Africa burned area product generation and validation with Landsat-8, Sentinel-2 and commercial Planetscope imagery

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11th Southern African Fire Network (SAFNet) Meeting, 2021
Zoom Online Meeting, 28-29 July 2021
AVHRR

1km NDVI
active fire detections

Red dots don’t provide reliable burned area

Okavango Delta, Botswana, Sept 6th 1989

Roy, Giglio, Kendal, Justice, 1999, IJRS
On the outstanding need for a long-term, multi-decadal, validated and quality assessed record of global burned area: Caution in the use of Advanced Very High Resolution Radiometer data

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MODIS

500m true color reflectance

Okavango Delta, Botswana, Sept 20th 2002
Typical MODIS
500m NIR reflectance time series

Day of burning

BRDF Effects

Persistence
NASA MODIS burned area product conceptual detection scheme (applied to each one pixel time series)

Roy, Lewis, Justice, RSE, 2002
NASA MODIS burned area product conceptual detection scheme (applied to each one pixel time series)
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Roy, Lewis, Justice, RSE, 2002
NASA MODIS burned area product conceptual detection scheme (applied to each one pixel time series)
**NASA MODIS burned area product conceptual detection scheme** (applied to each one pixel time series)

\[ Z = \frac{\hat{\rho} - \rho}{\sigma} \text{ low} \]

where \( \hat{\rho} \) is the observed \( \rho \) and \( \rho \) is the predicted \( \rho \).
NASA MODIS burned area product conceptual detection scheme (applied to each one pixel time series)

\[ Z = \frac{\hat{\rho} - \rho}{\sigma} \text{ high} \]

Roy, Lewis, Justice, RSE, 2002
Movie:

5 Months of 500m MODIS mapped burning, Okavango Delta, Botswana

Roy, Lewis, Justice, RSE, 2002
SAFNet burned area validation protocol

- Compare MODIS burned area product with independent spatially explicit burned area data derived from multitemporal Landsat ETM+ data

- SAFNet field trip held to develop the mapping protocol and to discuss southern African fire information needs, Zimbabwe-Zambia, July 2000

- SAFNet members map the areas burned between 2+ Landsat acquisitions, augmented by limited fieldwork

- Consensus mapping protocol to ensure regionally consistent independent validation data

- protocol followed 2000-2002 at ~11 ETM+ scenes/year

NASA MODIS Collection 6 500 m Burned Area Product Global Validation following CEOS protocol: comparison with burned area maps interpreted from Landsat-8 two date image pairs

Locations of 558 Landsat-8 two date image pairs 16 days apart interpreted into burned, unburned, and unmapped classes

Omission Error (0-1) = 0.72
Commission Error (0-1) = 0.40

Boschetti, Roy, Giglio, et al. RSE, 2019
Giglio, Boschetti, Roy, et al. RSE, 2018
New Global moderate resolution era

Landsat 8, 9, 10

ESA Sentinel 2A & 2B

Land Imaging Technology and System Innovation

2015 - 2020 - 2025 - 2030
Li, J and Roy, D.P. 2017
Landsat Sentinel-2 30 m
burned area conceptual detection scheme
(applied to each one pixel time series)
To first order the change in reflectance due to burning is dependent on the fraction of area burned $f$ and combustion completeness $cc$. 
Synthetic training data
spectral library
f. cc model

Landsat-8 & Sentinel-2
Spectral Response Functions

Random Forest Classification
to 30m f x cc

30m f x cc
Landsat 8

Kafue National park, Zambia

Day 155 2016

2000 x 2000 30m pixels

false color surface NBAR
Sentinel 2A

Kafue National park, Zambia

Day 164 2016

2000 x 2000 30m pixels

false color surface NBAR
Synthetic training data
spectral library
\( f \times cc \) model

\( f \times cc, \rho_{\text{pre-fire}}, \rho_{\text{post-fire}} \)

Landsat-8 & Sentinel-2
Spectral Response Functions

\( f \times cc, \rho_{\text{sensor band}, \text{pre-fire}}, \rho_{\text{sensor band, post-fire}} \)

Random Forest Classification
to 30m \( f \times cc \)

L-8 30m tiles
S-2 30m tiles

Roy, Huang, Boschetti, Giglio, Yan, Zhang, Li, 2019, Landsat-8 and Sentinel-2 burned area mapping - a combined sensor multi-temporal change detection approach, RSE, 231, 111254.

Current algorithm requires only 3 parameters
MODIS tile h20v10

7 x 7 WELD tiles
Number of cloud-free observations
July 2016
Landsat 8
Sentinel-2A

1
2
3
4
median 5
6
≥7

1112 x 1112 km
MODIS tile h20v10
Day of burning
Sentinel-2A
Landsat-8
July 2016

1112 x 1112 km
MODIS tile h20v10
Day of burning
Sentinel-2A
Landsat-8
July 2016

Angola,
Lunda Sul
Province

159 x 159 km
Day of burning
MODIS
500m MCD64
July 2016

Angola,
Lunda Sul
Province

159 x 159 km
Day of burning
Sentinel-2A
Landsat-8
August 2016

Angola,
Lunda Sul
Province

159 x 159 km
<table>
<thead>
<tr>
<th>Date</th>
<th>Color Code</th>
</tr>
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<tbody>
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<td>0-2</td>
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<td>24-27</td>
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<tr>
<td>28-31</td>
<td></td>
</tr>
</tbody>
</table>

Angola, Lunda Sul Province

159 x 159 km
Day of burning
Sentinel-2A
Landsat-8
Sept. 2016

Angola, Lunda Sul Province
159 x 159 km
Day of burning
MODIS
500m MCD64 C6
Sept. 2016

Angola, Lunda Sul Province
159 x 159 km
Sentinel-2 & Landsat-8 30m burned area July 2019
Sentinel-2 & Landsat-8 30 m

Jan 2019
Sentinel-2 & Landsat-8 30 m

Mar 2019
Sentinel-2 & Landsat-8 30 m

Apr 2019
Oct 2019

Sentinel-2 & Landsat-8 30 m
Ground assessment
Kruger National Park, South Africa, October 2018
Drone assessment
Kruger National Park, South Africa, October 2018
Isalo National Park
Madagascar

630 nm
820 nm
545 nm

Surface reflectance

15.4 × 10.7 km
5134 × 3568 3 m pixels

Dove-R
July 16th 2019
Dove-R

July 25th 2019

630 nm
820 nm
545 nm

surface reflectance

Near Johannesburg,
South Africa

6.4 x 6.0 km
2123 x 1997 3 m pixels
Near Johannesburg, South Africa

6.4 × 6.0 km
2123 × 1997 3 m pixels

Dove-R

July 30th 2019

630 nm
820 nm
545 nm

surface reflectance
PlanetScope temporal characteristics quantified: 12 months, globally 175.8 million images were acquired by 100-133 unique sensors on orbit per month

30.3 hour global median average revisit interval

72% of land acquired with <36 hour average revisit interval

The high temporal global coverage provided by the PlanetScope constellation will benefit new applications in particular those concerned with assessment of rapidly changing phenomena, and phenomena that cannot be resolved at moderate or coarse resolution
Planet
July 3rd

630nm
820 nm
545 nm

Preliminary Example validation

Zambia
Western Province

110 x 110 km
36600 x 36600 3m pixels
Planet
July 31st

630 nm
820 nm
545 nm

Preliminary Example validation

Zambia
Western Province

110 x 110 km
36600 x 36600 3m pixels
Day of burning
July
Sentinel-2A/2B
Landsat-8

Preliminary Example validation

0-2
3-5
6-8
9-11
12-14
15-17
18-20
21-23
24-27
28-31

Harmonized Landsat Sentinel-2
110 x 110 km
3660 x 3660 30m pixels
Draft comparison of July burned proportions mapped by 3 m PLANET reference and 30 m Landsat-8 & Sentinel-2

Preliminary example validation results

<table>
<thead>
<tr>
<th></th>
<th>PLANET reference (assumed to be truth)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Burned [km²]</td>
</tr>
<tr>
<td><strong>Burned [km²]</strong></td>
<td>83.7</td>
</tr>
<tr>
<td><strong>Unburned [km²]</strong></td>
<td>173.6</td>
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<tr>
<td><strong>Column total [km²]</strong></td>
<td>257.0</td>
</tr>
</tbody>
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Overall accuracy = 97%  Omission error [0-1] = 0.40  Commission error [0-1] = 0.67
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Boschetti, Roy, Giglio, et al. *RSE*, 2019
Giglio, Boschetti, Roy, et al. *RSE*, 2018
PlanetScope Burned Area Mapping!

- Deep learning model trained on 92 Landsat-8 two-date image pairs and corresponding 30 m burned area interpretations (derived previously for the NASA MODIS burned area product validation)

- Model applied to classify 607 PlanetScope 3 m pairs at 91 locations across Africa
Illustration of 256 × 256 30 m pixel patches derived from a two-date Landsat image pair containing a burn

Non-spatially overlapping patches used for training (red) and validation (grey)
Deep Learning classification of Planetscope two-date 3 m burned area based on Landsat training

After relative normalization of Planetscope data

White = burned

- Deep learning model trained on 92 Landsat-8 OLI 2-date image pairs and corresponding 30 m burned area interpretations (derived for the NASA MODIS burned area product validation)
- Deep learning model applied to 607 two-date Planetscope image pairs acquired across Africa
- <10% commission and omission burned/unburned classification error !?
Summary

Good news

• AVHRR -> MODIS -> Landsat/Sentinel-2 -> PlanetScope
• New medium resolution burned area product developed to take advantage of freely available Sentinel-2 and Landsat-8 NASA HLS, to provide improved mapping of
  - small and spatially fragmented burns
  - low combustion completeness burns
  - ephemeral burns
• NASA HLS V1.5 is great, a mature multi-sensor ARD

Ongoing research

• PLANET multi-date images used to validate 30m Sentinel-2 Landsat-8 30 m burned area product
• Developed an automated deep learning PLANET time series burned area mapping algorithm
  • use results to validate the Sentinel-2 Landsat-8 30m burned area product for all of Africa