WWF

FIRE COMPASS

Fire Data From Space

Satellite Data in Global Fire Monitoring

IMPRINT

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Fire data from space:

SATELLITE DATA IN GLOBAL FIRE MONITORING

Forest fires have a negative effect on our climate, ecosystems, infrastructure and health. In the context of global warming, with an increase in droughts and changing forest structures, in many regions the risk of forest fires is rising, as is the interest in accurate assessments and effective control.[1]

This requires effective forest monitoring and early warning systems that enable continuous monitoring and provide reliable data for risk assessments as well as for the short- and long-term planning of actions. Satellite-based Earth observation—known as remote sensing—is a key and relatively cost-effective method here. In fact, it is *the* method of choice for the comprehensive, standardised detection and monitoring of fire events across the globe that is repeatable several times a day.

The monitoring of forest fires has changed significantly since the 1970s. For centuries, fire detection relied on local observations, for example by fire lookout towers or patrols.[2] However, the data thus gathered was restricted to individual regions, limiting comparability with data from larger areas. The launch of the first Landsat satellites in the 1970s marked the beginning of the era of satellite-based fire observation, a technology that has since been developed continuously.

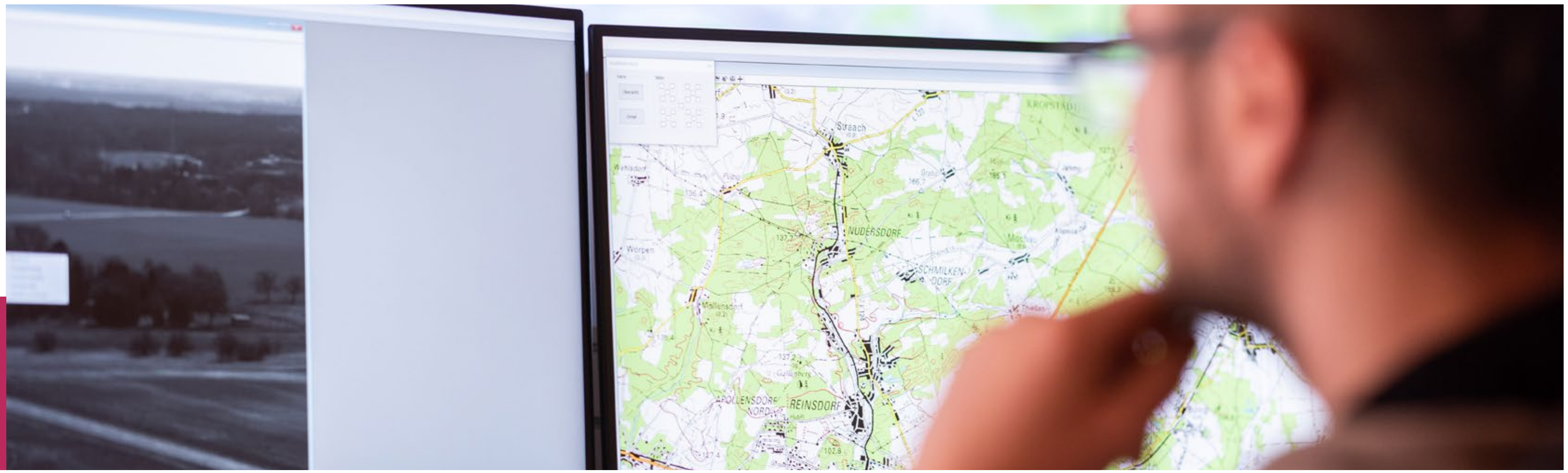
In 2022, the Grafwegen fire lookout tower was removed: surrounded by trees taller than itself, its former function had become obsolete thanks to modern cameras.

Satellite data provide essential information for monitoring fires—from real-time detection to long-term analysis.

Today, satellite sensors such as MODIS (Moderate Resolution Imaging Spectroradiometer), VIIRS (Visible Infrared Imaging Radiometer Suite) and Sentinel provide high-resolution data that support both quasi-real-time monitoring and long-term analysis. Web-based platforms such as EFFIS (European Forest Fire Information System)[3] for Europe or the Global Fire Atlas[4] for global analyses and visualise these data in a user-friendly way.

In Germany, current assessments of forest and wildfires (uncontrolled fires in natural vegetation) generally rely on a combination of satellite-based remote sensing and reports from local authorities. Brandenburg, for example, has established the IQ FireWatch camera system, using more than 100 cameras for rapid fire detection.[5, 6] Satellite systems rely on thermal imaging data to identify active fires; these data are then automatically processed and displayed in systems such as EFFIS, forming an integral part of today's multi-stage fire monitoring practice. Local forestry offices and/or fire brigades confirm the fires and coordinate response operations. The affected areas are subsequently mapped, often using satellite imagery, and incorporated into national and European statistics.

For Germany, active forest fires from the past seven days are also displayed in the W*aldmonitor* (“Forest Monitor”).[7] The lack of a consistent methodology is, however, a major challenge. Many countries still use different systems to compile forest fire statistics and assess the risk of wildfire, and some regions do not even have systematic fire recording yet. This complicates comparisons of national and cross-regional statistics and datasets and, in some cases, limits the ability to make such comparisons altogether. Satellite-based systems, by contrast, offer a uniform methodology and independent data source from which freely available information can be obtained. The chapter of the German version of this publication, entitled *Waldbrände in Deutschland* (“Forest Fires in Germany”), for example, compares national statistics with satellite-based data from EFFIS.



Early detection on-screen:
using 360°cameras, IQ FireWatch can detect even the slightest development of smoke and trigger an alarm.

THE PHYSICAL BASICS OF FIRE DETECTION

The human perception of light covers wavelengths of roughly between 380 nanometres (nm) (blue light) and 780 nanometres (nm) (red light) on the electromagnetic spectrum.[8] Earth observation satellites, on the other hand, use additional wavelength ranges to obtain information about the Earth's surface (Figure 1). In addition to the light visible to the human eye, they are also capable of detecting infrared light (IR) and microwaves (MW). There are two types of sensor systems: passive and active. Passive systems measure the solar radiation reflected from the Earth's surface, which includes visible, near-infrared (NIR) and short-wave infrared (SWIR) light as well as thermal radiation emitted by the Earth in the mid-wave infrared (MWIR) and long-wave infrared (LWIR) ranges. By contrast, active systems such as radars transmit their own electromagnetic pulses and measure the returning signal.

Figure 1 on the next page provides an overview of the different wavelength ranges and the satellites most commonly used for observing fires. Since requirements vary depending on the area of application—such as early detection, monitoring or damage analysis—and imaging technologies come with certain technical limitations, a wide range of specialised satellite systems are in use.

FIGURE 1:
Wavelength ranges and their designations

VIS: Light visible to humans

NIR: Near-infrared

SWIR: Short-wave infrared

MWIR: Mid-wave infrared

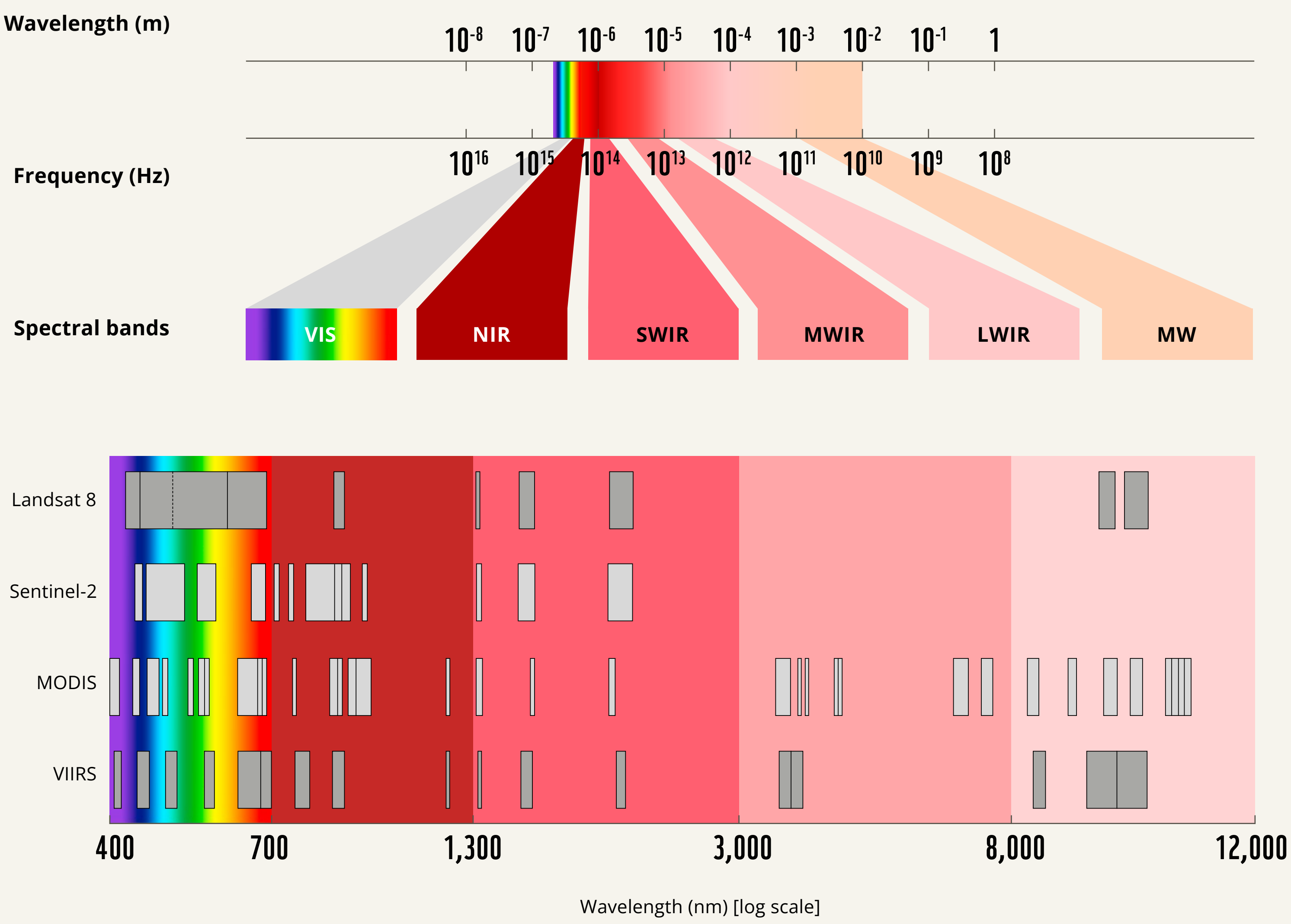
LWIR: Long-wave infrared

MW: Microwaves

The visible range of the electromagnetic spectrum, i.e. the light we can see, covers wavelengths ranging from approximately 380 nm to 780 nm. A nanometre (nm) is one billionth of a metre, i.e. 1 x 10^{-9} metres. The visible range lies between approximately 3.8 x 10^{-7} and 7.8 x 10^{-7} metres.

Key satellites used in fire observation and their spectral characteristics. Each grey bar indicates a wavelength range in which a satellite system records either the solar radiation reflected by the Earth, or the thermal radiation emitted by the Earth's surface.

Source: [9], modified



The better the spatial resolution, the smaller—for technical reasons—the area usually covered by the satellite image and the longer the interval between two images of the same region.

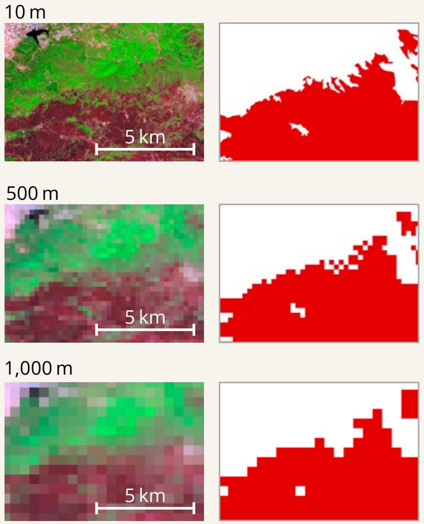


FIGURE 2:
The above images show how the spatial resolution of satellite data effects the mapping of burned areas. As the pixel size increases, and resolution decreases, details disappear and burned areas are only roughly visible.

Source: [14], modified

Passive optical and thermal sensors are the primary tools used for detecting forest fires. In addition to their spectral properties—i.e. which and how many wavelength ranges a satellite can register —satellite sensors also differ in their spatial and temporal resolution. Spatial resolution describes the smallest area a sensor can still distinguish as an individual image element (pixel). The higher the spatial resolution, the more detailed the resulting image (see Figure 2). Temporal resolution indicates how much time has passed between two images of the same region, in other words, how frequently a satellite can observe an area. Depending on the system, this can range from just a few minutes, as with weather satellites, to several weeks, when high-resolution sensors are used. As a rule, the higher the spatial resolution, the smaller the area captured in a single image and the longer the interval between two images which capture the same region. The technology thus currently has its limitations.

In recent years, the shortcomings of low temporal resolution have been reduced through the combined use of data from satellite systems such as Landsat and Sentinel-2. Newer sensor technologies, such as Sentinel-2 and PlanetScope's Dove satellites[10], further mitigate these limitations by employing multiple satellites at the same time.[11] A similar principle has been applied since March 2025, when OroraTech and the German Aerospace Centre (DLR) successfully launched a satellite constellation comprising eight satellites to detect forest fires.[12] Likewise, in the same month the first prototype satellite of the FireSat constellation was launched; operated by non-profit organisation Earth Fire Alliance, this constellation is expected to comprise more than 50 satellites by 2030.[13]

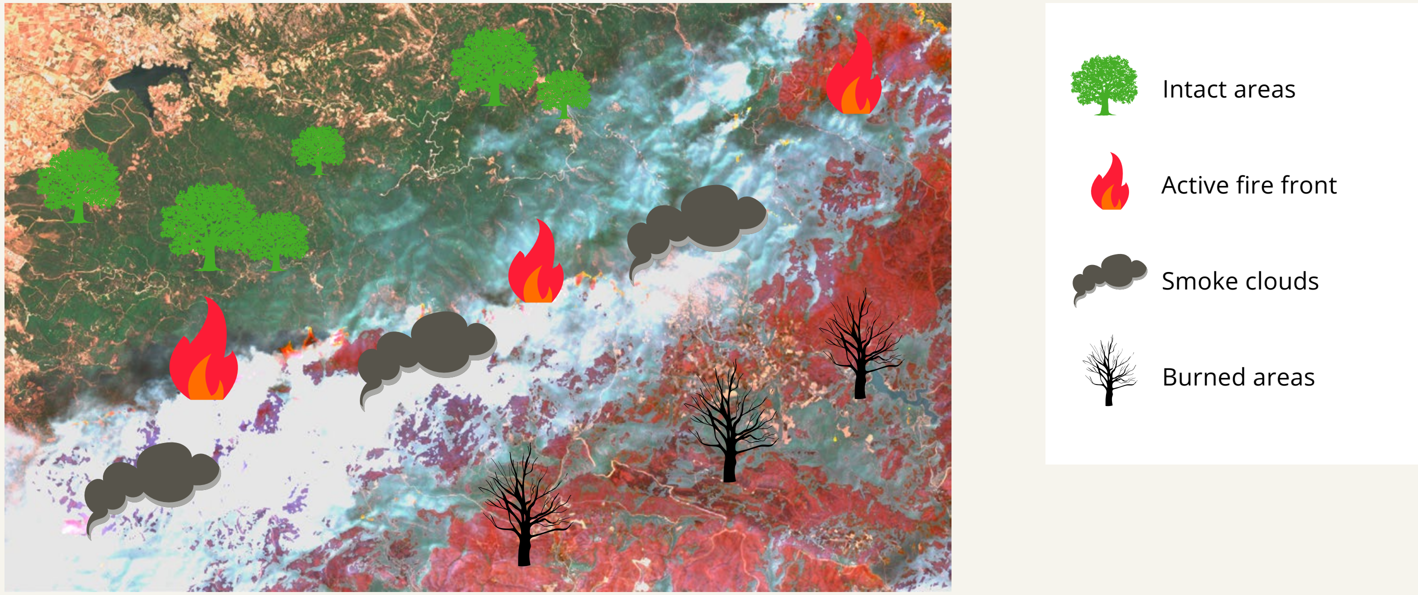
While these developments help detect fires more rapidly, older datasets are still needed to analyse long-term trends. Comparing data from different sources remains challenging as their spatial, spectral and temporal characteristics often differ.

Optical remote sensing makes use of the fact that every type of surface on Earth—such as forests, open soil, water and even fire—reflects sunlight in its own characteristic way. These typical patterns across different wavelengths are known as spectral or reflectance signatures. Much like fingerprints, they help distinguish different surfaces and materials in satellite imagery.

Unlike burned vegetation, healthy vegetation reflects solar radiation very strongly in the near-infrared range. Figure 3 illustrates how fire appears on satellite imagery and compares simulated spectral signatures. Surface fires spread along the ground and are generally less intense. In contrast, crown fires reach the canopy and are associated with much more intense fires; they can cause severe damage to the forest stand. Smoke and combustion products also exhibit distinctive spectral signatures. Dense clouds of smoke, for example, absorb blue light and appear as a grey to brownish colour in optical images, while trace gases such as carbon monoxide "swallow" light in certain wavelength ranges of the infrared spectrum, known as absorption bands.

FIGURE 3:

Top: **satellite image of the fire in Evros, Greece, in August 2023.**
The image combines visible light (band 2, blue, and band 3, green) with short-wave infrared SWIR imaging (band 12) to show the fire front, which was approximately 70 kilometres long at the time the image was captured on 23 August. The smoke cloud extended more than 1,600 kilometres south-westwards towards Tunisia. Burned areas appear in the image as reddish-brown areas.



Bottom: **using the example reflectance signatures of different surfaces, burned areas can be distinguished from other types of surface.**
The differences between healthy vegetation and areas affected by surface or crown fires are clearly visible. As surface fires do not reach the canopy, the reflectance signature shows a mixture of healthy vegetation and charcoal. Crown fires, by contrast, usually consume all vegetation, producing a reflectance signature resembling that of pure ash. In other words, reflectance signatures vary according to the intensity of the fire, allowing conclusions to be drawn about the severity of the fire.

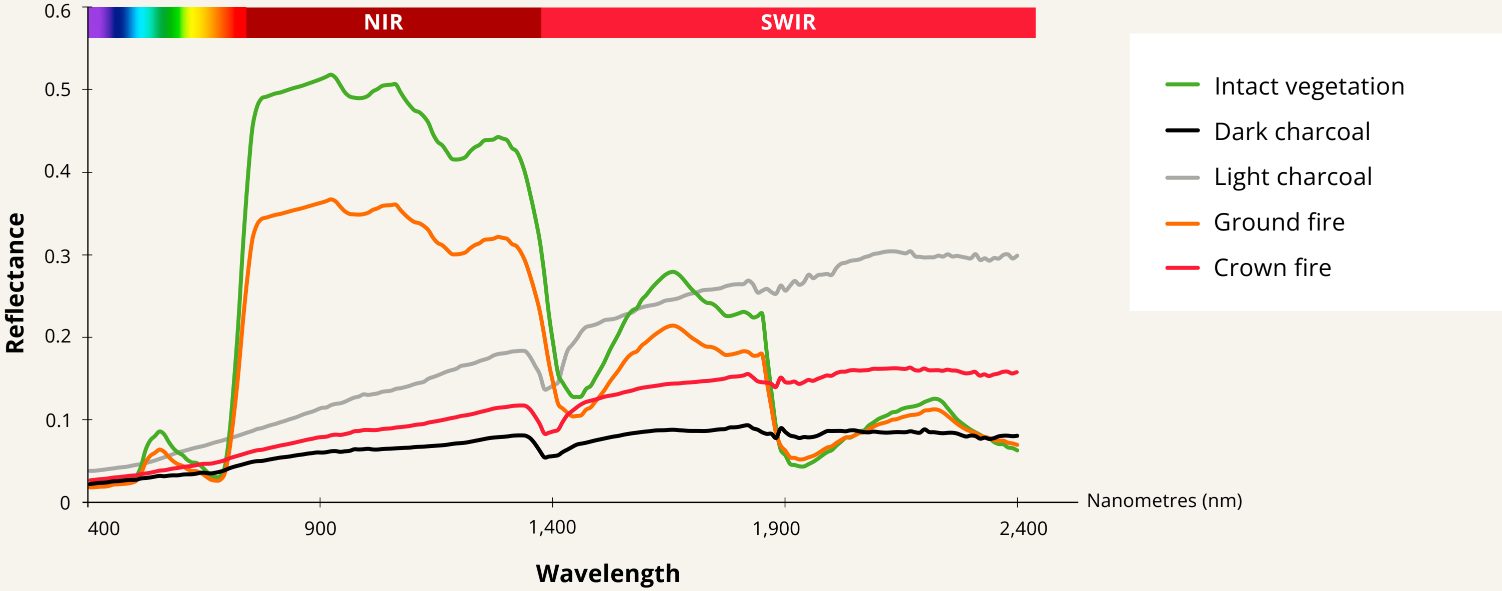
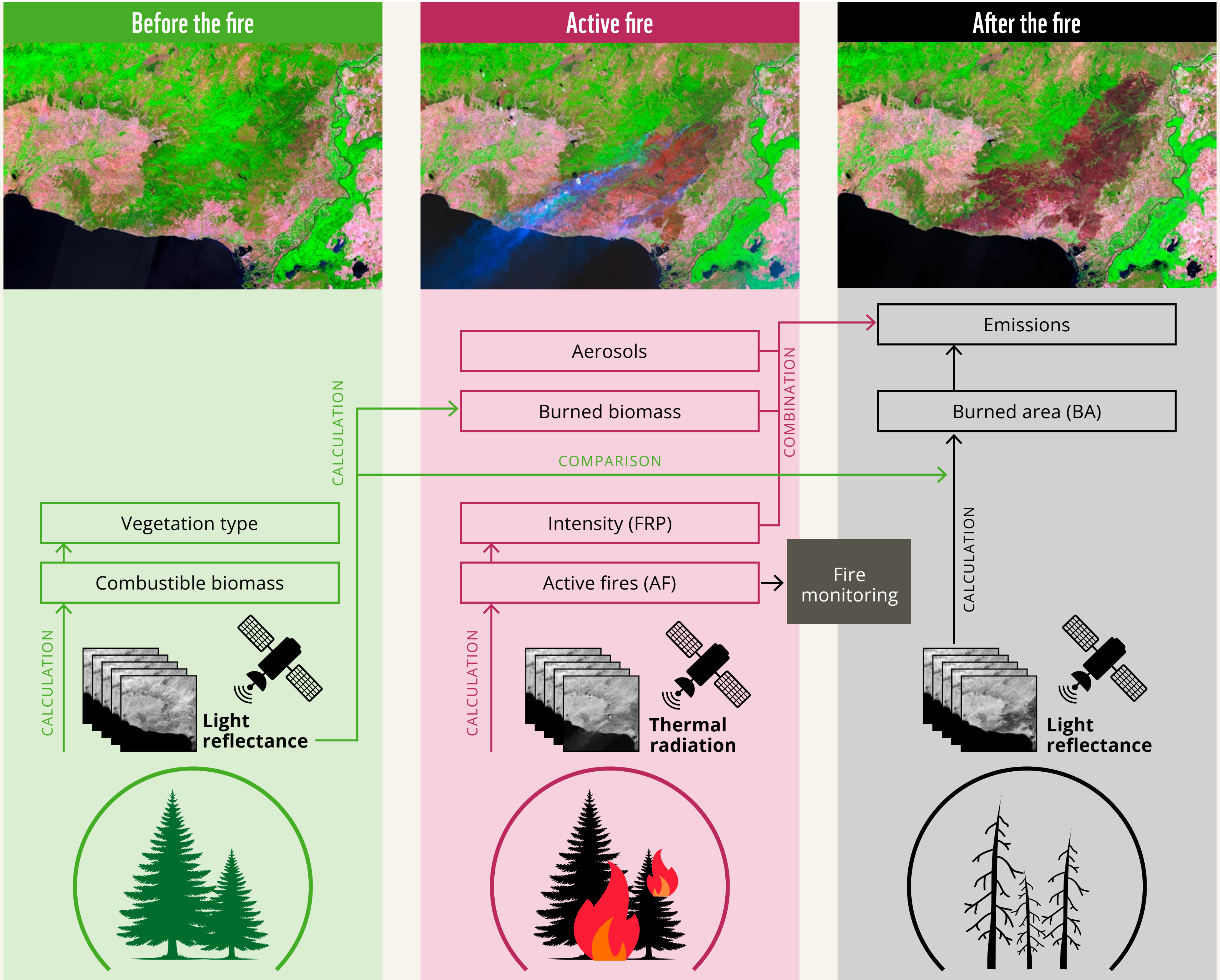


FIGURE 4:
The schematic representation shows how the reflectance and thermal data obtained through remote sensing help estimate emissions, map burned areas and track individual fire events.
The top row shows three false-colour images of the Evros fire in 2023. These Sentinel-2 satellite images use the short-wave infrared (SWIR, band 12), near-infrared (NIR, band 8) and red (band 4) ranges to reveal features that would remain hidden in a standard photograph: healthy vegetation appears in vivid green, while burned areas are shown in reddish-brown tones. In the centre image, smoke plumes are shown in blue-violet.

Source: [9], modified; satellite images: [15]



Depending on their sensors, satellites provide early warnings, high-resolution damage maps and enable global monitoring. Each technology plays its own unique part.

Active fires emit strongly in the mid-infrared range (at wavelengths of approximately three to four micrometres [μm]), which makes them stand out clearly against cooler backgrounds. The radiative power of these fires (FRP) correlates with fire intensity, which in turn depends on the available combustible biomass and the type of vegetation. Figure 4 illustrates how combining different types of information can enrich the dataset, for example by providing insights into the extent of burned areas (BA), the status of active fires and the dynamics of individual fire events. The glossary (p. 24) summarises the key parameters in the remote sensing of fires.

As mentioned above, the choice of satellite system depends on the specific task:

- Data provided by the MODIS and VIIRS active fire products (AF products) are used in the **rapid detection of active fire sources**, also known as hotspots; NASA's FIRMS fire warning system (Fire Information for Resource Management System; see Table 2) makes this data available in quasi-real-time (with a delay of approx. three hours). Even though MODIS only offers a spatial resolution of one by one kilometre in the thermal range, it can still detect fires starting from 1,000 square metres due to their high temperatures.[16] These products enable a rapid response in the event of disaster. While they serve as early warning systems, they do not record the precise area affected by fire, instead providing targeted information about active fires and their intensity.

- The MODIS and VIIRS Burned Area products (BA products) are suitable for the **comprehensive global monitoring of burned areas.** These products provide large-scale, automatically generated, and consistent datasets several times a day, but with lower spatial detail (e.g. MODIS with 500 by 500 metres).

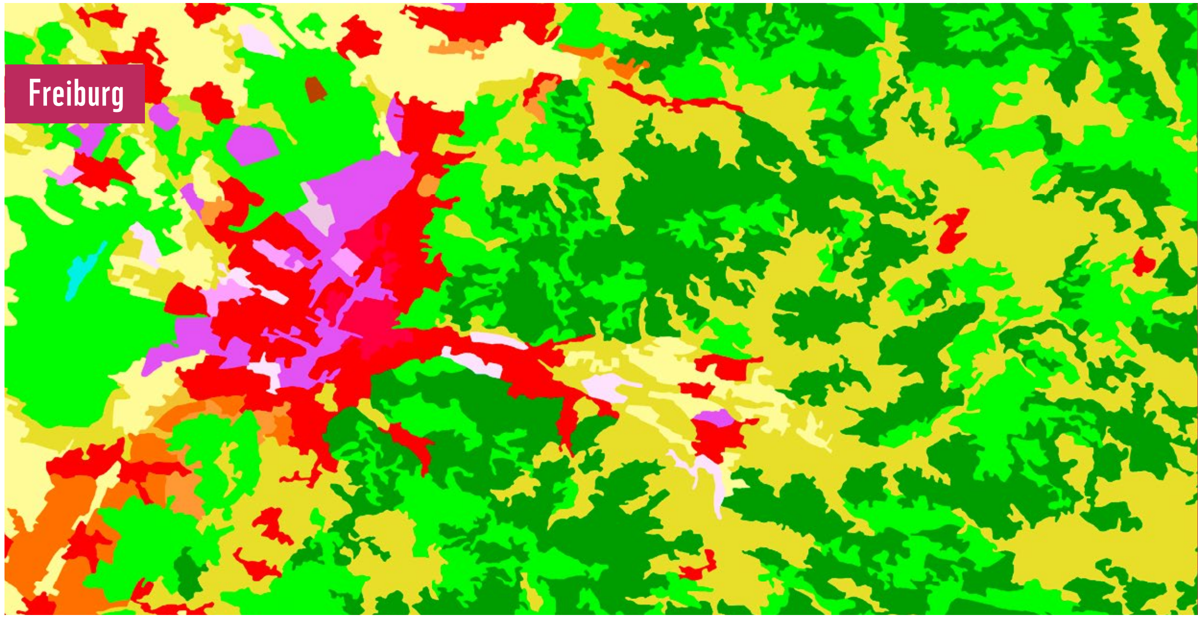
- High-resolution sensors such as Landsat or Sentinel-2 are used for **detailed damage assessments and the mapping of burned areas after a fire.** These systems provide precise measurements; however, their data are only available every five to 16 days. Landsat sensors offer a pixel size of 30 by 30 metres, while Sentinel-2 data even offer a pixel size of up to ten by ten metres.

Satellite sensors also differ in their sensitivity to clouds and smoke. Optical sensors with high spatial resolution enable detailed analyses, but they are more weather dependent and provide data with a greater time lag. Thermal sensors, on the other hand, can detect active fires even in slightly cloudy conditions. They provide information rapidly, if in less detail (Table 1).

For Germany, EFFIS records fires of approximately 30 hectares or more. Since 2015, Sentinel-2 has also enabled the detection of smaller fires; MODIS and VIIRS data are still used as well. However, for the sake of comparability with previous years, only fires covering an area of 30 hectares or more are included. National statistics compiled by the Federal Ministry of Agriculture, Food and Regional Identity (BMLEH), which are based on reports from forestry authorities, also record significantly smaller fires, resulting in systematic differences in total area estimates. EFFIS, by contrast, provides consistent, satellite-based information across Europe with comparable methodological standards.

The satellite systems used for monitoring fires also include:

- weather satellites, which provide observations several times an hour.[17] However, their spatial resolution is rather coarse (several kilometres in the thermal detection).
- active radar systems, such as Sentinel-1, which are less affected by clouds than optical sensor systems. These data are used in the RADD (Radar for Detecting Deforestation) application, for example.[18]
- satellite systems for atmospheric observation, such as TROPOMI[19], which detect trace gases and can be used to observe emissions from fires, for instance.
- ground- and satellite-based lightning detectors, such as the GLM (Geostationary Lightning Mapper), which provides information on lightning strikes that could potentially ignite forests fires, operating aboard the GOES-R weather satellites. This information is made available in the FWAS (Fire Weather Alert System) app, for example, to support firefighting operations.[20]



CLC Code

- 111: Continuous urban fabric
- 112: Discontinuous urban fabric
- 121: Industrial or commercial units
- 124: Airports
- 132: Dump sites
- 141: Green urban areas
- 142: Sports and leisure facilities
- 211: Non-irrigated arable land
- 221: Vineyards
- 222: Fruit trees and berry plantations
- 231: Pastures
- 242: Complex cultivation pattern
- 244: Agro-foresty areas
- 311: Broad-leaved forest
- 312: Coniferous forests
- 313: Mixed forests
- 321: Natural grasslands
- 324: Transitional woodland/shrub
- 512: Water bodies

Why it takes more than fire pixels

Remote-sensing-based information alone cannot reliably distinguish vegetation and forest fires from other types of fire. Accurate classification requires a combination of satellite-based fire data and information on the respective vegetation type, which can also be derived from remote sensing data.
Within the EU, the CORINE Land Cover (CLC) dataset provides standardized information on land cover and land use.[21]

Only a few operational satellite data products specifically identify forest fires. This is further complicated by the question of how a forest is defined; in fact, forest cover datasets are based on different definitions.[22] The most widely used definition is that of the FAO, the Food and Agriculture Organisation of the United Nations (UN), which defines a forest as an area larger than half a hectare with trees taller than five metres and a canopy cover of at least ten percent.[23] The Global Land Analysis and Discovery (GLAD) dataset *Global forest loss due to fire*, by contrast, defines a forest as an area with trees taller than five metres and a canopy cover exceeding 30 percent.[24]

Differing forest definitions and data sources explain why fire statistics for a given region can vary so widely.

Not all forests are equal: from sparse savannah woodlands to dense tropical forests—the definition determines what is included in forest fire statistics

TABLE 1:

Comparison of different satellite sensors and their most important satellite data products.
For better readability, pixel resolutions of, for example, 50 m x 50 m are shown as 50 m.

	FireSat	OroraTech[13, 25, 26]	Landsat/Sentinel-2 (e.g. GLAD [24])	MODIS/VIIRS—Burned Area (BA) (e.g. MCD64A1 [27])	MODIS/VIIRS/Sentinel-3—Active Fire (AF) (e.g. MOD14A1[28]/ FIRMS[29])
Product type	Real-time fire detection, fire sources, fire spread predictions, fire intensity	Real-time fire detection, fire spread predictions, burned areas	Post-fire analyses, extent of damage	Burned areas and temporal progression	Rapid fire detection, fire sources, fire intensity
Spatial resolution (pixel size)	High: 50 m	Moderate: 200 m	High: 10-30 m	Moderate: 500 m (MODIS), 375 m (VIIRS)	Moderate: 1 km (MODIS), 375 m (VIIRS)
Temporal resolution	Very high: hourly	Very high, 2025: every 12 hours, by end of 2028: up to 30 minutes globally	Low: every 5-16 days	High: several times a day, information provided as daily summaries	Very high: several times a day
Cloud/smoke sensitivity	Low	Low for smoke in thermal detection, but cloud dependent	High	Moderate (high resolution often helps compensate)	Low for smoke in thermal detection, but cloud dependent
Availability	Quasi in real time; first prototypes in 2025, full constellation (50+ satellites) by 2030	Quasi in real time; alerts in few minutes	Often after a fire event, only after fire incidents	Automated, global, regular updates; rapid availability within days	Quasi in real time (3 hours for FIRMS, sometimes less than 1 hour for regional products)
Active fire detection	Yes, minimum area approx. 5 m × 5 m	Yes, with AI-supported onboard analysis; minimum area approx. 4 m × 4 m	No	No	Yes, active fires (hotspots), minimum area approx. 1,000 m^2 (MODIS) and 10 m^2 (VIIRS)
Burned area detection	Yes, burned areas, high resolution	Yes, burned areas, high resolution, minimum area approx. 10 m × 10 m	Very detailed; minimum area approx. 10 m × 10 m (Sentinel-2), 30 m × 30 m (Landsat)	Coarse but global and up to date; minimum area approx. 500 m × 500 m (MODIS), 375 m × 375 m (VIIRS)	No
Typical applications	Early warning, response operation planning, disaster control, climate adaptation	Early warning, response operation planning, risk modelling, climate adaptation	Damage assessment, ecological studies, forestry	Global statistics, basis for emission calculations, rapid BA overviews, fire regime	Early warning, monitoring, disaster control
Advantages	Tracking of fire progression and behaviour analysis	Quasi-real-time detection, high resolution, global coverage	Very high level of detail, precise fire boundaries	Automated, consistent, extensive	Allows for quick overview and rapid response
Disadvantages	Still in development, limited historical data, commercial offer	Still in development, limited historical data, commercial offer	Often delayed availability, weather dependent	Moderate spatial resolution, no detail	No exact burned areas, only targeted hotspots
Costs	Various pricing models	Various pricing models	Publicly available, no direct costs	Publicly available, no direct costs	Publicly available, no direct costs

Fire Evros, Greece 2023

The Evros fire in Greece in August 2023 is considered the largest forest fire ever recorded in the European Union (see the chapter of the German version of this publication, entitled *Im Brennpunkt: die Mittelmeerregion Europas* ("A hotspot: Europe's Mediterranean region")).[30] The Sentinel-2 satellite image in Figure 5 from 23 August 2023[14] shows the affected region in high spatial resolution (20 metres), with both the burned area and the smoke development clearly visible. Next to it, the Copernicus Forest Type dataset from 2018 visualises the predominant forest cover[31], providing a basis to assess the actual forest areas affected. The MODIS Active Fire product from the same day (derived from MOD14A1)[28] maps active fire sources based on thermal infrared measurements with a spatial resolution of roughly one by one kilometre. To the right of this image, the MODIS Fire Radiative Power (FRP) product (also derived from MOD14A1) shows the radiation intensity of the fires as an indicator of their thermal energy and potential emissions. The MODIS Burned Area (BA) product (MCD64A1)[27] helped record the total burned area and temporal development of the fires in August and September 2023. Finally, EFFIS uses Sentinel-2 data to show the severity of the fires, in other words, the extent of vegetation damage.[32] Owing to its high spatial resolution, this map provides far more detailed information than the MODIS-based products.

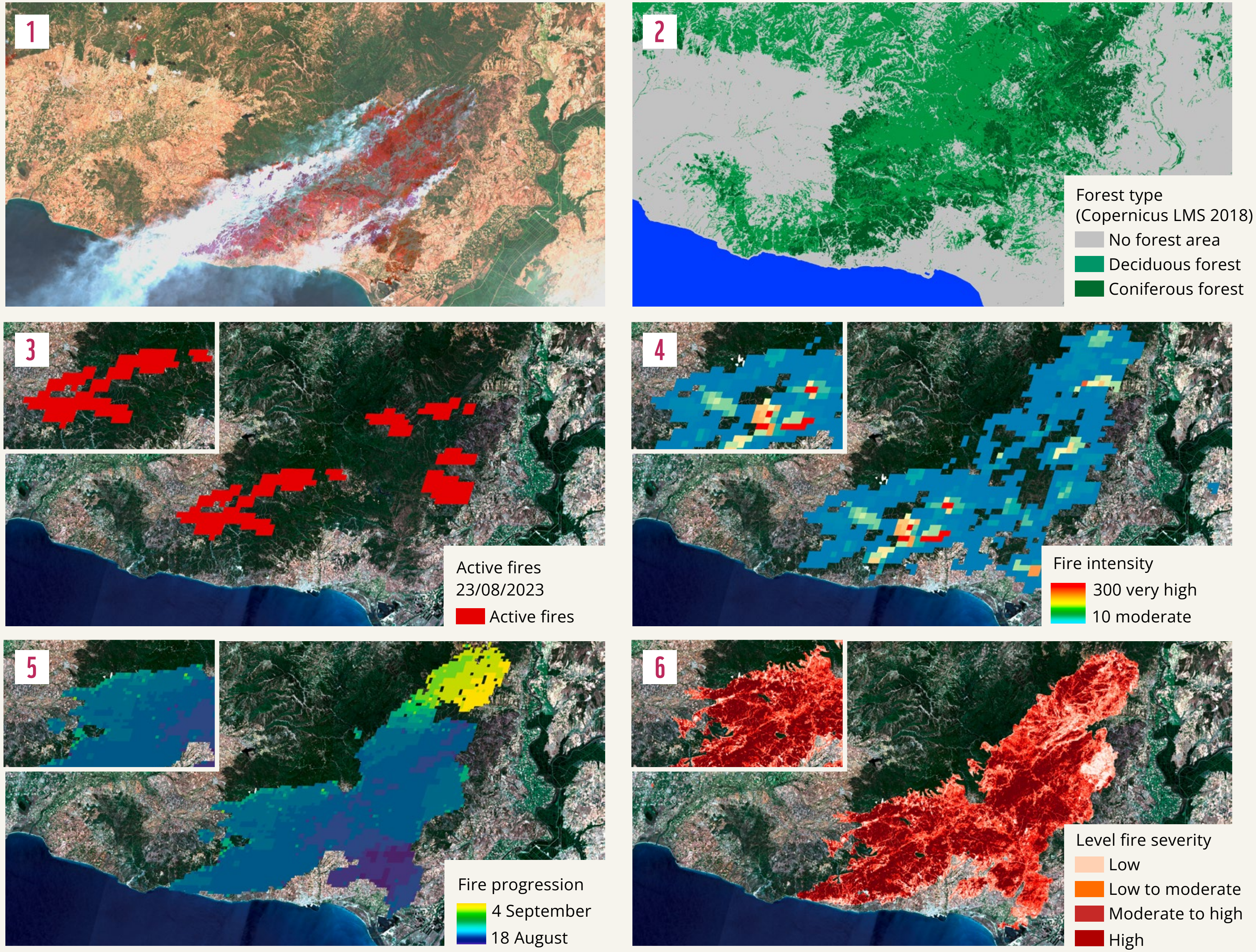


FIGURE 5:

The images show the Evros fire of August 2023 as captured by various satellite data products.

1 Sentinel-2 satellite image, 23/08/2023[14]

2 Copernicus Forest Type 2018[31]

3 MODIS active fire for 23/08/2023[28]

4 MODIS fire intensity (FRP) in megawatts (MW) for the month of August 2023, based on daily active fire observations[28]

5 MODIS burned area August/September 2023[27]

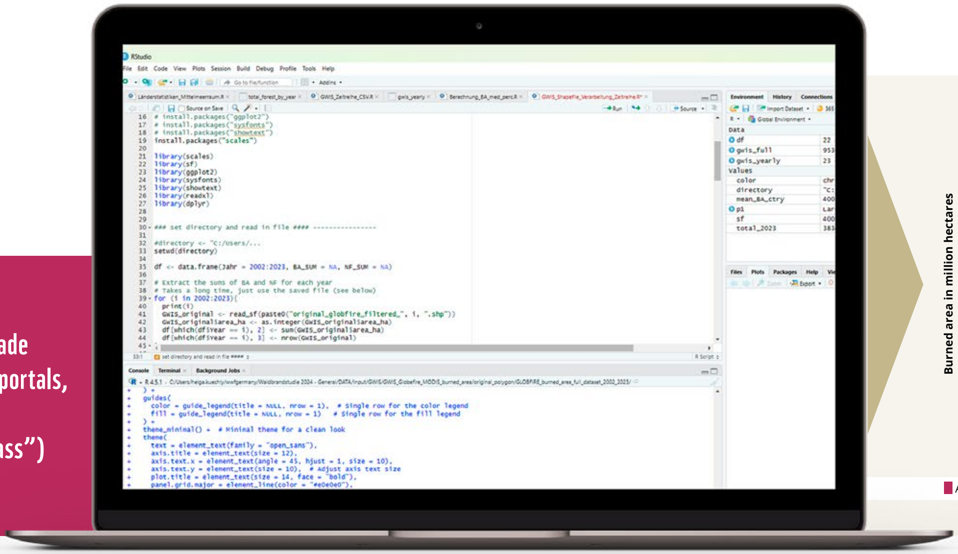
6 EFFIS Sentinel-2 fire severity[32]

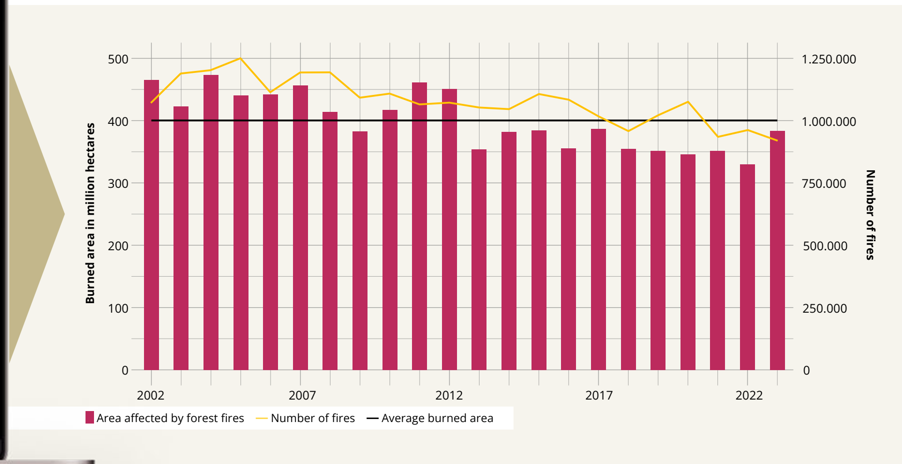
GLOBAL DATASETS AND PORTALS

User-friendly platforms such as Global Forest Watch or GWIS make fire data accessible to everyone and issue automated alerts on request.

Numerous organisations such as the National Aeronautics and Space Administration (NASA)[33] and the European Space Agency (ESA)[34] provide global fire datasets based on satellite observations. These global datasets are particularly valuable for comparing different regions or analysing developments over the course of many years. Many of the data portals presented in this chapter (see Tables 2 and 3) draw on the satellite systems discussed above, such as MODIS and VIIRS. However, the portals differ in their thematic focus and areas of application. To meet these specific needs, the underlying satellite data is sometimes processed in different ways, combined with other datasets or supplemented with proprietary analyses to address specific questions, for example on the frequency, extent or intensity of fires. This helps explain the variations observed in the different fire statistics.

MODIS and VIIRS active fire products are particularly suitable for **real-time monitoring** and can be accessed through platforms such as FIRMS[29] or Global Forest Watch (GFW)[35] (and *Waldmonitor*[7] in Germany). Those interested in **long-term** trends, emissions or detailed analyses of fire events can use datasets such as the Global Fire Emissions Database (GFED)[36] or GlobFire[37]. Some platforms, including the Global Wildfire Information System (GWIS)[38] and Global Forest Watch (GFW)[35], also offer user-friendly dashboards that require no specialist knowledge. These allow users to visualise fire data, download datasets, or configure automatic alerts (Figure 6). GFW provides data and interactive tools to monitor and visualise changes in forests worldwide. In addition, the *Global forest loss due to fire* (GLAD) dataset offers specific information on forest fires.[24] This dataset shows fire-related forest loss in high spatial detail (30 by 30 metres) from the year 2000 on.





From raw data to visualisation: this R script uses GWIS data, made available through user-friendly portals, to create customised diagrams. Our *Feuerkompass* ("Fire Compass") also draws on this data.

FIGURE 6:

Overview of the Global Forest Watch (GFW) portal. Users can define areas for which they would like information on forests and forest fires. In this example, the Evros region has been selected, which is outlined in black within the tool. Users can then request that various statistics be displayed for the selected area, for example forest loss caused by fires according to the *Global forest loss due to fire* (GLAD) dataset (see Table 2). In addition, users can set up automatic email notifications for detected changes (forest areas, fires), for which the portal automatically generates statistics.

Source: [35]

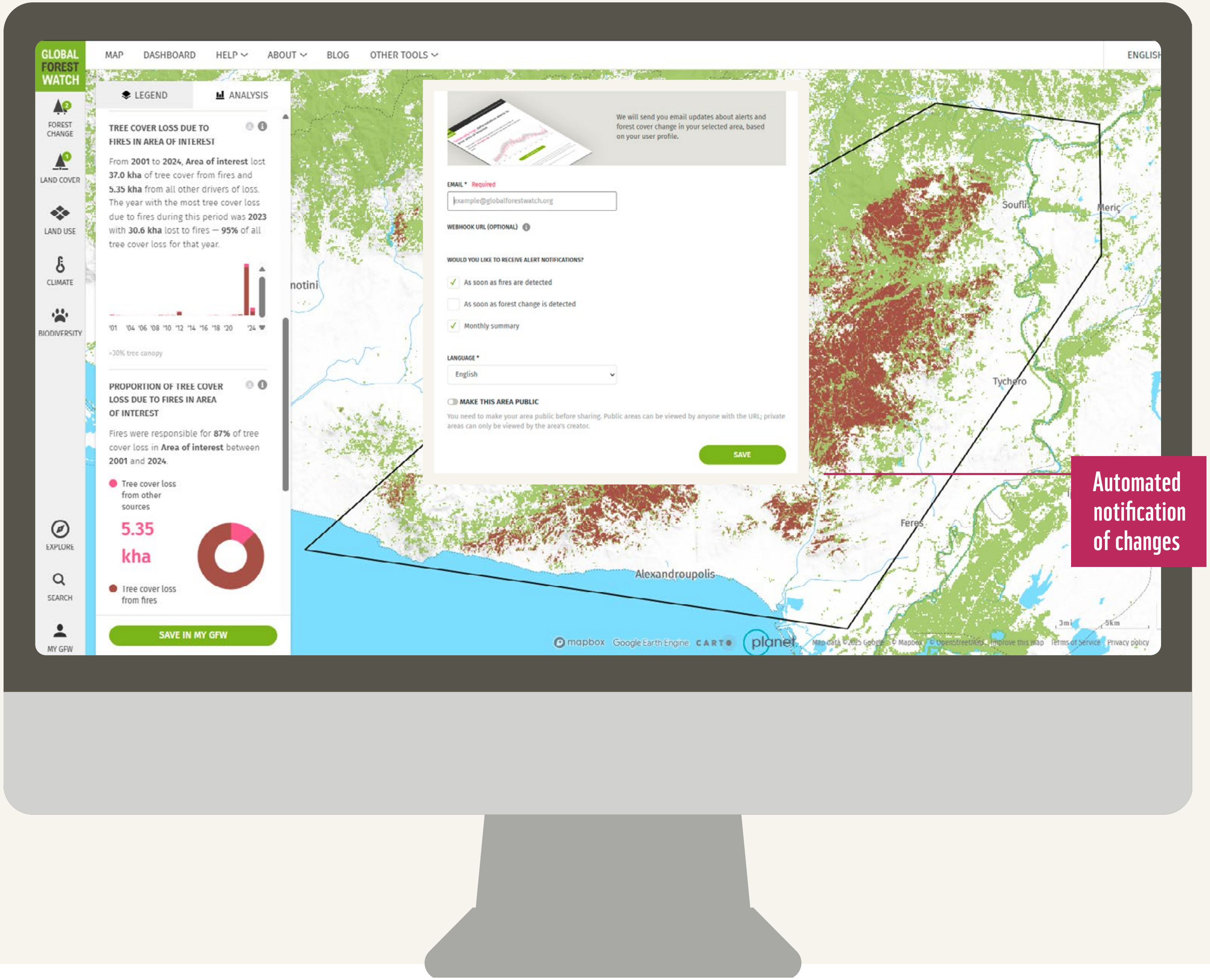


TABLE 2:
Global fire datasets. Datasets marked with [forest fire icon] refer specifically to forest fires, while [portal icon] indicates user-friendly portals. For better readability, pixel resolutions such as 5 m x 5 m are shown as 5 m. Depending on the application, fire databases are updated at intervals ranging from quasi real time to once a year. Clicking on a product name will take you directly to the corresponding website.

Product / Portal	Type	Resolution	Period	Description and areas of application
▸ **ESA FireCCI** (Fire Climate Change Initiative)[39]	Burned area	300 m / 250 m / 0.25° (~25 km)	From 1982	Long-term datasets for climate research and global analyses; emphasis on consistency and accuracy
▸ **Sentinel-3 World Fire Atlas**[40]	Active fires as point data	500 to 1,000 m (MMU)	From 2016	Monthly global overview of night-time fires → statistical analyses and visualisations
▸ **CAMS-GFAS** (Copernicus Atmosphere Monitoring Service—Global Fire Assimilation System)[41]	Fire emissions	~10 to 30 km	From 2015	Part of the EU atmospheric programme; provides emission data (CO_2, CH_4, N_2O) using satellite and ground data; uses TROPOMI and OCO-2, among others
▸ **GlobFire**[37]	Burned area, fire events	500 m (vector-based)	From 2001	Fire dynamics (size, duration) → detailed event analysis and historical trends
▸ **GFAS** (Global Fire Atlas)[4, 36]	Burned area, fire events	500 m	2003-2016	Analysis of fire dynamics (spread, duration); comparable to GlobFire
[portal icon] ▸ **FIRMS-Portal** (Fire Information for Resource Management System)[29]	Burned area, active fires	Depends on the sensor	Real-time and historical since 2000	Fire alerts; user-friendly portal for quick access and download of MODIS/VIIRS fire data → monitoring
[portal icon] ▸ **GWIS-Portal** (Global Wildfire Information System)[42]	Burned area, emissions	Depends on the sensor	Real-time and historical	User-friendly portal; integrated analysis platform including emissions; policy, research and risk assessment; GWIS country profiles are based on MODIS Burned area and GlobFire; other statistics are based on near-real-time products → Policies, research and risk assessments
[forest fire icon] ▸ **GLAD** (Global forest loss due to fire)[24]	Forest loss	30 m	From 2001 to 2024	Shows forest loss due to fire → forestry, nature conservation and land use analyses
▸ **GFED BA** (Global Fire Emissions Database—Burned Area)[36]	Burned area, emissions	0.25° (~25 km)	From 1997 to 2022	Combination of fire areas and emissions → climate research and air quality studies
▸ **FINN** (Fire INventory from NCAR)[43]	Emissions	0.1° (~10 km)	From 2002	Combines active fires and land cover to calculate emissions → climate research and air quality studies
[forest fire icon] [portal icon] ▸ **GFW** (Global Forest Watch)[35]	Active fires, forest loss	Variable	Real-time and historical	User-friendly portal; fire alerts → forest monitoring and environmental reporting

REGIONAL DATASETS

Regional datasets supplement satellite images with ground-based information, providing more accurate results for local needs.

In addition to global fire datasets, many regions offer specialised systems tailored to local conditions and requirements (Table 3). These regional datasets often feature higher spatial resolution or combine satellite observations and ground-based information. As a result, they offer significant advantages for disaster control, land use planning and research, as they address local needs more specifically and meaningfully complement global products. To date, such systems are most common in countries and regions with strong research infrastructures, while other areas continue to rely exclusively on global products. Table 3 provides an overview of available regional datasets, focusing on portals that provide user-friendly access.

In North America, several established portals provide information ranging from real-time detection of active fires (FIRMS USA/Kanada[44], Canadian Wildland Fire Information System [CWFIS[45]]) to fire severity analyses (Burned Area Emergency Response [BAER[46]], Monitoring Trends in Burn Severity [MTBS[47]]), and vegetation and fire modelling (LANDFIRE[48]).

In South Africa, the Advanced Fire Information System (AFIS[49]) supports fire brigades and land management authorities with a real-time warning system that combines multiple satellite sensors and offers practical services such as SMS alerts. Other regional systems, such as EFFIS[50, 3] in Europe, the Brazilian MapBiomas Fire Project[51] and the system operated by Chile's Corporación Nacional Foresta (CONAF[52]) provide specialised information on burned areas, fire risks and emissions, thereby supporting disaster control as well as research and political consulting.

One particularly noteworthy cross-regional system is the Open National Forest Inventory of Wildland Fires and Burned Area Records (ONFIRE[53]) database. ONFIRE is the first compact, global collection of national burned area statistics presented in a uniform grid format. It integrates historical and current data from Australia, Canada, Chile, Europe and the USA into a common grid (1 degree by 1 degree), covering periods dating back to the 1950s. The data are primarily based on national sources and ground photography.

Regional datasets support firefighting efforts. Here, firefighters are working to contain a fire.

TABLE 3:

Examples of regional fire datasets. Datasets marked with [forest fire icon] refer specifically to forest fires, while [portal icon] indicates user-friendly portals. For better readability, pixel resolutions such as 5 m x 5 m are shown as 5 m. Depending on the application, fire databases are updated at intervals ranging from quasi real time to once a year. Clicking on a product name will take you directly to the corresponding website.

Continent	Product / Portal	Type	Resolution	Time	Special features
AFRICA					
South Africa	▸ **AFIS**[49] (Advanced Fire Information System)	Active fires, early warnings	375 m to 1 km	Real time	African real-time early-warning system with SMS alerts, combining MODIS and VIIRS
Sub-Saharan Africa	▸ **ESA FireCCI**[54, 39, 55] (Fire Climate Change Initiative): FireCCISFD11 and FireCCISFD20	Burned area	Sentinel-2 (20 m)	2016 and 2019	Detects small fires in sub-Saharan Africa
ASIA					
India	▸ **Forest Fire Alert System**[56] (FAST 3.0)	Active fires, early warning	375 m to 1 km	Since 2004 (FAST 3.0 since 2019)	National early warning system of the Forest Survey of India (FSI); SMS/email alerts; dashboard and statistics at provincial level
Indonesia (in part belonging to Oceania)	▸ **SiPongi**— Karhutla Monitoring System[57]	Active fires, burned area	Variable	Real-time and historical	Daily updates on active fires; annual burned area statistics at provincial level
South Korea	▸ **KFFIS**[58] (Korea Forest Fire Information System)	Active fires, burned area (statistics)	Point data/ provincial level	Real-time and historical	Official portal of the Korea Forest Service; shows active fires and statistics at provincial level, but only in Korean
EUROPE					
Europe	▸ **CEMS**[59] (Copernicus Emergency Management Service)	Rapid mapping	Variable	Real-time	Provides rapid mapping of fires as well as of hazardous and damaging events
Europe	▸ **EFFIS**[50] (European Forest Fire Information System)	Burned area, fire events	20 to 500 m	Real-time and historical	Europe-wide fire information system; combines MODIS (from 30 ha) and Sentinel-2 (from 5 ha); provides daily updates on burned areas and annual reports based on national fire statistics and fire risk predictions; part of the EU's Copernicus Emergency Management Service for disaster prevention
Europe	▸ **ZKI-DLR**[60, 61] (Center for Satellite Based Crisis Information—German Aerospace Center) Fire Monitoring	Burned area, fire severity	Variable	Real-time	Fire monitoring by the German Aerospace Centre (DLR); combination of MODIS, Sentinel-3 and VIIRS with interactive map of potentially endangered areas

OCEANIA					
Australia	▸ **TERN**[62] (Terrestrial Ecosystem Research Network) Data Portal	Burned area, fire dynamics	Variable	From 1987	Satellite data and ground-based, national focus
Australia	▸ **Fires in Australia's forests**[63]	Burned area; planned vs. unplanned fires	100 m	2011 to 2021	Various datasets from the Australian provinces, excluding the Northern Territory
Australia	▸ **Bushfire Near-real time and Historical Extents**[64]	Burned area	Variable	From 1900	Integration of various datasets from ground observations, aerial photographs and satellite data; excluding the Northern Territory
NORTH AMERICA					
North America	▸ **FIRMS USA/Kanada**[44] (Fire Information for Resource Management System)	Active fires	375 m to 1 km	Real-time	Regional FIRMS version with higher resolution
Canada	▸ **CWFIS**[45] (Canadian Wildland Fire Information System)	Active fires, burned area (including for forest areas)	~250 m to 1 km	Real-time and historical	Combines satellite data with ground statistics; interactive maps; historical data also available, such as NBAC (National Burned Area Composite) and CNFDB (Canadian National Fire Database)
Canada	▸ **NFD**[65] (National Forestry Database)	Burned area (statistics)	Provincial level	From 1990	Annual reports on number of forest fires and burned areas
Canada	▸ **CIFFC**[66] (National Interagency Fire Centre)	Active fires, burned area (statistics)	Variable	From 1983	Exchange of daily fire reports, coordination of response operations and compilation of statistics and situation reports; National Wildland Fire Situation Report
USA	▸ **BAER**[46] (Burned Area Emergency Response)	Fire severity, emergency mapping	30 m	From 2001	Damage assessment for emergency response measures
USA	▸ **Burn Severity Portal**[67]	Burned area, fire severity	30 m	From 1983	Access to MTBS, BAER (see table) and others via map portal
USA	▸ **LANDFIRE**[48]	Fire regime, severity	30 m	From 2001	Provides vegetation and fire modelling for planning purposes
USA	▸ **MTBS**[47] (Monitoring Trends in Burn Severity)	Burned area, fire severity	30 m	From 1984	Maps major U.S. fire events using Landsat (30 m); assessment of severity; visualisation via map portal
USA	▸ **NIFC**[68] (National Interagency Fire Center)	Fire statistics, situation reports	Variable	From 1983	Central U.S: coordination centre for wildfire management and resource mobilisation; coordinates national fire data and situation reports

SOUTH AMERICA					
Brazil	**▸ MapBiomas Fire Project**[51]	Burned area	10 to 30 m	From 1985	Brazilian fire mapping project using Landsat and Sentinel-2; strong focus on Cerrado and the Amazon; provides high-resolution data for research and land use planning; expansion of MapBiomas to include Indonesia and Argentina
Chile	**▸ CONAF**[52] (Corporación Nacional Forestal)	Burned area (statistics), forecast maps	Point and area data	Real-time and historical	Chile's official national fire system; visualization of individual fires with location, area, time and status; updates every 5 minutes; monthly and annual statistics available for each municipality and region
CROSS-REGIONAL					
Australia, Europe, Chile, etc.	**▸ ONFIRE**[53] (Open National Forest Inventory of Wildland Fires and Burned Area Records)	Burned area (statistics)	1° (~100 km)	From 1950	Consolidation of national fire statistics (often ground observations) with long time series (some statistics dating back to 1950); mapped on a 1° grid; supplements satellite gaps (e.g., undergrowth fires, smoke cover)
The tropics	**▸ CTrees DL-DEGRAD**[69] (Deep Learning Degradation)	Forest degradation incl. fires	Approx. 5 m	From 2017	Deep-learning-based dataset with extremely high resolution; based on data from Norway's International Climate and Forest Initiative (NICFI)

WHAT SATELLITES SHOW US ABOUT FIRES—AND WHERE THEIR LIMITS LIE

Satellite data are an indispensable foundation for detecting forest and vegetation fires worldwide, monitoring them over the long term and, in future, analysing them even more precisely in real time with the help of AI.

Satellites provide invaluable information about forest, vegetation and wildfires. They allow us to track changes in the frequency, extent and seasonality of fires over the course of many years. Usable data from the Landsat programme, for example, date back to the 1980s. A general challenge is ensuring continuity across successive satellite missions as instruments reach end-of-life. MODIS instruments are expected to end in 2026-2027, increasing the importance of cross-mission alignment. This requires consistent algorithms, well-calibrated sensors, standardised definitions and careful post-processing of data. Thus long-term datasets can help to identify global shifts in fire behaviour like no others.

To verify satellite results, they are often compared with other sources, such as on-site inspections, high-resolution aerial photographs or drone imagery. Nevertheless, uncertainties remain: small fires, fires that die out quickly, or fires that are hidden beneath dense smoke and tree canopies may go undetected. In addition, satellites occasionally mistake hot surfaces above industrial facilities, photovoltaic plants or volcanoes for actual fires.

Another limitation is the time required to process and publish satellite data, which currently still rules out real-time use. Furthermore, sensors are unable to identify "forest" fires in the literal sense; they simply detect anomalous temperatures or surface properties. Only by combining an area's heat signatures or abnormal radiation patterns with land cover information can we conclude whether we are looking at a fire in a forest area.

And ultimately, as discussed above, there is no globally consistent definition of "forest". What qualifies as a forest area in one country may not be classified as such in another, complicating international comparison.

Satellite data are nonetheless the cornerstone of modern vegetation and forest fire detection, monitoring and assessment. Their strength lies in the combination of global coverage, regular repetition rates and comparable measurement techniques. Satellite data on active fire sources, burned areas and atmospheric composition provide a comprehensive picture—from early detection and fire mapping to emission estimates. Challenges remain and include methodological development, improvements in data accuracy and comparability, and the integration of other data sources such as ground and meteorological data. Satellite data will play an even greater role in the future: The increasing number of satellites, enhanced technical capabilities and growing use of artificial intelligence (AI) will allow us to detect fires at an early stage, monitor them in real time and map damaged areas accurately and consistently. In addition, optimised models are expected to improve the assessment of fire risks, opening up new opportunities for nature conservation and climate protection. WWF too makes extensive use of Earth observation data, which have long since become an indispensable basis for a growing number of applications.

Glossary of important fire detection terms

Parameter	Description
Active fire (AF) / Hotspots	Active fire fronts at the time the satellite image was taken. Fires are distinguishable from their cooler surroundings due to their high temperatures. Thermal information also helps estimate the fire's intensity [Fire Radiative Power (FRP)].
Fire events	Duration of a fire (start to end of the event)
Burned area (BA)	The area affected by fire. Burned areas are typically identified using changes in reflectance in the visible and infrared spectral range.
Fire severity	A measure of the immediate effects of a fire on vegetation (above ground) and on soil (below ground), e.g. through the loss or decomposition of organic matter. Fire severity is often derived from changes in reflectance in the visible and infrared spectral range.
Fire Radiative Power (FRP)	A measure of the heat radiation emitted by an active fire, expressed in megawatts (MW). It provides an indication of fire intensity and combustible consumption.
Emissions (e.g. CO_2, CO, NO_x)	Estimated quantities of gases and particles released during a fire. They depend on the area, the material burned and typical release rates (emission factors).
Fuel load	The amount of biomass present in an area, expressed in tonnes per hectare (t/ha). Fuel load is an important factor, influencing emissions and Fire Radiative Power (FRP).
Smoke plume	Detection and modelling of particle and gas propagation.
Wildfire	International term for uncontrolled fires in natural vegetation, regardless of whether they occur in forests, grasslands, wetlands or bush regions.

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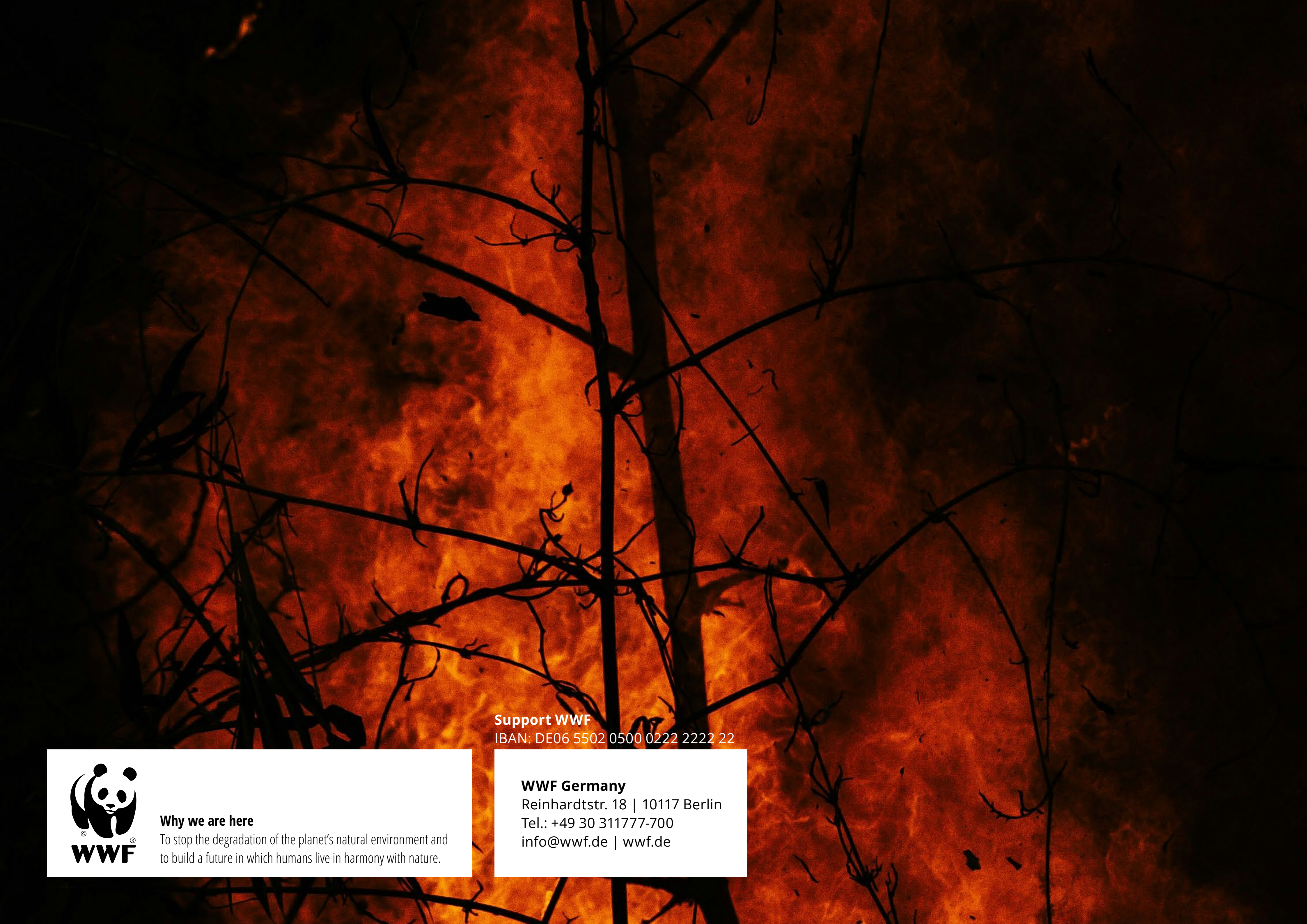

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Why we are here
To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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