How unique are fire patterns across the boreal forest?

A means to exploring variability using the Landsat data archive

Ignacio San-Miguel, Integrated Remote Sensing Studio, University of British Columbia
Nicholas C. Coops, Integrated Remote Sensing Studio, University of British Columbia
David W. Andison, Bandaloop Landscape-Ecosystem Services

Integrated Remote Sensing Studio

fRI Research
Informing Land & Resource Management

7th March 2018
Webinar series HLP

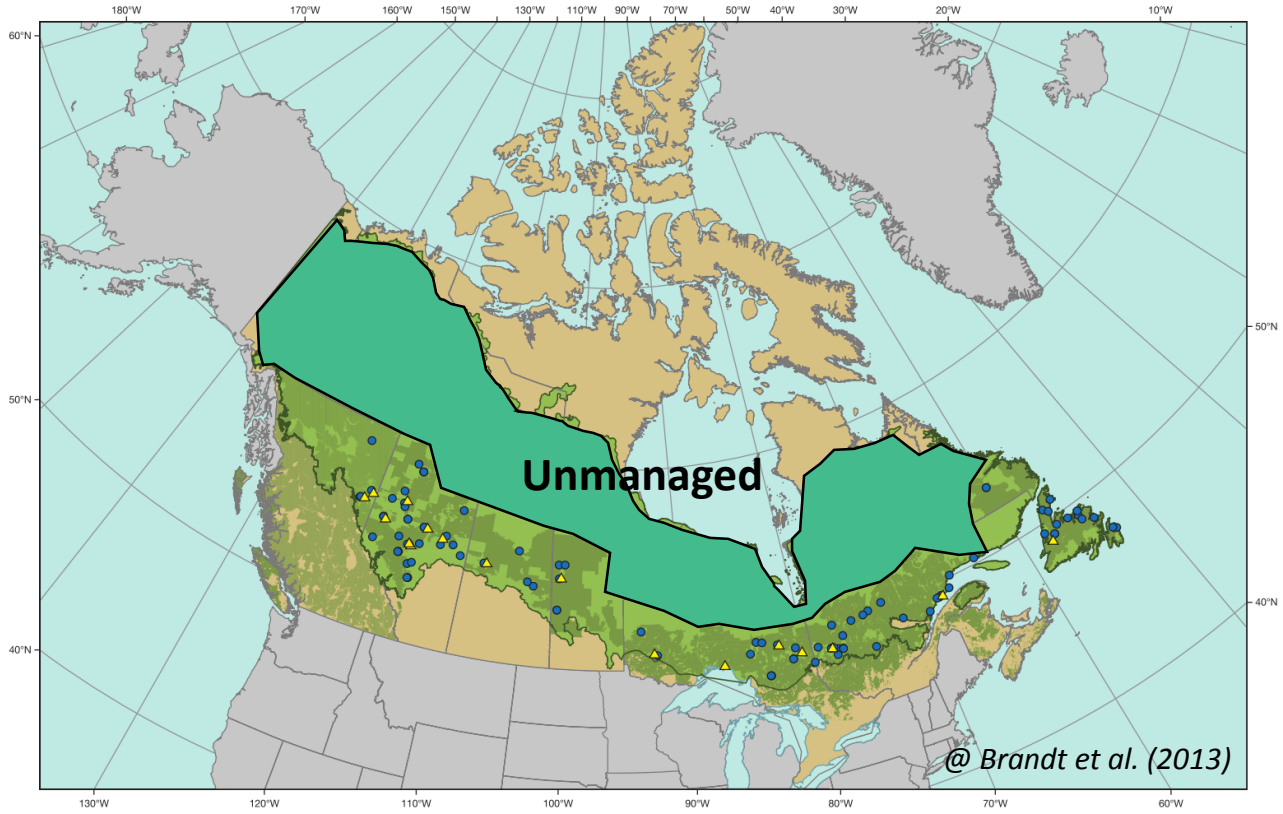
Understand natural fire regimes

Need

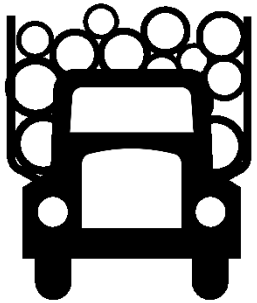
- Details of fire regimes
- Extent of applicability

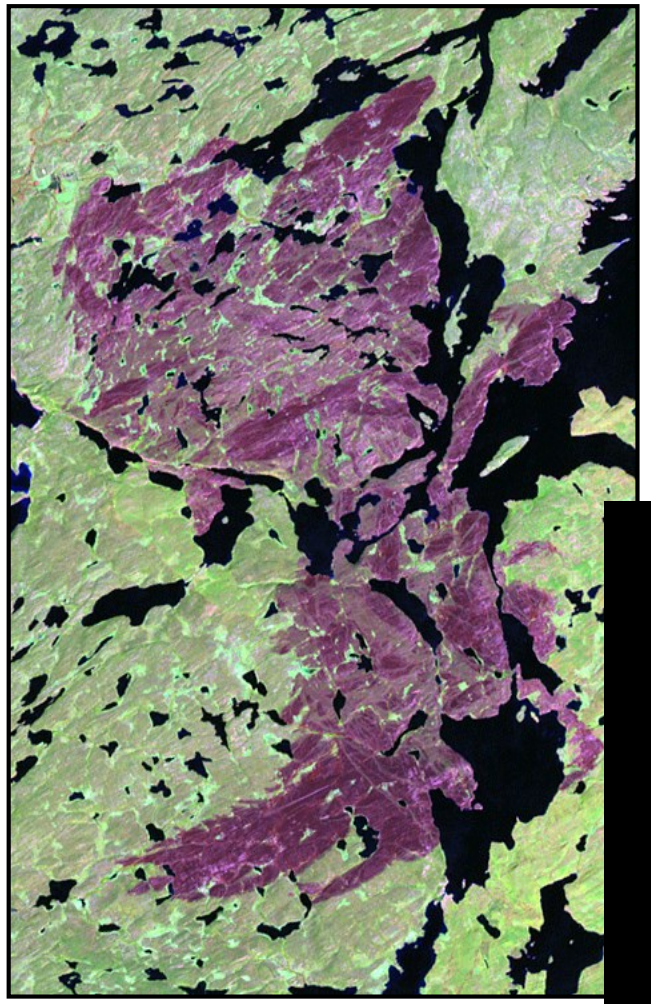
Why

- Forest management
- Regime shifts
- Quantify anthropogenic influence



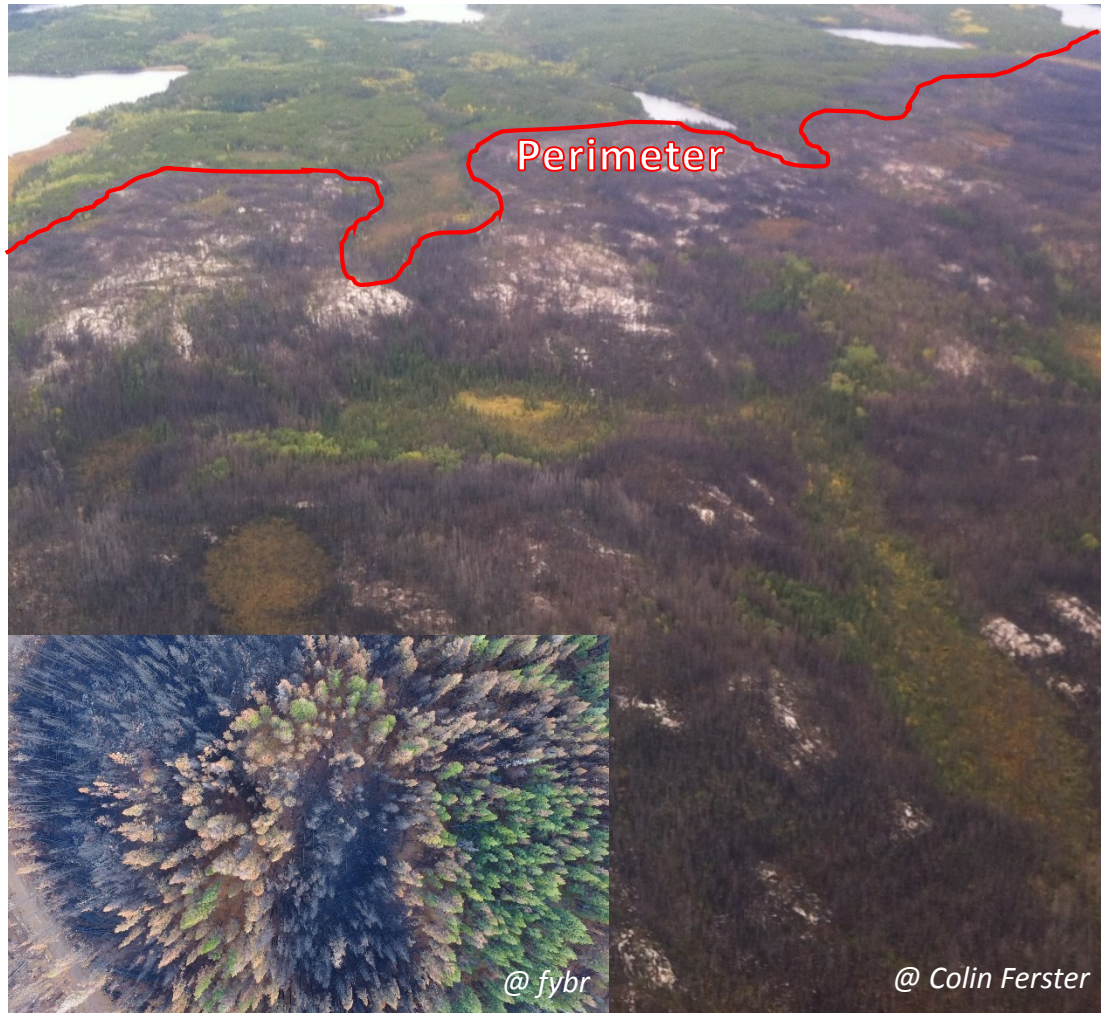
Current practice and policy in Canada





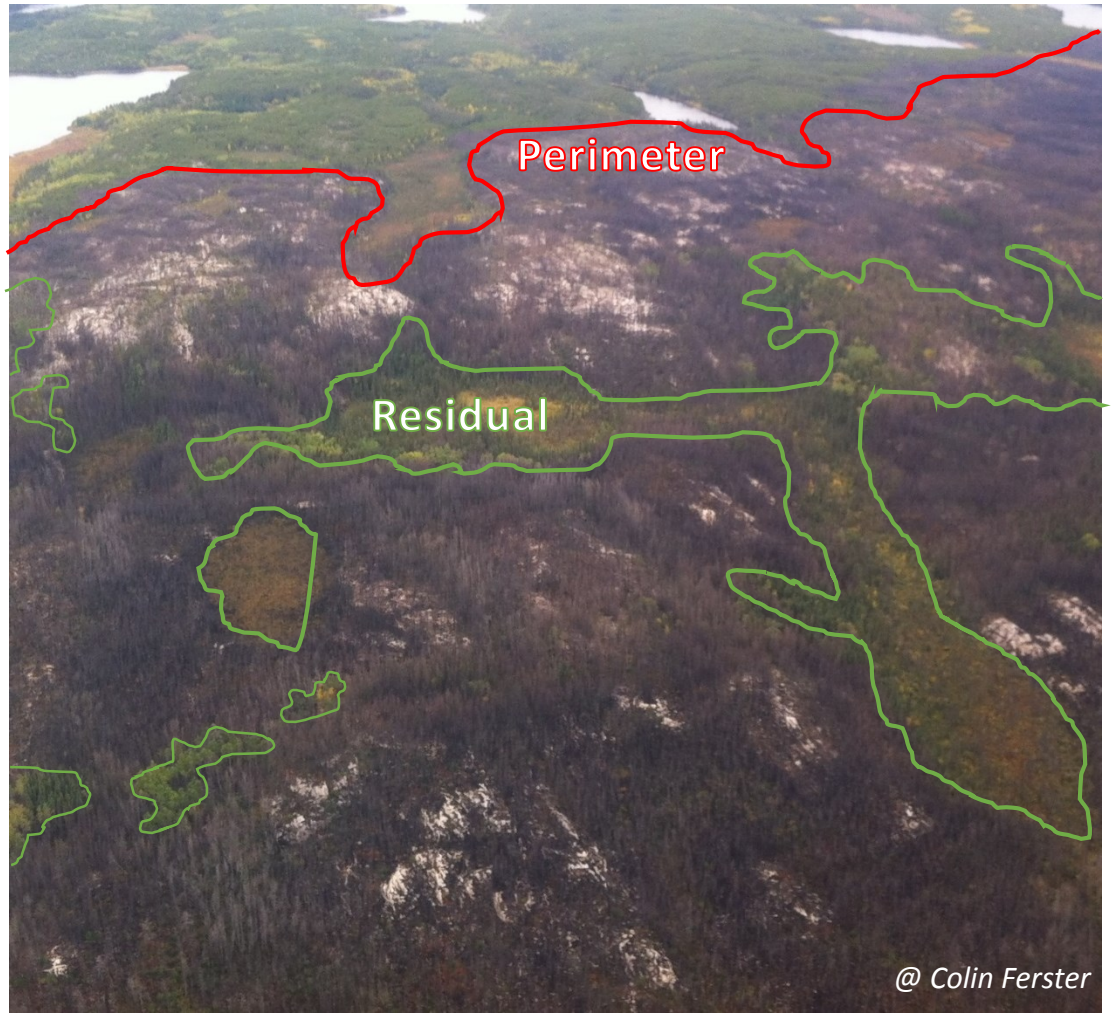
Disturbance regime in unmanaged areas

- Fire primary agent
  - 2 Mha yearly
  - lighting-caused (~80%)
  - 97% burned by the largest 3% fires
- Highly variable patterns
  - fuzzy and variable edges

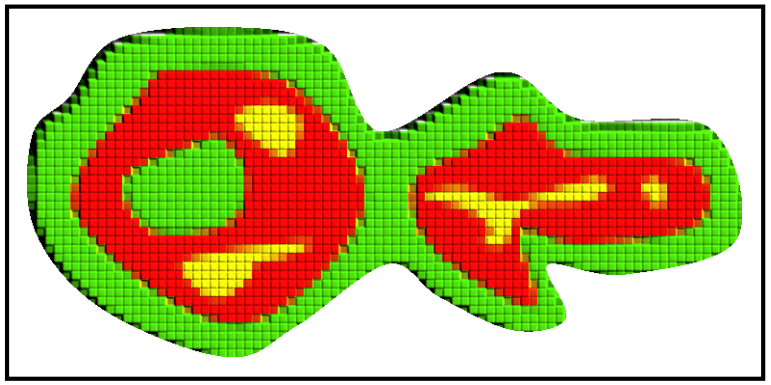


In particular… residual vegetation

- Significant contribution 40-60%
  Soverel et al. (2010); Andison and McCleary (2014)
- Important for resilience
  - Re-vegetation *Oliver (1981)*
  - Re-colonization *Banks et al. (2011)*
  - Connectivity *Courtois et al. (2004)*

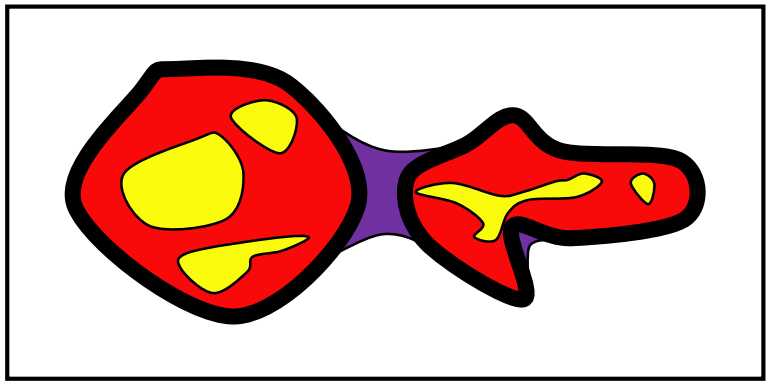


How challenging this is...



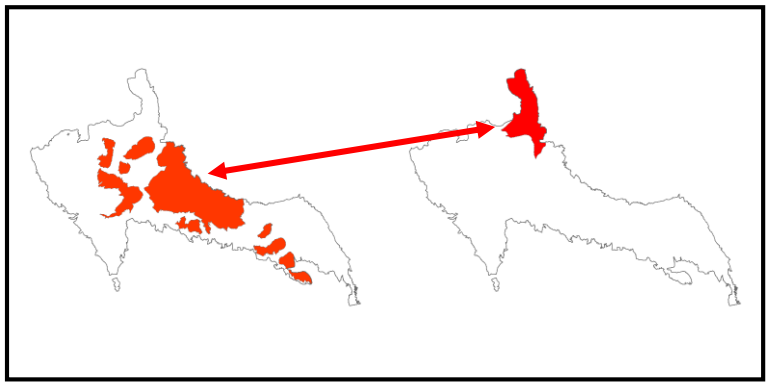
Cost-effective & repeatable mortality maps

- Fire weather
- Land cover & climate
- Topography



Consistent spatial language to define events

- Consistent
- Repeatable



A set of fire metrics

- Comparable across regions
- Relevant for management

… but how much do we know?

What we know...

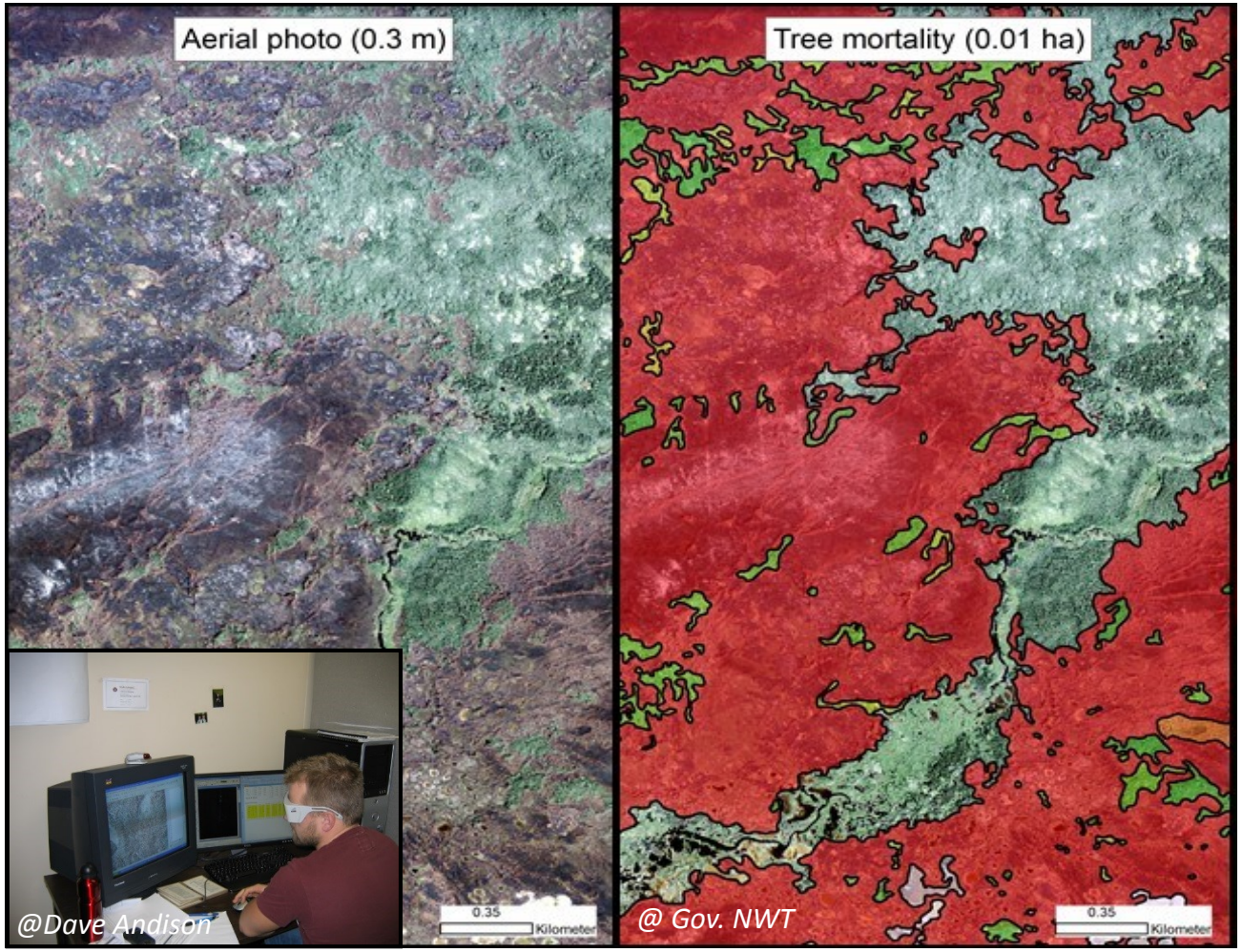
- high variability
- patterns region-specific
- important amount of residual vegetation

However...

- Few studies
- Only a small subset of fires
- Studies are not comparable

… Why?

Photo interpretation is precise but <u>expensive</u>



A large photo-interpreted database of 129 fires

Value:

- Differences across regions

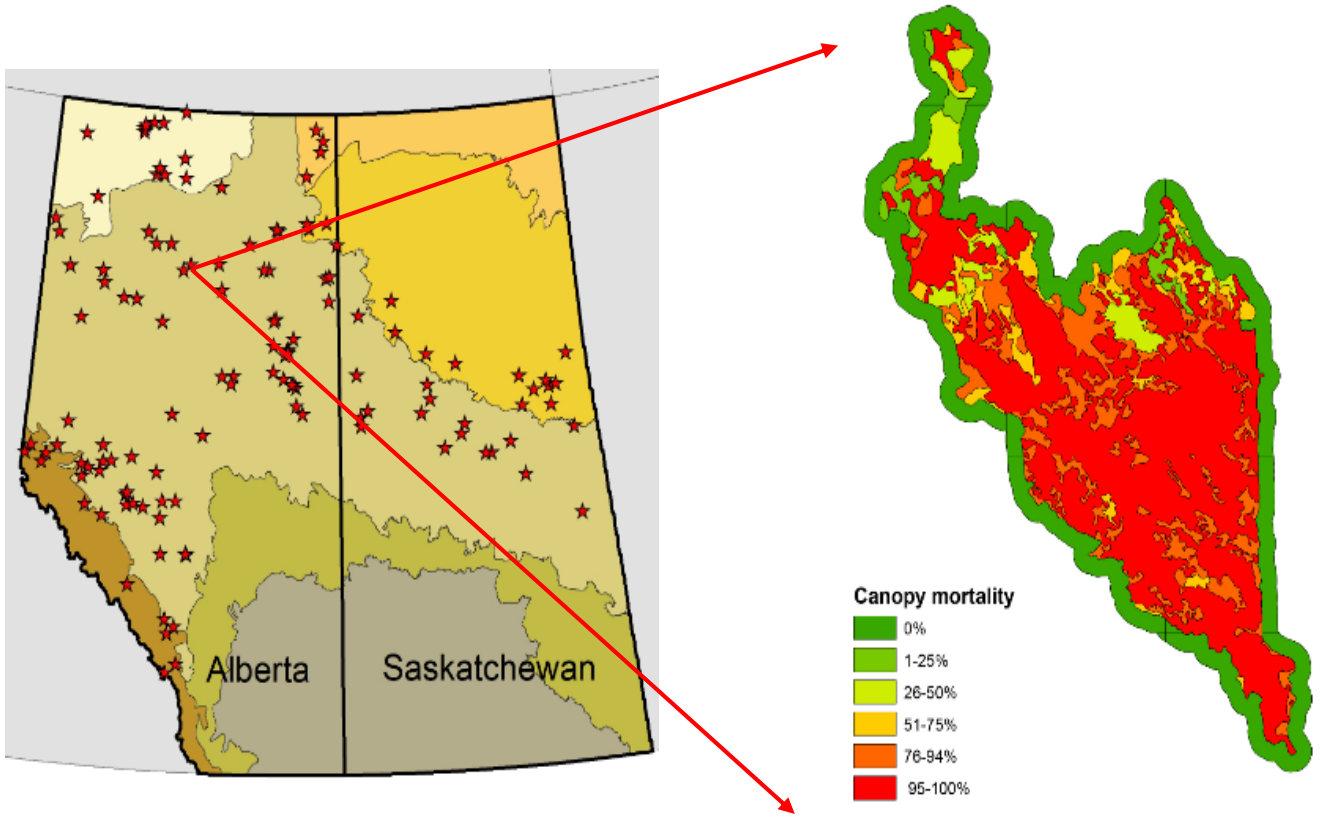
  Andison and McCleary (2014)

- Deviances from natural variability (harvesting)

  Pickell et al. (2013)

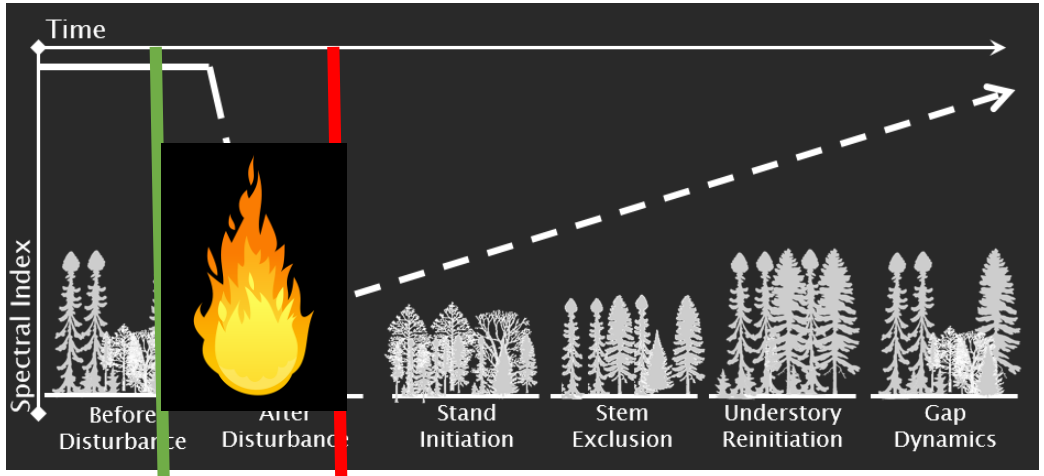
However:

- More than 1M$!

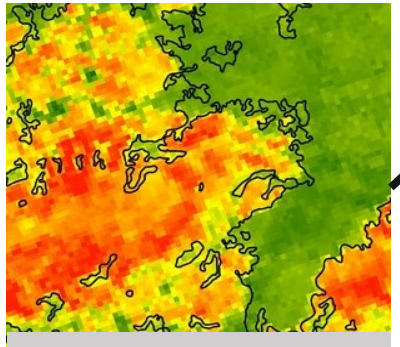


… Why?

Satellite data is free but requires field data

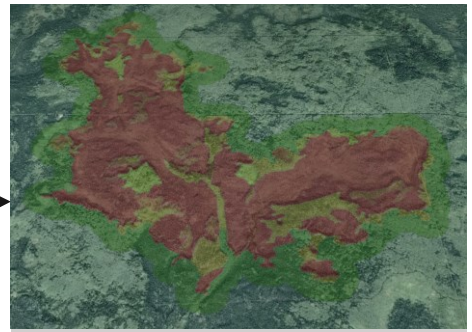


Pre-fire − Post-fire =



Landsat change

Plot-level severity



Burn severity maps

… which also presents challenges…

Logistics

- Expensive and difficult to collect in remote locations
- Many plots to cover a highly heterogeneous landscape

Plot-level severity

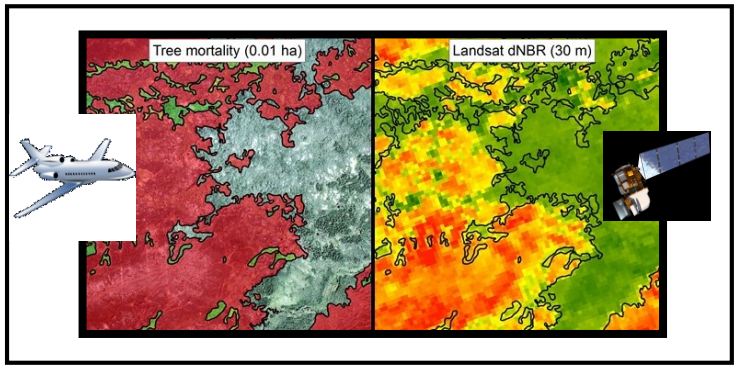
Interpretability & comparability

- CBI is somewhat subjective, and varies with the observer
- Not physically measurable & less useful for managers (averaged across strata)

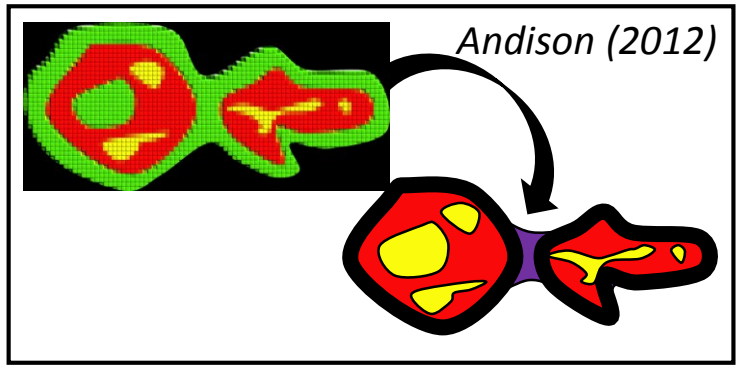
…. and studies are not comparable…

- What are we mapping?
- How many classes?
- What data & methods?
- How to define the perimeter objectively?
- What metrics are relevant?
- How can we compare those metrics across/within regions?

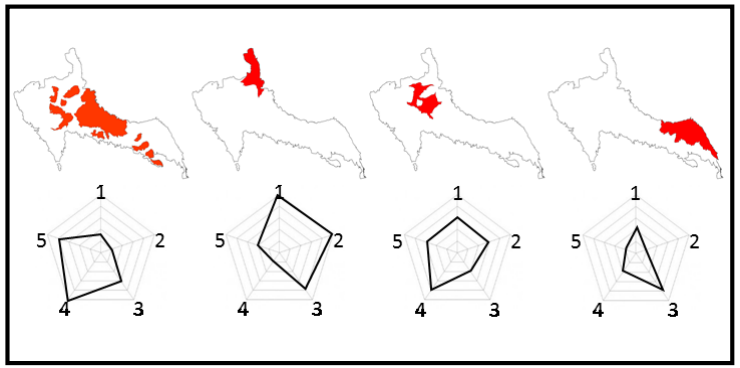
The proposed framework



Cost-effective & repeatable mortality maps



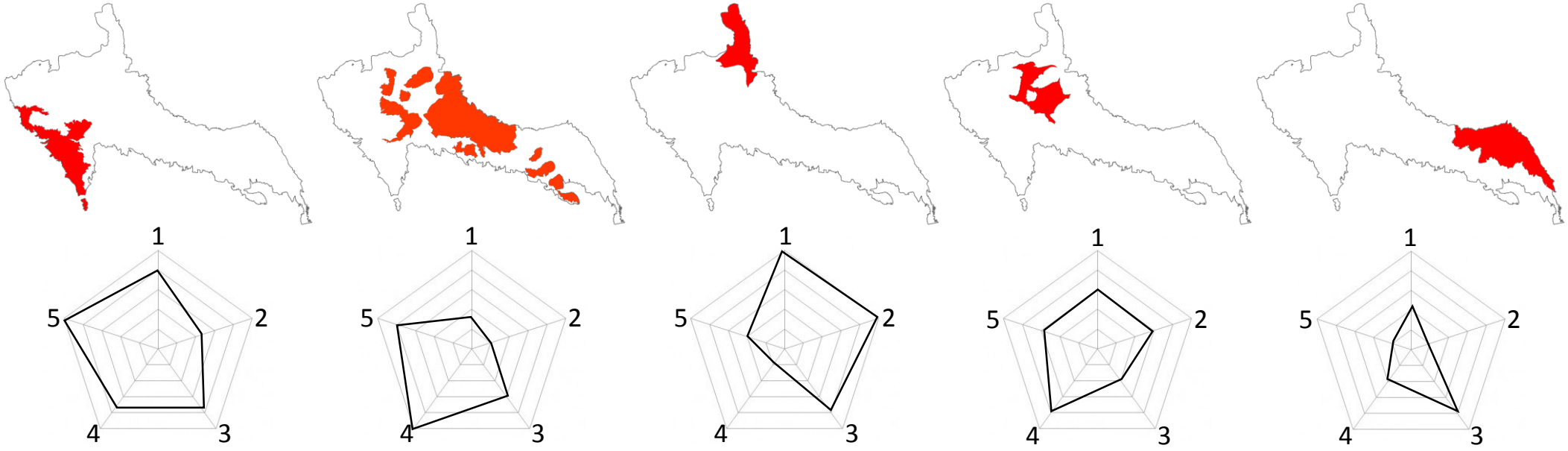
Consistent spatial language to define patch-fire events



A set of fire metrics & statistical analyses to compare across regions

Objective

Can a Landsat-based approach be used to generate a large enough sample size – of sufficient accuracy – to differentiate the fire pattern signature between ecoregions across the boreal plains ecozone in Canada?



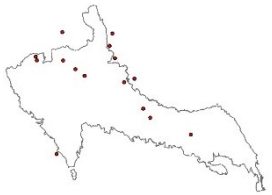
Previous work with Landsat data

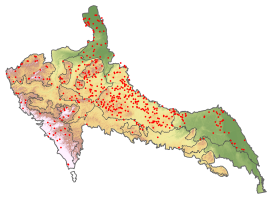
- At the most 3 classes of mortality can be separated with Landsat
  - Unburned: 0-5%
  - Partial mortality: 6-94%
  - Complete mortality: 95-100%

San-Miguel et al. (2017)

- We can produce comparable fire metrics to aerial interpretation[2]

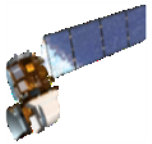
San-Miguel et al. (2017)



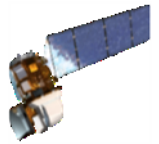


3-class API data

Landsat predictor variables



Landsat predictor variables



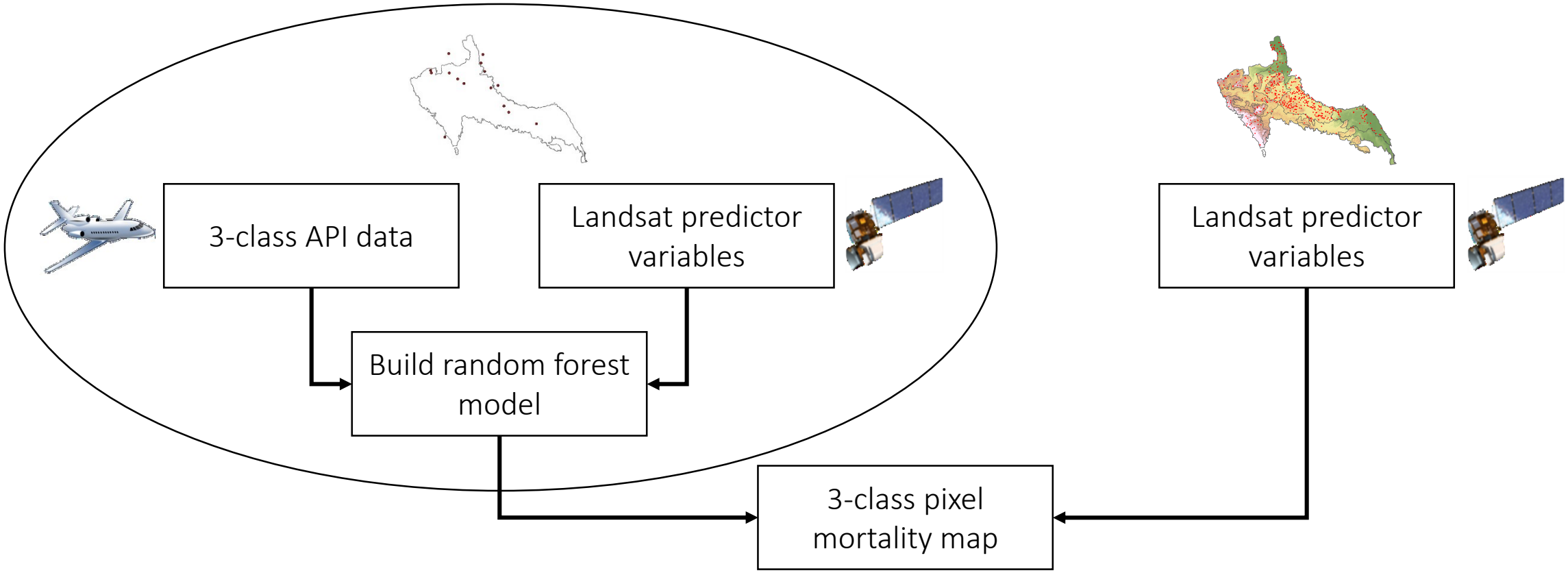
Build random forest model

3-class pixel mortality map

Calculate events

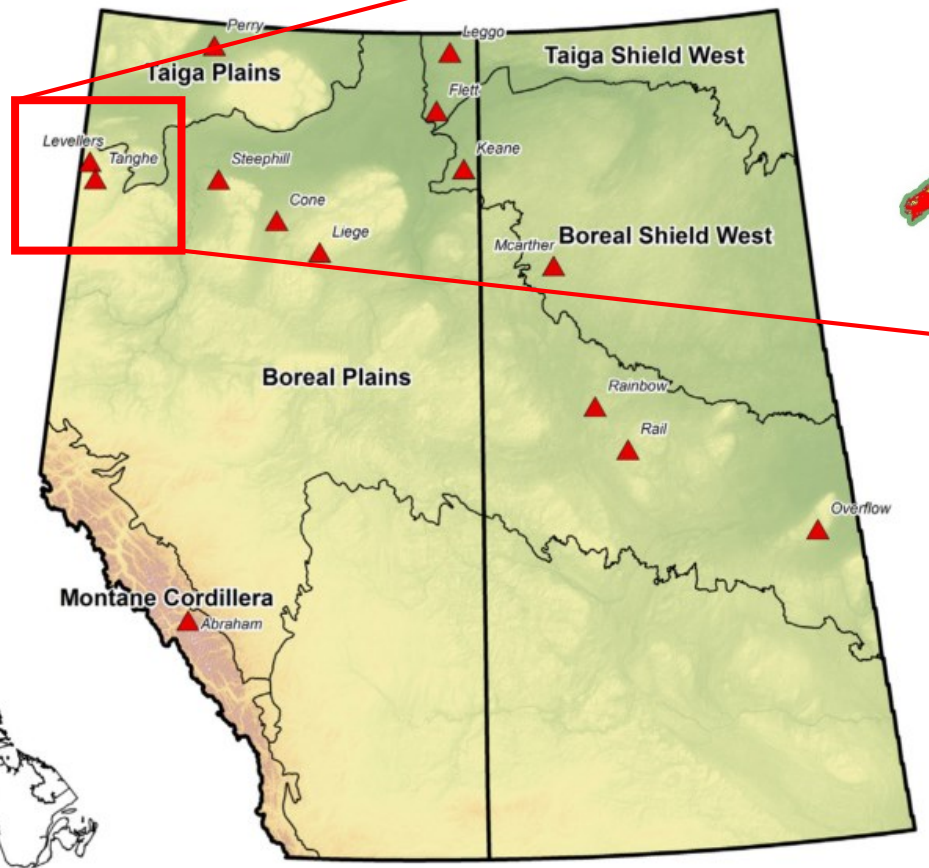
Calculated 7 pattern metrics

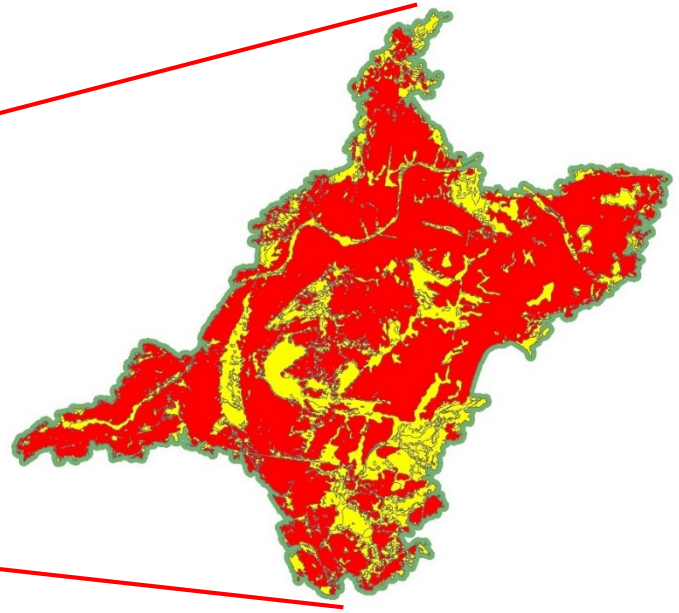
We trained a model to predict mortality maps



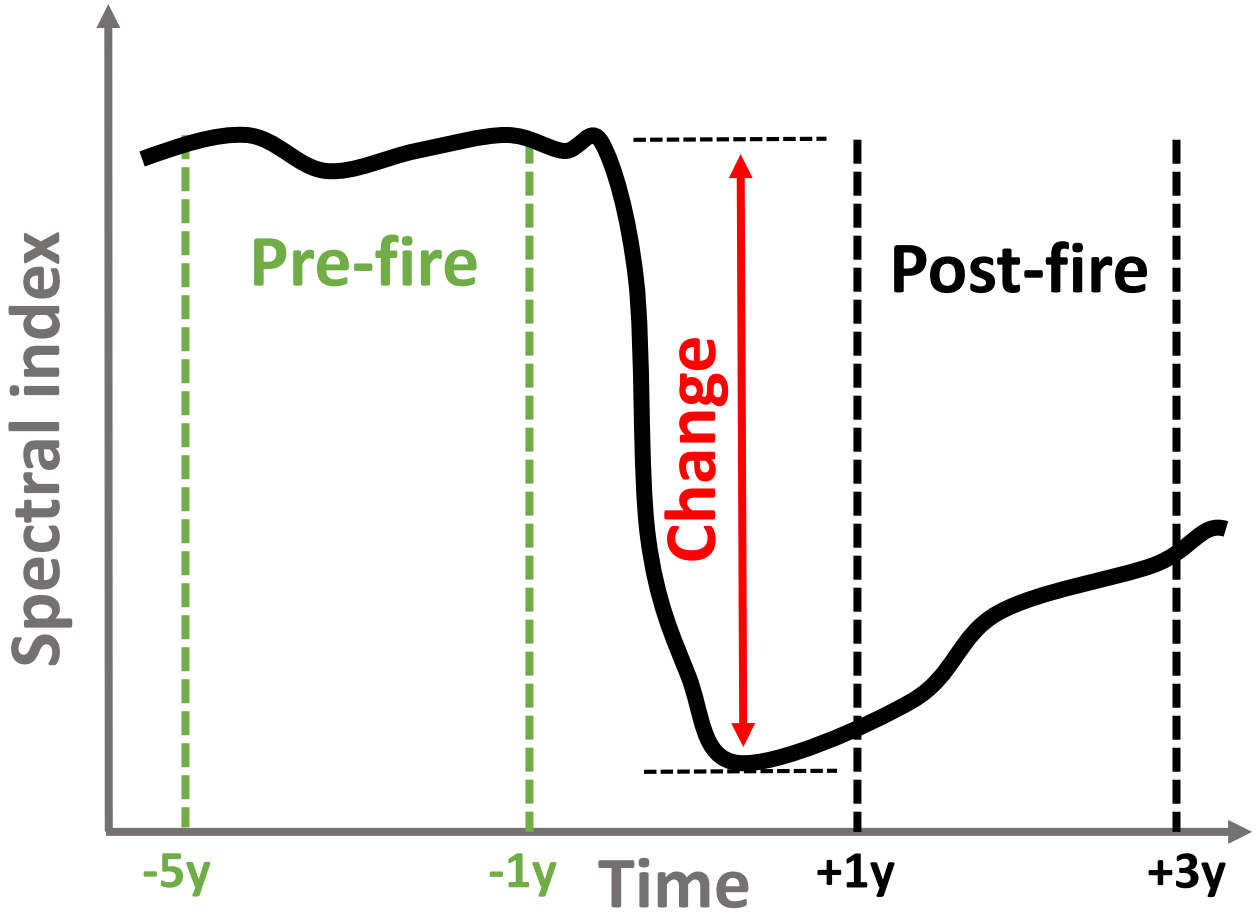
...with the observed mortality

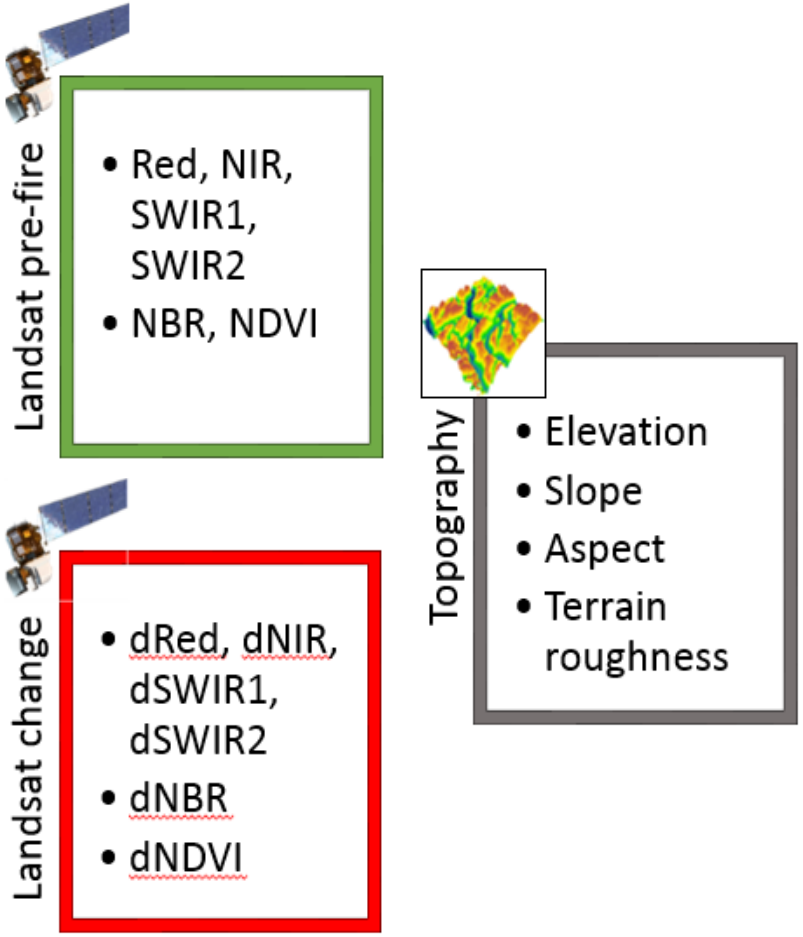
- 15 fires for calibration
- 3 classes of mortality
  - Unburned: 0-5%
  - Partial mortality: 6-94%
  - Complete mortality: 95-100%





...and the Landsat variables as predictors



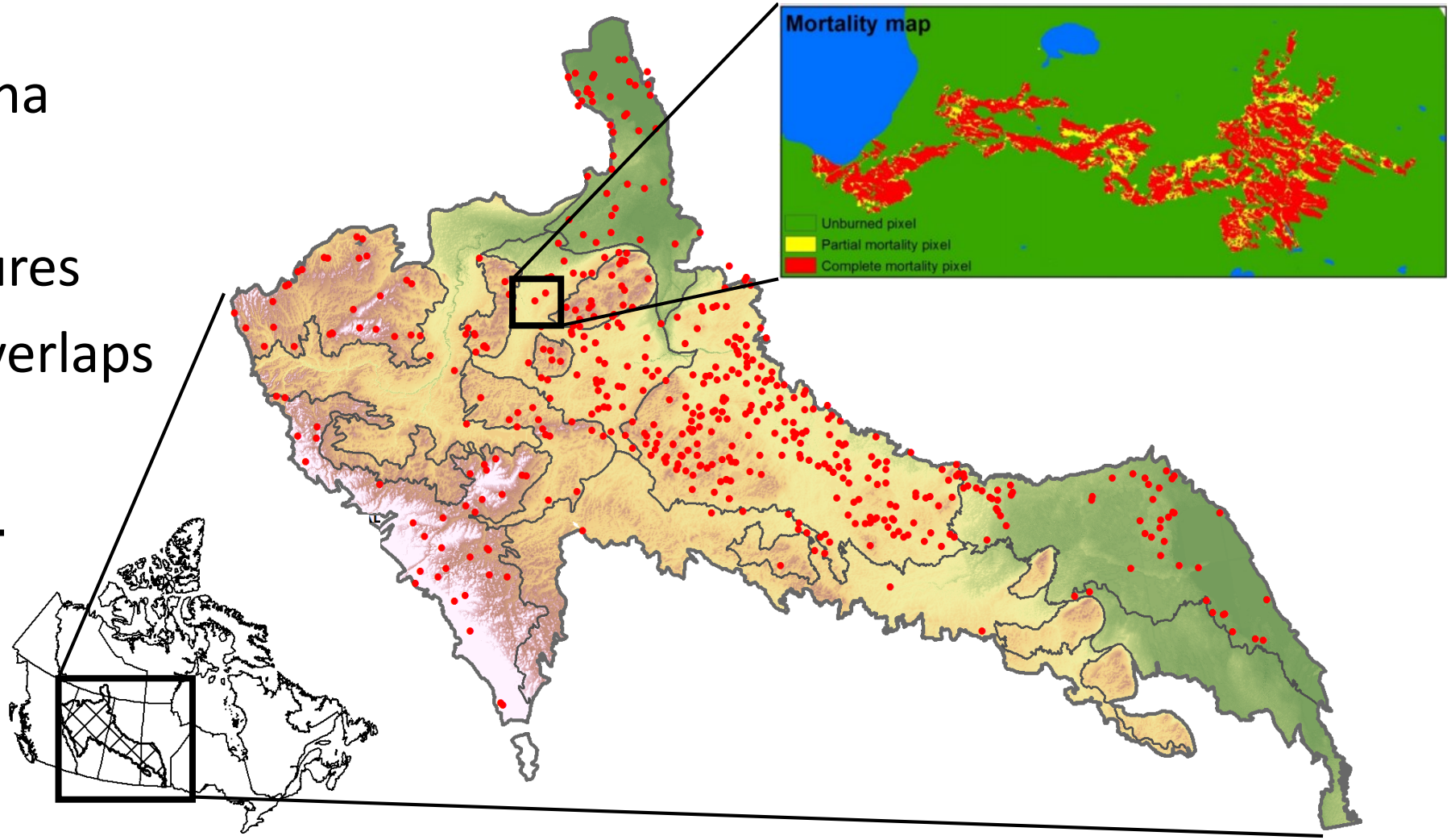


San-Miguel et al. (2017)

We applied the model to new fires

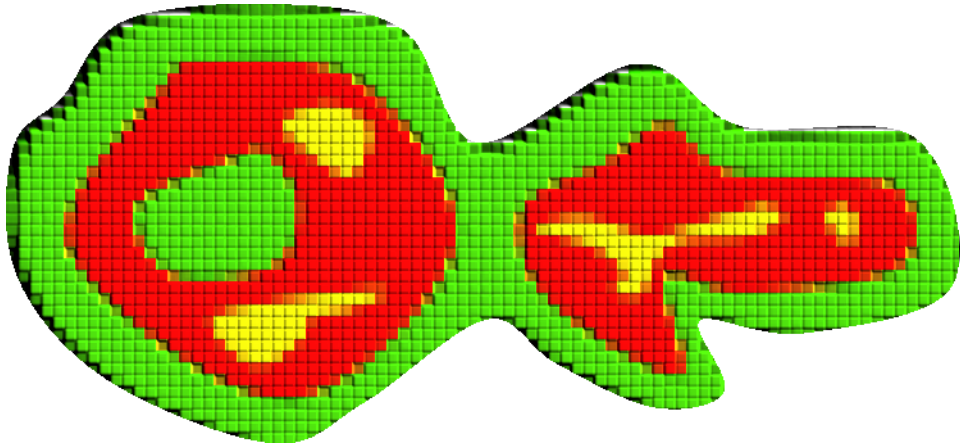
- Perimeter >100 ha
- 1985-2014
- No cultural features
- No recent fire overlaps
- No data gaps

507 fires

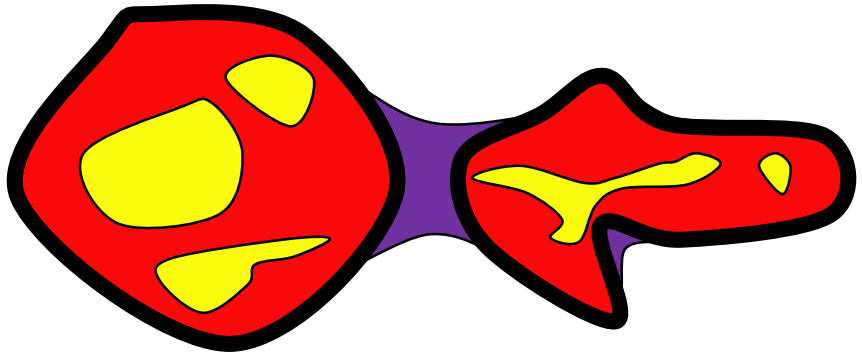


…calculated the disturbance events

Pixel mortality map



Patch disturbance event



~~Unburned~~

Partial mortality

Complete mortality

Island remnants

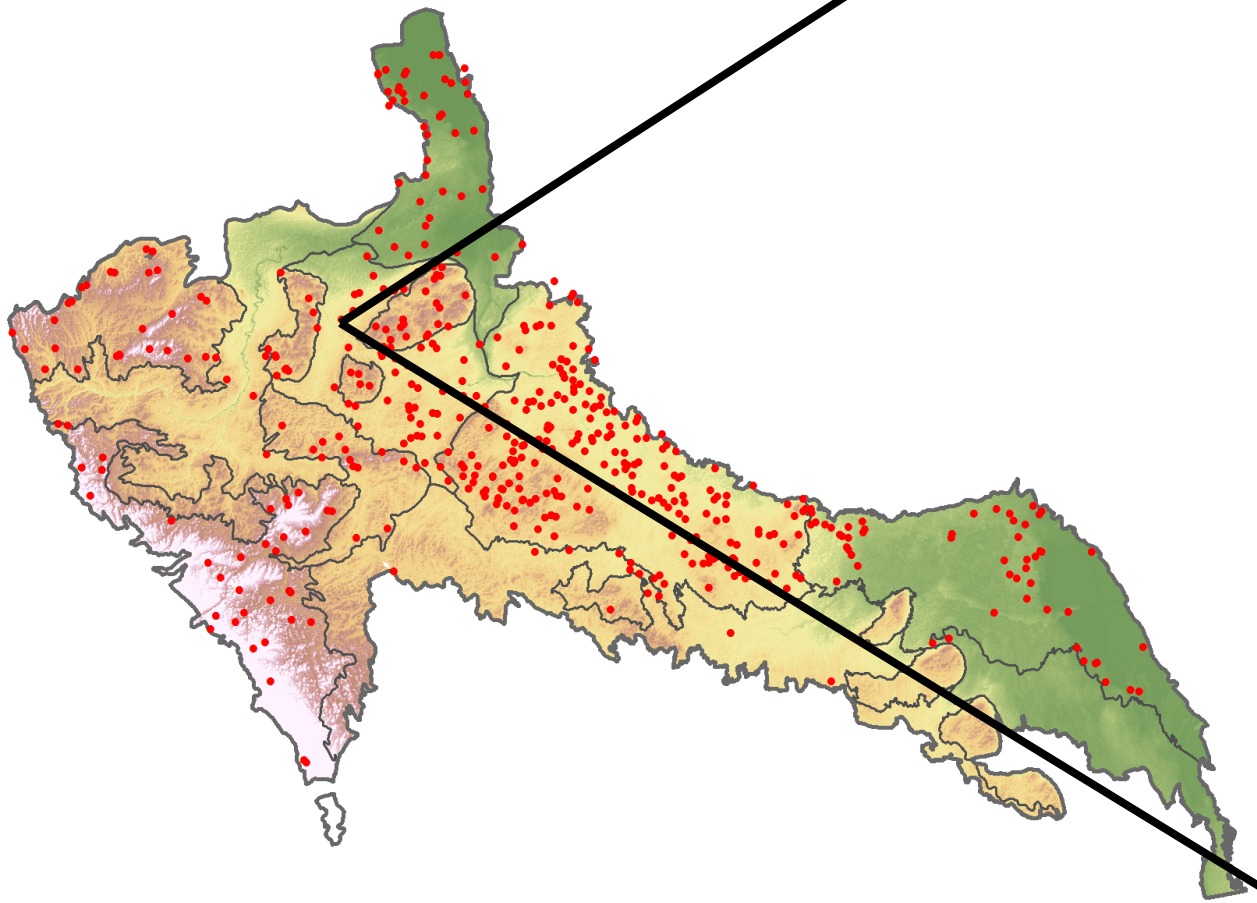
Disturbed

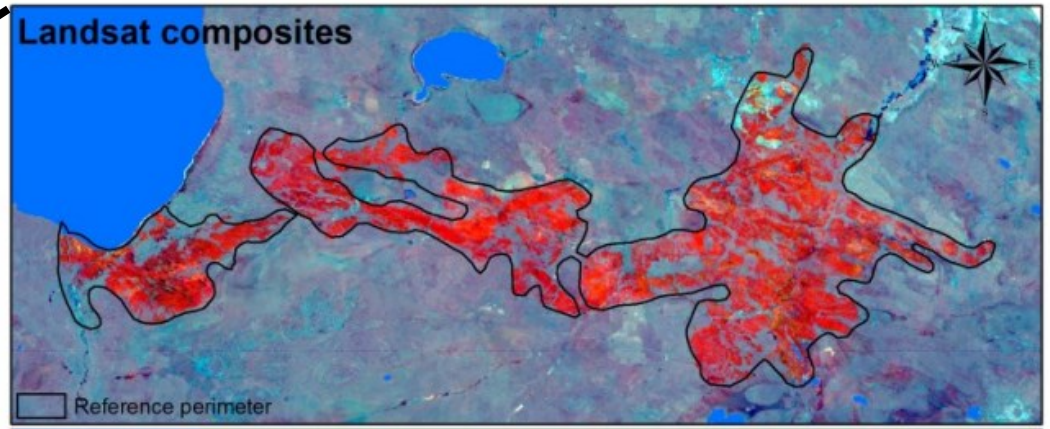
Burned patches

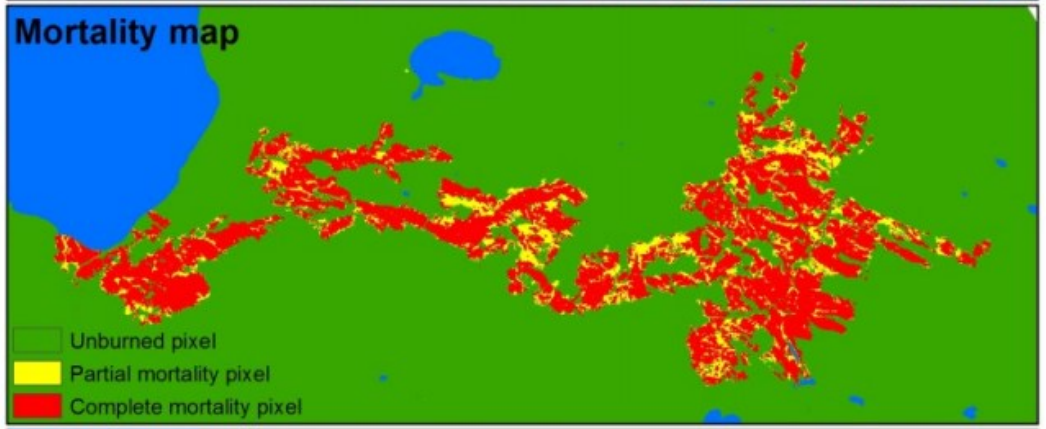
Matrix remnants

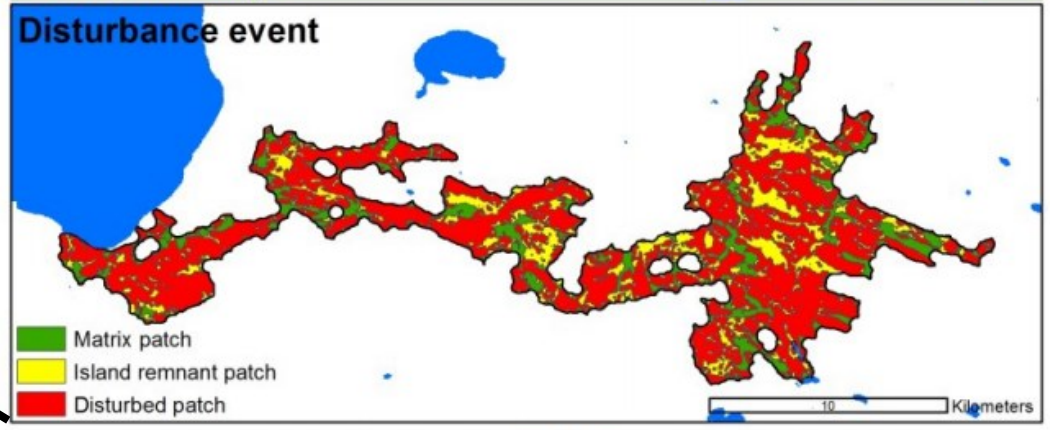
Andison (2012)

This is a real example









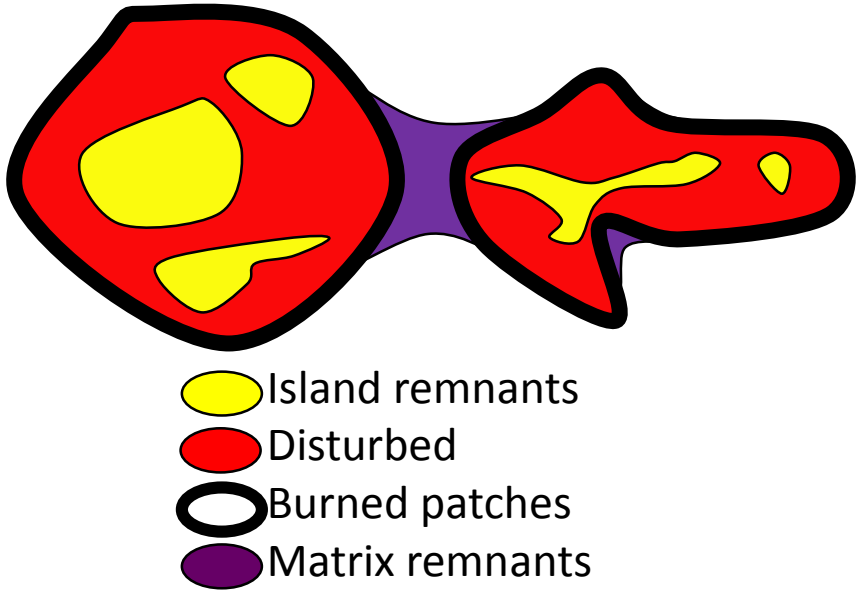
… and calculated the 7 fire pattern metrics

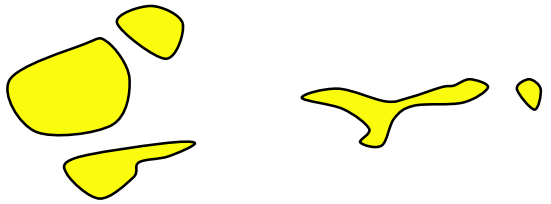
Lay out the harvesting footprint

Lay out the details within

Type	Metric	Calculation
Event scale	Event area (ha) [EA]	$total\ area$
	Shape index (no unit) [SI]	$\frac{island\ area}{event\ area} \times 100$
Within-fire event	% of islands, matrix, or total remnants (%) [IR, MR, TR]	$\frac{class}{event\ area} \times 100$
	Number of disturbed patches (patches) [NDP]	$total\ patches$
	Largest disturbed patch (%) [LDP]	$\frac{maximum\ patch\ area}{event\ area} \times 100$

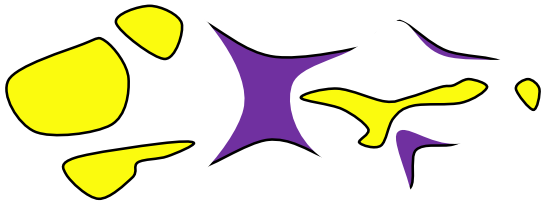
Graphic example of some metrics





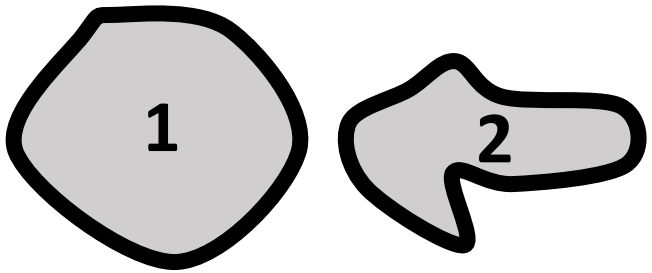
% Islands remnants [%]

$$\frac{island\ remnants}{total\ fire\ size}$$



% Total remnants [%]

$$\frac{island + matrix}{total\ fire\ size}$$



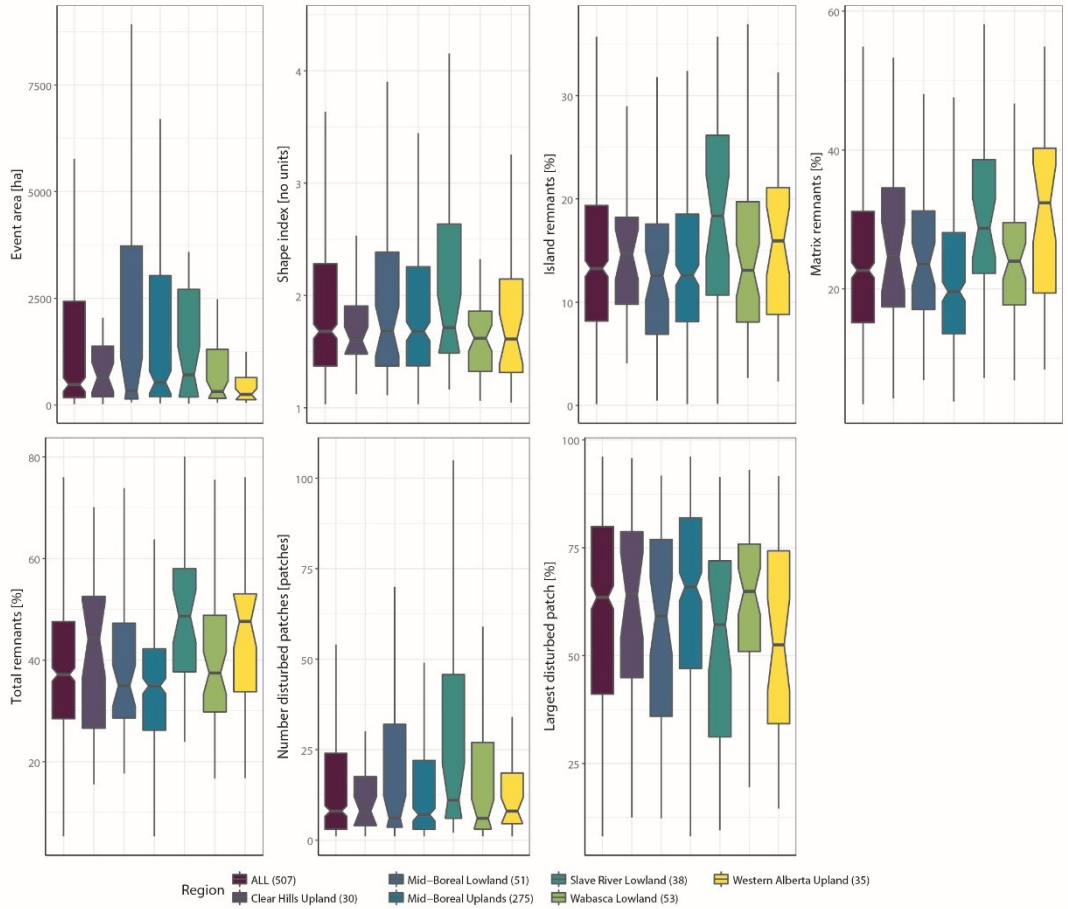
Number of disturbed patches

$$n.\,burned\ patches$$

San-Miguel et al. (2017)

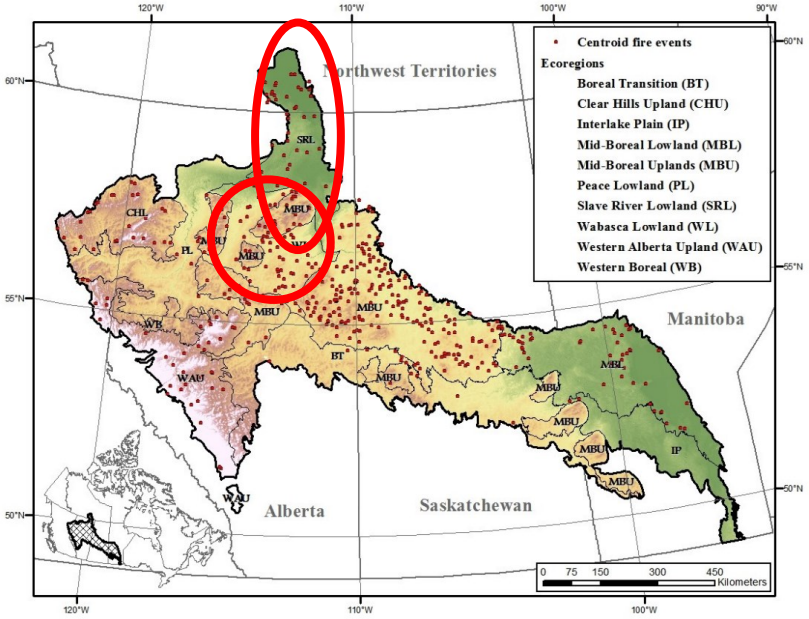
We found high variability within the ecozone

- Total remnants ranged from 5 to 91% with median value of 39%
- The percentage of the largest disturbed patch (LDP) ranged from 8% to 96% with a median of 63%

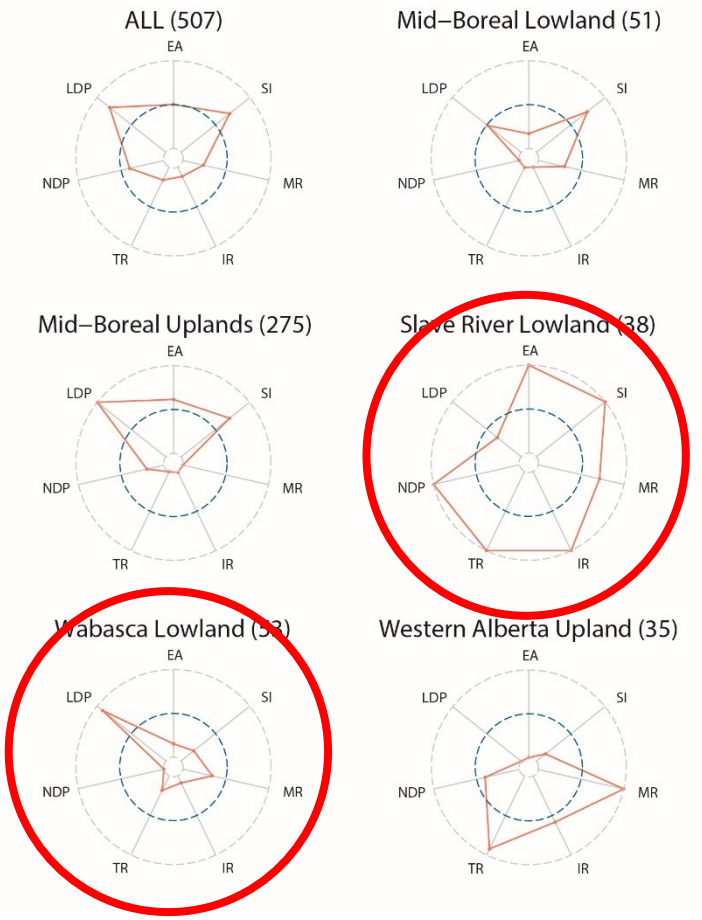


… and between ecoregions

Existence of unique “signatures” of burning patterns in the areas of study



- Smaller
- Regular
- Little residuals
- Few patches
- A very large dominant disturbed patch



- Big-sized
- Convoluted
- Many residuals
- Many patches
- Little dominance of the largest disturbed patch

We tested hypothesis about drivers of fire patterns

Mid-Boreal Uplands

more fuels
more connected
more intensity
less natural breaks

---

less residuals
less & **bigger** patches

Slave River Lowland

less fuels
less connected
less intensity
more natural breaks

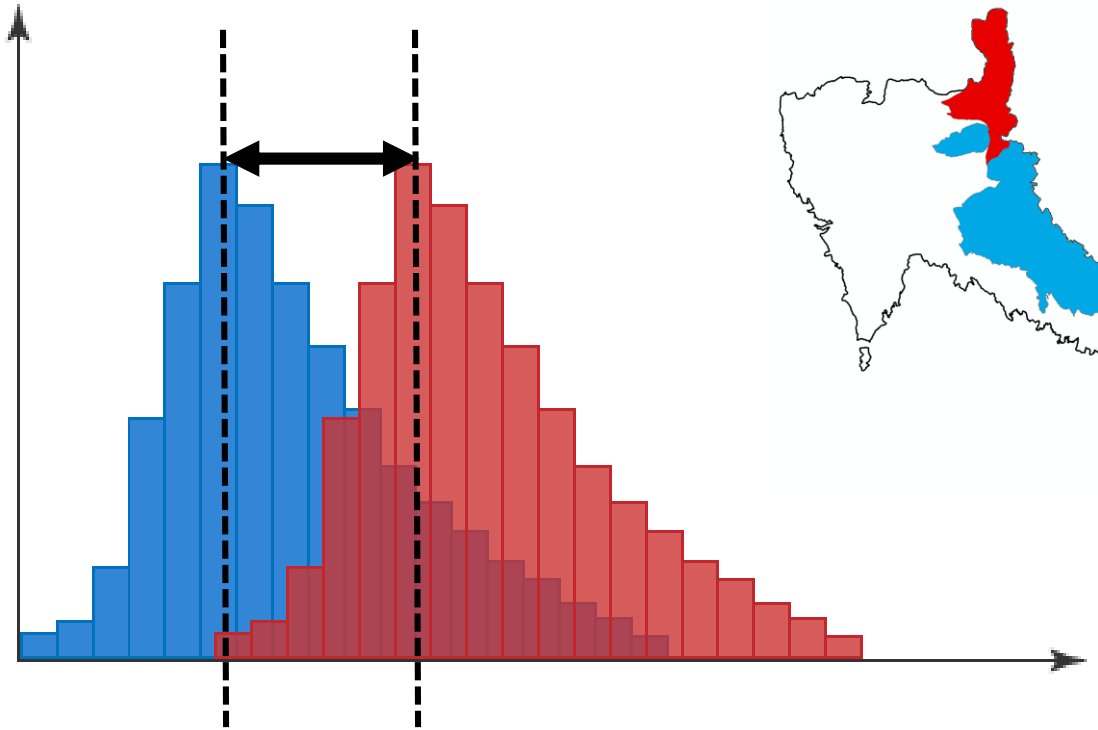
---

more residuals
more & **smaller** patches

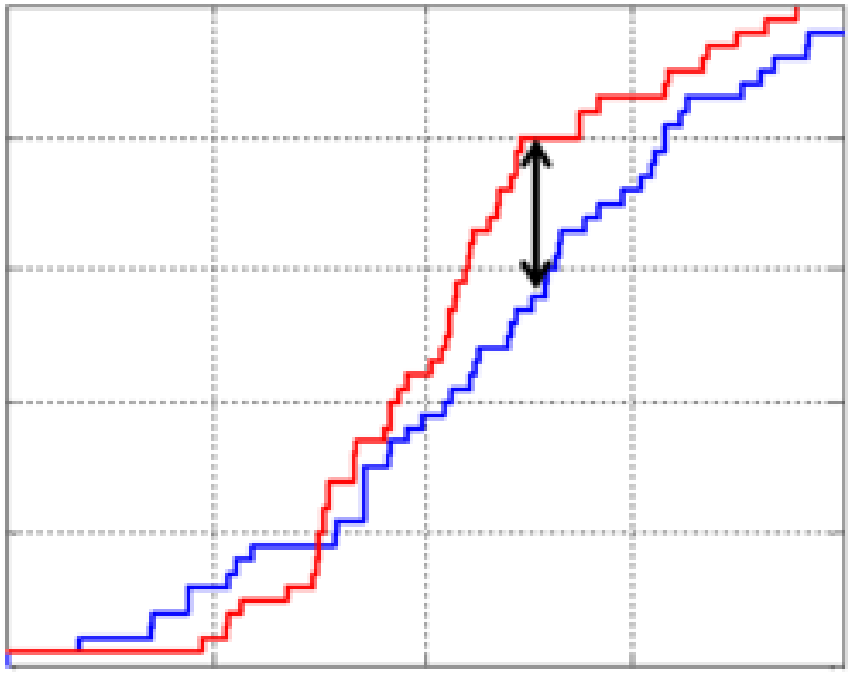
Using two statistical analyses

★ < 0.01 significance

Mann-Whitney-Wilcoxon test of median difference



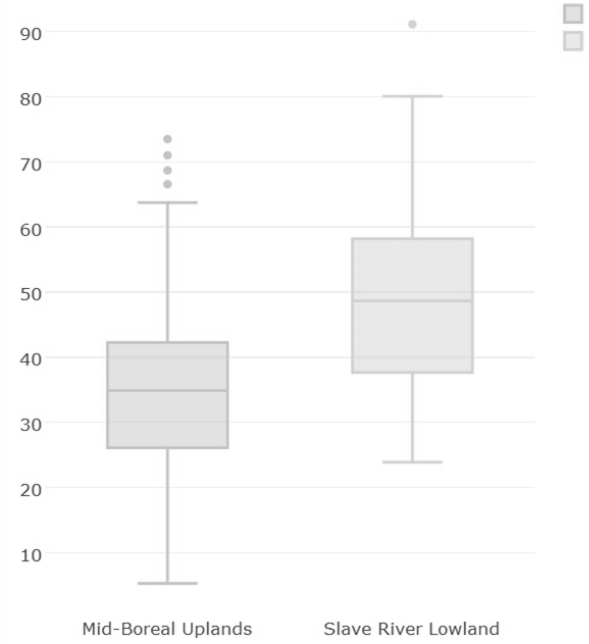
Kolmogorov-Smirnov goodness-of-fit test



These are the summaries per region

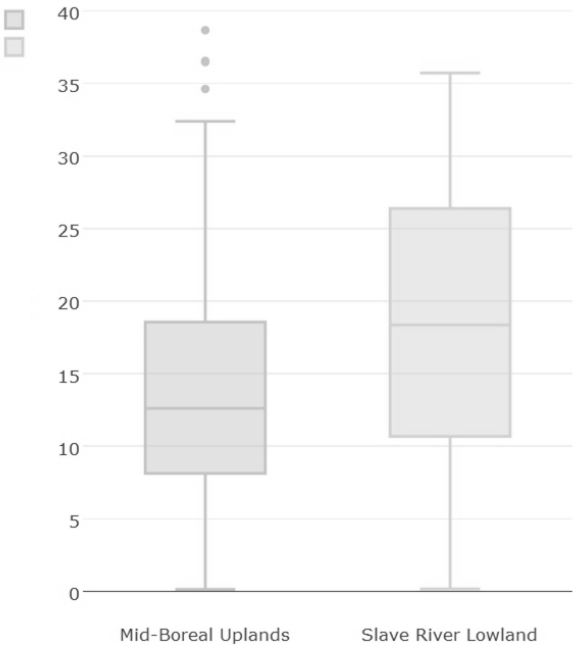
- High variability in residual levels
- MBU less residuals & larger & smaller patches

% Total remnants



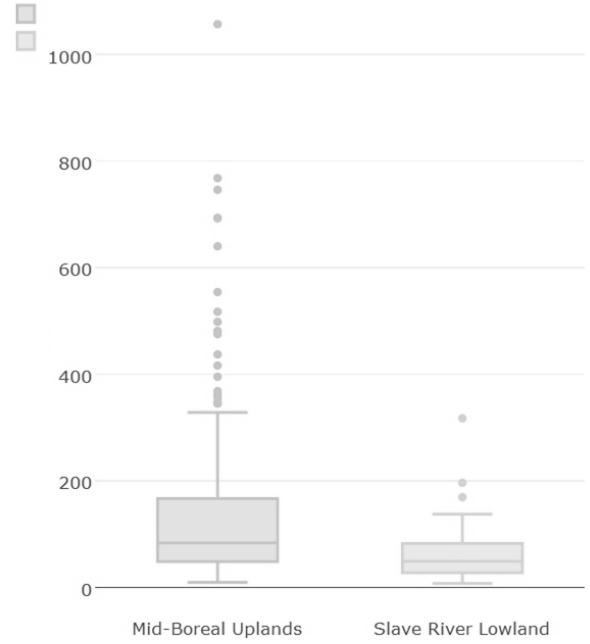
MBU < SRL

% Islands remnants



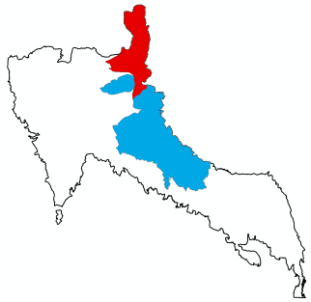
MBU < SRL

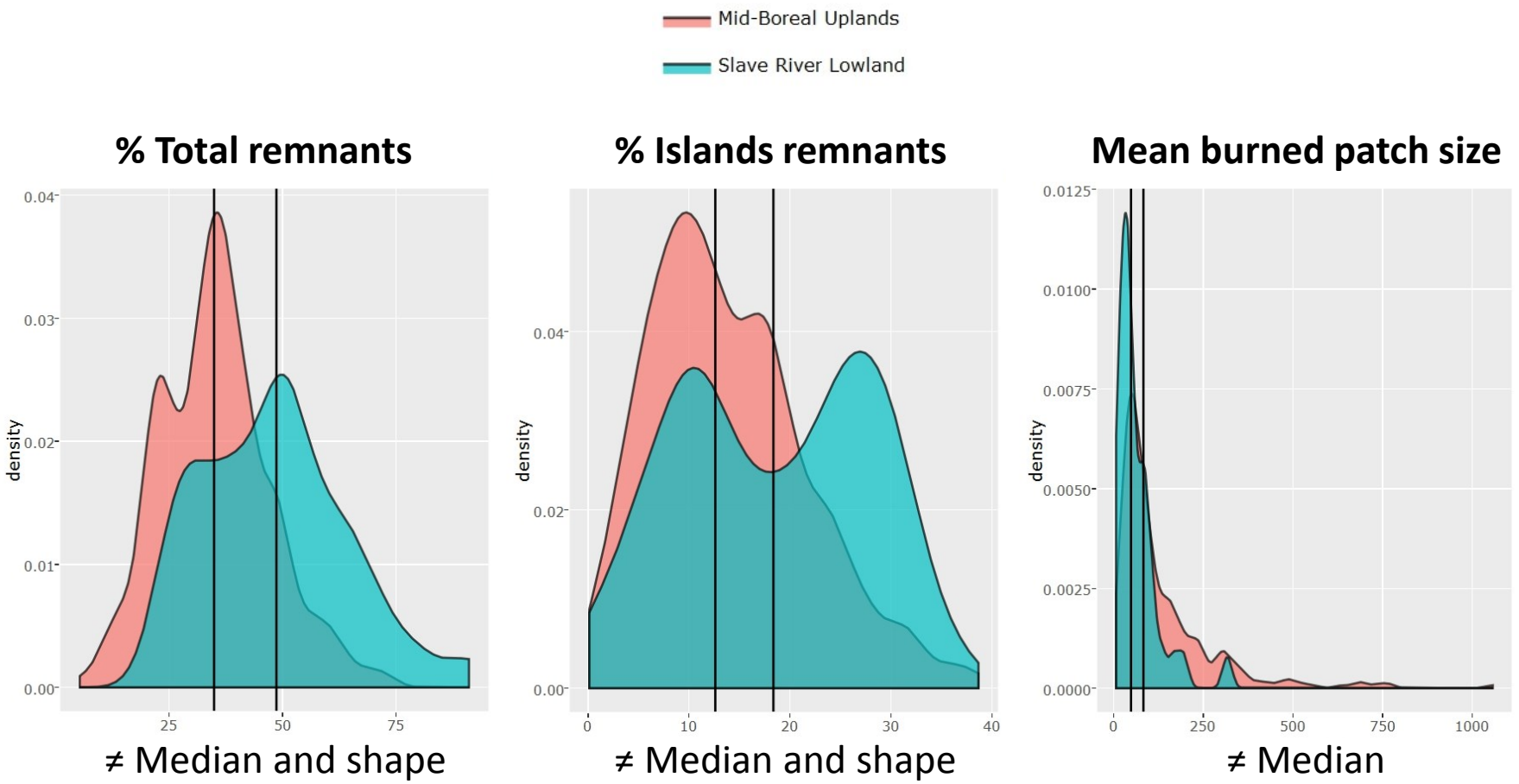
Mean burned patch size



MBU > SRL

… and these are the differences we found





This is how it all came together

Mid-Boreal Uplands

more fuels
more connected
more intensity
less natural breaks

---

less residuals
less & **bigger** patches

less amount & **less** complex (shape)
- % Island remnants
- % Total remnants

less & **bigger** patches
- Mean burned patch size

Slave River Lowland

less fuels
less connected
less intensity
more natural breaks

---

more residuals
more & **smaller** patches

more amount & **less** complex (shape)
- % Island remnants
- % Total remnants

more & **smaller** patches
- Mean burned patch size

Contribution of the proposed framework

- **Cost-effective** - Helped unify a growing collection of fire pattern data into comprehensive databases
- **Repeatable & consistent** – quantify variability & reveal differences across regions
- **Relevant for managers** – based on a tangible, physically measurable fire effect that can be translated into management decisions
- **Flexible** – new metrics can be added to suit specific needs e.g. distance to seed source

Application

It offers a single method with one spatial language so that one can measure and compare fire patterns across regions

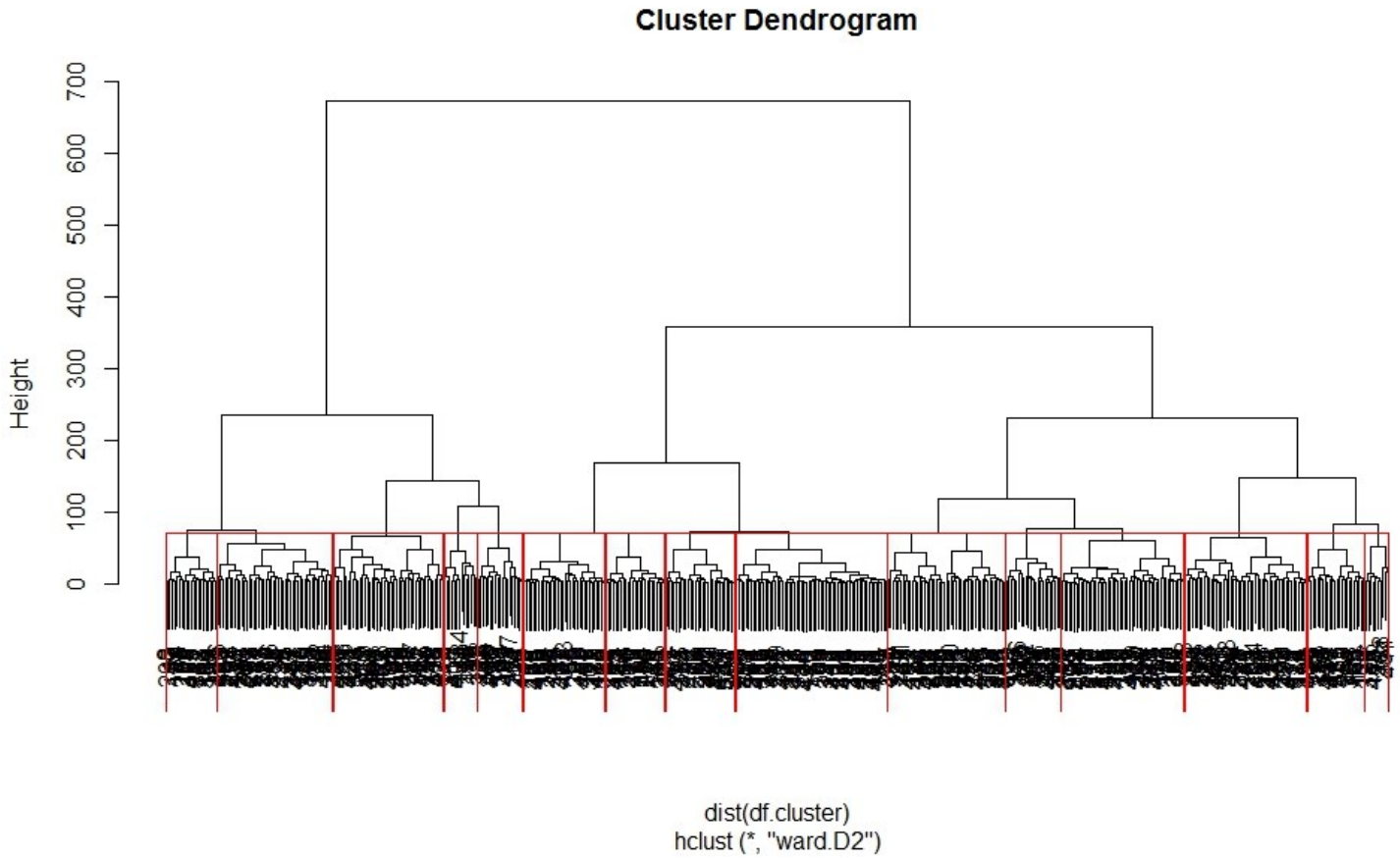
Baseline information that permits:

- **To characterize an area of study** given several metrics
- **To formulate and test hypotheses** like linkages between fire behaviour and patterns, and climate

Considerations

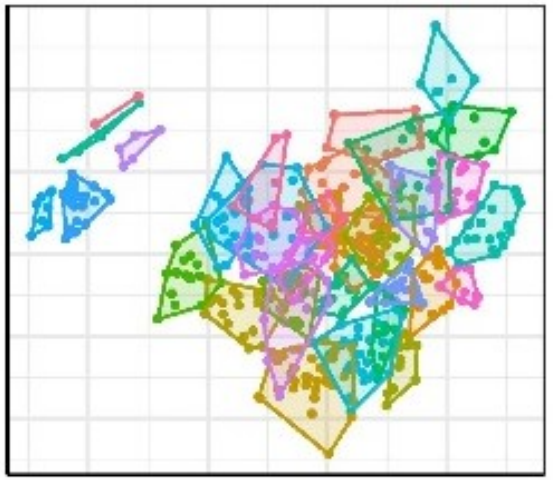
- **Trees must be the dominant vegetation** - wetlands with sparse or not-treed vegetation present a challenge
- **Reference data needed** - The model relies on perimeter and dates from fire databases
- **The partial mortality class is broad** (5-94% mortality)
- **Only last 30 years** - Only fires within the Landsat data archive (last 30 years)
- **API data is needed** - to calibrate it to another area of study

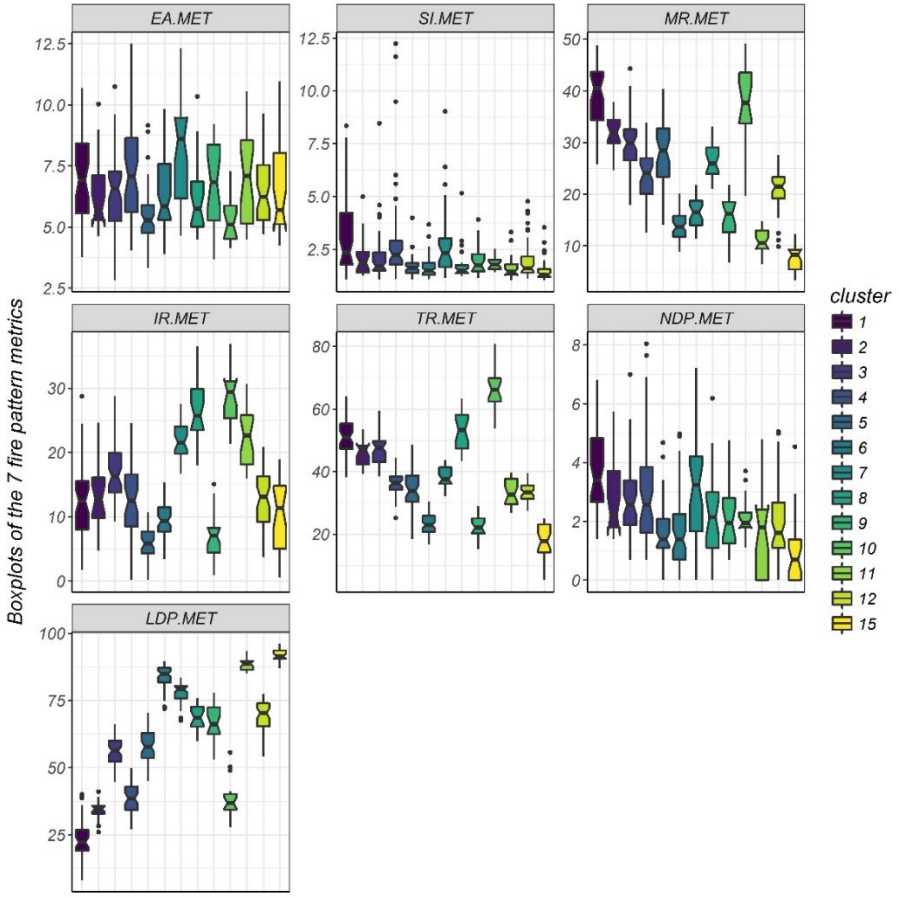
Future work
Currently we are creating independent zones



...and trying to explain them with environmental data

- Daily weather from closest meteorological stations
- Monthly interpolated weather data
- Annual land cover data
- % area disturbed prior to the fire





Thank you!

Funding:

NSERC
CRSNG

Forestry
University of British Columbia

Government of Saskatchewan

Support:

Integrated Remote Sensing Studio

ignacio.sanmiguel@alumni.ubc.ca

References

- Brandt J, Flannigan M, Maynard D, Thompson I (2013) An introduction to Canada's boreal zone: Ecosystem processes, health, sustainability, and environmental issues. Environmental Reviews 21, 207–226.
- Banks, S.C., Dujardin, M., Mcburney, L., Blair, D., Barker, M., Lindenmayer, D.B., 2011. Starting points for small mammal population recovery after wildfire: recolonisation or residual populations? Oikos 120, 26–37. http://dx.doi.org/ 10.1111/j.1600-0706.2010.18765.x.
- *Courtois, R., Ouellet, J., Dussault, C., Gingras, A., 2004. Forest management guidelines for forest-dwelling caribou in Quebec. For. Chron. 80, 598–607. http://dx.doi.org/10.5558/tfc80598-5.*
- *San-Miguel, I., Andison, D.W., Coops, N.C., Rickbeil, G.J.M., 2016. Predicting post-fire canopy mortality in the boreal forest from dNBR derived from time series of Landsat data. Int. J. Wildland Fire 25, 762–774. http://dx.doi.org/10.1071/ WF15226.*
- San-Miguel, I., Andison, D.W., Coops, N.C., 2017. Forest Ecology and Management Characterizing historical fire patterns as a guide for harvesting planning using landscape metrics derived from long term satellite imagery. For. Ecol. Manage. 399, 155–165. doi:10.1016/j.foreco.2017.05.021
- Andison, D.W., 2012. The influence of wildfire boundary delineation on our understanding of burning patterns in the Alberta foothills. Can. J. For. Res. 42, 1253–1263. http://dx.doi.org/10.1139/x2012-074.
- Andison, D.W., McCleary, K., 2014. Detecting regional differences in within-wildfire burn patterns in western boreal Canada. For. Chron. 90, 59–69. http://dx.doi. org/10.5558/TFC2014-011.
- Soverel, N.O., Perrakis, D.D.B., Coops, N.C., 2010. Estimating burn severity from Landsat dNBR and RdNBR indices across western Canada. Remote Sens. Environ. 114, 1896–1909. http://dx.doi.org/10.1016/j.rse.2010.03.013.