ESA Climate Change Initiative – Fire_cci
D1.1 User Requirements Document (URD)

Project Name	ECV Fire Disturbance: Fire_cci
Contract Nº	4000126706/19/I-NB
Issue Date	15/12/2022
Version	8.1
Author	Florent Mouillot
Document Ref.	Fire_cci_D1.1_URD_v8.1
Document type	Public

To be cited as: Mouillot, F. (2022) ESA CCI ECV Fire Disturbance: D1.1 User requirements document, version 8.1. Available from: https://climate.esa.int/en/projects/fire/key-documents/

Project Partners

Prime Contractor/ Scientific Lead & Project Management	UAH – University of Alcala (Spain)
Earth Observation Team	UAH – University of Alcala (Spain) UPM – Universidad Politécnica de Madrid (Spain) CNR-IREA - National Research Council of Italy – Institute for Electromagnetic Sensing of the Environment (Italy)
System Engineering	BC – Brockmann Consult (Germany)
Climate Modelling Group	CNRS - Laboratory for Sciences of Climate and Environment (France) VU – Vrije Universiteit Amsterdam (Netherlands)

Distribution

Affiliation	Name	Address	Copies
ESA	Clément Albergel (ESA)	clement.albergel@esa.int	electronic copy
Project Team	Emilio Chuvieco (UAH) M. Lucrecia Pettinari (UAH) Amin Khaïroun (UAH) Magí Franquesa (UAH) Consuelo Gonzalo (UPM) Ángel Mario García Pedrero (UPM) Dionisio Rodríguez Esparragón (UPM) Daniela Stroppiana (CNR) Matteo Sali (CNR) Thomas Storm (BC) Florent Mouillot (CNRS) Philippe Ciais (CNRS) Guido van der Werf (VU)	emilio.chuvieco@uah.es mlucrecia.pettinari@uah.es amin.khairoun@uah.es magin.franquesa@uah.es consuelo.gonzalo@upm.es angelmario.garcia@upm.es dionisio.rodriguez@ulpgc.es stroppiana.d@irea.cnr.it sali.m@irea.cnr.it thomas.storm@brockmann-consult.de florent.mouillot@ird.fr philippe.ciais@lsce.ipsl.fr g.r.vander.werf@vu.nl	electronic copy

Summary

This document is the version 8.1 of the User Requirements Document for the Fire_cci+ Phase 2 project. It refers to Task 1, Work Package 1000. It describes burned area requirements according to the user needs, providing background information to the data provider.

	Affiliation/Function	Name	Date
Prepared	CNRS	Florent Mouillot	15/12/2022
Reviewed	UAH – Project Manager UAH - Science Leader	M. Lucrecia Pettinari Emilio Chuvieco	15/12/2022
Authorized	UAH - Science Leader	Emilio Chuvieco	15/12/2022
Accepted	ESA - Technical Officer	Clément Albergel	16/12/2022

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

Document Status Sheet

Issue	Date	Details
1.0	01/12/2010	First Document Issue
2.0	09/02/2011	Restructured and updated Document
3.0	08/07/2011	Full (re)writing of sections 3, 4 and 5
3.1	10/07/2011	Editorial reworking
3.3	26/07/2011	Layout and formal review
3.4	31/08/2011	Layout and formal review
3.5	14/09/2011	Review addressing ESA comments
4.0	26/11/2015	First document for Phase 2 of Fire_cci. Full (re)writing of the document
4.1	15/01/2016	Review addressing ESA comments
5.0	22/09/2016	Revised version of the document
5.1	30/12/2016	Addressing comments of CCI-FIRE-EOPS-MM-16-0128
5.2	20/12/2017	Revised version of the document
6.0	01/08/2019	Full rewriting of the document synthesising all user requirement surveys with recent scientific publications and product developments
7.0	27/11/2019	Major reorganization of the text according to the comments on ESA-CCI-EOPS-FIRE-MEM-19-0322
7.1	26/03/2021	Update of the document
7.2	28/04/2021	Addressing comments of Fire_cci D1.1 URD v7.1 RID
8.0	13/12/2022	Rewriting of the whole document
8.1	15/12/2022	Addressing comments of ESA's Technical Officer

Document Change Record

Issue	Date	Request	Location	Details
2.0	04/02/2011	ESA, Fire_cci partners	Whole document	Major editing taking into account review comments by S. Plummer (ESA) and other information and feedback
3.0	08/07/2011	ESA,	Sections 3, 4 and 5	Full (re)writing of indicated sections
3.1	10/07/2011	Fire_cci	Whole document	Editorial
3.3	26/07/2011	Fire_cci partners	Whole document	Literature review on user requirements and products, layout and formal review
3.4	31/08/2011	GAF	Whole document	Typo and grammar correction, updating references

Issue	Date	Request	Location	Details
3.5	14/09/2011	IRD, LSCE, JÜLICH	Whole document Section 3.1	Revision following review comments from Stephen Plummer (ESA), updating references, Data Inter-comparison – separated paragraph introduced
4.0	26/11/2015	MPIC, Fire_cci partners	Whole document	New naming convention for the document New format and layout Full (re)writing of the document
4.1	15/01/2016	ESA	Sections 1, 2.1, 3, 3.1.4, 3.2, 4.1.1, 4.1.3, 4.1.5, 4.1.6, 4.2, 5.1, 5.2.4, 5.4, 5.4.1, 5.4.2, 5.4.4, 5.4.6, 6.5. Table 1 Section 4.1 Section 5.1 Section 7 Annex 1	Minor changes in the text Minor changes in the line corresponding to Fire_cci The sub-sections of this section were re-ordered New paragraphs added New references added Inclusion of new acronyms
5.0	22/09/2016	MPIC, Fire_cci partners	Section 3 Section 4 Section 4.1.2 Section 4.1.4 Section 4.2 Section 5 Section 6 Annex 2	Updated and expanded; characteristics of burned area products with on-going development are discusses separately from "obsolete" products Updated and expanded. Added description of BB5CMIP6 Added description of FireMIP benchmark system New web of science database query on publications using burned area information Restructured, updated and synthesized Restructured and updated Added annex with commonly used definitions
5.1	30/12/2016	ESA	Section 3.1.5 Section 3.2 Sections 3.3, 5.1, 5.2.6 Section 5.2.8 Sections 6.1, 6.2	Changed the reference of C-GLOPS to GIO-GL1. Sentence added to better interpret the error results, and Figure 1 replaced. Small changes in the text. Last sentence deleted. Information added.
5.2	20/12/2017	MPIC	Sections 1, 3.2, 5.2.12, 5.2.13 Sections 2.1, 4.1.1, 5.2.6, 5.2.14, 6, 6.2 Section 2.4 Section 3.1 Section 4.1.4 Section 4.1.5 Section 5.1 Section 5.2.1 Section 5.2.7 Section 5.2.8 Section 5.3	Text expanded. Small changes in the text. Deleted section of structure of the document. Updated tables, added new sub-sections with new products. Added summary on FireMIP workshop October 2017. Added study by Lehsten et al. (2010). Added GCOS-200 (2016) and update FireMIP requirements, added IBBI 2017 workshop. Update results from user requirement surveys, including Fire_cci product user statistics and the 2017 Fire_cci user workshop survey. Expanded on explanations of what uncertainty characterisation mean. Expanded on quality assurance indicator requirements. Expanded on on-going user requirement surveys, including GCOS survey.

Issue	Date	Request	Location	Details
			Section 6.1 Section 6.3 Section 6.4 Annex 2 Annex 3 Annex 4	Specified temporal resolution requirements. Added uncertainty characterisation. Specified ancillary data layer requirements. Updated description of measurement uncertainty. Added Fire_cci user survey form. Added 2017 Fire_cci user workshop report
6.0	01/08/2019	MPIM	All sections	Rewriting of the entire document towards a user requirement document synthesis, while, at the same time, updating it for recent burned area product developments, applications and recently released scientific publications.
7.0	27/11/2019	ESA – MPIM	Sections 1, 2.1, 2.2, 7 Sections 3, 4 Section 5 Sections 6.2, 6.3, 6.7	Sections updated Information rearranged, with new sections and subsections created New section added Text expanded
7.1	26/03/2021	MPIM UAH	Sections 1, 2.1, 4.2.1, 4.2.2, 5 Section 3 and sub-sections Section 6 and sub-sections Section 7	Minor text updates Added information on burned area products released since the URD v7.0; moved table with outdated burned area products into the Annex Text updated. Added new sub-section describing burned area product requirements for fire danger and early warning systems Text updated. Added table summarising key requirements
7.2	28/04/2021	UAH	Table 1 Table 6 Section 8	Some items updated Identified the references with the participation of Fire_cci consortium members. Additional references were added. More references added.
8.0	28/11/2022	CNRS	All document	Rewriting of the whole document.
8.1	15/12/2022	UAH	Section 5	Section expanded.

Table of Contents

1. Background and objectives

Burned area generated at global scale from remote sensing has emerged in the early 2000's with the MODIS sensor providing a continuous and fruitful information on its local, interannual and seasonal variations. Major applications were the global understanding of climate and human constraints on fire hazard, benchmarking of fire modules embedded in dynamic global vegetation models (DGVMs Hantson et al. 2016), biosphere atmosphere interactions, or fire/vegetation interactions. After the initial development of the MODIS burned Area dataset at 0.5° resolution (Roy et al. 2005, 2008), increasing refinements on fire detections, the inclusion of small fires hardly captured at coarse resolution (Giglio et al. 2010), the combination of fire signal as fire radiative power during fire event in addition to the post-fire surface reflectance, allowed for better characterization of the burned area. At the same time, the increasing use of these data in the scientific community, identified detection failures or data formatting issues making them hard to use for certain purposes, while the increasing computing facilities allowed for finer spatial and temporal resolution, and longer term simulations. The remote sensing scientific community then had to account for these requested user needs to deliver the most suitable dataset for the research question addressed. Since recently, the development of new sensors, better performances and increasing knowledge in signal analysis for burned area detection, could lead to a larger panel of available datasets.

The FireCCI project started in 2010 and aimed at providing original burned area datasets at the global scale based on an initial user requirement to fulfil targeted user requests not fully met in the existing panel of burned area products. Developments within this project lead to the early delivery of FireCCI41 from the MERIS sensor at 300m resolution for the period 2005-2011 (Chuvieco et al. 2016), followed by FireCCI50 (Chuvieco et al. 2018) and the current FireCCI51 (Lizundia-Loiola et al. 2020a) based on the MODIS sensors at raw spatial resolution of 250m over the period 2001-2020, fulfilling one of the user requests to get better information on small fires at finer resolution. In addition, the FireCCILT11 (Oton et al. 2021) based on the AVHRR sensor allowed for the long term burned area reconstruction since 1982 at coarse resolution (5km) prolonging backward our current understanding of burned area trends, and fulfilling the second major user request identified in URD1.0. Finally, the FireCCISFD20 (Chuvieco et al. 2022) provides a continental scale burned area dataset for Africa at 10m resolution from the Sentinel 2 sensor for the year 2019, and providing a keystone information on small fire identification.

All these datasets now differ in their resolution, their temporal coverage, their detection accuracy, and the miscellaneous information associated to these data as the quality assessment, vegetation affected, burn date, or fire intensity. In turn, end-users now face both the benefits of getting an access to various and complementary information, but also the penalty of multiplying analysis across datasets, or arbitrarily choosing one dataset over the other. In order to provide a user-based guideline to new and useful developments of burned area within the FireCCI project, we investigated how the scientific community of end-users have been aware and actually used the newly delivered BA datasets within the FireCCI project, in order to identify potential caveats to be fixed and propose new developments for the next generation of BA datasets using previous and forthcoming sensors.

To reach this goal, we combined a bibliographical review of scientific papers citing the FireCCI BA products listed above, and interviewed one of the major user group of end-user in the fire modelling community (FIREMIP) (Rabin et al. 2016) for a direct feedback on their methodological issues and concerns.

2. FireCCI51: a global burned area dataset 2001-2021 at pixel (250m) and grid (0.25°) resolution.

We screened the 119 publications citing Chuvieco et al. (2018) referring to the FireCCI50 delivery and the subsequent FireCCI51 (Lizundia et al. 2020a) within WOS (until October 30th 2022) and published in referenced journals. 22 citations were linked to at least one partner of the project, leaving 97 publications from independent end-users. We could classify these 119 citations into few main targets : i) 23 publications cited FireCCI51 as a reference dataset within the scientific community for information (in introduction, discussion) but did not actually use it, ii) 11 publications actually used FireCCI51 for global or regional Land/atmosphere carbon budget assessment, iii) 36 publications refer to the methodological advances developed in FireCCI51 for further use in local developments or new sensors, iv) 23 publications aimed at assessing the quality of FireCCI51 in comparison to reference data or other global burned are products, v) 7 publications assess the local or global fire weather relationships, vi) 3 publications identified global or local fire regimes, vii) 5 publications investigated fire impact and viii) 11 publications used FireCCI51 for DGVMs benchmarking. We detail below the lessons learned from how the authors cite FireCCI51.

2.1. FireCCI51 acknowledged as an international reference dataset

With 23 references to FireCCI51 in the scientific literature, FireCCI51 was widely cited in bibliographical reviews of keystone burned area datasets in various of research as methodological developments (Chuvieco et al. 2019), fire impacts on ecosystems (Jones et al. 2022, Konko et al. 2021, Lindersson et al. 2020, Chuvieco et al. 2020, Mayr et al. 2019, Li et al. 2022a, Xiao et al. 2022) or human societies (Bilbao et al. 2019). In these reviews, FireCCI51 was cited aside MCD64A1 (Giglio et al. 2010) derived from the MODIS sensors at 500m resolution covering the 2001-present period (The MCD64A1 (collections 5 and 6) algorithms integrate the 1 km MODIS AF product (MOD14A1 and/or MYD14A1), MODIS reflectance data, and land cover product to detect area burned (Giglio et al 2009, 2018a,b), and GFED4s (Van der Werf et al. 2017, Randerson et al. 2012) combining MCD64A1 and fire hotspots MCD14ML at 0.5° resolution but covering the 1997-present period using ATSR and TRMM and providing an indirect estimating small fires, a major advantage mostly acknowledged by end users. FireCCI51 was also acknowledged as a reference dataset (Pereira et al. 2022), when other alternative dataset were used as hotspots VIIRS or MCD14ML (Kong et al. 2022, Reddy and Sarika 2022), or local fine resolution data as Landsat or Sentinel (Sivrikaya and Kucuk 2022, Rovithakis et al. 2022, Ganem et al. 2022, Wei et al. 2021, Shirashi et al. 2021, Sibley et al. 2019), acknowledging the efforts on finer resolution (Miranda et al. 2022) provided by FireCCI51, but still insufficient for local studies (Abdikan et al. 2022).

An unexpected interest in FireCCI51, was the original validation step on fire patches and fire size distribution derived from pixel-level aggregation (further published as the FRY database by Laurent et al. 2019) cited by Mahood et al. (2022), Humber et al. (2022) and Balch et al. (2020) and implemented for MCD64A1 burned area data. This overview highlights the visibility of FireCCI51 in the scientific community within its recent delivery time and compared to the longer lasting MCD64A1 and GFED4s.

2.2. FireCCI51 still ongoing quality assessment

Since its delivery in 2019, FireCCI51 has been evaluated a regional or global scale with equivalent other burned area products. In the Mediterranean basin Katagis and Gitas (2022) concluded on better small fires detection but overall no major improvement compared to MCD64A1, Galizia et al. (2021a) concluded on better patch identification from pixel level MCD64A1, while Turco et al. (2019) found better correlation with national burned area statistics with FireCCI51, still warning on filtering out non forest areas and keeping statistics at coarse resolution. At national level in countries with small fires, Achour et al. (2021) and Majdalani et al. (2022) warned still the missing small fires but increasing confidence in FireCCI51 compared to MCD64A1, a significant benefit of the finer resolution in FireCCI51.

For the boreal forest, Moreno Ruiz et al. (2019) in Alaska, and Chen et al. (2021) warned of the 50% missed burned area in MCD64A1 and 40% in FireCCI51, with a lower commission error in FireCCI51. This observation, lead to new methodological developments for better accuracy in these ecosystems and provided in the local ABBA database (Chen et al. 2021), a method that could be tested and implemented in the forthcoming global burned area products and a BA database that could be used for future continental accuracy assessment.

For the tropics, acknowledged as being a critical region for burned area identification from remote sensing due to a high cloud cover, Jiao et al. (2022) identified poor but still better BA identification from FireCCI51 compared to MCD64A1, while Vetrita et al. (2021), Valencia et al. (2020), and Rodrigues et al. (2019), Campagnolo et al. (2021) or Correa et al. (2022) blamed the poor FireCCI51 accuracy in cloudy conditions. Moreno et al (2021) pointed out the highest discrepancies between MCD64A1 and FireCCI41 in the tropical forests, making this ecosystem a future target of improvement.

A major weakness of FireCCI51, but overall a common weakness on other BA products as MCD64A1, was the poor BA identification in croplands, as in wheat fields of Ukraine (Hall et al. 2021), where omission errors reached 80% and commission 75% due to high confusion with changes in reflectances due to harvest.

Beside burned area, Pinto et al. (2020) provided an evaluation of burn dates from VIIRS sensor compared to MCD64A1 and FireCCI51 and pointed out the higher uncertainty in the latter one, with major consequences on fire spread rate identifications, a keystone process in fire model benchmarking. They pave the route for combining near real time hotspots into future burned area products for a better assessment of the burn date within fire patches at the pixel-level.

Overall, FireCCI51 is now widely considered as a reference dataset for global burned area accuracy assessment and inter-comparisons with newly delivered products (Ramo et al. 2021, Boschetti et al. 2019, Moreno Ruiz et al. 2020, Oton et al. 2021, Stroppiana et al. 2022, Franquesa et al. 2020, 2022a,b, Gajardo et al. 2021, Belanguer Plomer et al. 2021), or training finer resolution semi-automated burned area detection tools at local scale (Dixon et al. 2022). These comparisons, despite being necessary for end user information, can bring confusion with an additional concern on the diverging temporal trends between FireCCI51 and other BA products (Worden et al. 2020).

2.3. FireCCI51 for carbon Land/atmosphere interactions

One of the main goal of generating burned area and other essential climate variables at the global for the ESA climate change initiative, is the refinement of the land/atmosphere interactions. The reference database regarding this topic is the GFED4s data, using a combined burned area from MCD64A1 and hostpots to be used in the biogeochemical model CASA (Van der Werf et al. 2017, Randerson et al. 2012) and in turn covering the 1997-present period, outcompeting FireCCI51 regarding the temporal coverage. However, an increasing number of recent studies mention FireCC51 as a potential alternative burned area data source (Silva et al. 2020, Bastos et al. 2022, Yin et al. 2020). Some authors specifically mention the weaknesses in FireCCI51 as in the Boreal region, where Romanov et al. (2022) provided, for Boreal Asia, a fire-driven carbon budget using Land Cover CCI, but intentionally preferred to use MCD64A1 with a better reliability in taking into account active fires and under cloudy conditions as stated in Humber et al (2019).

Nevertheless, FireCCI51 was recently actually used for carbon budget emissions from terrestrial burning, due to its finer resolution as in India (Karthik et al. 2022), or as an alternative data source to provide uncertainty in carbon emissions. It was mostly used in addition to the reference GFED4s burned area, or MCD64A1 (Wu et al. 2022, di Giuseppe et al. 2021, Chen et al. 2020), or the recently delivered fine resolution Landsat-based global BA product (Pessoa et al. 2021). The recent global carbon budget from Bastos et al. (2020) illustrates how the various databases now available at global scale are considered as an uncertainty information itself, actually more considered than the intrinsic uncertainty information delivered in FireCCI51 (Brennan et al. 2019). This observation points out the interest of end-users for uncertainty in the carbon budget application, but they might better understand their own uncertainty based on multiple datasets BA variations (as illustrated in Hantson et al. 2016), than the uncertainty provided (potentially not enough explained, discussed and assessed in the literature?). Efforts should be devoted by BA providers in better illustrating the impact of the intrinsic uncertainty layer, and a multisource merged product with inter-product variability might be of interest at this stage of increasing burned area datasets availability.

2.4. FireCCI51 as reference methodological innovation in new product developments

Our extended bibliographical review of FireCCI51 citations revealed a huge amount of studies referring to FireCCI51 for its methodological innovation and potential transposition for new sensors. Mostly, recent studies refer for FireCCI51 methodology for Sentinel 2-based burned area development at finer 10m resolution since 2018 (Farhadi et al. 2022, Roteta et al. 2019, 2021a,b, Zanetti et al. 2021, Zhang et al. 2021, Pinto et al. 2021, Pacheco et al. 2021, Knopp et al. 2020, Tanase et al. 2020, Filipponi 2019), Landsat based burned area a 30m extending back to 1984 (Zhang et al. 2020, Hawbaker et al. 2020, Bar et al. 2020, Wozniak and Aleksandrowicz 2019, Long et al. 2019, Daldegan et al. 2019), AVHRR based burned area at coarse resolution back to 1982 (Oton et al. 2019, 2021a), Synergy (Lizundia-Loiola et al. 2022, FIRECCIS310), VIIRS (Fernandez Manso et al. 2020) or MODIS improvement itself (Lizundia Loiola et al. 2020a, 2021, Campagnolo et al. 2019, De Bem et al. 2020, Belenguer-Plomer et al. 2019a,b,2021). Humber et al. (2019) also cited FireCCI51 for the relevance of fire patch identification from the pixel-level information, further developed for the MCD64A1 BA data. We can identify from these ongoing developments the user needs for finer resolution

(10m with Sentinel2 to 30m from Landsat), a longer period (back to 1982 with either Landsat at fine resolution or AVHRR at coarser resolution), or with better performances with new sensors (VIIRS).

This citation report on BA detection methods also points out FireCCI51 weaknesses and ongoing improvements on grasslands fires by using geostationary meteorological satellites (Chen et al. 2022b), and cropland burnings from Landsat (Liu et al. 2021) or Sentinel 2 (Van Dijk et al. 2021), previously pointed out in FireCCI51 intercomparisons papers as a major weakness. Ongoing developments also illustrate a keystone information missing in FireCCI51 and requested by the scientific community regarding the burn severity as reviewed in Kurbanov et al. (2022) and recently developed in the global MOSEV database (Alonso-Gonzalez et al. 2021). This request should be considered in the forthcoming developments of global BA products as an additional layer.

Finally, FireCCI51, as the other global burned area datasets, would benefit from a near real time delivery of information (Yuan et al. 2020), as already for hotspots from the FIRMS interface (https://firms.modaps.eosdis.nasa.gov/active_fire/), or EFFIS automated processing chain for Europe (https://effis.jrc.ec.europa.eu/), providing to the media or scientific community emergency data on extreme events.

2.5. FireCCI51 in burned area hazard and impact analysis and modelling

Beside the carbon land/atmosphere interactions assessment for which it was intially built, FireCCI51 burned area data have been widely used in fire hazard and impact analysis, and modelling, making this scientific community a group of end-users with specific requirements.

Global burned area data are widely used for large scale atmospheric impact fire hazard or continental scale extreme event analysis. FireCCI51 provides gridded monthly burned area or pixel-level daily information suitable for both analyses. FireCCI51 has recently been used aside the other global BA data GFED4s for the influence of Sea Surface Temperatures (SST) on the forthcoming fire hazard (Meng and Gong 2022) as well as atmospheric teleconnections in arctic boreal fires (Zhao et al. 2022) at coarse resolution (Tang et a. 2021). FireCCI51 provided an additional dataset for uncertainty assessment to the studies, with the sufficient and easy to access and manipulate coarse resolution dataset as provided by GFED4s. At finer temporal scale, the daily burned date of the pixel-level information was used to infer daily fire weather leading to large fires (Ermitao et al. 2022, Dong et al. 2021, Wang et al 2021, Silva et al. 2019) including heat waves and drought. Authors used the burn date as the actual burning day when this information actually refers to the date when a change in the surface reflectance was observed after the fire occurred, potentially affected by missing images or clouds. Uncertainty related to this information is covered in the FireCCI51 description paper (Lizundia-Loiola et al. 2021), but potentially hardly considered as it's not delivered as an uncertainty layer per se. Thermal anomalies from fire hostpots MCD14ML or VIIRS (available since 2012) actually provide better accuracy in the burn date, a keystone information that should be improved or better characterized as an uncertainty layer in future developments. This information would help preventing potential fake signals in the fire weather analysis when these weather conditions can change fast from one day to the other.

Fire regime, describing the seasonal and interannual variation of burned area in a given region mostly rely on global burned area for global assessment. They actually mostly rely on MCD64A1 until now, with few examples actually using FireCCI51, potentially a neglected scientific community in the communication and dissemination strategy. Bar et al. (2021) used both FireCCI51 and MCD64A1 for fire regime characterization in Himalaya, and Lizundia Loiola et al. (2020b) use FireCCI51 for the extreme 2019 fire season in Amazonia, and Bowman et al. (2020) covered the 2019-2020 extreme fire season in Australia based on FireCCI51 data. Lourenco et al. (2023) combined FireCCI51 and the small fire database FireCCISFD11 to detect peatland fires in Angola. The use of FireCC51 in the tropics seems to be still problematic for end users. As previously pointed out for carbon budget and accuracy assessments, MCD64A1 is usually preferred due to the SWIR band with a daily revisit when cloud persistence limits imagery quality. Efforts should be devoted to increase the accuracy in this region. Some few environmental studies using FireCCI51 additionally focused on assessing the post-fire recovery in tropical forests (De Keersmaecker et al. 2022, Machida et al. 2021) and boreal forests (Cazzolla Gatti et al. 2021, Guo et al. 2021) where FireCCI51 was although previously criticized. A global assessment of fire impact on soil moisture (Sungmin et al. 2020) benefited from the CCI project combining both datasets

The fire modelling community, using climate-driven dynamic global vegetation models (DGVMs) to simulate land/atmosphere interactions and the terrestrial carbon budget including fires impacts, has been an active user group in the last years, particularly through the Fire Model Intercomparison Project (FIREMIP, Rabin et al. 2016). They use global burned area for model benchmarking along the last century and the recent decades. Early stages of the project relied on GFED4s (van der Werf et al. 2017, Randerson et al. 2012), accounting for small fires, covering the longest period since 1997, and providing a coarse resolution (0.5° and 0.25°) sufficient for the coarse resolution of the models. Since the delivery of FireCCI50 in 2018 and FireCCI51 in 2020, most publications arising from this group make the effort of using both GFED4s and FireCCI51 (Harrison et al. 2021, Seiler et al. 2021, Wu et al. 2021, Hantson et al. 2020, Lasslop et al. 2019, 2020, Forkel et al. 2019a,b,c, Teckentrup et al. 2019, De Paula et al. 2019). For this community, the GFED4s remains the dataset covering the longest period and assumed to better consider small fires. With its finer 250m resolution FireCCI51 was intended to cover the gap of MCD64A1 initially fulfilled by implementing fire hotspots into the GFED4s database. FireCCI51 did not convince yet the added value of the small fires detected at 250m resolution in this community, so an enhanced evaluation of this specific small fire part of the FireCCI51 dataset should be further provided in the forthcoming products.

2.6. The fire patch database FRY derived from FireCCI50

As soon as FireCCI50 was delivered, a side product of a fire patch database FRY (Laurent et al. 2018) derived from the pixel-level burn date was produced, by aggregating neighbouring pixels within a time lag lower than a given cut-off threshold into a similar fire patch. This database contains the location of fire patches globally, their morphological features, dating, and vegetation type affected, based on both FireCCI50 and MCD64A1, making FireCCI the first global database to provide an easy accessible information on fire patches globally. With 48 citations in WOS since 2018, this side product contributed to the dissemination of the FireCCI data. This initiative actually inspired subsequent studies using new pixel-aggregation methods and data formats, including easy to use shapefile polygons: the updated FRY1.2 (Laurent et al. 2019 including fire radiative power from MCD14ML) and Global Fire Atlas (Andela et al. 2019), GlobFirm (Artes et al. 2020) or FIRED (Balch et al. 2020a,b, Mahood et al. 2022), these latter ones only using MCD64A1. To date, FRY remains the only fire patch database using FireCCI data. Fire patch quality assessments were performed regarding their boundary (Humber et al. 2019), their reliability a function of fire size (Campagnolo et al.

2021, Jiao et al. 2022) and compared to referenced events in Europe (Galizia et al. 2021a, Katagis and Gitas 2021) and US (Moreno et al. 2020, Chuvieco et al. 2018) or inter-compared (Moreno et al. 2021). This database was rapidly used from the fire modelling community (Forkel et al. 2019c, Lasslop et al. 2019, Teckentrup et al. 2019) and referenced as added value to the fire science community (Chuvieco et al. 2019, 2020, Mignan et al. 2022, Da silva et al. 2019, Tacaks et al. 2021, Zhao et al. 2021, Sharma et al. 2022, Haas et al. 2022, Castro et al. 2022, Humber et al. 2022, Li et al. 2022b). This database was used for fire event analysis (rather than total burned area) in south America (Rodrigues et al. 2019, Silva et al. 2021, Santos et al. 2021, Fidelis et al. 2019), the Mediterranean basin (Curt et al. 2021, Genet et al. 2021, Galizia et al. 2021b), the boreal forest (Tomshin et al. 2021) or globally (Garcia et al. 2022, Pausas 2022, Millington et al. 2022). The pixel aggregation method has been further used with other sensors as VIIRS (Li et al. 2020, Santos et al. 2020, Pinto et al. 2021) or other (Lizundia Loiola et al. 2020, 2022). Improvements in the fire patch databases mostly came from pixel aggregation methods (particularly for multi ignitions merging into one single fire patch), fire rate of spread from fire duration (from maximum and minimum burn date within the patch), and fire intensity by merging burned area data with Fire radiative power from MCD14ML and VIIRS (Laurent et al. 2019, Jones et al. 2022). Ongoing perspectives and developments try and improve the fire dating potentially biased by image quality due to cloud cover (Pinto et al. 2020), and internal fire spreading (Huot et al. 2022, Humber et al. 2022, Chen et al. 2022a). The location of fire ignition based on the minimum fire date within the patch is also a keystone information to provide as in the Fire Atlas. This information highly depends on the quality of the burn date identification, and combining hostpots and pixel burned could refine this information. Forthcoming databases on fire patches will have to face these challenges with hopefully improved pixel-level fire dating and fire intensity, as well as new challenges in pixel aggregation for fine resolution datasets at 10m resolution from Sentinel 2, where a single fire event can be actually fragmented into smaller ones if a spatial buffer is not considered, as for example when a fire crossed a fire break as road or a small river over 1 or 2 pixels.

3. FireCCILT11 long term burned area from AVHRR

Among the user requirements stated in URDv1.0, a specific request on the longest as possible period was mentioned. As a response to this request, the FireCCILT11 was delivered by Oton et al. (2019,2021) to fulfil this scientific gap, when global burned area data hardly go back to 2001 (FireCCI51, MCD64A1) or 1997 (GFED4s). This recently delivered database was quickly integrated to the reference global Burned area datasets (Kurbanov et al. 2022, Chuvieco et al. 2020), with 21 citations in WOS. Mostly the innovative methodological developments were cited (De Luca et al. 2022, Abdi et al. 2022, Abdikan et al. 2022, Glushkov et al. 2022, Bas et al. 2021, Saatchi et al. 2021, De Luca et al. 2021, Peng et al. 2021, Seydi et al. 2021, Wozniak & Aleksandrovicz 2019, Stroppiana et al. 2022, Xu et al. 2022, Gaveau et al. 2022, Oton et al. 2021) for similar AVHRR development and Sentinel 2 applications. Keystone long-term fire trends could be captured (Oton et al. 2022) with their climate drivers (Descals et al. 2022), with subsequent fire effects on ecosystems and biogeochemical cycles as the land/Atmosphere carbon budget (Van Marle et al. 2022), grazing/fire interactions (Hao et al. 2021), long term post fire recovery in Boreal Forests (de Andres et al 2021) or deforestation in Amazonia (Xu et al. 2020). However, the quality and coarse resolution of this dataset can be misleading on many purposes when used as any other Burned area data at 250m/500m resolution. Giglio et al. (2022) identified caveats in the dataset, and Xu et al. (2020)'s conclusion on deforestation were controversial. The delivery of this dataset is significant step forward in understanding the long term changes in the global fire regimes but should be used carefully, and would need further quality assessment.

4. End-user survey: the FIREMIP modelling group

Based on our bibliographical review, we identified the FIREMIP (fire modelling intercomparison project, Rabin et al. 2016) group as an active end-user actually regularly using various global burned area data including FireCCI data. During the October 2022 annual FIREMIP meeting, FireCCI burned are datasets (FireCCI51, FireCCILT11 and FireCCISFD20) were presented as well as forthcoming objectives. We investigated how this community welcomed the new data and their requests for future developments. Their answers confirmed our bibliographical analysis that GFED4s represents a keystone information for their analysis due the time period covered (since 1997, compared to 2001 or even 2003 for FireCCI51) and the consideration of small fires. The lack of targeted accuracy assessment on small fires in FireCCI51 make the end-user suspicious on how this additional burned area is truly related to actual small fires or an additional artificial and hardly reliable noise. In absence of demonstration of better reliability of FireCCI51 over GFED4s for small fires, the benefit of the longer period provided by GFED4s is the most valuable for their study. However, they actually inserted FireCCI51 as reference dataset in their model benchmarking as we observed in our bibliographical, and they acknowledge the benefit of the uncertainty layer. Based on these numerous datasets available, a feeling of confusion is actually mentioned on how to analyse these datasets separately and merge them to get an inter-product uncertainty value. They are impressed by the recent results coming from the newly delivered FireCCISFD20 in Africa, revisiting their model calibration, and definitely have consideration and trust in this database. They remain unfortunately unable to use it in the present form as it covers only one year in 2019. Any suggestion or dataset to readjust the historical burned area from FireCCI51 to this updated version, would be more than welcome. On the contrary, after provisional local analysis of FireCCILT11, they remain suspicious on the reliability of this database to be used for their model benchmarking in the present form.

The current formats and resolutions (0.25°) are enough regarding the coarse resolution of their models. Until now, the fire patch database is seldom used, as their models are hardly ready to be evaluated at the patch level. However, they encourage the continuing of this development, bringing insights in the fire size distribution, rate of spreads and fire durations, as well as fire intensity (median within the patch) at the global level that might of interest for some models.

5. Synthesis and recommendations

We aimed here at synthesizing the user feedbacks from the FireCCI efforts in providing new burned area datasets to the scientific community. We investigated how the data have been used across various applications, and how they have been evaluated in their local accuracy. This fruitful investigation was complemented by a user survey from the modelling community FIREMIP, an active end user group. Regarding the low usage of FireCCI data in the environmental impacts and fire hazard, we should devote more time in disseminating to this community.

From our analysis, we propose the following recommendations:

- Pixel-level information at 250m (FireCCI51) and 20m (FireCCISFD20) have been highly used and cited as a main recent achievement, revisiting ecosystem functioning and atmospheric impacts associated to fires. Spatial and temporal extension of FireCCISFD20 to the global level, and near real-time updates of FireCCI51 will increase further studies and key findings on fire impacts.

- At the grid level (0.25°), a main goal, if reachable, would be to propose a corrected (even extrapolated with associated uncertainty) BA information accounting for the quality of the FireCCISFD20 for 2019 applied to the long-term coverage of FireCCILT11 or FireCCI51, so that the now acknowledged significant underestimation of coarse resolution BA dataset would be adjusted over the whole 2001-present period.
- A better demonstration of the significant improvement in small fire detection from FireCCI51 compared to GFED4s would better convince the users on the benefits of this dataset. At the grid level (0.25°), extending back to 1997 with a similar approach as GFED4s would also be a significant added value.
- Improvements of the FireCCI51 and forthcoming burned area products in cloudy areas as the tropics or the boreal forest based on local methodological developments would greatly enhance its use for these regions.
- Information on fire severity is one of the new keystone variable requested by users, and initiated in the MOSEV database that should be implemented in the forthcoming global burned area datasets.
- Uncertainty in the burn date was assessed but users would benefit from it being inserted as an additional uncertainty layer at the pixel level. Improvements would be welcome for daily fire weather identification, fire spread, and pixel aggregation into patches.
- A merged product at the pixel-level and grid-level combining the main existing current BA datasets (MCD64A1, GFED4s, FireCCI51) including the inter-product uncertainty would benefit the end-user community, now facing a large panel of information from which they have to choose or perform multiple impact studies.
- Fire patch identification from pixel-level information is a significant side dataset that should be continued and updated with better information on the dating, duration, shapefiles and rate of spread, and ignition point, in an easy to use format (yearly shapefile and attribute table), as well as synthetic information on fire size distribution, mean fire size, intensity, duration/rate of spread at 0.25° or 0.5°.

6. Bibliography

Abdi, A. M., Brandt, M., Abel, C., & Fensholt, R. 2022. Satellite remote sensing of savannas: Current status and emerging opportunities. Journal of Remote Sensing, 2022.

Abdikan S, Bayik C, Sekertekin A, Bektas Balcik F, Karimzadeh S, Matsuoka M, Balik Sanli F. 2022. Burned area detection using multi-sensor SAR, optical, and thermal data in Mediterranean pine forest. Forests. 18;13(2):347.

Achour H, Toujani A, Trabelsi H, Jaouadi W. 2022. Evaluation and comparison of Sentinel-2 MSI, Landsat 8 OLI, and EFFIS data for forest fires mapping. Illustrations from the summer 2017 fires in Tunisia. Geocarto International. 16;37(24):7021-40.

Alonso-González E, Fernández-García V. 2021. MOSEV: a global burn severity database from MODIS (2000–2020). Earth System Science Data.13(5):1925-38.

Andela, N., Morton, D. C., Giglio, L., Paugam, R., Chen, Y., Hantson, S., ... & Randerson, J. T. (2019). The Global Fire Atlas of individual fire size, duration, speed and direction. Earth System Science Data, 11(2), 529-552.

Artés, T., Oom, D., De Rigo, D., Durrant, T. H., Maianti, P., Libertà, G., & San-Miguel-Ayanz, J. (2019). A global wildfire dataset for the analysis of fire regimes and fire behaviour. Scientific data, 6(1), 1-11.

Balch JK, St. Denis LA, Mahood AL, Mietkiewicz NP, Williams TM, McGlinchy J, Cook MC.2020. Fired (Fire events delineation): An open, flexible algorithm and database of us fire events derived from the modis burned area product (2001–2019). Remote Sensing. 12(21):3498.

Bar, S, Parida, BR, Pandey, AC, 2020. Landsat-8 and Sentinel-2 based Forest fire burn area mapping using machine learning algorithms on GEE cloud platform over Uttarakhand, Western Himalaya. Remote sensing applications-society and environment.18:100324.DOI10.1016/j.rsase.2020.100324

Bar S, Parida BR, Roberts G, Pandey AC, Acharya P, Dash J. 2021. Spatio-temporal characterization of landscape fire in relation to anthropogenic activity and climatic variability over the Western Himalaya, India. GIScience & Remote Sensing.58(2):281-99.

Bas, S., Debaecker, V., Kocaman, S., Saunier, S., Garcia, K., & Just, D. (2021). Investigations on the Geometric Quality of AVHRR Level 1B Imagery Aboard MetOp-A. PFG–Journal of Photogrammetry, Remote Sensing and Geoinformation Science, 89(6), 519-534.

Bastos, A., O'Sullivan, M.,Ciais, P., Makowski, D., Sitch, S.,Friedlingstein, P., et al. 2020. Sources of uncertainty in regional and globalterrestrial CO2exchange estimates.Global Biogeochemical Cycles,34,e2019GB006393. https://doi.org/10.1029/2019GB006393

Belenguer-Plomer, MA, Chuvieco, E, Tanase, MA. 2019a. Temporal Decorrelation of C-Band Backscatter Coefficient in Mediterranean Burned Areas. Remote Sensing. 11(22):2661. DOI10.3390/rs11222661

Belenguer-Plomer, MA, Tanase, MA, Fernandez-Carrillo, A, Chuvieco, E. 2019b. Burned area detection and mapping using Sentinel-1 backscatter coefficient and thermal anomalies. Remote Sensing of Environment. 233:111345. DOI10.1016/j.rse.2019.111345.

Belenguer-Plomer MA, Tanase MA, Chuvieco E, Bovolo F. 2021. CNN-based burned area mapping using radar and optical data. Remote Sensing of Environment. 260:112468.

Bilbao, B, Mistry, J, Millan, A, Berardi, A, 2019. Sharing Multiple Perspectives on Burning: Towards a Participatory and Intercultural Fire Management Policy in Venezuela, Brazil, and Guyana. Fire. 2(3):39. DOI10.3390/fire2030039

Boschetti, L, Roy, DP, Giglio, L, Huang, HY, Zubkova, M, Humber, ML.. 2019. Global validation of the collection 6 MODIS burned area product. Remote Sensing of environment. 235:111490. DOI10.1016/j.rse.2019.111490

Bowman, D, Williamson, G, Yebra, M, Lizundia-Loiola, J, Pettinari, ML, Shah, S, Bradstock, R, Chuvieco, E. 2020. Wildfires: Australia needs national monitoring agency. 584, 7820 :188-191. DOI10.1038/d41586-020-02306-4

Brennan, J, Gomez-Dans, JL, Disney, M, Lewis, P. 2019. Theoretical uncertainties for global satellite-derived burned area estimates. Biogeosciences. 16(16): 3147-3164. DOI10.5194/bg-16-3147-2019

Campagnolo, ML, Oom, D, Padilla, M, Pereira, JMC. 2019. A patch-based algorithm for global and daily burned area mapping. Remote Sensing of Environment. 232:111288. DOI10.1016/j.rse.2019.111288.

Campagnolo ML, Libonati R, Rodrigues JA, Pereira JM. 2021. A comprehensive characterization of MODIS daily burned area mapping accuracy across fire sizes in tropical savannas. Remote Sensing of Environment. 252:112115.

Castro, I., Stan, A. B., Taiqui, L., Schiefer, E., Ghallab, A., Derak, M., & Fulé, P. Z. 2022. Detecting Fire-Caused Forest Loss in a Moroccan Protected Area. Fire, 5(2), 51.

Cazzolla-Gatti RC, Velichevskaya A, Dudko A, Fabbio L, Notarnicola C. 2021. The smokescreen of Russian protected areas. Science of The Total Environment. 785:147372.

Chen, AP Tang, RY Mao, JF Yue, C Li, XR Gao, MD Shi, XY Jin, MZ Ricciuto, D Rabin, S Ciais, P Piao, SL 2020. Spatiotemporal dynamics of ecosystem fires and biomass burning-induced carbon emissions in China over the past two decades. Geography and sustainability. 1 (1): 47-58. DOI10.1016/j.geosus.2020.03.002

Chen D, Shevade V, Baer A, Loboda TV. 2021.Missing Burns in the High Northern Latitudes: The Case for Regionally Focused Burned Area Products. Remote Sensing. 13(20):4145. https://doi.org/10.3390/rs13204145.

Chen, Y., Hantson, S., Andela, N., Coffield, S. R., Graff, C. A., Morton, D. C., ... & Randerson, J. T. 2022a. California wildfire spread derived using VIIRS satellite observations and an object-based tracking system. Scientific data, 9(1), 1-15.

Chen J, Zheng W, Wu S, Liu C, Yan H. 2022b. Fire Monitoring Algorithm and Its Application on the Geo-Kompsat-2A Geostationary Meteorological Satellite. Remote Sensing.14(11):2655.

Chuvieco E., Yue C., Heil A., Mouillot F, Alonso-Canas I., Padilla M., Pereira J. M., Oom D., Tansey K. 2016. A new global burned area product for climate assessment of fire impacts. Global Ecology and Biogeography, 25 (5), p. 619-629. ISSN 1466-822X. https://doi.org/10.1111/geb.12440C

Chuvieco E., Lizundia-Loiola J., Pettinari M. L., Ramo R., Padilla M., Tansey K., Mouillot Florent, Laurent P., Storm T., Heil A., Plummer S. 2018. Generation and analysis of a new global burned area product based on MODIS 250 m reflectance bands and thermal anomalies. Earth System Science Data, 10 (4), p. 2015-2031. https://doi.org/10.5194/essd-10-2015-2018

Chuvieco, E, Mouillot, F, van der Werf, GR, San Miguel, J, Tanase, M, Koutsias, N, Garcia, M, Yebra, M, Padilla, M, Gitas, I, Heil, A, Hawbaker, TJ, Giglio, L. 2019. Historical background and current developments for mapping burned area from satellite Earth observation. Remote Sensing of Environment. 225:45-64. DOI10.1016/j.rse.2019.02.013

Chuvieco E, Aguado I, Salas J, García M, Yebra M, Oliva P. 2020. Satellite remote sensing contributions to wildland fire science and management. Current Forestry Reports. 6(2):81-96.

Chuvieco E, Roteta E, Sali M, Stroppiana D, Boettcher M, Kirches G, Storm T, Khairoun A, Pettinari ML, Franquesa M, Albergel C. 2022. Building a small fire database for Sub-Saharan Africa from Sentinel-2 high-resolution images. Sci Total Environ. 1;845:157139. doi: 10.1016/j.scitotenv.2022.157139.

Correa DB, Alcântara E, Libonati R, Massi KG, Park E. 2022. Increased burned area in the Pantanal over the past two decades. Science of The Total Environment. 835:155386.

Curt T., Aissa A., Dupire S. 2020. Fire activity in Mediterranean forests: the Algerian case. Fire 3(4):58.

Daldegan, G. A., Roberts D.A., and de Figueiredo Ribeiro F.. 2019. Spectral mixture analysis in Google Earth Engine to model and delineate fire scars over a large extent and a long time-series in a rainforest-savanna transition zone. Remote Sensing of Environment 232: 111340.

da Silva Júnior, L. A. S., Delgado, R. C., Pereira, M. G., Teodoro, P. E., & da Silva Junior, C. A. (2019). Fire dynamics in extreme climatic events in western amazon. Environmental Development, 32, 100450.

de Bem PP, de Carvalho Júnior OA, de Carvalho OL, Gomes RA, Fontes Guimarães R. 2020. Performance analysis of deep convolutional autoencoders with different patch sizes for change detection from burnt areas. Remote Sensing. 12(16):2576.

de Keersmaecker W, Rodríguez-Sánchez P, Milencović M, Herold M, Reiche J, Verbesselt J. 2022. Evaluating recovery metrics derived from optical time series over tropical forest ecosystems. Remote Sensing of Environment. 274:112991.

de Andrés, E. G., Shestakova, T. A., Scholten, R. C., Delcourt, C. J., Gorina, N. V., & Camarero, J. J. (2022). Changes in tree growth synchrony and resilience in Siberian Pinus sylvestris forests are modulated by fire dynamics and ecohydrological conditions. Agricultural and Forest Meteorology, 312, 108712.

De Luca, G., Silva, J. M., & Modica, G. (2021). A workflow based on Sentinel-1 SAR data and open-source algorithms for unsupervised burned area detection in Mediterranean ecosystems. GIScience & Remote Sensing, 58(4), 516-541.

de Paula, MD, Gimenez, MG, Niamir, A, Thurner, M, Hickler, T. 2020. Combining European Earth Observation products with Dynamic Global Vegetation Models for estimating Essential Biodiversity Variables. International journal of digital earth. 13(2):262-277. DOI10.1080/17538947.2019.1597187

Descals, A., Gaveau, D. L., Verger, A., Sheil, D., Naito, D., & Peñuelas, J. (2022). Unprecedented fire activity above the Arctic Circle linked to rising temperatures. Science, 378(6619), 532-537.

Di Giuseppe F, Benedetti A, Coughlan R, Vitolo C, Vuckovic M. A. 2021. Global Bottom-Up Approach to Estimate Fuel Consumed by Fires Using Above Ground Biomass Observations. Geophysical Research Letters. 48(21):e2021GL095452.

Dixon DJ, Callow JN, Duncan JM, Setterfield SA, Pauli N. 2022. Regional-scale fire severity mapping of Eucalyptus forests with the Landsat archive. Remote Sensing of Environment. 270:112863.

Dong X, Li F, Lin Z, Harrison SP, Chen Y, Kug JS. 2021. Climate influence on the 2019 fires in Amazonia. Science of the Total Environment. 794:148718.

Ermitao T, Gouveia CM, Bastos A, Russo AC. 2022. Interactions between hot and dry fuel conditions and vegetation dynamics in the 2017 fire season in Portugal. Environmental Research Letters. 17(9):095009.

Farhadi, H., Mokhtarzade, M., Ebadi, H., & Beirami, B. A. 2022. Rapid and automatic burned area detection using sentinel-2 time-series images in google earth engine cloud platform: a case study over the Andika and Behbahan Regions, Iran. Environmental Monitoring and Assessment, 194(5), 1-19

Fernández-Manso A, Quintano C. 2020. A synergetic approach to burned area mapping using maximum entropy modeling trained with hyperspectral data and VIIRS hotspots. Remote Sensing. 12(5):858.

Fidelis, A., Alvarado, S. T., Barradas, A. C. S., & Pivello, V. R. (2018). The year 2017: Megafires and management in the Cerrado. Fire, 1(3), 49.

Filipponi, F. 2019. Exploitation of Sentinel-2 Time Series to Map Burned Areas at the National Level: A Case Study on the 2017 Italy Wildfires. Remote Sensing. 11(6):622. DOI10.3390/rs11060622

Franquesa M, Vanderhoof MK, Stavrakoudis D, Gitas IZ, Roteta E, Padilla M, Chuvieco E. 2020. Development of a standard database of reference sites for validating global burned area products. Earth System Science Data. 12(4):3229-46.

Franquesa M, Lizundia-Loiola J, Stehman SV, Chuvieco E. 2022a. Using long temporal reference units to assess the spatial accuracy of global satellite-derived burned area products. Remote Sensing of Environment. 269:112823.

Franquesa M, Stehman SV, Chuvieco E. 2022b. Assessment and characterization of sources of error impacting the accuracy of global burned area products. Remote Sensing of Environment. 280:113214.

Forkel, M, Druke, M, Thurner, M, Dorigo, W, Schaphoff, S, Thonicke, K, von Bloh, W., Carvalhais, N. 2019a. Constraining modelled global vegetation dynamics and carbon turnover using multiple satellite observations. Scientific reports. 9: 18757.DOI10.1038/s41598-019-55187-7.

Forkel, M, Dorigo, W, Lasslop, G, Chuvieco, E, Hantson, S, Heil, A, Teubner, I, Thonicke, K , Harrison, SP. 2019b. Recent global and regional trends in burned area and their compensating environmental controls. Environmental research communications. 1(5):051005. DOI10.1088/2515-7620/ab25d2.

Forkel, M, Andela, N, Harrison, SP, Lasslop, G, van Marle, M, Chuvieco, E, Dorigo, W, Forrest, M, Hantson, S, Heil, A, Li, F , Melton, J, Sitch, S, Yue, C, Arneth, A. 2019c. Emergent relationships with respect to burned area in global satellite observations and fire-enabled vegetation models. Biogeosciences. 16(1):57-76. DOI10.5194/bg-16-57-2019

Gajardo J, Mora M, Valdés-Nicolao G, Carrasco-Benavides M. 2021. Burned Area Classification Based on Extreme Learning Machine and Sentinel-2 Images. Applied Sciences. 12(1):9.

Galizia, L. F., Curt, T., Barbero, R., & Rodrigues, M. 2021a. Assessing the accuracy of remotely sensed fire datasets across the southwestern Mediterranean Basin. Natural Hazards and Earth System Sciences, 21(1), 73-86.

Galizia, L. F., Curt, T., Barbero, R., & Rodrigues, M. 2021b. Understanding fire regimes in Europe. International Journal of Wildland Fire, 31(1), 56-66.

Ganem KA, Xue Y, Rodrigues AD, Franca-Rocha W, Oliveira MT, Carvalho NS, Cayo EY, Rosa MR, Dutra AC, Shimabukuro YE. 2022. Mapping South America's Drylands through Remote Sensing—A Review of the Methodological Trends and Current Challenges. Remote Sensing. 14(3):736.

García, M., Pettinari, M. L., Chuvieco, E., Salas, J., Mouillot, F., Chen, W., & Aguado, I. 2022. Characterizing Global Fire Regimes from Satellite-Derived Products. Forests, 13(5), 699.

Gaveau, D. L., Descals, A., Salim, M. A., Sheil, D., & Sloan, S. 2021. Refined burned-area mapping protocol using Sentinel-2 data increases estimate of 2019 Indonesian burning. Earth System Science Data, 13(11), 5353-5368.

Genet, M., Daniau, A. L., Mouillot, F., Hanquiez, V., Schmidt, S., David, V., ... & Sánchez-Goñi, M. F. 2021. Modern relationships between microscopic charcoal in marine sediments and fire regimes on adjacent landmasses to refine the interpretation of marine paleofire records: An Iberian case study. Quaternary Science Reviews, 270, 107148.

Giglio, L., Loboda, T., Roy, D. P., Quayle, B. and Justice, C. O. 2009. An active fire based burned area mapping algorithm for the MODIS sensor, Remote Sens. Environ., 113(2), 408–420, doi:10.1016/j.rse.2008.10.006.

Giglio, L., Randerson, J. T., van der Werf, G. R., Kasibhatla, P. S., Collatz, G. J., Morton, D. C. and Defries, R. S. 2010. Assessing variability and long-term trends in burned area by merging multiple satellite fire products, Biogeosciences, 7(3), 1171–1186, doi:10.5194/bg-7-1171-2010.

Giglio, L., Boschetti, L., Roy, D. P., Humber, M. L., & Justice, C. O. 2018a. The Collection 6 MODIS burned area mapping algorithm and product. Remote sensing of environment, 217, 72-85.

Giglio, L., Boschetti, L., Roy, D., Humber, M., Hall, J. V. 2018b Collection 1 VIIRS Burned Area Product User's Guide, Version 1.0. [online] Available from: https://viirsland.gsfc.nasa.gov/PDF/VIIRS_C1_BA_User_Guide_1.0.pdf.

Giglio, L. and Roy, D. P. 2020. 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, Science of Remote Sensing, 2, 100007, https://doi.org/10.1016/j.srs.2020.100007.

Giglio, L., & Roy, D. P. 2022. Assessment of satellite orbit-drift artifacts in the long-term AVHRR FireCCILT11 global burned area data set. Science of Remote Sensing, 5, 100044.

Glushkov, I., Zhuravleva, I., McCarty, J. L., Komarova, A., Drozdovsky, A., Drozdovskaya, M., ... & Prishchepov, A. V. 2021. Spring fires in Russia: Results from participatory burned area mapping with Sentinel-2 imagery. Environmental Research Letters, 16(12), 125005.

Guo, M., Li, J., Yu, F., Yin, S., Huang, S., & Wen, L. 2021. Estimation of post-fire vegetation recovery in boreal forests using solar-induced chlorophyll fluorescence (SIF) data. International Journal of Wildland Fire, 30(5), 365-377.

Hall, J. V., Argueta, F., & Giglio, L. 2021. Validation of MCD64A1 and FireCCI51 cropland burned area mapping in Ukraine. International Journal of Applied Earth Observation and Geoinformation, 102, 102443.

Hantson S. Arneth A., Harrison S., Kelley D.I., Prentince I.C., Rabin S.S., Archibald S., Mouillot F., Arnold S.R., Artao P., Bachelet D., Ciais P., Forrest M., Firedlingstein P., Hickler T., Kaplan J.O., Kloster S., Knorr W., Lasslop G., Li F., Mangeon S., Melton S., Meyn A., Sitch S., Spessa A., van der Werf G., Voulgarakis A., Yue C. 2016. The status and challenge of global fire modelling. Biogeosciences 13(11):3359-3375.

Hantson S, Kelley DI, Arneth A, Harrison SP, Archibald S, Bachelet D, Forrest M, Hickler T, Lasslop G, Li F, Mangeon S. 2020. Quantitative assessment of fire and vegetation properties in simulations with fire-enabled vegetation models from the Fire Model Intercomparison Project. Geoscientific Model Development. 13(7):3299-318.

Harrison SP, Prentice IC, Bloomfield KJ, Dong N, Forkel M, Forrest M, Ningthoujam RK, Pellegrini A, Shen Y, Baudena M, Cardoso AW. 2021. Understanding and modelling wildfire regimes: an ecological perspective. Environmental Research Letters. 16(12):125008.

Haas, O., Prentice, I. C., & Harrison, S. P. (2022). Global environmental controls on wildfire burnt area, size, and intensity. Environmental Research Letters, 17(6), 065004.

Hao, W. M., Reeves, M. C., Baggett, L. S., Balkanski, Y., Ciais, P., Nordgren, B. L., ... & Yue, C. (2021). Wetter environment and increased grazing reduced the area burned in northern Eurasia from 2002 to 2016. Biogeosciences, 18(8), 2559-2572.

Hawbaker TJ, Vanderhoof MK, Schmidt GL, Beal YJ, Picotte JJ, Takacs JD, Falgout JT, Dwyer JL. 2020. The Landsat Burned Area algorithm and products for the conterminous United States. Remote Sensing of Environment. 1;244:111801.

Huot, F., Hu, R. L., Goyal, N., Sankar, T., Ihme, M., & Chen, Y. F. (2022). Next Day Wildfire Spread: A Machine Learning Dataset to Predict Wildfire Spreading From Remote-Sensing Data. IEEE Transactions on Geoscience and Remote Sensing, 60, 1-13.

Humber, ML, Boschetti, L., Giglio, L. 2019. Assessing the Shape Accuracy of Coarse Resolution Burned Area Identifications. IEEE transactions on geoscience and remote sensing. 58(3): 1516-1526. DOI10.1109/TGRS.2019.2943901

Humber M., Zubkova M., Giglio L. 2022. A remote sensing-based approach to estimating the fire spread rate parameter for individual burn patch extraction. International Journal of Remote Sensing 43 (2), 649-673.

Jiao, M., Quan, X., & Yao, J. 2022. Evaluation of Four Satellite-Derived Fire Products in the Fire-Prone, Cloudy, and Mountainous Area Over Subtropical China. IEEE Geoscience and Remote Sensing Letters, 19, 1-5.

Jones MW, Abatzoglou JT, Veraverbeke S, Andela N, Lasslop G, Forkel M, Smith AJ, Burton C, Betts RA, van der Werf GR, Sitch S. 2022. Global and regional trends and drivers of fire under climate change. Reviews of Geophysics. e2020RG000726.

Karthik V, Bhaskar BV, Ramachandran S, Gertler AW. 2022. Quantification of organic carbon and black carbon emissions, distribution, and carbon variation in diverse vegetative ecosystems across India. Environmental Pollution. 309:119790.

Katagis T, Gitas IZ. 2022. Assessing the Accuracy of MODIS MCD64A1 C6 and FireCCI51 Burned Area Products in Mediterranean Ecosystems. Remote Sensing.14(3):602.

Knopp L, Wieland M, Rättich M, Martinis S. 2020. A deep learning approach for burned area segmentation with Sentinel-2 data. Remote Sensing. 12(15):2422.

Kong X, Wang X, Jia M, Li Q. 2022. Estimating the Carbon Emissions of Remotely Sensed Energy-Intensive Industries Using VIIRS Thermal Anomaly-Derived Industrial Heat Sources and Auxiliary Data. Remote Sensing. 14(12):2901.

Konko Y, Afelu B, Kokou K. 2021. Potentialité des données satellitaires Sentinel-2 pour la cartographie de l'impact des feux de végétation en Afrique tropicale: application au Togo. BOIS & FORETS DES TROPIQUES. 347:59-73.

Kurbanov E, Vorobev O, Lezhnin S, Sha J, Wang J, Li X, Cole J, Dergunov D, Wang Y. 2022. Remote sensing of forest burnt area, burn severity, and post-fire recovery: a review. Remote Sensing. 14(19):4714.

Lasslop G, Hantson S, Harrison SP, Bachelet D, Burton C, Forkel M, Forrest M, Li F, Melton JR, Yue C, Archibald S. 2020. Global ecosystems and fire: Multi-model assessment of fire-induced tree-cover and carbon storage reduction. Global Change Biology. 26(9):5027-41

Lasslop, G, Coppola, AI, Voulgarakis, A, Yue, C, Veraverbeke, S. 2019. Influence of Fire on the Carbon Cycle and Climate. Current climate change reports. 5(2):112-123. DOI10.1007/s40641-019-00128-9

Laurent P., Mouillot F., Yue C., Ciais P., Moreno M.V., Nogueira J.M.P. 2018. FRY: a global database of fire patch functional traits derived space-borne burned area products. Scientific data 5:180132.

Laurent P. Mouillot F., Moreno M.V., Yue C., Ciais P. 2019. Varying relationships between fire radiative power and fire size at a global scale. Biogeosciences 16(2):275-288.

Li, P., Xiao, C., Feng, Z., Li, W., & Zhang, X. 2020. Occurrence frequencies and regional variations in Visible Infrared Imaging Radiometer Suite (VIIRS) global active fires. Global change biology, 26(5), 2970-2987.

Li, F Lawrence, DM Jiang, Liu, Lin, ZD 2022a. Fire Aerosols Slow Down the Global Water Cycle. Journal of Climate 35 :22,3619-3633. DOI10.1175/JCLI-D-21-0817.1

Li, S., Rifai, S., Anderson, L. O., & Sparrow, S. 2022b. Identifying local-scale meteorological conditions favorable to large fires in Brazil. Climate Resilience and Sustainability, 1(1), e11.

Lindersson, S, Brandimarte, L, Mard, J, Di Baldassarre, G. 2020. A review of freely accessible global datasets for the study of floods, droughts and their interactions with human societies. Wiley interdisciplinary reviews-water.7(3):e1424. DOI10.1002/wat2.1424

Lizundia-Loiola, J, Oton, G, Ramo, R, Chuvieco, E. 2020a. A spatio-temporal active-fire clustering approach for global burned area mapping at 250 m from MODIS data. Remote Sensing of environment. 236:111493. DOI10.1016/j.rse.2019.111493

Lizundia-Loiola, J, Pettinari, ML, Chuvieco, E. 2020b. Temporal Anomalies in Burned Area Trends: Satellite Estimations of the Amazonian 2019 Fire Crisis. Remote sensing 12(1): 151. DOI10.3390/rs12010151.

Lizundia-Loiola J, Franquesa M, Boettcher M, Kirches G, Pettinari ML, Chuvieco E. 2021. Implementation of the Burned Area Component of the Copernicus Climate Change Service: From MODIS to OLCI Data. Remote Sensing. 26;13(21):4295.

Lizundia-Loiola, J, Franquesa, M, Khairoun, A , Chuvieco, E. 2022. Global burned area mapping from Sentinel-3 Synergy and VIIRS active fires. Remote sensing of environment. 282: 113298. DOI10.1016/j.rse.2022.113298

Liu J, Wang D, Maeda EE, Pellikka PK, Heiskanen J. 2021. Mapping Cropland Burned Area in Northeastern China by Integrating Landsat Time Series and Multi-Harmonic Model. Remote Sensing. 13(24):5131.

Long, TF, Zhang, ZM, He, GJ, Jiao, WL, Tang, C, Wu, BF, Zhang, XM, Wang, GZ, Yin, RY. 2019. 30 m Resolution Global Annual Burned Area Mapping Based on Landsat Images and Google Earth Engine. Remote Sensing. 11(5):489. DOI10.3390/rs11050489

Lourenco, M; Woodborne, S and Fitchett, JM, 2023. Fire regime of peatlands in the Angolan Highlands. Env. Monitoring and assessment. 195 (1).

Machida WS, Gomes L, Moser P, Castro IB, Miranda SC, da Silva-Júnior MC, Bustamante MM. Long term post-fire recovery of woody plants in savannas of central Brazil. 2021. Forest Ecology and Management. 493:119255.

Mahood AL, Lindrooth EJ, Cook MC, Balch JK. 2022. Country-level fire perimeter datasets (2001–2021). Scientific data.9(1):1-8.

Majdalani G., Koutsias N., Faour G., Adjizian-Gerard J., Mouillot F. 2022. Fire regime analysis in Lebanon (2001-2020): combining remote sensing data in scarcely documented area. Fire 5(5):141.

Mayr, S, Kuenzer, C, Gessner, U, Klein, I, Rutzinger, M. 2019. Validation of Earth Observation Time-Series: A Review for Large-Area and Temporally Dense Land Surface Products. Remote Sensing. 11(22): 2616. DOI10.3390/rs11222616

Meng M, Gong D. 2022. Winter North Atlantic SST as a Precursor of Spring Eurasian Wildfire. Geophysical Research Letters. 49(18):e2022GL099920.

Mignan, A. 2022. Categorizing and Harmonizing Natural, Technological, and Socio-Economic Perils Following the Catastrophe Modeling Paradigm. International Journal of Environmental Research and Public Health, 19(19), 12780.

Millington, J. D., Perkins, O., & Smith, C. 2022. Human Fire Use and Management: A Global Database of Anthropogenic Fire Impacts for Modelling. Fire, 5(4), 87.

Miranda A, Mentler R, Moletto-Lobos Í, Alfaro G, Aliaga L, Balbontín D, Barraza M, Baumbach S, Calderón P, Cárdenas F, Castillo I. 2022. The Landscape Fire Scars

Database: mapping historical burned area and fire severity in Chile. Earth System Science Data. 14(8):3599-613.

Moreno, M. V., Laurent, P., & Mouillot, F. 2021. Global intercomparison of functional pyrodiversity from two satellite sensors. International Journal of Remote Sensing, 42(24), 9523-9541.

Moreno MV, Laurent P, Ciais P, Mouillot F. Assessing satellite-derived fire patches with functional diversity trait methods. Remote Sensing of Environment. 2020 Sep 15;247:111897.

Moreno-Ruiz JA, García-Lázaro JR, Arbelo M, Cantón-Garbín M. 2020. MODIS Sensor Capability to Burned Area Mapping—Assessment of Performance and Improvements Provided by the Latest Standard Products in Boreal Regions. Sensors. 20(18):5423.

Moreno-Ruiz, JA, Garcia-Lazaro, JR, Arbelo, M, Riano, D. 2019. A Comparison of Burned Area Time Series in the Alaskan Boreal Forests from Different Remote Sensing Products. Forests.10(5):363. DOI10.3390/f10050363

Oton, G, Ramo, R, Lizundia-Loiola, J, Chuvieco, E. 2019. Global Detection of Long-Term (1982-2017) Burned Area with AVHRR-LTDR Data. Remote Sensing. 11(18):2079. DOI10.3390/rs11182079

Otón G, Pereira JM, Silva JM, Chuvieco E. 2021a. Analysis of trends in the firecci global long term burned area product (1982–2018). Fire. 4(4):74.

Otón G, Lizundia-Loiola J, Pettinari ML, Chuvieco E. 2021b. Development of a consistent global long-term burned area product (1982–2018) based on AVHRR-LTDR data. International Journal of Applied Earth Observation and Geoinformation 103(10):102473 https://doi.org/10.1016/j.jag.2021.102473

Pacheco AD, Junior JA, Ruiz-Armenteros AM, Henriques RF. 2021. Assessment of k-nearest neighbor and random forest classifiers for mapping forest fire areas in central portugal using landsat-8, sentinel-2, and terra imagery. Remote Sensing.13(7):1345.

Pausas, J. G. 2022. Pyrogeography across the western Palaearctic: A diversity of fire regimes. Global Ecology and Biogeography, 31(10), 1923-1932.

Peng, J., Wu, C., Wang, X., & Lu, L. (2021). Spring phenology outweighed climate change in determining autumn phenology on the Tibetan Plateau. International Journal of Climatology, 41(6), 3725-3742.

Pereira G, Longo KM, Freitas SR, Mataveli G, Oliveira VJ, Santos PR, Rodrigues LF, Cardozo FS. 2022. Improving the south America wildfires smoke estimates: Integration of polar-orbiting and geostationary satellite fire products in the Brazilian biomass burning emission model (3BEM). Atmospheric Environment. 273:118954.

Pessôa AC, Anderson LO, Carvalho NS, Campanharo WA, Junior CH, Rosan TM, Reis JB, Pereira FR, Assis M, Jacon AD, Ometto JP. 2020. Intercomparison of burned area products and its implication for carbon emission estimations in the amazon. Remote Sensing. 12(23):3864.

Pinto MM, Trigo RM, Trigo IF, DaCamara CC. 2021. A practical method for high-resolution burned area monitoring using sentinel-2 and viirs. Remote Sensing. 13(9):1608.

Pinto, MM Libonati, R Trigo, RM Trigo, IF DaCamara, CC. 2020. A deep learning approach for mapping and dating burned areas using temporal sequences of satellite images. ISPRS journal of photogrammetry and remote sensing. 160:260-274. DOI10.1016/j.isprsjprs.2019.12.014

Rabin, S. S., Melton, J. R., Lasslop, G., Bachelet, D., Forrest, M., Hantson, S., Kaplan, J. O., Li, F., Mangeon, S., Ward, D. S., Yue, C., Arora, V. K., Hickler, T., Kloster, S., Knorr, W., Nieradzik, L., Spessa, A., Folberth, G. A., Sheehan, T., Voulgarakis, A., Kelley, D. I., Prentice, I. C., Sitch, S., Harrison, S., and Arneth, A.: The Fire Modeling Intercomparison Project (FireMIP), phase 1: experimental and analytical protocols with detailed model descriptions, Geosci. Model Dev., 10, 1175–1197, https://doi.org/10.5194/gmd-10-1175-2017, 2017.

Ramo, R Roteta, E Bistinas, I van Wees, D Bastarrika, A Chuvieco, E van der Werf, GR. 2021. African burned area and fire carbon emissions are strongly impacted by small fires undetected by coarse resolution satellite data. Proceedings of the National Academy of Sciences 118(9):e2011160118.

Randerson, J. T., Chen, Y., van der Werf, G. R., Rogers, B. M., Morton, D. C. 2012.Global burned area and biomass burning emissions from small fires, J. Geophys. Res., 117, G04012, doi:10.1029/2012JG002128.

Reddy CS, Sarika N. 2022. Monitoring trends in global vegetation fire hot spots using MODIS data. Spatial Information Research. 30(5):617-32.

Rodrigues, JA, Libonati, R, Pereira, AA, Nogueira, JMP, Santos, FLM, Peres, LF, Santa Rosa, A, Schroeder, W, Pereira, JMC, Giglio, L, Trigo, IF, Setzer, AW. 2019. How well do global burned area products represent fire patterns in the Brazilian Savannas biome? An accuracy assessment of the MCD64 collections. International journal of Applied earth observation and geoinformation. 78:318-331. DOI10.1016/j.jag.2019.02.010

Romanov AA, Tamarovskaya AN, Gloor E, Brienen R, Gusev BA, Leonenko EV, Vasiliev AS, Krikunov EE. 2022. Reassessment of carbon emissions from fires and a new estimate of net carbon uptake in Russian forests in 2001–2021. Science of The Total Environment. 846:157322.

Roteta, E, Bastarrika, A, Padilla, M, Storm, T, Chuvieco, E. 2019. Development of a Sentinel-2 burned area algorithm: Generation of a small fire database for sub-Saharan Africa. Remote Sensing of environment. 222: 1-17. DOI10.1016/j.rse.2018.12.011

Roteta E, Bastarrika A, Franquesa M, Chuvieco E. 2021a. Landsat and Sentinel-2 based burned area mapping tools in google earth engine. Remote Sensing.13(4):816.

Roteta E, Bastarrika A, Ibisate A, Chuvieco E. 2021b. A Preliminary Global Automatic Burned-Area Algorithm at Medium Resolution in Google Earth Engine. Remote Sensing. 13(21):4298.

Rovithakis A, Grillakis MG, Seiradakis KD, Giannakopoulos C, Karali A, Field R, Lazaridis M, Voulgarakis A. 2022. Future climate change impact on wildfire danger over the Mediterranean: the case of Greece. Environmental Research Letters.17(4):045022.

Roy, D. P., Jin, Y., Lewis, P. E., and Justice, C. O. 2005. Prototyping a global algorithm for systematic fire-affected area mapping using MODIS time series data, Remote Sens. Environ., 97, 137–162.

Roy, D. P., Boschetti, L., Justice, C. O. and Ju, J. 2008. The collection 5 MODIS burned area product - Global evaluation by comparison with the MODIS active fire product, Remote Sens. Environ., 112(9), 3690–3707, doi:10.1016/j.rse.2008.05.013.

Saatchi, S., Longo, M., Xu, L., Yang, Y., Abe, H., Andre, M., ... & Elmore, A. C. 2021. Detecting vulnerability of humid tropical forests to multiple stressors. One Earth, 4(7), 988-1003.

Santos, F. L., Libonati, R., Peres, L. F., Pereira, A. A., Narcizo, L. C., Rodrigues, J. A., ... & Setzer, A. W. 2020. Assessing VIIRS capabilities to improve burned area mapping over the Brazilian Cerrado. International Journal of Remote Sensing, 41(21), 8300-8327.

Santos, F. L., Nogueira, J., Souza, R. A. D., Falleiro, R. M., Schmidt, I. B., & Libonati, R. (2021). Prescribed burning reduces large, high-intensity wildfires and emissions in the Brazilian savanna. Fire, 4(3), 56.

Seiler C, Melton JR, Arora VK, Wang L. 2021. CLASSIC v1. 0: the open-source community successor to the Canadian Land Surface Scheme (CLASS) and the Canadian Terrestrial Ecosystem Model (CTEM)–Part 2: Global benchmarking. Geoscientific Model Development. 14(5):2371-417.

Seydi, S. T., Akhoondzadeh, M., Amani, M., & Mahdavi, S. 2021. Wildfire damage assessment over Australia using sentinel-2 imagery and MODIS land cover product within the google earth engine cloud platform. Remote Sensing, 13(2), 220.

Sharma, S. K., Aryal, J., & Rajabifard, A. 2022. Remote Sensing and Meteorological Data Fusion in Predicting Bushfire Severity: A Case Study from Victoria, Australia. Remote Sensing, 14(7), 1645.xSibley, AM. 2019. Wildfire outbreaks across the United Kingdom during summer 2018. Weather. 74(11):397-402. DOI10.1002/wea.3614

Silva, CHL, Anderson, LO, Silva, AL, Almeida, CT, Dalagnol, R, Pletsch, MAJS, Penha, TV, Paloschi, RJ, Aragao, LEOC. 2019. Fire Responses to the 2010 and 2015/2016 Amazonian Droughts. Frontiers in earth science. 7:97.DOI10.3389/feart.2019.00097

Silva CV, Aragao LE, Young PJ, Espirito-Santo F, Berenguer E, Anderson LO, Brasil I, Pontes-Lopes A, Ferreira J, Withey K, França F. 2020. Estimating the multi-decadal carbon deficit of burned Amazonian forests. Environmental Research Letters. 15(11):114023.

Silva, P. S., Nogueira, J., Rodrigues, J. A., Santos, F. L., Pereira, J. M., DaCamara, C. C., ... & Libonati, R. 2021. Putting fire on the map of Brazilian savanna ecoregions. Journal of Environmental Management, 296, 113098.

Sivrikaya F, Küçük Ö. 2022. Modeling forest fire risk based on GIS-based analytical hierarchy process and statistical analysis in Mediterranean region. Ecological Informatics. 68:101537.

Shiraishi T, Hirata R, Hirano T. 2021. New inventories of global carbon dioxide emissions through biomass burning in 2001–2020. Remote Sensing.13(10):1914.

Sungmin, O, Hou, XY, Orth, R. 2020. Observational evidence of wildfire-promoting soil moisture anomalies. Scientific report. 10(1):11008. DOI10.1038/s41598-020-67530-4

Stroppiana, D., Sali, M., Busetto, L., Boschetti, M., Ranghetti, L., Franquesa, M., ... & Chuvieco, E. 2022. Sentinel-2 sampling design and reference fire perimeters to assess accuracy of Burned Area products over Sub-Saharan Africa for the year 2019. ISPRS Journal of Photogrammetry and Remote Sensing, 191, 223-234.

Takacs, S., Schulte to Bühne, H., & Pettorelli, N. (2021). What shapes fire size and spread in African savannahs?. Remote Sensing in Ecology and Conservation, 7(4), 610-620.

Tanase, MA, Belenguer-Plomer, MA, Roteta, E, Bastarrika, A , Wheeler, J, Fernandez-Carrillo, A, Tansey, K, Wiedemann, W, Navratil, P, Lohberger, S, Siegert, F, Chuvieco, E. 2020. Burned Area Detection and Mapping: Intercomparison of Sentinel-1 and Sentinel-2 Based Algorithms over Tropical Africa. Remote Sensing. 12(2):334. DOI10.3390/rs12020334

Tang R, Mao J, Jin M, Chen A, Yu Y, Shi X, Zhang Y, Hoffman FM, Xu M, Wang Y.2021. Interannual variability and climatic sensitivity of global wildfire activity. Advances in Climate Change Research. 12(5):686-95.

Teckentrup, L, Harrison, SP, Hantson, S, Heil, A, Melton, JR, Forrest, M , Yue, C, Arneth, A., Hickler, T, Sitch, S, Lasslop, G. 2019. Response of simulated burned area to historical changes in environmental and anthropogenic factors: a comparison of seven fire models. Biogeosciences. 16(19):3883-3910. DOI10.5194/bg-16-3883-2019.

Tomshin, O., & Solovyev, V. (2021). Spatio-temporal patterns of wildfires in Siberia during 2001–2020. Geocarto International, 1-19.

Turco, M, Herrera, S, Tourigny, E, Chuvieco, E, Provenzale, A. 2019. A comparison of remotely-sensed and inventory datasets for burned area in Mediterranean Europe. International journal of applied earth observation and geoinformation. 82: 101887. DOI10.1016/j.jag.2019.05.020

Valencia GM, Anaya JA, Velásquez ÉA, Ramo R, Caro-Lopera FJ. 2020. About validation-comparison of burned area products. Remote Sensing. 12(23):3972.

van Marle, M. J., van Wees, D., Houghton, R. A., Field, R. D., Verbesselt, J., & van der Werf, G. (2022). New land-use-change emissions indicate a declining CO2 airborne fraction. Nature, 603(7901), 450-454.

van der Werf, G. R., Randerson, J. T., Giglio, L., van Leeuwen, T. T., Chen, Y., Rogers, B. M., Mu, M., van Marle, M. J. E., Morton, D. C., Collatz, G. J., Yokelson, R. J., and Kasibhatla, P. S.: 2017. Global fire emissions estimates during 1997–2016, Earth Syst. Sci. Data, 9, 697–720, https://doi.org/10.5194/essd-9-697-2017.

van Dijk, D., Shoaie, S., van Leeuwen, T., & Veraverbeke, S. 2021. Spectral signature analysis of false positive burned area detection from agricultural harvests using Sentinel-2 data. International Journal of Applied Earth Observation and Geoinformation, 97, 102296.

Vetrita Y, Cochrane MA, Priyatna M, Sukowati KA, Khomarudin MR. 2021. Evaluating accuracy of four MODIS-derived burned area products for tropical peatland and non-peatland fires. Environmental Research Letters. 16(3):035015.

Wang X, Di Z, Li M, Yao Y. 2021. Satellite-Derived Variation in Burned Area in China from 2001 to 2018 and Its Response to Climatic Factors. Remote Sensing.13(7):1287.

Worden J, Saatchi S, Keller M, Bloom AA, Liu J, Parazoo N, Fisher JB, Bowman K, Reager JT, Fahy K, Schimel D. 2020. Satellite observations of the tropical terrestrial carbon balance and interactions with the water cycle during the 21st century. Review of geophysics 59(1):e2020RG000711

Wozniak, E, Aleksandrowicz, S. 2019. Self-Adjusting Thresholding for Burnt Area Detection Based on Optical Images. Remote Sensing. 11(22):2669. DOI10.3390/rs11222669

Wei, M., Zhang, Z., Long, T., He, G., & Wang, G. 2021. Monitoring Landsat based burned area as an indicator of Sustainable Development Goals. Earth's Future, 9(6), e2020EF001960.

Wu, C., Sitch, S., Huntingford, C., Mercado, L. M., Venevsky, S., Lasslop, G., ... & Staver, A. C. 2022. Reduced global fire activity due to human demography slows global warming by enhanced land carbon uptake. Proceedings of the National Academy of Sciences, 119(20), e2101186119.

Wu C, Venevsky S, Sitch S, Mercado LM, Huntingford C, Staver AC. 2021. Historical and future global burned area with changing climate and human demography. One Earth.4(4):517-30.

Xiao H, Zhang X, Yan M, Zhang L, Wang H, Ma Y, Liu J. 2022. The Temporal-Based Forest Disturbance Monitoring Analysis: A Case Study of Nature Reserves of Hainan Island of China From 1987 to 2020. Frontiers in Environmental Science. 2022:411.

Xu, H., Zhang, G., Zhou, Z., Zhou, X., Zhang, J., & Zhou, C. 2022. Development of a Novel Burned-Area Subpixel Mapping (BASM) Workflow for Fire Scar Detection at Subpixel Level. Remote Sensing, 14(15), 3546.

Xu, X., Jia, G., Zhang, X., Riley, W. J., & Xue, Y. 2020. Climate regime shift and forest loss amplify fire in Amazonian forests. Global change biology, 26(10), 5874-5885.

Yin Y, Bloom AA, Worden J, Saatchi S, Yang Y, Williams M, Liu J, Jiang Z, Worden H, Bowman K, Frankenberg C. 2020. Fire decline in dry tropical ecosystems enhances decadal land carbon sink. Nature communications. 11(1):1-7.

Yuan, Y, Lin, L, Huo, LZ, Kong, YL, Zhou, ZG, Wu, B, Jia, Y. 2020. Using An Attention-Based LSTM Encoder-Decoder Network for Near Real-Time Disturbance Detection. IEEE journal of selected topics in applied earth observation and remote sensing. 13: 1819-1832. DOI10.1109/JSTARS.2020.2988324.

Zanetti, M., Marinelli, D., Bertoluzza, M., Saha, S., Bovolo, F., Bruzzone, L., ... & Costantini, M. 2019. A high resolution burned area detector for Sentinel-2 and Landsat-8. In 2019 10th International Workshop on the Analysis of Multitemporal Remote Sensing Images (MultiTemp) (pp. 1-4). IEEE.

Zhang, Z., Long, T., He, G., Wei, M., Tang, C., Wang, W., ... & Zhang, X. 2020. Study on global burned forest areas based on Landsat data. Photogrammetric Engineering & Remote Sensing, 86(8), 503-508.

Zhang Q, Ge L, Zhang R, Metternicht GI, Du Z, Kuang J, Xu M. 2021. Deep-learning-based burned area mapping using the synergy of Sentinel-1&2 data. Remote Sensing of Environment. 264:112575.

Zhao Z, Lin Z, Li F, Rogers BM. 2022. Influence of atmospheric teleconnections on interannual variability of Arctic-boreal fires. Science of The Total Environment. Art. 156550.

Zhao, G., Cui, X., Sun, J., Li, T., Wang, Q. I., Ye, X., & Fan, B. 2021. Analysis of the distribution pattern of Chinese Ziziphus jujuba under climate change based on optimized biomod2 and MaxEnt models. Ecological Indicators, 132, 108256.

Annex 1: Acronyms and abbreviations

AVHRR	Advanced Very High Resolution Radiometer
BA	Burned Area
CASA	Carnegie-Ames-Stanford-Approach
CCI	Climate Change Initiative
DGVMs	Dynamic Global Vegetation Models
EFFIS	European Forest Fire Information System
ESA	European Space Agency
EU	European Union
FireMIP	Fire Model Intercomparison Project
FIRMS	Fire Information for Resource Management System
FRP	Fire Radiative Power
GFA	Global Fire Atlas
GFED	Global Fire Emissions Database
HS	Hotspot
LTDR	Land Long Term Data Record
m	Metres
MIPs	Model Intercomparison Projects
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
TRMM	Tropical Rainfall Measuring Mission
URD	User Requirements Document
VIIRS	Visible Infrared Imaging Radiometer Suite
WoS	Web of Science