How unique are fire patterns across the boreal forest?

A means to exploring variability using the Landsat data archive
Understand natural fire regimes

Need
• Details of fire regimes
• Extent of applicability

Why
• Forest management
• Regime shifts
• Quantify anthropogenic influence

@ Brandt et al. (2013)
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 expensive
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
... which also presents challenges...

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

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

Andison (2012)
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 interpretation²

San-Miguel et al. (2017)
Build random forest model

3-class pixel mortality map

Calculate events

Calculated 7 pattern metrics
We trained a model to predict mortality maps

3-class API data

Landsat predictor variables

Build random forest model

3-class pixel mortality map

Landsat predictor variables
...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

<table>
<thead>
<tr>
<th>Pre-fire</th>
<th>Post-fire</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5y</td>
<td>+3y</td>
<td></td>
</tr>
<tr>
<td>-1y</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Spectral index

- Red, NIR, SWIR1, SWIR2
- NBR, NDVI

Landsat change
- dRed, dNIR, dSWIR1, dSWIR2
- dNBR
- dNDVI

Topography
- Elevation
- Slope
- Aspect
- Terrain roughness

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

Andison (2012)
This is a real example
... and calculated the 7 fire pattern metrics

<table>
<thead>
<tr>
<th>Type</th>
<th>Metric</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event scale</td>
<td>Event area (ha) [EA]</td>
<td>total area</td>
</tr>
<tr>
<td></td>
<td>Shape index (no unit) [SI]</td>
<td>( \frac{\text{island area}}{\text{event area}} \times 100 )</td>
</tr>
<tr>
<td>Within-fire event</td>
<td>% of islands, matrix, or total remnants (%) [IR, MR, TR]</td>
<td>( \frac{\text{class}}{\text{event area}} \times 100 )</td>
</tr>
<tr>
<td></td>
<td>Number of disturbed patches (patches) [NDP]</td>
<td>total patches</td>
</tr>
<tr>
<td></td>
<td>Largest disturbed patch (%) [LDP]</td>
<td>( \frac{\text{maximum patch area}}{\text{event area}} \times 100 )</td>
</tr>
</tbody>
</table>
Graphic example of some metrics

% Islands remnants [%]
\[
\frac{\text{island remnants}}{\text{total fire size}}
\]

% Total remnants [%]
\[
\frac{\text{island + matrix}}{\text{total fire size}}
\]

Number of disturbed patches
\[n.\text{burned patches}\]

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

Mann-Whitney-Wilcoxon test of median difference

Kolmogorov-Smirnov goodness-of-fit test

☆ < 0.01 significance
These are the summaries per region

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

Slave River Lowland

- less fuels
- less connected
- less intensity
- more natural breaks
- more residuals
- more & smaller patches

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

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

**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!

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References


