BOREAL FOREST RECOVERY DETECTED WITH LANDSAT TIME SERIES

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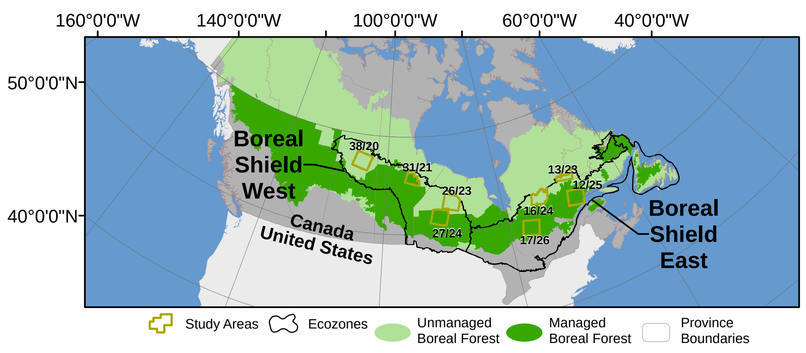
1. INTRODUCTION

- The boreal forests of Canada can be divided into regions of similar conditions named ecozones.
- The Boreal Shield ecozone is the largest, with forests often subject to stand replacing harvest & fire disturbances.
- Suggestions to divide this ecozone in two are based on differing climates & disturbance regimes
- Up to half of Boreal Shield forests lack spatially explicit information to analyze change over time
- Post-disturbance forest recovery is important to monitor for management purposes & forest dynamics.
- Remote sensing technology has demonstrated the capacity to monitor large areas & can offer insights into how different regions are changing
- Landsat time series offers an effective approach to monitor large forested areas for change over time
- Using Landsat time series, disturbance events can be well characterized, and post-disturbance forest recovery can be spectrally monitored to report on the reestablishment & maturation of treed vegetation

2. STUDY AREA



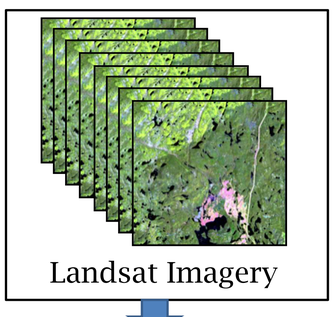
Topography of the Boreal Shield Ecozone is generally rolling and hilly, with many small lakes, streams & rocky outcrops; forest cover prevails upon the landscape.

Forests in the Boreal Shield ecozone are dominated black (*Picea mariana*) and white spruce (*Picea glauca*), though mixed broadleaf stands also occur.

	West	East
Summer Mean Temperature	13°C	13°C
Winter Mean Temperature	-20°C	-1°C
Annual Precipitation	400mm	1000mm
Climatic Conditions	Colder & Drier	Cold & Moist
Most Common Disturbances	Fire & Harvest	Harvest & Insects

3. METHODS

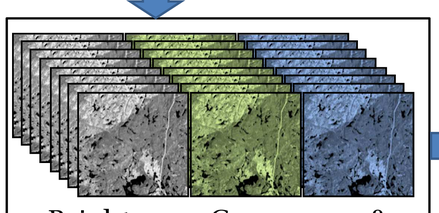
IMAGE PROCESSING

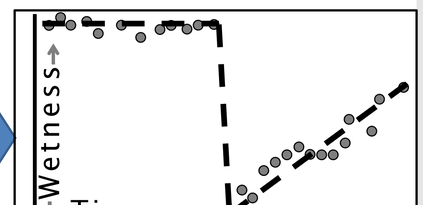


8 scenes of Landsat Imagery were:

- Divided between Boreal Shield East and West sections
- Converted to Surface Reflectance
- Masked for Clouds & Forest Cover
- Converted to Tasseled Cap Components
- Composited into Annual Images
- Temporally Segmented
- Disturbances Located & Filtered for Stand Replacing Severity

Then, recovery trajectories were extracted for each remaining disturbed pixel for each ecozone section.


Brightness, Greenness, & Wetness Time Series

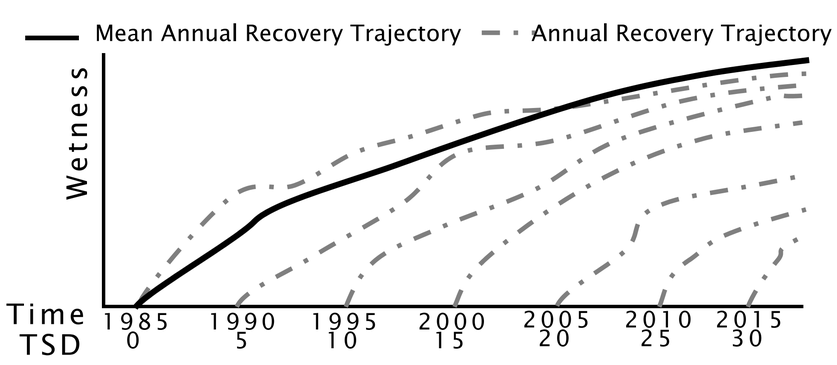


Temporal Segmentation

RECOVERY CHARACTERIZATION

Per-Pixel Recovery Trajectories were:

1. Normalized by Time Since Disturbance (TSD) & mean spectral values at each year of recovery calculated



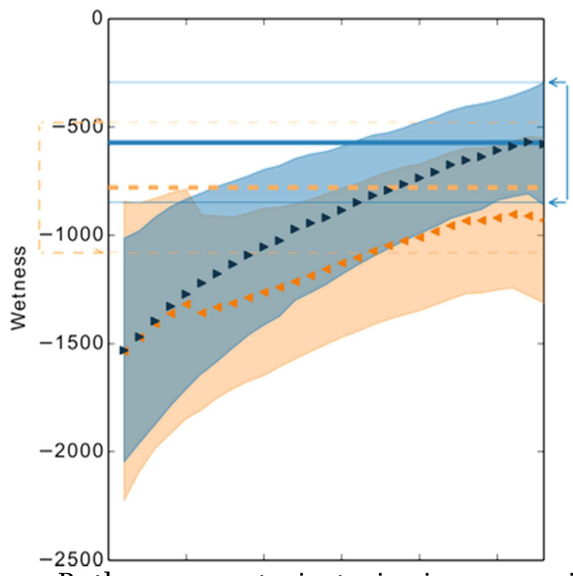
2. Characterized with Cohen's *d* to determine meaningful levels of difference over time between:
   - 2.1. The average recovery trajectory of each ecozone section and their undisturbed mean
   - 2.2. Boreal Shield East & West mean recovery trajectories

$$\text{Cohen's } d = \frac{\bar{x}_1 - \bar{x}_2}{\sigma_{pooled}}$$

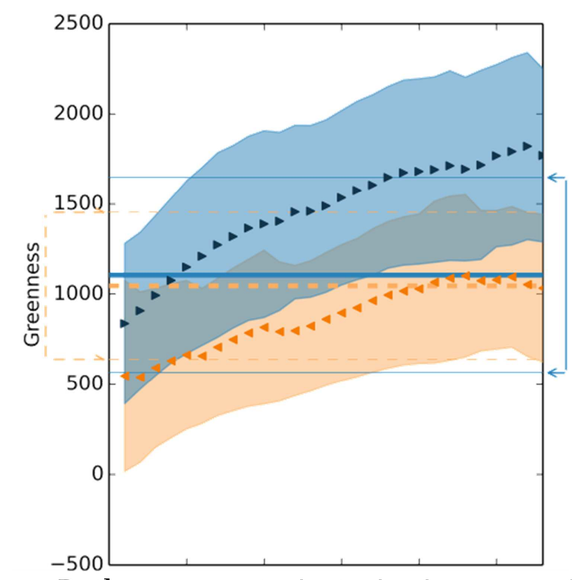
$\bar{x}_1$ & $\bar{x}_2$ = means of 2 different groups
σ_{pooled} = pooled standard deviation

4. RESULTS

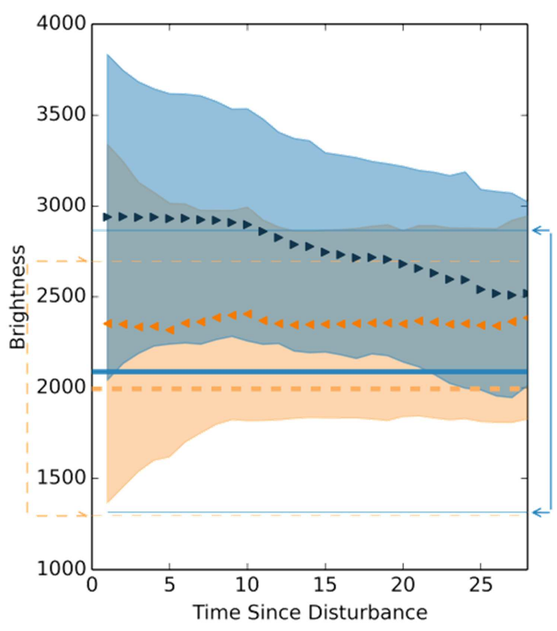
SPECTRAL RECOVERY TRAJECTORIES



- Both recovery trajectories increase with time
- West recovery values are within stable range after 16 years
- East recovery trajectory ends near the stable mean, but West does not

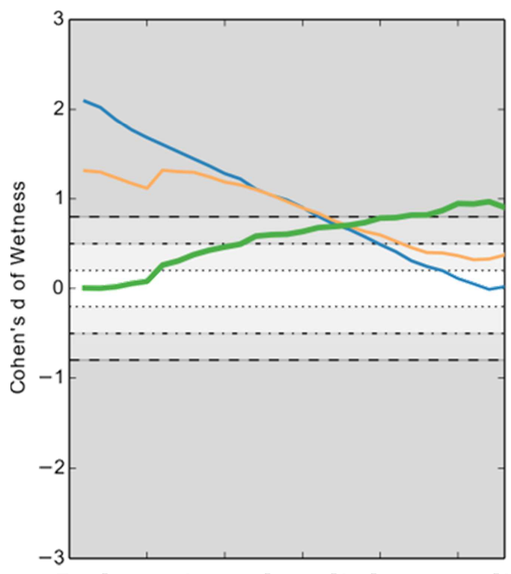


- Both recovery trajectories increase with time
- East trajectory exceeds its stable mean and range
- West trajectory ends in values near the stable mean

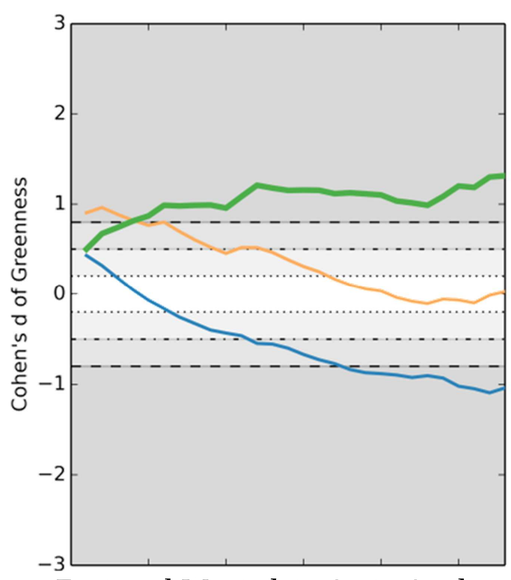


- East recovery trajectory decreases with time, but not West trajectory
- West recovery shows little to no change
- East trajectory is within stable range after 11 years

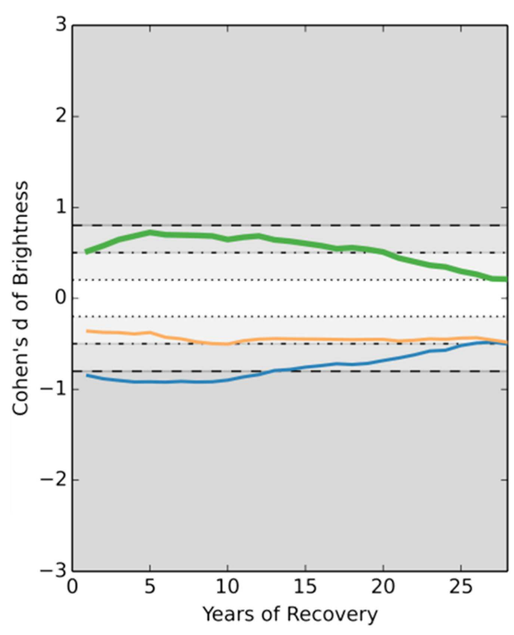
COHEN'S *d* TRAJECTORIES



- Both sections show little to no difference to their stable means by the end of the time series
- East/West comparison trajectory shows little initial difference, but ends in large difference



- East and West *d* trajectories have similar shapes, but different ranges
- East/West comparison trajectory shows a large difference that persists from 5 years of recovery and on



- The East *d* trajectory indicates decreasing difference over time
- West *d* trajectory shows little change over time
- East/West comparison trajectory shows moderate difference at first, then ending with little difference

4. CONCLUSIONS

- A clear definition of forest recovery must be predefined, as multiple stakeholders may have conflicting views of recovery
- Landsat time series can generate meaningful forest recovery information across large areas
- Spectral recovery trajectories track the reestablishment of vegetation towards canopy closure, or when the spectra of a recovering forest resemble that of nearby undisturbed vegetation or its previous undisturbed state
- Shortwave Infrared driven vegetation indices outperform Near-Infrared indices when tracking forest recovery
- Division of Boreal Shield ecozone into East & West sections is further reinforced by
  1. Wetness, Greenness, & Brightness average annual recovery trajectories showing substantial differences between sections
  2. Both Wetness & Greenness East/West comparison trajectory endpoints indicate a large difference in recovery
- Spectral data aligns with known forest recovery patterns in both sections
  1. East Boreal Shield Forests recover through an initial broadleaf dominance, replaced by conifers over time
  2. West Boreal Shield forests recover through conifer self replacement after disturbance

ACKNOWLEDGEMENTS

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