Post-fire Mapping Support in the USDA Forest Service:
Burn Severity Assessment and the RSAC BAER Imagery Support Program

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Outline

• Wildfire intensity and severity
• Soil burn severity vs. vegetation severity
• Field and satellite-based perspectives of burn severity
• Spectral reflectance and normalized burn ratio
• RSAC post-fire mapping programs
• Remote sensing in support of Burned Area Emergency Response (BAER) Teams
• Burned Area Reflectance Classification (BARC)
• Exercise introduction

Fire Intensity

• Amount of energy or heat released per unit time or area
  – Encompasses several specific types of fire intensity measures

• Byram (1959): “The rate of energy or heat release per unit time, per unit length of fire front, regardless of its depth.”

Fire (Burn) Severity

- The effect of a fire on ecosystem properties, often defined by the degree of mortality of vegetation
  - Relates to soil heating, large fuel and duff consumption, consumption of the litter and organic layer beneath trees and isolated shrubs, and mortality of buried plant parts

- Degree to which a site has been altered or disrupted by fire; loosely, a product of fire intensity and residence time
Fire Intensity vs. Burn Severity

During Fire

After Fire

Soil Heating

CONVECTIVE HEAT

ORGANIC LITTER

CONDUCTIVE AND RADIANT HEAT

A HORIZON

ASH

WATER REPELLENT LAYER

Soil Burn Severity

Soil Burn Severity

• The fire-induced changes in physical, chemical, and biological soil properties that impact hydrological and biological soil functions
Soil Burn Severity vs Vegetation Burn Severity

- Surface/subsurface condition and above-ground biomass—both important factors in assessing burn severity

Soil burn severity
- The effect of a fire on physical and biological soil properties
- Includes char depth, organic matter loss, altered color and structure, and reduced infiltration

Vegetation burn severity
- The effect of a fire on vegetation
- Includes tree mortality and canopy cover loss

www.treesearch.fs.fed.us/pubs/36236
Field Perspective

- Ground-based severity assessments may include:
  - Composite Burn Index (CBI)
  - Visual observation of burned area mosaic
  - Water repellency tests
Satellite Perspective

2007 Black Pine 2 Fire, Idaho, USA
Connecting the Dots

• How do we connect pixels in a satellite image to burn severity on the ground?
Response to EM Energy

Spectral response curve of typical vegetation from 0.4 to 2.6 µm

- Relatively high green response due to chlorophyll pigmentation
- High near infrared response due to healthy plant cell structure
- Relatively low responses in the mid-infrared due to water absorption
Typical Spectral Signatures

Typical Spectral Response Curves in the 0.4 to 2.6 µm Region...

- Healthy Vegetation
- Clear Water
- Dry, Bare Soil

Reflectance

Wavelength (µm)
The goal of remote sensing is to take advantage of differences in spectral response curves to distinguish one thing from another.
Healthy Vegetation vs. Burned Areas

Exploiting Spectral Response Curves

Healthy Vegetation

Burned Areas

Reflectance

Wavelength (µm)

Landsat
Near infrared

Landsat
Shortwave infrared
Where’s the wildfire?

NBR = (NIR - SWIR) / (NIR + SWIR)

Normalized Burn Ratio (NBR)
Classified (Thematic) Burn Severity

Differenced Normalized Burn Ratio (dNBR)

dNBR = Pre-fire NBR - Post-fire NBR

Burned Area Reflectance Classification (BARC)
- Classified burn severity based on dNBR (program specific)

Black Pine 2 Fire (2007)
Sawtooth NF
73,000 acres
Satellite-Based Burn Severity Mapping Programs at RSAC

• **Burned Area Emergency Response (BAER) Imagery Support**
  – *Emergency assessment*
  – Assesses severity effects on soils
  – Supports hazard mitigation and emergency stabilization activities by USFS/DOI BAER teams

• **Rapid Assessment of Vegetation Condition after Wildfire (RAVG)**
  – *Initial assessment*
  – Assesses forest damage based on vegetation burn severity
  – Supports reforestation/restoration decision-making for USFS forest silviculturists

• **Monitoring Trends in Burn Severity (MTBS)**
  – *Extended assessment*
  – Identifies location, extent and ecological burn severity of all current/historical large fires
  – Supports monitoring of national fire policy effectiveness
Burned Area Emergency Response (BAER)

- Forest Service/DOI fast track emergency assessment
  - 100s of acres to 100,000s of acres
- Assess fire effects on soil and watershed hydrologic function (erosion and flood potential)
- Prescribe and implement emergency stabilization measures to mitigate potential hazards to:
  - Life
  - Property
  - Long-term soil productivity
  - Water quality
  - Natural resources
- BAER response plan is required within 7 days of fire containment
Remote Sensing in Support of the BAER Process

• Potential areas of impaired soil hydrologic function and other hazards are identified via change detection methods using satellite imagery
• Remote sensing products used by BAER teams to focus necessary field verification and analysis to areas of concern
  – Minimizes field time
  – Increases BAER team safety
• Facilitates rapid development of a geospatial soil burn severity product by BAER team
  – Improved product compared to previous methods
  – Used in analysis/modeling to determine necessary BAER treatments
• RSAC provides support to USFS BAER teams; EROS supports DOI BAER teams
  – Consistent products for all agencies
  – Support provided since 2001

## 2015 BAER Imagery Support Program Sensors

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Spatial Resolution</th>
<th>Temporal Resolution (days)</th>
<th>Analysis</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat 8 OLI</td>
<td>30 m</td>
<td>16</td>
<td>dNBR</td>
<td>USGS EROS</td>
</tr>
<tr>
<td>Landsat 7 ETM+</td>
<td>30 m</td>
<td>16</td>
<td>dNBR</td>
<td>USGS EROS</td>
</tr>
<tr>
<td>EO-1 ALI</td>
<td>30 m</td>
<td>16 or fewer (Targetable)</td>
<td>dNBR</td>
<td>NASA Goddard Space Flight Center/USGS EROS</td>
</tr>
<tr>
<td>DEIMOS-1 and UK DMC</td>
<td>22 m</td>
<td>10-20</td>
<td>dNDVI</td>
<td>USDA Foreign Agriculture Service - Satellite Image Archive</td>
</tr>
<tr>
<td>SPOT 5</td>
<td>10 m/20 m</td>
<td>11 or fewer (Targetable)</td>
<td>dNDVI</td>
<td>USGS EROS/Hazard Data Distribution System</td>
</tr>
</tbody>
</table>
Image (Scene) Selection Considerations

- Timing (initial vs extended assessment)
- Burn visibility (clouds, shadows, smoke, snow, terrain shadows, data gaps)
- Scene-pair matching (phenology, terrain shadows)
- Single-scene option

2007 Black Pine 2 Fire, Initial vs extended (MTBS) assessment
Common Challenges with Satellite Imagery

• Clouds!
  – and other obscuring factors

• Data gaps
  – Landsat-7 SLC-off data gaps (May 2003 to present)

• Sensor logistics
  – Data center issues, tasking priority for non-Landsat sensors

2013 Silver Fire in Landsat-7 imagery
Data Processing

Image processing method depends on which sensor is used...

\[
NBR = \frac{(NIR - SWIR)}{(NIR + SWIR)}
\]
\[
dNBR = \text{Pre-fire NBR} - \text{Post-fire NBR}
\]

\[
NDVI = \frac{(NIR - \text{RED})}{(NIR + \text{RED})}
\]
\[
dNDVI = \text{Pre-fire NDVI} - \text{Post-fire NDVI}
\]

2014 Myers Fire, Idaho, USA
Field Validation/Calibration/Correction

- **BARC**: Preliminary burn severity product
- **Soil burn severity (SBS)**: Official product based on field observations
  - Often created by calibrating BARC
  - May include corrections to defined polygons

2014 Myers Fire, Idaho, USA
Common Additional Processing Options

• Raster to vector
• KMZ or PDF
Exercise: Create a 4-class BARC

• Create NBR and dNBR from Landsat imagery
• Determine burn severity thresholds and create thematic burn severity raster
• [Optional] Convert 4-class raster to vector
• [Optional] Create KMZ
Contacts and Tech Support

For help and information regarding BAER imagery support:

<table>
<thead>
<tr>
<th>US Forest Service:</th>
<th>Department of Interior:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carl Albury</td>
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<td><a href="mailto:calbury@fs.fed.us">calbury@fs.fed.us</a></td>
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</tr>
<tr>
<td>(801) 975-3351</td>
<td>(605) 594-2745</td>
</tr>
</tbody>
</table>

To order BAER imagery, go to the BAER Imagery Support website:
http://svinetfc6.fs.fed.us/birch/

For additional information, please visit the RSAC BAER website:
http://www.fs.fed.us/eng/rsac/baer/
Post-fire Mapping Support in the USDA Forest Service

Comments or questions?

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