INTERNATIONAL ONLINE CONFERENCE
Forest ecosystems in the conditions of climate change:
biological productivity and remote sensing
28-29 September 2021

Accuracy estimation of two global burned area products at national scale

Thomas Katagis, Ioannis Z. Gitas

Laboratory of Forest Management and Remote Sensing,
Aristotle University of Thessaloniki, Greece
http://fmrs.web.auth.gr/
e-mail: thkatag@for.auth.gr
Forest Fires

- Ecosystem disturbance
- Impact
  - Ecological
  - Economical
  - Social
- Climate change
  - Frequency
  - Severity

Evia, Greece 2021: AFP/Getty Images
Amazon forest (source: Victor Moriyama)
Siberian forest (source: Moscow Times)
Burned Area Information

Information on **Burned Areas (BA)** is important for:

- Supporting fire risk assessment and fire regime studies.
- Modeling fire impacts on human health.
- Estimating burned biomass and GHG emissions.
- Providing input for dynamic global vegetation models (DGVMs).
- Understanding the interactions between climate and fire activity, worldwide.
- Generating products that meet the GCOS Essential Climate Variable (ECV) requirements.
Global Burned Area Products

- Global fire datasets are mainly derived by low-coarse resolution Earth Observation (EO) satellite sensors.
- These sensors provide systematic spatio-temporal assessments on fire activity and generate consistent time-series of BA estimates.

https://geogra.uah.es/fire_cci/firecci51.php
### Global Burned Area Products

Indicative list of current global BA products from satellite remote sensing systems

| Product     | Period   | Release   | Sensor/Method                  | Resolution spatial | Resolution temporal | File format | Data Layer | Reference                                      | Data access                                      |
|-------------|----------|-----------|--------------------------------|--------------------|---------------------|-------------|------------|------------------------------------------------|-------------------------------------------------|
| C3SBA10     | 01/2017  | TBA; early 2020 | OLCI SRC & MODIS CS HS | p: 300m g: 0.25° | p: 1-2d g: m | NetCDF | p: DOB, CL, LC g: BA, UNC, FBNUR, FOA, LC | Lazoudis-Louda et al., (2020, in review)     | TBA                                             |
| VNP964C1    | 10/2019  | as sample | VIIRS C1 SRC & VIIRS C1 HS | p: 500m            | p: d               | HDF4 | p: DOB, DOBUNC, QA, DOB (F&L) | https://e4ftl01.ciesas.usgs.gov/VIIRS/VNP964A1.001 |                                                |
| FireCCIL1001 | 02/2017  | (beta)    | AVHRR2-3, BA scaled w/MCD64C6 | g: 0.25°          | g: m               | NetCDF | g: BA, UNC, FBNUR, FOA, LC | Otten & Passerini (2019) | https://catalogue.ceda.ac.uk/uuid/4f377a544355456d7e7dec0e53352 & https://edc.climatescience.nsc.edu.au/edc-scddatset/satellite-fire-burned-area |                                                |
| GlobFire    | 11/2018  |           | data mining on MCD64C6 pixel | p: 21 ha           | p: cut 5d          | SQL, SHP | p: NORPH, DOB | Artés et al., (2020) | https://doi.org/10.1394/PANGAEA.AEA.893333 |                                                |
| FireCCi51   | 11/2018  |           | MODIS C0 SRC & MODIS C0 HS | p: 250m g: 0.25° | p: d g: m          | NetCDF | p: GeoTiff & NetCDF4, 6 continental tiles | Lazoudis-Louda et al., (2020) | https://doi.org/10.1394/PANGAEA.AEA.893333 |                                                |
| FRY         | 09/2018  |           | flood-fill on (a) MCD64C6 pixel | p: 5pixels g: 1°   | p: cut 3, 5, 9 & 14d time-average | CSV, NetCDF | p: SHP, GeoTiff | Laurent et al., (2018, 2019) | https://doi.org/10.13144/0e999f1c-7e20-4ac-8853-7692603020 |                                                |
| GFA         | 08/2018  |           | ignition point plus growth dynamics on MCD64C6 pixel | p: 21ha g: 500m p: b g: 0.25° | p: avg | NetCDF | p: IGNS, PER, DOB, MORPH, DYN | Andela et al., (2019) | https://doi.org/10.3334/ORNLDAAC/1042 & DAAC |                                                |
| MCD64CMQ    | 11/2020  | 10/2018   | see MCD64C6 | g: 0.25° g: m | HDF4 | BA, FOA, QA, LC | Gaglio et al., (2018a) | ftp://fire-burnt@fuwo.geog.mund.edu/ MCD64CMQ-C6 |                                                |
| GABAM       | 02/2018  |           | Landsat8 SRC | p: 35m p: y | GeoTiff-10°tiles GEO-WGS84 | BA | BA | Long et al., (2019) | https://vsdi.gislab.in/post/gabam2015/ |                                                |
| MCD64C5     | 11/2020  | Nov now (lag ~6m) | MODIS C0 SRC & MODIS C0 HS | p: 500m | p: d | HDF4-10°tiles GeoTiff & SHP-24 tiles | DOB, DOBUNC, QA, DOB (F&L) | Gaglio et al., (2018a) | ftp://user.burnt_data@ba1.geog.mund.edu/collectors6/ |                                                |
| GIO-Gl v1 500m | 04/2016  | Nov now (lag ~3d) | PROBA-V SRC | p: 300m | p: d | NetCDF & GeoTiff | DOB, NOO, SEAS | Tamney et al., (2009) | https://land.copernicus.eu/global/products/ba (registration required) |                                                |

Heil A. (2019) ESA CCI ECV Fire Disturbance: D1.1 User requirements document, version 7.0. Available from: https://www.esa-fire-cci.org/documents
Challenges in global BA assessments

- Robust validation of satellite derived products remains an ongoing effort.
- Low availability of high-quality reference data is a critical issue.
- Differences among the various BA products in terms of spatial BA estimates, and especially at smaller scales.
- Significant errors of omission and commission due to products’ low resolution and due to the variety of ecosystems and vegetation types worldwide.

Although a Stage 3 validation has been achieved for MODIS BA products, there is still ‘space’ for further research on their reliability.
Aim and objectives

To assess the accuracy of two publicly available MODIS BA products, MCD64A1 C6 and MODIS FireCCI51, at national scale in a Mediterranean region.

Specific objectives:

- To generate a forest fire database based on the pixel-level information contained in the satellite BA products
- To compare the BA product database with a high resolution reference dataset and estimate its accuracy in fire detection
- To compare the BA product database with a high resolution reference dataset and estimate its spatial performance in terms of area burned (ha)
Study area: Greece

- **Total area**: 131,960 km²
- **Study period**: Fire seasons 2016 and 2017

[Reference data (S2)]

[EFFIS - Annual Country Statistics for Greece](https://effis.jrc.ec.europa.eu/apps/effis.statistics.portal/effis-estimates/EU/EL)
Datasets (I)

1. MODIS Burned Area MCD64A1 C6
   
   ![MODIS Burned Area MCD64A1 C6](https://lpdaac.usgs.gov/products/mcd64a1v006/)
   
   **https://lpdaac.usgs.gov/products/mcd64a1v006/**

2. MODIS FireCCI51
   
   ![MODIS FireCCI51](https://climate.esa.int/en/projects/fire/data/)
   
   **https://climate.esa.int/en/projects/fire/data/**

|                      | MCD64A1 C6                                                                 | FireCCI51                                                                 |
|----------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------|
| **Spectral information** | RED (2), SWIR (5,7), daily 500m                                        | RED (1) NIR (2), daily 250 m                                              |
| **Sensor**           | Terra+Aqua MODIS                                                          | Terra MODIS                                                               |
| **Active fire info**  | MCD14ML (1 km)                                                           | MCD14ML (1 km)                                                           |
| **Spatial resolution**| 500 m                                                                    | 250 m                                                                    |
| **Time step**        | monthly                                                                   | monthly                                                                   |
| **Coverage period**   | 2001-present                                                              | 2001-2019                                                                |
| **Temporal window of detection** | 10 days                                                                  | 8 days                                                                   |
| **Algorithm**        | Multi-temporal burn sensitive Vegetation Index (VI) dynamic thresholding | Temporal compositing of GEMI index and two-phase region growing algorithm |
| **Layers**           | burn date, burn date uncertainty, QA, first & last day of detection       | date of burn (JD), confidence level (CL), land cover (LC)                  |
3. Sentinel-2 Burned area reference dataset (2016-17)

- Reference BA dataset was initially based on the maps generated by the Object-based Burned Area Mapping (OBAM) service of the Greek National Observatory of Forest Fires (NOFFi) (http://epadap.web.auth.gr).
- Additional automated mapping of Sentinel-2 imagery was performed to generate a complete dataset.
Methods – Workflow

Pre-processing

- Download monthly BA products (GeoTiff files)
- Clip to country extent (May-October)
- Reprojection to local UTM zone
- Mask non valid pixels (QA) and agricultural areas
- Aggregation of burned pixels to fire patches

Accuracy analysis

- Create error matrices (BA product vs. reference map vectors)
- Generate S2 reference burned area maps
- Compute accuracy metrics ($Oe$, $Ce$, etc.)
- Assess fire detection accuracy
- Assess spatial accuracy of burned area
Methods – Accuracy metrics

- Two types of error matrices were generated, one including number of fires and the other the area burned (ha).
- Errors of omission ($Oe$) and commission ($Ce$) were calculated from the standard error matrix, as well as the Dice Coefficient ($DC$).

\[
Oe = 1 - \frac{B_t}{B_{S2}}, \quad Ce = 1 - \frac{B_t}{B_{MODIS}}, \quad DC = \frac{2B_t}{B_{S2} + B_{MODIS}}
\]

where $B_t =$ the number of fires correctly detected,
$B_{S2} =$ Sentinel-2 reference fires.
$B_{MODIS} =$ all the fires detected by the MODIS products

- Additional spatial comparison was performed by means of regression between the proportion of burned area reported by the product and the proportion reported by the reference maps, within a 5x5 km grid cell.
Individual pixels labeled as burned by the BA products were grouped based on spatial and temporal adjacency (maximum sequential burn period 16 days) to create single fire patches.

- Very small fires < 10 ha were sieved.
- Vector maps of burned areas were created for Greece for 2016 and 2017, as derived by the MCD64A1 and FireCCI51 products.
Results: *Accuracy assessment*

### I. Assessment of fire detection capability

|       | Fires > 10 ha |       | Fires > 100ha |
|-------|--------------|-------|--------------|
|       | $B_t$  | $B_f$ | $NB_f$ | $Oe$ | $Ce$ | $DC$ | $S2$ fires | $B_t$  | $NB_f$ | $Oe$ | $S2$ fires |
| 2016  |       |       |       |       |       |       |       |       |       |       |       |
| MCD64A1 | 24    | 6     | 24    | 0.50  | 0.20  | 0.62  | 48     | 23    | 4     | 0.15 | 27     |
| CCI51 | 41    | 24    | 7     | 0.15  | 0.37  | 0.73  |         | 32    | 3     | 0.09 | 35     |
| 2017  |       |       |       |       |       |       |       |       |       |       |       |
| MCD64A1 | 40    | 7     | 42    | 0.51  | 0.15  | 0.62  | 82     | 23    | 4     | 0.15 | 27     |
| CCI51 | 44    | 25    | 38    | 0.46  | 0.36  | 0.58  |         | 32    | 3     | 0.09 | 35     |

$B_t$: true detections of fires; $B_f$: number of fires erroneously detected; $NB_f$: number of fires omitted

### II. Assessment of burned area (ha)

|       | Fires > 10 ha |       | Fires > 100ha |
|-------|--------------|-------|--------------|
|       | $B_t$  | $B_{MODIS}$ | $B_{S2}$ | $Oe$ | $Ce$ | $DC$ |       | $B_t$  | $B_{MODIS}$ | $B_{S2}$ | $Oe$ |
| 2016  |       |       |       |       |       |       |       |       |       |       |       |
| MCD64A1 | 19398 | 23576 | 27703 | 0.30  | 0.18  | 0.76  | 19374 | 23327 | 26588 | 0.27 |
| CCI51 | 20807 | 29180 |         | 0.25  | 0.29  | 0.73  | 20227 | 28167 |       | 0.24 |
| 2017  |       |       |       |       |       |       |       |       |       |       |       |
| MCD64A1 | 15624 | 21683 | 21230 | 0.26  | 0.28  | 0.73  | 15337 | 20625 | 19140 | 0.20 |
| CCI51 | 14560 | 22193 |         | 0.31  | 0.34  | 0.67  | 14006 | 20955 |       | 0.27 |

$B_t$: common area; $B_{MODIS}$: area mapped by MODIS products; $B_{S2}$: area mapped by Sentinel-2
Results: *Regression metrics*

Results of the regression conducted between the proportions of burned area of each product and the Sentinel-2 reference map within 5 x 5 km grid cells.

|          | 2016 | 2017 |
|----------|------|------|
|          | \(R^2\) | Slope  | Intercept | \(R^2\) | Slope  | Intercept |
| MCD64A1  | 0.952 | 0.983  | -0.012    | 0.945  | 1.171  | -0.009    |
| FireCCI51| 0.894 | 0.975  | 0.006     | 0.793  | 1.016  | 0.002     |
BA product performance

- MCD64A1 C6 provided more consistent results in fire detection and burned area estimates, despite its lower resolution (500m). NIR/SWIR information presumably increases its performance.

- Their **spatial performance** also indicated good agreement with the reference data.

- MCD64A1 C6 and FireCCI51 exhibited satisfactory results in **detection** of larger fires (> 100 ha) occurring in forest and semi-natural areas.

- The 250 m FireCCI51 product exhibited relatively **higher sensitivity in detection of smaller** (<100 ha) fires.

- A significant level of **variability** between these products exists due to their different mapping methods.
Conclusions

- This research provides a **preliminary assessment** of the reliability and limitations of global BA products for the country of Greece.

- Not many similar studies have been conducted at country level in the Mediterranean region that include comparison vs. higher resolution data.

- The results have **implications for the usefulness** of global BA products in climate and vegetation disturbance studies conducted by the scientific community and potential end users.

- Further work is needed for a more rigorous assessment at country level by including additional fire seasons for comparison.
Acknowledgements
This work is part of a post-doctoral research co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme «Human Resources Development, Education and Lifelong Learning» in the context of the project “Reinforcement of Postdoctoral Researchers - 2nd Cycle” (MIS-5033021), implemented by the State Scholarships Foundation (IKY).