Remote Sensing of Burn Severity

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Seminar III
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Topics

- Introduction
- Normalized Burn Ratio (NBR)
  - Ground measurement: Composite Burn Index (CBI)
  - Assessing the performance of NBR
- Modified CBI & NBR
  - Relative dNBR (RdNBR)
  - Relativized Burn Ratio (RBR)
  - Geometrically structured Composite Burn Index (GeoCBI)
- Discussion and conclusion
Introduction

<table>
<thead>
<tr>
<th>Fire intensity</th>
<th>Energy released</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire severity or Burn severity</td>
<td>Organic matter loss</td>
</tr>
</tbody>
</table>

Ecosystem response
- Erosion
- Vegetation recovery

Societal impacts
- Loss of life or property
- Suppression costs

Keeley J. E. (2009)
Introduction

P. Morgan et al. (2014)

Ecological effects

Severity

Indices from remote sensing

- dNBR
- RdNBR
- NDVI
- SAVI
- MSAVI
- NDS
- WIR

... and more
Introduction

P. Morgan et al. (2014)
NBR: Normalized Burn Ratio

- **NBR** requires SWIR in the TM/ETM sensors (band 7)
- **NBR** is sensitive to the changes in live green vegetation, moisture content, and some soil conditions which may occur after fire
- **NBR** takes values ranging between -1 and 1

\[
\text{NBR} = \frac{\text{Band}4 - \text{Band}7}{\text{Band}4 + \text{Band}7} = \frac{\text{NIR} - \text{SWIR}2}{\text{NIR} + \text{SWIR}2}
\]

**Band 4** = near-infrared (0.76–0.90 μm)

**Band 7** = shortwave infrared (2.08–2.35 μm)
NBR: Normalized Burn Ratio

\[ dNBR = NBR_{\text{pre-fire}} - NBR_{\text{post-fire}} \times 1,000 \]

Severity levels and example range of dNBR (scaled by 10^3)

<table>
<thead>
<tr>
<th>Severity level</th>
<th>dNBR range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced regrowth, high</td>
<td>-500 to -251</td>
</tr>
<tr>
<td>Enhanced regrowth, low</td>
<td>-250 to -101</td>
</tr>
<tr>
<td>Unburned</td>
<td>-100 to +99</td>
</tr>
<tr>
<td>Low severity</td>
<td>+100 to +269</td>
</tr>
<tr>
<td>Moderate-low severity</td>
<td>+270 to +439</td>
</tr>
<tr>
<td>Moderate-high severity</td>
<td>+440 to +659</td>
</tr>
<tr>
<td>High severity</td>
<td>+660 to +1300</td>
</tr>
</tbody>
</table>

**Note:** dNBR less than -550, or greater than +1,350 may also occur, but are not considered burned. It may be caused by misregistration, clouds, or other factors not related to real land cover differences.
NBR: Normalized Burn Ratio

Case study: Camp Gurnsey, Wyoming (USA) in 2006
**NBR: Normalized Burn Ratio**

- **Extended Assessment (EA)**
  - Severity based on post-fire assessment at peak of green of next growing season
  - Forests/shrublands

- **Initial Assessment (IA)**
  - Severity based on immediate post-fire assessment
  - Grasslands/shrublands

Initial and extended assessments require imagery from different periods.
Composite Burn Index (CBI)

- Ground measure of burn severity
  - An index to represent the magnitude of fire effects (magnitude of change from pre-fire conditions)
  - A comparable values regardless of community type/location/time
  - CBI ranges from 0.0 to 3.0 (unburned to highest severity)
  - Designed for moderate-resolution remote sensing applications (i.e. LANDSAT)
  - The vegetation is considered to be composed of 5 strata
# CBI: Composite Burn Index

De Santis A. and E. Chuvieco (2009)

<table>
<thead>
<tr>
<th>Burn severity</th>
<th>High</th>
<th>Moderate-high</th>
<th>Moderate</th>
<th>Low</th>
<th>Unburnt</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBI</td>
<td>3</td>
<td>2.85</td>
<td>2.45</td>
<td>0.9</td>
<td>0</td>
</tr>
</tbody>
</table>

**Example**

<table>
<thead>
<tr>
<th></th>
<th>B+C</th>
<th>LAI</th>
<th>D+E</th>
<th>LAI</th>
<th>Sub-Stratum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brown</td>
<td>1.7</td>
<td>Brown</td>
<td>0.01</td>
<td>DCH</td>
</tr>
<tr>
<td></td>
<td>Brown</td>
<td>0.1</td>
<td>Brown</td>
<td>0.1</td>
<td>DCH</td>
</tr>
<tr>
<td></td>
<td>Brown</td>
<td>0.7</td>
<td>Green</td>
<td>0.7</td>
<td>DCH</td>
</tr>
<tr>
<td></td>
<td>Brown</td>
<td>1.8</td>
<td>Green</td>
<td>1.8</td>
<td>50% Soil</td>
</tr>
<tr>
<td></td>
<td>Brown</td>
<td>2.5</td>
<td>Green</td>
<td>2.5</td>
<td>50% DCH</td>
</tr>
</tbody>
</table>

DCH = Dark Charcoal
B = Low shrubs
C = Tall shrubs
D = Intermediate trees
E = Big trees

CBI: Composite Burn Index

CBI - Spatial Resolution

Plot level (30m)

Aerial photo (resolution 0.3-1 m)

LANDSAT NBR (resolution 30 m)
CBI vs. dNBR


Case study: the south side of San Francisco Peak (a) Year 2001, (b) Year 2002

<table>
<thead>
<tr>
<th>Severity (%)</th>
<th>2001 Producer’s accuracy</th>
<th>2001 User’s accuracy</th>
<th>2002 Producer’s accuracy</th>
<th>2002 User’s accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unburned</td>
<td>100</td>
<td>70.8</td>
<td>58.8</td>
<td>76.9</td>
</tr>
<tr>
<td>Low</td>
<td>71.4</td>
<td>78.1</td>
<td>74.3</td>
<td>70.3</td>
</tr>
<tr>
<td>Moderate</td>
<td>60</td>
<td>78.9</td>
<td>76</td>
<td>67.9</td>
</tr>
<tr>
<td>High</td>
<td>80</td>
<td>70.6</td>
<td>80</td>
<td>85.7</td>
</tr>
<tr>
<td>Overall</td>
<td>75.0</td>
<td>70.6</td>
<td>72.8</td>
<td>85.7</td>
</tr>
<tr>
<td>KHAT</td>
<td>0.659</td>
<td>0.619</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>0.0038</td>
<td>0.0043</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z-statistic</td>
<td>10.65</td>
<td>9.40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Assessing the performance of NBR


Isolines of the NBR

The ideal trajectory of changes in NIR & MIR

The actual trajectory of changes in NIR & MIR

\[ \Delta \text{NBR optimality} = 1 - \frac{|BB'|}{|UB|}, \quad 0 \leq \Delta \text{NBR optimality} \leq 1 \]
Relative dNBR (RdNBR)

J. D. Miller and A. E. Thode (2007)

**dNBR** = The absolute change index

**RdNBR** = The relative change index

\[
RdNBR = \left( \frac{\text{PreFireNBR} - \text{PostFireNBR}}{\sqrt{\text{ABS}(\text{PreFireNBR}/1000)}} \right)
\]

<table>
<thead>
<tr>
<th>Severity category</th>
<th>Field measured CBI severity value</th>
<th>Predicted dNBR</th>
<th>Predicted RdNBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unchanged</td>
<td>0–0.1</td>
<td>&lt;41</td>
<td>&lt;69</td>
</tr>
<tr>
<td>Low</td>
<td>0.1–1.24</td>
<td>41–176</td>
<td>69–315</td>
</tr>
<tr>
<td>Moderate</td>
<td>1.25–2.24</td>
<td>177–366</td>
<td>316–640</td>
</tr>
<tr>
<td>High</td>
<td>2.25–3.0</td>
<td>&gt;=367</td>
<td>&gt;=641</td>
</tr>
</tbody>
</table>

Moderate % Canopy Cover
NBR = 0.4
\[dNBR = 0.025\]
\[dNBR = 0.375\]

High % Canopy Cover
NBR = 0.8
\[dNBR = 0.05\]
\[dNBR = 0.75\]
Relativized Burn Ratio (RBR)

\[ RBR = \left( \frac{dNBR}{(NBR_{prefire} + 1.001)} \right) \]

Adding 1.001 to ensures that the denominator will never be zero
GeoCBI: A modified version of CBI

De Santis A. and E. Chuvieco (2009)

- 10 spectra were generated the severity scenarios by varying the FCOV (fraction of vegetation cover) from 0.1 to 1
- Simulation results show that changes in FCOV have a higher effect as the burn severity level decreases
- Geometrically structured Composite Burn Index (GeoCBI) was proposed.

\[
\text{GeoCBI} = \frac{\sum_{m_1}^{m_n} (\text{CBI}_m \times \text{FCOV}_m)}{\sum_{m_1}^{m_n} \text{FCOV}_m}
\]

where
- \( m = \) each vegetation stratum
- \( n = \) the number of strata
<table>
<thead>
<tr>
<th>Dry heath (<em>Calluna</em>)</th>
<th>Wet heath (<em>Erica</em>)</th>
<th>Grass-encroached heath (<em>Molinia</em>)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>unburned</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GeoCBI = 0</td>
<td>GeoCBI = 0</td>
<td>GeoCBI = 0</td>
</tr>
<tr>
<td><strong>moderate burn severity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GeoCBI = 0.51</td>
<td>GeoCBI = 0.41</td>
<td>GeoCBI = 0.43</td>
</tr>
<tr>
<td><strong>high burn severity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GeoCBI = 0.85</td>
<td>GeoCBI = 0.64</td>
<td>GeoCBI = 0.70</td>
</tr>
</tbody>
</table>

L. Schepers *et al.* (2014)
Coniferous forest

Shrub land

S. Veraverbeke et al. (2011)
GeoCBI: A modified version of CBI

De Santis A. and E. Chuvieco (2009)

S. Veraverbeke et al. (2011)
GeoCBI: A modified version of CBI

- For **case B**, GeoCBI would underestimate severity, similarly to the CBI.
- It is common to most optical remote sensing techniques (observed the reflectance from the *upper canopy*).
- From the point of view of short-term post-fire management, case B do not require a rapid intervention (low value of GeoCBI).

**Case A**
- Green canopies
- Low FCOV
- Dark charcoal substratum

**Case B**
- Green canopies
- High FCOV
- Dark charcoal substratum

**Case C**
- Green canopies
- High FCOV
- Unburnt soil substratum
GeoCBI: A modified version of CBI

Case study: the northern Cascade Range of Washington, USA

C. A. Cansler and D. McKenzie (2014)
C. A. Cansler and D. McKenzie (2014)

\[ \text{dNBR} = 36.4 + 158.6 \text{CBI} \]
\[ R^2 = 0.44, P < 0.001 \]

\[ \text{dNBR} = 55.8 + 152.5 \text{GeoCBI} \]
\[ R^2 = 0.40, P < 0.001 \]

\[ \text{RdNBR} = 117.1 + 300.5 \text{CBI} \]
\[ R^2 = 0.60, P < 0.001 \]

\[ \text{RdNBR} = 138.5 + 301.6 \text{GeoCBI} \]
\[ R^2 = 0.60, P < 0.001 \]
Discussion & conclusions

Burn severity assessment
- Soil burn severity / vegetation severity
- What imagery? : Moderate resolution remotely sensed imagery
- What index? : dNBR / RdNBR / RBR / etc.
- Timing of imagery? : Initial assessment / Extend assessment
- Field measures : CBI / GeoCBI

Opinions
- Severity level → Subjective?
- Validate process → Human error
- RS imagery conditions → Cloud cover/ cloud shadow
References


Thank you

謝謝

ขอบคุณครับ