Pro’s and Con’s of using remote sensing in fire research

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Initial thought

- Sophisticated
- Innovative

= Information

- Accurate
- Accessible
RS is a basic tool to retrieve fire information

Fuel moisture → Soils → Elevation / DTM
Fuel Types

Density → Duration / size → Recurrence

Meteorology / climate

Socio-economic Data / Trends
RS information to answer these questions:

• How much fuel is available to burn? Is it dry enough?

• Is there an active fire? Where? When did it start? How is it growing? How much energy?

• How much area is burned? How often? When in the year? How much biomass is consumed?

• Are fire characteristics changing?
<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Multi-variable</td>
<td>• Products $\neq$ methods</td>
</tr>
<tr>
<td>• Multi-parameter.</td>
<td>• Analysis $\neq$ Data</td>
</tr>
<tr>
<td>• Multi-sensor.</td>
<td>generation</td>
</tr>
<tr>
<td>• Multi-temporal.</td>
<td>• Validation &amp;</td>
</tr>
<tr>
<td>• Multi-scale.</td>
<td>Uncertainty charact.</td>
</tr>
<tr>
<td>Pros</td>
<td>Cons</td>
</tr>
<tr>
<td>--------------------</td>
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<td>Multi-temporal.</td>
<td></td>
</tr>
<tr>
<td>Multi-scale.</td>
<td></td>
</tr>
</tbody>
</table>
Multivariable: Fire risk

Fire risk = Danger * Vulnerability

- Danger
  - Ignition
  - Cause
    - Human
    - Lightning
  - Propagation
    - Fuel moisture content
      - Live
      - Dead
    - Fuel types
    - Slope – weather conditions
  - Recovery time
  - Ecological value
  - Socio-economic value
    - Total value of environmental services
    - Actual value of environmental services
    - Houses and infrastructure

Fireglobe project
Chuvieco et al., 2014, IJWF
Fire risk = Danger * Vulnerability

- Danger
  - Ignition
  - Cause
    - Human
    - Lightning
  - Propagation
    - Fuel moisture content
      - Fuel types
    - Slope – weather conditions
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- Vulnerability
  - Ecological value
  - Socio-economic value

- Risk
  - Actual value of environmental services
  - Houses and infrastructure

Fireglobe project
Chuvieco et al., 2014, IJWF
National-scale results

Value of ecosystem services

Chuvieco et al., 2014, IJWF
Global results:
Loss of Ecological Values

Chuvieco et al., 2014, GEB
## Multi-parameter: fuels

<table>
<thead>
<tr>
<th></th>
<th>Passive optical</th>
<th>Lidar</th>
<th>Radar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horizontal continuity</strong></td>
<td>some</td>
<td>some</td>
<td>some</td>
</tr>
<tr>
<td><strong>Vertical distribution</strong></td>
<td>no</td>
<td>yes</td>
<td>some</td>
</tr>
<tr>
<td><strong>Biomass loads</strong></td>
<td>no</td>
<td>yes</td>
<td>some</td>
</tr>
<tr>
<td><strong>Surface conditions</strong></td>
<td>no</td>
<td>some</td>
<td>some</td>
</tr>
<tr>
<td><strong>Crown bulk density</strong></td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>
Multi-parameter: CBD

Riaño et al., 2004, RSE
Multispectral and LiDAR data fusion for fuel type mapping using Support Vector Machine and decision rules

Mariano García a,⁎, David Riaño b,c, Emilio Chuvieco a, Javier Salas a, F. Mark Danson d

a Department of Geography, University of Alcalá, Alcalá de Henares, 28801 Madrid, Spain
b Institute of Economics and Geography, Spanish National Research Council (CSIC), Alhucemas 26-28 28037 Madrid, Spain
c Center for Spatial Technologies and Remote Sensing (CSTARS), University of California, 250-N, The Barn, One Shields Avenue, Davis, CA 95616-8617, USA

Table 5
confusion matrix of the fuel types classification after applying decision rules.

<table>
<thead>
<tr>
<th>Classified data</th>
<th>Reference data</th>
<th>Total</th>
<th>User's accuracy (%)</th>
<th>Error of commission (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FT 0</td>
<td>FT 1</td>
<td>FT 3</td>
<td>FT 4</td>
</tr>
<tr>
<td>FT 0</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FT 1</td>
<td>1</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FT 3</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>FT 4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>FT 5</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FT 6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FT 7</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>13</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Producer's accuracy</td>
<td>76.92</td>
<td>92.31</td>
<td>90</td>
<td>90.91</td>
</tr>
<tr>
<td>Error of omission (%)</td>
<td>23.08</td>
<td>7.69</td>
<td>10</td>
<td>9.09</td>
</tr>
</tbody>
</table>
Multi-temporal: finding trends

Figure 3. Locations of fires (red symbols) flagged with an identifiable problem from the original federal fire occurrence database.

Figure 5. Annual percent number of BLM usable fire records from the coarse quality controlled U.S. federal wildland fire database for the period 1970-2000.

Figure 6. Annual percent number of BLM usable fire records from the coarse quality controlled U.S. federal wildland fire database for the period 1970-2000.
Burned area time series

Chuvieco et al., 2008, RSE
Multi-temporal medium-scale

• Rapid Eye:
  – 5 bands: 6.5 m at nadir.
  – 5 satellites: up to 1 day revisiting time.

• Sentinel 2 (MSI):
  – 13 bands (10, 20, 60 m)
  – 5 to 2 days temporal frequency.
Earth engine

Earth Engine › Landsat Annual Timelapse 1984-2012

https://earthengine.google.org
Multi-scale: fuel parameters

Ground

Airborne

Garcia et al. 2011, IJAEO

Garcia et al., 2010, RSE
Multi-scale: fuel parameters

Global Fuel Map

Pettinari et al. 2014, IJWF
Multi-scale: post-fire assessment
Multi-scale: medium-scale sensors

Validation results for the three study areas

<table>
<thead>
<tr>
<th></th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear regression</td>
<td>$y=0.963x+0.032$</td>
<td>$y=0.495x+1.443$</td>
<td>$y=1.046x-0.062$</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.43</td>
<td>0.69</td>
<td>0.96</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.19</td>
<td>0.18</td>
<td>0.21</td>
</tr>
</tbody>
</table>

De Santis and Chuvieco, 2009, RSE
Multi-scale: global scale

Averaged Burned Area (2006-2008) from Fire_CCI
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Products ≠ Methods
Examples of FMC maps

10th June

FMC % of dry weight
- < 35
- 35 - 70
- 71 - 105
- 106 - 140
- > 140

28th August

geogra.uah.es/fireglobe
Fire propagation

Chuvieco and Martin, 1994, IJRS

Veraberveke et al., 2014, IJWF
Analysis ≠ Data generation

Pereira et al., 2015, PLOS
Burned patch analysis

Mouillot et al., 2015
Fire size distribution

Hantson et al., 2015, GEB

<table>
<thead>
<tr>
<th>Variable</th>
<th>$R^2$</th>
<th>AIC</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>cropland</td>
<td>0.35*</td>
<td>1607.2</td>
<td>+</td>
</tr>
<tr>
<td>log_{10}(pop_dens)</td>
<td>0.31*</td>
<td>1723.7</td>
<td>+</td>
</tr>
<tr>
<td>precipitation</td>
<td>0.22*</td>
<td>2031.6</td>
<td>+</td>
</tr>
<tr>
<td>pasture</td>
<td>0.21*</td>
<td>2069.9</td>
<td></td>
</tr>
<tr>
<td>NPP</td>
<td>0.12*</td>
<td>2320.8</td>
<td></td>
</tr>
<tr>
<td>AET:PET</td>
<td>0.11*</td>
<td>2356.8</td>
<td>+</td>
</tr>
<tr>
<td>tree</td>
<td>0.08*</td>
<td>2443.3</td>
<td></td>
</tr>
<tr>
<td>log_{10}(net income)</td>
<td>0.06*</td>
<td>2491.8</td>
<td></td>
</tr>
</tbody>
</table>

*$P < 10^{-5}$.
Validation & Uncertainty

Saunders, 2010
Uncertainty characterization: Monthly confidence level (%)

![Map of January uncertainty characterization](image)

- The map illustrates the monthly confidence level for January.
- The color gradient represents the confidence levels, with higher confidence indicated by red.
- The map highlights areas with varying levels of confidence across different regions.

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If you need further analysis or specific data points, please let me know!
The need for product intercomparision
Seasonal trends in carbon emissions

Yue et al., 2015
Validation metrics

- **Accuracy:**
  - Interval-scale data: RMSE / $R^2$.
  - Categorical scale: confusion matrix (OA, OE, CE, DC, Kappa...).

- **Bias:**
  - Over / underestimation.

- **Stability:**
  - Non-parametric Friedman test of variance
  - Wilcoxon t trends.
Validation sample

Legend
- Study Sites
- Global Validation

130 Pairs of Landsat images for spatial validation
110 Pairs for temporal validation
Reference files

• Generated from a semiautomatic algorithm (BAMS) over a pair of Landsat images

False color composition (RGB 743)
BAMS

https://bastarrika.wordpress.com/

REMOTE SENSING
ISSN 2072-4292
www.mdpi.com/journal/remotesensing

Article

BAMS: A Tool for Supervised Burned Area Mapping Using Landsat Data

Aitor Bastarrika 1,*, Maite Alvarado 2,*, Karmele Artano 3,*, María Pilar Martínez 1,*, Amaia Mesanza 1,*, Leyre Torre 1,*, Rubén Ramo 3,*, and Emilio Chuvieco 3,*


OPEN ACCESS

remote sensing
Spatial variation of accuracy (2008)

Padilla et al., 2015, RSE
Temporal variation of accuracy (2001-2007)

Padilla et al., 2014, RS
Limitations of HS products

- MODIS HS is a great product, but it has limitations caused by fire-size, clouds,...
- How much burned area is not accounted for in current BA products?

<table>
<thead>
<tr>
<th></th>
<th># Fires</th>
<th>BA (Km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Undetected</td>
<td>Detected</td>
</tr>
<tr>
<td>&lt;50Ha</td>
<td>41.521</td>
<td>17.357</td>
</tr>
<tr>
<td>50Ha - 100Ha</td>
<td>1.622</td>
<td>1.842</td>
</tr>
<tr>
<td>100Ha - 500Ha</td>
<td>1.036</td>
<td>2.448</td>
</tr>
<tr>
<td>&gt;500Ha</td>
<td>81</td>
<td>810</td>
</tr>
<tr>
<td>Total</td>
<td>44.260</td>
<td>22.457</td>
</tr>
</tbody>
</table>

Total of 66,717 burned patches, affecting to 31,578 km²
Based on 130 Landsat images for 2008: Rodríguez & Chuvieco, 2015
RS = (Good) Information

• “Information is the resolution of uncertainty” (Claude Shannon).

• “Information is not knowledge” (Albert Einstein)
  – Good information ≠ Good knowledge
  – Bad Information = Bad knowledge.
  – Good knowledge = Good information

Thank you!  emilio.chuvieco@uah.es