ESA Climate Change Initiative – Fire_cci
D4.2.7 Product User Guide – Long-term Small Fire Dataset (PUG-SFDL)

Project Name	ECV Fire Disturbance: FireCCI
Contract Nº	4000126706/19/I-NB
Issue Date	08/10/2024
Version	1.0
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Document Ref.	Fire_cci_D4.2.7_PUG-SFDL_v1.0
Document type	Public

To be cited as: A. Khairoun, M. L. Pettinari (2024) ESA CCI ECV Fire Disturbance: D4.2.7. Product User Guide – Long-term Small Fire Datasey, version 1.0. Available at: https://climate.esa.int/en/projects/fire/key-documents/

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Summary

This document is the version 1.0 of the Product User Guide for the Long-term Small Fire Dataset of the FireCCI project version 1.0 (FireCCISFDL10). It provides practical information about the use of this product, available for three pilot sites in Amazonia, eastern Sahel and western Siberia for the period 1990-2019. This product is based on the Landsat sensors (Landsat-4, 5, 7, and 8).

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Accepted	ESA - Technical Officer	Clément Albergel	11/10/2024

This document is not signed. It is provided as an electronic copy.

Document Status Sheet

Issue	Date	Details
1.0	08/10/2024	First Issue of the document.

Document Change Record

Issue	Date	Request	Location	Details

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1. General overview

This document contains practical information on how to use the FireCCI Long-term Small Fire Dataset (SFDL) product version 1.0 of the FireCCI project, which is based on the Landsat long-term archive. This document applies to the SFDL FireCCI v1.0 (FireCCISFDL10) corresponding to the period 1990-2019.

1.1. Introduction

The SFDL products comprise maps of burned area over three large-scale regions, covering Amazonia (24°S - 12°S; 47°W - 62°W), eastern Sahel (4°N - 16°N; 27°E - 43.5°E) and western Siberia (60°N - 74°N; 65°E - 87°E) (Figure 1). They were developed and tailored for their use by climate, vegetation and atmospheric modellers, as well as by fire researchers or fire managers interested in spatially detailed burned patterns.

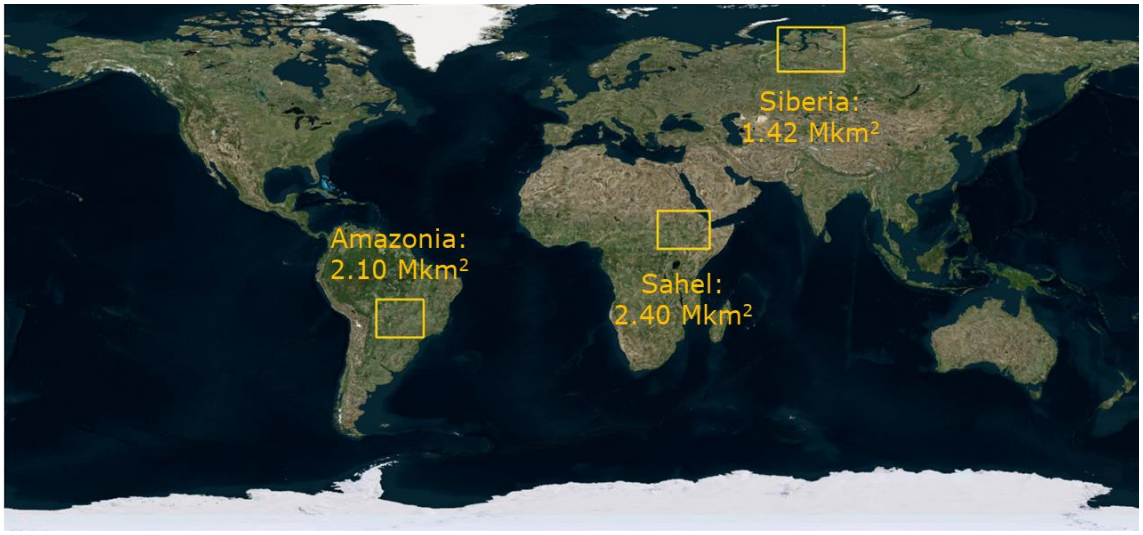


Figure 1: Location of the three areas covered by the FireCCISFDL10.

For these specific datasets, the FireCCI project produces burned area (BA) PIXEL product and its ancillary layers at 0.00025° (~ 30 m at the equator) (see Pettinari 2022).

1.2. Input data

The FireCCISFDL10 product uses the entire archive of acquisitions of Landsat data available on the Google Earth Engine platform (Gorelick et al., 2017) over the corresponding study areas. Imagery sources include Landsat-4 and Landsat-5 TM, Landsat-7 ETM+ and Landsat-8 OLI. Images were acquired every 16 days by each satellite, with a combined revisit frequency of approximately 8 days when two satellites were operational. The algorithm uses as input the Red, NIR, Short SWIR and Long SWIR bands at their original 30 m resolution to generate the BA product and the time series covers the period from January 1990 to December 2019. The processing tiles are described in detail in Subsection 2.4 and Annex 1.

The active fire information used to enhance the dating of the Siberian dataset was obtained from Collection 2 of the VNP14IMGML product (https://lpdaac.usgs.gov/documents/427/VNP14_User_Guide_V1.pdf) derived from the Suomi National Polar-orbiting Partnership Visible Infrared Imaging Radiometer Suite sensor (SNPP/VIIRS) at 375 m spatial resolution for the period 2012 onwards, whereas the period 2001-2011 was

enhanced using the Collection 6.1 of MCD14ML hotspots (https://www.earthdata.nasa.gov/s3fs-public/imported/MODIS_C6_Fire_User_Guide_B.pdf) derived from MODIS at 1 km spatial resolution (from Aqua and Terra satellites). Both datasets are downloaded from the NASA FIRMS platform (https://firms.modaps.eosdis.nasa.gov/download, last accessed in June 2024).

1.3. BA algorithm

The BA algorithm used for producing the FireCCISFDL10 BA product is described in the Algorithm Theoretical Basis Document (Khairoun and Solano, 2024).

2. Pixel BA product

The FireCCISFDL10 product is a GeoTIFF file with three layers indicating the date of detection (Figure 2), the confidence level and the land cover in the pixel detected as burned (see Section 0 for further detail).

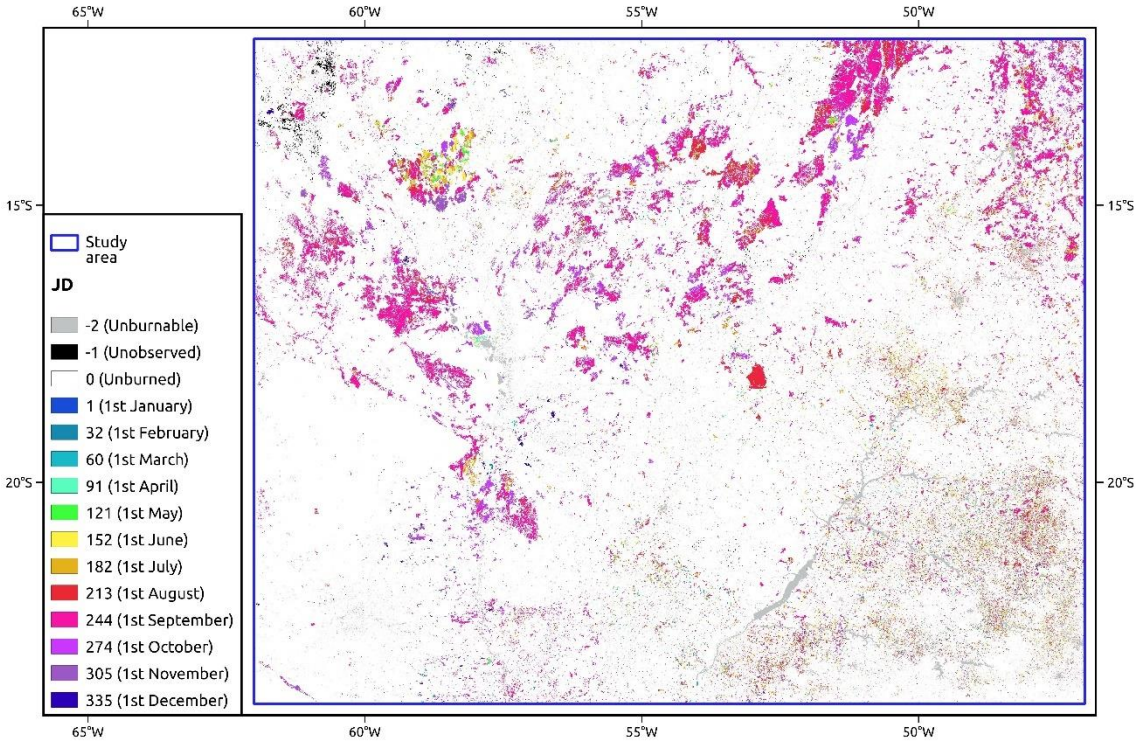


Figure 2: Day of the first burn detection day for all Amazonian region subsets in 2010.

2.1. Temporal compositing

The FireCCISFDL10 products are released as monthly composites so they can encompass those pixels that burn more than once during a calendar year. This may occur frequently in the Sahelian region where the dry season (and hence the burn season) and the fire period commonly occur between December and February; however, fires might ignite before or later than this period. In Amazonia, fire season generally extends from June to September, yet agricultural fires might also be observed throughout all the months of the year.

2.2. Spatial Resolution

The Spatial resolution of this BA product is 0.00025 degrees (approximately 30 m at the Equator) after the resampling of the original Landsat pixels (almost the same resolution) using the nearest neighbour method.

2.3. Product projection system

The Coordinate Reference System (CRS) used for the global BA products is a geographic coordinate system (GCS) based on the World Geodetic System 84 (WGS84) reference ellipsoid and using a Plate Carrée projection with geographical coordinates of equal pixel size. The coordinates are specified in decimal degrees. Information on product projection, ellipsoid and pixel size is included in the GeoTIFF file header, so every pixel in the file can be geographically referenced without the need of adding specific pixel indicators of geographical position.

2.4. Subsets

Depending on the latitude, the BA product is distributed in 2x2, 3x2 or 6x2 degree non-overlapping tiles. The Sahelian and the Amazonian regions' products are distributed using 2x2° tiles (both are below 50° latitude) while the Siberian dataset is distributed based on 3x2° tiles below 70°N latitude and using 6x2° tiles northwards (see Annex 1).

2.5. Product file naming conventions

The files for each sensor and month are named as follows:

<Indicative_Date>-ESACCI-L3S_FIRE-BA-<Indicative_Sensor> -<Additional_ Segregator>-fv<File_Version>-<Layer>.tif

<Indicative_Date>

The identifying date for this data set:

Format is YYYYMMDD, where YYYY is the four-digit year; MM is the two-digit month from 01 to 12 and DD is the two-digit day of the month from 01 to 31. For monthly products DD=01.

< **Indicative Sensor**>
For version 1.0 of the product, the sensor is LANDSAT.

<Additional_Segregator>

This is AREA_<ZONE>_<TILE_NUMBER> being the tile number of the subset index described in subsection 2.4.

ZONE is "AMAZONIA" for Amazonia, "SAHEL" for eastern Sahel and "SIBERIA" for western Siberia.

<**File_Version**>

File version number in the form n{1,}[.n{1,}] (That is 1 or more digits followed by optional . and another 1 or more digits). The most recent version is fv1.0.

<Layer>

As each layer is provided as an individual GeoTIFF file, the code of each layer is:

- JD: layer 1, corresponding to the Julian day, or day of the year of detection of the BA.
- CL: layer 2, corresponding to the confidence level
- LC: layer 3, corresponding to the land cover

Example:

20190701-ESACCI-L3S_FIRE-BA-LANDSAT-AREA_AMAZONIA_12S048W-fv1.0-JD.tif

2.6. Product attributes

The following subsections describe each of the layers of the product, including the name of the attributes in the GeoTIFF file, the units of the attributes and the data type, and some information useful for the correct use of the product. They also include examples of the pixel product layers.

2.6.1. Layer 1: Date of the first detection

Layer	Attribute	Units	Data Type	Notes
1 (JD)	Date of the first detection	Day of the year, from 1 to 366	Integer	Possible values: • 0 (zero): when the pixel is not burned. • 1 to 366: day of the first detection when the pixel is burned. • -1: when the pixel is not observed in the month. • -2: used for pixels that are not burnable: water bodies, bare areas, urban areas, permanent snow and ice.

When the pixel is characterized as burned, it is assumed that the complete pixel was burned, as for most BA products.

The date of detection of the burned pixel (usually also called the day of the year or Julian day) may not be coincident with the actual burning date, and it could correspond to several days afterwards, depending on image availability and cloud coverage. For areas with low cloud coverage, the detected date of burn should be very close to the actual date of burn, while in areas with high cloud coverage the date might be up to weeks after the fire is over.

The algorithm ignores the months of December, January and February in the case of Siberia as it is very unlikely to find fires or cloud-free images during that period. Therefore, for convenience, the JD layer was assigned to -1 in Siberia for these unprocessed months.

An example of this layer corresponding to December 2016 for Area 08N032E, located in eastern Sahel, is shown in Figure 3.

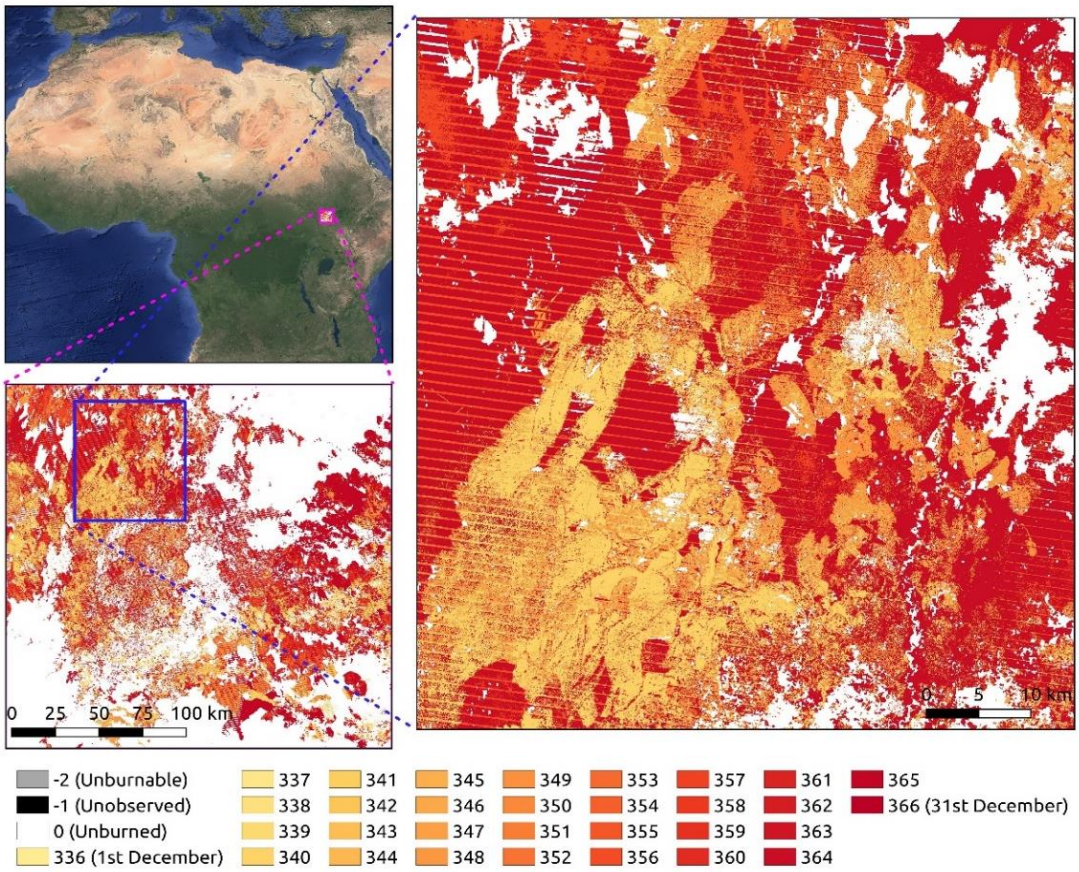


Figure 3: Example of the date of the first detection layer for the Sahelian tile 08N032E in December 2016. The figure shows the extent of the whole Area in the left panels, and a zoomed region in the right panel.

2.6.2. Layer 2: Confidence level

Layer	Attribute	Units	Data Type	Notes
2 (CL)	Confidence level	0 to 100	Integer	Probability of detecting a pixel as burned. Possible values: - 0 (zero): when the pixel is not observed in the month, or it is not burnable. - 1 to 100: Probability values. The closer to 100, the higher the confidence that the pixel has actually burned.

The confidence level was derived from the Random Forest classification probabilities. Since the classification was based on temporal composites of 3 to 9 months depending on the region and the year (Annex 2), the confidence layer of the entire compsiting period was used for all months within that perid (i.e. the CL layer is repeated in all the files corresponding to the months within a compositing period). The confidence level of Siberia in the months of December, January and February was assigned to 0 since these months were not processed. An example of this layer corresponding to December 2016 for Area 08N032E, located in eastern Sahel, is shown in Figure 4.

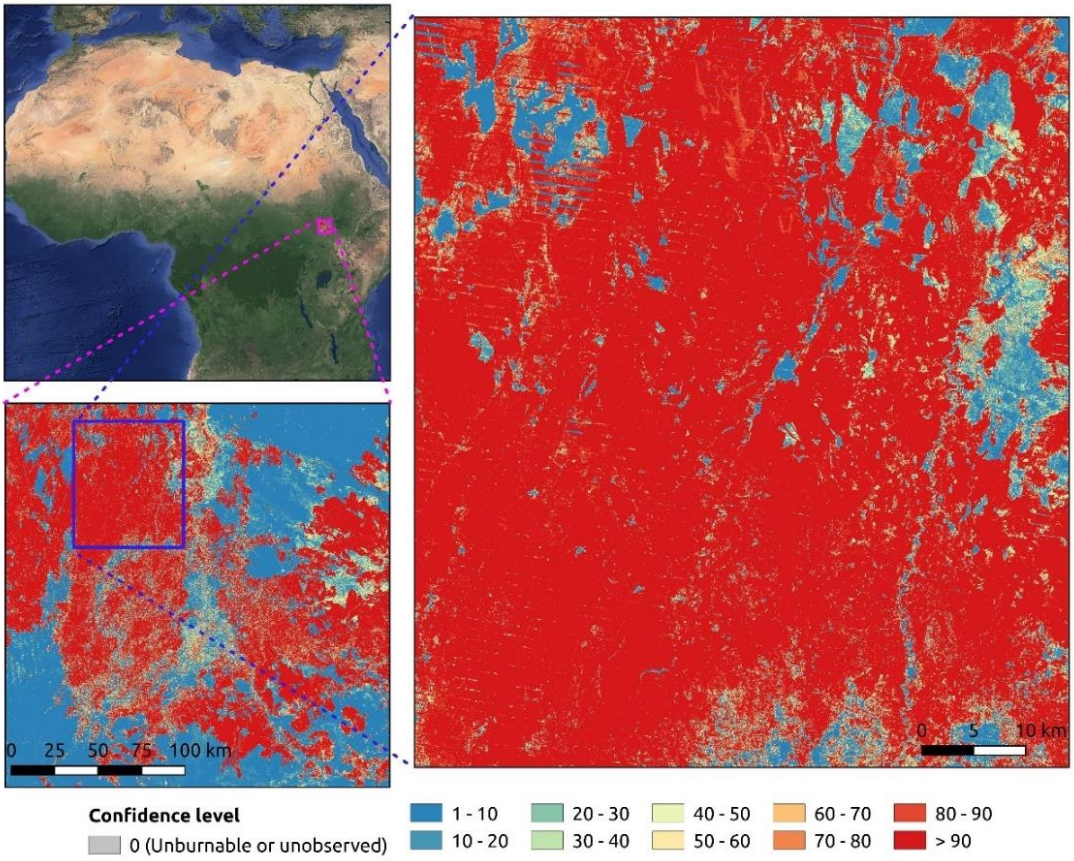


Figure 4: Example of the confidence level layer for the Sahelian tile 08N032E in December 2016. The figure shows the extent of the whole Area in the left panels, and a zoomed region in the right panel.

2.6.3. Layer 3: Land cover of burned pixels

Layer	Attribute	Units	Data Type	Notes
3 (LC)	Land cover of burned pixels	0 to 110	Byte	Land cover of the pixel detected as burned, extracted from the ESA HRLC map. Possible values: - 0 (zero): when the pixel is not observed in the month, it is observed and classified as not burned or it is not burnable (i.e. values of layer 1 between -2 and 0). This value is also used when the land cover classification of a burned pixel is missing. - 10-110: number of the land cover class in the reference map.

The land cover assigned to the pixel detected as burned was extracted from the ESA CCI HRLC 30 m dynamic maps (available at https://climate.esa.int/en/projects/high-resolution-land-cover/). Those maps are updated every 5 years for the period 1990-2015 (plus 2019). Except for the year 1990, in which the same year was used to classify burned pixels, the most recent anterior year was used (e.g., in the case of burned pixels of 2018 the HRLC map of 2015 was used to filter non-burnable areas and classify burned pixel cover). Unburned pixels are assigned the value 0. The land cover categories included in the BA product are listed in Table 1. Further information regarding the land cover map is available in ESA (2024).

Table 1: Land cover categories in Layer 3

Value	LC type description
0	Unburned, unobserved or unburnable
10	Tree cover evergreen broadleaf
20	Tree cover evergreen needleleaf
30	Tree cover deciduous broadleaf
40	Tree cover deciduous needleleaf
50	Shrub cover evergreen
60	Shrub cover deciduous
70	Grasslands
80	Croplands
90	Woody vegetation aquatic or regularly flooded
100	Grassland vegetation aquatic or regularly flooded
110	Lichens and mosses

Both the land cover information and the BA inputs are at a similar spatial resolution, which guarantees consistent identification of the burned area land cover type, and is considered crucial for the modellers community. However, we should note that pixels that are considered as unburnable (e.g., classified as barelands in the ESA HRLC map), are ignored from BA mapping (assigned to -2 in layer 1) even if the burn signal was strong. Therefore, errors included in the land cover map may also affect the information contained in the BA product, and hence the calculation of emissions using land-cover-based emissions factors would be affected.

An example of this layer corresponding to December 2016 for Area 08N032E, located in eastern Sahel, is shown in Figure 5.

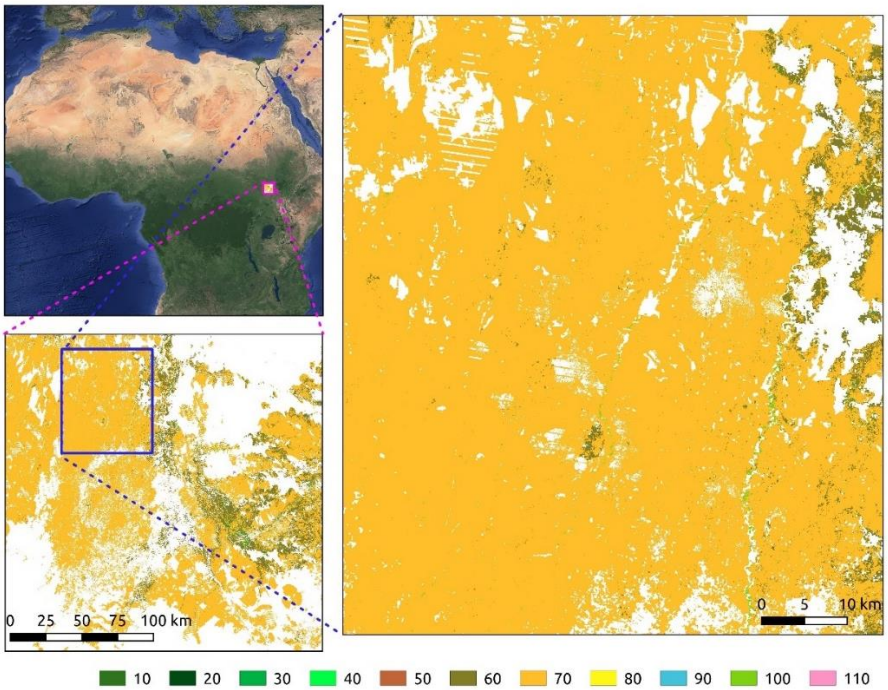


Figure 5: Example of the Land Cover layer for the Sahelian tile 08N032E in December 2016. The figure shows the extent of the whole Area in the left panels, and a zoomed region in the right panel.

2.7. File metadata

For each BA file product, an additional xml file with the same name is created. This file holds the metadata information following the ISO 19115 standard. The description of the populated fields is included in Annex 3.

3. Comparison with other burned area products

A preliminary comparison with FireCCI51 (Lizundia-Loiola et al., 2020) product shows that a considerably high number of small burned areas are being detected in FireCCISFDL10 compared to the coarser FireCCI51 due to the different spatial resolution (30 m vs 250 m) (Figure 6).

The product has been fully validated, and the full validation and intercomparison results can be found in the Product Validation and Intercomparison Report (Stroppiana et al., 2024).

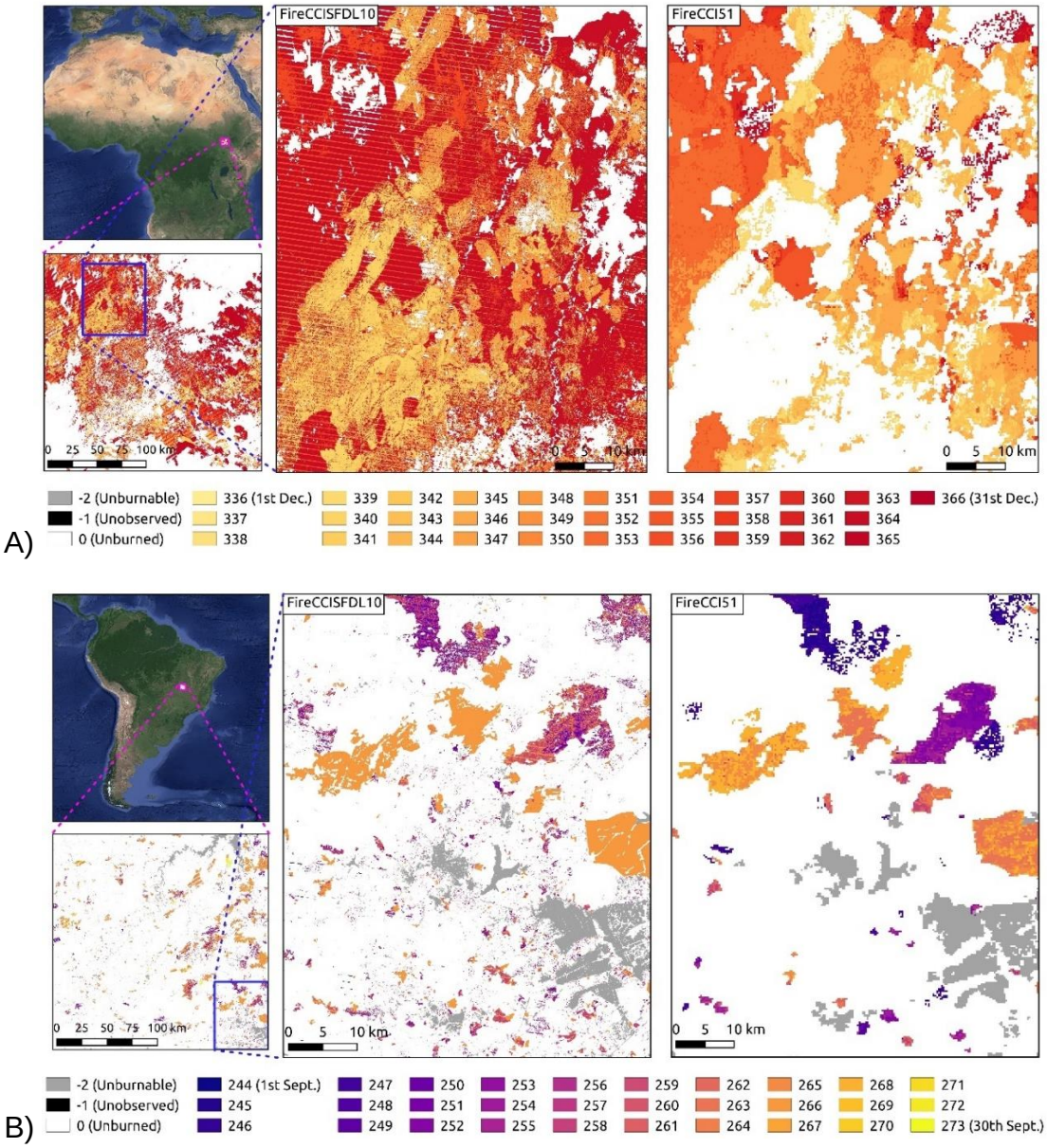


Figure 6: Intercomparison of FireCCISFDL10 BA and FireCCI51 products for two regions: A) December 2016 in Sahel, and B) September 2010 in Amazonia.

4. Data limitations and constraints

The main limitations of the FireCCISFDL10 product are related to the input data, particularly the imagery from Landsat-7. This satellite remains the most important data source for the 30-year time series, however, it has experienced a significant decline in image quality following the Scan Line Corrector (SLC) failure in 2003, resulting sometimes in patch discontinuity due to scan strip artefacts. This issue was partly mitigated in the post-processing smoothing phase.

In the case of Siberia, this study area might show a significant underestimation of BA, especially in 2012 when Landsat-7 was the only operational satellite. In this area, satellite imagery was highly contaminated by clouds, which obscured fire detection during the highest signal time span, subsequently leading to late fire detection in various cases (up to several weeks), or sometimes to the vanishment of weak signals coming from low-intensity ground fires before getting observed by satellite. To overcome the shortcomings of late fire detections active fires were employed, as indicated in Section 1.2. Additionally, some parts of fire patches might be missed due to the land cover filtering. In fact, the land cover input sometimes confuses open Tundra with barelands, which leads to omissions even if the fire signal is evident. Users are recommended to consider these limitations while using the Siberian dataset.

In the 1990s, when only Landsat-5 was fully operational and Landsat-4 provided very limited acquisitions, some areas were occasionally left unobserved for an entire year, perhaps leading to the omission of some fire events. This issue was most prominent in southwestern Sahel and southeastern Siberia (see Annex 4).

5. Data dissemination

The SFDL FireCCI v1.0 BA product is freely available from the FireCCI website: https://climate.esa.int/en/projects/fire/data/ and the CCI Open Data Portal: https://climate.esa.int/en/odp/#/dashboard.

6. References

ESA (2024). Climate Change Initiative Extension (CCI+) Phase 1 New Essential Climate Variables (NEW ECVS) High-Resolution Land Cover ECV (HR_LandCover_cci Product User Guide. Ref: CCI_HRLC_Ph1-D4.3_PUG_v2.2. Available at: https://climate.esa.int/media/documents/CCI_HRLC_Ph1-D4.3_PUG_v2.2.pdf.

Gorelick N, Hancher M, Dixon M, Ilyushchenko S, Thau D, Moore R. (2017) Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment; 202: 18-27.

Khairoun, A., Solano, E. (2024) ESA CCI ECV Fire Disturbance: D2.2.2 Algorithm Theoretical Basis Document-SFDL, version 1.3. Available at: https://climate.esa.int/en/projects/fire/key-documents/

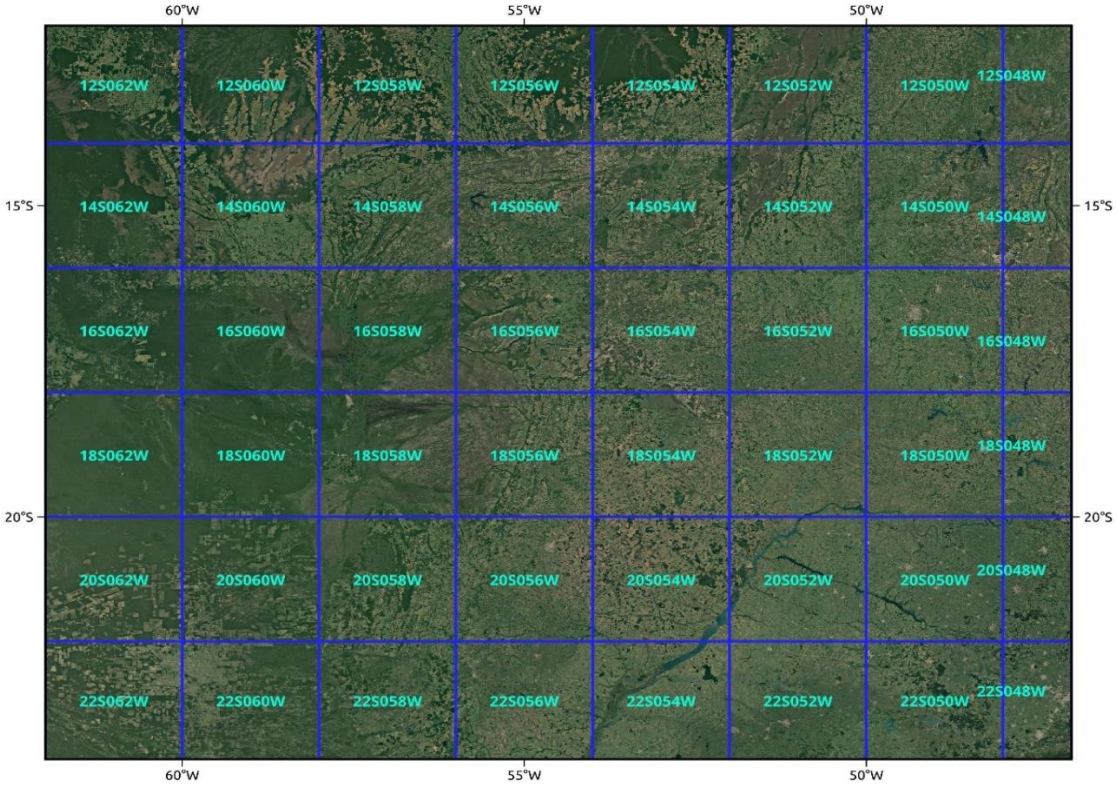
Lizundia-Loiola, J., Otón, G., Ramo, R., Chuvieco, E. (2020) A spatio-temporal active-fire clustering approach for global burned area mapping at 250 m from MODIS data. Remote Sensing of Environment 236, 111493, https://doi.org/10.1016/j.rse.2019.111493

Pettinari M.L. (2022) ESA CCI ECV Fire Disturbance: D1.2 Product Specification Document, version 7.0. Available at: https://climate.esa.int/en/projects/fire/key-documents/

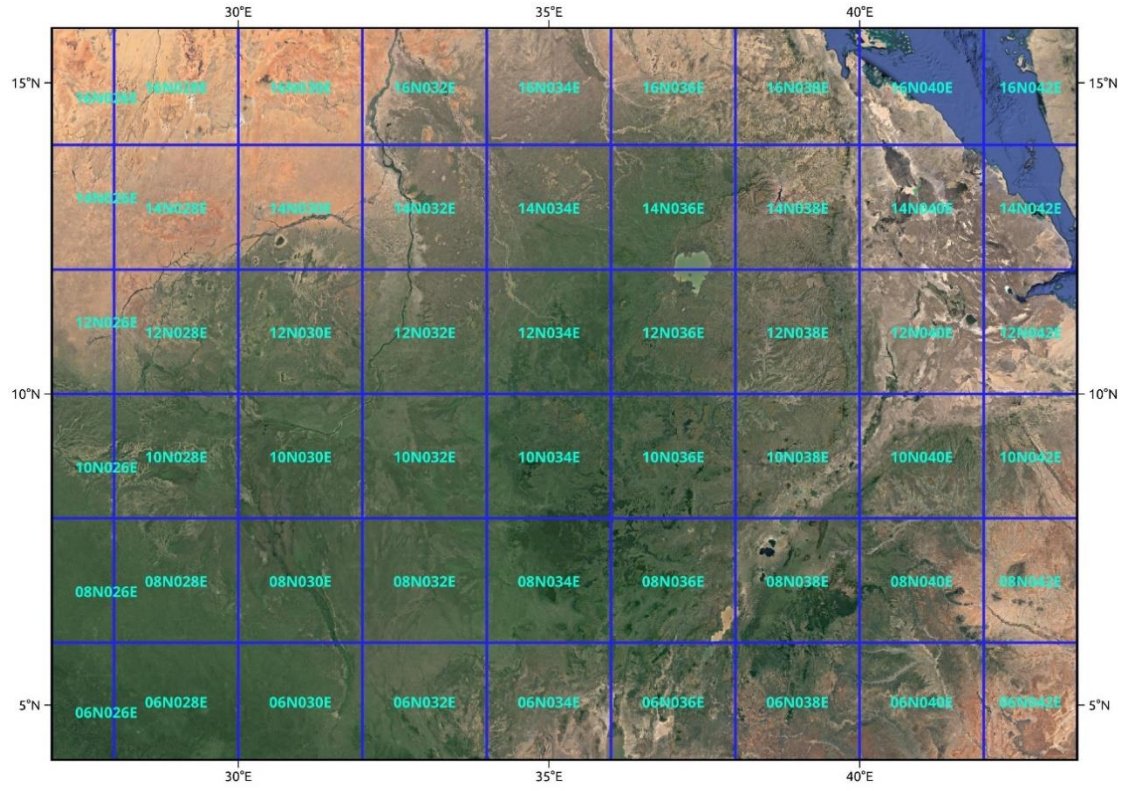
Stroppiana D, Mishra B, Sali M, Solano E, Khairoun A, Pettinari ML. ESA CCI ECV Fire Disturbance: D4.1 Product Validation and Intercomparison Report, version 3.0. Ref: Fire_cci_D4.1_PVIR_v3.0. Available at: https://climate.esa.int/en/projects/fire/key-documents/. 2024.

Annex 1: Tiling systems of the product datasets

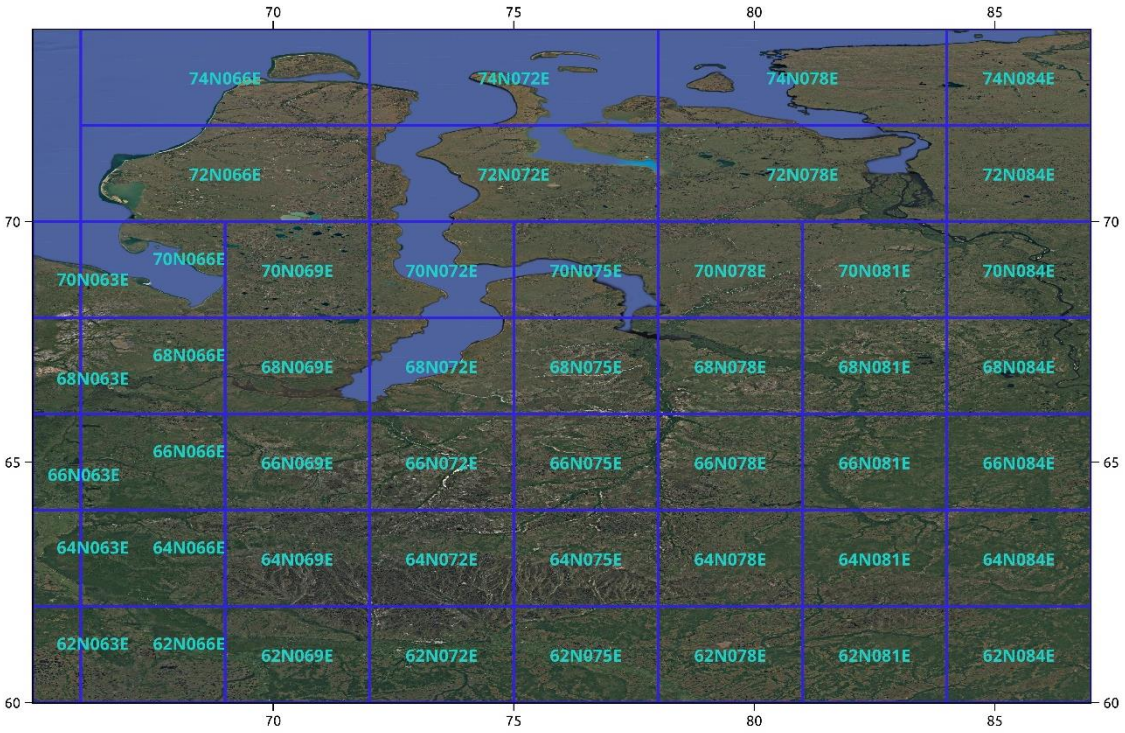
Amazonia:



Sahel:



Siberia:


70
75
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74N066E
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74N084E
72N066E
72N072E
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70
70N063E
70N066E
70N069E
70N072E
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64N084E
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62N081E
62N084E
60

Annex 2: Image availability and compositing periods by region

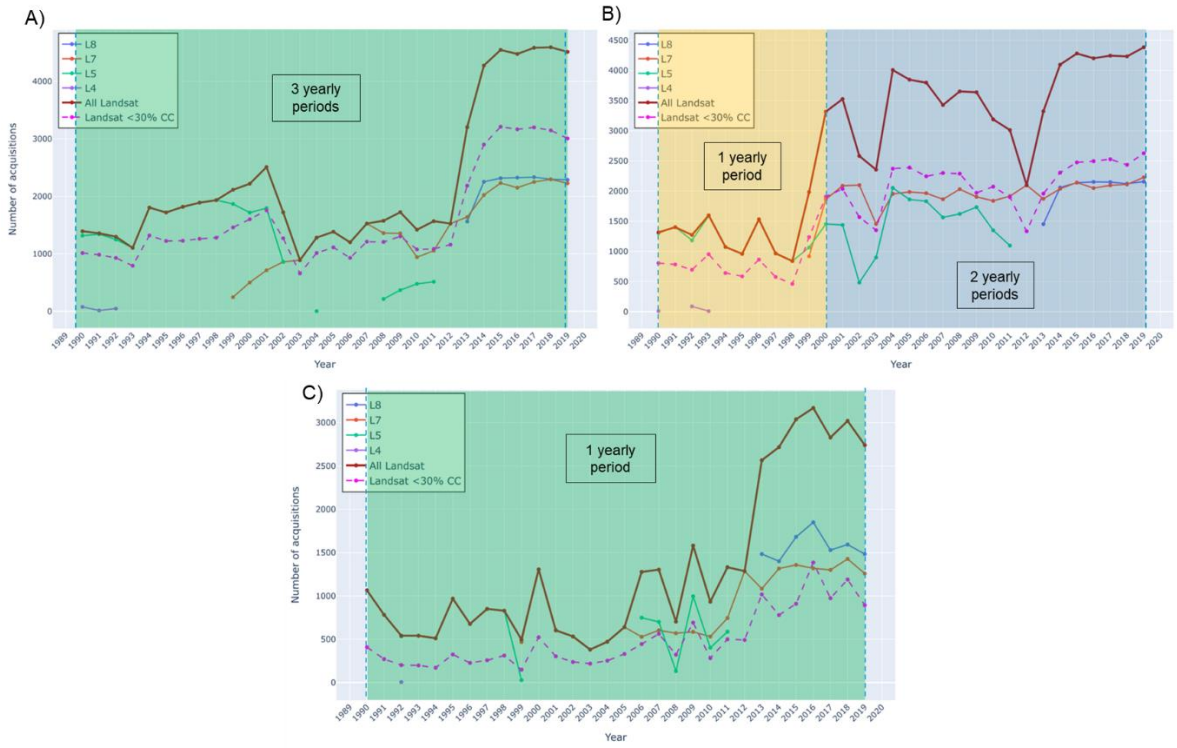


Image compositing was applied using the minimum NBR index to find the highest fire signal within a specific period. In the case of Sahel (A) 3 yearly periods were used:

1. Period 1: from 1st January to 31st March.
2. Period 2: from 1st April to 30th September.
3. Period 3: from 1st October to 31st December.

In the case of Amazonia (B), only one period extending from 1st April to 31st March was used in the 1990s. Then, two periods were used from 1st April 2000 onwards:

1. Period 1: from 1st April to 30th September.
2. Period 2: from 1st October to 31st March.

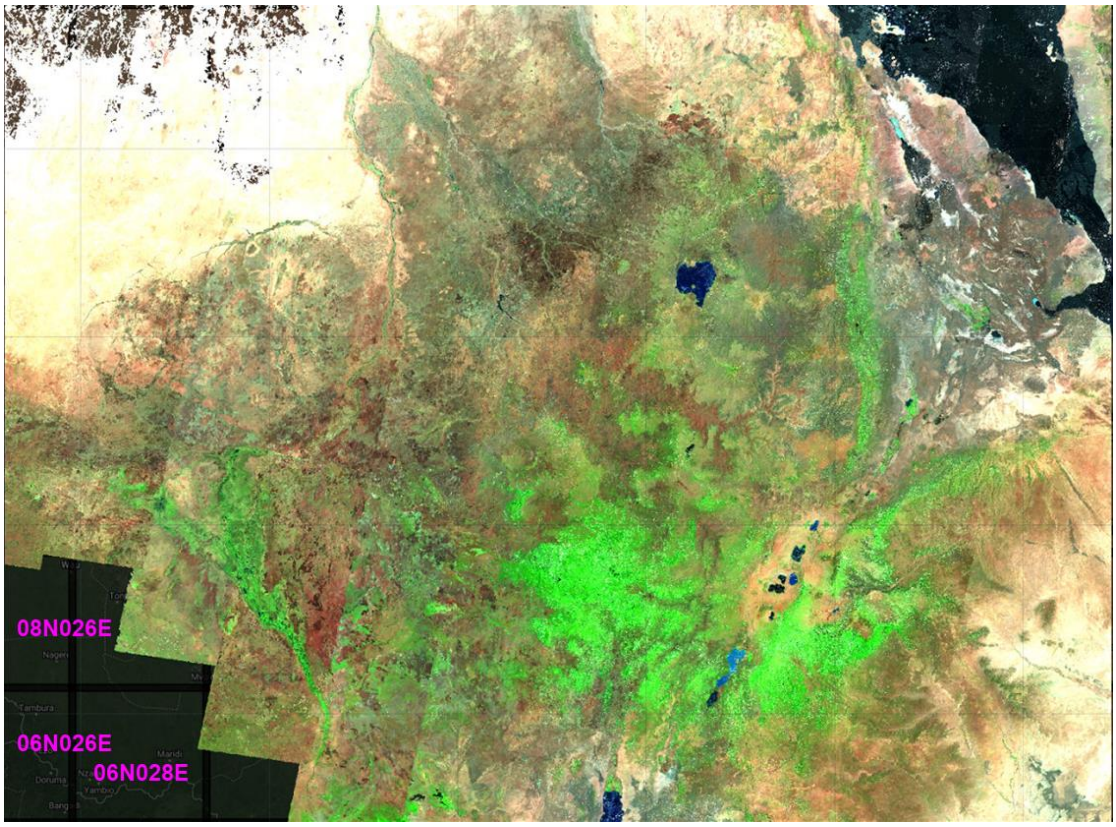
Only one yearly period from 1st March to 30th November was chosen to generate image composites for the Siberian region (C). The rest of the year was assumed unburnable due to climatic conditions.

Annex 3: Metadata of the pixel product (XML file)

In each XML file corresponding to the pixel product, the following fields are populated:

- Universal Unique Identifier
- Language
- Contact
- Date stamp
- Metadata Standard Name
- Reference System
- Citation
  - Title
  - Creation date
  - Publication date
  - DOI
  - Abstract (contains general information and information about each layer)
- Point of Contact
  - Resource provider
  - Distributor
  - Principal investigator
  - Processor
- Keywords
- Resource constraints
- Spatial resolution
- Extent:
  - Geographical extent
  - Temporal extent

Annex 4: Observation issues in the 1990s: Example of Sahel 1993



The figure is a RGB false color composite using SWIR, NIR, Red bands for all the Sahelian region during the year 1993. Tiles 06N026E, 08N026E and 06N028E were unobserved for their most parts.

Annex5: Acronyms and abbreviations

BA	Burned Area
CCI	Climate Change Initiative
CL	Confidence Level
CRS	Coordinate Reference System
ECV	Essential Climate Variables
ESA	European Space Agency
ETM+	Enhanced Thematic Mapper Plus
FIRMS	Fire Information for Resource Management System
GCS	Geographic Coordinate System
HRLC	High Resolution Land Cover
JD	Julian Day (day of detection of the burned area)
LC	Land Cover
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NIR	Near Infrared
OLI	Operational Land Imager
SFD	Small Fire Dataset
SFDL	Long-term Small Fire Dataset
SLC	Scan Line Corrector
SNPP	Suomi National Polar-orbiting Partnership
SWIR	Short-Wave Infrared
TM	Thematic Mapper
VIIRS	Visible Infrared Imaging Radiometer Suite
WGS84	World Geodetic System 84