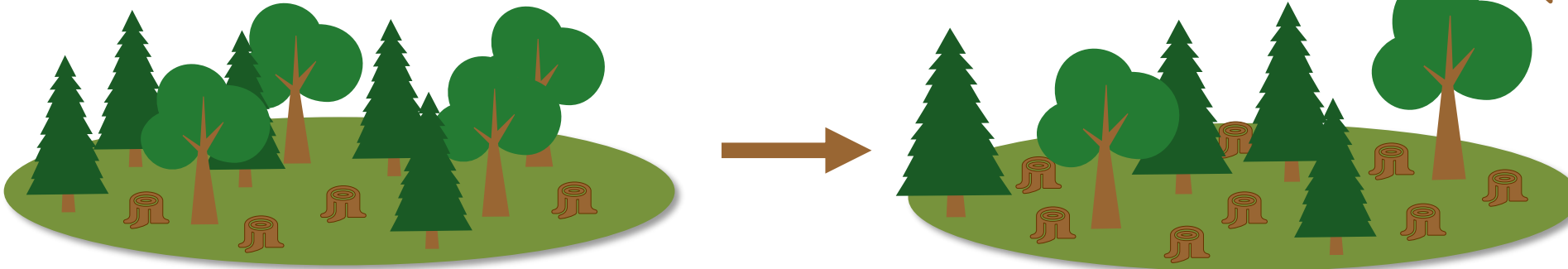
IMPROVED FOREST MANAGEMENT ON PRIVATE LAND

Baseline scenario (i.e., business-as-usual forest management)



- Typical management
- What would have happened to the forest

Project scenario (i.e., new forest management activities)



Difference between baseline and project

- New management activities
- Increased forest growth
- Decreased harvest

KEY ELEMENTS OF IFM ON PRIVATE LAND

Additionality

GHG removals must go beyond business-as-usual forest management practices

Baselines

The activities and GHG removals that were most likely to occur in the absence of the project

Forest Carbon Inventory

Measurements from the project site to determine how much carbon is stored over time

Leakage

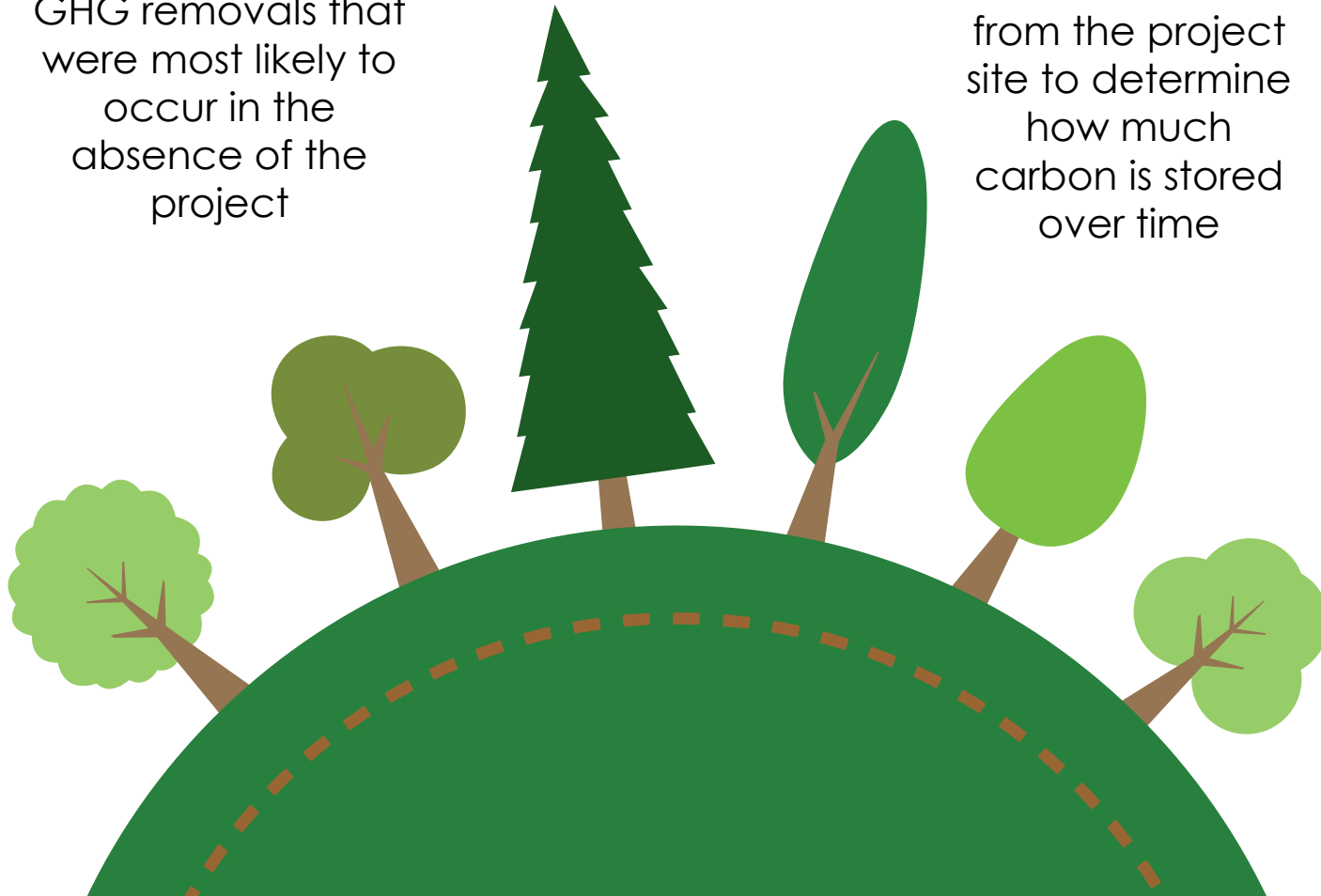
Accounts for GHG emissions that shift to outside the project site due to changes in harvest levels

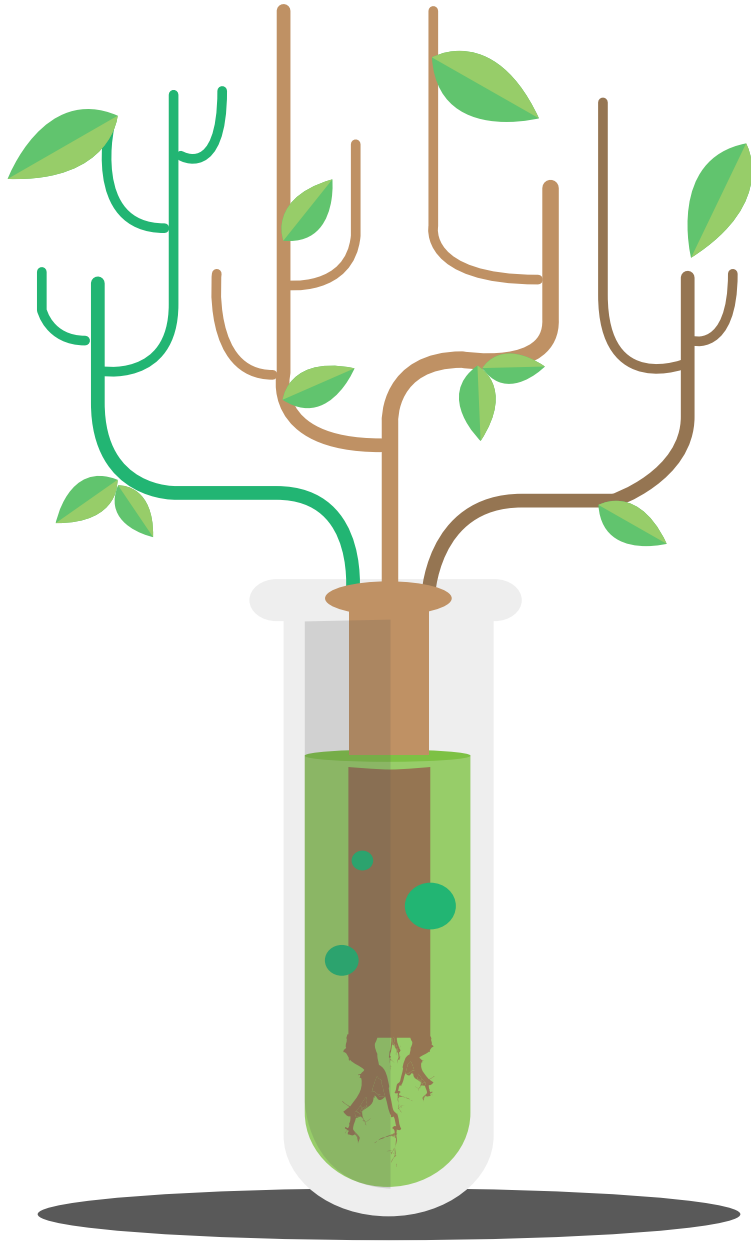
Environmental Safeguards

Ensures there is “no net harm” to the environment as a result of the project activities

Permanence

Ensures GHG removals that could be reversed are maintained for 100 years





IMPROVED FOREST MANAGEMENT ON PUBLIC LAND

- Approximately 38% of Canada's land area is forested land
 - 88% of forest land is provincial Crown and territorial public land
- Will have a similar scope to IFM on Private Land
 - Improving forest management to increase carbon stocks on managed forestlands
- Included land tenures: provincial Crown land and public land in the territories
- Excluded land tenures:
 - Private land and First Nation reserves (covered under IFM on Private Land)
 - Federal Crown land (e.g., national parks, military bases)

INFORMATION RESOURCES

- GHG Offsets Toolkit available at Canada.ca/GHG-Offsets-Toolkit.
 - In English, French, Ojibwe, Mi'kmaq, Woods Cree and Swampy Cree
 - Includes factsheets with information on carbon markets, offset credits and considerations for how to plan a project
 - Contains links to resources from Indigenous organizations
- [Canada's GHG Offset Credit System Regulations](#)
 - [Overview – Canadian Greenhouse Gas Offset Credit System Regulations under the Greenhouse Gas Pollution Pricing Act](#)
- [Improved Forest Management on Private Land v1.1 federal offset protocol](#)
 - [Federal offset protocol overview: Improved forest management on private land](#)



Qujannamiik, Nakurmiik

Máhsı

Mársı

Haj'

Thank you

Quana

kinanāskomitin

Quyainni

Merci

Masì



CONTACT INFORMATION

Offset & Emissions Trading Section

Carbon Markets Bureau

Environment and Climate Change Canada



creditscompensatoires-offsets@ec.gc.ca





Environment and
Climate Change Canada

Environnement et
Changement climatique Canada

ANNEX



Canada 

KEY FEATURES OF CANADA'S OFFSET CREDIT SYSTEM

Complementarity

- National in scope and complements Provincial and Territorial systems.
- Projects not eligible to register in jurisdictions where Provincial and Territorial protocol exists for the same activity.

Environmental Integrity

- Proponents must replace invalid credits.
- Environmental Integrity Account acts as a form of insurance for involuntary reversals (fires, pests, etc.).

Project start date

- Project must have started on or after January 1, 2017.
- Crediting period starts at the latter of either the date of registration or project start date. There is no-back crediting.

Exclusive Entitlement

- Proponents must have exclusive entitlement to claim the credits generated by the project.
- Projects that receive direct financial incentives may still be eligible if this requirement is met.

Aggregation of Projects

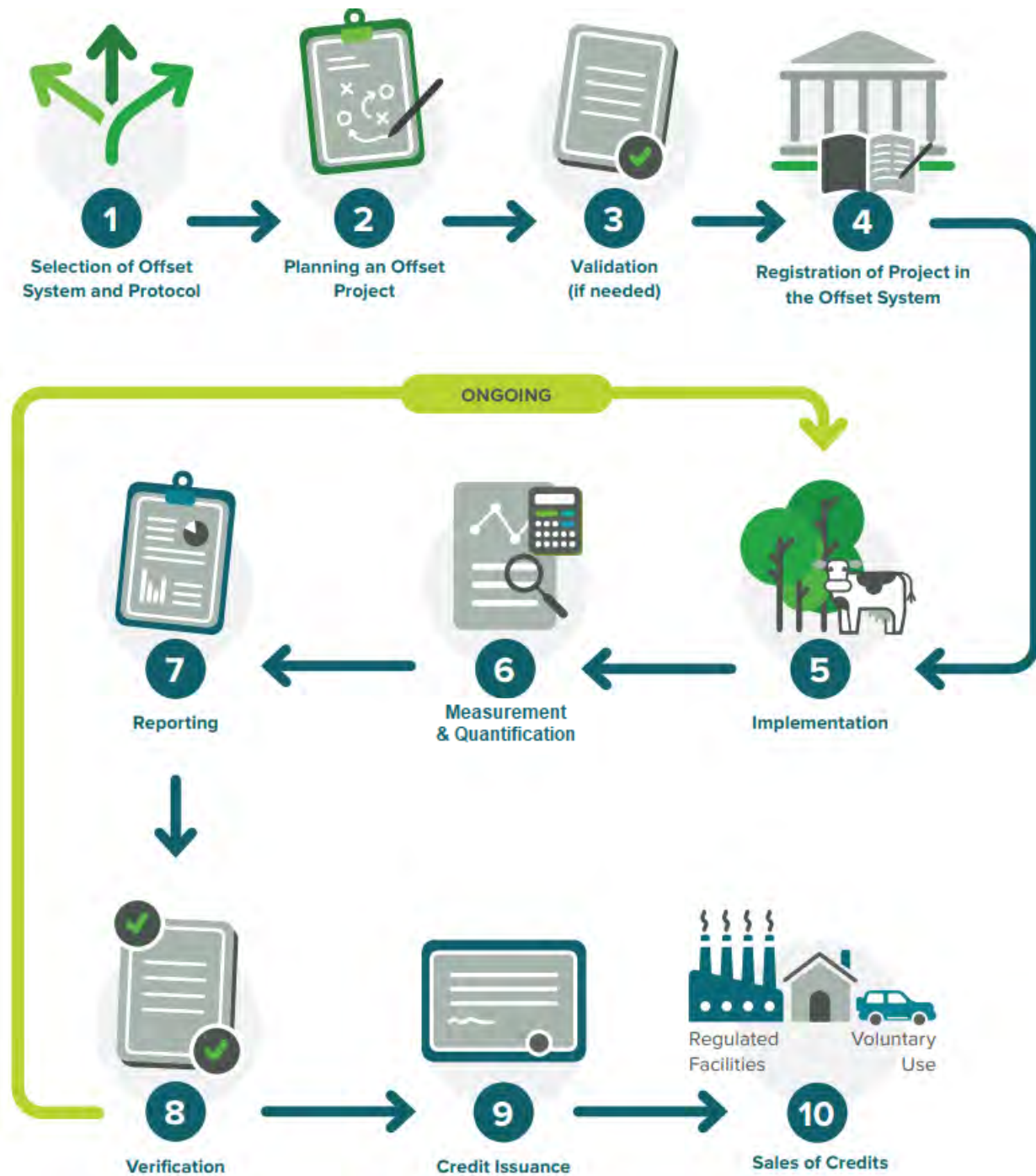
- Multiple projects can be aggregated to pool GHG reduction potential and reduce costs, provided they are same type and in the same province or territory.

Indigenous Focus

- Incorporating Indigenous perspectives into protocol development, particularly for nature-based activities.
- Tool kit developed to support capacity building.



STEPS IN AN OFFSET PROJECT



Policy gaps and solutions for land carbon in NWT – a focus on peatlands



Peatlands in the Hudson Bay Lowland, Canada
Photo: Lorna Harris



Dr Lorna Harris

**Director – Forests, Peatlands, and Climate Change
Wildlife Conservation Society (WCS) Canada**

Landscape Carbon Workshop - Yellowknife, Northwest Territories – February 6, 2025

WCS Canada's Forests, Peatlands, and Climate Change Program

National Peatland Policy Project

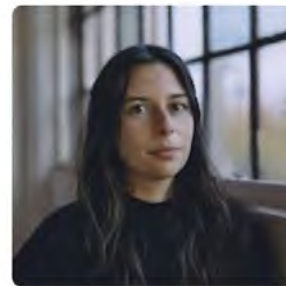
Our team



Lorna Harris
Director of Forests,
Peatlands and
Climate Change
Program



Victoria Goodday
Policy Lead -
Forests, Peatlands
and Climate
Change



Laura Tanguay
Policy Analyst -
Forests, Peatlands
and Climate
Change

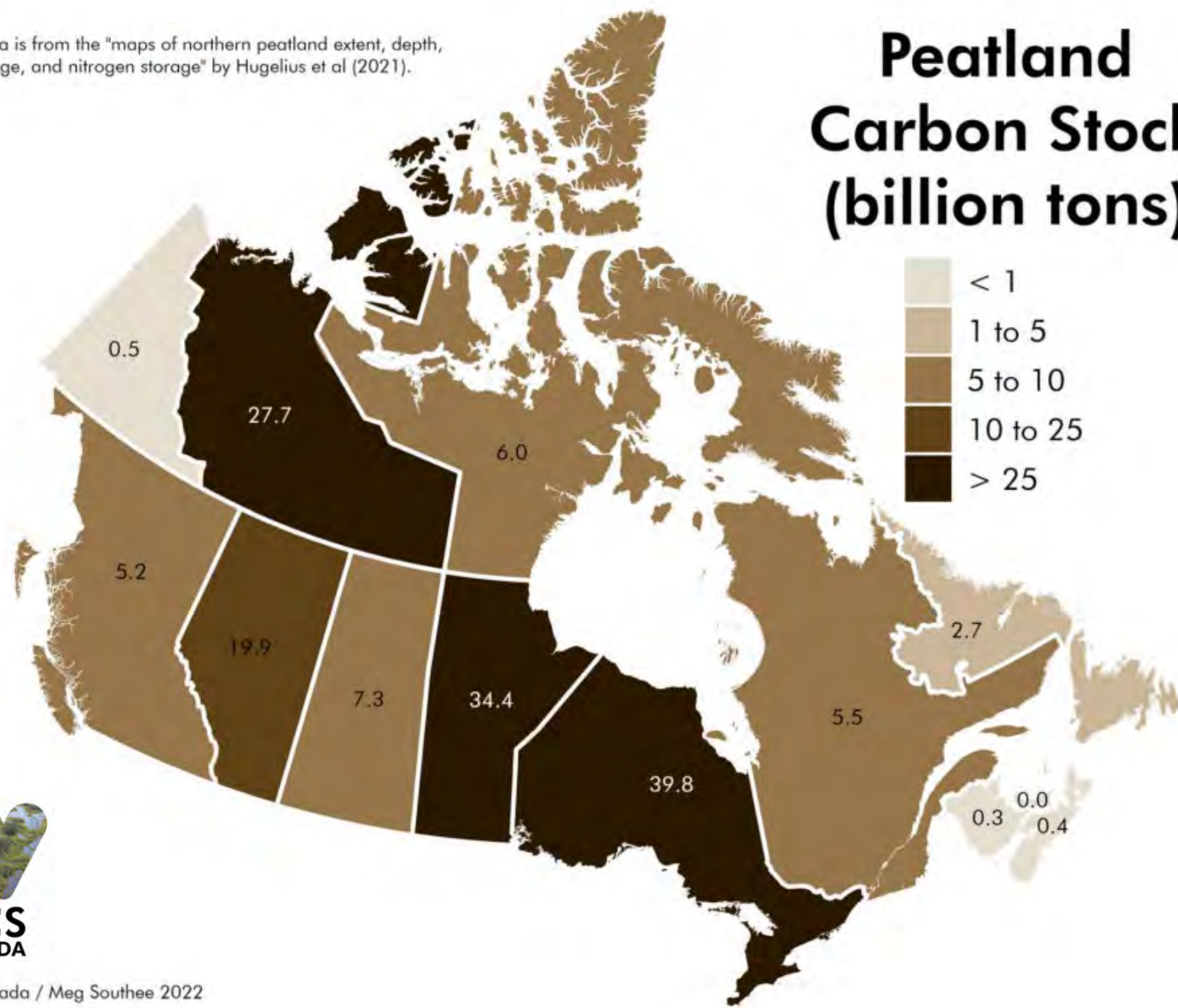


Nicola Radatus-
Smith
Research and
Outreach Assistant -
National Peatlands
Policy Project

Peatland data is from the "maps of northern peatland extent, depth, carbon storage, and nitrogen storage" by Hugelius et al (2021).

Province or territory	% peatland area within protected areas
Alberta	23.1
Yukon Territory	21.9
Quebec	19.5
Nova Scotia	15.5
British Columbia	14.2
Northwest Territories	13.3
Manitoba	13.2
Nunavut	10.7
Saskatchewan	9.8
New Brunswick	8.9
Ontario	8.8
Newfoundland and Labrador	6.1
Prince Edward Island	2.3
Canada total (this review)	13.1

Peatland Carbon Stock (billion tons)



National Peatland Policy Project

Objectives

Phase 1 (*current*):

Draw on collective experience to produce a vision and strategy for the protection and stewardship of peatlands across Canada.

- Identify workable solutions to current challenges
- Produce policy recommendations relevant to provincial, territorial, Indigenous, and federal governments to support realisation of the vision

Phase 2 (*late 2025-*):

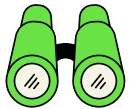
Work with decision-makers, policy-makers, influencers and others to support uptake and implementation of identified solutions and recommendations.

Policy Review

November 2024 Policy Brief



RESEARCH QUESTION: What law and policy is in place in Canada to protect peatlands and their essential carbon services?

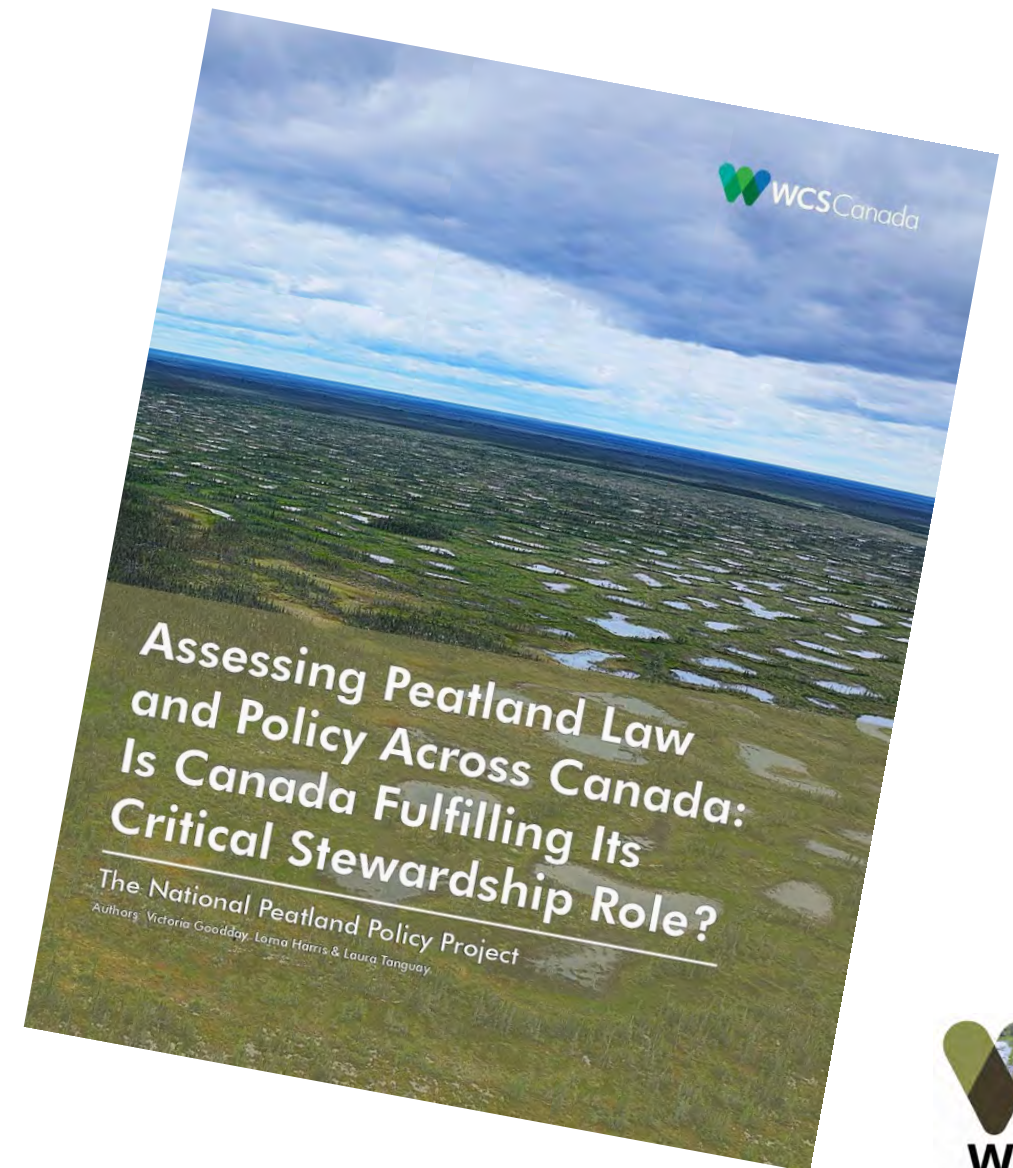


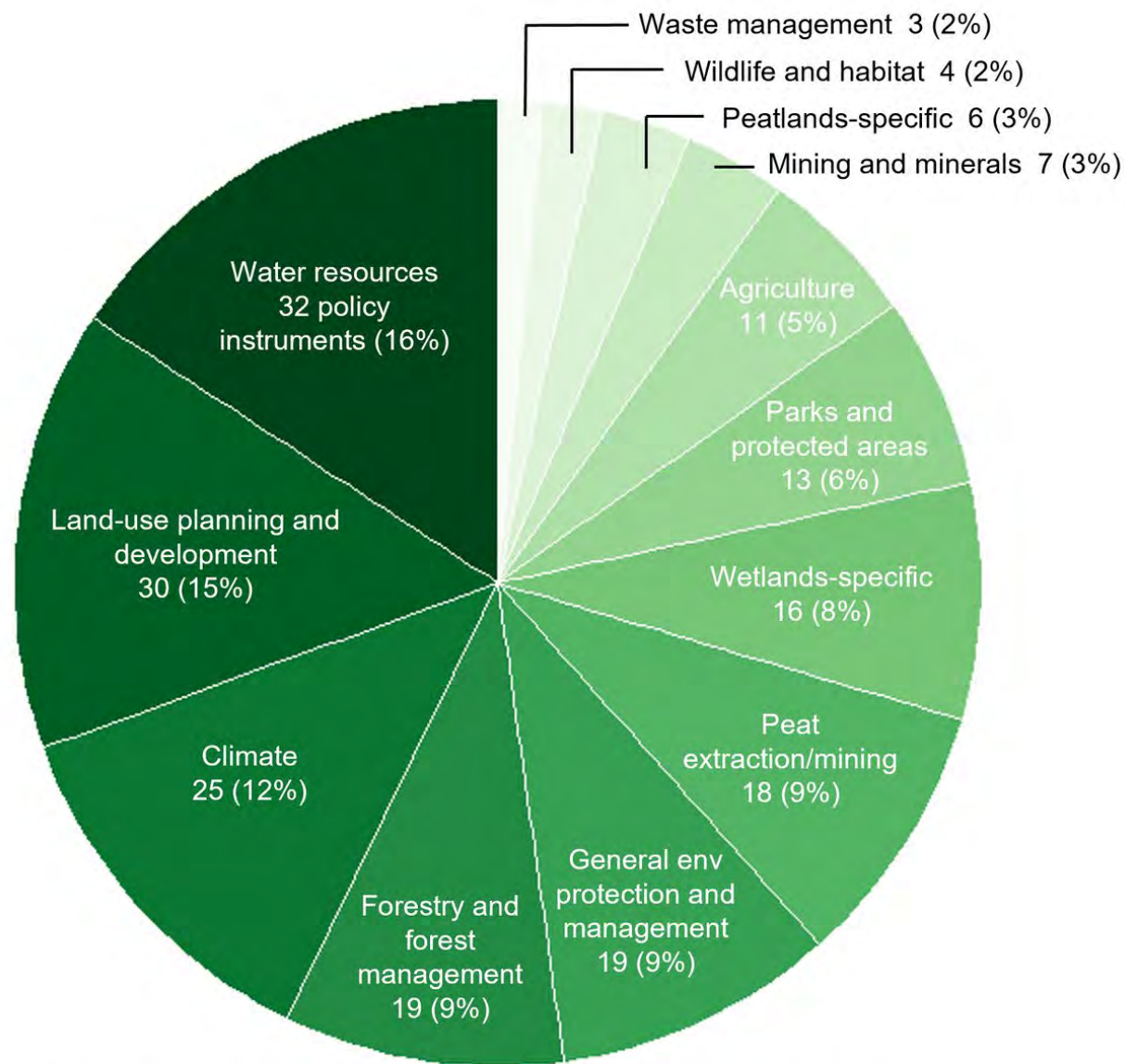
METHODS: (1) Systematic review of law and public policy using key terms to represent peatland and parent categories; (2) Qualitative data analysis.



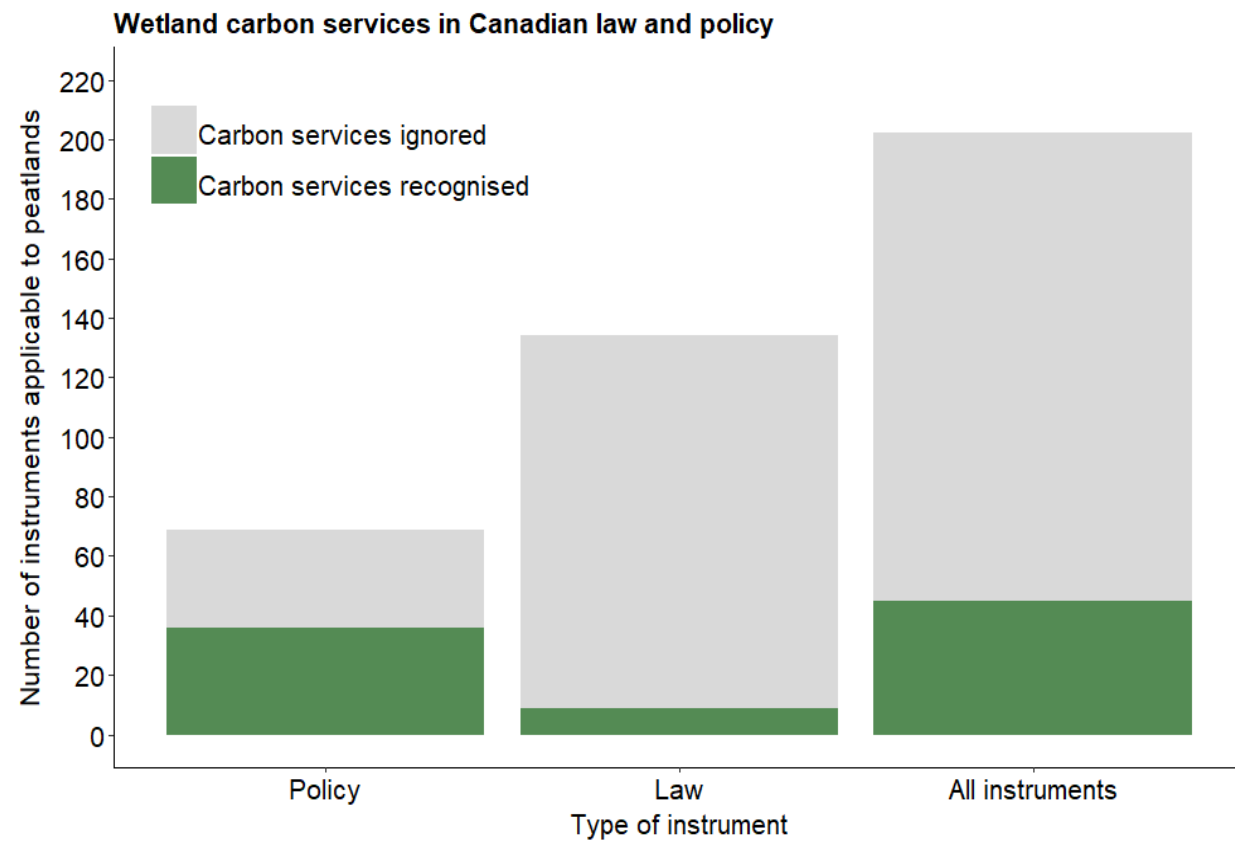
RESULTS: Over 2,300 legislative and policy instruments reviewed to result in 203 applicable instruments analyzed.

- Provisions directly applicable to peatlands





Policy and legislation applicable to peatlands in Canada
(number of instruments, total $n = 203$)



Ongoing External Engagement

Approach:

- National-level engagement (*national-scope groups and researchers; June 2024 national online workshop*)
- Regional meetings (*all provinces and territories*)
- Key collaborators

Objectives:

- 1 Open discussion of policy challenges and opportunities
- 2 Identify case study examples
- 3 Immediate network- and capacity-building, knowledge-sharing across geographies and sectors



Photo: Adam Kirkwood

Opportunities for Northwest Territories – for discussion

Develop a wetland policy that includes peatlands and their carbon services

Include peatland specific goals in new land-use planning policy framework (including in regional plans)

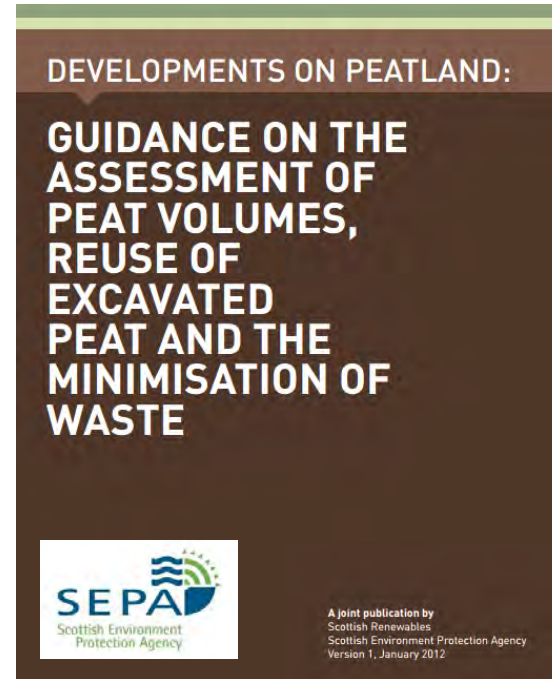
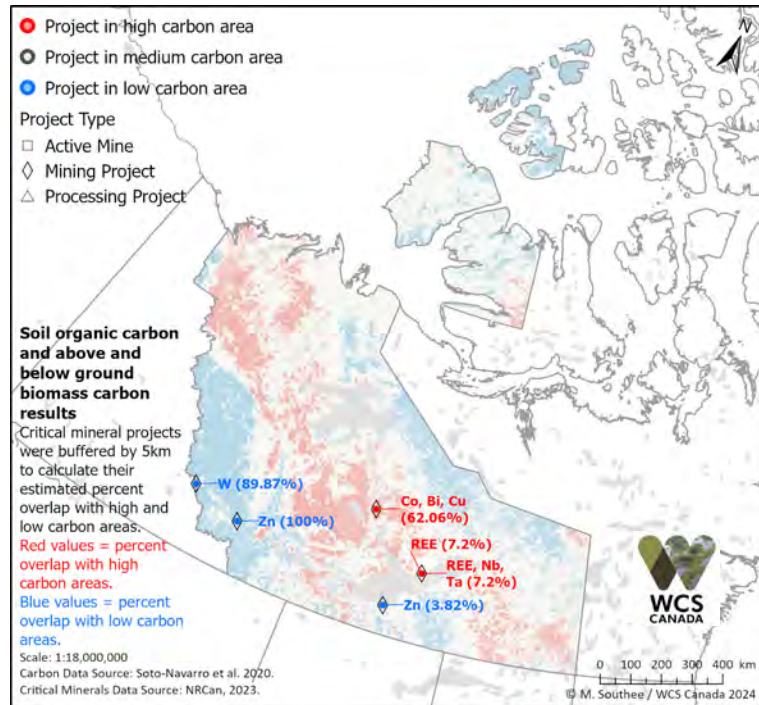
Add peatland protection goals to 2030 NWT Climate Change Strategic Framework and develop climate-smart decision support tools

Continue to add/extend Indigenous Protected and Conserved Areas (IPCAs), which have a key role in centering traditional knowledge and Indigenous governance in peatland stewardship

Add peatland protection goals to NWT Water Stewardship Strategy

Recognise the ecological importance and carbon services of peatlands in existing regulatory processes (e.g., Environmental Assessment guidance, Forest Management Regulations, NWT Land-Use Regulations)

Guidance and tools to support climate-smart decision-making

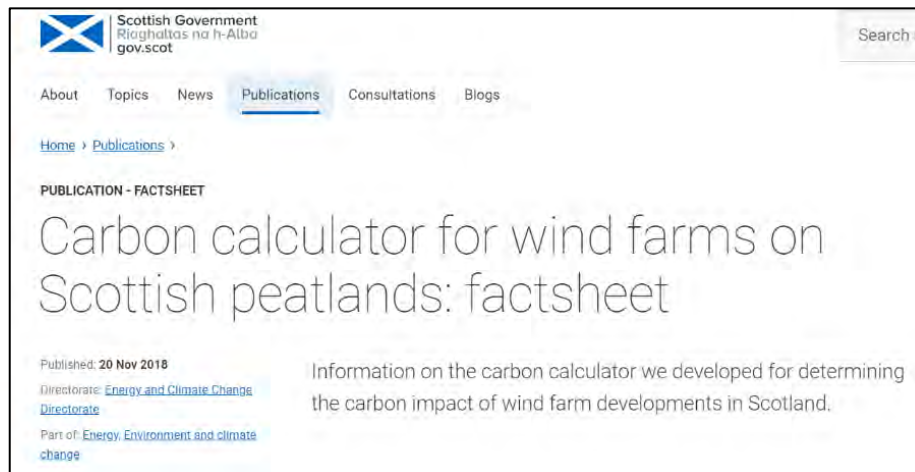


Gap between available knowledge, how accessible the knowledge is, and practical implementation of policy change

Tools to better inform project siting and mitigation options through a carbon and climate lens

Guidance on peat assessments (peat depth, type, spatial extent) to inform construction plans and approaches (e.g., floating roads, culverts)

Peat Management Plans including minimization and use of excavated peat, mitigation plans, restoration plans



Opportunities for Northwest Territories – for discussion

Develop a wetland policy that includes peatlands and their carbon services

Include peatland specific goals in new land-use planning policy framework (including in regional plans)

Contact us:

peatlands@wcs.org

www.wcscanada.org

Add peatland protection goals to 2030 NWT Climate Change Strategic Framework and develop climate-smart decision support tools

Continue to add/extend Indigenous Protected and Conserved Areas (IPCAs), which have a key role in centering traditional knowledge and Indigenous governance in peatland stewardship

Add peatland protection goals to NWT Water Stewardship Strategy

Recognise the ecological importance and carbon services of peatlands in existing regulatory processes (e.g., Environmental Assessment guidance, Forest Management Regulations, NWT Land-Use Regulations)

Thank you!



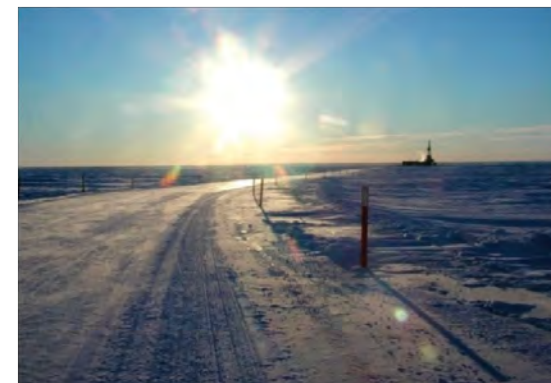
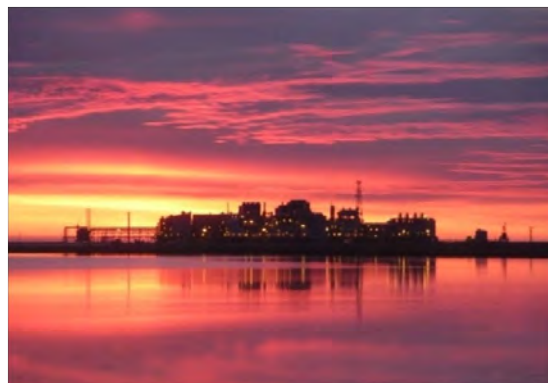


LAYING THE FOUNDATION

Policy and Governance Considerations for A Carbon Management Program



Presented by Trevor Fulton | Alaska Department of Natural Resources
NWT Landscape Carbon Workshop | February 6, 2025



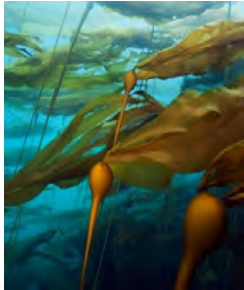


Alaska's Suite of Carbon Programs



Carbon Offset Program

- State develops carbon projects on state lands
- Goal: generate state revenue and environmental benefits; help businesses reduce emissions



Carbon Leasing

- State leases land to private entities to develop carbon projects
- Goal: create carbon management opportunities in the private sector; generate state revenue and environmental benefits



Underground Carbon Storage

- State leases subsurface space for carbon capture, injection, and storage
- Goal: create carbon storage opportunities in the private sector; generate state revenue from underground storage fees; create environmental benefits
- Rather than generating credits, businesses are eligible for federal tax incentives



Alaska's Carbon Offset Program

Policy Decisions

Voluntary vs. compliance – carrot or the stick?

Program goals – what do you want to accomplish?

Administrative capacity – who does the work?

Public and industry impacts – how do you anticipate, identify, and address impacts?



Alaska's Carbon Offset Program

Governance

Legal authority – legislative or administrative?

Implementation – who manages?

Revenue allocation – who will the money go to?

Crediting body - who verifies projects and issues credits?



GOVERNANCE

Conclusion



"Far and away the best prize that life has to offer is a chance to work hard at work worth doing."

– Teddy Roosevelt



Thank You!



Trevor Fulton



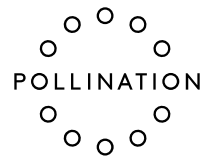
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dnr.alaska.gov/carbon



Foundation

Day 3, Session 4: Potential NWT Policy and Governance Needs

FEBRUARY 2025

Introduction

My Story – from an Indigenous led organisation to a global nature and climate not-for-profit

1997-2019



- Various roles, Broome, Australia
- Key highlights include: Land and Sea Management, Enterprise Development and National Heritage Listing



2020-Now



- Co-CEO Pollination Foundation, Melbourne Australia
- Key highlights include: Local to global knowledge exchange, incubating Indigenous-led nature credit projects, peer-to-peer learning and global advocacy.



Indigenous Fire Management

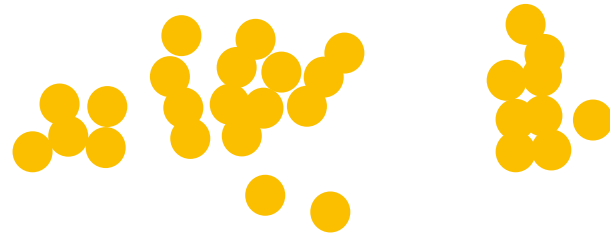
Highly skilled Indigenous rangers use traditional knowledge and techniques, together with modern science and technology, to fight fire with fire and reduce the likelihood of large uncontrolled wildfires.



 Northern Australian Savannas



Australia's leadership in Indigenous-led nature-based solutions



● Savanna Burning Projects

● Carbon Removals Projects

Industry Enablers: Lessons from Savanna Burning

- Founded on Indigenous knowledge, practice and technology
- Early corporate investment provided market confidence and credibility
- Method co-design with scientists, community, government and NGO's
- Indigenous Native Title Rights recognised in Australia's Carbon Credits (*CFI Act 2011*)
- Start-up costs financed via the Australian Government Fund
- Governance, capacity and workforce development via Indigenous Protected Area and Indigenous Ranger Programs
- Indigenous organisations engaged as Technical advisors
- Satellite technology MRV platform - NAFI

RESOURCES

Watch: How the savanna fire management method benefits the environment and Indigenous culture



<https://youtu.be/hMvgYP1ny8>

[Indigenous Carbon Industry Network](#)

[Kimberley Land Council](#)

[Northern Australian Fire Information](#)

[International Savanna Fire Management Initiative](#)





Polar Knowledge Canada

Landscape Carbon Workshop

Presented by Andrew Applejohn and Lynda Orman
Yellowknife, February 4 - 6, 2025



Polar Knowledge
Canada

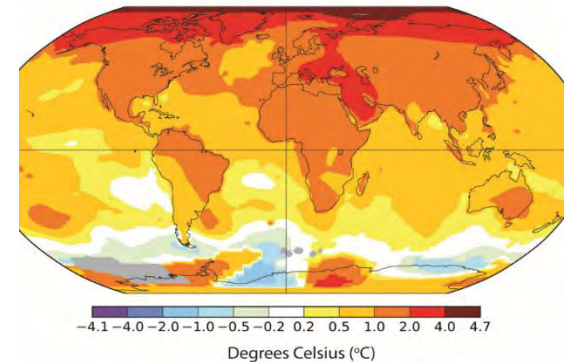
Savoir polaire
Canada

Canada 

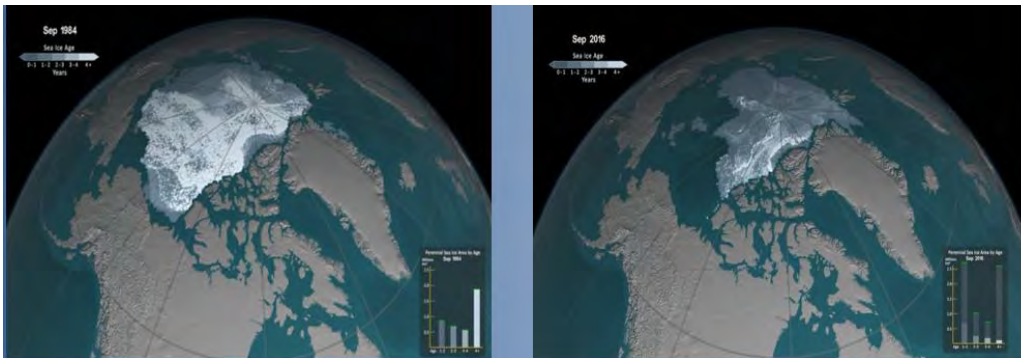
Arctic and Northern Warming - Climate Change

- Canada's Arctic is warming 3–4 times faster than other parts of the globe
- Loss of sea ice weakens polar vortex, affects global weather patterns
- Arctic amplification - less sea ice, warming, solar rays absorbed more on bare ground causing more melting; increased water vapour (GHG) amplifies warming, more moisture, precipitation
- Greening, browning, permafrost thaw, increased water evaporation, water vapour creates more precipitation, insulating snow and earlier thaw in Western Arctic

Change in Average Annual Temperature from 1971 to 2019

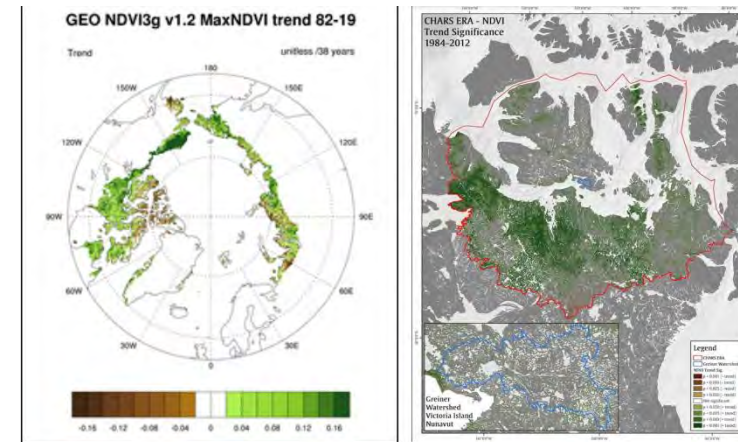


Changes in Average Annual temperature from 1971 to 2019. Areas of the planet that have warmed the most are shown in red.



Satellite images of polar ice in Sept. 1984 compared to Sept. 2016, showing extreme loss of sea ice in Beaufort Sea in 2016 (NASA).

<https://www.canada.ca/en/polar-knowledge/publications/aqhaliat/volume-4/environmental-change.html>

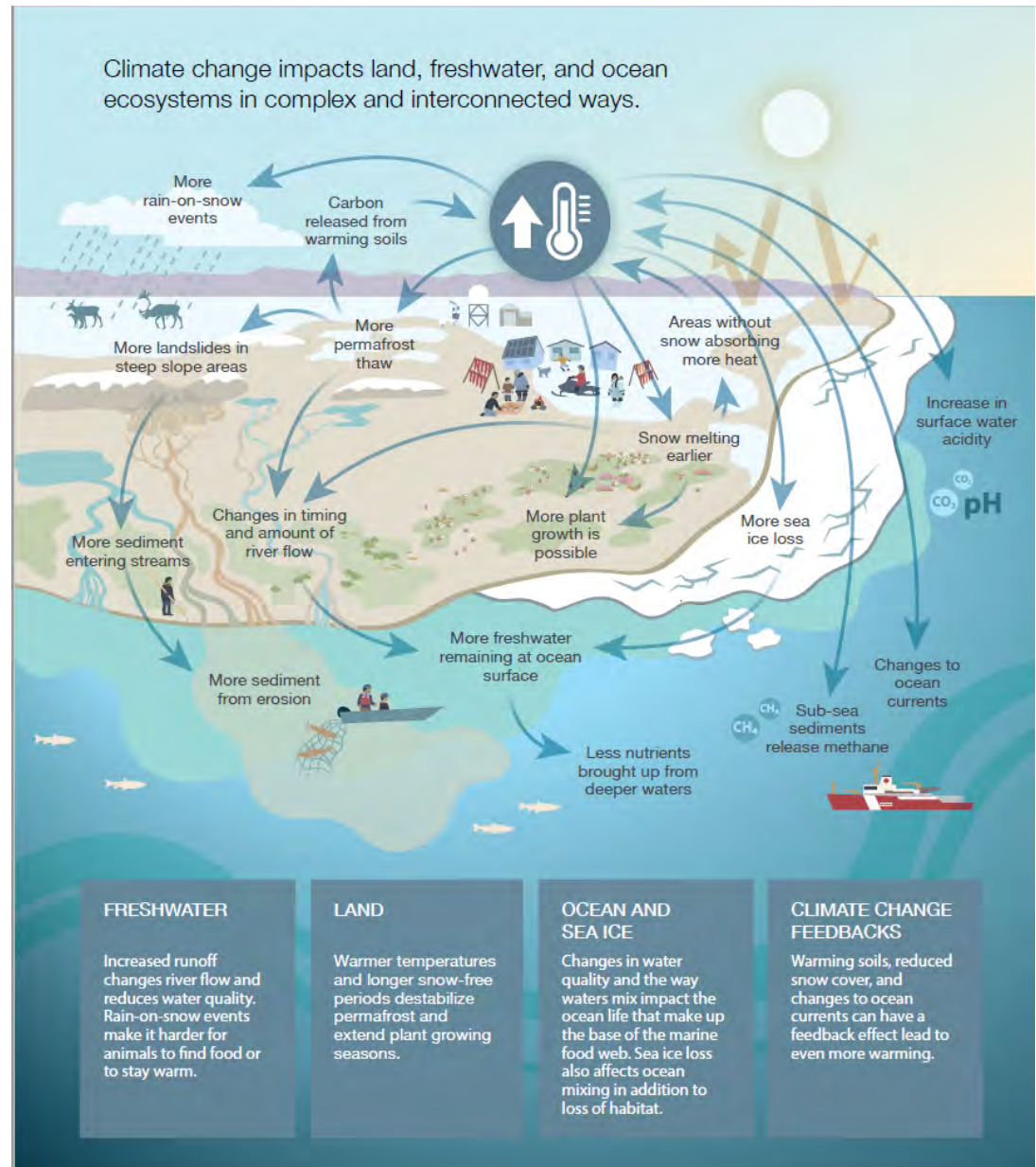


Tundra "greening" measured by satellites for the entire circumpolar area and Canada.

POLAR Working Group - Climate Change (KME)

- Collaboration in research
- Science & Indigenous knowledge
- Technical synthesis report
- Infographics
- Accessible, plain language
- Knowledge dissemination (*Aqhaliat*)

<https://www.canada.ca/en/polar-knowledge/publications/aqhaliat/volume-4/environmental-change.html>





Natural methane slick in peatland, Hillswick Ness (Photo credit: Lynda Orman)

Workshop Reflections - Where do we go from here?

- Identify **Knowledge Gaps** - quantify carbon and GHG sources, sinks
- Complete **Inventory Mapping** - eddy covariance + remote sensing, and community verification of carbon and greenhouse house gas (GHG) sources and sinks
- Build **Partnerships, Collaboration, and Cooperation** in research and knowledge sharing
- Integrate **Indigenous knowledge** in Boreal Forest and Wildfire Management Practices; manage fuel sustainably, apply new risk assessment AI tools

Where do we go from here?

- Community-driven **Indigenous Protected and Conserved Areas (IPCA)** – carbon, GHG sinks (peatlands, wetlands, boreal forest, watersheds)
- Develop **Carbon & GHG Economy** and IPCA guardianship and training opportunities in **Northern and Indigenous Communities**
- Strengthen **Policy, Research Coordination, Training and Capacity**
- Identify **New Areas for Research**
- Continue engagement and collaboration (e.g. GNWT-LC Working Group) to co-develop roadmap, blueprint for **GNWT Action Plan**, and federally for Canada



Natural methane slick in peatland, Hillswick Ness (Photo credit: Lynda Orman)

Summary: Landscape Carbon Workshop

Knowledge Gaps

Complete NWT mapping inventory of all carbon/GHG sink habitats (peatlands, wetlands, boreal forest, watersheds)

Conduct ground-truth verification of satellite imagery mapping and quantify carbon/GHG stores in partnership with Indigenous communities, incorporating IK

Prepare relative risk assessment and priority protection needs of key carbon/GHG sink habitats for NWT, and engage with Northern and Indigenous communities

Integrate Indigenous knowledge in Boreal Forest and Wildfire Management Practices

Enhance partnerships, collaboration, and cooperation between Northern and Indigenous communities, researchers, GNWT and other partners

Conduct apriori fire/flood risk assessments using state of the art AI research tools/modelling (million iterations) (e.g. AISIX Solutions Inc.) to strategically protect and conserve carbon/GHG sinks

Leverage fire behaviour/ flood technology that combines historical & current weather data, climate modelling, satellite imagery, and IK to help predict where hazards will happen

Community-driven Indigenous Protected and Conserved Areas (IPCAs)

Help to facilitate, provide support to Indigenous community-driven IPCA initiatives

Enhance training, strengths- based skills development to foster a Carbon/GHG Economy in Northern and Indigenous communities

Enhance Indigenous research and monitoring of carbon/GHG sources, in collaboration with other research partners

Summary: Landscape Carbon Workshop

Policy Development

Decision-makers to update, modernize environmental assessment policies in the context of climate change

Include Climate impacts – carbon accounting (gas flux change (GHG, methane, carbon): e.g. No Net Gain in Carbon/GHG

Include Ecosystem impacts - ecosystems services accounting: e.g. No Net Loss in Ecosystems Services, with mitigation offsets

New Areas of Research – NWT Carbon/GHG Budget + Mackenzie Basin Water Budget

Develop NWT Carbon/GHG Budget – determine management threshold and baseline against which to measure future change due to climate impacts

Develop Water Budget for Mackenzie Basin – determine management threshold and baseline against which to measure future change due to climate impacts and pre- and post- Alberta tar sands water extractions

Assess cumulative impacts on soil moisture levels of Mackenzie Basin affected lands and socio-economic/risk assessment impacts of low water on Mackenzie Basin for NWT

Expand Areas of Research – Atmospheric Aerosols

Develop research & monitoring and climate modelling of organic carbon dry deposition in NWT on FW ecosystems and possible S. Slave lands re: Alberta tar sands drift/dispersal (Liggio et al.)

Quantify and assess black carbon, polycyclic aromatic hydrocarbons and other volatile organic compounds in NWT; new science, policy review of Alberta-NWT Mackenzie Water Agreement

Collaborate to enhance sampling design, stratification, data sharing and interoperability with Indigenous-led aquatic research & monitoring in S. Slave to fill key data gaps

Landscape Carbon – New Policy Considerations

- Decision-makers – consider updating and modernizing environmental assessment review process in *context of climate change*
- Consider requiring development proposal proponents to newly include:
 - 1) **Climate impacts - *carbon and GHG accounting*** (gas flux change (GHG, methane, carbon etc.)
 - 2) **Ecosystem impacts - *ecosystems services accounting*** - in addition to purely economic cost:benefit analysis considerations in development proposals
- Consider renewed environmental review process policy to include:
 - 3) **No net loss in ecosystems services** (ecosystems services accounting/mitigation offsets)
 - 4) **No net gain in carbon/GHG emissions** (carbon credits/debits offsets, mitigation measures, and research to support development of standardized regional carbon offsets evaluations/equivalences

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Mársı • Kinanāskomitin • Thank you
Merci • Hąj' • Quana • Qujannamiik
Quyanainni • Mahsı • Máhsı • Mahsì