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Fire and legacy carbon loss

Mack-01

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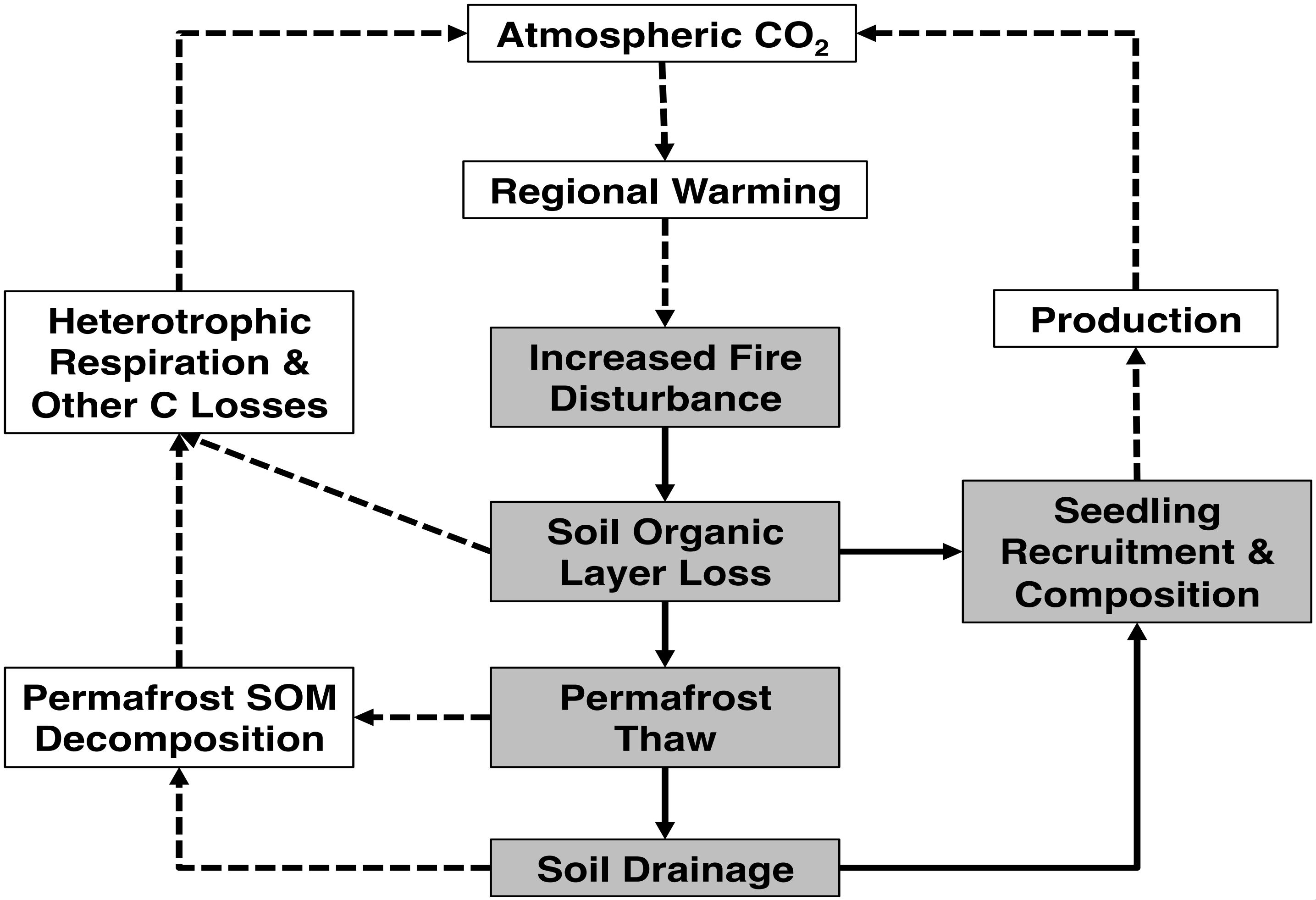
Institutional Collaborations

- NAU, UAF, WHRC
- National Park Service, Denali National Park (Dave Schirkauer)
- Bonanza Creek Long Term Ecological Research Program (Roger Ruess)
- Alaska Fire Science Consortia (Randi Jandt)
- Division of Forestry, Government the Northwest Territories (Kris Johnson)
- Wilfred Laurier University (Jennifer Baltzer)
- University of Guelph (Merritt Turetsky)

When will deeper burning drive changes in the carbon cycle?



Combustion of legacy carbon

- Increased depth of burning could shift northern ecosystems across a C cycle threshold: from net accumulation of C from the atmosphere over multiple fire cycles, to net loss.
- Yet for this shift to occur, burning must release carbon that:
  – Escaped previous fires and/or
  – Is “irreplaceable” under current carbon cycling conditions.
- We term this legacy carbon.
- Few studies have examined the relationship between depth of burning and age of carbon combusted.
- Thus, we propose to determine controls over legacy carbon combustion in arctic tundra and boreal forest ecosystems.

Legacy carbon loss indicates:

- Negative net ecosystem carbon balance (NECB) over multiple disturbance intervals.

- Current disturbance severity is outside of historic variability.

Hypothesis: Ecosystems that experience legacy C loss will be more likely to cross threshold states in permafrost and plant species composition that catalyze state changes the carbon cycle.

Science Questions

1. **What are the ecosystem, landscape and regional controls over the combustion of legacy C in forest and tundra regions of the ABoVE Domain?**
2. **What are the consequences of legacy C loss for post-fire permafrost dynamics, vegetation regeneration, and the initiation of successional trajectories?**

Tier 2 Science themes addressed: carbon pools, disturbance regime, flora, permafrost

Science Objectives

1. Develop a mechanistic understanding of the ecosystem, landscape and fire characteristics that control legacy C loss from tundra and boreal forest wildfires in the ABoVE Domain.
2. Estimate the magnitude of legacy C loss across landscapes within fire scars.
3. Determine ecosystem response to legacy C loss and fire severity, focusing on ecosystem vulnerability to state change in permafrost and vegetation composition.
4. Project ecosystem response to legacy C loss and fire severity across fire scars and identify the ecosystems, landscape positions, and regions at the greatest risk of state change under an intensifying fire regime.

Tundra fires north of Denali Nat'l Park

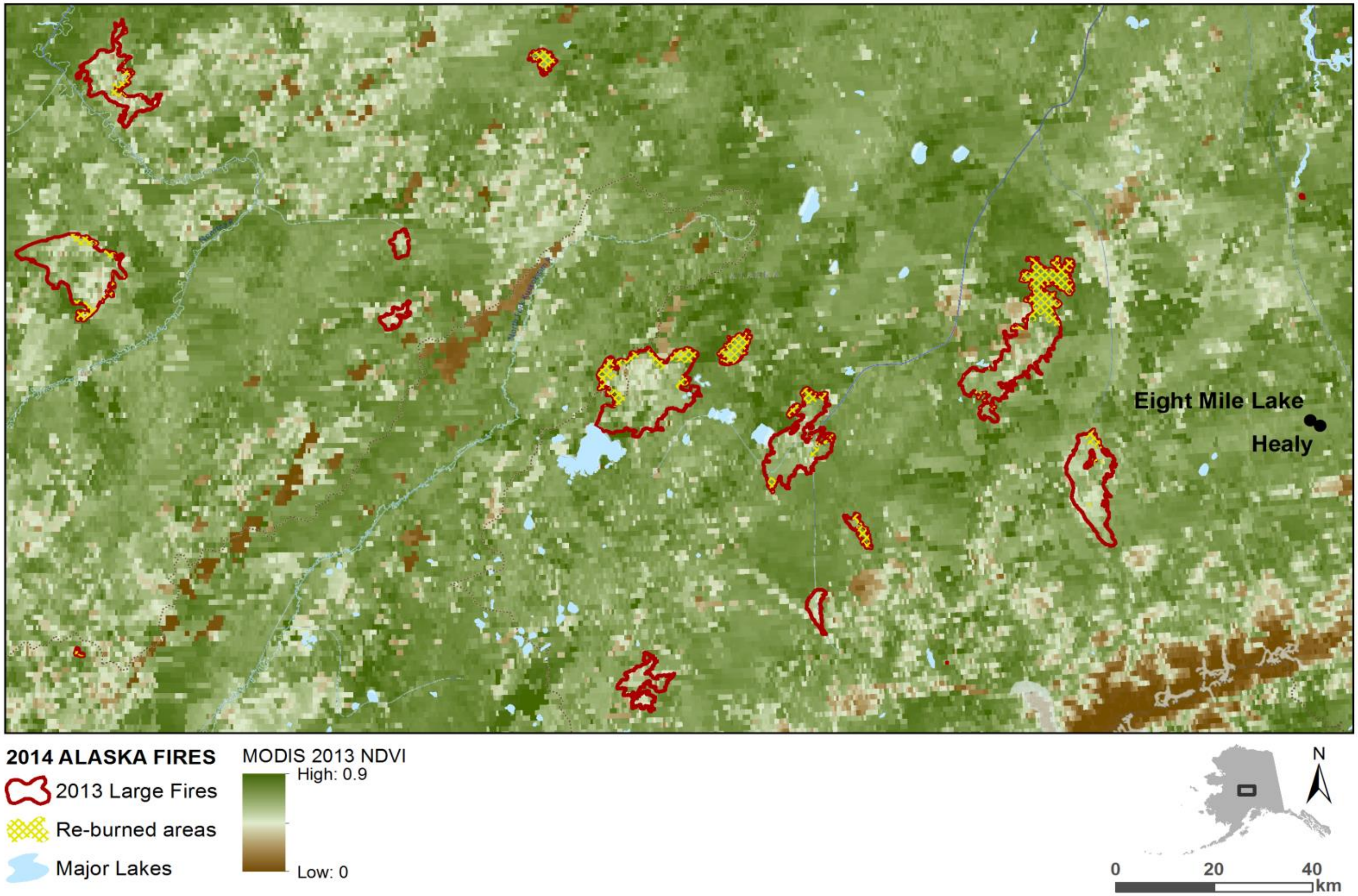


Figure 4. *2013 fire scars in Denali National Park and Preserve on the North Slope of the Alaska Range, west of Healy, Alaska.*

Boreal fires in Northwest Territories

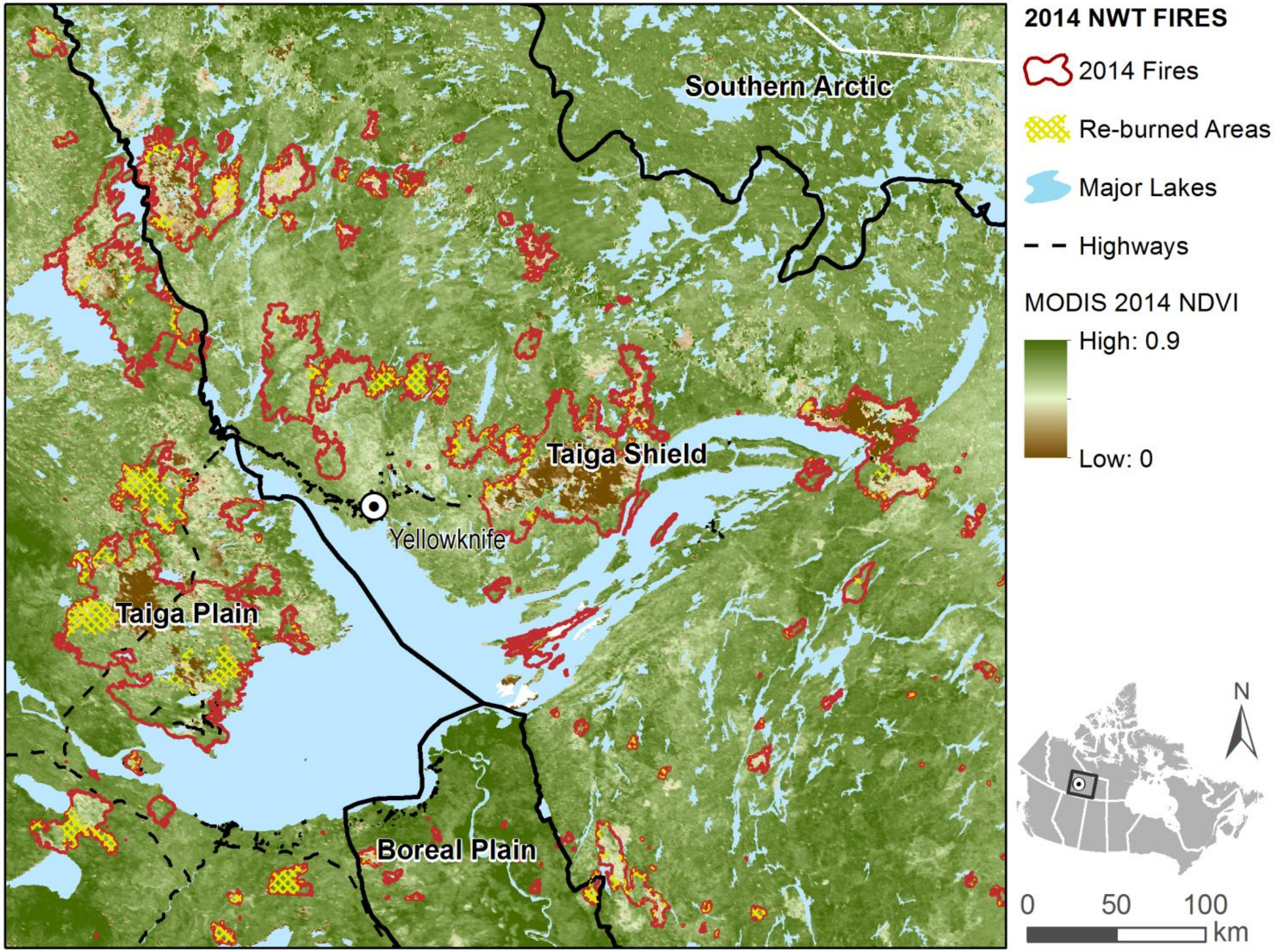
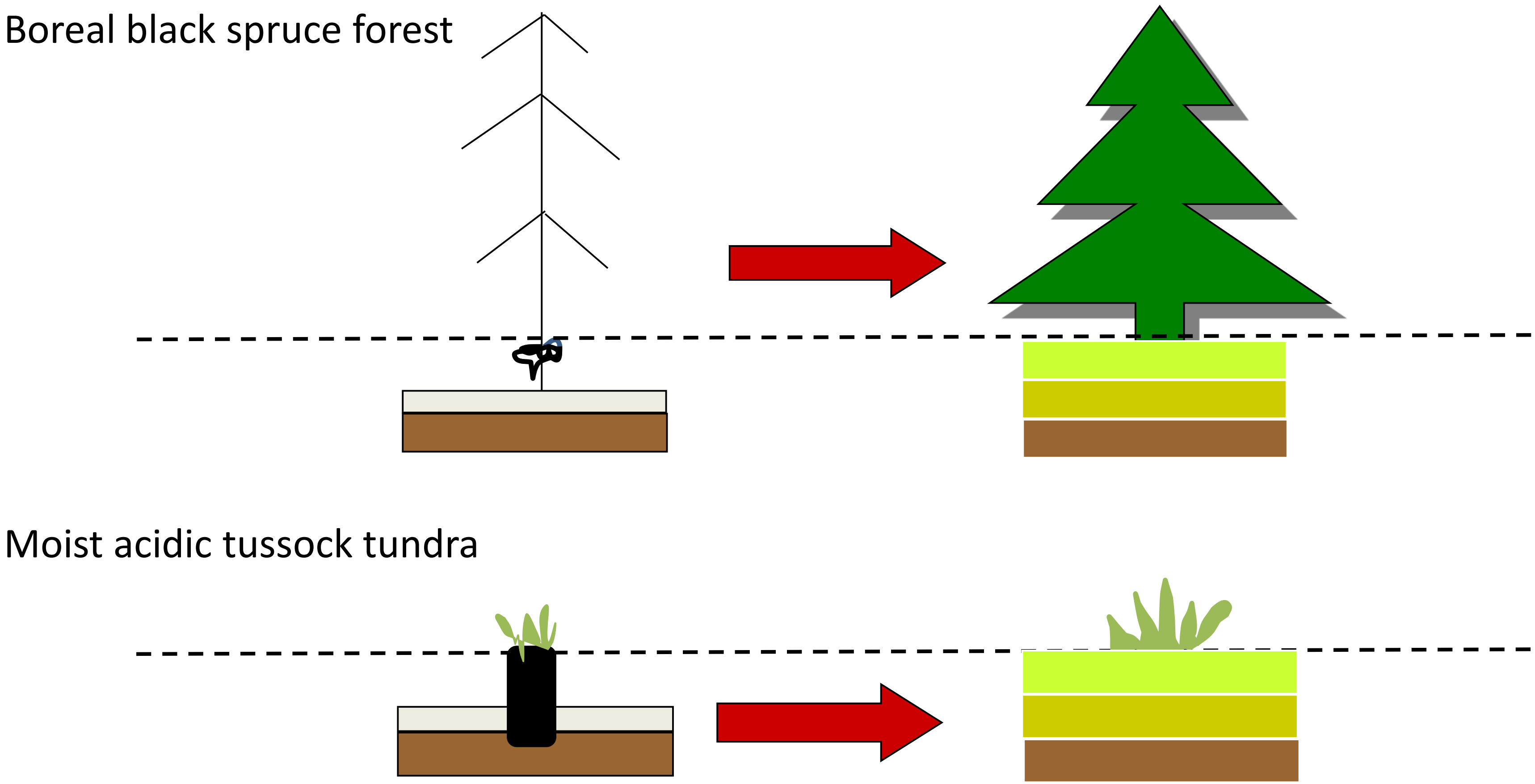


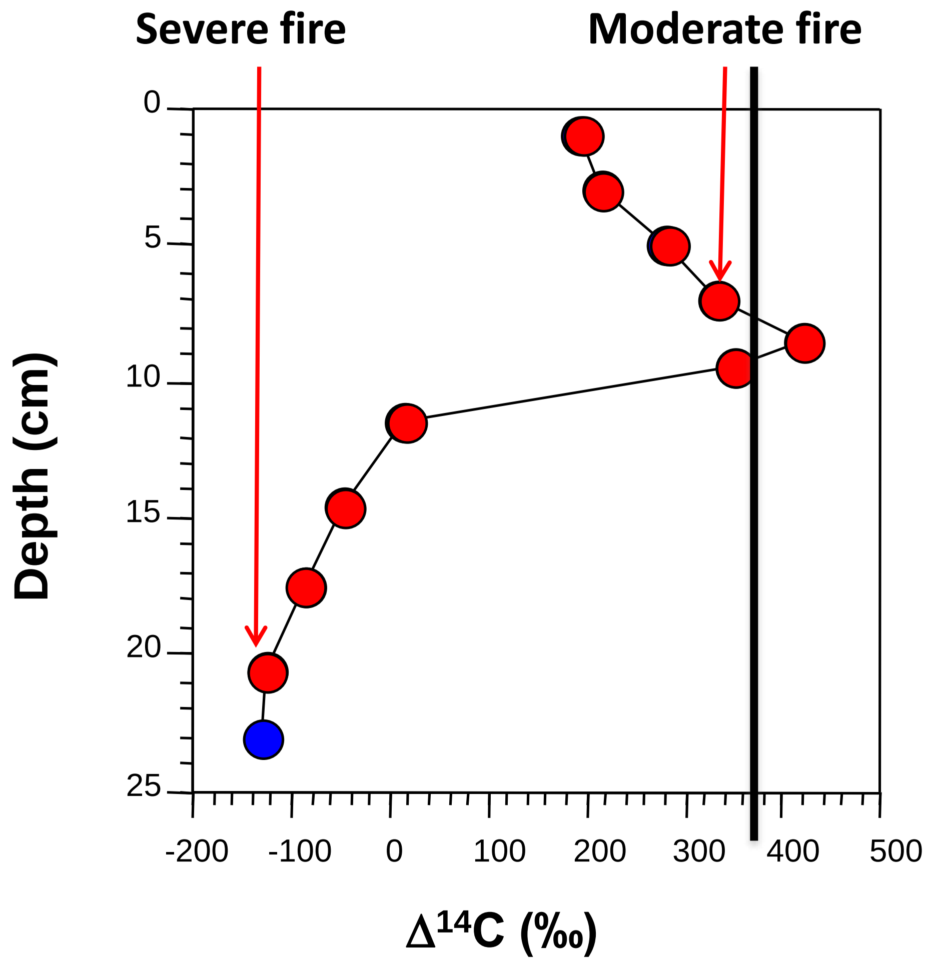
Figure 5. *2014 fire scars on the Taiga Shield, near Yellowknife, Northwest Territories, Canada.*

Quantifying depth of burning and element loss



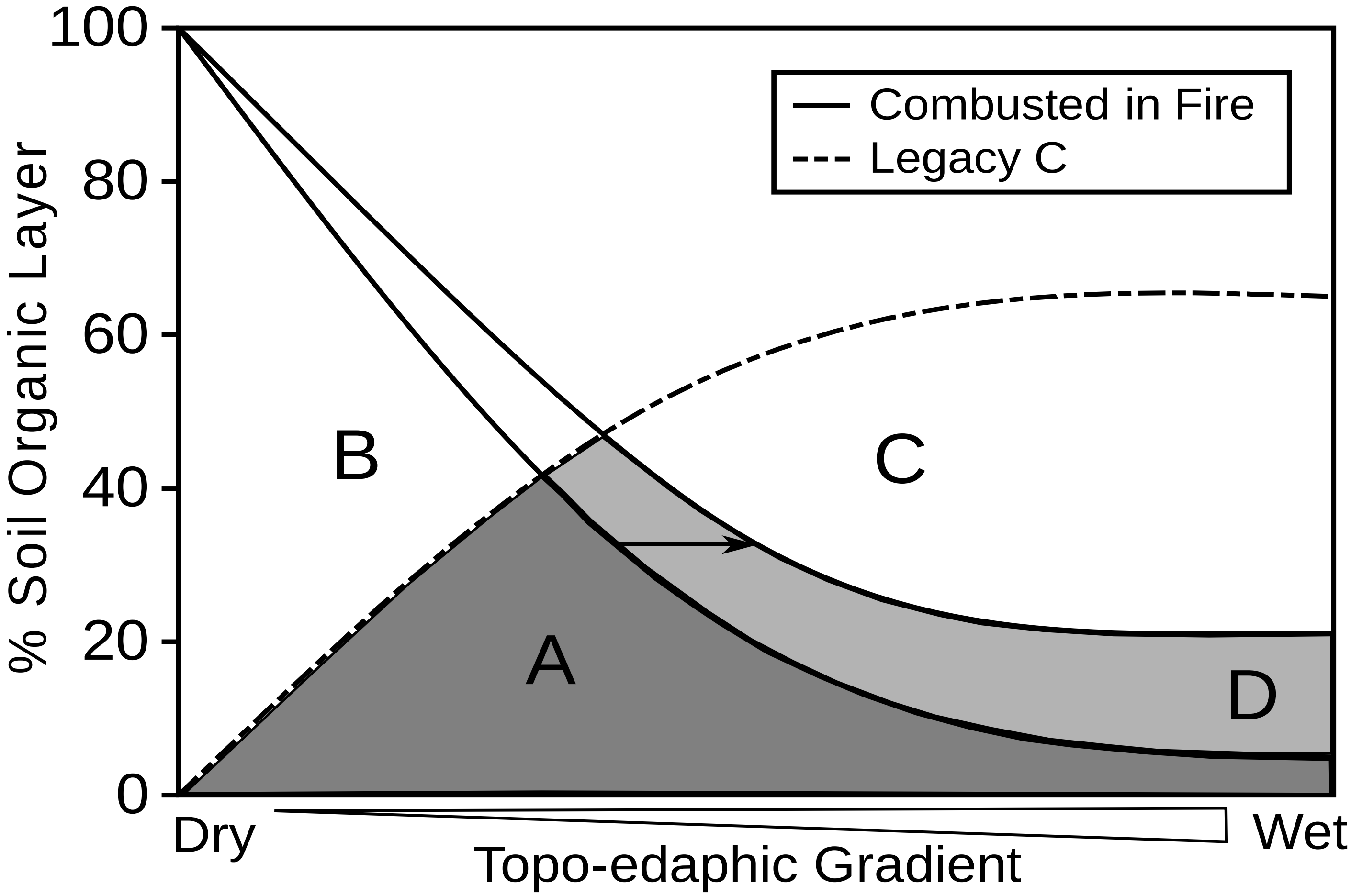
Estimate pre-fire soil and plant pools from post-fire “botanical benchmarks”, plant allometry, and regional soil composition data

Are fires burning legacy carbon?



D. R. Schell, unpublished data

Landscape controls over legacy C loss



Ground measurements

- Nested sampling design—landscape position within sites, sites within burns, burns within regions
- Combustion losses of C and N (soils, plants, coarse woody debris)
  - Measure residual organic matter pools
  - Estimate pre-fire pools and calculate loss
  - Calibrate methods for new regions—NWT forest, Denali tundra
- Stand age, radiocarbon age of basal soil organic layer, residual profile, and burned surface
- Environmental variables (pre-fire veg., slope, aspect, soil texture…)
- Monitoring of post-fire permafrost degradation, subsidence and changes in drainage
- Monitoring of post-fire vegetation regeneration, seed limitation, successional trajectories

Remote sensing will be used to:

- Constrain sampling and define “domain of inference” for field sampling
  - Pre-fire vegetation
  - Slope and aspect
  - Fire history (e.g., timing of burning, time after fire)
  - Random selection of sites
- Develop geospatial scaling rules for legacy C loss, and scale field measurements to landscapes and fire scars
- Create vulnerability maps for forecasting change in permafrost and successional trajectory

Spaceborne Remote Sensing

Dynamic variables
Landscape-freeze thaw status (e.g. PalSAR, SMAP)
Surface wetness (e.g. MEASURES products)
Vegetation productivity (Landsat/MODIS VIs)
Snow covered area (MODIS product)
Surface albedo (MODIS products)
Land surface temperature (MODIS products)

Less dynamic variables
Land cover class (multiple sources)
Vegetation cover (multiple sources)
Thermokarst class (e.g., Belshe et al. 2013)
Vegetation cover (composition, type, density)
Deciduousness (Landsat/MODIS, e.g. Beck et al 2011)
Size of vegetation patches, shape metrics (edge/area)

Geospatial data

Static variables
Topography (slope, slope position, aspect, insolation)
Surficial geology (as per ABoVE CEP)
Ecoregion classification (as per ABoVE CEP)
Proximity to water feature (Carrol project water bodies)
Drainage class (primary, secondary, etc.)

Fire variables
Date of burning
Fire weather at time of burn
Rate of burning (MODIS hot spot), smoldering evidence
Overlap with past burn--% area, time
Distance to burn edge

Modeling--statistical

- **Hierarchical mixed modeling and structural equation modeling to test our ecosystem and landscape-scale hypotheses and define scaling rules.**

- **Geospatial modeling—boosted regression, classification trees, segmentation--to scale and forecast field results to landscape.**

Science Questions & Objectives

- Our proposed research tackles societal needs at two scales.
  - For stakeholders in the global climate system, we will improve our understanding of the mechanisms through which environmental change affects C cycling feedbacks to climate, an important component of climate regulation.
  - For regional and local stakeholders such as land and fire managers, we will improve our ability to project the impacts of fire severity on ecosystem properties, including the goods and services provided to humans and fauna that use these habitats.