

Earth Observation against environmental crimes

A review of users and usages worldwide

Contents of the presentation

- Introduction to the project
- General Analysis
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- Case studies



Introduction to the project

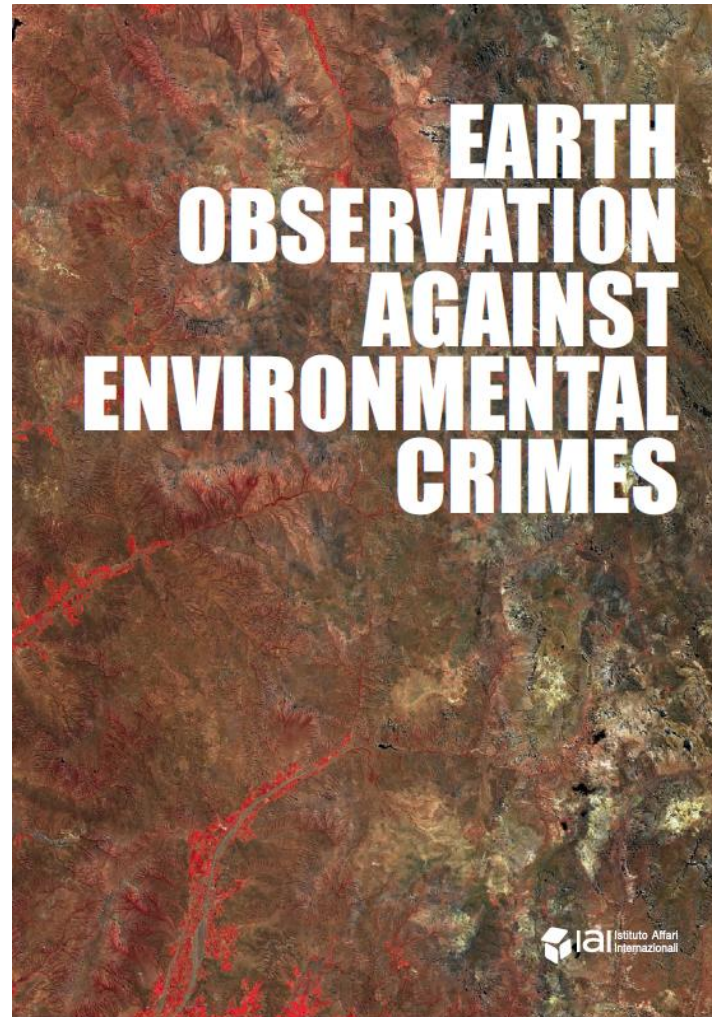
About the project

- ❏ Project led by IAI, funded by the European Space Agency (ESA)
- ❏ Focus on enforcement of environmental regulations, not on monitoring
- ❏ Criminal but also administrative laws involved
- ❏ Global focus
- ❏ All major environmental crime sectors covered



Introduction to the project

The final report



Introduction to the project

Research questions

Main research questions:

-  Better understanding of the impact and potential of satellites on enforcement
-  What are the main elements favouring the uptake of satellite analysis
-  Cases studies that can be replicated



Introduction to the project

Research Methodology

Research methodology:

-  Desk research, field research, interviews (38)
-  Work in Brazil, Indonesia, Mexico, Costa Rica, South Africa, Vietnam, Thailand, and several EU countries
-  Validation workshops (4, 60+ participants from enforcement agencies, NGOs, judiciary, international organisations)



Introduction to the project

Structure of the report

❏ Structure of the report and of the analysis:

- ❏ General Analysis: how is EO applied against environmental crimes, what are the players involved, what are pros and limitations, how we can overcome obstacles
- ❏ Sectorial Analysis: focus on main sectors of application, as well as minor/growing ones.
- ❏ Case studies: a selection of 10 of the most successful applications globally



General analysis Overview

Reforestation in the Monteverde Cloud Forest Reserve of Costa Rica. Contains modified Copernicus Sentinel data (2020), processed by ESA.

GENERAL ANALYSIS

1. FUNDAMENTALS OF SATELLITE EO USE AGAINST ENVIRONMENTAL CRIMES

This report sits at the intersection of two topics: environmental crimes and Earth Observation (EO), two areas often requiring dedicated expertise. This section therefore provides a series of crucial notions needed to understand more advanced findings concerning the two sectors. While not aiming at being fully exhaustive for either category, the section is intended to provide the groundwork for understanding of the rest of analysis – for experts in each of the fields, as well as newcomers to both. To that end, this section covers the essentials of both domains, environmental crimes and satellite EO, before exploring how they intersect, from the earliest applications to the current state of play.

Wildfires in Portugal. Contains modified Copernicus Sentinel data (2020), processed by ESA.

GENERAL ANALYSIS

2. EO AND ENVIRONMENTAL CRIME LEGISLATION

This section focuses on the interaction between legislation adopted in the global fight against environmental crimes, and the use of EO. It aims at understanding how such legislation has recently evolved, and if it is already effective to maximise the contribution of EO in environmental enforcement. This section concentrates on three different levels: international treaties, EU legislation (as it is the most advanced from an environmental perspective) and national systems (from a general perspective, and including a few selected cases). It also dedicates specific attention to the issue of certification and the burden of proof.

The Belchatów coal mine in Poland. Contains modified Copernicus Sentinel data (2020), processed by ESA.

GENERAL ANALYSIS

3. LANDSCAPING THE USE OF EO AGAINST ENVIRONMENTAL CRIMES

This part includes the core findings of this report, and focuses on how EO is used in the global fight against environmental crimes, concentrating on the major points. It begins by discussing how usage varies among different actors, from enforcement agencies to the judiciary, international organisations and NGOs. It then discusses the main factors influencing applications, listing the main benefits (particularly savings in resources, increase in detection rates, deterrence effects) and obstacles affecting applications (not only technical, but also legislative, judicial, operative, etc.).



General analysis

Overview

- ❏ Fundamentals of satellite EO use against environmental crimes: definitions, main trends in environmental crime, current landscape
- ❏ EO and environmental crime legislation: interaction between EO uses and national and international environmental laws
- ❏ Landscaping the use of EO against environmental crimes: main actors, main uses, main benefits and obstacles



General analysis

Sectoral analysis

Main areas

-  Illegal logging/forestry crime
-  Illegal mining
-  Fishery Crime
-  Pollution

Other areas

-  Illegal sand mining
-  Illegal construction
-  Wildlife crime
-  Waste trafficking



General analysis

Main results

- ❏ **A new wave of environmental crimes**
 - ❏ Quantitatively bigger
 - ❏ New players
 - ❏ New criminal methodologies
- ❏ **A new endowment of satellite data and of analytical tools**
- ❏ **A slow but steady increase in applications**
- ❏ **A number of significant advantages compared to traditional methodologies**
- ❏ **Still limited use in court**



General analysis

Main results/2

- ❖ **Potential is still much greater than current application:**
 - ❖ Cultural/awareness factor
 - ❖ A few technological limitations
 - ❖ Impact of organisations' structures
 - ❖ Above all: legislative and policy frameworks behind and slow to adapt
- ❖ **A strong need to mainstream EO in the fight against envicrime**



Main advantages

Main advantages:

-  Saving time and resources on activities already currently performed
-  Performing tasks that would be otherwise impossible



Main advantages/2

Advantages:

-  Possibility to perform inspections on a distance
-  Saving resources
-  Automation
-  Prevention and deterrence effect
-  Completeness of information: Time and geographical coverage
-  Objectivity
-  Support to damage estimation and to restoration activities
-  Cross-border investigations



General analysis

Main limitations

Limitations:

 *Technical*

 *Operative*

 *Judicial*

 *Legislative*

 *Political*

 *Socio-economic*



Main limitations/2

Main limitations:

-  Work on the ground is often still necessary (*operative*)
-  In some countries evidence needs to be certified to be accepted (*judicial*)
-  Some regions face specific issues related to weather/landscape (*technical*)
-  Specific laws or regulations are required to mainstream use (*legislative*)
-  Political opposition against the use of EO has been an issue (*political*)
-  Very High Resolution images are sometimes required (and need to be purchased) (*technical/operative*)



Legislative Review

- ❏ **Legislative review, main results for international legislation:**
 - ❏ In several cases, applications are explicitly named or anyway expected to be applied in Guidelines and Annexes
 - ❏ Some treaties are readier/show more involvement than others for the use of satellites
 - ❏ Limited capability of influencing national legislation/enforcement
- ❏ **EU:**
 - ❏ Progressively integrating satellite analysis
 - ❏ Still much more in Guidance documents and strategies than in actual legislation
 - ❏ A few missed chances (Envicrime Directive, WSR) and some promising elements (EUDR, Nature Restoration Law)



Legislative review/2

❏ Legislative review, main results for national/sectorial legislation:

- ❏ Very significant differences across sectors
- ❏ Still a much more significant mention of satellites in administrative than criminal law
- ❏ Some promising areas (IUUF), some consolidated ones (forestry) and some mixed results (mining)
- ❏ Positive interaction with different tools
- ❏ Interaction with other issues related to environmental crime legislation
- ❏ Some sectors not covered at all (despite the potential)



General analysis

Certification

- ❏ **Legislative review, the issue of certification:**
 - ❏ A problem not across all countries
 - ❏ No significant differences between common/civil law
 - ❏ Could be a serious impediment to proceedings
 - ❏ Structured methodologies work well: USA, Peru
 - ❏ The case of AI and the black box issue: Costa Rica



Sectoral analysis Overview

SECTORAL ANALYSIS

1. FORESTRY CRIME

Forests and peatland on the Likouala-aux-Herbes
in Congo DRC. Contains modified Copernicus
Sentinel data (2020), processed by ESA.

SECTORAL ANALYSIS

2. ILLEGAL POLLUTION

The MV Wakashio oil spill in Mauritius. Contains modified
Copernicus Sentinel data (2020), processed by ESA.

SECTORAL ANALYSIS

3. FISHERY CRIME

TUNISIA

Sicily

A visualisation of data from fishing vessels
(dark vessels are in yellow) in the Mediterranean
between Sicily and Tunisia. Credit ESA
(data source: Psoto et al., 2024/Global Fishing Watch)



Sectoral analysis Overview



Sectoral analysis

Forestry crime



Sectoral analysis

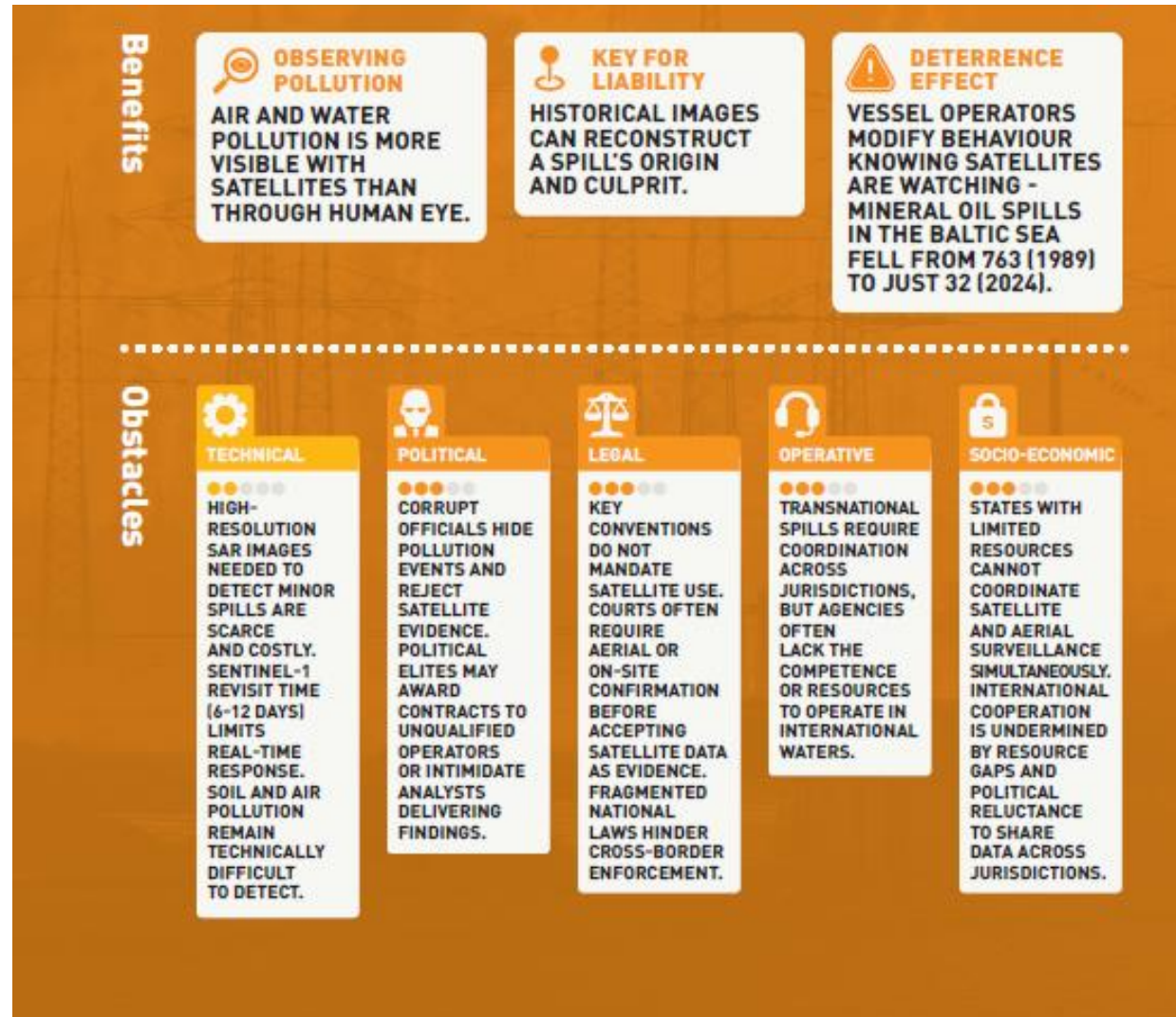
Forestry crime

- ❏ Pro: Envicrime where satellites are applied the most. Optical and radar images are used to detect logging, forest changes, assess the legality of licences, and detect illegal timber trade.
- ❏ Cons: Satellites are not mentioned in key int.l binding arrangements (CITES) or their use is only recommended (EUDR)



Sectoral analysis

Illegal pollution



Sectoral analysis

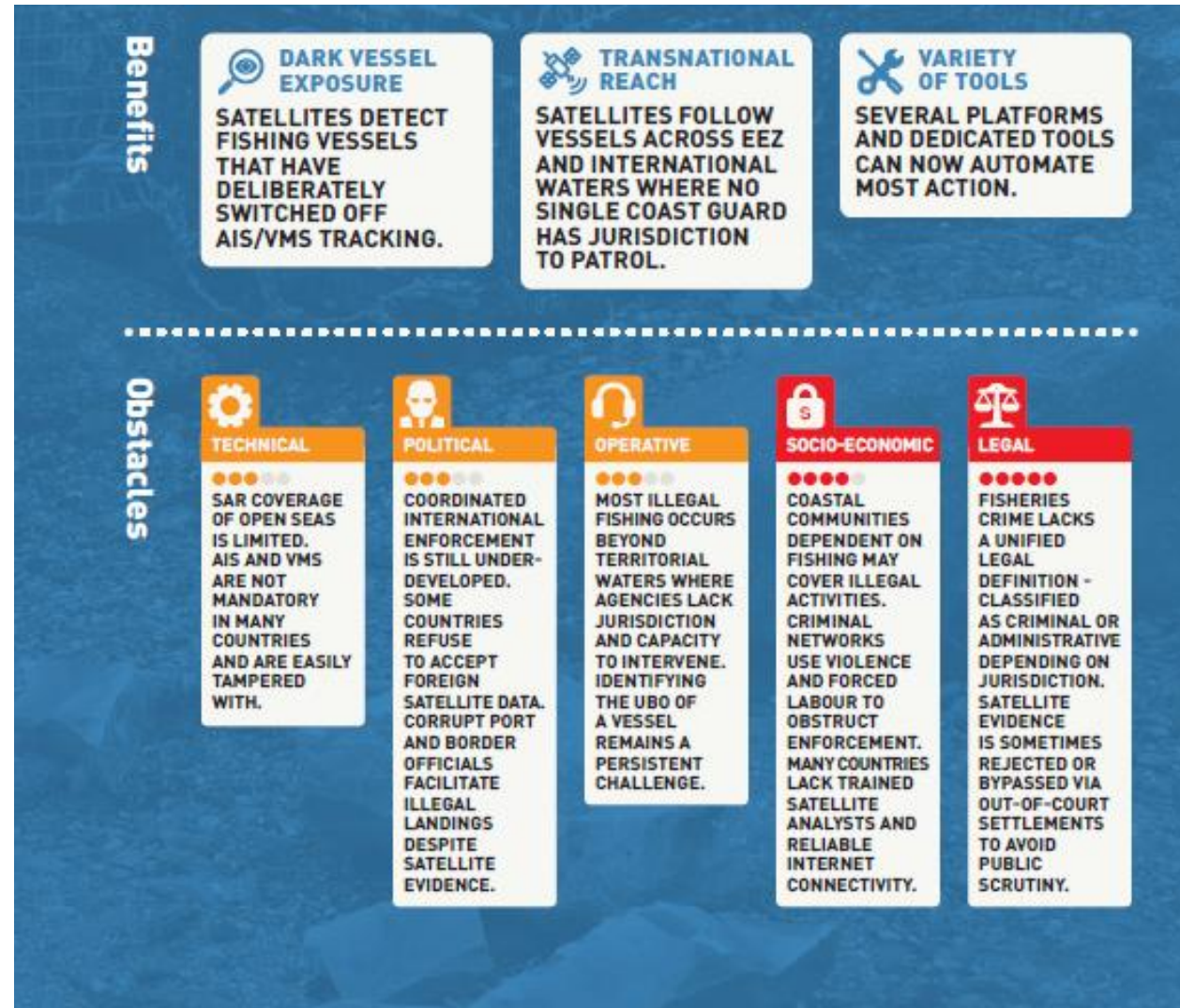
Illegal pollution

- ❏ Pro: crime with relevant recent developments, where satellites are used to detect water, soil and air pollution also through the detection of nitrogene, sulphur and methane.
- ❏ Cons: Satellites cannot be the sole legal evidence as they don't establish liability; High costs of aerial surveillance; legal fragmentation.



Sectoral analysis

Fishery crime



Sectoral analysis

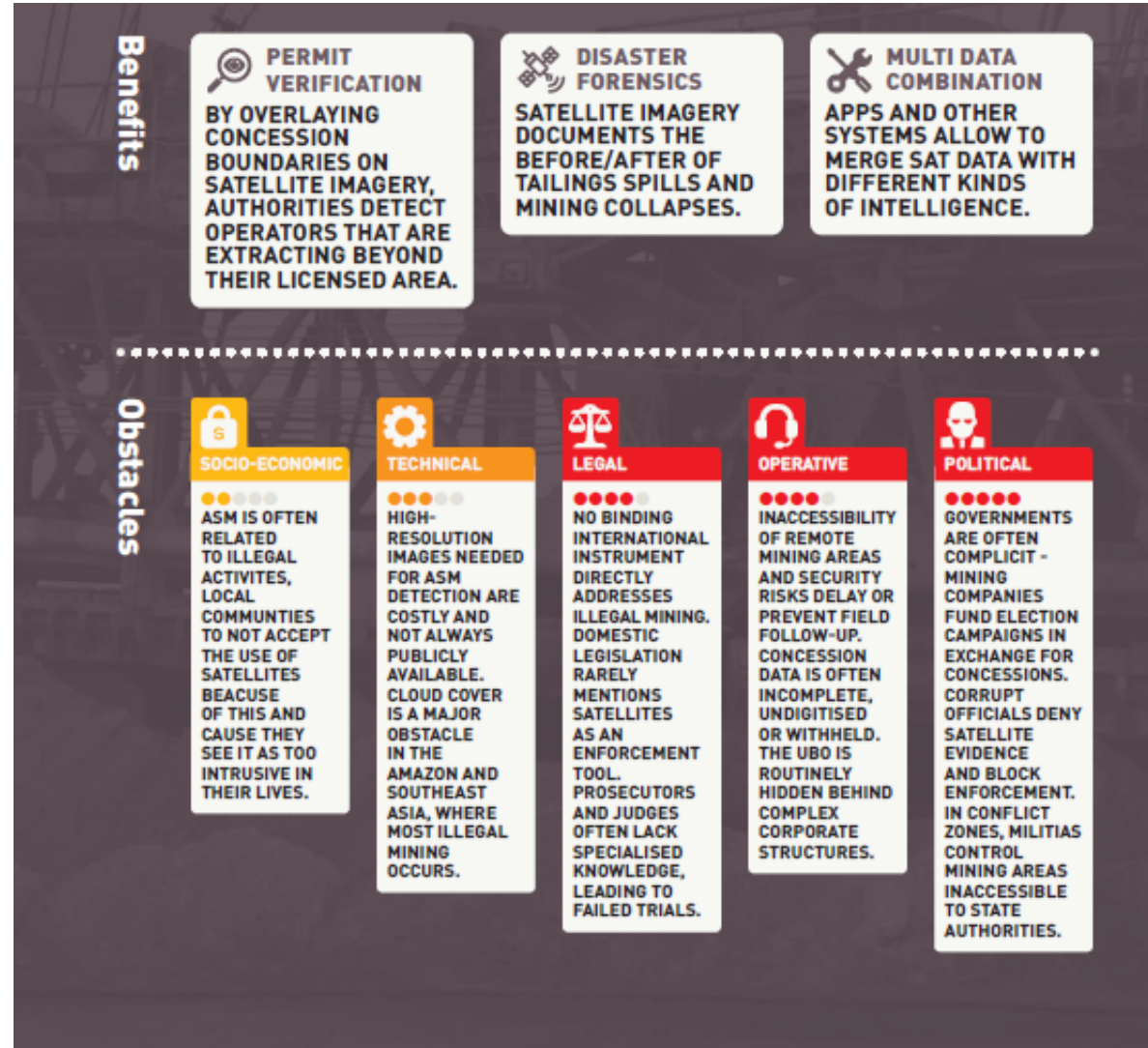
Fishery crime

- ❏ Pro: Satellites can monitor vast areas regardless of sea/weather/light conditions. Relevant efforts by UNODC, EMSA, and NGOs
- ❏ Cons: IUUF recently emerged as a serious crime; lack of satellites considerations into legal frameworks; lack of international cooperation and reluctance to accept foreign satellite evidence.



Sectoral analysis

Illegal mining



Sectoral analysis

Illegal mining

- ❏ Pro: high quality view of vast areas, less need for field inspections in remote/dangerous areas; satellites are used to compare licences and detect smuggling of minerals
- ❏ Cons: No int.l legal framework on mining; satellites less used in some regions as mining is a relative novelty for the region. Strong economic obstacles.



Sectoral analysis

Other areas

Other areas:

Illegal sand mining:

-  High potential on damage estimation

-  Low potential in investigations

-  Low application

Illegal construction

-  Limited use in investigations, high in monitoring

Wildlife crime

-  Hard to detect via EO, but tech is good for context analysis



Case studies

Overview



Overview/2

Common Criteria

Applicability of EO:

-  Effective and central use of Sentinels
-  Across several sectors

High Enforcement Potential:

-  Concrete impact, not just monitoring
-  Leads to investigations or court evidence

Methodology:

-  A mixture of interviews, desk research, and field research



How to read a case study

❏ Table:

- ❏ Description and readability

❏ Structure:

- ❏ Overview - Entities, sector, and EO application

- ❏ Benefits - Advantages over traditional methods

- ❏ Obstacles - Technical, legal, and political limits

- ❏ Replicability - Potential for scaling elsewhere



Case studies

EO to detect IUU fishery by EFCA (6)

6. EO to detect and intercept fishery crime by the European Fisheries Control Agency

Entity responsible for the analysis: European Fisheries Control Agency (EFCA) [European agencies]
Enforcement actor: Member States Fisheries Control Authorities & 3rd country stakeholders
Topic: Illegal Unreported and Unregulated Fisheries [IUU]
Status: Implemented for monitoring and enforcement cases
Main sources of satellite data: Sentinel-1, Sentinel-2, Copernicus Contributing Missions
Replicability: High

All the information that is not cited have been provided by a representative of EFCA.

6.1 OVERVIEW

One of the organizations that uses EO extensively and methodically to perform fisheries surveillance globally is the European Fisheries Control Agency (EFCA). EFCA is responsible for promoting and organising the coordination and co-operation between national fisheries control and inspection authorities so that the rules of the Common Fisheries Policy (CFP) are respected and applied effectively. The area of operation is vast, as it covers not only the European Union waters, but also European countries' exclusive economic zones (EEZ's) and International Waters¹⁰ [i.e., North Atlantic, West Africa, Indian Ocean], which make up about 80% of EFCA-monitored waters.

EFCA has longstanding cooperation with the European Maritime Safety Agency (EMSA), SATCEN and cooperates with ESA under a specific MoU. This allows EFCA to have access to a complete and integrated maritime picture through wide area surveillance using SAR imagery, vessel detection using correlation algorithms for the identification of potential inspection targets, and provision of high-resolution SAR and optical imagery on request, available through the Copernicus Contributing Missions

(EMSA, 2018). The majority of the images used are SAR with 20 to 2m resolution; about 85% of the images have these characteristics, while during specific requests, high resolution SAR (0.5m resolution) is available.

Outputs of the said services are used and integrated at EFCA with other data sources, such as vessel position data and other relevant fisheries-related information, in a 'toolbox' approach. This feeds into either a risk analysis approach or is used for direct operational and tactical support for fisheries control operations. With this objective in mind, a Space & Surveillance Technologies Support Hub was created at EFCA which provides for enhanced tools to transform EO data into actionable deliverables to support its own operations and those of EU Member States fisheries control authorities. EO vessel detection outputs are automatically correlated with Vessel Monitoring Systems (VMS), which track licensed fishing vessels via mandatory onboard transponders, and Automatic Identification Systems (AIS), a broader maritime tracking system used by many commercial vessels. The resulting outputs are used for EFCA's own operations, the National European fisheries, control authorities

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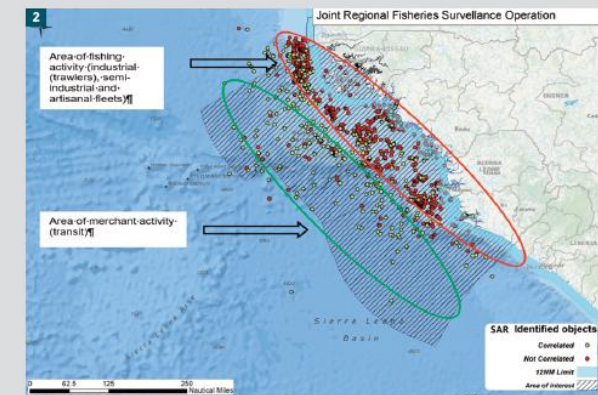
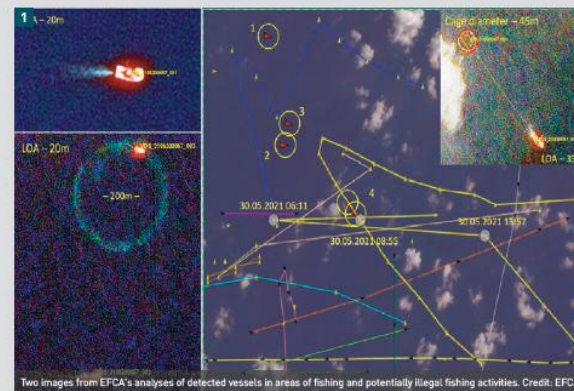
and the European Commission; the analysis is not open access for the wider public.

There are two main services that EFCA offers: routine monitoring and rush mode or short notice, which is specifically requested by member states in a precise maritime zone. A typical example of the routine mode can be seen from the operation in Bassas da India in the Indian Ocean.

In the Indian Ocean, the French EEZ encompasses numerous islands and atolls, which host an enormous wealth of biodiversity and serve as a nursery area for marine life. Consequently, many of these areas are declared Marine Protected Areas (MPA). Its remoteness and size pose a particular challenge when it comes to ensuring the continuous presence of patrol assets in the area. In June 2022, routine CMS acquisitions topped up with high-resolution optical imagery were ordered and analysed in support of French patrol units in the area coordinated by the French Fisheries Monitoring Centre. The

analysis detected small vessels within the Zélee Bank MPA. Consequently, a French fisheries patrol vessel was dispatched to the area for further investigation. Upon arrival, about 20 km eastwards of the initial position, the inspection team was able to intercept a fishing vessel with eight crew on board, and 126 kg of illegally caught fish, 14 fishing lines, and 11 harpoons were apprehended (EMSA, 2022). Although this case focuses on small artisanal fishing vessels (around 10 m in length), their impact can be devastating for the fragile ecosystem.

A subsequent example of the work of EFCA has been in the Mediterranean, within their regular monitoring activities. Following the acquisition of various SAR images, a cluster of small fishing vessels was detected in an area known to be prone to use of driftnet (a fishing practice which is illegal). Using a tip and cue approach, a series of high-resolution optical imagery was ordered in an attempt to detect potentially illegal fishing



activity. Systematic analysis and processing of the optical imagery indeed revealed the presence of such driftnets, as the floating devices could be visualised, and even allowed for measuring the length of the deployed gears. Follow-up operational deployment in the area led to the interception of one of the vessels involved in this illicit activity.

6.2 BENEFITS

For almost a decade now EFCA is rolling out and developing the use of EO for fisheries surveillance, in close cooperation with the relevant entrusted entities and space technology bodies. Since then several advantages have come to light.

The first is cost efficiency: due to their remoteness and extent, patrolling the high seas with classic means is quasi-impossible or comes at a very high cost. Focused operational outputs

can provide 24/7 guidance to surface and air maritime patrol means, thus ensuring cost-effective and targeted deployment of patrol means. This has a major impact on fuel and other operational costs.

The reliability of the operations is equally relevant. EO technologies are mainly used to support operational activities, which ultimately could result in legal proceedings; any deliverable produced needs to be complete, trustworthy, and authenticated. Furthermore, the data and information sources and methodologies used need to be classified and verified in terms of reliability. Performing continuous quality and reliability checks, EFCA ensures that the outputs are the best possible base for launching operational actions or legal proceedings.

Thirdly, the effectiveness of the operations, the EO images provide a real and measurable impact on the capacity to detect non-compliance. The



EO to detect IUU fishery by EFCA (6)

Case Overview:

-  Entities - EFCA / Fisheries Control Agency

-  Sector - IUU fishery

How was EO used:

-  Sentinel-1 for wide-area maritime surveillance

-  Cross-referenced with tracking data to flag suspicious vessels

-  Tip-and-cue with HR imagery when suspicious activity is detected



EO to detect IUU fishery by EFCA (6)

❏ Benefits:

- ❏ Cost-efficient, cutting fuel and operational costs
- ❏ Deterrence effect and identification of dark vessels

❏ Obstacles:

- ❏ Satellite revisit time, coordination with third-country partners

❏ Replicability:

- ❏ Already replicable via the EO + AIS/VMS + HUMINT approach



Investigations of Palm-oil-driven wildfires in Indonesia (3)

3. Investigations on palm-oil-driven wildfires in Indonesia

Entity responsible for the analysis: Prof. Bambang Hero Saharjo, IPB University (academia)
Enforcement actor: Ministry of Forestry and Environment
Topic: Forestry crime
Status: Used in active and concluded cases, used as evidence in court
Main sources of satellite data: Sentinel-1, Sentinel-2
Replicability: High

All the information that is not otherwise cited has been provided by Prof. Bambang Hero Saharjo.

3.1 OVERVIEW

Wildfires triggered by the expansion of palm oil production have been one of the major environmental crimes affecting Indonesia in the past two decades. While fires spiked in 2015–2016, the issue is seeing a resurgence in recent years, with record hotspots detected again in 2023 and in 2025 [Jong 2025]. Wildfires are usually triggered by companies owning large-scale plantations of oil palms, in order to clear the land more rapidly from natural forests, and to change the soil PH of peatland to be more favourable for oil palm cultivation. The issue affects mostly South Sumatra, and Central and South Kalimantan, where most oil palm plantations are located, and where some of the last remaining primary forest in Indonesia is located (largely in Kalimantan). Wildfires have a significant, multifaceted impact on Indonesia, and even on neighbouring countries: not only do they represent a major cause of deforestation, as up to 2.13 million hectares have been burned in 2023 alone [Oneill 2024], but they also generate serious amounts of smoke that frequently reaches Malaysia and has triggered several diplomatic complaints [Jong 2023]. Uncontrolled deforestation also increases soil erosion, contaminates water sources and

represents a direct threat to the safety and health of nearby and even distant communities.

EO has been one of the most consolidated, successful and common tools to counteract wildfires in Indonesia, particularly since 2015–2023; the new endowment of data thanks to the Sentinel mission, more public attention to the issue after critical years, and changes in national legislation regarding the burden of proof for wildfire cases have allowed for a greater employment of satellite data in the monitoring of fires, and in forensic analysis for investigations [Colantoni and Sangiorgio 2024].

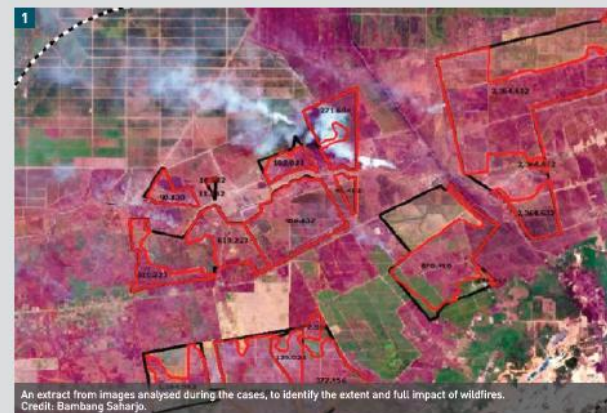
Generally speaking, EO is employed in Indonesia against wildfires by a variety of players, and on a variety of occasions. For example, local NGOs in Sumatra and in Kalimantan such as Jikalahari and Titian have Geographic Information System (GIS) experts who use ESA's Global Wildfire Information System (GWIS) and the National Aeronautics and Space Administration's (NASA) Fire Information for Resource Management System (FIRMS) to discover active fires, evaluate through open-source intelligence (OSINT) and use their local network to investigate the most relevant ones. They then collect evidence using mostly commercial drones.

The most complex applications are however performed by expert witnesses working for the Indonesian national police, and usually belonging to academia. This is particularly the case for Prof. Bambang Hero Saharjo, part of the IPB University and one of the most advanced and involved users of EO against wildfires for forensic analysis. Satellite data are employed in a number of ways, and to collect a number of different sorts of information; generally speaking, EO investigations on wildfires aim at understanding ecological damage (in terms of biodiversity, but also soil damage, water storage and carbon release, for instance), economic damage (replanting of the landscape and maintenance of new forests, loss of profits by communities and land owners) and restoration costs (revegetation, restoration costs and hydrological system repair costs in particular).

The methodology presented in this case study was applied by Prof. Bambang Saharjo on a major fire in South Kalimantan in August 2025.

The total area affected was 1,514.9 hectares in three different locations, and it is alleged the fire was triggered by palm oil company PT SSM in an area it owns, and which it is partially authorised to cultivate [AntaraNews 2025]. This methodology is however a standard approach that is systematically applied for such cases, and is based on a few crucial steps:

- **Preparatory actions:** Obtaining the concession maps to see how much of the fire happened inside the company's area, and how much it extended beyond this. Sentinel-2 imagery is then overlayed on the concession map and on the location of detected hotspots to calculate the area of fires.
- **EO analysis:** The expert witness then proceeds to analyse the imagery to detect possible evidence related to the cause of the fire, or to other criminal actions: preparatory activities, such as the opening of water channels to prevent the fire spreading towards agricultural land or selective cutting of valuable



species inside the forest, for instance; or where the fire has originated (inside the concession block or outside).

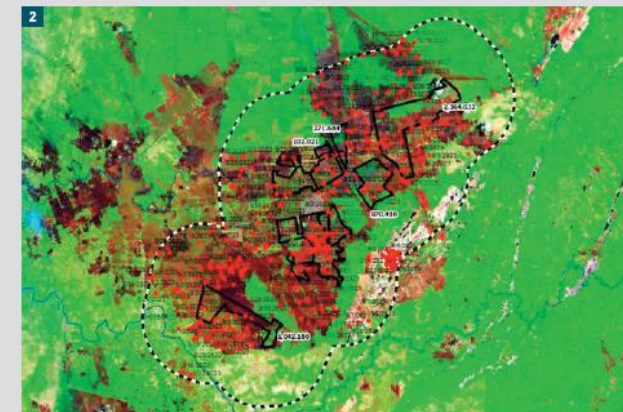
- **Evaluation:** Environmental damages are then calculated to understand the amount of biomass that has been burned, the ecological value of the area before and after the fire, and the damage inflicted to critical landscape elements such as rivers or water reserves. If the area was peatland also the ground water level is measured, since it if falls under a threshold (40 cm) this may indicate significant damage to the soil.
- **Work on the ground:** The expert witness performs then checks on the ground, also to see if fire control infrastructures were in place and if they were used.

The expert witness consolidates all information in a standard report, which is then transmitted to enforcement authorities (usually the General Attorney's office).

3.2 BENEFITS

Benefits of using EO against wildfires in Indonesia are well known, as the application is among the most consolidated. Generally speaking, they can be summarised in terms of accessibility of the territory, relevance of time series and information provided by the imagery in terms of damage evaluation and forensic analysis.

Oil palm plantations and the company's concessions in general are frequently hard to access and monitor; this is in some cases due to the structure of the Indonesian landscape, but on most occasions companies actively impede entry into the area, or even nearby. Most fires are indeed detected using the GWIS and FIRMS systems, and this also happened in the case detailed in Image X: it was spotted using satellite data, followed by an inspection on the ground by police officers. This is particularly relevant for NGOs, whose work is crucial as they provide key evi-



Investigations of Palm-oil-driven wildfires in Indonesia (3)

❏ Case Overview:

❏ Entities - Professor Saharjo / Ministry of Environment

❏ Sector - Illegal wildfires

❏ How was EO used:

❏ Sentinel imagery overlaid on concession maps

❏ Time series are used to estimate ecological damages

❏ Dossier sent to the relevant authorities



Investigations of Palm-oil-driven wildfires in Indonesia (3)

❏ Benefits:

- ❏ Access to restricted plantation areas
- ❏ Accuracy in estimating damage, limiting offenders' ability to conceal it

❏ Obstacles:

- ❏ Cloud coverage, time series
- ❏ Political and economic resistance

❏ Replicability:

- ❏ Highly replicable +500 cases by Prof. Saharjo alone
- ❏ Adaptation needed for different landscapes/sectors



Thank you!

