COPERNICUS

Market report - February 2019

Prepared by PwC for the European Commission

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Luxembourg: Publications Office of the European Union, 2016

ISBN 978-92-79-98973-5

doi 10.2873/011961

Catalogue number: ET-04-19-024-EN-N

Printed in France

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Market report

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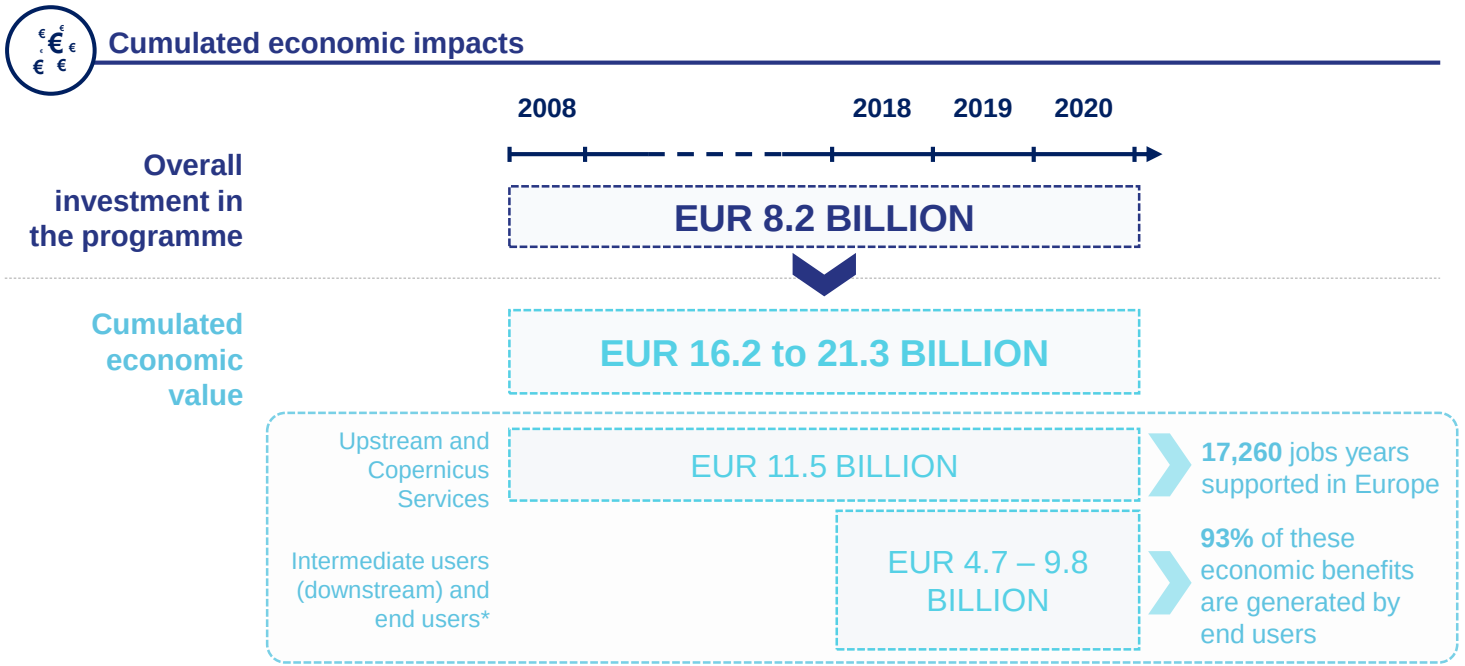
Note: This Market Report updates the content of the previous Copernicus Market Report, published in 2016. The update relies on the re-assessment of the previous value chains, and includes 2 additional value chains on the Response to Natural Disasters and Security. Some of the analysis for the sizing of economic impacts relies on a past study prepared by PwC for the European Commission and published in 2017: Copernicus ex-ante societal impact. Additional details can be found on the quantification methodologies in this study.

OVERVIEW OF COPERNICUS PROGRAMME BENEFITS

MAIN RESULTS

From 2008 up to 2020, the total investments in the Copernicus programme are forecasted to reach EUR 8.2 billion. Over the same period, this investment will generate economic benefits between EUR 16.2 and 21.3 billion (excluding non-monetary benefits). This economic value is generated through the added value created in the upstream space industry, the sales of Copernicus-based applications by downstream service suppliers and the exploitation of Copernicus-enabled products by end users in various economic sectors. It is important to note that the intermediate and end users benefits are only computed for the 2018 – 2020 period while the costs of the programme are considered from 2008.



** The study includes 10 value chains: Agriculture, Forestry, Urban Monitoring, Coastal and Marine Exploitation and Preservation , Oil & Gas, Renewable Energies, Air Quality, Insurance for Natural Disasters, Response to Natural Disasters and Security. A conservative approach was applied for extrapolating downstream and end user benefits based from experts consultation, since the aim of this study is to provide robust figures. In addition, many user benefits are non-monetary in nature and could not be quantified.*

Examples of Copernicus impacts

Social impacts

- Reduced casualties in natural disasters
- Improved robustness for food security
- Improved management of air quality in cities

Environmental impacts

- Reduced areas burnt by wildfires through better civil protection responses
- Higher accuracy for the monitoring of compliance with environmental policies
- Reduced oil spill damages on ecosystems
- Improved fish stock management

Strategic impacts

- Strengthened collaboration between states at global scale for civil protection
- Development of EU industry competitiveness

OVERVIEW OF INTERMEDIATE USERS' BENEFITS (1/2)

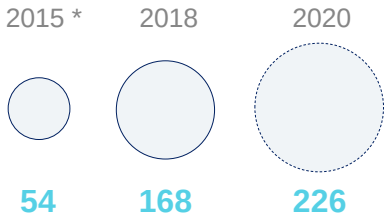
MAIN RESULTS

Intermediate users constitute the main link between the satellite images of Copernicus and the community of end users. Also designated as downstream providers, they are typically providers of Value Added Services, processing raw data into exploitable information for end users. In 2018, the benefits of Copernicus in the downstream market are estimated to be between EUR 125 and 150 million, up from EUR 54 million in 2015 (these benefits were assessed for the 10 value chains covered in this report). They are expected to grow at a CAGR of around 15% up to 2020. The main drivers for the growth of these markets are the remaining gap between end users' specific needs for tailored products and their current offer, and the progressive adoption of EO-based solutions in some industries such as renewable energies.

REVENUES

Copernicus impact for intermediate users of the 10 selected value chains

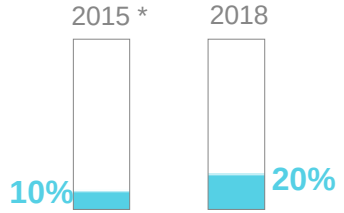
Enabled revenues for intermediate users in Europe (EUR million)



Expected average annual growth rate up to 2020

+ 15%

Average penetration of Copernicus data with regards to EO data



** 2015 values are based on a set of 8 value chains only, not taking into account the Response to natural disasters and Security.*

COPERNICUS UPTAKE (2017)

72 %

+6 pts / 2016

Proportion of EO companies exploiting **Copernicus data** in Europe

38 %

+11 pts / 2016

Proportion of EO companies exploiting **Copernicus services** in Europe

28 TB

+133 % / 2016

Volume of downloads from the Data Access Systems

300,000

+44% / Q1 2018

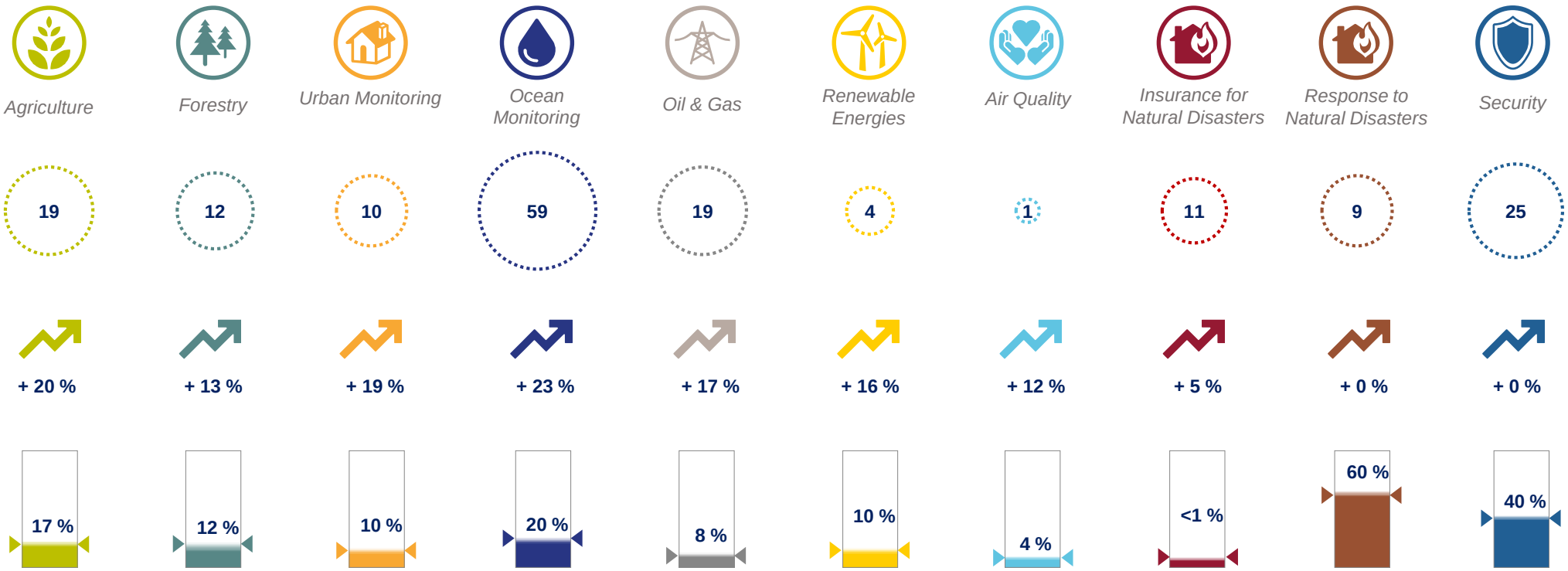
overall **registered users on the different hubs (ESA, EUMETSAT, ECMWF, EEA, Mercator Ocean International and JRC)**

OVERVIEW OF INTERMEDIATE USERS' BENEFITS (2/2)

MAIN RESULTS

Copernicus benefits vary between the value chains, depending on the contribution of Earth Observation (EO) in the industry activities (driving the revenues for downstream players) and the penetration rate of Copernicus within this EO data. Although some value chains remain rather challenging as potential growth segments for Copernicus, such as insurance, overall the industries considered all foresee a positive evolution of Copernicus uptake and hence of its economic impacts.

DETAIL PER VALUE CHAIN



The penetration of Copernicus data takes into account the Sentinel data, Copernicus Services products, and also contributing missions data when procured in the frame of Copernicus Services. The latter explains in particular the high penetration rates for response to Natural Disasters and Security.

OVERVIEW OF END USERS' BENEFITS

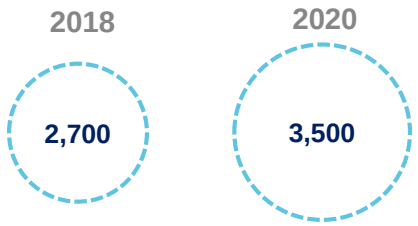
MAIN RESULTS

End users' benefits are generated either through the exploitation of Copernicus-enabled products provided by intermediate users, or through direct use of Copernicus data by end users. End users represent much larger markets than the Earth Observation (EO) downstream market, and therefore even moderate contributions of Copernicus in terms of data inputs can potentially generate large benefits, for instance for oil and gas companies, or agricultural cooperatives. End users generally have very specific needs, but demonstrate high willingness to pay to access tailored EO products with real added value to their business.

ECONOMIC BENEFITS

Copernicus impact for end users of the 10 selected value chains :

Economic benefits for end users in Europe (EUR million)



Expected average annual growth rate up to 2020

+ 14%

DETAIL PER VALUE CHAIN

Copernicus enabled revenues for 2018 (EUR million)

Average annual growth rate up to 2020

Agriculture — 318 — + 31 %

Forestry — 77 — + 46 %

Urban Monitoring — 24 — + 17 %

Ocean Monitoring — 190 — + 4 %

Oil & Gas — 417 — + 17 %

Renewable Energies — 137 — + 25 %

Air Quality — 537 — + 3 %

Insurance — 14 — + 5 %

Civil protection — 670 — + 12 %

Security — 308 — + 8 %

OVERVIEW OF COPERNICUS PROGRAMME BENEFITS

EXAMPLES OF KEY FACTS

Although the value chains analysed in this report can be complex and involve various dynamics, a selection of key messages is presented below for each. These statements are only examples and are not exhaustive depictions of the value chains.

20 to 100 %

Agriculture is a fast-growing sector when it comes to the utilization of EO-based products, especially for smart farming. Copernicus ranges from 20% all the way to 100% of the EO data used in solutions.

Forestry offers a high potential for growth in the coming years due to the implementation of environmental protection policies at national and European levels.

Growth potential

Higher resolution

The improved spatial resolution of Sentinel data (compared to previous open data satellite images) and the associated Copernicus services (Urban Atlas, high resolution layers) are a huge driver for the uptake of Copernicus in urban monitoring.

1% reduction of overall fuel consumption by big shipping companies can be expected from using surface current models. This represents about 17 M€ per year.

17 M€

Barrel price

The heavy fluctuation of oil prices, which fell from US$115 per barrel in 2014 to under US$35 in 2016 and up to US$ 60 by early 2019, significantly impacts the value chain, especially in willingness to invest in major projects.

The extension of renewable energy farms, the management of the intermittency of renewable energies and the rising needs of smart cities create a need for new types of jobs.

New jobs

50 to 80 %

Share of data coming from the Copernicus Atmosphere Monitoring Service (CAMS) in services related to air quality. This contributes to companies' viability in a sector with low willingness to pay.

Estimated maximum share of overall insurance and reinsurance companies exploiting Copernicus data for their activities related to natural disasters.

5 %

80 %

Share of flood events in Europe for which the Copernicus Emergency Management Service (CEMS) has provided forecasts and maps of the situation.

Total area of the combined Exclusive Economic Zone of EU Member States, making it the largest in the world. This constitutes a challenge for maritime surveillance and security operations at sea.

20M km²

OVERVIEW OF COPERNICUS PROGRAMME BENEFITS

EXAMPLES OF USE CASES

The wide range of applications to which Copernicus contributes can be illustrated more concretely through relevant use cases on selected applications. In addition to the examples provided here, a more thorough list of use cases per value chain is provided throughout the rest of this report.

19 %

Decreased consumption of water, fertilisers and pesticides through Earth Observation-based smart farming services in Greece. On top of this, the production also increased by 10%.

-10 % economic losses

The 20% economic losses undergone by the mussels industry in 2017 due to the climatic conditions could have been reduced to 10% with the Rheticus project, using CMEMS products and Sentinel-3 data.

Allergy sufferers

Apps offering forecasts of pollen dispersion enable allergy sufferers to plan better their outdoor activities.

98 %

Percentage of scenes that can be observed cloud-free more than 4 times a year thanks to the 13 spectral bands of Sentinel-2 satellites.

25,000 images

Individual SAR images contained in the NPA's Global Offshore Seepage Database (GOSD), covering 90% of the world's offshore sedimentary basins.

2 hours

Delay between the activation of CEMS and the acquisition of the satellite data, achieved in some situations, thanks to the floods Early Warning System.

80 %

Cost reduction per year for displacement monitoring service while using Sentinel data instead of traditional monitoring sources.

1 to 3 M€

Increased project return per 100 MW produced through wind energy, if using the Copernicus ERA5 to reduce uncertainties.

2.4 Tons

Cocaine seized by Spanish customs on a vessel that had been monitored through the Maritime Surveillance Service.

EARTH OBSERVATION MARKET

IN A NUTSHELL

- Earth Observation (EO) applications and technologies are used in a wide range of applications, covering land, marine and atmosphere monitoring.
- In 2017, the global EO economy was estimated to be between EUR 9.6 and 9.8 billion, divided between EO satellites sales (the upstream section of the supply chain), and the EO data acquisition, processing and transformation into information products for end users (the downstream section). The global market is mostly driven by the upstream market, which constitutes about 70% of the total revenues. The global EO downstream market is estimated to be between EUR 2.6 and 2.8 billion, mainly driven by governmental applications, which represent between 50% and 60% of the revenues.
- While upstream revenues tend to oscillate over the years depending on the fluctuating needs for large EO satellites, the downstream market shows constant growth, at an expected CAGR of 7% up to 2022.
- In 2017, the European EO economy was valued at between EUR 2.7 and 3.1 billion. The EO upstream segment was valued at EUR 1.9 billion, which represents about two thirds of the revenues of the European EO economy. The revenues of the downstream market amounted to between EUR 750 and 1,200 million.
- Similarly to the global EO economy, the EO downstream sector in Europe shows stable growth over the years, and is expected to maintain a CAGR above 6% in the coming years.
- The EO downstream market is undergoing strong trends such as changes in business models towards near-real time applications, more and more integrated solutions, cloud computing and the use of artificial intelligence to improve the value of analytics.
- EO 2.0 players are entering the market with an innovative approach. These stakeholders, vertically integrated, have in-house capabilities to manufacture satellites but also to handle the data and develop and offer services.
- In this context, Copernicus is ramping up in terms of user uptake, benefitting from an increasing user awareness, a gain in maturity of the Services, and the progressive adaptation of the intermediate market to fulfil end users' specific needs.

OVERVIEW OF EARTH OBSERVATION

What is Earth Observation?

Earth Observation (EO) refers to the use of remote sensing technologies to monitor land, marine (seas, rivers, lakes) and atmosphere. Satellite-based EO relies on the use of satellite-mounted payloads to gather imaging data about the Earth's characteristics. The images are then processed and analysed in order to extract different types of information that can serve a very wide range of applications and industries.

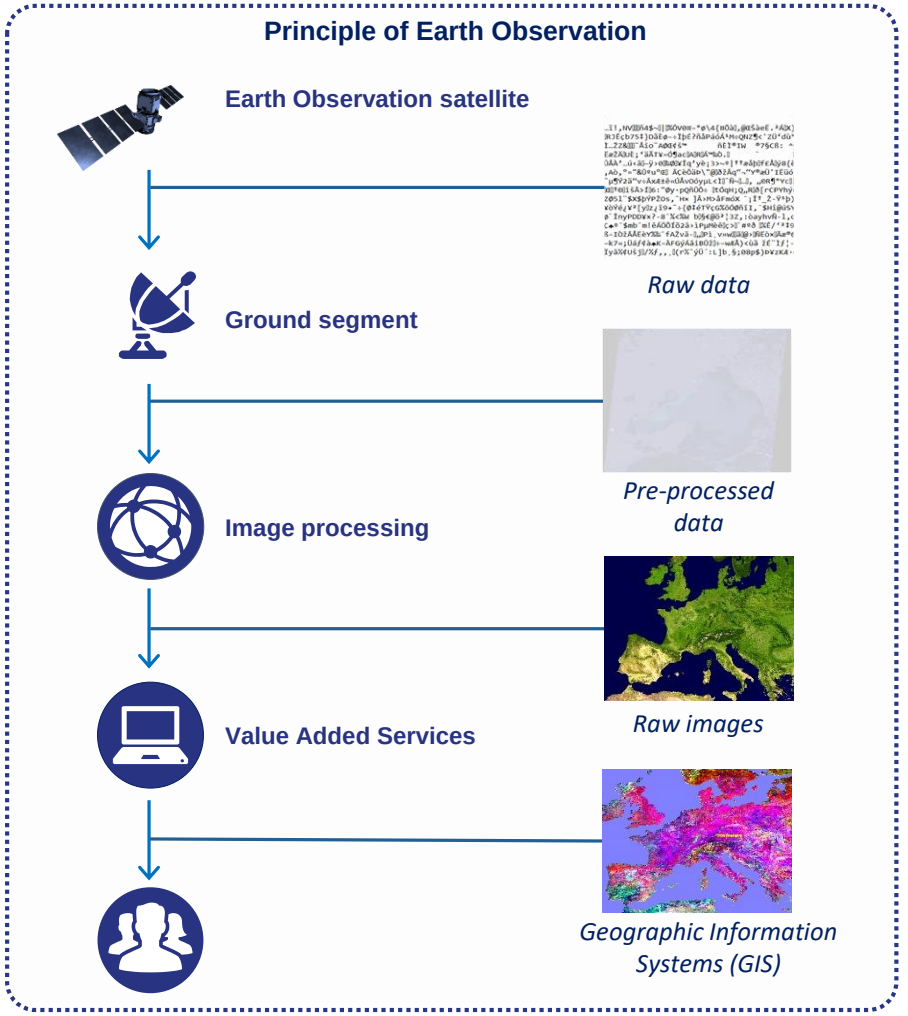
EO technologies utilize different types of sensors on their payloads:

- **Optical or thermal sensors** are payloads monitoring the energy received from the Earth due to the reflection and re-emission of the Sun's energy by the Earth's surface or atmosphere. They operate between the visible and infrared wavelengths of the electromagnetic spectrum.
- **Radar sensors** are payloads operating in the lower part of the spectrum (longer wavelengths). Most of these sensors send energy to Earth and monitor the energy received back from the Earth's surface or atmosphere, enabling day and night monitoring during all weather conditions.

The second essential parameter in EO is the sensor resolution.

- **Spatial resolution** defines the size of the pixels analysed by the sensors. EO satellites can be distributed into 3 categories based on this parameter (the boundaries between these categories can vary depending on the source):
    - **Low and medium resolution**: more than 10 meters per pixel;
    - **High resolution (HR):** between 1 and 10 meters per pixel;
    - **Very-High Resolution (VHR):** less than 1 meters per pixel, also called sub-metric imagery. The use of VHR imagery with a higher resolution than 0.3 meters is subject to restrictions that limit it to government applications.
- **Temporal resolution** defines the frequency at which the data is acquired for a defined area. The needs can vary substantially for this parameter as well, with applications requiring images every day or in only a few hours (for emergency operations for instance), whilst others require an update every few weeks.
- In the case of optical sensors, another type of parameter can differentiate the payloads, which is the **spectral resolution**. This is defined by the width of the spectrum bands that can be distinguished by the payload, enabling some applications that require the ability to analyse specific wavelengths.

The last key parameters considered for remote sensing techniques are the **coverage** and usually the associated **re-visit frequency.** Flying in orbit enables satellites to offer a global coverage with a single spacecraft, while aerial or in-situ sensors have regional or local coverage. Orbital geometry however limits the frequency of fly-by over a same location (typically once per day to once every few days) while local monitoring allows a higher persistence, from a new acquisition every few hours down to near real time.



OVERVIEW OF EARTH OBSERVATION

The 3 stages of the Earth Observation value chain

Earth Observation stimulates economic activity involving diverse categories of companies:

- **The upstream industry** refers to the space industry in charge of developing and manufacturing the infrastructure. This includes the space infrastructure (the satellites) and also the ground segment for satellite operations (mission control and management of the payloads). The upstream also includes the launch operations.
- **The downstream industry** is part of the EO value chain, and includes the companies and institutional actors whose activities revolve around the processing of EO data and the creation of Value Added Services (VAS) based on this data. These players tend to be experts in EO, and can be perceived as “intermediate users”.
- **The end users** consist of the wider base of businesses and institutional players for which EO-derived products is an input, but whose core activity is not centred on EO. End users tend to be non-experts in EO, and therefore typically rely on intermediate users to have access to the relevant input information and products for their activity.

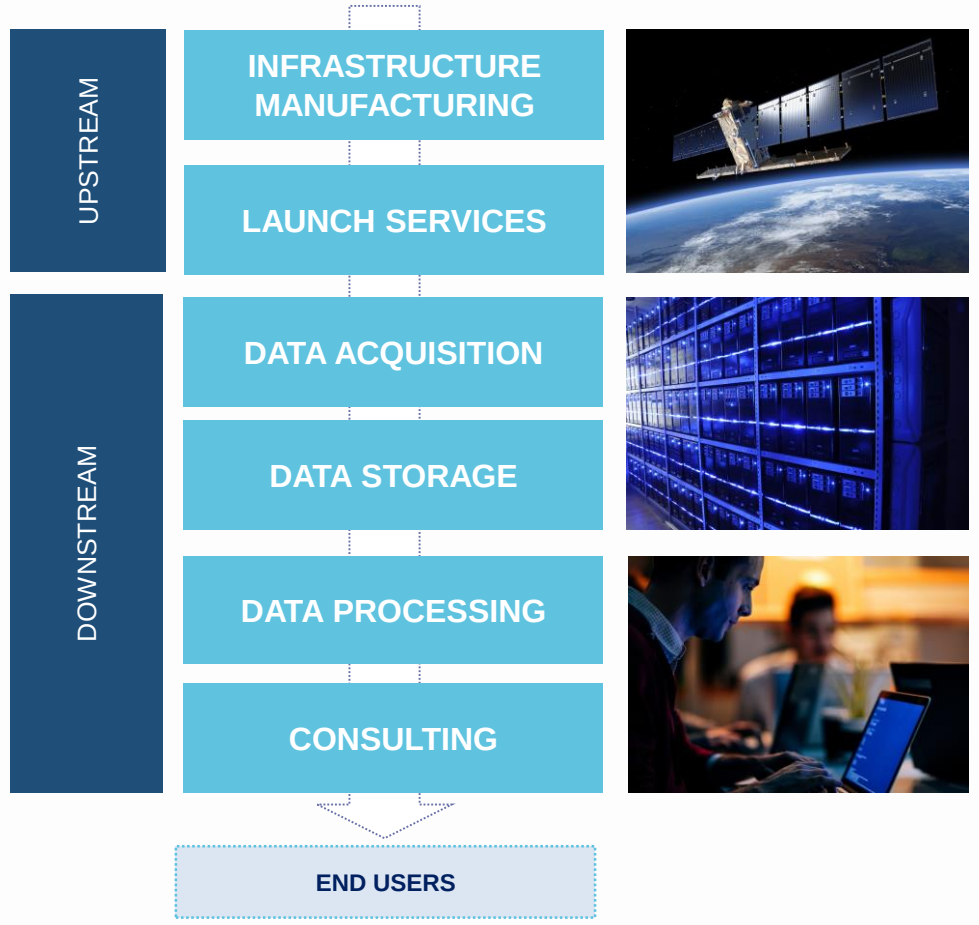
€ 9.6 to 9.8 billion
Global revenues of the overall EO industry in 2017
+27% / 2015

€ 7 billion
Global revenues of the EO upstream industry in 2017
+39% / 2015

€ 2.6 to 2.8 billion
Global revenues of the EO downstream industry in 2017
+12% / 2015

Sources: PwC, NSR, Frost & Sullivan, SIA

The Earth Observation value chain



OVERVIEW OF EARTH OBSERVATION

The variety of addressed markets implies a need for solution tailoring

The ubiquity of geo-spatial tools, information and applications highlights the wide usage that is made today of satellite imagery. The users of Earth Observation (EO) data are present in many industries, each with very specific needs.

However raw data cannot be exploited directly, as it is generally the information contained in the images that is of value. Hence, EO data alone does not bring value, but creates it through the applications that derives from it.

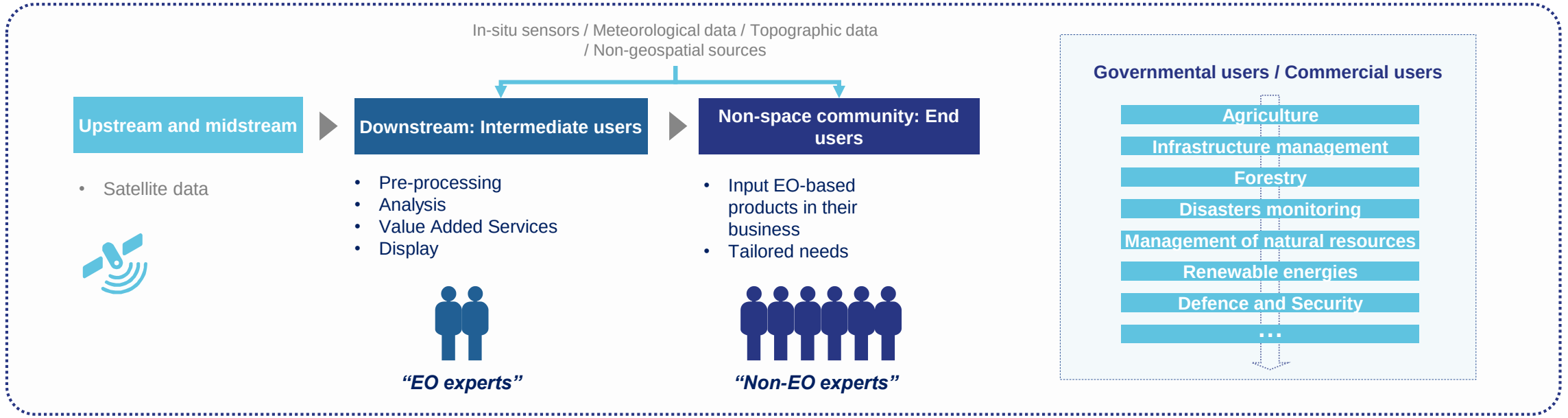
The role of intermediate users is crucial in the EO value chain, as the interface between the satellite technical features and the end users' specific needs.

EO-based solutions call for different levels of data integration

Because the core activity of end users is not directed at EO products, they generally combine the geo-spatial products they receive with their own relevant sources of information for their business (for instance the type of crops, the function of the infrastructure, the profile of their customers, the reports from their agents, etc.). On top of this integration with their usual data sets, end users are also embracing more and more the benefits of combining multiple digital sources in the frame of Big Data applications.

Therefore the challenge for intermediate users goes further than that of the imagery features (pixel size, revisit time, wavelength, geographical area, etc.), and is increasingly involving digital capabilities and multi-source solutions.

Terminology and roles for Earth Observation intermediate users and end users



THE EARTH OBSERVATION UPSTREAM AT GLOBAL SCALE

€ 7 billion

Global revenues of the EO upstream industry in 2017

A global upstream market of EUR 7 B in 2017

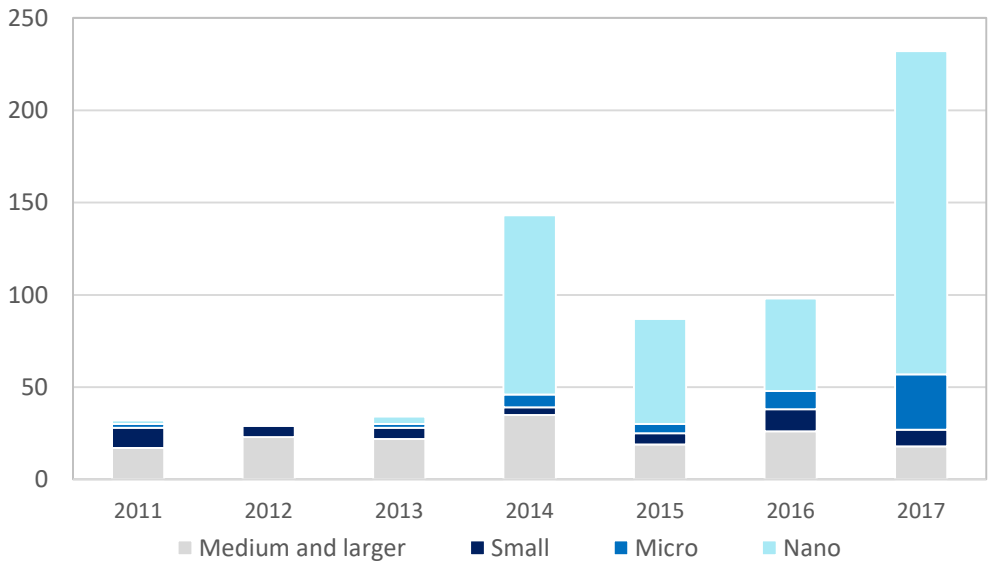
The Earth Observation (EO) upstream market was estimated around EUR 7 B in 2017, down from around EUR 7.2 B in 2016. The market size is fluctuating from one year to the other depending on the orders, which can vary substantially. For instance according to the Satellite Industry Association, in 2016 civil EO satellites represented only 12% of the satellite manufacturing market (the rest of the market being military surveillance satellites), while in 2017 they represented nearly half of the market.

Between 2011 and 2017, the number of EO payloads sent has been multiplied by more than 7, driven by the explosion of nanosatellites

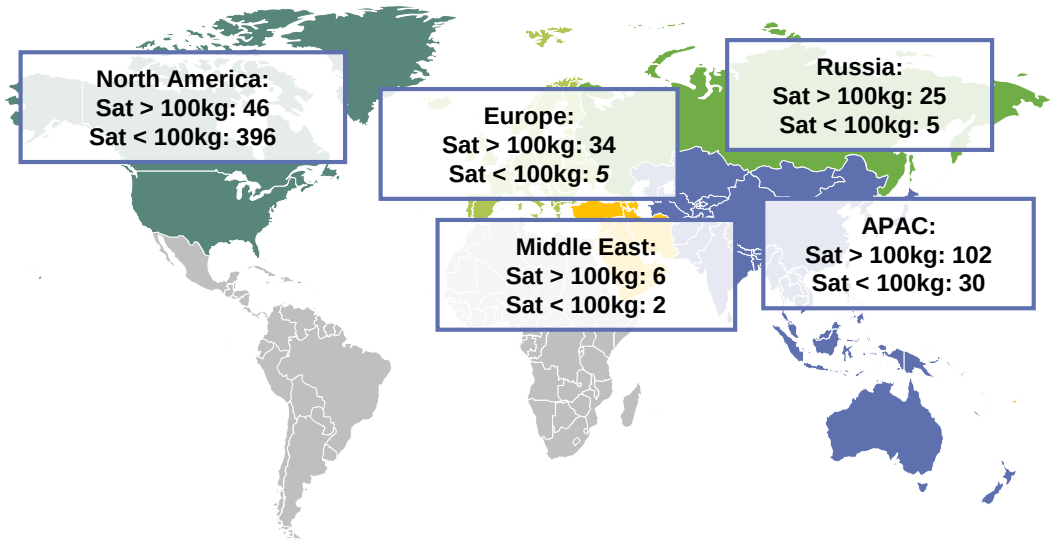
While the number of satellites above 100 kg that are launched every year has remained relatively steady over the past years, smaller satellites have witnessed a skyrocketing increase, with the nanosatellites segment jumping from no more than 10 a few years ago, up to 175 in 2017, experiencing a +250% growth just between 2016 and 2017. Planet's constellation represented nearly 80% of these nanosatellites.

The presence in California of the current 2 leaders in terms of constellation size (Planet and Spire) gives a strong lead of the USA within the nanosatellites segment. China on the other side is the largest producer of large satellites (above 1 ton), driven in particular by the launches of Gaofen and Yaogan satellites to fulfil respectively civilian and military applications.

Evolution of EO payloads sent by mass category, 2011-2017 (Source: PwC)



Geographical repartition of EO satellites manufacturing , 2011-2017 (Source: PwC)



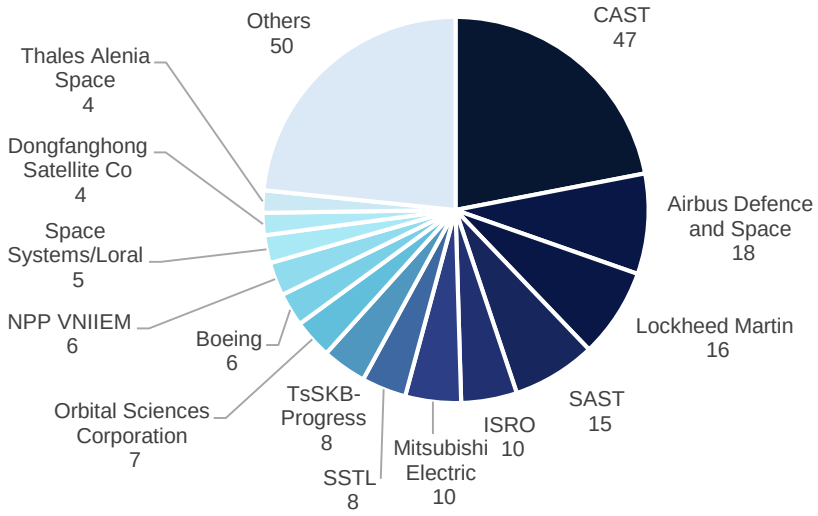
THE EARTH OBSERVATION UPSTREAM MARKET AT GLOBAL SCALE

Governmental applications remain the main segment for satellites above 100kg, but recent nanosatellites constellations reverse the trend towards commercial applications

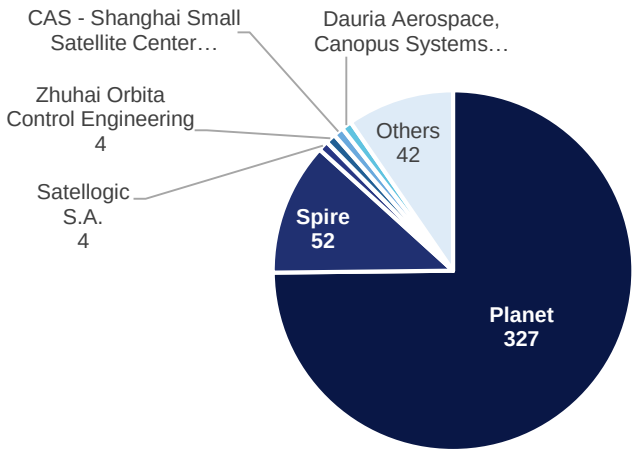
Over the 2011 – 2017 period, more than 85% of the satellites above 100kg were serving governmental customers, balanced between civilian and military applications. The situation is different for smaller satellites. Since 2014 and 2015, the Cubesat-based constellations of Planet and Spire, which are oriented towards commercial applications, represented more than 75% of the satellites below 100 kg launched. It can be noted that in terms of overall mass launched, governmental satellites still constituted more than 90% of the total on the 2011 – 2017 period.

The market for satellites above 100 kg is rather fragmented, with 15 manufacturers having produced 4 satellites or more out of the 216 total, and dominated by the Chinese Space Agency, Airbus Defence & Space and Lockheed Martin. For micro and nanosatellites, the market is consolidated, largely dominated by Planet (more than 300 satellites launched) and Spire (more than 50 satellites launched).

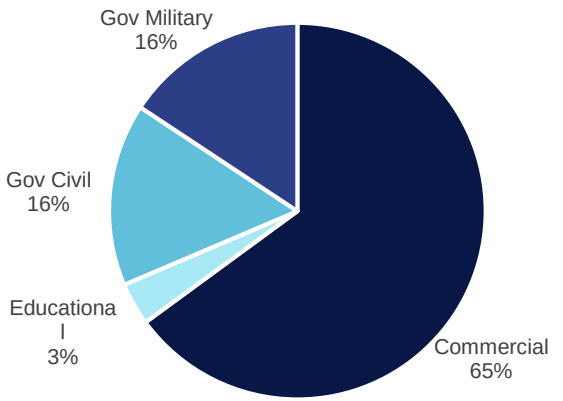
Number of EO satellites > 100kg by manufacturer, 2011-2017 (Source: PwC)



Number of EO satellites < 100kg by manufacturer, 2011-2017 (Source: PwC)



Number of EO payloads sent, by customer, 2011-2017 (Source: PwC)



THE EARTH OBSERVATION UPSTREAM MARKET IN EUROPE

€ 1.9 billion

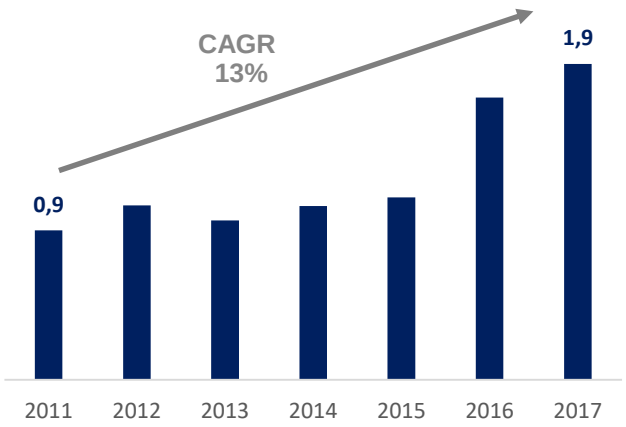
Revenues of the European EO upstream industry in 2017

The EO upstream segment represents nearly EUR 2 B market in 2017

In 2017 sales of Earth Observation space systems by the European space manufacturing industry reached EUR 1.9 billion, representing about 21% of all European space systems manufacturing revenues. It is predominantly domestic, with 88% of revenues coming from European sources.

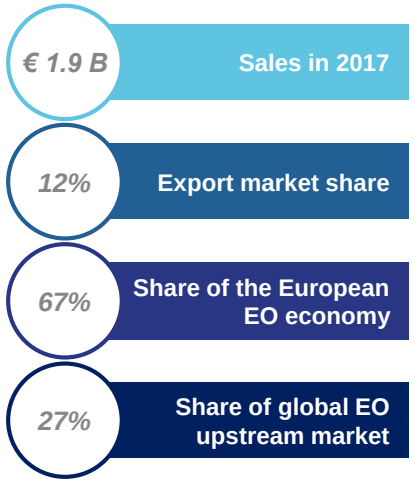
If the market had been relatively steady before 2014, it then experienced an aggressive growth of 82% between 2014 and 2017. This growth could potentially be explained by the delivery of several EO spacecraft systems by European manufacturers to European and Non-European customers in 2016, 2017 and 2018, such as the Sentinel constellation provided by Thales Alenia Space and Airbus Defence and Space for ESA (1A, 1B, 2A, 2B, 3A), the DMC-3 constellation (1, 2, 3) provided by SSTL for ISRO and Jason 3 provided by Thales Alenia Space for CNES.

Evolution of European EO upstream sales, EUR B

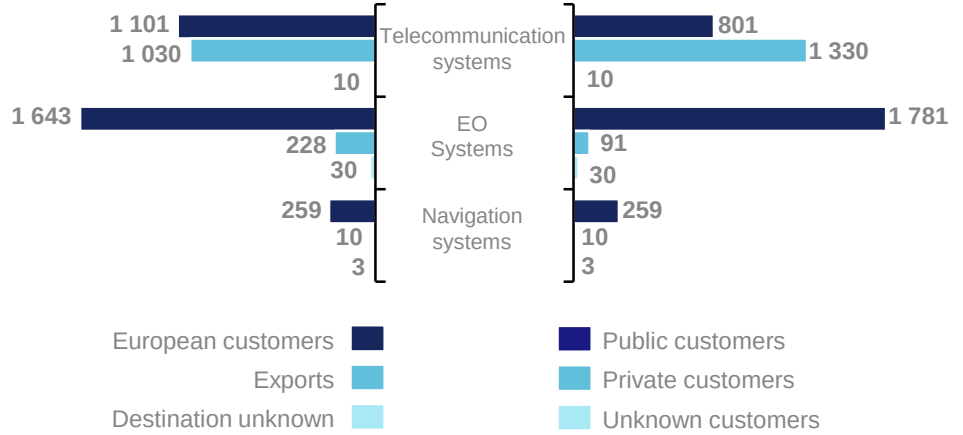


Source: Eurospace, 2017, Facts & Figures

European Earth Observation upstream industry in 2017



Sales by system
European Customers Vs Exports
EUR M, 2017



Sales by system
Public Vs Private customers
EUR M, 2017

Source: Eurospace, 2017, Facts & Figures

The European upstream industry for EO remains largely driven by institutional demand

Historically, governmental programmes have been the main source of revenues for EO upstream activities in Europe. While the situation changed significantly for the markets of launch systems and telecommunication satellites over the past decades, as of 2017 it remains true for EO systems, for which public customers still represented over 90% of the industry revenues in 2017.

THE EARTH OBSERVATION UPSTREAM MARKET IN EUROPE

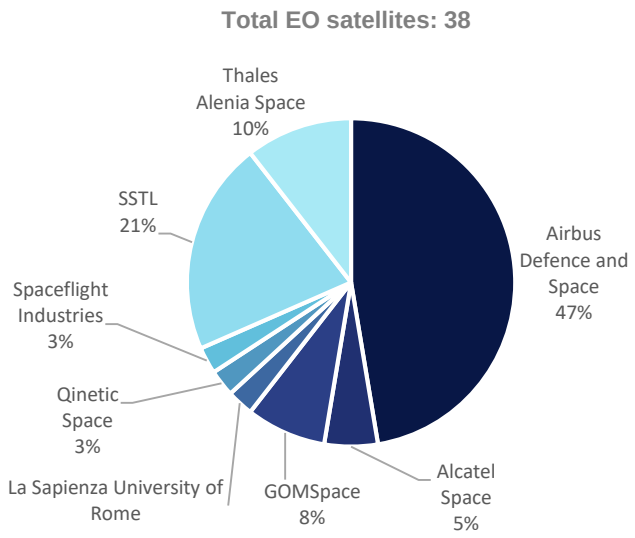
Europe is mainly positioned on the large satellite segment

While the growth of the global EO payload manufacturing market was driven by the explosion of the nanosatellite segment between 2011 and 2017, the European market remained focused on the traditional segment of satellites over 100 kg. It is expected to continue growing in the coming years with the introduction of new rideshare capabilities of the new European launchers, Ariane 6 and Vega-C. All in all, only 4 nano and 1 micro satellites produced in Europe were sent between 2011 and 2017, underlining the absence of large constellations programmes to stimulate the manufacturing of these satellites. Recent contracts (such as the first units of the OneWeb constellation by Airbus Defence and Space) could suggest a change in this trend.

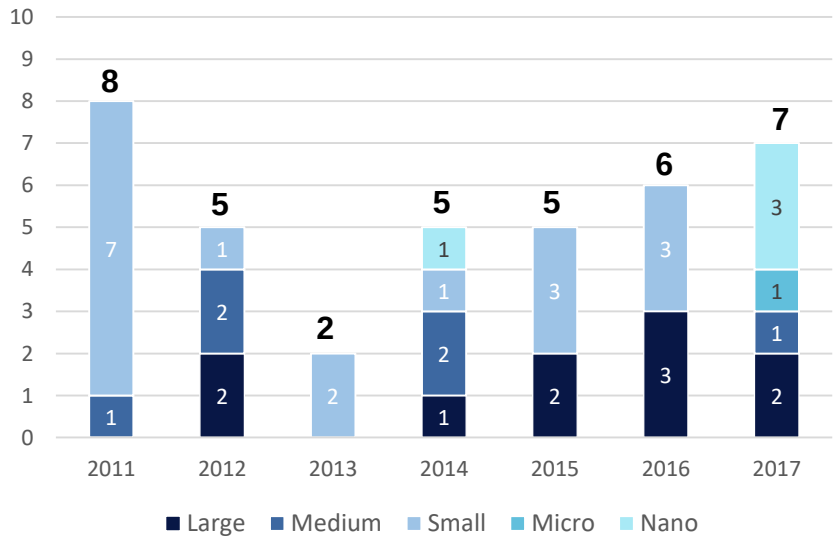
Vision of the supply and market shares

The European EO payload manufacturing market is shared among a few historical players such as Airbus Defence and Space, SSTL and Thales Alenia Space, responsible together of nearly 80 % of the total. Mainly positioned within the segment of satellites over 100 kg, they are foreseen to remain so in the coming years, with for instance about 20 such satellites launched over 2018 and 2019. Other players such as QINETQ Space, Spaceflight and GOMSpace are positioned within the micro and nano segments, as well as research centres and universities such as CNES, DLR or Sapienza University of Rome.

Share of all EO payloads by European manufacturers, 2011-2017 (Source PwC)



European Upstream EO Payload market by mass, 2011-2017
(Source PwC)



Main European EO Payload manufacturers by mass
(Source PwC)

THE EARTH OBSERVATION DOWNSTREAM MARKET AT GLOBAL LEVEL

€ 2.6 to 2.8 billion

Global revenues of the EO downstream industry in 2017

A nearly EUR 3 B market in 2017, with a 7% average annual growth rate up to 2022, driven by information products and Big Data

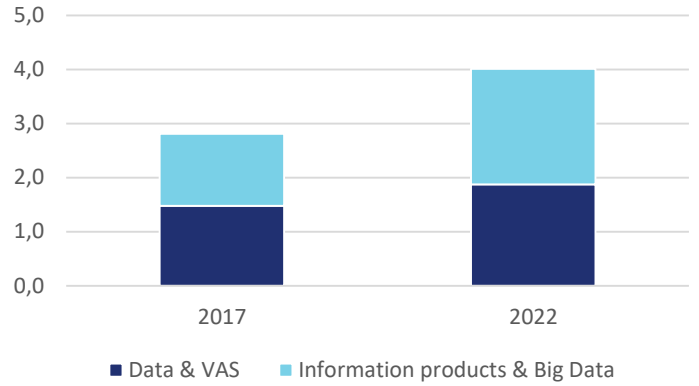
Traditionally, the satellite imagery market was segmented between data sales and Value Added Services (VAS).

However over the years, the sales of information products and Big Data analytics have become a sizeable share of the market revenues, and are expected to be the largest share of the revenues by 2020. **In 2017, Northern Sky Research estimated the global market at around EUR 2.8 B, split between data and VAS for EUR 1.5 B, and information products and Big Data for EUR 1.3 B.**

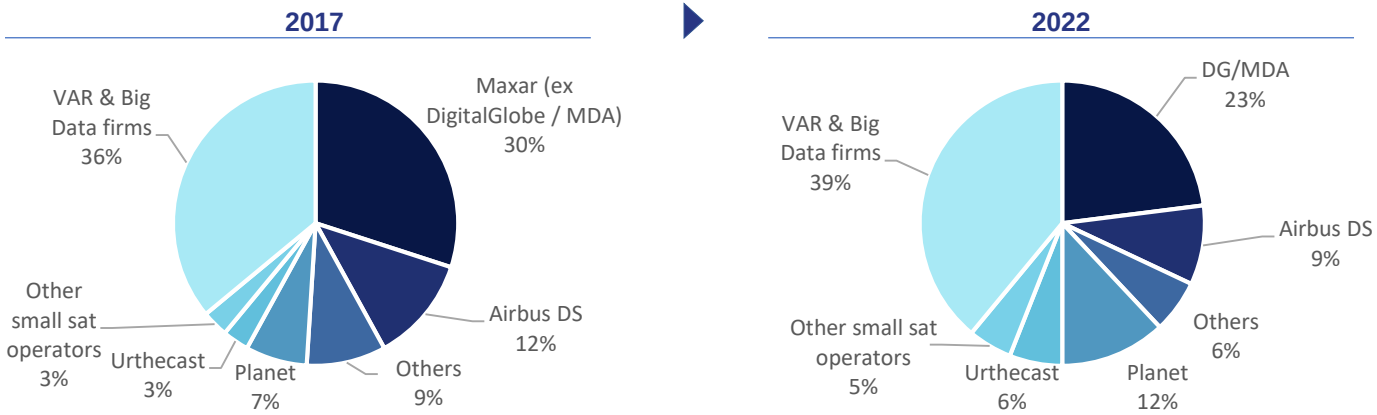
Among the different segments, Big Data solutions remain a minor share for the moment, but experience the largest growth with a Compound Annual Growth Rate (CAGR) of over 25% on the 2017-2022 period. By 2022, the market is expected to reach EUR 4 B, driven by information products and by Big Data (+60%).

Cloud platform holders, providing storage and easy access as well as cloud processing power and tools for basic image processing, are expected to play a major role in the EO data market in the coming decade, as already witnessed for instance with Amazon Web Services and its open data pilot project based on Landsat data.

Satellite imagery market worldwide, EUR B
(Source: NSR)



World Market Share – Data, VAS, IP and Big Data products
(Source: PwC)



Others: e-Geos, Antrix, DCMii, Earth-i / VAR: Value Added Resellers

New entrants on the market are expected to trim the shares of legacy players

Incumbent market leaders such as DigitalGlobe (Maxar Technologies group) and Airbus Defence & Space are facing increasing competition from new entrants who establish their differentiation on analytics and insights.

First movers on the market such as Planet and Urthecast have an advantage among NewSpace players, although the large number of companies with Big Data and Value Added Resellers profiles is expected to also capture more market shares in the future.

Traditional players tend to rely on well-established governmental contracts and long term relationships with them, and still benefit from the large demand for governmental applications, representing about 57% of the total revenues.

THE EARTH OBSERVATION DOWNSTREAM MARKET AT GLOBAL LEVEL

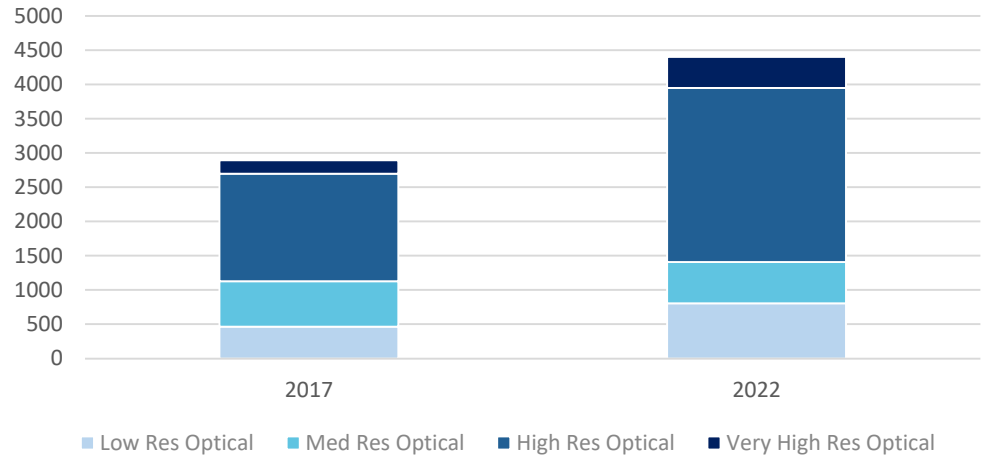
The EO downstream market is undergoing a shift in market shares, aspiring for increasingly more high and very high resolution data

The majority of the satellite imagery market relies on the provision of high and very high resolution (spatial resolution below 1m), which together represent about 60% of the total revenues. The weight of this data should keep increasing in the coming years to reach about 68% by 2022. Subsequently, even if the low resolution data market shares are expected to continue to increase slightly, the overall market for medium and low resolution data (10m pixels and more) is likely to taper off and decrease by 6% in total revenues between 2017 and 2022.

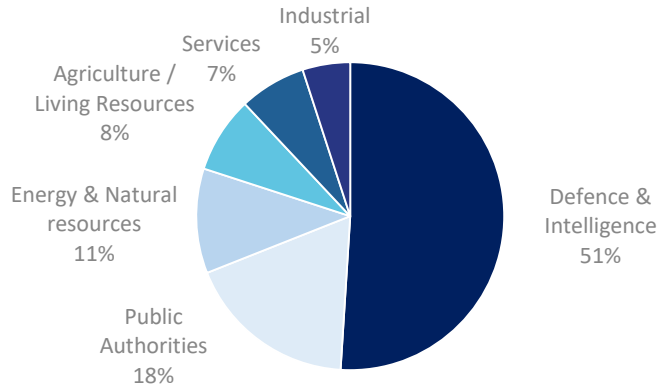
Although the revenue shares of medium and low resolution imagery is decreasing, there is a growing demand for open data services

The user uptake for open source policy programmes is increasing, in particular for Copernicus as the most recent entrant on the market. This leads to an almost constant market share in terms of revenues for the low resolution market (>5m spatial resolution), despite a strong pricing difference with sub-metric data. In the meantime, the medium resolution segment (1m – 5m spatial resolution) is the only one expected to shrink between now and 2022.

EO Optical Market by Resolution 2017 – 2022, M
(Source: PwC)



Segmentation of EO Optical High Resolution Market by Industry Vertical Application, % (Source: PwC)



HR and VHR data are strongly driven by defence and intelligence markets, with commercial markets catching up

On sub-metric resolution data, defence and intelligence customers represent more than half of the market, totalling nearly 70% when accounting for public authorities. Defence customers focus on ultra-high resolution, in particular since they have access to restricted resolutions (below 30cm or 50cm). Public authorities are important consumers mostly for city planning or traffic management applications.

Commercial markets such as agriculture, living resources, energy and resources, although representing about a third of the revenues, show higher growth rates, with CAGR between 12% and 16% expected in the coming years. Agriculture tends to be driven by precision farming applications (crops stress) while energy and natural resources rely on VHR for geological insights.

THE EARTH OBSERVATION DOWNSTREAM MARKET IN EUROPE

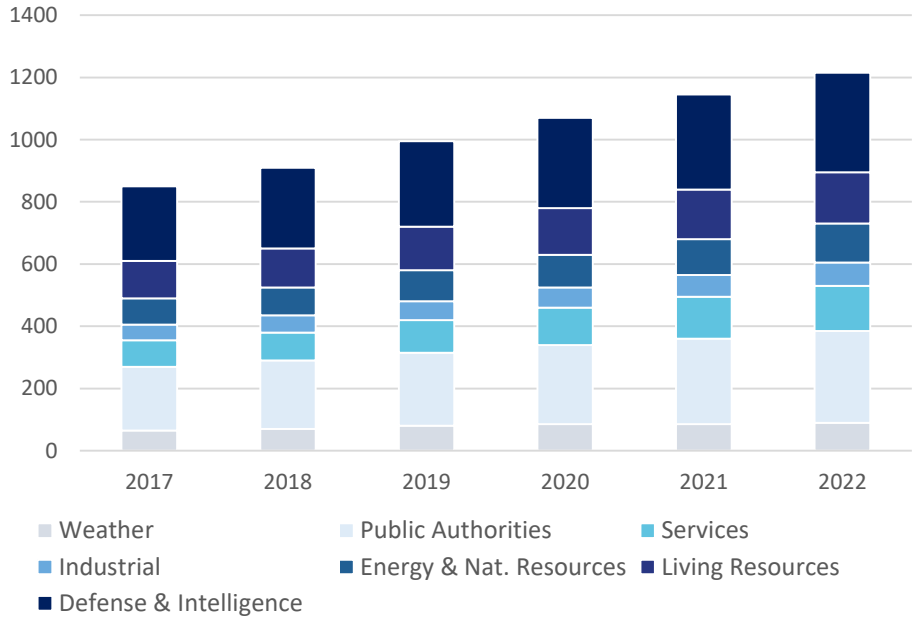
€ 950 million

Revenues of the European EO downstream industry in 2017

33 %

Share of European EO downstream revenues in the global EO downstream market

European EO downstream market forecast by vertical
(Source: NSR)

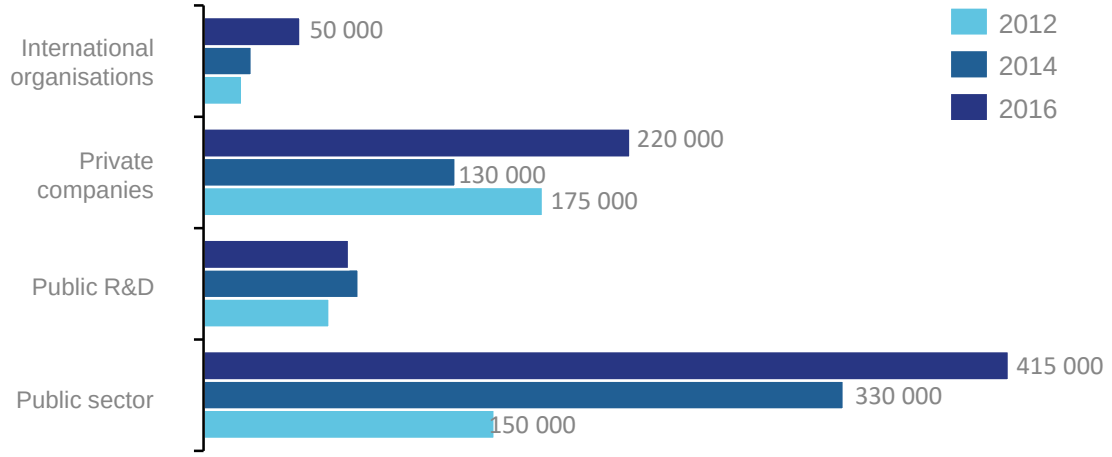


The European EO downstream market is expected to grow from around EUR 970 M in 2017 to EUR 1.3 by 2022 at an average annual growth rate of over 6%

The EU EO downstream market is expected to experience a steady growth over the next decade, benefiting, just like the EO upstream segment, from a growing non-domestic demand from emerging countries willing to access EO applications. Depending on the sources, the market estimates vary considerably, between EUR 750 M and EUR 1.2 B in 2017, and a CAGR between 6% and 12%, showing a similar strong growth in both cases.

The public sector, which has been driving the demand for EO services since 2012, is likely to continue doing so, representing about half of the demand when combining civil and defence applications. This growth follows the global EO downstream market growth, even though it is less aggressive than the North American market.

Comparison of EO downstream sales by customer segment in the EU, EUR K
(Source: EARSC)



THE EARTH OBSERVATION DOWNSTREAM MARKET IN EUROPE

Defence and Intelligence, Energy, Natural and Living Resources are responsible for the majority of the demand

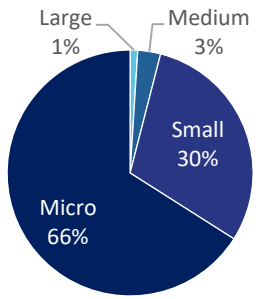
Defence and Security needs in the wake of the migrant crisis and geopolitical tensions are increasing, as the EU continues to increase military spending to address armed and geo-political conflicts within and around its regions. Similarly, and resulting from the strong will to achieve sustainable and performing energy production, resources-related verticals are highly requesting EO services, for resource identification, tracking, optimization and monitoring.

European SMEs are the main actors to address the increasing demand for EO services

The availability of Sentinel data has benefitted the large European SME sector, which is mainly into Value Added Services and Information Products. Although traditional big players such as Airbus D&S and e-Geos still have important shares as suppliers, developers and sellers, the introduction of cloud-based platforms for data exploitation has significantly helped SMEs to gain contracts and develop themselves.

European active EO companies in 2016

(Source: EARSC)



Vertical	Applications	Main suppliers
Weather	*Commercial weather data enabling risk management for aviation, transportation and agriculture*	cloudeo
Public Authorities	*Policy making and regulatory enforcement, Population demographics/epidemiology, Border control, Maritime security, Strategic asset monitoring, Emergency response, Humanitarian relief work, Urban planning, Maritime spatial planning*	AIRBUS DEFENCE & SPACE
Living Resources	*Sector monitoring, surveillance, mapping, tracking of crop yield, optimization of irrigation, assessment of land-use, tracking of scarce resources, fisheries and aquaculture*	SparkInData
Industrial	*Industrial asset monitoring (telecom infrastructure), Topology monitoring for cellular network coverage, Shipping route monitoring, Construction monitoring, Utilities monitoring, IoT solutions, Performance monitoring, Competitive intelligence*	e-geos AN ASI / TELESPAZIO COMPANY
Defence & Intelligence	*Strategic theatre-level military surveillance, tactical surveillance /military preparation of the battlefield, monitoring of ground assets and critical structures*	Atos
Energy & Nat. Resources	*All stages of exploration, build out, remediation, and decommissioning with in-house analysis: Oil exploration, Mining exploration, Oil spill preparedness and response, Crisis management, soil erosion monitoring, optimization of renewable energy production*	GEOCENTO earth imaging
Services	*Commercial mapping for urban mobility, Geo-Information Services-based risk management for financial industry, EO-enabled smart contracts for insurance*	eodc
		HEXAGON GEOSPATIAL

THE TRENDS IN EARTH OBSERVATION

Trend #1 – Diversification of users and their demands

The demand for EO satellites and their data is growing, as markets for applications become increasingly diversified and providers are able to deliver solutions for users who previously would not have been targeted.

Two areas where demand is expanding rapidly is within emerging economies, where solutions can support the growth of a country in a multitude of ways, including urban expansion, agriculture, natural disaster challenges, etc.; and in the intelligence community, above all for security and defence.

Indeed, defence and intelligence is the largest vertical, accounting for 43% of the market, followed by public authorities, energy/natural resources, services, and then agriculture.[1]

There is also a growing interest in EO-based solutions by non-technical end-users. These types of users especially require intelligence rather than being provided raw data. This is because they do not have strong technical knowledge or storage capacity in-house; instead, they need specific insights to be delivered to them in order to help their decision-making process.

Digital services, especially those pertaining to Big Data solutions, are also enjoying a rising demand. Such actors normally have large internal repositories of data, which they cannot exploit to its full potential without a provided solution that has the ability to process significant volumes of data in order to provide trends and insights.

Trend #2 – Evolution of business models

The recent emergence of low-cost small satellite technology has helped enable EO companies to transform their business models, based on the abundance of near real-time, low resolution imagery. As microsatellites become cheaper to manufacture thanks to commercial off-the-self components and miniaturization, new entrants are disrupting the market by introducing large constellations into orbit. This in turn provides ever-increasing production and access to new data.

There has also been a shift in the value proposition of certain manufacturers and data providers, who are seeking to evolve from providing infrastructure or data only, to a more integrated solution approach. By extending down the value chain and providing information/insights to the customers, it will help them to capture more of the market – especially to those users who specifically require intelligence due to the lack of technical knowledge/infrastructure for performing their own analytics.

Companies that have traditionally been EO data providers, such as e-GEOS and DigitalGlobe, have now started to offer integrated solutions to customers such as intelligence actors, in order to supply imagery and analytics as quickly as possible for rapid response.

[1] *Source: Strategy&, 2017, Earth Observation: Satellite Imagery Market Dynamic*

THE TRENDS IN EARTH OBSERVATION

Trend #3 – Cloud computing

Cloud computing continues to be a fast-growing market, enabling new, easier ways to access data, and facilitating large-volume storage. As users do not need to download and store the data on their own hardware, it reduces cost of access, giving users access to a wide range of different sources of data with a unique entry point. The strong competition amongst cloud providers, such as Amazon Web Services (AWS), Google, Microsoft, Oracle or IBM, helps to decrease cost of storage also.

Beyond simply accessing and storing the data, cloud computing is the on-demand delivery of computing power, servers, databases, networking, software, analytics and other resources that greatly support the development of new applications and solutions. This range of resources, combined with the low costs, helps feed into new business models for the geospatial market.

Trend #4 – Data analytics and processing

The introduction of new ways to process data and apply analytics had led to the deployment of innovative solutions for producing intelligence for the end-user, especially now that geospatial data can be better integrated with other types of data. Trends in data handling and analytics include the introduction of artificial intelligence (AI) and machine learning, which is a branch of AI based on the concept that systems can learn from data, identify patterns, and make decisions with as little human intervention as possible.

Predictive analytics aims to use techniques such as data mining, statistical modelling/algorithms and machine learning to make predictions about likely future outcomes.

Data fusion, which is the integration of multiple data sources and types in order to derive additional insights, has enabled the creation of more complex solutions, with the inclusion of geospatial data.

Trend #5 – Data democratization and pricing

There has been a shift towards data democratization, which is where the data is accessible to all, and hence there is no bottleneck created at the gateway to retrieving the data. This is obvious when it comes to social media data for example, but the Copernicus program has also led the initiative of allowing Earth observation data to be free and easily accessible to any and all end users.

The addressable market is also seeing an overall decrease in price for imagery, which is expected to drive a 4% decline in the existing market, but which will be offset by the expansion of the customer base in existing and new use cases. This effect is limited to the price of the data itself only, whilst analytics remain constant.

Willingness to pay is different depending on the market, with defence and intelligence actors willing to pay more for high-resolution imagery, versus a sector such as agriculture, which is fast growing in the uptake of EO data, but is price sensitive. The introduction of small satellite constellations, leading to broader availability of lower-priced imagery, is expected to expand EO usage for these types of sectors.

Source: PwC

Significant changes within the EO sector, with more satellite imagery available thanks to small satellite constellations and data democratization, combined with the evolution of innovative, efficient ways to process and analyse data, has led to new opportunities for developing solutions and addressing different markets.

EARTH OBSERVATION IN THE CONTEXT OF BIG DATA

Trend #6 - EO is more and more exploited in the Big Data context

The significant volume of data now being produced by Copernicus and other EO satellites has introduced a challenge to EO companies on how to manage, process and disseminate this data, whilst simultaneously creating an opportunity for large IC players, such as Google and Amazon, who are well-positioned to tackle the question of big data.

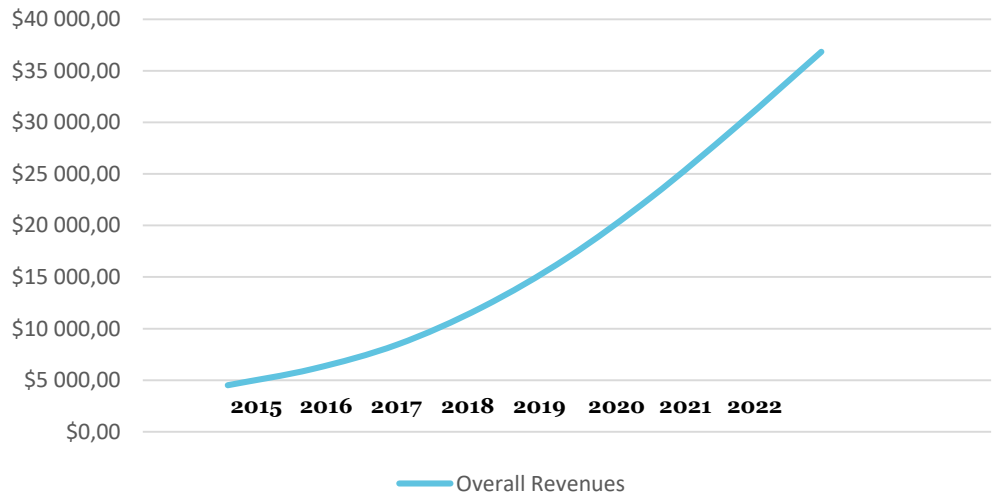
Big data are large volumes of data that are too great or complex for traditional data processing, but which can be analysed to reveal trends and associations.

The market of Big Data Analytics (BDA) based on satellite imagery relies on the processing, analysis and fusion of multiple images and other data sources in order to create intelligence not previously available. Hence, the current digital economy and big data model are disrupting the market of intermediate users by driving traditional EO services' business models towards digital services based on strong computing power, cloud-based platforms and the fusion of more and more data sources.

The Copernicus programme is one of the key originators of the Big data Analytics market within Earth Observation. This is thanks to the volume and variety of data it provides, as well as its ongoing continuity. New entrants to the sector are able to develop and test algorithms on this large volume of standardized data free of charge before introducing their solution to the market, and this has helped lower the barrier to entry for start-ups and SMEs especially. Future private constellations of small satellites may reduce the share of Copernicus contribution to the EO big data analytics market over the years; with Copernicus contributing 40%-60% of the overall European Big Data Analytics relying on imagery by 2020-2021, and then stabilizing.

Source: PwC

Forecast of the Global Big Data Analytics market
(Source: Frost & Sullivan)



EO big data revenues are expected to grow globally at an average CAGR of 27% over the period 2015-2025, highlighting a strong commercial interest. Hence, there is a strong opportunity for EO providers to capture some of this extremely fast growing market of Big Data Analytics using imagery.

EARTH OBSERVATION IN THE CONTEXT OF INTELLIGENCE

Trend #7 - Intelligence applications benefit from EO data

One of the areas with growing opportunities in the market of Big Data Analytics with imagery is the government and intelligence sector, including defence, legal intelligence, disaster preparedness and law enforcement.

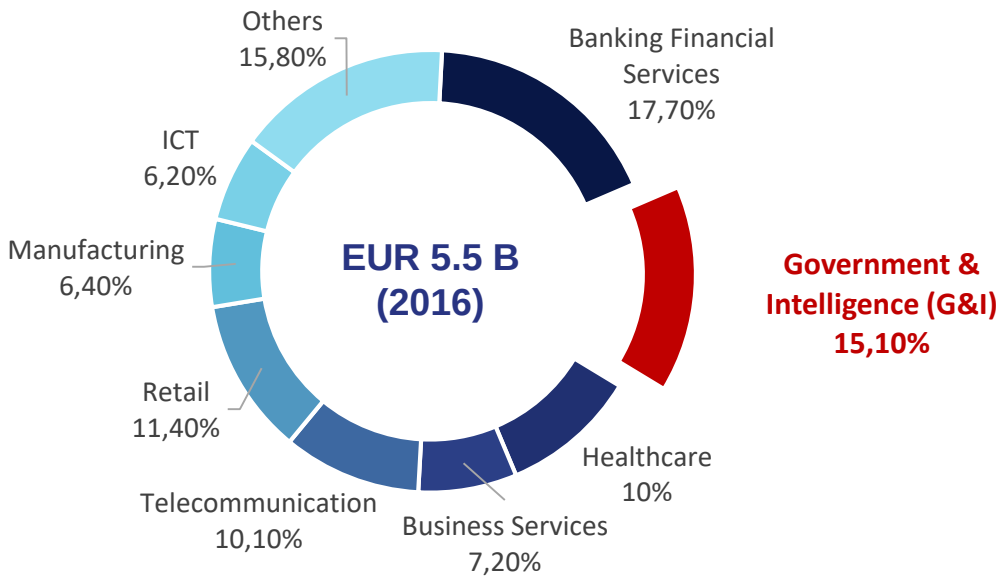
Defence customers especially are experiencing a growing need for improved intelligence services in order to respond to threats on a global scale, from terrorism to natural disasters. These threats demand more responsiveness and efficiency, whilst growing collaborations between security actors, especially in Europe, lead to a higher requirement of interoperable solutions. These trends combined have encouraged defence and security actors to shift focus towards digital services.

As stated in trend #1 “diversification in users and their demands”, there is an increase in customers who are seeking intelligence and actionable insight from services providers in order to support decision-making, rather than processed data to integrate into their own solutions. Defence and security actors especially have large data repositories that require specialized solutions in order to glean insight.

Defence actors often have strong analytical knowledge, but are facing the challenge of how to process the significant volume of data they possess, whilst security protection and emergency actors are often lacking in technical knowledge, and require flexible and on-demand situational awareness.

Imagery-based solutions for providing intelligence can support cases such as border surveillance, civil disturbance, crisis monitoring, crisis mitigation and response, and terrorism.

Current Big Data Analytics market – breakdown per segment (2018)
(Source: Frost & Sullivan)



Processing certain types of data, such as HR imagery data, where a person or property may be identifiable, highlights a risk regarding privacy. National security objectives also need to be considered carefully. For example, the US decided to limit access to HR imagery over some territories, such as Israel.

THE COPERNICUS PROGRAMME

IN A NUTSHELL

- The Copernicus programme is the European Union's Earth Observation flagship programme. As of 2018, a total of EUR 6.5 billion has been co-invested by the European Commission and the European Space Agency. By the end of 2020, the programme is expected to represent a total of EUR 8.2 billion investments, covering the space component and the Copernicus services.
- Through its set of components that collect data from various sources – EO satellites (the Sentinels, contributing missions) and a multitude of in-situ sensors on the ground, at sea, or in the air – Copernicus responds to the needs of European citizens in their daily lives.
- Copernicus has six thematic services (Land, Marine, Atmosphere, Climate, Emergency and Security) supporting the development of many applications. The Copernicus services process and analyse the data, integrate it with other sources, offering Geo-Information Systems (GIS) products to their users, and serving public authorities and commercial businesses.
- The Copernicus programme provides data and services that support added value in several non-space domains, for diverse and numerous different user segments related to Agriculture, Forestry, Urban monitoring, Transport, Tourism, Climate change and Environment, Maritime exploitation and preservation, Energy and Natural resources, Disasters management, Insurance, Health, Security and Defence, Development, and Cooperation.
- This report focuses on 10 promising downstream domains/user segment ensembles – referred to here as "value chains" – in which Copernicus programme output is currently used: Agriculture, Forestry, Urban monitoring, Ocean monitoring, Oil & Gas, Renewables energies, Air quality management, Insurance for natural disasters, Response to natural disasters and Security.

COPERNICUS, EUROPE'S EYES ON EARTH

The Copernicus programme

Copernicus is the European flagship programme on Earth Observation. Its aim is to observe the planet and its environment in order to improve the knowledge and understanding of different phenomena occurring, and ultimately to bring benefits to European citizens. The main rationale for Copernicus is to fill some gaps in European EO capabilities, and to ensure European institutions and industry have access to useful and key EO data, in a free and open manner. It results from a joint initiative between the European Union (EU), its Members States, and the European Space Agency (ESA).

The implementation of the programme is under the responsibility of the European Commission for its three components: the Copernicus services, the space component and the in-situ component.

ESA is in charge of the development of the space component, which includes the operation of certain Copernicus satellites currently in orbit (e.g. Sentinel-1, 2). ESA, together with EUMETSAT, also coordinates the delivery of data from the space component and its dissemination to the users.

The in-situ component is under the central coordination of the European Environmental Agency (EEA). In this mechanism, Member States are involved in the provision and calibration of data from ground sensors, which support the production of Copernicus products.

The space component

The space component includes the procurement, launch and operation of the Sentinel satellites, the operation of the ground segment, and the distribution of Sentinels and contributing missions' data. Indeed, Copernicus is built on two sets of space assets:

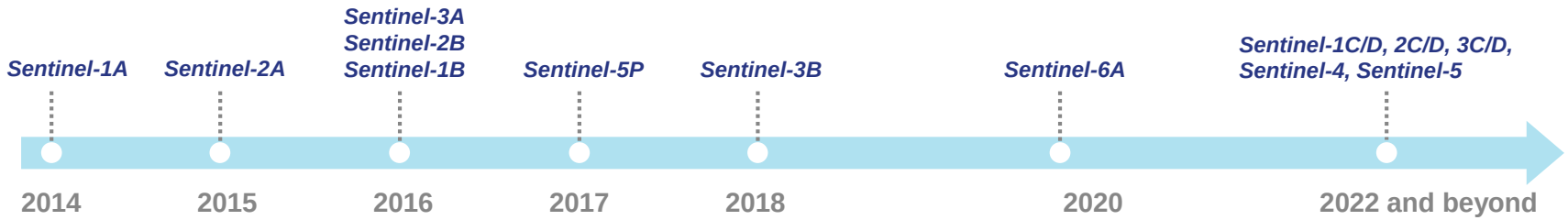
Firstly, the Sentinels are a family of EU-owned satellites, which have been specifically designed to meet the needs of the Copernicus services and their users. Currently, Sentinel-1, 2, 3 and 5p have been launched. Sentinel-4, 5 and 6 are expected in the coming years. Sentinel-1, 2, 3, 5p and 6 are dedicated spacecraft with different sensors (e.g. radar, optical, altimetry), whilst Sentinel 4 and 5 are instruments on-board EUMETSAT's weather satellites.

The Sentinels are complemented by contributing missions, which exist independently. These missions are operated by the European Space Agency (ESA) (e.g. ERS), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the EU Member States, other third party countries (e.g. Landsat or MODIS in the USA) or commercial providers (e.g. Deimos, Pleiades). Contributing missions are particularly key as they provide Copernicus with very high resolution data that cannot be obtained through the Sentinels, or compensate for Sentinels that have not been launched yet.

There are around 30 contributing missions, covering the following features:

- Synthetic Aperture Radar (SAR) to observe day and night the land and the ocean;
- Optical sensors to monitor land activities and ocean dynamics;
- Altimetry systems for sea-level measurement;
- Radiometers to monitor land and ocean temperature;
- Spectrometers for measurements of air quality

Actual and planned launch dates of the Sentinels (Source: European Commission, European Space Agency)



COPERNICUS, EUROPE'S EYES ON EARTH

The in-situ component

Copernicus also relies on in-situ data that is on-site or from local measurements, mostly belonging to EU Member States or international research infrastructures, and which are made available to Copernicus through agreements.

It includes observations from the ground, sea and airborne sensors, as well as geospatial references and ancillary data licensed or provided for use in the Copernicus programme. More recently, in-situ data has found new sources in sensors and imagery gathered by Unmanned Aerial Vehicles (UAVs) or crowdsourcing (e.g. OpenStreetMap)

In-situ data has two roles:

- To calibrate, supplement and validate satellite missions data to ensure it is delivering sustainable and reliable data over time.
- To help Copernicus service operators and the space component to produce products, and deliver services that are requested by end users.

When multiple services require the same data, the data access is coordinated by each Copernicus service operator or by the European Environment Agency (EEA).

The service component

Copernicus possesses six services that address different thematic areas, corresponding to daily needs of European citizens: Atmosphere, Marine Environment, Land, Climate Change, Emergency Management and Security. The services exploit Sentinel data, contributing mission data or in-situ data to provide products and information that support commercial, institutional and research applications.

Copernicus Atmosphere Monitoring Service (CAMS)

CAMS is managed by the European Centre for Medium-Range Weather Forecasts (ECMWF) and has the aim to continuously monitor the composition of the Earth's atmosphere at global and regional scales through the provision of near-real time data and forecasts products. It is mostly used for health, renewable energy, or climatology issues.

Copernicus Marine Environment Monitoring Service (CMEMS)

CMEMS is managed by Mercator Océan International, with the aim to provide regular and systematic information about the physical state and dynamics of the ocean and marine ecosystems. Its products cover the global oceans and the European regional seas, through the provision of observations and forecasts. It is mostly used for ship routing services, offshore operations or aquaculture.

Copernicus Land Monitoring Service (CLMS)

CLMS is split into three components: the Global component (managed by the DG Joint Research Centre (JRC), the Pan-European component, and the Local component (managed by the European Environmental Agency - EEA). It has the aim to provide geographical information on land cover, land use, land cover-use changes over the years, vegetation state and the water cycle. It is mostly used for forest management, water management, agriculture or food security.

Copernicus Climate Change Service (C3S)

C3S is managed by the European Centre for Medium-Range Weather Forecasts (ECMWF) and has the aim to respond to changes in the environment and society associated with climate change, through the provision of information for monitoring and predicting climate change and help to support adaptation and mitigation strategies. It is mostly used for climate, weather and renewable energy monitoring.

Copernicus Emergency Management Service (CEMS)

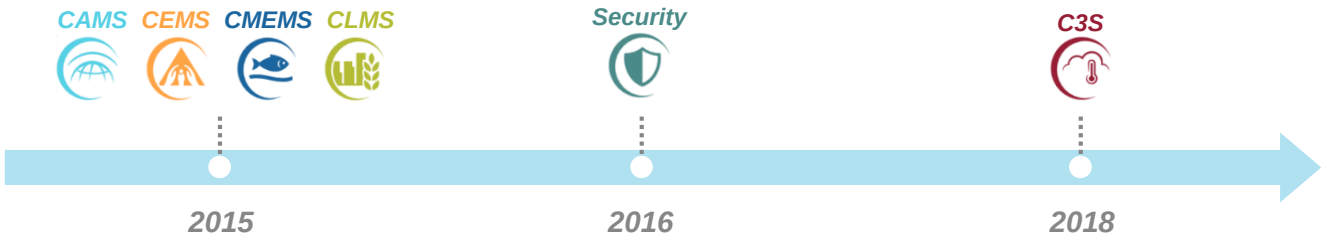
CEMS encompasses two components: the early warning component is managed by the DG Joint Research Centre (JRC) and the mapping component is managed by DG for European Civil Protection and Humanitarian Action (DG ECHO). The aim of the former is to deliver warnings and risk assessments of floods and forest fires, while the mapping service provides map and geo-information products for all types of natural and man-made disasters. CEMS intervenes both at European and global levels.

Copernicus Security Service

The Copernicus Security service aims at improving crisis prevention, preparedness and response in three domains: border surveillance (managed by FRONTEX), maritime surveillance (managed by EMSA) and support to EU External Action (managed by EU SatCen). It is mostly used to support related European Union policies by providing information in response to the security challenges Europe is facing.

COPERNICUS, EUROPE'S EYES ON EARTH

Date at which the Copernicus services were operational *(Source: ESA, EC)*



The EO services sector and Copernicus

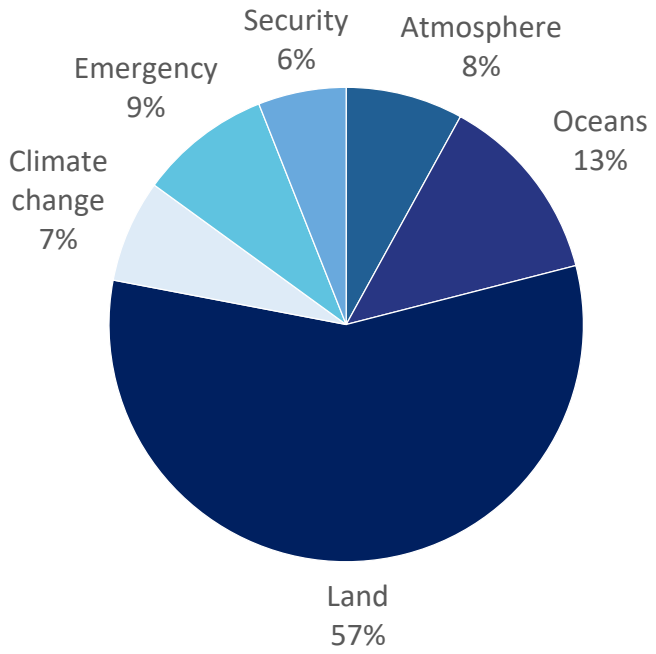
Although few EO services companies are large and well established with vertical integration (e.g. Airbus Defence & Space, Deimos, e-Geos), the most common profile for EO services companies are small and very small companies (66% of companies with less than 10 employees, 95% with less than 50 employees according to EARSC). This split in terms of size has remained the same for the last 6 years.

According to the European Association of Remote Sensing Companies (EARSC), in 2016 the EO services sector comprised of around 460 companies in Europe. The number of companies involved in EO services has increased by 13% compared to 2015 and by about 65% compared to 2012, for an average of 7.3% p.a.. Of these 460 European companies, approximately 25% were Copernicus users as of 2017 and the number of companies focusing on the development and sales of value added services and products based on Copernicus data has continued to increase in the last few years.

The Copernicus programme can benefit a wide range of actors: citizens, policy makers, researchers, commercial users, private and public users and the scientific community. These actors provide data and services that support added value in several non-space domains. This support is ensured by the availability of Copernicus raw data (used by 60% of companies that are Copernicus users) as well as the products from operational services (32% of companies are using Copernicus products).

Companies generated a total of EUR 92.3 M revenues driven by Copernicus data and information in 2016, which represents 76% of the revenues these companies generate from the use of open and free data, putting Copernicus as a leader in the domain of free EO data. Beyond this, companies are optimistic on the impact Copernicus can have on their business in the future and these numbers should therefore increase in the next years.

Companies' interest in Copernicus services
(Source: EARSC)



COPERNICUS, EUROPE'S EYES ON EARTH

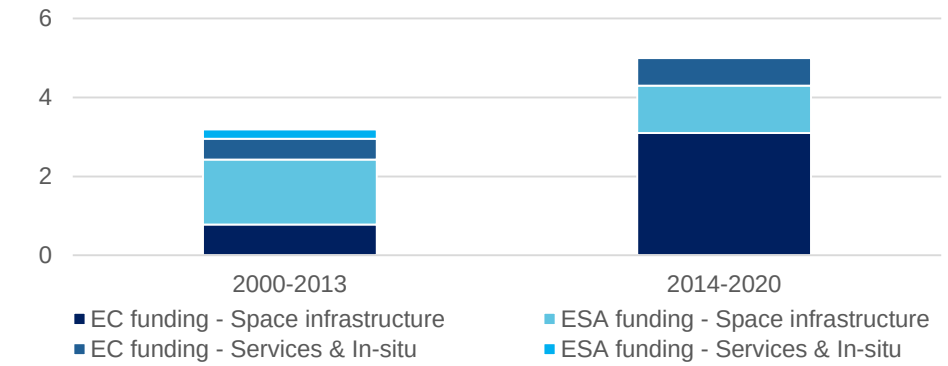
Copernicus infrastructure and services investment

The Copernicus programme is co-funded by the European Commission and ESA. As previously stated, ESA, together with EUMETSAT on specific aspects, is predominantly in charge of the development of the space components, also referred to as the Copernicus infrastructure, whilst the European Commission is in charge of the implementation and management of all three components.

On the period 2000-2013, EUR 3.2 B were invested into the programme, with 76% of the budget (EUR 2.4 B) going to the space component and notably the development of the Sentinels in the first years. This investment into the space component was divided between the EC, which contributed with EUR 0.8 B, and ESA with EUR 1.7 B. The services and in-situ components received the rest, at EUR 0.8 B. The EC funded the largest part (68%) and contributed with EUR 500 M, while ESA contributed with EUR 240 M.

On the period 2014-2020, EUR 5 B were invested into the programme, with 86% of the budget (EUR 4.3 B) going to the space component. This investment was divided between the EC, which contributed to EUR 3.1 B, and ESA with EUR 1.2 B. The Services and In-situ components received EUR 0.7 B, entirely funded by the EC. While the Services are managed by the EC, the in-situ component is managed by the European Environmental Agency (EEA).

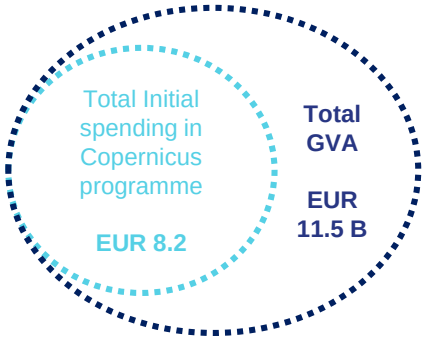
Investment into Copernicus, EUR B (Source: European Commission, European Space Agency)



Impact of Copernicus spending on the EO upstream industry

The cascading effect of spending into Copernicus in the European economy generates Gross Value Added (GVA) both within the space sector (for about 60%) and outside the space sector (about 40%). Based on past studies conducted[1], the comparison of the total GVA generated in the European upstream industry and the initial spending in the Copernicus programme gives a GDP multiplier ratio of 1.4, leading to a total GVA impact for the Copernicus programme of EUR 11.5 billion on the period up to 2020.

Transactional impact of investment in the upstream of the Copernicus programme up to 2020 (GDP impact) (Source: PwC, Cambridge Econometrics)



For 1€ spent by public funds in Copernicus upstream activities, the Gross Value Added in the economy is 1.4€ (without accounting for any impact from exploitation)

As one of the core impacts of Copernicus, it constitutes a great opportunity for companies to capitalise on public expenditure, and leads to job creation and more global economic growth. Based on the most recent data, total expected investment in the programme is expected to support a total of around 17,260 person-years in Europe, of which 76% are directly in the space sector, and considered to be high-skilled employees.

In addition to these impacts, the Copernicus programme is expected to generate around EUR 1.65 billion until 2021 in government taxes, product taxes and employee social security contributions.

DATA DISSEMINATION: A CRITICAL DRIVER FOR USER UPTAKE

The Copernicus Data and Information Access Services (DIAS)

In 2017, the European Commission launched an initiative to develop the Copernicus Data and Information Access Services (DIAS) that facilitate access to Copernicus data and information from the Copernicus services.

Today, data can be accessed through dedicated access portals set up by the Entrusted Entities for each Copernicus service, each requiring a dedicated login. National access mechanisms for Copernicus data exist in some European Countries, which are called Collaborative Ground Segments and focus on the distribution of data and information (not only from Copernicus) that is of particular usefulness to national users.

However, most of these only allow the downloading and sometimes exploitation of the information accessed through a web mapping service (WMS). Anyone wanting to process the data further would have to compute and visualise the data with software on their own computer.

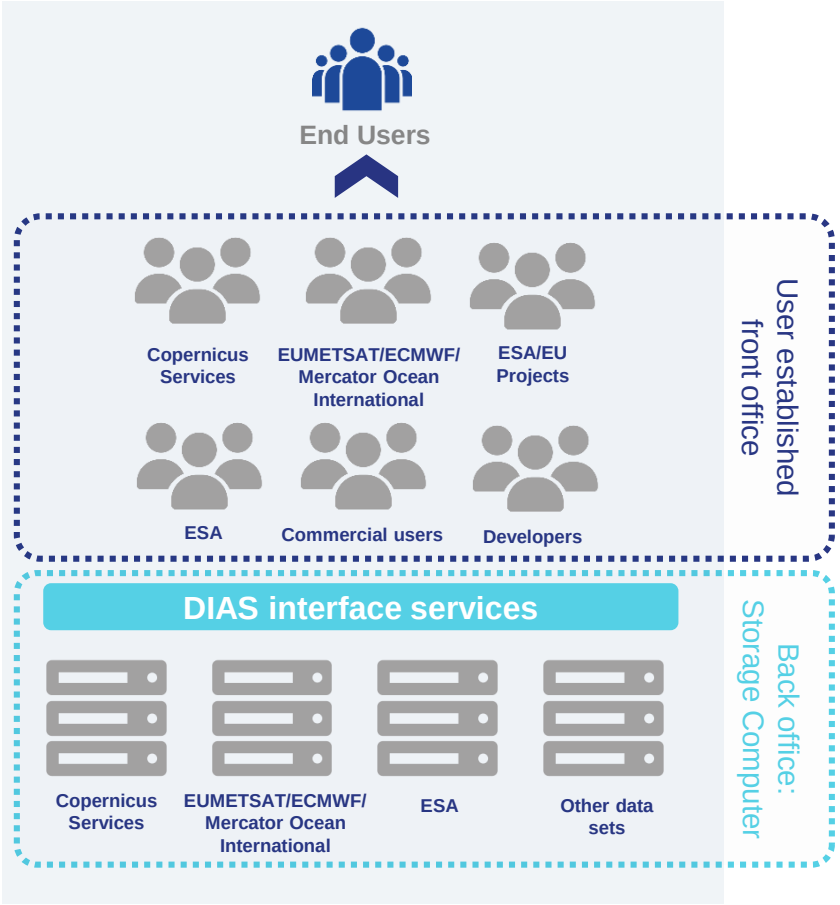
The EC has identified the opportunity to federate this shared need to access the Copernicus data and information close to processing facilities that allow further value extraction from the data, and respond through a dedicated service approach that is complementary to traditional data downloading. This new service approach, the DIAS, offers access to Copernicus data and information close to processing facilities and, through this, creates the possibility to easily build applications and offer added-value services.

ESA launched a tender to establish DIAS services in 2017. Four consortia were chosen to set up DIAS computing environments under ESA management, and a fifth consortium is managed by EUMETSAT, ECMWF and Mercator Ocean International (MOI).

List of DIAS consortia selected

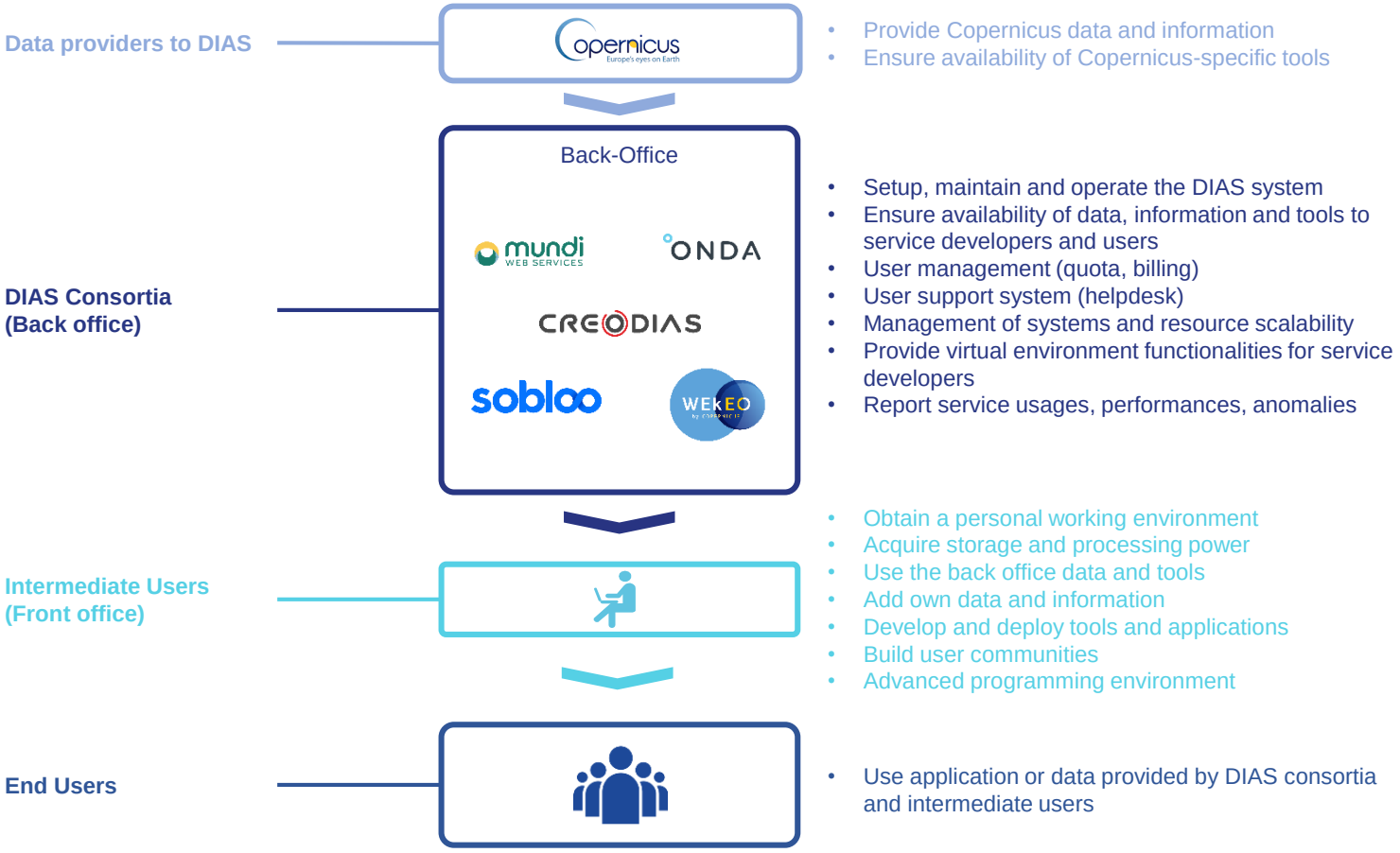
Consortium	**Mundi Web Services**	**Creodias**	**Sobloo**	**Onda**	**Wekeo**
Platform provider	ATOS	Creotech	Airbus	Serco	EUMETSAT / ECMWF / Mercator Ocean Int.

Architecture for the DIAS interfaces
(Source: European Commission)



DATA DISSEMINATION: A CRITICAL DRIVER FOR USER UPTAKE

Tasks and contributions from the DIAS ecosystem
(Source: European Commission)



Copernicus DIAS structure and task allocation

All DIAS platforms provide access to Copernicus Sentinel data, as well as to the information products from Copernicus' six operational services, together with cloud-based tools (open source and/or on a pay-per-use basis). DIAS consortia exists and operate alongside the Entrusted Entity in providing access to data.

Each of the five competitive platforms also provides access to additional commercial satellite or non-space data sets as well as premium offers in terms of support or priority. Thanks to a single access point for the entire Copernicus data and information, DIAS allows the users to develop and host new applications in the cloud, while removing the need to download bulky files from several access points and process them locally.

Each DIAS consortium runs its own back office where all storage and computing are performed. These back offices are the starting point for the development of a front office and intermediate users applications. This chain, starting with the back office and ending with the users, generates a flow of information that transforms hard data into useful services for society and businesses. This model lowers the barriers to entry for users, enabling them to build applications.

COPERNICUS CONTESTABLE USER BASE

Copernicus could benefit a wider user base than the current one

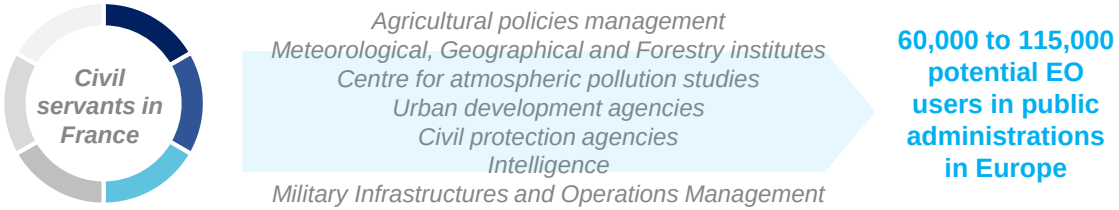
Besides the European commercial base of EO companies, Copernicus data and products benefit a much wider user base, which includes public authorities, students, researchers, non-EO companies, NGOs and citizens. The potential users of Copernicus who are not yet using it are also called “contestable user base”. Although precise figures on the exact potential user base remain challenging to obtain and would require a thorough assessment, an attempt to provide an order of magnitude is performed for this report.

The contestable user base for public authorities, researchers and academics

European public authorities represent a major source of potential users of Copernicus data and Services. The number of potential users within European governmental entities is estimated based on the number of civil servants employed in ministries (and affiliated authorities), whose activities can be directly related to the benefits of GIS products, and hence of EO data: **Agriculture, Environment**, **Urbanism, Civil protection**, and S**ecurity/Defence.** In order to have a more realistic figure, only the sub-administrations of these ministries with direct relevance were selected**.** Based on a detailed analysis for France, the total number of civil servants was extrapolated to Europe (assuming it could be used as a representative average for the EU Member States).

Potential Copernicus users in public administrations in Europe

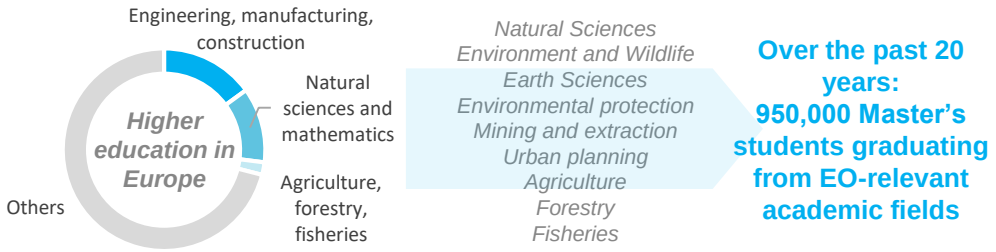
(Source: French DGAFP, Eurostat, PwC analysis)



The number of skilled people who could use EO data and Copernicus is also reflected in the number of Master level students in Europe. Out of the 1.6 million students graduating each year from a Master’s degree (or equivalent), the share of students considered in the contestable user base is defined based on the academic courses in higher education that are relevant to EO data and products. About 30% of the students in tertiary education study engineering, natural sciences or agriculture, out of which EO-related courses are isolated to: Natural Sciences, Environment, Natural Environment and Wildlife, Earth Sciences, Environmental Protection Technologies, Mining and Extraction, Agriculture, Forestry, and Fisheries. Overall it represents around 3% of the total number of graduating students. When considering the Master’s students base **over the past 20 years, it can be estimated that in the order of 950,000 students are knowledgeable and skilled in EO-relevant topics**.

Higher education students in Europe (Master’s degree and above)

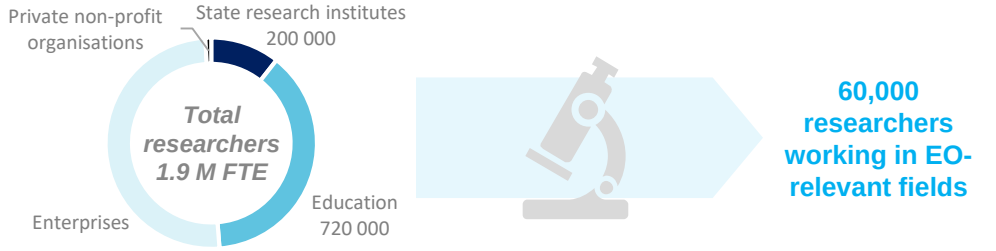
(Source: Eurostat, PwC analysis)



Assuming a similar share of EO-relevant fields in research fields as in academic courses, the 1.9 million people research community in Europe represents a total of 60,000 potential users.

Potential Copernicus users in the research community in Europe

(Source: Eurostat, PwC analysis)



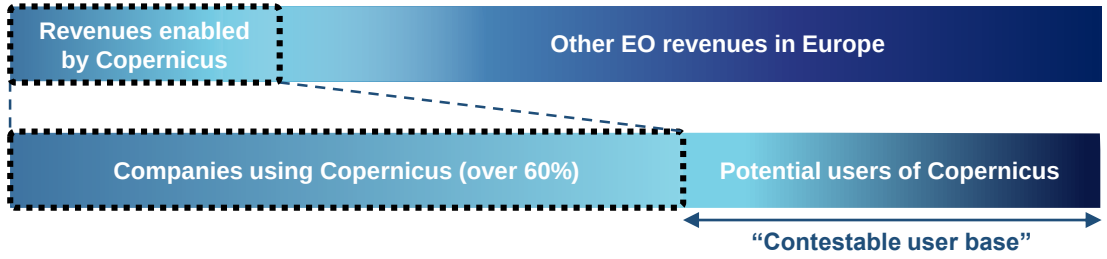
COPERNICUS CONTESTABLE USER BASE

The contestable user base for commercial users

While Copernicus enabled revenues represent a limited share of the overall intermediate user market, (between 10% and 20%), the share of EO-knowledgeable professionals in Europe using Copernicus is much larger. This is partly linked to the fact that the cost of data influences the price of the derived products. Hence open data-based products tend to have a smaller weight in revenues than their weight in "number of users". In Europe, the latest EARSC survey within the industrial base of EO companies suggests that **at least 60% of the companies use Copernicus data or services**. Considering the total employment of the EO downstream sector in Europe (around 7,000 people in 2017), this represents in the order of 180 companies who could contribute to the uptake of Copernicus in the future.

The European EO active community of commercial intermediate users

(Source: EARSC, PwC analysis)



7000
Employees of European EO companies

At least 60% of EO companies using Copernicus

Up to 2,000 to 3,000 people not using Copernicus yet

The sizing of the community for commercial end users (non-EO companies across all industrial sectors) exploiting EO products is more challenging, due first to the number of sectors to be considered and secondly due to the discrepancies in EO data uptake and maturity from one industry to another.

Hence it is not possible to provide a number for the contestable user base on end user markets, although the number is expected to be in a different order or magnitude than the intermediate market, based on the size of the economic sectors.

Other user communities

Finally, on top of the commercial and institutional bases, statistics from ESA Open Access Hub suggest that about **14,000 of its users are other types of users such as NGOs and EU citizens**.

Overall Copernicus contestable user base in Europe

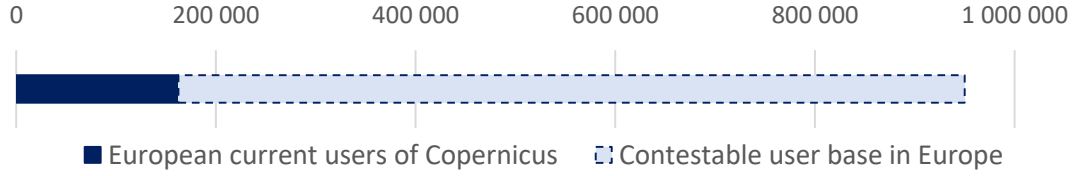
The final Copernicus contestable user base is obtained by comparing the total potential user base and the current users of Copernicus. Out of the 300,000 registered Copernicus users, around 40% of the Sentinel data users are European. It is expected to be higher for the users of Copernicus Services, being largely adopted by public authorities. Assuming 80% of the Copernicus Services users are European entities, the total number of European registered users is assessed at around 162,000.

As the Master's students who graduated in the past 20 years represent a risk of double counting with potential users of other communities, the potential users of the other communities are deducted from the students number to ensure conservative value for the contestable user base.

Based on the figure presented above, the Copernicus contestable user base in Europe can be estimated up to 780,000 potential users.

Copernicus contestable user base in Europe

(Source: Eurostat, Serco, French DGAFP, PwC analysis)



COPERNICUS CONTESTABLE USER BASE

The end-users value chains not analysed in this report can be qualitatively assessed at high level

As mentioned above, the user base for non-EO companies ("commercial end users") is more challenging to estimate due to the varying number of companies, relevant jobs, applications and technology maturity across all the possible industrial sectors potentially exploiting GIS products. To complete the detailed analysis of the 10 value chains presented in this report, a high level qualitative assessment of some of the main other sectors is presented below, to capture the main applications and drivers, and stress that the quantified benefits of this assessment remain a partial vision of the overall Copernicus programme impacts.

	Impact on the intermediate users market	EO impacts and applications for end users	Potential Contribution of Copernicus	Overall expected impact
 Meteorology	*Substantial share of the market for intermediate users, representing close to EUR 50 M per year in Europe.*	*Improved data veracity using multiple sensors enables better forecast models, allowing cost avoidance. Commercial weather data serves transportation, energy needs forecasts, aviation, or agriculture, although strongly competing with free datasets available from governments. Applications could cover weather forecasts, risk management and decision support.*	*Copernicus could be valuable as meteo data needs low spatial resolution (dozen meters to km scale), as illustrated by the future operation of Sentinel 4 and 5 by EUMETSAT on-board Metop-SG and MTG.*	***Increasing contribution of EO and Copernicus to meteorology through numerical weather predictions*** 
 Geology	*Limited contribution to the market for intermediate users, estimated around EUR 25 M per year in Europe.*	*EO supports mineral exploration, not only for prospecting but also to map potential access corridors to exploration areas. It helps to assess environmental impacts of large projects. Applications could cover reflection and absorption properties of soil, interpretation of surface lithology (clays, oxides, etc.), analysis of vegetation cover, etc.*	*Copernicus is an asset to geologists' needs for multi-wavelength images to identify differences in structural features. The near-infrared bands are particularly useful. Geology does not require a high revisit frequency nor very high resolution, and is compatible with rather standardised products.*	***High overall impact as effective mapping of soil composition has high economic stakes*** 
 Tracking of Biodiversity	*Substantial market share estimated around EUR 90 M per year in Europe, balanced between land and marine ecosystems-related activities.*	*Monitoring biodiversity aims at improving our understanding of ecosystems and assessing their vulnerability. The combination of EO data with ground observations and robust modelling of socio-ecological systems is crucial to improving management practices. Applications could cover habitat extent and condition monitoring, species distribution, analysis of anthropogenic pressures, etc.*	*Open data policy has a critical impact on the uptake of EO by users, fostering the use of Copernicus. Standardisation of the data is also a key concern. Biodiversity tracking also requires monitoring at various spatial resolutions, revisit frequencies and spectral bands.*	***Medium to high overall impact as highly strategic for environment preservation*** 

COPERNICUS CONTESTABLE USER BASE

	Impact on the intermediate users market	EO impacts and applications for end users	Potential Contribution of Copernicus	Overall expected impact
Topography / Land use	*One of the main segments for EO products delivered by intermediate users, weighing between EUR 100 M and 200 M per year in Europe.*	*Economic impact could be high with land use and urban planning becoming a subject of importance in Europe, related to demographics. Coupled with block chain technologies enabling smart contracts for land certificates and transactions, EO services can be expected to significantly benefit public and private end users. Applications could focus on topography situation awareness, supporting land reform programmes facilitating the issuance of land certificates, delineation of titled land parcels, security of land property and agricultural productivity, etc.*	*With strong interest for open data services, government and public bodies could directly benefit from Copernicus DIAS. In addition, technical capabilities of Copernicus allowing the coverage of large areas could address topography needs for medium/low resolution as well as high resolution for specific requirements.*	***Strong expected economic impact thanks to a variety of field of applications***
Cultural Heritage	*Limited impact as it is less mature, with high discrepancies between Member States.*	*There are high stakes on archaeology as Europe hosts a significant number of important cultural sites facing a large amount of challenges (natural and pollution risks). Local entities having trouble protecting their cultural assets could benefit from the Copernicus open data policy. Applications could cover management and protection of cultural assets, protection against global warming threats (ground motion, sea level, flooding, acid rains), against pollution, and against human threats (illegal looting, oil spills, destruction from war, destruction for religion reasons, etc.). Copernicus could also contribute to change detection and thermal analysis to reveal buried buildings.*	*Copernicus could bring very interesting and direct contributions to Cultural Heritage preservation, as it helps to cover large areas and deliver open data services for public local entities. Furthermore, end users could benefit from Copernicus' added value for accurate comparative analysis in time, using multi-spectral, radar and optical sources in different resolutions.*	***High strategic stakes for European cultural heritage preservation and understanding***
Consumer Research	*Limited segment for EO products delivered by intermediate users, weighing between EUR 70 M and 80 M per year in Europe, mainly aggregated in Urban Areas and focusing on Services.*	*Economic impact could be high as private end users long for reliable and actionable insights on their customers through data to support strategic decisions. Yet, they often have limited exploitable geospatial data and no infrastructure to efficiently collect it. Copernicus could contribute to observation campaigns to study consumers' habits, behaviours, attendance and evolution, identification of best geospatial configuration for business networks and shops, or traffic monitoring.*	*Covering large areas to deliver comparative analysis in time, Copernicus could significantly benefit private end users to build strategic knowledge on consumers, and creating interests for non-experts users to access evolved products through its services.*	***High economic impact driven by the private end user segment focused on B2C services***

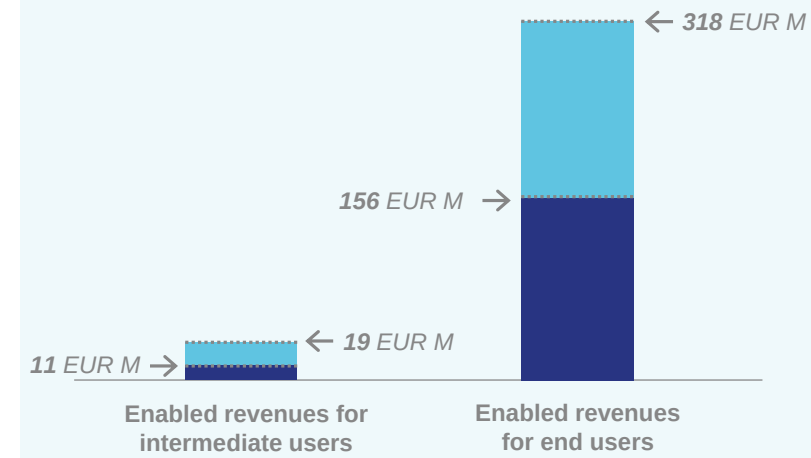
AGRICULTURE

KEY TAKEAWAYS

- The agricultural sector is beginning to emphasize sustainability in the face of global challenges, including climate change, population growth and the increasing competition for land, water and energy resources.
- The market is fragmented, with intermediate users including a variety of actors: start-ups, small and medium sized enterprises (SMEs), larger corporations, and purely scientific players such as research organisations and universities.
- The typology of end users is quite balanced between public players (such as governmental authorities needing precise information for specific policies and regulations, or to monitor specific issues), and private players (agricultural corporations, food companies, agronomic advisors, etc.).
- Farmers, who are the primary end users for agricultural products based on EO data, may face difficulties in accessing or paying individually for the service. Thus, the direct clients of intermediate users are in many cases agricultural cooperatives which then distribute the products to the farmers they represent. Farmers may also struggle to implement these services due to a lack of infrastructure (e.g. strong broadband connection) or digital knowledge.
- Sentinel-1 and -2 data is used by many public and private service providers in order to develop their products and applications. The volume and accessibility of data has encouraged start-ups and SMEs within the sector.

Copernicus economic impact (2018)

(Source: PwC)



COPERNICUS APPLICATIONS

- Smart farming applications such as yield mapping, input management and farm management recording
- Field scale and crop dynamics mapping and monitoring
- Irrigation management and drought monitoring
- Crop production and food security monitoring and agriculture development

KEY COPERNICUS PRODUCTS

- Copernicus Land Monitoring Service (CLMS) Land Cover
- Normalised Difference Vegetation Index (NDVI),
- Leaf Area Index (LAI),
- Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
- Fraction of Green Vegetation Cover (FCOVER)
- Surface Soil Moisture
- Dry Matter Productivity

AGRICULTURE

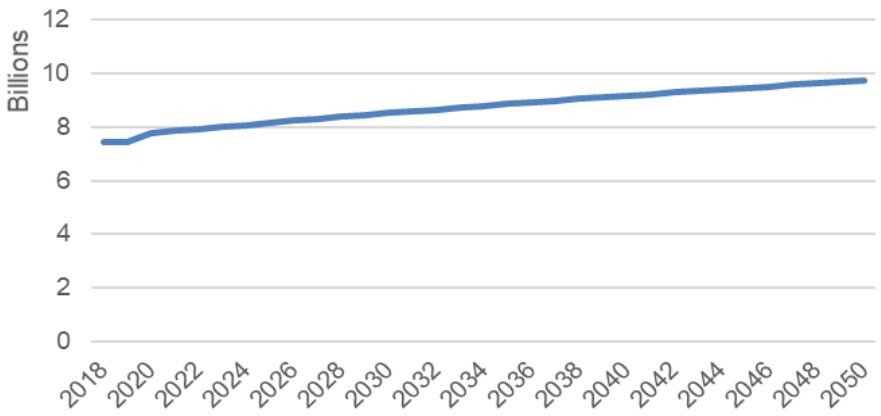
A VITAL SECTOR THAT IS SHIFTING FOCUS TOWARDS SUSTAINABILITY

The agriculture sector plays a crucial role in the global economy, and is rapidly evolving due to the emergence and development of numerous techniques, especially in the face of a changing environment. In the coming years, agriculture will have to tackle several significant pressures, including an increase in the world population, the threat of climate change, and the intensifying competition of increasingly scarce land, water and energy resources. Indeed, the world's population is projected to grow from 7.4 billion in 2018 to 9.7 billion by 2050, causing a need to increase food production from the current 8.4 billion tonnes to around 13.5 billion tonnes a year.

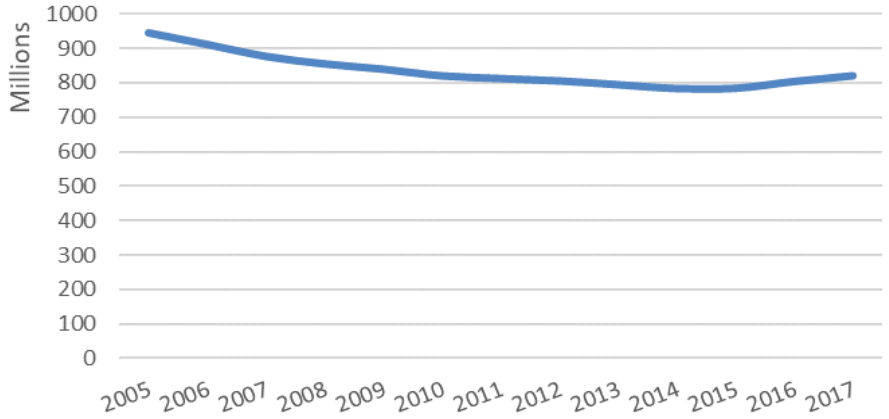
Climate change could cut crop yields, especially in the most food-insecure regions, whilst the agricultural sector itself along with forestry and land use change, are responsible for 25% of greenhouse gas emissions.[1] Agriculture also accounts for 70% of water use, whilst generating unsustainable levels of pollution and waste.

Source: The World Bank, The Food and Agriculture Organization of the United Nations

Total population in the world (Source: The World Bank)



Number of undernourished people in the world (Source: FAO)



A report by the Food and Agriculture Organization of the United Nations (FAO) in 2018 found that the number of hungry and undernourished people increased from around 804 million in 2016 to 821 million in 2017 – and in fact has been rising since 2014. Malnutrition can lead to illness or health crises.

These challenges have led to a push for sustainable agriculture. Today, European farmers face the dilemma of continuing to produce food to ensure food security and profitability, whilst also trying to reduce their impact on the environment and climate, as well as protecting the surrounding biodiversity.

The Common Agricultural Policy (CAP) in Europe is the primary source of funding for European farmers, and is a partnership between agriculture and society. It seeks to support farms and improve their productivity, whilst ensuring they can make a reasonable living. It also aims to help tackle climate change and the sustainable management of natural resources. In order to benefit from the CAP, farmers must ensure they are compliant with the goals of the policy, including the environmental and sustainability aspects.

To increase global food production while ensuring a preserved environment, agriculture will need to increase its productivity by using innovative technologies, such as EO-data solutions.

AGRICULTURE

A SECTOR WHERE EO DATA HAS A LONG HISTORY

Agriculture was one of the first downstream EO markets to emerge, and there continues to be a growing interest in how EO solutions can support the challenges faced by the sector. Satellite imagery can make a significant contribution to the efficiency of modern agricultural practices. Often EO data is combined with in-situ data in order to produce more focused and localized results for the farmer, whilst aerial data from drones can act as complementary data.

EO-enabled applications can add value to a number of sub-sectors, including crop-related activities (e.g. crop health monitoring, crop inventories, crop types monitoring), water management (e.g. soil moisture, crop irrigation, drought monitoring) and land use optimization and management.

The market is rather fragmented, with a wide range of players operating in the development of value-added services, including start-ups and SMEs, large corporations, and scientific actors.

Smart/precision agriculture

Precision farming is the most prominent agricultural domain where EO can play a significantly beneficial role. Farmers can utilize EO data to help identify and quantify various farming inputs across the farm, in order to tailor farming practices. This allows farmers to increase productivity by optimizing the use of water, fertilizers, seeds and pesticides, leading to improved profitability and cost efficiency. By reducing the amount of inputs used, the farmer can also help protect the environment by reducing pollution.

Crop monitoring

The monitoring of crops can have a variety of impacts. Land use classification can help to assess crop location changes, and see if there are any issues arising by identifying troubling changes or trends.

Monitoring can also be used to support subsidy control, thereby reducing the need for on-the-spot checks, which are both costly and limited in scale. In Europe, this has a significant impact on the Common Agricultural Policy (CAP) especially. Projects such as Sentinels for Common Agriculture Policy (Sen4CAP) and peRsonalized public sErvices in support of the implementation of the Common Agricultural Policy (RE.CAP) aim to utilize Sentinel and other Copernicus data in order to improve compliance across the CAP.

Above all, crop monitoring can help identify environmental factors that need to be taken into consideration.

Water management and drought monitoring

Data such as wetness indicators can help identify the level of irrigation needed in regions. On top of this, monitoring the crops and surrounding land will indicate if there is unhealthy vegetation and a lack of water, or if there is an increase in algae in the water, which could indicate fertilizer pollution.

WHY EARTH OBSERVATION?	APPLICATIONS	BENEFITS	END USERS
SMART/PRECISION AGRICULTURE	• Yield mapping • Input management • Farm management recording & decision-making support	• More efficient and appropriate use of agricultural inputs, helping protect the environment • Increased productivity and yield, leading to improved profitability and cost efficiency	• Farmers • Agricultural cooperatives
CROP MONITORING	• Seasonal mapping of cultivated areas • Support to subsidy controls	• Assessment of crop location changes • Better monitoring of food security issues • Efficient/cheaper controls, limiting need for on-the-spot checks • Reduction of the risks during performance of controls	• Public authorities (national, regional) – who are focused on food security • Farmers (performing the control) • Public authorities (providing the subsidies)
WATER AND DROUGHT MANAGEMENT	• Wetness indicators, soil moisture • Crop mapping • Input management (to decrease water pollution)	• Prevents pollution of water systems • Helps determine irrigation needs • Prevention/improved monitoring of droughts • Supports combatting food insecurity	• Decision makers (e.g. national public authorities, international bodies)

AGRICULTURE

DRIVERS AND CHALLENGES FOR THE ADOPTION OF EO FOR AGRICULTURE

There has been a push towards promoting sustainable agriculture in recent years, aiming to have farms that are economically profitable whilst also balancing its social impacts and ensuring it is as environmentally-friendly as possible. Many EO data solutions can be utilized to help support sustainable agriculture initiatives, such as water management and preventing pollution of the soil, water and air.

Many developing countries are threatened by food security issues, arising primarily from natural conditions. However, opportunities for solutions where EO data can contribute to monitoring the impacts of such events are continuing to emerge. The international initiative GEOGLAM (Group on Earth Observations Global Agricultural Monitoring Initiative) helps monitor, amongst others, countries at risk for food insecurity, including providing timely early warning on general food shortages, and the detection of hot spots affecting farmers' livelihood.

Public end-users, such as governmental bodies and local authorities, are looking towards EO-data driven monitoring solutions to help identify and measure main crop production areas and ensure farmers are compliant with policies that require responsible farming. These solutions are helping to lower costs, as traditional methods of monitoring have been on-the-spot checks, which are both high in cost and limited in scale.

DRIVER 1

There is a trend towards sustainable agriculture, where farmers aim to balance economic profitability with being socially and environmentally responsible

DRIVER 2

Developing countries are facing food security issues, which can be addressed in part by EO-based solutions that provide early warnings and detect hot spots affecting the farmers.

DRIVER 3

Public authorities are starting a shift towards utilizing monitoring services and tools in order to ensure compliance with regulation

CHALLENGE 1

Companies providing EO solutions for agriculture find it too complex to deliver products direct to farmers; their clients remain intermediate users, such as cooperatives people already delivering agronomic services

CHALLENGE 2

For many farmers, there is a lack of broadband or infrastructure to support the shift to digitalization, as well as a digital skills gap in utilizing the products.

CHALLENGE 3

Many farmers still remain unaware of these solutions and the added value they can bring.

Most companies developing EO-based solutions for agriculture are limited in how to approach customers. It is too complex to sell directly to farmers, due to the number of farmers and the fragmented state of the sector. Instead, they provide products to farming cooperatives or agronomic advisors. However, some countries do not have many farming cooperatives, and private agronomic advisors can be too expensive for small farms. Hence, there is a large proportion of the market not easily accessed by these companies.

Whilst the shift to digitalization is advancing within Europe, there are many countries where farmers struggle to implement new technological features due to remote locations and hence a lack of broadband connectivity or supporting infrastructure. There is also a digital skills gap amongst some farmers, who feel as if they do not have the necessary knowledge to utilize technological solutions easily.

There is still a challenge in raising awareness amongst farmers regarding EO-based solutions, both for what is currently on the market as well as the benefits that utilizing such a product could bring. Education and training for farmers for implementing these types of technology is still necessary, so that they understand how to integrate these services into their decision-making process.

AGRICULTURE

THE VALUE CHAIN OF EO DATA FOR AGRICULTURE

ACQUIRING EO DATA

Overall data needs

- Open data (Sentinels, Landsat, MODIS, Copernicus contributing missions) for low and medium resolution data to monitor variations over time and identify hot spots
- Sentinel-2 is especially important for agriculture applications, whilst Sentinel-1 is a good complementary source
- Update frequency (revisiting time) of a few days an attractive feature of Sentinels
- Sometimes Sentinels and contributing missions of Copernicus do not provide high enough resolution for applications for precision agriculture, and so commercial/private data will be purchased instead (e.g. SPOT, Rapideye, Worldview)
- Open source data is paramount for start-ups and SMEs trying to develop new solutions. It is even important for more established players, considering farmers to not want to pay for high-price solutions. The ratio of open source to commercial data varies greatly depending on the application/company.
- Aerial data, e.g. from drones, is complementary

PROCESSING NEEDS AND CAPABILITIES

Data format and in-house capabilities

- Data processing to turn satellite images into solutions that provide decision-making support to end users
- EO data is becoming increasingly combined with in-situ data, such as soil samples, in order to have a better overall understanding of the scenario
- Two main types of profiles needed for in-house capabilities: experts with remote sensing backgrounds, and agronomists
- Several service providers use dedicated platforms to access or process the data specifically for agriculture
- Value-added service companies sometimes establish partnerships with other organizations, such as research centres, in order to have specialized knowledge in a specific topic
- There are many opportunities for SMEs and start-ups to build solutions – open, high quality, and easily accessible data lowers the barriers for the intermediate market
- There is a trend towards seeking more automation and machine learning within certain applications

USERS & NEEDS

Non exhaustive list

- Maps/images of parcels of land, that use colour codes to represent crop disease or lack of irrigation
- For precision agriculture, solutions can provide information about amount of water or fertilizer needed for a specific portion of the land parcel, for example
- Farmers can use these types of solutions to improve yield productivity and hence become more profitable
- Public authorities can utilize these tools to monitor the environment and ensure farmers are compliant with environmental regulations
- Trends build over time from this data can help farmers with following year crops, and help public authorities identify areas to focus on for policies
- Mapping of crop diseases or lack of water can highlight challenges facing food security in developing countries
- Value added service companies have to provide specific training for clients or end users (agronomists, farmers) so that the information can be fully exploited

AGRICULTURE

THE OPEN DATA POLICY HAS SUPPORTED AN INCREASE OF SOLUTIONS ON THE MARKET

Sentinel data often acts as a primary source of data for agricultural solutions, especially Sentinel-2.

However, Sentinels are rarely the only source of data utilized; usually, it is combined with other EO sources (e.g. Landsat for historical data, commercial data if high resolution or specific tasking required), aerial imagery (e.g. drones act as complementary data) and in-situ data (e.g. soil sample data). There has been an increase in the number of start-ups providing EO-based solutions within the agricultural sector, and this can be attributed in large part to the introduction of the Copernicus programme, with its free and open data policy.

The principal uses of Copernicus in the agriculture sector are for helping monitor the agricultural land use and for the compliance of farmers to EU-Agriculture directives that are focused on achieving a more sustainable farming sector, as well as helping to assess crop conditions and yield forecast in precision agriculture and food security applications.

	Copernicus strengths	Copernicus weaknesses
Copernicus is a first choice for many service providers, thanks to the reliability of its service. The quality of its data, such as its resolution and revisit time, allows service providers to develop dependable and qualitative agricultural products, that they may not be able to otherwise offer if the programme wasn't available.	***SENTINEL DATA IS RELIABLE AND POPULAR TO USE***	
Farmers are unwilling to pay large amounts of money for EO-based solutions. Therefore, the free and open data policy allows companies to develop, improve and provide services at a lower cost, thanks to the lack of data acquisition fees. It has fostered a favourable environment for start-ups/SMEs.	***PROVIDING FREE EO DATA IS CRUCIAL TO SUPPORT BOTH INITIAL UPTAKE AND MATURE PRODUCTS***	
The variety of EO products made available with the help of Copernicus helps to address sub-sectors such as precision farming techniques, water management techniques, products for public authorities, etc. The products are functional and hence easily adapted to different scales and user needs.	***THE VARIETY OF EO PRODUCTS AVAILABLE ALLOW FOR MANY SUB-SECTORS TO BE ADDRESSED***	
At the heart of the Common Agricultural Policy is the farmer subsidy system. To ensure compliance with regulation and allow farmers to receive these subsidies, a control system is in place. To date, this has been primarily on-the-spot checks and paperwork. Copernicus monitoring solutions can help make this more efficient, reducing the cost and time spent.	***COPERNICUS IS HELPING TO MODERNIZE THE CAP MONITORING PROCESS***	
Some applications of precision agriculture, for example vineyard monitoring, can require higher resolution than Sentinel-2 provides. For example, the requirement may be around 3-5m instead of the minimum 10m that Copernicus provides.		***FOR SPECIFIC PRECISION AGRICULTURE APPLICATIONS, SENTINEL RESOLUTION MAY NOT BE ENOUGH***

AGRICULTURE

COPERNICUS BENEFITS FOR AGRICULTURE

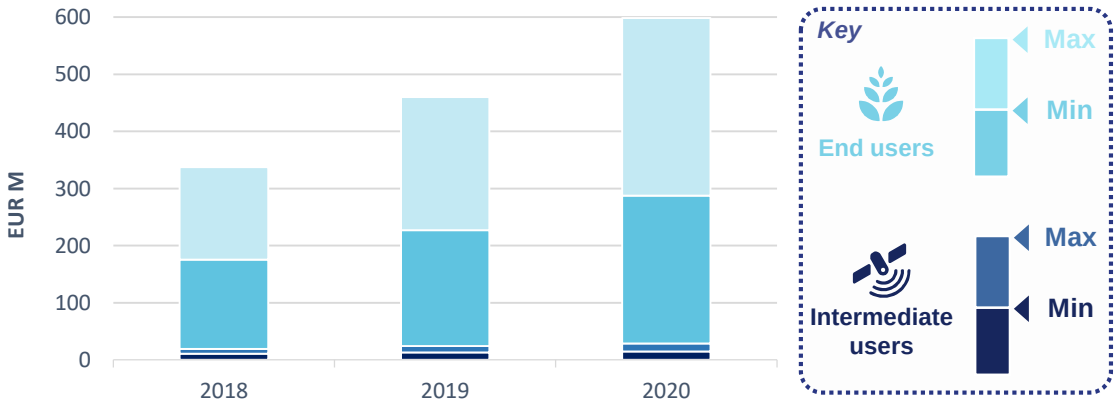
Precision farming services represent a large proportion of revenues generated by EO services within the agricultural sector, helping to improve profitability of the farmer.

For intermediate users, the majority stakeholders interviewed utilized Copernicus data within their solutions. However, the degree of reliance varied greatly, ranging from 20-30% of the EO data used, up to 90-100%. Sometimes this was based on solutions requiring more precise resolution, and hence utilizing more commercial data, and at the other end, there are start-ups who rely heavily on the fact that Copernicus data is free and easily accessible.

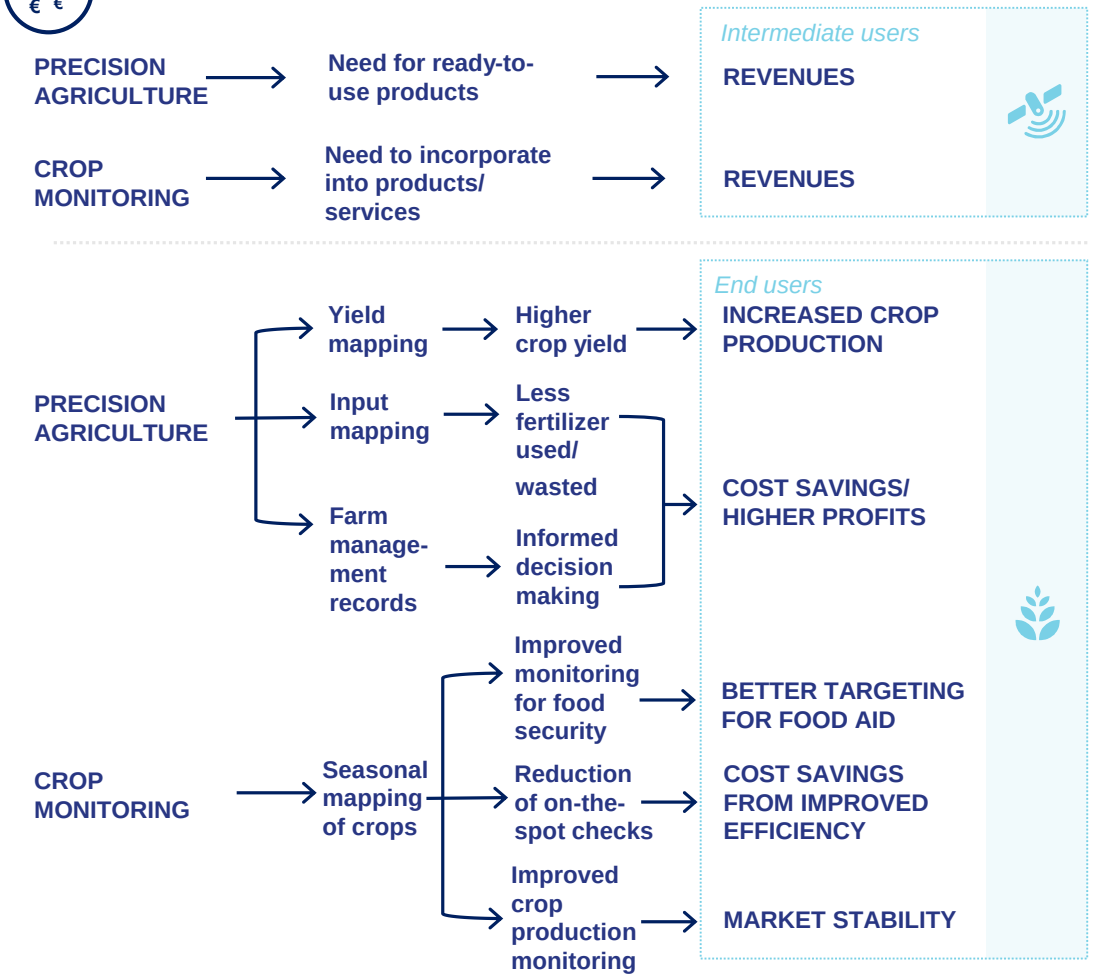
Revenues enabled by Copernicus are expected to rise in the upcoming decade, especially since the majority of intermediate stakeholders are utilizing more and more Copernicus data in their solutions. As mentioned before, there is also a rise in start-ups and SMEs in the sector, who are capitalizing on the free and easily accessible data. Benefits for intermediate users is therefore estimated to lie within EUR 11 to 19 M in 2018, which can rise to EUR 15 to 29 M by 2020. This is only considering precision agriculture applications, which is where the majority of the commercial market is focused. For end users, benefits are estimated as EUR 156 to 318 M in 2018, rising to EUR 259 to 570 M by 2020. This is including precision agriculture, environmental monitoring, water management, and food security.

Economic benefits of Copernicus through its contribution to agriculture sector

(Source: PwC)



Economic impacts



AGRICULTURE

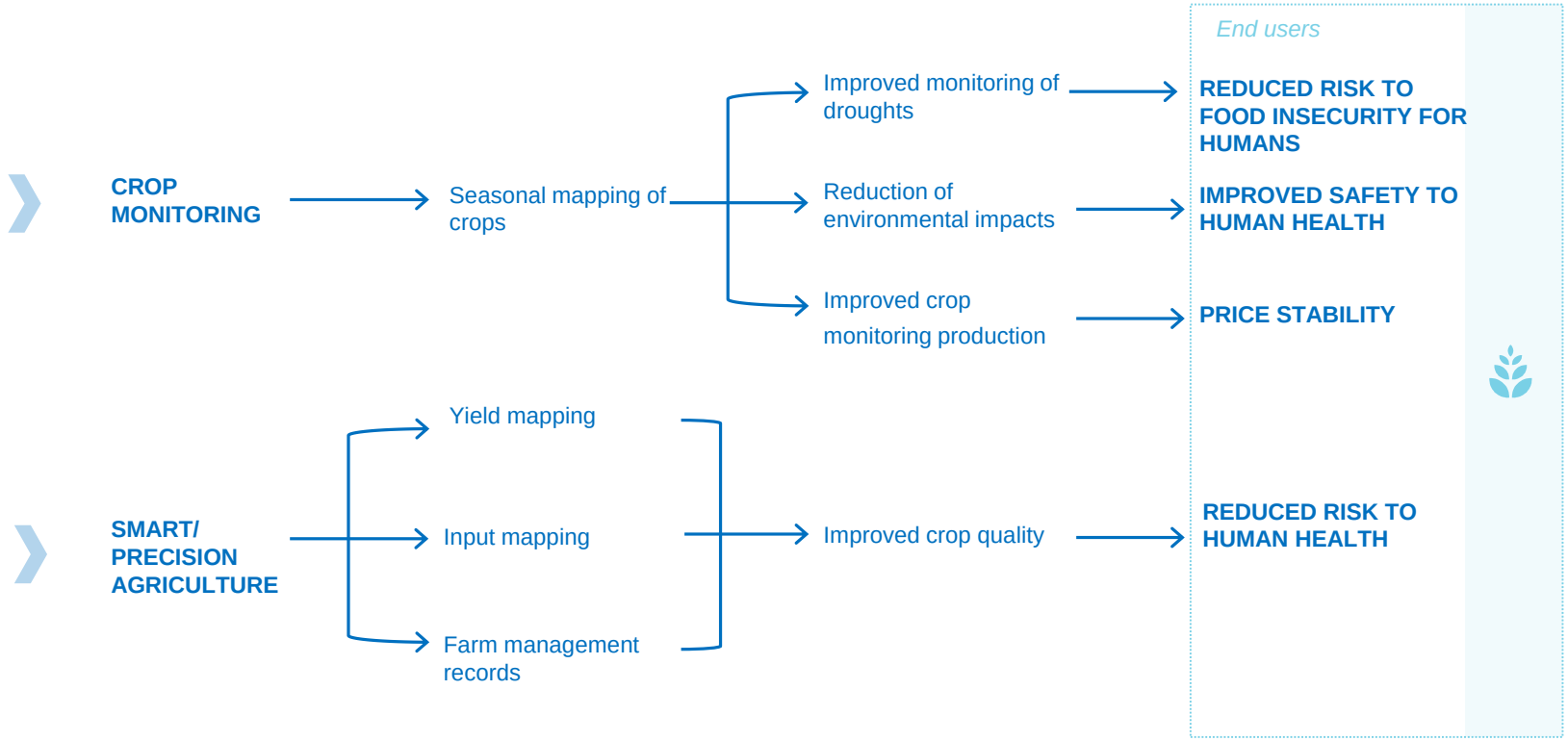
COPERNICUS BENEFITS FOR AGRICULTURE

Social impacts

Precision agriculture applications based on Sentinel-2 data help farmers to produce more food of better quality, which has fewer risks for human health.

Decreasing the negative environmental impacts, such as water and air pollution, helps protect human health also.

Detecting change in crop health in a timely manner is crucial in the support to early warnings and decision making on food security. This aids in lowering costs and increasing the effectiveness of reducing hunger in stricken areas.



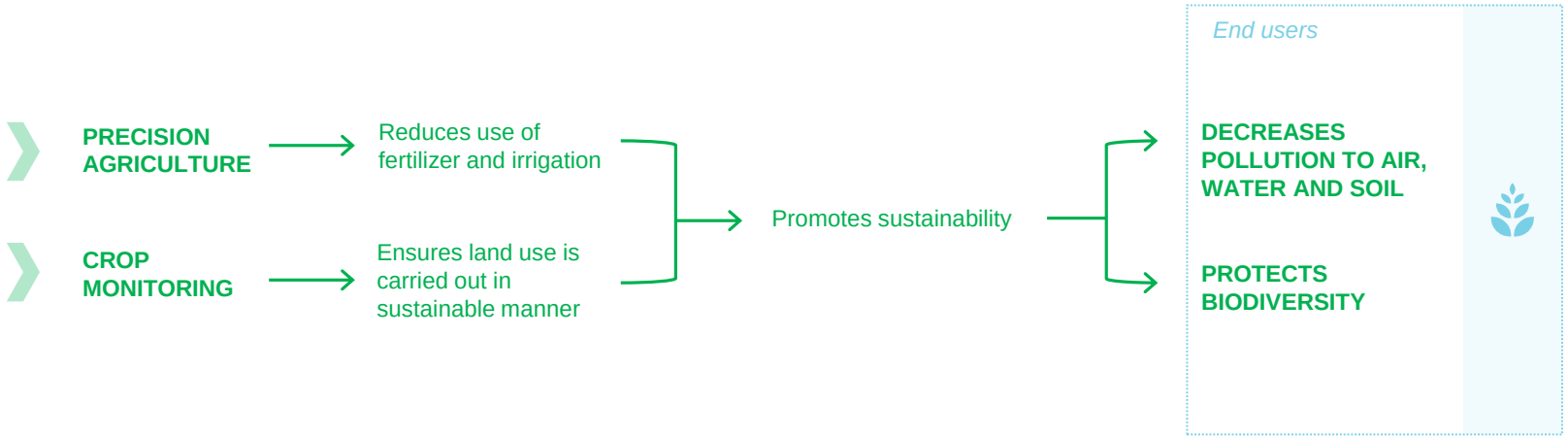
AGRICULTURE

COPERNICUS BENEFITS FOR AGRICULTURE

Environmental impacts

Precision farming services reduce the potential negative impacts of agriculture on the environment by enabling a more efficient and appropriate use of inputs such as fertilizers. By confirming the crops are receiving the correct quantity of fertilizer, it protects the environment by decreasing the likelihood of pollution to the soil, air and water. This in turn helps protect human health as well as the surrounding biodiversity.

Monitoring services also help ensure that farming activities are in compliance with regulation that seeks to support overall sustainability in the sector.



Strategic impacts

Copernicus supports innovation in the EU through its free and open data policy and provision, which encourages the development of SMEs.

Copernicus also supports the development of monitoring tools and other services, which help ensure the continued implementation of EU policies, especially those of the Common Agricultural Policy.

- **SUPPORTING INNOVATION THROUGH ITS FREE AND OPEN DATA POLICY**
- **PROVIDING MONITORING TOOLS TO HELP ENSURE THE CONTINUED IMPLEMENTATION OF EU POLICIES**
- **POSITIONING EUROPE AS A WORLD LEADER IN COMBATTING GLOBAL FOOD INSECURITY**

AGRICULTURE/ CASE STUDY

EO for smart farming and CAP performance
Gaiasense

EO FOR SMART FARMING

THE CHALLENGE FACED BY GREEK FARMERS

Farmers in Greece are facing increasing challenges in today's climate that can significantly impact their crop yield, including climate change, the need for high irrigation, and crop susceptibility to pest attacks. Moreover, many traditional practices utilized not just by Greek farmers, but by farmers all over the world, are non-sustainable, draining the natural resources and impacting the environment by polluting water, air and soil systems with fertilizers and other inputs.

Smart farming is an integrated approach for the management of agricultural activities, and understanding a way in which these challenges facing the farming community can be addressed. It can provide digital, data-driven advisory services to farmers or agronomic advisors, and helps both with increasing profitability and yield, whilst also encouraging an environmentally-friendly approach to farming practices.

Advisory services provided often focus on fertilization, irrigation, and pest management, aiming to minimize the use of inputs such as water, fertilizes and pesticides. This also helps enable the farmer to be compliant with the regulatory framework of the EU.

THE ROLE OF GAIASENSE

Gaiasense is a Smart Farming (SF) platform developed by Neuropublic, which provides EO-based monitoring services to farmers, agricultural advisors, and researchers, collecting data from satellite imagery, farm logs, and the Internet of Things sensors, amongst other information. It covers 10 different types of cultivations and its infrastructure is installed in 12 regions throughout Greece – covering over 200,000 acres.

There are four dimensions to the Gaiasense service: remote, field, eye and farm. Remote sensing data is collected via satellites and other aerial vehicles, allowing users to have a detailed and up-to-date picture of the plant's health and status of the soil. These are presented via indices such as for vegetation (e.g. NDVI) and water status (e.g. NDWI). It aims to provide not only an overview of crops and fields for their variabilities, but also the change over time during the growing season. The field data meanwhile is collected by telemetric stations installed at selected points of certain parcels, in order to record, analyse and interpret atmospheric and soil data. The 'eye' dimension allows agricultural consultants and producers to record information during observations during field visits, whilst "farm" records the actions that the farmer carries out in the field and for the crops.

COPERNICUS CONTRIBUTION TO FARMERS AND POLICY MAKERS IN GREECE

CONTRIBUTION OF GAIASENSE FOR FARMERS AND POLICY MAKERS IN GREECE

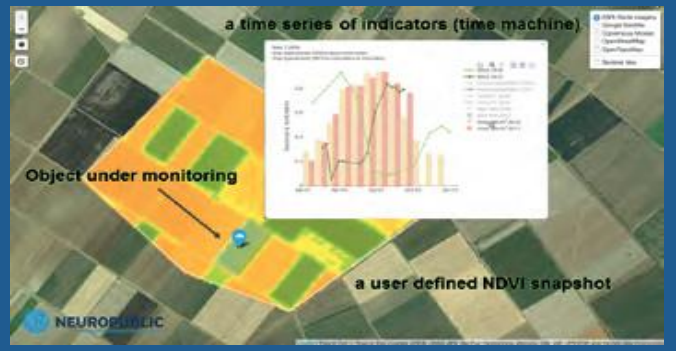
Gaiasense uses remote sensing methods to process Copernicus raw data and services hosted on its hubs. The platform provided incorporates three modules, which operate independently, and aim to:

1. Search for new Sentinel-2 imagery
2. Download the new images
3. Perform required processing on the optical satellite images (e.g. atmospheric correction, cloud masking)

The initial data is then output as higher-level products such as NDVI or LAI vegetation indices, which can be extremely informative for smart farming techniques. The platform automatically assigns the extracted information to the agricultural parcels/management units within the Gaiasense database, whilst incorporating additional information such as meteorological data for extra context.

The services provided are not only for farmers and their advisors, but can support scientific research as well as introduce spatial analytics intelligence for CAP performance and efficiency management for policymakers. Through providing smart farming services for two years, results have indicated that production can be increased by an average of 10% whilst decreasing the consumption of water, fertilisers and pesticides by an average of 19%.

Future developments aim to include more data from Sentinel missions, so that data from more wavelengths can be examined, as well as providing a shorter revisit time. Other extensions may include crop growth models and weather forecasts powered by satellite data.



A demo view depicting fields in Central Macedonia
(Source: contains modified Copernicus Sentinel data via Gaiasense, Neuropublic)

AGRICULTURE/ CASE STUDY

Verifying agricultural subsidies SATIKAS

Põllumajanduse Registrite ja Informatsiooni Amet

Tartu Ülikool · Universitas Tartuensis · 1632

CGI

EO FOR VERIFYING AGRICULTURAL SUBSIDIES

THE CHALLENGE FACED BY ESTONIAN PAYING AGENCY

Farmers in the EU must follow the rules laid out in the European Common Agricultural Policy (CAP) in order to qualify for subsidy payments, which ensure a farmer has a support system against volatile market prices whilst also safeguarding the environment.

The role of sharing and verifying these farmer subsidy claims lies with the Paying Agency (PA) of each Member State. The level of non-compliance is very small; however, since the annual budget of the CAP totals €50 billion, the overall EU-wide economic impact can be significant. Currently, Paying Agencies have predominantly relied on on-the-spot verification checks by inspectors. However, thanks to growing labour costs, these field visits are becoming more expensive every year.

THE ROLE OF SATIKAS

The Estonian Agricultural Registers and Information Board (ARIB), in cooperation with Tartu Observatory and CGI Estonia, built an automated infosystem SATIKAS, which uses Sentinel-1 and Sentinel-2 optical satellite imagery to verify if farmers are following the mowing requirements set up under the CAP. This is one of the most common requirements for farmers, and is often violated on land that is not under intense agricultural use.

SATIKAS operates May to October each year, to cover the entire growing season, and can detect all mowing activity on agricultural grassland in Estonia. Each season, over 100 Sentinel-1 radar images and more than 50 Sentinel-2 optical images are used within SATIKAS. For each land parcel, deep learning technology is applied to its Sentinel-1 and 2 parameters in order to detect mowing events, differentiating between areas that are mowed, areas that are not, and those that have been mowed late.

Mowing detection results presented on public web map of Lääne-Viru County.
(Source: contains modified Copernicus Sentinel data via SATIKAS

COPERNICUS CONTRIBUTION TO VERIFYING SUBSIDY CLAIMS IN ESTONIA

CONTRIBUTION OF SATIKAS IN VERIFYING CAP SUBSIDIES

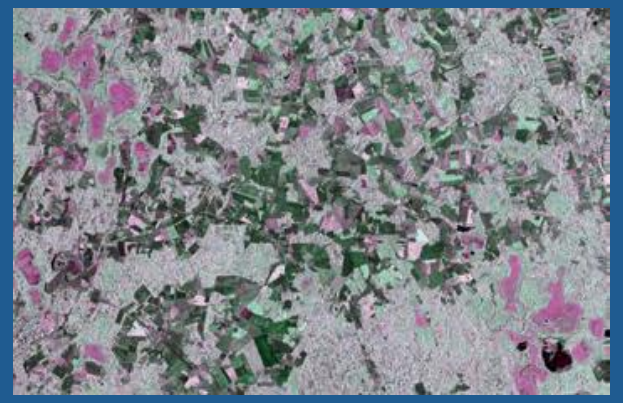
In late summer and autumn, where cloud coverage can be over 70%, Sentinel-1 radar is extremely valuable. However, accuracy is best when both Sentinel-1 and Sentinel-2 data are used. Within the validation results, overall accuracy increased from 85% with only Sentinel-1 data, to 94% when combined with Sentinel-2.

An open web map publishes the results in virtual real time, which can be accessed by the general public. ARIB specialists also receive detailed reports, helping to reduce the need for costly field visits, and saving the time of field inspectors, who now only need to visit those fields that are indicating issues rather than wasting time visiting ones that have none. By publishing on the web map, and sending ‘early warning’ reminders via email, it also works as a reminder for farmers who have not yet fulfilled the mowing requirements.

By encouraging compliance and detecting more incidents of non-compliance, SATIKAS has helped to reduce false payments. The economic impact in Estonia is estimated at being around €500,000 per year, whilst the total economic impact of similar systems if operated at an EU-level would be around two orders of magnitude greater.

The ultimate goal will be to extend the functionality of SATIKAS with monitoring of grazing detection, harvesting detection, crop classification and flooded fields mapping, and eventually reach a level of capabilities that allow for subsidy decisions to be made without field visits.

Thanks to solutions such as SATIKAS, spending of the EU can be reduced, and those freed resources can be utilized for future technological developments.



Lääne-Viru County on false colour composite
(Source: contains modified Copernicus Sentinel data via SATIKAS

AGRICULTURE/ CASE STUDY

EO for efficient farming against drought
FruitLook

EO AGAINST DROUGHT

THE CHALLENGE OF DROUGHT IN THE WESTERN CAPE OF SOUTH AFRICA

The ongoing drought in the Western Cape of South Africa is one of the longest and hardest-hitting in living memory. The agriculture sector is especially vulnerable to droughts, and farmers are facing loss of jobs, financial distress, an inability to grow crops, and a difficulty in finding and buying feed for their animals.

This drought is currently affecting two of its largest industries: fruit and wine production. These industries represent almost a third of the province's exports, and hence are of huge fiscal importance. It is vital that production is optimized at the same time as farmers reduce their ecological impact and improve their efficient use of water resources. Balancing these will bring both economic and environmental benefits.

THE ROLE OF FRUITLOOK

To address the need for efficient use of water resources, the Western Cape Department of Agriculture (WCDoA) collaborated with the Dutch company eLEAF to produce an online platform FruitLook. The goal is to monitor vineyards and orchards, predominantly utilizing frequently updated satellite imagery and weather information.

One of the indicators needed in order to improve water use efficiency is understanding how much water is consumed through crop production. This is known as 'actual Evapotranspiration' (ETact), and it can be difficult information to obtain thanks to the complicated and costly in-situ measurements required.

In contrast, FruitLook offers not only spatial variation, which is not provided under in-situ measurements, but also provides the data to farmers for free, as the service is fully-funded by the WCDoA.

200,000ha of vineyards & orchards are monitored by FruitLook per week
(Source: Copernicus4Regions, FruitLook)

COPERNICUS CONTRIBUTION AGAINST DROUGHT IN SOUTH AFRICA

CONTRIBUTION OF FRUITLOOK IN THE WESTERN CAPE OF SOUTH AFRICA

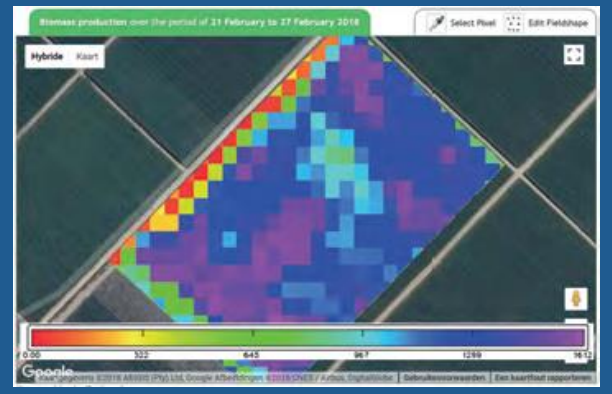
Sentinel-2 data is essential for the weekly data products provided by FruitLook, where it services an area of 9 million ha, including 200,000 ha of fruit crops. By using satellite information technologies such as Pixel Intelligence Mapping, farmers can analyse crop growth and water consumption over time and space. They access this information by a web portal, where the data is provided down to a field-by-field basis.

The service offers 9 different information sets, including biomass production to show how the crop is growing, and an evapotranspiration deficit parameter to indicate if the crops are experiencing stress.

Farmers can benefit greatly from FruitLook, using the platform to monitor crop development, detect and locate growth problems, and evaluate and improve water management. Overall, the aim is to optimize resource use as much as possible, which is even more essential during drought conditions, and improve management decisions, which is reflected in the productivity and efficiency of their water use.

Results can already be seen: water use efficiency of FruitLook users has increased by between 10% and 30%.

Farmers who make better-informed decisions help not only to save water, but can bring about beneficial environmental impacts as well, such as understanding what inputs to apply and where. FruitLook can help identify diseased blocks of plants, indicating what areas need to be sprayed by pesticides. By targeting only the infected block, the application of pesticides is reduced, saving costs and reducing the environmental impact.



Variation in crop growth
(Source: Copernicus4Regions, FruitLook)

FORESTRY

KEY TAKEAWAYS

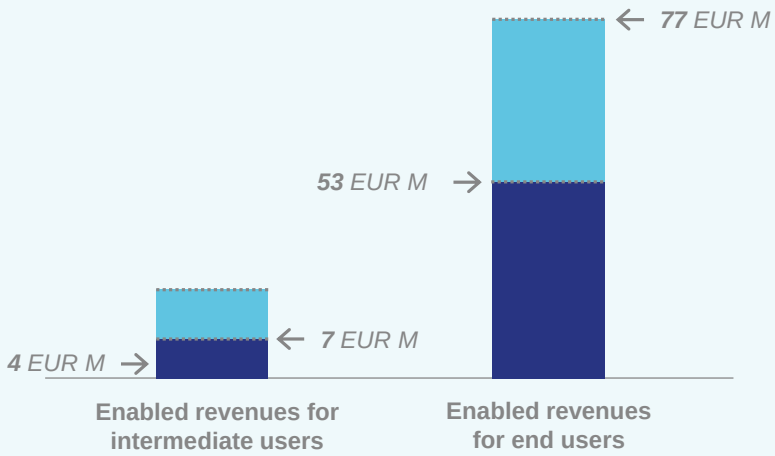
- 80% of forest area globally is under government control – where the emphasis is often on forest management, in terms of conservation and protection.
- Global initiatives, such as the UN's Programme on Reducing Emissions from Deforestation and Forest Degradation (REDD), require participating countries to obtain highly accurate and precise data on forests and thus represent opportunities for intermediate users.
- Both Sentinel-1 and 2 data are recognised sources of valuable information along the forestry value chain.
- Copernicus data provides forest authorities accurate forest mapping, which is particularly useful for storm damages assessment, inventory and validation of forest strand for wood purchasers.
- Intermediate users of EO data in the forestry domain include several private players (from micro-companies to larger players), public research institutions, and forestry management organisations.
- Forestry-aimed EO products are currently being used by public end users mainly (90%), rather than by private end users (10%).

COPERNICUS APPLICATIONS

- Specific land cover tools such as the High Resolution Layer (complementary to land cover in a 20m resolution)
- Products to support the EU network of nature protection areas, in order to foster biodiversity
- Maps to monitor land that is in proximity of freshwater ecosystems
- Inventories of land cover historical imagery to highlight changes in land cover
- An upcoming small woody features product, that is based on Very High Resolution data and will be able to monitor small areas of trees
- Sentinel 2 Systematic Mosaic production tool

Copernicus economic impact (2018)

(Source: PwC)



KEY COPERNICUS PRODUCTS

- Copernicus Land Monitoring Service
- Forest maps, including type and tree-cover density, at European scales
- Continuous low-to-medium resolution biophysical variables related to vegetative health at global scales

FORESTRY

A MARKET HISTORICALLY BENEFITTING FROM EO

When the formal sector is referred to, and also taking into account its indirect and induced effects, the forestry industry figures show an estimated total of 45.15 million jobs globally and labor for a comprehensive income of $580 billion per year. The European Union accounts for approximately 5% of the world's forests, and the forested area of the EU is slowly increasing.

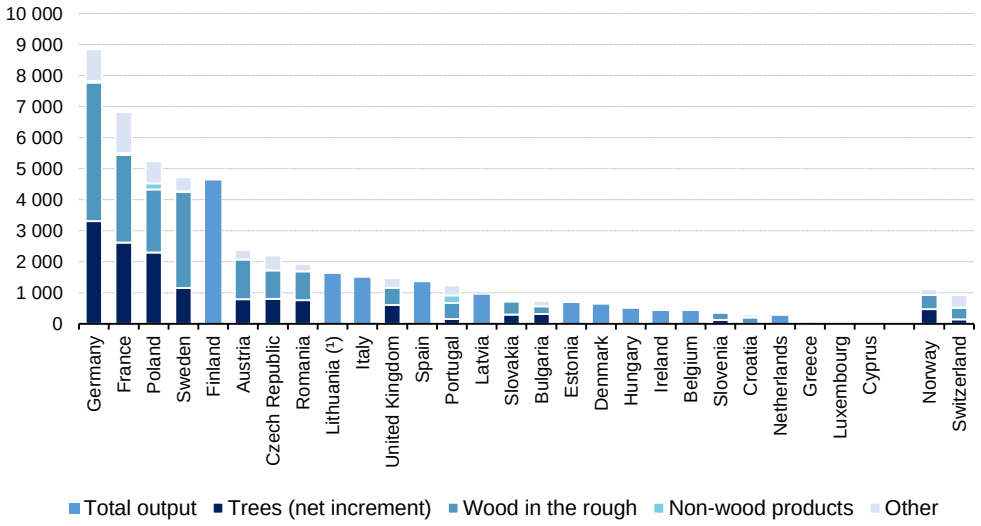
Several industries are connected to forestry, such as timber harvesting, to provide a continuous supply of trees for economically optimal wood production, fuel wood supplies as an affordable energy source, and also indirect applications such as forest management and certification. The output of the forestry and logging activity by type of output among the EU-28, Norway and Switzerland is shown in the graph. Evidence also shows that forests and trees contribute to the global economy in terms of livelihoods and food security for many rural areas, sustainable consumption and production, climate change mitigation, as well as sustainable economic growth and employment.

Although a lack of systematic data makes it nearly impossible to provide precise figures, it is estimated that the number of people involved informally in the forest sector is in the order of 50 million.

80% of forest area globally is under government control – where the emphasis is often on forest management, in terms of conservation and protection.
Both the formal and informal forest sectors include large numbers of small or micro businesses, while at the other end of the scale there are also very large companies. On a larger scale, there may be a need to address potential barriers to investment, often financial or infrastructure related.

Output of forestry and logging by type, 2015

(Source: Eurostat)



By 2050, the world population is expected to reach 9.8 billion, while income per capita is expected to triple.
This will lead to increased harvesting of many natural resources, including wood, as well as more waste. Using wood (including wood waste and residues) more efficiently to meet this demand is crucial to achieving a more resource-efficient, circular and bio-based economy.
In this sense, forest management and certification plays a significant role in ensuring the efficient protection, development, and utilization of forest resources. EO becomes a crucial tool to forest managers, through two broad and interrelated categories: resource inventory and monitoring; and analysis, modeling, and forecasting to support decision making.

EO spatial data input, editing, and mapping are extensively used during the inventory and monitoring phases. In the modeling phase, overlays, reclassifications and suitability analyses are part of the decision making process. More sophisticated forecasts and simulations are then used to assess management decisions before any intervention is made on the ground.

Sources: OECD

FORESTRY

FOREST MANAGERS CAN BENEFIT FROM EO THROUGH TWO TYPES OF ACTIVITIES

Resource Mapping

EO data provides forest authorities with accurate forest mapping, which is extremely useful for storm damages assessment, inventory, and validation of forest strand for wood purchasers. Thanks to time series of satellite images, forest authorities are also able to detect change in the land cover/land use in forest areas, such as illegal clear cut for example, or urban area expansion threatening the ecosystem. All this information supports the implementation of EU policies aimed at sustainably managing and eventually safeguarding the forests.

Resource Monitoring

Satellite EO is a fundamental tool for deriving statistics on deforestation and land use change and is critical to monitoring sustainable development in local, national, regional and global scales.

At the global level, since 1990, information collected by FAO for its Forest Resources Assessments (FRA) through country reporting has been consistently supported by remote-sensing data, and by a growing dataset of satellite imagery and new software for image processing and interpretation.

The World Resources Institute's Global Forest Watch (GFW) also takes advantage of national coverage satellite EO data (Landsat) to provide information with 30m resolution accuracy. Such information is presented through an online forest monitoring system which helps forest management stakeholders to create custom maps, observe forest trends, receive alerts or download data on their area or the entire world.

The UN Convention to Combat Desertification (UNCCD) initiated a series of Good Practice Guidance reports to aid countries in selecting, processing and analyzing databases to report against deforestation and forest fire, with EO integrated solution.

Moreover, the REDD+ initiative of the UN Framework Convention on Climate Change (UNFCCC) looks to provide financial aid for countries, to encourage forest maintenance and preservation, aimed at reducing emissions from deforestation and forest degradation, boost conservation and sustainable management of forests, and enlarge forest carbon stocks.

In support of REDD+, the Global Forest Observations Initiative (GFOI) strives to ensure ready-available national coverage of EO data and to provide Guidance Documentation with Methods (MGD) that will facilitate reporting consistent with the relevant IPCC Good Practice Guidelines.

WHY EARTH OBSERVATION?	APPLICATIONS	BENEFITS	END USERS
RESOURCE MAPPING	• Inventory of forest resources • Monitoring changes in resources over time • Evaluating land productivity for forest types given biophysical and climatic factors.	• Improved monitoring techniques • Provide basis for risk assessment • Identification of potential areas of intervention	• Forest managers • NGOs • Governmental institutions
RESOURCE MONITORING	• Timber harvesting • Silviculture • Fire management • Prediction of fuel wood and other resource supplies	• Land use and post-fire erosion monitoring • Prevent deforestation • Demand assessment for wood related products and resources • Vegetation health management	• Forest managers • NGOs • Governmental institutions • Timber managers • Fuel wood resources managers

FORESTRY

DRIVERS AND CHALLENGES FOR THE UPTAKE OF EO BY FOREST MANAGERS

EO data is mostly used by national forest agencies to monitor the compliance of the forest owners to the law. Indeed, rules have been implemented to prevent private owners of forests from depleting this national asset. In these regards, the development of clear-cut maps will enable the authorities to enforce the rules in the forestry sector. Forest agencies in other European countries use commercial satellite imagery to prepare their maps.

Preserving forest ecosystems and green infrastructure is crucial for peoples' well-being. They are hosting global biodiversity, and they provide benefits to society and the economy via the provision of ecosystem services (soils erosion protection, watershed regulation, climate regulation, carbon storage and water/air purification). EO data provides forest authorities accurate forest mapping. Thanks to time series of satellite images, forest authorities are able to detect change in the land cover/land use in forest areas, such as illegal clear cut.

Lastly, sustainable management of forests requires activities like replanting within 3 years after the clear-cut and one or even two pre-commercial thinning within the 10 years after replanting. These are costly investments for private owners if they only looked at short term optimization of returns. However, in the long term (approximately 80 years) the profitability of the forest is improved as this sound asset management results in more wood for the final clear cut. EO leads to improved yields in the forest sector, by monitoring forest owners compliance to sustainable practices.

DRIVER 1

Cost reduction in monitoring compliance to forest management best practices (for national forest agencies)

DRIVER 2

Improve and preserve forest ecosystems and green infrastructures

DRIVER 3

Improved yields in forest industry thanks to sustainable management (increasing volume and quality of timber in the long term)

CHALLENGE 1

For some parameters, the methodologies for producing maps at scale have not been developed or validated

CHALLENGE 2

EO data from satellites, manned aircraft, or UAVs still need major enhancements to map given characteristics.

CHALLENGE 3

The change in the signal detected by the EO instrument(s) over time is not necessarily related to changes in the forest characteristics

One of the main challenges of using EO data for forest mapping is constructing time series on given characteristics. Large budgets do not guarantee the quality of forestry variation maps; for many aspects (e.g. biodiversity) there is still a need to develop or validate methodologies for producing maps at scale, not to mention the impossibility to retroactively collect new data from past data gathering. Mapping variations over time still relies on the analysis of suboptimal historical satellite datasets, while mapping certain parameters may involve extensive ground research and data.

Secondly, there seems to be a gap between users' expectations on actual quality of data, and what this data can actually accurately map, especially within a reasonable budget for the users.

Moreover, the change in the signal over time detected by EO sensors does not necessarily reflect variations in the forest features, but may indicate changes in atmospheric conditions, vegetation seasonal changes or humidity conditions, or even the actual calibration of the sensor itself. The accuracy of such maps thus needs to be assessed through further ground data or independent EO products, and to rely on EO data and methods that are least likely to cause misconception in the resulting map.

FORESTRY

THE VALUE CHAIN OF EO DATA

	ACQUIRING EO DATA	PROCESSING NEEDS AND CAPABILITIES	USERS & NEEDS
	Overall data needs • Open data (Landsat, Sentinel, MODIS) for low and medium resolution data to monitor variations over time and identify hot spots • Needs for higher resolutions for forest restoration (10m or less) • Commercial satellite data for higher resolution on specific locations	**Data format and in-house capabilities** • Production of grid maps • Integration of EO data with other data sources, UAVs and ground data for precision and variation in forest mapping • Forest maps sold to local forest authorities and government institutions.	**Non exhaustive list**
Resource Mapping	• Systematic and updated data available at several resolutions • Mostly used by companies specifically dealing with EO data processing and Forest Monitoring NGOs. • Roughly 60% of data is coming from Sentinel, thanks to the improved resolution (10m) compared to other open data sources	• Commercial users acquire and process forest data and create spot maps on the forest status, based on the end users' specific needs • NGOs, governmental institutions and forest monitoring agencies either directly acquire satellite data or buy them by commercial data providers	• Tree cover density maps • Forest type maps
Resource Monitoring	• Satellite data often not sufficient for some class of forest characteristic changes over time • Low resolution more than often integrated with high resolution (about 30% of the data used is from commercial satellites)	• Commercial users acquire and process forest data, combine with different satellite sources to build time series, highlight variations and identify hot spots • NGOs, governmental institutions and forest monitoring agencies either directly acquire satellite data or buy them from commercial data providers	• Inventory of land covers to identify potential variations • Riparian zone maps to monitor lands in proximity of freshwater ecosystems • Biodiversity monitoring (still need enhancements)

FORESTRY

COPERNICUS DATA MAKES A DIFFERENCE IN TERMS OF UPDATE AND RESOLUTION, BUT FACES THE CHALLENGE OF INTERNATIONAL AWARENESS AND DATA CONTINUITY

Historically Landsat has been used to answer Forestry EO needs, but during the last two years there has been a significant uptake in Sentinel data related to forestry; more and more Sentinel data is being exploited thanks to its enhanced and higher resolution. In addition, Landsat is nowadays more and more integrated with Sentinel data at a country scale.

Forest restauration is seen as a high potential area for users uptake. Nowadays roughly 30% to 40% of forest restoration data is from Copernicus, and users agree in foreseeing huge Copernicus data uptake for this activity in the future. There has also been a shift in countries' awareness on Copernicus, mainly due to the enhanced data accessibility and processing granted by the DIAS initiative.

However, DIAS is still under implementation and the limited market awareness around it leads players to sometimes revert either to lower resolution or to commercial providers. Also, algorithms to monitor specific kind of variations over time are still based on Landsat data, and the process of constructing algorithms to integrate Sentinel data has only just started.

Copernicus strengths	
The implementation of the DIAS makes it much easier to access and process Sentinel data. It enhances Copernicus' competitiveness with respect to other EO international programs, such as Landsat.	***COPERNICUS DIAS IS FACILITATING DATA ACCESS BOTH FOR INTERMEDIATE AND END USERS***
The improvement of spatial resolution of Sentinels over previous open source satellite data is a strong differentiator for forest resource mapping and monitoring forest variations.	***IMPROVED SPATIAL RESOLUTION***
The open data policy allows for initial experimental projects before developing deeper EO skills. This is of particular importance for NGOs and Non-Profit organisations operating in the forestry sector, often facing issues in budget, or even SMEs with limited financial capacity.	***PROVIDING FREE EO DATA IS CRUCIAL TO SUPPORT INITIAL UPTAKE***

Copernicus weaknesses	
AWARENESS OF THE DATA IS STILL LOW AND ACCESS TO THE DATA IS NOT INTUITIVE	The access to the data hubs and the channels to download data can be complex to find for non-experts and players with limited resources. In some cases, either lower resolution (Landsat or MODIS) or commercial arrangements are more attractive as they are readily accessible.
DIFFICULTIES IN INTEGRATION BETWEEN DIFFERENT PROVIDERS	To monitor certain variation (i.e. deforestation), algorithms are based on older datasets (Landsat), with different resolutions and characteristics. It is still an issue to integrate Sentinel's data into such algorithms, resulting in flaws in monitoring given characteristics and variations over time.

FORESTRY

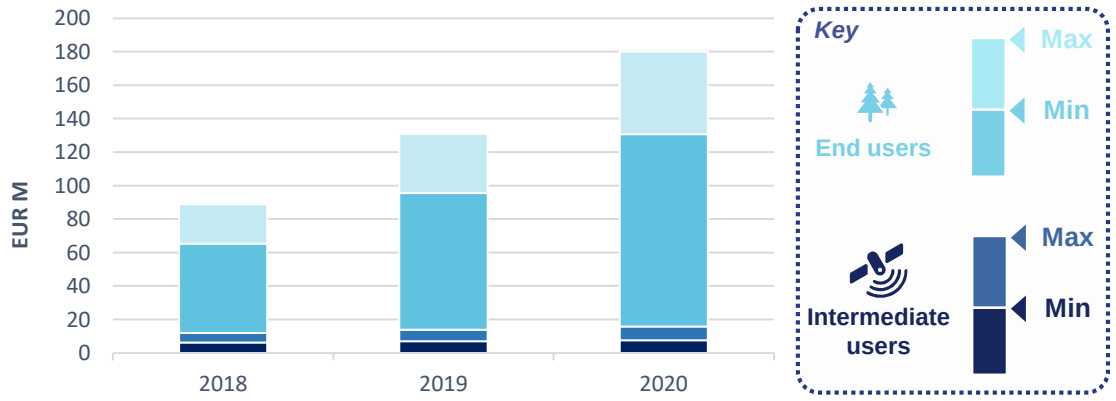
COPERNICUS BENEFITS FOR FORESTRY

Based on the EARSC industry survey on the EO downstream market, intermediate users' revenues in the forestry domain are approximately EUR 36.5 M. Some 90% of the stakeholders interviewed are using Copernicus data and Copernicus data currently contributes approximately 11.5% of the total amount of EO data used (conservative estimate), suggesting a conservative value of Copernicus enabled revenues for forestry management around EUR 6.2 M in 2018. A higher estimate based on the Geo-Information Systems (GIS) market for forestry leads to Copernicus-enabled revenues of EUR 12 M in 2018.

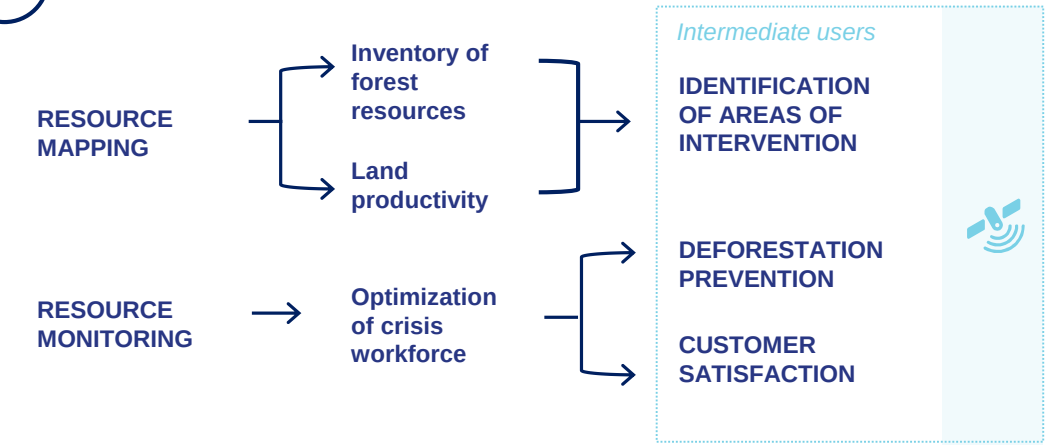
The value of Copernicus data to end users (e.g. forest owners) is estimated as the benefits derived from the improvement and preservation of green infrastructures (Copernicus Land Monitoring Services provide a common framework for a frequently updated monitoring system of environmental change at European scale), and forest yields (Copernicus contribution, in this case, is the percentage of Copernicus data used to develop clear cut map replacing commercial data), and the cost reduction in monitoring compliance to the EU policies (EO data is clearly the optimal tool to develop clear-cut maps, which will enable the authorities to enforce the rules in the forestry sector). In 2018, it represented approximately **EUR 53.3** M as a conservative value.

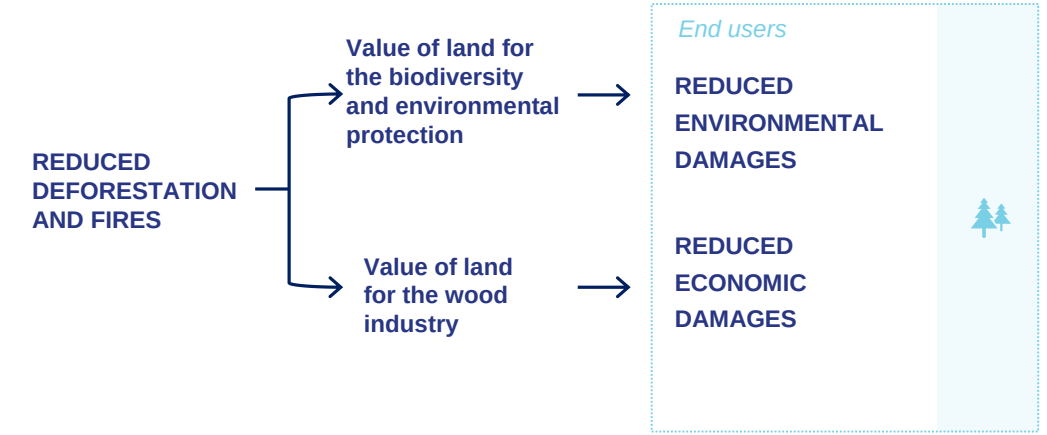
Economic benefits of Copernicus through its contribution to Forestry

(Source: PwC)



Economic impacts





FORESTRY

COPERNICUS BENEFITS FOR FORESTRY

Social impacts

Copernicus plays a significant role in forest preservation and monitors forests in urban areas through programs such as the REDD+ initiative of the UN or the High Resolution Layer (for urban green areas monitoring).

Forests, urban forests and green areas can be incorporated into public health programs and policies to promote mental and physical health and help in putting a halt to morbidity and mortality by producing relaxation, alleviating stress, encouraging social cohesion and physical activity, and reducing exposure to atmospheric pollution, noise and excessive heat.

Another social benefits relies on the concept of Forest farming, i.e. cultivation of high-value specialty crops under a forest canopy that is intentionally modified or maintained to provide shade levels and a habitat to favor growth and enhance production levels. This is of high importance for populations in developing countries living in the neighborhood of rainforests.

			End users
GREEN AREAS MAPPING	Identification of forests, urban forests and green areas	Promotion of healthcare programs related to green areas	**ENHANCED QUALITY OF LIFE FOR PEOPLE**
FOREST COMPOSITION ASSESSMENT	Identification of potential forest areas to initiate forest farming	Rising populations' awareness on forest resources	**SUSTAINABLE RESOURCES EXPLOITATION**

FORESTRY

COPERNICUS BENEFITS FOR FORESTRY

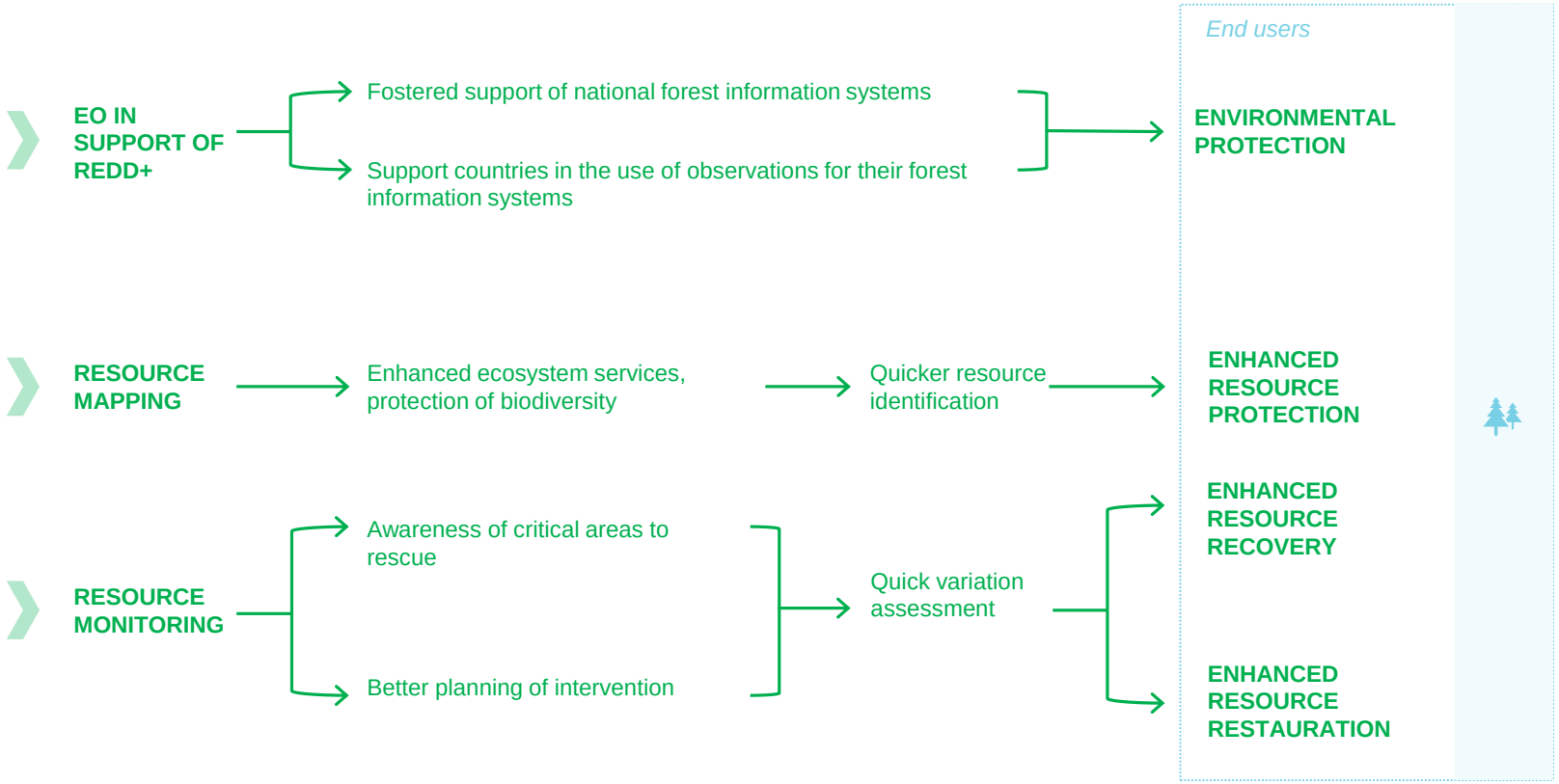
Environmental impact

The REDD+ initiative of the UN Framework Convention on Climate Change (UNFCCC) encourages forest maintenance and preservation for climate mitigation.

In support of REDD+, the Global Forest Observations Initiative (GFOI) strives to ensure ready available national coverage of EO data and to provide countries with Methods and Guidance Documentation (MGD) that will facilitate reporting consistent with the relevant IPCC Good Practice Guidelines.

Forests host a significant proportion of Europe's rich biodiversity, and they provide very important benefits to society and the economy via the provision of ecosystem services (soils erosion protection, watershed regulation, climate regulation, carbon storage and water/air purification). Hence preserving forest ecosystems and green infrastructure is crucial for countries' well-being.

Copernicus products are enhancing a growing set of different analyses previously performed at lower resolution (Landsat). They enhance assessment of the conservation status by covering more areas, and analysis of, and by early change detection, thus helping to ensure the sustainability of the ecosystem and the compliance to global directives.



FORESTRY / CASE STUDY

Starling-VERIFY YOUR FOREST IMPACT
Airbus Defence & Space

AIRBUS

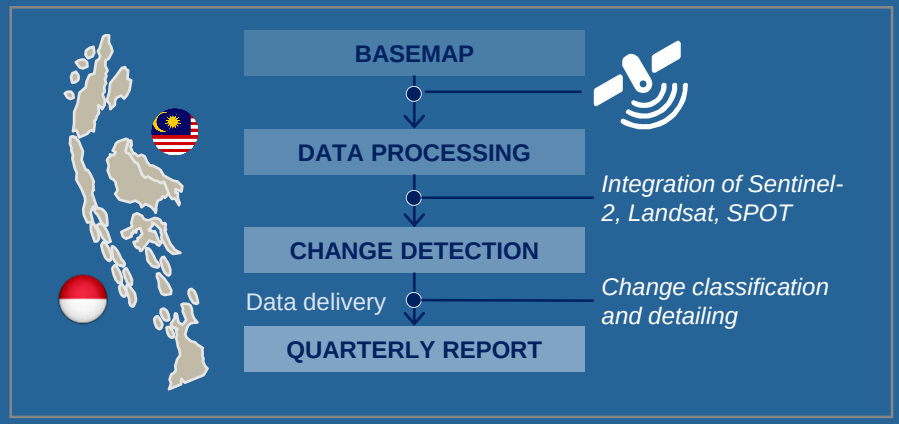
STARLING SUPPORT TO "NO DEFORESTATION" COMMITTMENT

AIRBUS DS TOOL FOR FOREST MONITORING

Starling is a global forest monitoring service that uses satellite imagery, combining the expertise of both partners in remote sensing, massive image processing, food supply chain management and forest conservation.

The Starling production process began with the creation of a reference Land Use map or 'basemap', for the target region; it then systematically processes satellite imagery acquired during the year, from multiple sources, in order to detect changes made to the forest cover as small as 0.5 ha. This information is consolidated into quarterly monitoring reports, which are delivered to the users.

Since June 2017, the Starling service aims to provide a reliable and near real-time monitoring tool in Indonesia and Malaysia, (where development of palm oil plantations is a strong driver of tropical deforestation), in order to help companies all across the food supply chain to achieve their 'no deforestation' commitment.



Starling workflow

COPERNICUS CONTRIBUTION TO HALT DEFORESTATION

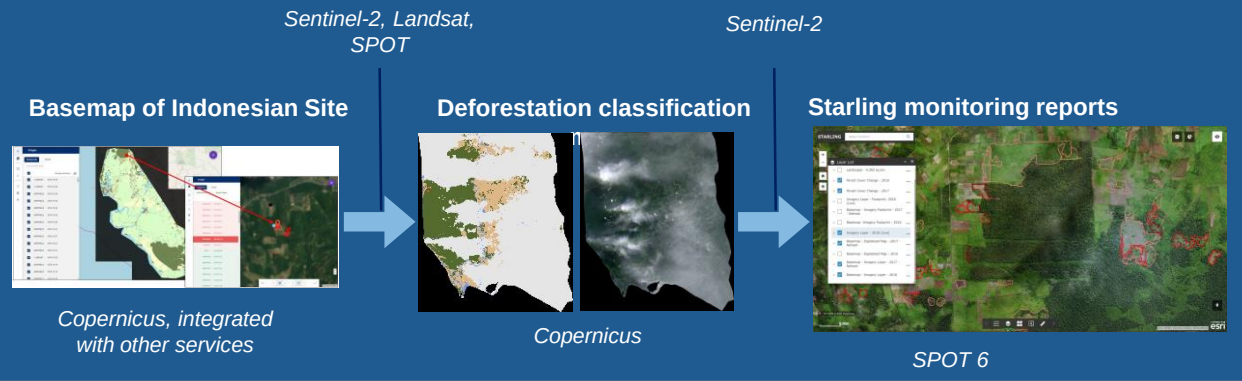
CONTRIBUTION TO MONITORING DEFORESTATION IN INDONESIA AND MALAYSIA

In 15 months of operation, Starling has already processed thousands of Copernicus Sentinel-2 and Landsat-8 images. For the Sumatra Island alone (about 500,000 km2), 3500 Copernicus Sentinel-2 scenes and 900 Landsat scenes were exploited.

The capabilities of the Sentinel-2 mission of the European Union's Copernicus programme, with its twin satellites and a combined imaging swath of 580 km (compared to 185 km for Landsat), are key in this process.

Despite the challenging atmospheric conditions, with dominant cloud flocks, 98% of scenes can be observed cloud-free more than four times a year.

Elise Boisliveau, Starling production operator, confirms, "Copernicus Sentinel-2 and the Cloud technology enabled us to enter a new era. Thanks to the Cloud, the production has never been so easy. A user-friendly interface helps us monitor the production chain and perform the final quality control before releasing the products."



The Basemap was produced using Copernicus Sentinel-2, Landsat, and SPOT images, at 20m resolution. Deforestation classification map is based on Copernicus Sentinel-2 image. Starling monitoring reports displayed on SPOT-6 identifies deforested areas from the last four quarterly reports. (Source: Airbus, ESA)

FORESTRY / CASE STUDY

PIN 11e EDF E-AD DRC program land use indicator for ecological integrity

CIFOR

CIFOR INDICATOR AREAS OF INTERVENTION

CIFOR PROGRAMMES FOR FOREST PRESERVATION AND MANAGEMENT IN CONGO

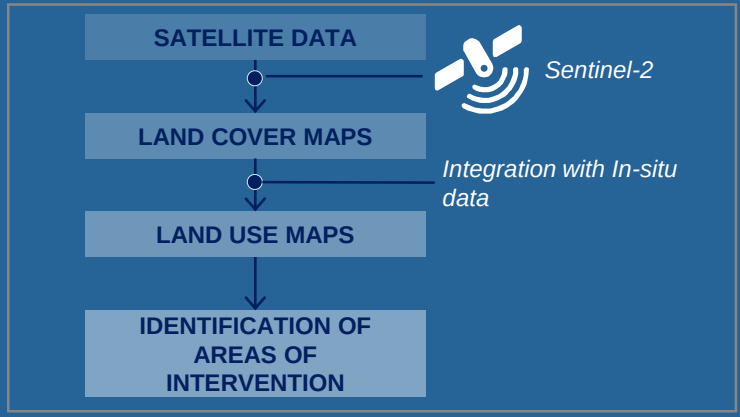
In the context of biosphere reserves, the relationship between natural landscape conservation and agriculture is not so dichotomous. The PIN 11e EDF E-AD DRC program will therefore seek to strike a balance between the strict conservation of protected areas and its natural habitats and the better management of forest and agricultural landscapes on the outskirts of parks for the benefit of local people.

The indicator will be built on the basis of analyses provided by the JRC Copernicus program.

To benefit from this support, it is necessary to identify the zones and the surface to be analysed and to request inclusion of this zone in the capture and analysis of images protocol. An analysis of past dynamics (2010-2015) is also possible. The areas included in the program are:

- The Biosphere reserve of Yagambi;
- Salonga, Virunga, Garamba and l'Upemba National parks

The Salonga and Virunga NPs were included in the first contract starting in 2017. The other protected areas will be in the second contract starting in 2018.



Project workflow
(Source: CIFOR)

COPERNICUS PRODUCTS AND POTENTIAL FINAL OUTPUT

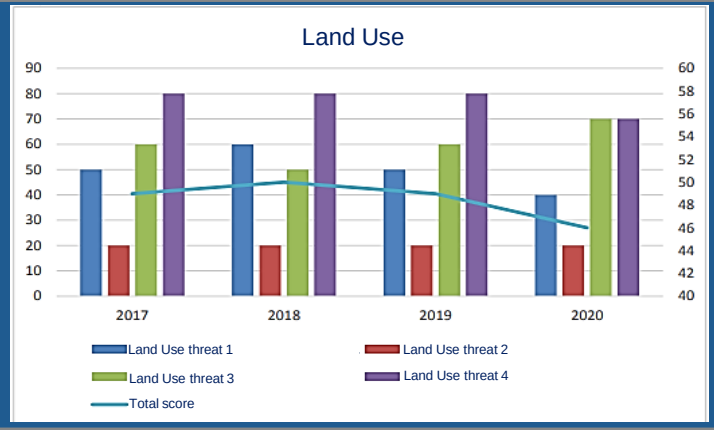
CONTRIBUTION TO SUSTAINABLE FOREST MANAGEMENT THROUGH A VARIETY OF PRODUCTS

Several products can be provided by the Copernicus programme:

- Raster maps: in the form of pixels (identical size) having been broken down individually in one of the identified land-use categories;
- Vector maps: identical pixels will have been merged to form homogeneous polygons representing a type of land use;
- Landscape metrics and land use variation.

Each product makes it possible to express the evolution dynamics of land use change:

- Raster product: allows user to count the pixels for each category and compare between different images, see the quantitative evolution of land uses;
- Vector product: calculates the expansion areas of different land uses. The comparison of different surfaces gives a land use transformation index. Vector representation also makes it easier to represent conflict zones, uncontrolled extensions, or ecological restoration;
- Landscape metrics provide commonly-used and standardized indices to track the land dynamics of a territory.



Most effective visualisation of presentation
(Source: CIFOR)

URBAN MONITORING

KEY TAKEAWAYS

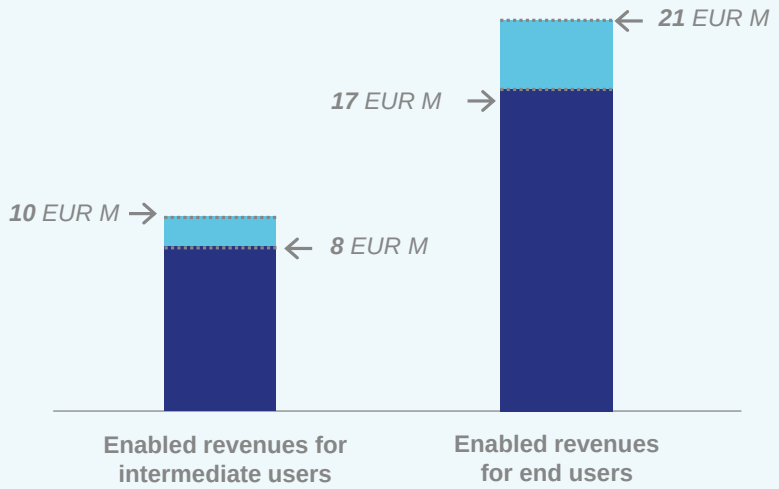
- Intermediate users are mainly Value Added Service companies, startups and SMEs.
- End users are predominantly local, regional and national authorities.
- Sentinel-1 radar data is used for change detection and the development of 3D models.
- Sentinel-2 optical data provides relevant data for urban growth monitoring thanks to its high spatial resolution optical imagery.
- A number of global urban datasets derived from EO have been developed, such as the Global Human Settlement Layer (GHSL) and the World Settlement Footprint 2015 (WSF2015).

COPERNICUS APPLICATIONS

- Indicators to help cities monitor their progress in implementing conservation efforts and their success in halting the loss of urban biodiversity
- Methods to map and assess urban adaptation to climate change, environmental/socio-economical characterization and map green urban areas in and around cities
- Maps of green urban areas in and around cities' ecosystems
- Inventories of land cover historical images to highlight changes in city boundaries and peripheral areas in order to monitor urban sprawl
- Measurement of ground displacements before and after earthquakes in urban areas using multi-temporal InSAR techniques to identify seismic precursor signals.

Copernicus economic impact (2018)

(Source: PwC)



KEY COPERNICUS PRODUCTS

- Copernicus Land Monitoring Service
- The CORINE Land Cover inventory, which includes data related to urban fabric

URBAN MONITORING

A KEY TO CHARACTERIZE THE IMPACT OF HUMAN SETTLEMENT

With large concentrations of people, property and wealth, cities are expanding as never before, with half of the global population now living in urban areas (see graph). The world is urbanizing at an unprecedented rate: more than 50% of the world's population live in cities, which will grow to 66% by 2050, out of a total of 9.8 billion people. Alongside the multitude of opportunities that rapidly expanding cities face, there are also a number of challenges. Economic disruptions, social strife, and environmental disasters are increasingly occurring within cities which are expanding boundaries.

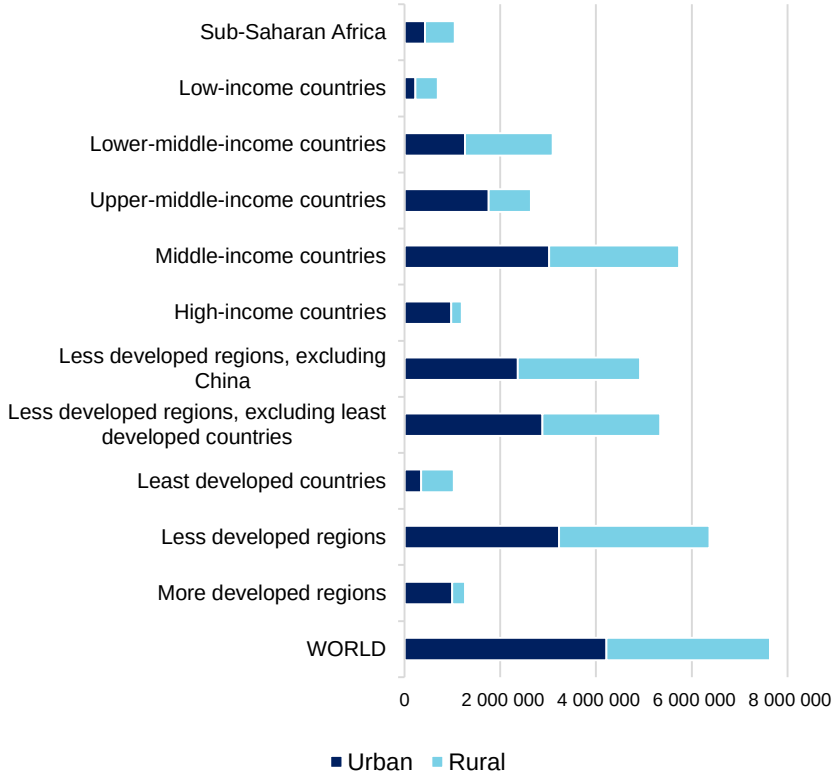
The world's urban population is growing four times faster than its rural population. 90% of this growth is occurring in developing regions, and Africa currently has the fastest rate of urban growth, at more than 5% per year.

Such occurrences place huge pressure on often limited infrastructure and public services; according to OECD, governments worldwide will have to invest approximately $71 trillion by 2030 to provide adequate overall global infrastructure for electricity, road and rail transport, telecommunications, and water, which is 3.5% of the world's annual GDP from 2007 to 2030.

Sources: UN

Population of Urban and Rural Areas at Mid-Year (000), 2018

(Source: UN, "World Urbanization Prospects", 2018)



Urban expansion definitely needs to be monitored to ensure it proceeds on a sustainable basis, does not impair or overexploit environmental resources, nor worsen the quality and life and safety of urban population. Thus, the ever growing area of cities can make urban monitoring incredibly difficult to achieve.

Earth Observation, in this sense, represents a key tool in at least two subsets of the whole framework of activities and markets which are nested under the label of urbanization: urban planning and urban risk management.

Urban planning is a process concerned with the development and design of land use and the construction environment, including air, water, and infrastructures, such as transportation, communications, distribution networks and the provision of municipal services to residents and visitors. Urban planners work with the cognate fields of architecture, landscape architecture, civil engineering, and public administration to achieve strategic, policy and sustainability goals.

Risk assessment is a methodology aimed at determining the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat, or harm, to people, property, livelihoods in the urban environment. Results from the risk assessment should enable action and form the foundation for planning and implementing disaster risk reduction measures.

URBAN MONITORING

EO SUPPORTS URBAN AUTHORITIES THROUGH 2 TYPES OF ACTIVITIES

Urban Planning

A number of global urban datasets derived from EO have been developed, such as the Global Human Settlement Layer (GHSL) and the World Settlement Footprint 2015 (WSF2015).

The former provides global spatial information about human settlements over time, including built-up area, population density, and settlement maps.

The latter is the first global layer generated at 10 meters resolution based on both optical and radar imagery. It will allow the precise mapping of human settlements in urban, suburban environment.

The Copernicus Land Monitoring Service (CLMS) provides products and data such as HR and VHR satellite imagery, Land Cover, High Resolution Layers, and Land Surface Temperature.

Urban risk management

Urban Heat Islands occur when air temperatures in urban areas are higher than in surrounding rural areas. They are caused by the density of buildings, the absence of green spaces and the accumulation of anthropogenic heat. EO products provide data enabling the analysis of the factors listed above, a better understanding of Urban Heat Islands and therefore ways to design smarter cities which avoid the occurrence of this phenomenon.

Satellite imagery can also support traffic management systems in increasing the level of road safety in urban areas by providing additional data on areas and road segments that are at risk for both road users and pedestrians.

Lastly EO can measure ground displacements before and after urban earthquakes using multi-temporal InSAR techniques to identify seismic precursor signals. Satellite imagery can provide estimates of the ground deformation and its temporal evolution by exploiting large datasets of SAR imagery that spans 72 months before and 16 months after the main shock.

WHY EARTH OBSERVATION?	APPLICATIONS	BENEFITS	END USERS
URBAN PLANNING	• Spatial information about human settlements over time • Land cover inventories on urban fabric • Land cover and land use information for urban areas	• Responsive decision making on planning and environmental issues • Enhanced resource management, allocation and urban sustainability	• Landscape architects • Civil engineers/architects • Public Administration • Government and institutions • Commercial users
URBAN RISK MANAGEMENT	• Information on road safety in specific road segments • Estimates on ground deformation to identify early earthquake signals • Identifications of factors determining Urban Heat Areas	• Early warning • Anticipate threats to urban population and environment • Reduction of damages • Reduction to mortality rates linked to urban threats	• Architects • Landscape architects • Civil engineers • Public Administration

URBAN MONITORING

DRIVERS AND CHALLENGES FOR THE ADOPTION OF EO FOR URBAN MONITORING

Thanks to EO, researchers and decision makers no longer need to rely on classification products that are only relevant for specific locations, points in time or according to a specific definition. With basic off-the-shelf supervised image classification algorithms, publicly-available EO datasets and cloud-based computation platforms, extraction of meaningful information about Earth across space and time becomes easier and more accessible.

The growth and densification of urban areas pose social, economic and environmental challenges as the health, comfort and consumption needs of city dwellers must be addressed, while environmental damages caused by human activities and excessive resource consumption must be avoided. Sustainable urban development can be reached by making cities smarter and by integrating the usage of information and communication technology into the decision-making process of urban planning and development. The support of EO and remote sensing technologies can facilitate access to the necessary data enabling the analysis of urban drivers and the monitoring of the urban environment.

DRIVER 1

Need for improvement in resource management, resource allocation, and sustainability; EO can characterize urban environments to a degree of accuracy simply not attainable only with in-situ data.

DRIVER 2

Growing urban areas demand more accurate and up-to date monitoring in order to spot problem areas and anticipate threats to urban population and environment

CHALLENGE 1

Including and combining the relevant existing information from EO urban data, in order to obtain multiscale inputs

CHALLENGE 2

Mapping land cover at a national or regional scale is challenging due to specific characteristics of the urban environment

CHALLENGE 3

Lack of historical reference data and other computational constraints

The process of using EO data to characterize urban areas cannot avoid the fact that more and more data inputs on urban environments is being collected and stored. Combining the relevant existing information with satellite imagery data is a significant challenge in building multiscale models that are vital to construct global models.

Secondly, mapping land cover on a national or regional scale is a challenge due to the lack of high-resolution global imagery, the spectral heterogeneity and complexity of land, and the small and fragmented spatial configuration which characterizes many cities.

Lastly, clear issues are posed by the lack of historical reference data and other computational constraints. While these studies map the land cover and land use with high precision in local settings, their transferability to other regions is unknown and potentially problematic. In the last decade, several classification products have been developed to map urban land and the human footprint globally. While these and other datasets provide essential information about urbanization, they typically characterize urbanization in a specific point in time. Promoting sustainable development requires monitoring urbanization in high frequency without being constrained by the specific characteristics of existing products.

URBAN MONITORING

THE VALUE CHAIN OF EO DATA FOR URBAN MONITORING

ACQUIRING EO DATA

Overall data needs

- Roughly 90% of satellite data comes from commercial satellites to monitor land use in urban areas.
- Remote data, which records the physical characteristics of Earth to measure the spatial-physical characteristics of urban environments.
- Different sensors (radar sensors vs multispectral high-res) record distinct urban characteristics (brightness, temperature, height, density, texture).
- Integration with airborne and ground data needed for specific features (i.e. building characteristics).
- Spatial resolution is a driving factor in monitoring fragmented and heterogeneous urban areas.
- Thermal bands are inputs for classification to increase the accuracy of detection of industrial and dense urban areas (typically warmer).

PROCESSING NEEDS AND CAPABILITIES

Data format and in-house capabilities

Private Users

- Off-the-shelf supervised image classification algorithms
- Cloud computing platforms, such as Google Earth Engine for land use/cover mapping by integrating publicly available data and geographically specific reference data
- Data processing, data analysis and data sale
- Storage of historical data to build long term database (>10 years)

Institutional Users

- Publicly available EO datasets, integrated with statistical data collected by local authorities and aerial data
- Storage of historical data to build long term database (>10 years)

USERS & NEEDS

Non exhaustive list

- Low-cost tools taking advantage of publicly available EO data and cloud-based computational platforms to map urban land use and cover
- EO data classification tools using administrative vector data as reference for supervised image classification
- Models assessing the association between the extent of built-up land cover and the distribution of the population and economic activity
- Estimates of the ground deformation and its temporal evolution by exploiting large datasets of SAR imagery

URBAN MONITORING

COPERNICUS DATA MAKES A DIFFERENCE IN TERMS OF UPDATE AND RESOLUTION, BUT FACES THE CHALLENGE OF INTERNATIONAL AWARENESS AND DATA CONTINUITY

Sentinel-1 radar data is used for change detection and the development of 3D models. It provides all-weather imagery with a rapid revisit period (6 days), a wide area coverage and a millimeter accuracy. Sentinel-1 data can also be used for road and other transportation route mapping. Sentinel-2 data provides relevant data for urban growth monitoring thanks to its high spatial resolution optical imagery.

The open data policy allows for initial experimental projects before developing deeper EO skills. This is of particular importance for governmental institution relying on public spending money, or even SMEs with limited financial capacity.

The main weakness of Copernicus for urban monitoring application lies in the domain of land use, in which commercial satellites imagery is still dominant due to the need of high resolution. Uptakes in this domain are foreseen at a very experimental level, and will be detailed in the case study.

Copernicus strengths	Copernicus weaknesses
Sentinel-1 is well suited to disseminate radar images covering large areas and enabling temporal comparison. Its spatial resolution is a strong differentiator for monitoring fragmented urban ecosystems.	***IMPROVEMENT OF SPATIAL RESOLUTION***
The emergence of advanced algorithms to extract data from satellite imagery, or greater computational power open new opportunities for urban remote sensing applications. Technological progress opens new opportunities for Copernicus' Urban Monitoring application.	***TECHNOLOGICAL PROGRESS SUCH AS ADVANCED ALGORITHMS***
The implementation of the DIAS made it much easier to access and process Sentinel data, and enhanced Copernicus competitiveness with respect to other EO international programs such as Landsat.	***COPERNICUS DIAS IS FACILITATING DATA ACCESS FOR INTERMEDIATE USERS***
	LAND USE APPLICATIONS LARGELY DEPEND ON COMMERCIAL SATELLITES
	To monitor land use in urban areas, a vast majority of satellite data comes from commercial satellites. Users do not foresee a significant uptake possibility, unless the resolution is further enhanced

URBAN MONITORING

COPERNICUS BENEFITS FOR URBAN MONITORING

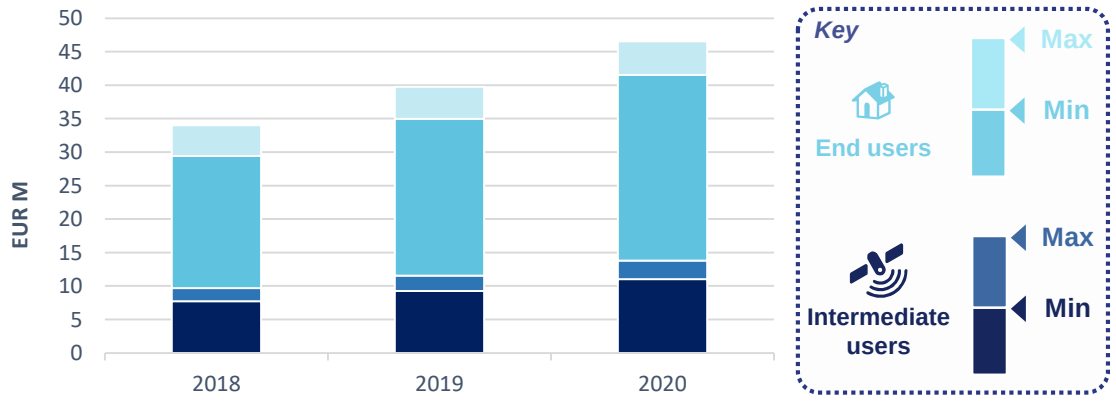
The revenues of EO intermediate users (i.e. downstream service providers) attributable to urban monitoring are estimated to have amounted to some EUR 77 million in 2018. According to the stakeholders interviewed, Copernicus generates at minimum 10% of their revenues, leading to a conservative estimate of the Copernicus-enabled revenues of EUR 8 million in 2018 for downstream providers. A more optimistic estimate based on the Geo-Information Systems (GIS) market for urban monitoring leads to around EUR 10 million Copernicus-enabled revenue.

In addition, according to market studies, Smart Cities produces a 25% Return on Investment (ROI). It is assumed that EO contributes positively to the development of smart cities, and generate a comparable ROI for investors, the estimated benefit for end users (i.e. the municipalities acquiring intermediate users products and services) would represent between EUR 10 and 12 million in 2018.

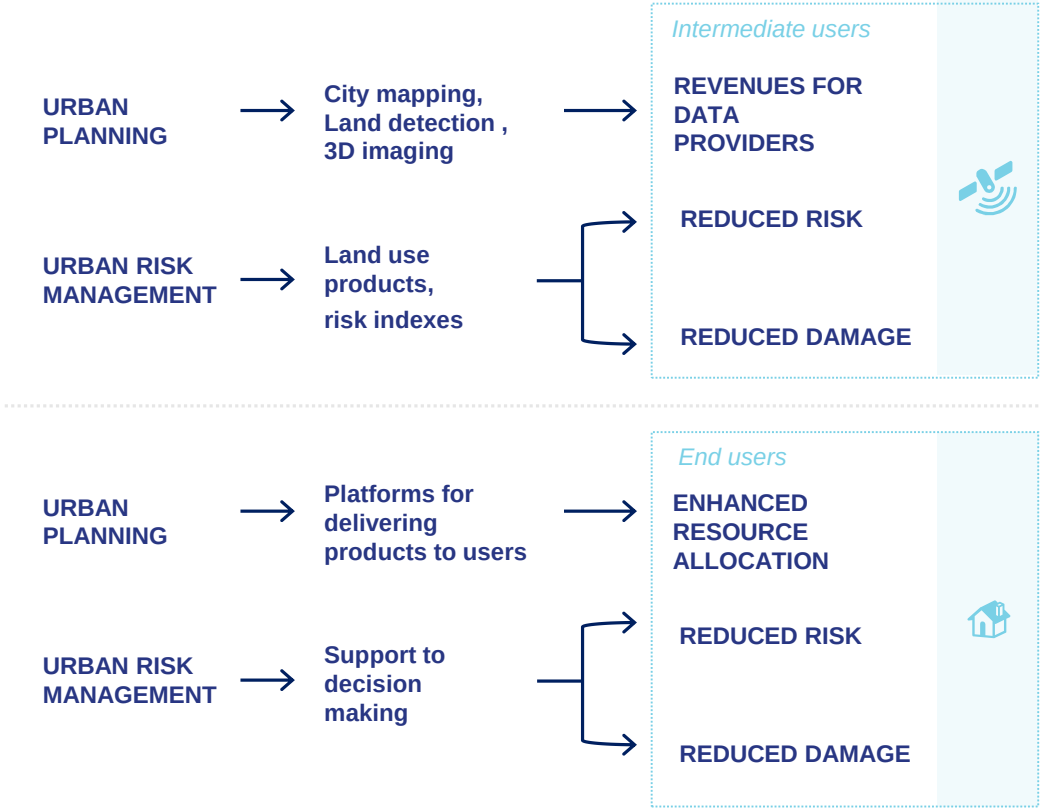
The EO market for Urban Monitoring is expected to grow by 17% every year from 2015 to 2020. Assuming a constant share of Copernicus-enabled revenue (10%), a conservative estimate of the expected value of Copernicus data by 2020 is around EUR 35 million. This includes EUR 11 million for intermediate users and EUR 24 million of end user benefits.

Economic benefits of Copernicus through its contribution to urban monitoring

(Source: PwC)



Economic impacts



URBAN MONITORING

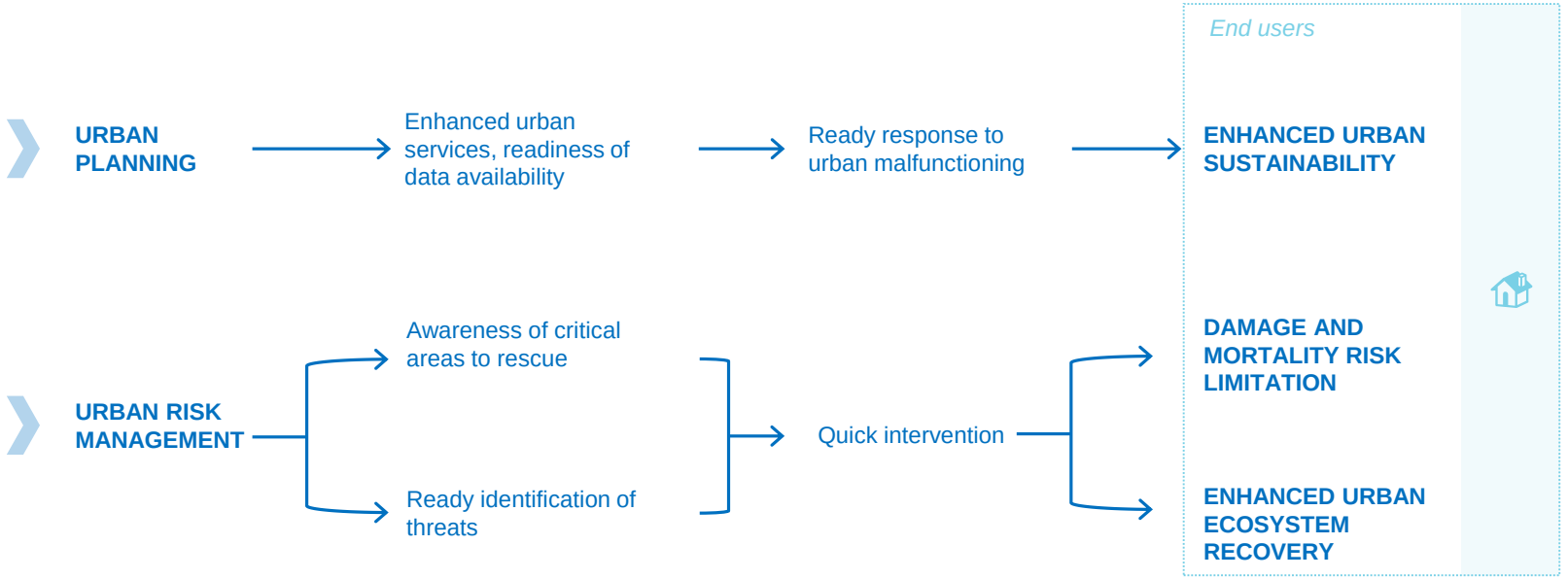
COPERNICUS BENEFITS FOR URBAN MONITORING

Social impacts

Global sustainability frameworks objectives involve the enhancement, by 2030, of inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries. Achieving such target requires supporting all countries in monitoring their urban extent and delineating precisely the built-up footprint of their cities.

Automatic urban extent mapping is based on a combination of temporal statistics of C-band SAR backscattering data from the Sentinel-1 and Envisat satellites and multi-spectral optical data from Landsat and Sentinel-2.

Such a global urban mapping service can help countries and cities without technical and financial resources to have a regular monitoring of their urban development and to characterize their human settlements – even in remote regions where no other sources of information are available.



URBAN MONITORING

COPERNICUS BENEFITS FOR URBAN MONITORING

Environmental impact

Sentinel data can be used to identify and track urban sprawl. Urban sprawl causes extensive environmental damages, mainly due to increased traffic and energy consumption, as well as greenhouse gas emissions, noise pollution, poor air quality, and so-called Urban Heath Islands. Global gradual – and often unnoticed – urban sprawl has a direct negative impact on ecosystems, human health and quality of life.

The Copernicus Land Monitoring Service as well as the Urban Atlas provide land use information over Europe's main urban areas, and are employed as a tool to analyze environmental trends.

URBAN SPRAWL TRACKING → Identification of prominent environmental issues → Implementation of policies to protect urban ecosystem → **REDUCED ENVIRONMENTAL PRESSURE**

End users

Strategic impacts

The world has its first stand-alone Urban Sustainable Development Goal (USDG) as part of the post 2015 United Nations Sustainable Development Agenda.

Poor data, lack of strong city data collection capacities and localization are challenges for using the USDG as a tool to improve urban areas.

USDG encourages reforms if anchored in local institutions and initiatives informed by open, inclusive data collection and monitoring.

Copernicus' products related to urban monitoring are valuable tools in improving the sustainability of urban areas. Copernicus' international competitive advantage on these specially designed products and its more frequent updating as compared to traditional methods (survey based ground and aerial data) and to Landsat, are crucial in determining the characteristic of fragmented city landscapes.

ENHANCE PUBLIC AUTHORITIES WORKFLOW AND DECISION MAKING PROCESS BY INTEGRATING SENTINEL PRODUCTS AND DATA

INCREASE PRESENCE OF EUROPE ON GLOBAL SUSTAINABILITY FRAMEWORK

URBAN MONITORING/ CASE STUDY

Innovators EO4CBI space4environment

SPACE4ENVIRONMENT IN SUPPORT OF CITY BIODIVERSITY INDEX

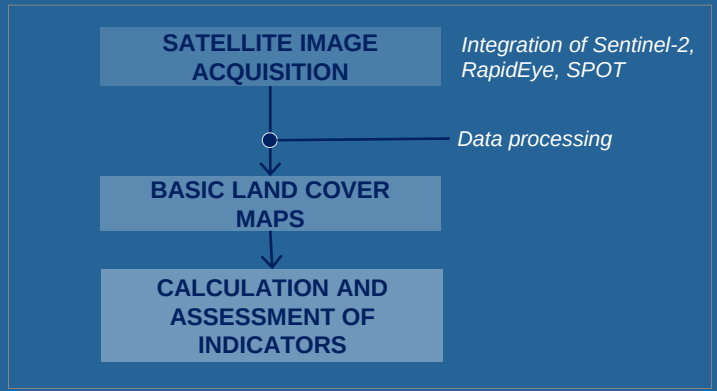
EO4CBI AS A TOOL FOR THE IDENTIFICATION AND ASSESSMENT OF URBAN GREEN AREAS

Space4environment is a company founded in 2007, and who is using space data to provide space for the environment. It developed the EO4CBI tool to monitor indicators in the CBI.

The CBI index is conceived as a self-assessment tool to evaluate the state of biodiversity in cities. It includes 23 indicators, 4 of which (1,2,11,12) are assessable through EO data.

The EO4CBI service comprises land cover maps for one reference year (mostly 2015 or 2016) derived from high resolution EO data. It includes:

- 5 major classes such as agriculture; buildings, roads, paved grounds, mining areas; forest; meadows, grasses and pastures; and water.
- Vegetated and not vegetated areas layer
- Candidate natural areas levels 1 and 2 layers



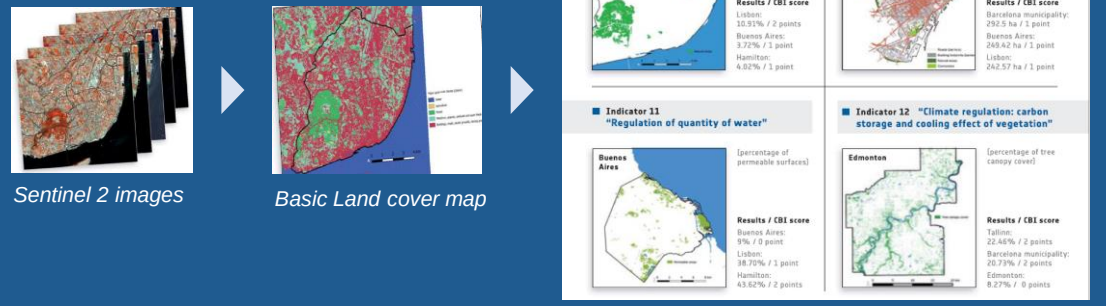
EO4CBI workflow
(Source: Space4environment)

EO4CBI APPLICATION

EO DATA IN SUPPORT OF CBI INDICATORS

The tool relied on EO data from Sentinel-2, RapidEye, and SPOT. It has been used and tested in 10 cities around the world, across 2014 to 2016.

- Barcelona (Spain)
- Tallinn (Estonia)
- Edmonton (Canada)
- Buenos Aires (Argentina)
- Hamilton (New Zealand)
- Addis Ababa (Ethiopia)
- Lisbon (Portugal)
- Luxembourg (Luxembourg)
- Portland (USA)
- Stockholm (Sweden)



Example of the Indicators
(Source: Space4environment)

URBAN MONITORING / CASE STUDY

Continuous, semi-automatic monitoring of ground deformation
TRE Altamira

TRE ALTAMIRA

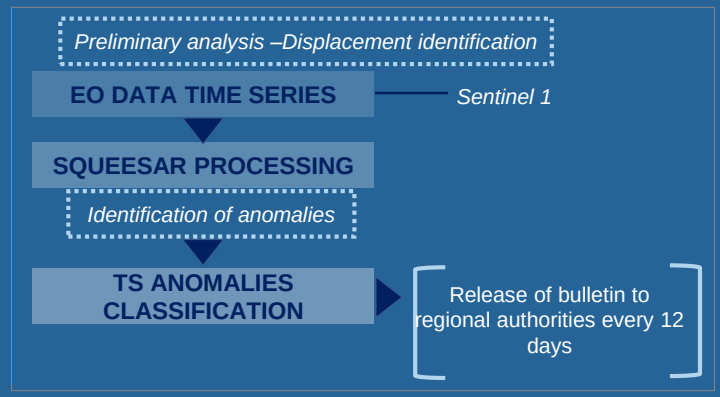
TRE-A PROCESSING CHAIN OVERVIEW AND WORKFLOW

CONTRIBUTION OF TRE ON DISPLACEMENTS IN TUSCANY (2016)

TRE Altamira (TRE-A) engineers set up a systematic processing chain of Sentinel-1 acquisitions to create continuously updated ground deformation data, marking the transition from static satellite analyses, based archive images, to dynamic monitoring of ground deformation.

Displacement time series, systematically updated with the most recent available Sentinel-1 acquisition, are analyzed to identify anomalous points (i.e., points where a change in the dynamic of motion is occurring).

The presence of a cluster of persistent anomalies affecting elements at risk determines a significant level of risk, with the necessity of further analysis. In an article published by Nature Scientific Reports, TRE-A has shown that the Sentinel-1 constellation can be used for continuous and systematic tracking of ground deformation phenomena at the regional scale. This case study has been applied in Tuscany (Italy), starting from September 2016.



TRE-A workflow for monitoring ground deformation
(Source: TRE Altamira)

TRE-A PROCESSING CHAIN DETAILED APPLICATION AND RESULTS

SQUEE-SAR TECHNOLOGY APPLIED TO ANOMALIES CLASSIFICATION

For the initial implementation of the continuous monitoring of Tuscany, the entire ESA images archive of Sentinel-1 was acquired and then processed by means of the SqueeSAR technique. SqueeSAR analysis is designed to identify a sparse grid of measurement points for which it is possible to estimate, with millimetre accuracy the mean yearly velocity (in mm/yr) and displacement time series along the satellite line of sight.

Whenever a time series (TS) shows non-linear behaviour, a breaking point is identified and defined. The average deformation rates before and after the breaking point are calculated: whenever their difference is higher than a certain threshold, points are labelled as anomalous points.

Information on persistent anomalies affecting elements at risk is routinely delivered every 12 days to regional authorities in charge of the geo-hazard management practices, in the form of monitoring bulletins. All delivered data can be accessed via a web-service tool.

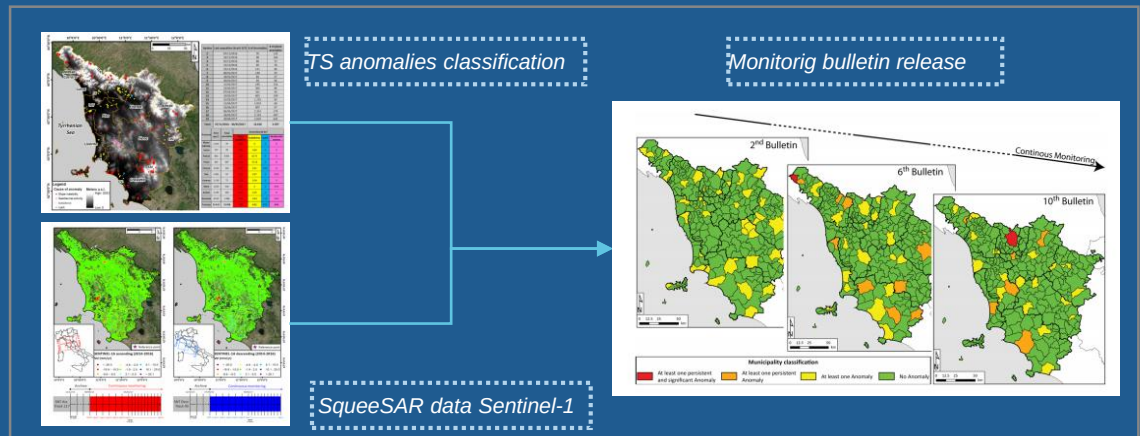


Illustration of the process from data acquisition, time series analysis and bulletin delivery
(Source: TRE Altamira)

URBAN MONITORING / CASE STUDY

I.MODI, Structural Services For Structural Monitoring

Survey Lab

Survey Lab

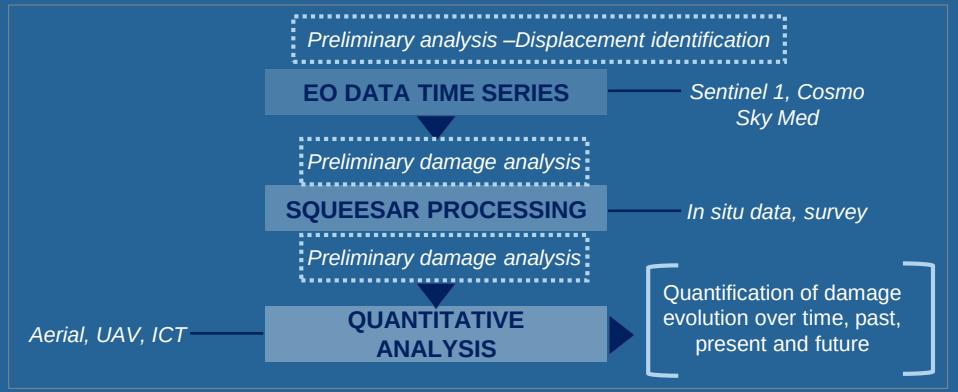
I.MODI OBJECTIVES OVERVIEW AND WORKFLOW

I.MODI, A TOOL TO MONITOR STRUCTURAL DISPLACEMENTS IN URBAN AREAS

The I.MODI project (Implemented MOnitoring system for structural DIsplacement) aims to exploit the business opportunity generated by the increasing need to have a systematic monitoring system able to detect the stability of buildings in large urban areas and to control critical civil infrastructures threatened by natural and man-made processes.

It focuses on the exploitation of Earth Observation data to create an added value service where the integration between EO technologies, aerial, ground based data and ICT represent the core of the system and becomes easily accessible from users. It focuses on 3 major classes: buildings, roads and dykes.

A customized web service will be developed to fully integrate EO data into standard procedures based on in-situ technologies (GNSS and ground surveys). EO and non-EO inputs will be linked and managed using ICT technology to provide a value-added service to end users (companies, professional operators and private citizens). Large-scale testing and validation activities will be conducted in collaboration with end users, including public authorities and private companies.



I.MODI workflow for Structural Monitoring

I.MODI FIELD OF APPLICATION

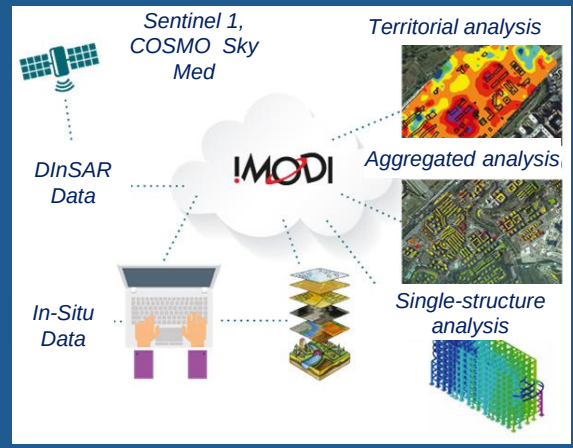
I.MODI'S CUSTOMIZED WEB SERVICE

Current satellite missions collect data with high frequency, even every 15 days. Past missions undertook a historical analysis using archived data, which from 1992 to now cover the entire Earth.

- Wide Area Analysis
- Overview of the magnitude and distribution of the subsidence process overlapped to surface and subsoil interferences
- Buildings Classification

A displacement indicator, derived from the magnitude of the settlements, is associated to each structure providing a ranking to be used for prioritizing further actions.

Each map is associated with an information form that summarizes the main conclusion of the interpretation analysis.



Rationale of I.MODI customized web service (Source: Survey Lab)

COASTAL AND MARINE EXPLOITATION AND PRESERVATION

KEY TAKEAWAYS

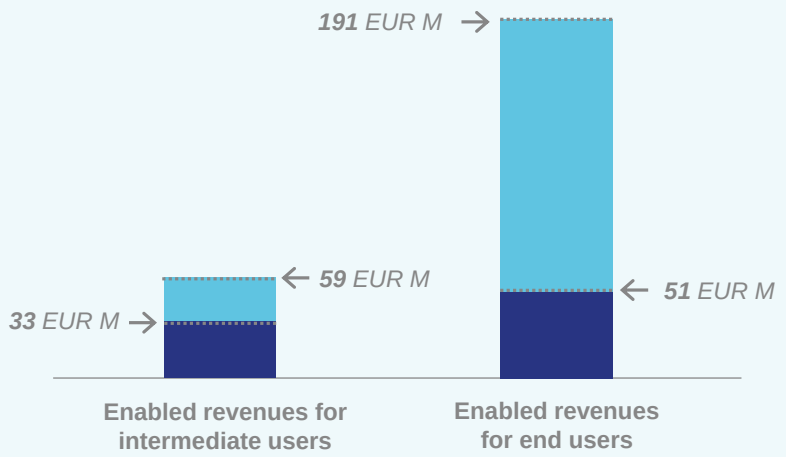
- This value chain is focused on several domains related to coastal and marine exploitation and preservation, such as fisheries, water quality, shipping and maritime transport.
- If final users remain mostly from the public sector, there is a strong uptake from the private sector as well as more and more public-private interactions on marine and maritime activities.
- Considering the current context of climate change, oceans and coastal areas are facing even more changing conditions than they are used to, which makes this domain in search of accurate data, both near-real time, forecasted and also long-term.
- The Copernicus Marine Environment Monitoring Service (CMEMS) counts more than 15,000 users today compared to 5,000 users two years ago.
- Sentinel-3 has been the main value-added in the recent product evolution of CMEMS.

COPERNICUS APPLICATIONS

- Mapping of fishing zones
- Forecasting algal blooms
- Better forecasting of new areas accessible due to ice melting
- Water depth, winds, waves and current monitoring for renewable energies and ship routing
- Forecasts of regional sea level rising and storm surges
- Monitoring and prevention of coastal erosion
- Supporting environmental regulations and Marine Protected Areas

Copernicus economic impact (2018)

(Source: PwC)



KEY COPERNICUS PRODUCTS

- Raw data: mostly Sentinel-3, complemented by Sentinel-1
- Products: CMEMS sea level, wave, currents, sea surface temperature and chlorophyll-A

COASTAL AND MARINE EXPLOITATION AND PRESERVATION

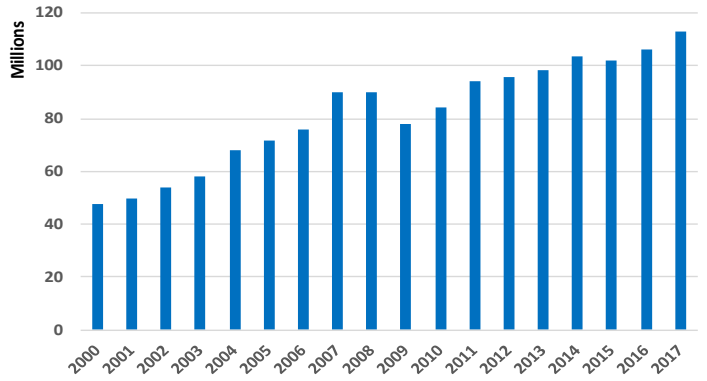
A WIDE VARIETY OF ACTIVITIES

The current assessment looks at the support a wide variety of marine and maritime applications can receive from the use of Earth Observation data and ocean modelling. More precisely, marine EO information can benefit maritime exploitation (with ship navigation, including in ice areas, fisheries management, ocean surveillance, development of marine renewable energies, etc.) and marine and littoral preservation (with protection of coastal areas, sustainable fishing, aquaculture, preservations of Marine Protected Areas (MPAs), water quality and biodiversity, respect of Marine Strategy Framework Directive (MFSD) and Common Fisheries Policy (CFP), monitoring of algal bloom, etc.).

These activities are broad and have a variety of different needs, hence require the use of different types of information. According to the European Association of Remote Sensing Companies (EARSC) 2017 industry survey, the proportion of revenues from products derived by the EO services sector for the ocean and marine thematic sector represented 20% of the sales mix, being the second most important sector after the land sector. This value has nevertheless decreased compared to 2012 when the ocean and marine sector represented about 27% of the revenues. This decrease is not due to a lack of interest from EO services product developers but rather from a growth of other domains (such as atmosphere and climate) for which EO offered less possibilities few years ago.

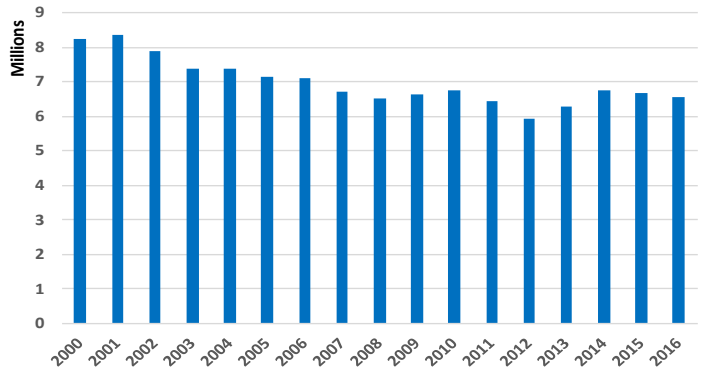
Container port traffic in the European Union (in million TEU)

(Source: World Bank)



Total fisheries production in the European Union (in metric tons)

(Source: World Bank)



More precisely, according to EARSC 2017 Industry Survey, the current EO product sales mix encompasses fisheries (about 4.4%), ships (about 4.1%), marine ecosystems (about 3.8%), coastal (3.4%), metocean and sea and icebergs (about 2%) and snow and ice (about 0.2%). As a result, these domains will be the ones where most focus is put within this report.

For instance, European citizens consumed about 25.1 kg of fish each year in 2015, for 24.7 kg in 2013, over 350,000 people have jobs related to fishing and fish processing and 6.4 million tonnes of fish are produced each year in Europe (making Europe the world's fourth largest fishing industry). This example emphasises that fisheries is an important market for which the availability of marine data, which can improve techniques, should generate benefits.

The second domain where most revenues from EO products are generated is ship traffic. Indeed, this is a growing domain as emphasised by the container port traffic, which moved from 102 M Twenty-foot Equivalent Unit (TEU) in 2015 to 113 M TEU in 2017 in the European Union. Similarly, EO data and marine information products that can support such activities have the possibility to generate major revenues and also significant cost-savings for the maritime industry.

Sources: European Commission

COASTAL AND MARINE EXPLOITATION AND PRESERVATION

OVERVIEW OF THE TYPE OF SUPPORT PROVIDED BY EO DATA TO MARINE ACTIVITIES

EO and modelled data can support most domains in the maritime and marine field

Information derived from altimetry and ocean colour are particularly key for all marine and maritime activities. For instance, ship routing can be optimised with the availability of measurements of sea surface water height, sea surface temperature and thus the development of current maps. Aquaculture requires EO data from water quality, chlorophyll-A content. Marine information results from the integration of many EO data sources including additional meteorological or climatological ones, and many in-situ sources in ocean models. If forecasts, long term reanalysis of the past, and projections for the future are provided, real-time observation provided by Synthetic Aperture Radar (SAR) imagery is the second top use for ice risk identification, ship traffic monitoring and marine safety. The interest in optical data, i.e. from Sentinel-2, is getting higher especially in coastal areas. As a result, most of the spectrum of EO data is used in this activity sector.

WHY EARTH OBSERVATION?	APPLICATIONS	BENEFITS	END USERS
FISHING & AQUACULTURE	• Mapping of fishing zones • Forecasting algal blooms • Fish stock numerical modelling • Fish farm site optimisation • Fishing site sitting	• Increase productivity • Limit the waste of contaminated shellfish • Facilitates the performance inventory of aquaculture • More efficient and eco-friendly fishing • Support sustainability of fish stocks	• Fish farmers and fishermen • Public authorities • Environmental agencies • citizens
SHIPPING & ICE NAVIGATION	• Supporting icebreakers in routing • Optimization of navigation routes (safe, comfortable, accessible) • Water depth, winds, waves and current forecasts • Drifts forecasts in case of loss at sea or icebergs	• Reduced cost of navigation • Decreased ecological impact • Reduced marine accidents • Avoid loss of goods • Save fuel	• Ship owners and operators • Citizens • Public authorities • Maritime rescue centers and ice breakers
WATER QUALITY & MARINE ECOSYSTEMS	• Impact of climate on marine ecosystems • Forecasting jellyfish blooms • Managing reef ecosystems • Bathing waters monitoring	• Improved protection of aquatic species and marine biodiversity • Reduced plastic waste in ocean • Increase tourism	• Citizens • Research centers • Environmental agencies • International organisations
COASTAL MANAGEMENT	• Monitoring shoreline and prevention of coastal erosion • Managing reef ecosystems • Renewable energies development and operations • Bathymetry and sedimentation	• Shoreline conservation • Improved coastal and marine spatial planning • Improve public health • Develop blue economy	• International organisations and NGOs • National agencies • Environmental agencies • Industry
POLICIES	• Mapping of Marine Protected Areas • Supporting energy package and development of renewables • Respect MFSD, CFP • Supporting environmental regulations • Supporting sustainable development goals	• Facilitate decision-making to protect marine ecosystems • Facilitate conducting extensive monitoring • Control the fisheries and aquaculture production • Improved public health • Support climate change; mitigation and resilience	• Public authorities • Citizens • Municipalities • European administrations

COASTAL AND MARINE EXPLOITATION AND PRESERVATION

DRIVERS AND CHALLENGES FOR THE UPTAKE OF EO DATA FOR MARINE ACTIVITIES

With EO data, a variety of products can be developed, whether maps (e.g. fishing zones maps), images of specific locations, or forecasts showing the evolution of a specific parameter (e.g. color of the ocean). Thanks to the combination of various data, the need of the user can be met. EO data integrated into marine information from models has the advantage to be available on a regular basis along long time periods both past and future, as well as in real time and short term forecasts.

Considering the rapidly changing environment in a global warming context, it is essential to build on this continuous observation to both understand the changing environment while preparing for resilience to climate change and to adapt to climate risks. Additionally, real-time observation supports day-to-day the development of the blue economy, seas and oceans conservation and use of ocean as places of freedom and leisure.
All is based on EO data continuously assimilated into models and helping to provide correct solutions to often complex problems.

Beyond this, environmental pressure has pushed public authorities to take measures towards a better preservation of Marine Protected Areas (MPAs) or biodiversity coupled with sustainable and eco-friendly exploitation of resources. Therefore, EU policies like the European Common Fisheries Policy (CFP) regulates fishing to avoid fish stocks collapsing, controlling and enforcing good practices. Thanks to EO data, such regulations can be easier respected by fishermen.

Ocean knowledge remains key for the future and the availability of continuous, consistent EO data on temperature, chlorophyll, depth of the sea, wind, etc. is essential.

DRIVER 1

Conditions in oceans and along the coasts can rapidly change and continuous monitoring is key

DRIVER 2

EO has the ability to contribute to most of the main maritime and marine activities, as different products can be derived (maps, images, forecasts, etc.)

DRIVER 3

In a context of global warming, the monitoring of ocean conditions (e.g. ice melting, biodiversity) is and is expected to remain a major stake

CHALLENGE 1

Long time series of EO data are necessary to combine various types of data and various scales into models

CHALLENGE 2

The sector is very diverse and products need to be tailored for specific applications

In such a vast environment as the ocean, developing performing models requires the ability to gather significant amounts of EO data of various types, in long time series. Both real-time analyses and forecasts may be needed or a combination of optical, altimetry and radar data can be necessary. This implies a certain level of expertise from users, who often are EO experts or oceanographers. A wider audience can still be reached but remains currently small in number, and who make direct use of value-added services developed by intermediate users into legacy systems.

Depending on the type of activities performed, products will strongly vary in their content. This implies that intermediate users often do not work cross-field but in niche markets, which have particular needs.

COASTAL AND MARINE EXPLOITATION AND PRESERVATION

THE VALUE CHAIN OF EO DATA FOR MARINE EXPLOITATION AND PRESERVATION

ACQUIRING EO DATA

Satellite data

- *Jason satellites (Sentinel-6 series - future)*
- ENVISAT
- NASA satellites (NOAA)
- Landsat
- Sentinel data
  - Sentinel-1 for shipping & sea ice navigation, and fishing & aquaculture
  - Sentinel-2 for water quality & marine ecosystems
  - Sentinel-3 for most application domains
- Data bought from private satellite operators (Cosmos, Radarsat, etc.)
- Copernicus products (CMEMS)
- Meteorological and hydrology data

In-situ data (in particular for environmental monitoring, aquaculture, water quality)

- Physical oceanography networks (ARGO, drifters, arctic buoys, gliders,…)
- Bathymetry
- Biogeochemistry sensors (BGC-ARGO)
- HF radars

PROCESSING NEEDS AND CAPABILITIES

Use of data processing platforms

- Copernicus marine service (CMEMS)
- Nephelae (IFREMER)
- SeaDataCloud
- EMODNET (DG MARE)

Use of in-house capabilities

- Combination of EO expertise and knowledge from specialised oceanographers or biologists
- Development of in-house capabilities on niche sectors with specific needs

Fusion of EO data with other types of data

- Market trends
- Historical data and harvesting trends for fishermen and farmers

USERS & NEEDS

Non exhaustive list

Fishing & aquaculture
- Origin tracing, algae and phytoplankton mapping, water depth charting and bathymetry, fish-shoals mapping, inventory and monitoring of aquaculture and fishery structures

Shipping & sea ice
- Improved navigation routes

Water quality & marine ecosystems
- Habitats mapping, applications to support research on species movements and behaviours

Coastal management
- Weather forecasts, movements of marine soil, large waves forecasts and mapping

Policies
- Development of new environmental measures

COASTAL AND MARINE EXPLOITATION AND PRESERVATION

DEPENDING ON THE FIELD OF ACTIVITY, DIFFERENT TYPES OF COPERNICUS DATA ARE USED

Fishing & aquaculture

Fishermen and aquafarmers require accurate real time and forecasts information on fish growth rates and fish health, which depends on water conditions. Some of this information is available in models based on CMEMS products and Sentinel-1 and 3 EO data. Forthcoming CMEMS products (such as Microneckton) should also support sustainable fishing.

Shipping & sea ice navigation

Navigation can be supported through the availability of current maps and sea ice conditions that enable real-time mapping for winter navigation and fuel savings, decreasing air pollution.

Water quality & marine ecosystems

For water quality purposes, the key element is to have good spectral characteristics. Sentinel-2 & Sentinel-3 prove useful and are leveraged by CMEMS in its analysis and forecast model products. CMEMS is also currently working on the development of acidity products that will prove crucial for protecting coral reef and the biodiversity of MPAs.

Coastal management

Users of EO data often require very high resolution models. However, CMEMS is currently working to improve the resolution of its observation products for coastal users, from a 1km spatial resolution to 500m, which is in line with users' needs.

Policies

All Copernicus data and CMEMS products mentioned above can support the implementation of policies aimed at regulating fishing activities or protecting the environment. The health of oceans is reported annually in the CMEMS Ocean State Report.

	Copernicus strengths	Copernicus weaknesses
Considering the constantly changing environment of the oceans and coasts, near-real time information proves very useful for users. Sufficient data is also available for the development of forecasts.	***CONTINUOUS PROVISION OF CMEMS DATA IN NEAR-REAL TIME***	
The use of EO in the marine and maritime sector is growing thanks to the availability of more and more free data and products of great quality, notably thanks to the recent launch of Sentinel-3. End users are more aware of the reliability of this European flagship programme and thus have trust in its products.	***MORE AWARENESS AND BIGGER TRUST IN COPERNICUS***	
Sentinel-3 has helped to improve the type of applications Copernicus can support, notably by providing altimetry data, sea surface temperature and ocean color. The coverage is global and the provision of data frequent.	***NEW DATA AVAILABLE THANKS TO SENTINEL-3***	
		DATA ACCESS DIFFICULTIES OR DELAYS
Although some actions have been taken to address the issue, there are still problems with delays or missing data on the ESA Open Access Hub. Users are able to select the tiles of Sentinel data they need but face difficulties with the large volumes of data that can be downloaded.		
		NOT SUFFICIENT RESOLUTION FOR SOME APPLICATIONS
Resolution is improving but for some activities, in particular coastal monitoring, there is a need for higher resolution (for instance, waves can only be detected if their height is higher than 0.4m), necessitating this gap to be compensated with commercial data.		

COASTAL AND MARINE EXPLOITATION AND PRESERVATION

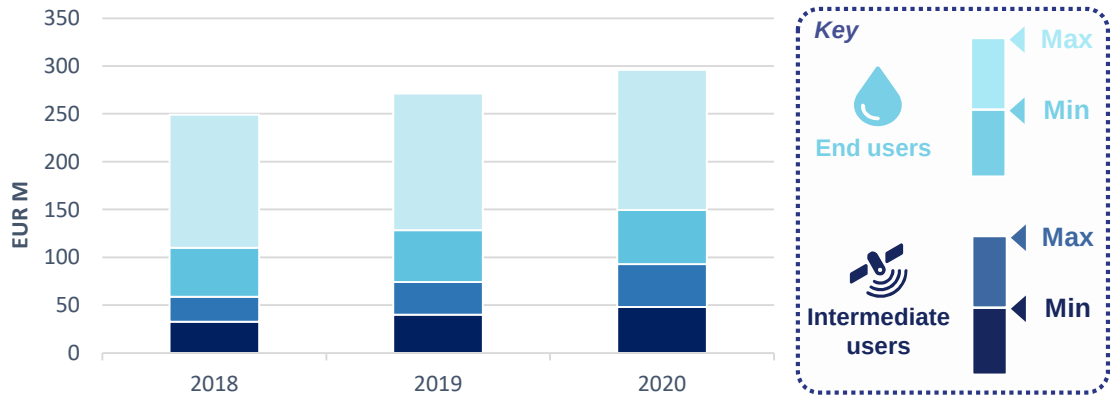
COPERNICUS BENEFITS FOR COASTAL AND MARINE EXPLOITATION AND PRESERVATION

Several business opportunities result from the use of Copernicus-derived products for marine and maritime applications. For instance, the improvement of ship routing thanks to Copernicus helps to better plan the arrival into port and save 1 to 2% of fuel. Copernicus free and open policy can stimulate market opportunities, especially because products can significantly rely on Copernicus (about 80-90% for some water quality products, more than 50% for some aquaculture/fisheries products).

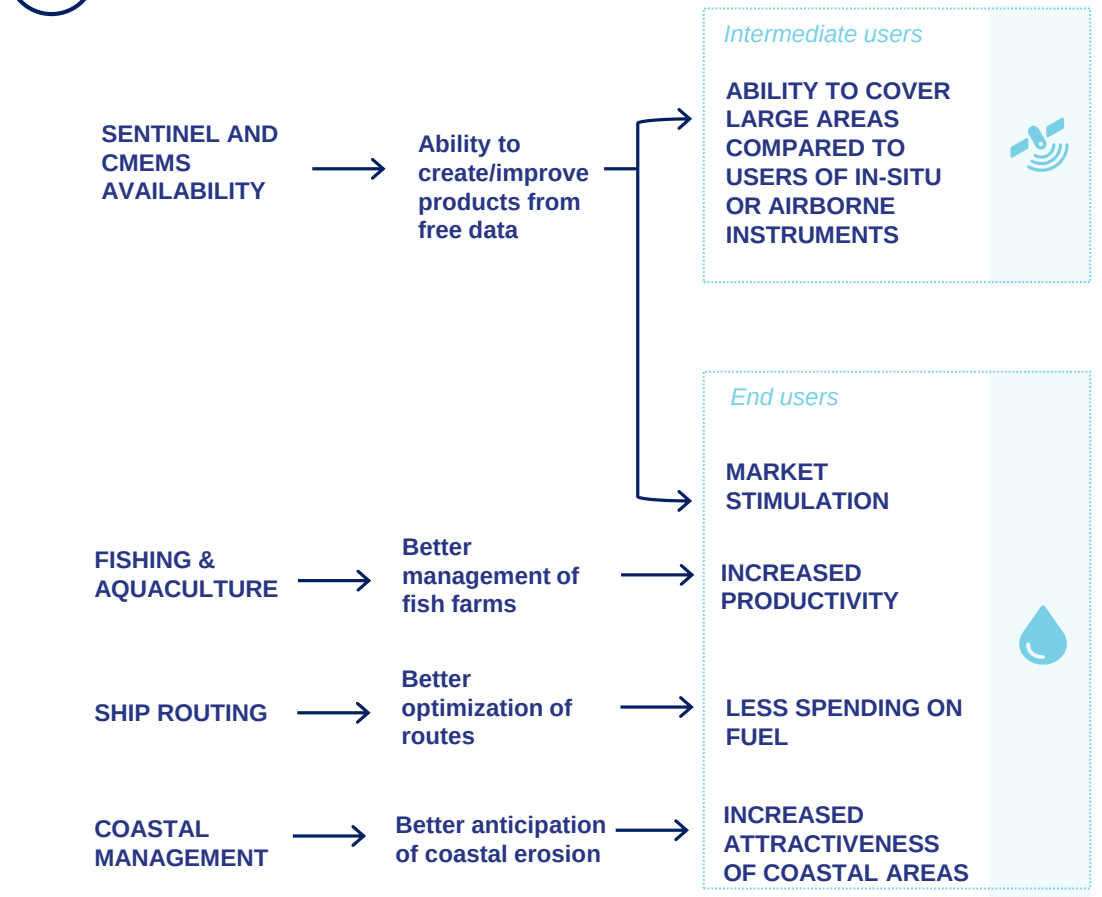
Economic benefits for intermediate users are linked to the development of value-added services to marine and maritime industries oriented towards profit (e.g. ship traffic, fishing). In 2018, this represented between EUR 33 M and EUR 59 M.

End users benefits are rather linked to the development of products supporting environmental assets (e.g. biodiversity, support to policies) and are often combined with intermediate user products to make the most of Copernicus and EO data. In 2018, this represented between EUR 51 M and EUR 191 M. End users are most likely to be public authorities, who represent 80% of 15 000 CMEMS users (though private and public entities collaborate a lot).

Economic benefits of Copernicus through its contribution to marine exploitation and preservation (Source: PwC)



Economic impacts



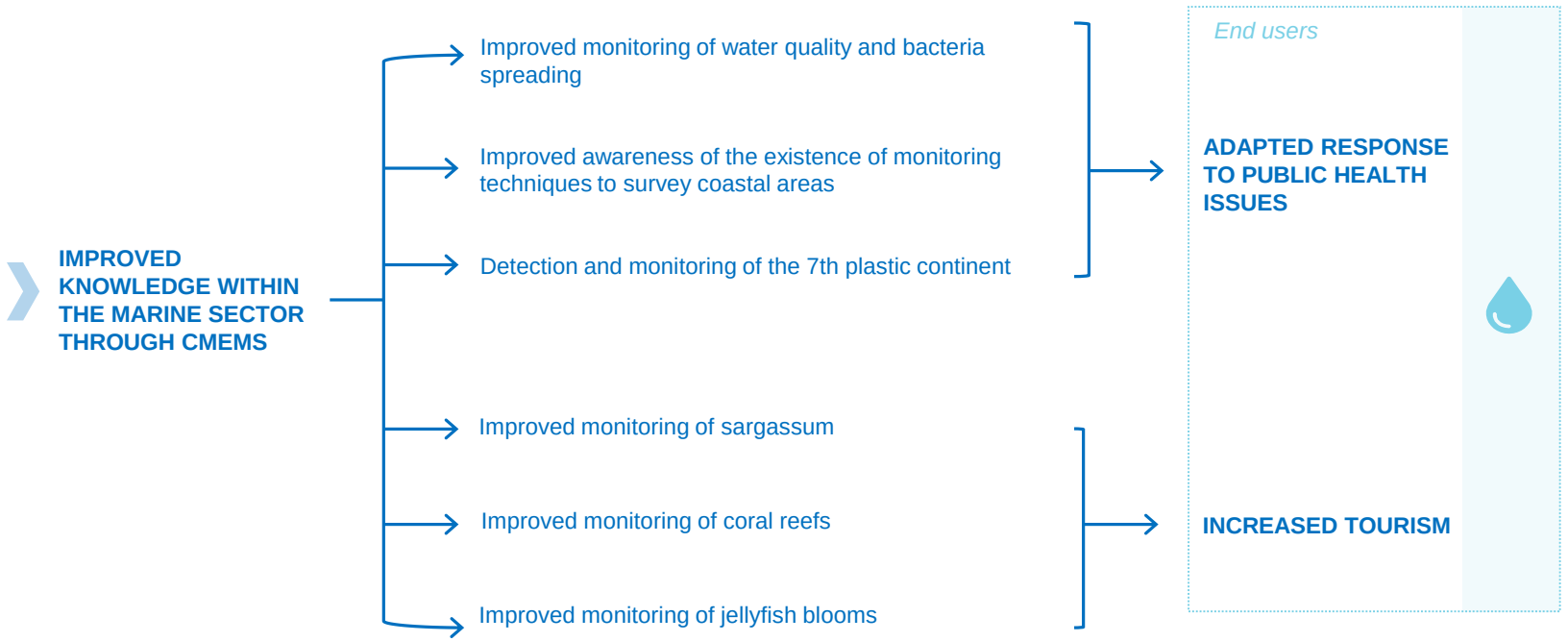
COASTAL AND MARINE EXPLOITATION AND PRESERVATION

COPERNICUS BENEFITS FOR COASTAL AND MARINE EXPLOITATION AND PRESERVATION

Social impacts

The large amount of data available helps increase the level of knowledge on the marine and maritime sector for scientists but also public authorities and citizens. It gives a strong incentive to ask for more information and help protect the environment, because data is regularly available (compared to once a month for in-situ as before). New environmental plans can thus be developed and there is a bigger willingness to take actions and feel concerned about the environment.

Use of Copernicus and EO data by societal associations on plastic litter detection, coral reef restoration are key examples of the rise of social responsibility.



COASTAL AND MARINE EXPLOITATION AND PRESERVATION

COPERNICUS BENEFITS FOR COASTAL AND MARINE EXPLOITATION AND PRESERVATION

Environmental impacts

The increase in accuracy for several applications brought by the availability of Copernicus data is key for the environment. For instance, fuel saved from improved ship routing helps reduce greenhouse gases (GHG) emissions. Additionally, the availability of Copernicus supports the development of the marine renewable energy market (e.g. Ocean Thermal Energy Conversion - OTEC, SeaWater Air Conditioning - SWAC); a 10% increase in accuracy for ocean currents can lead to a 20% increase in energy produced, hence the usefulness of Sentinel-3, which increased the precision of CMEMS current products.

INCREASED KNOWLEDGE ON WATER CONDITIONS WITH CMEMS PRODUCTS

- Diminished reliance on fuel thank to optimised routing → *End users*: **REDUCED GHG EMISSIONS**
- Ability to monitor new aspects of the environment (e.g. surveillance of fish farming, of coastal water) → *End users*: **SUPPORT TO THE DEVELOPMENT OF MARINE RENEWABLE ENERGIES**; **SUPPORT TO SUSTAINABLE FISHING**

Strategic impacts

Copernicus can prove a strong asset in supporting the design of environmental policies and to verify the various regulations are indeed applied (e.g. ensure fish stocks are sustainable). Copernicus can therefore be a tool for law enforcement.

Use of ocean acidification pH products based on EO data and CMEMS for Sustainable Development Goal (SDG) 14 at the United Nations level reporting is a key way to achieve recognition..

- **Provision of statistics and trends on marine and maritime activities**
- **Provision of the Ocean State Report by CMEMS**

→ *End users*: **DESIGN ENVIRONMENTAL AND FISHERY POLICIES**; **TRACK IF REGULATIONS ARE RESPECTED**

COASTAL AND MARINE EXPLOITATION AND PRESERVATION / CASE STUDY

Feeding of models boosting aquafarms' profitability

Planetek Italia

NEEDS AND CHALLENGES OF AQUACULTURE

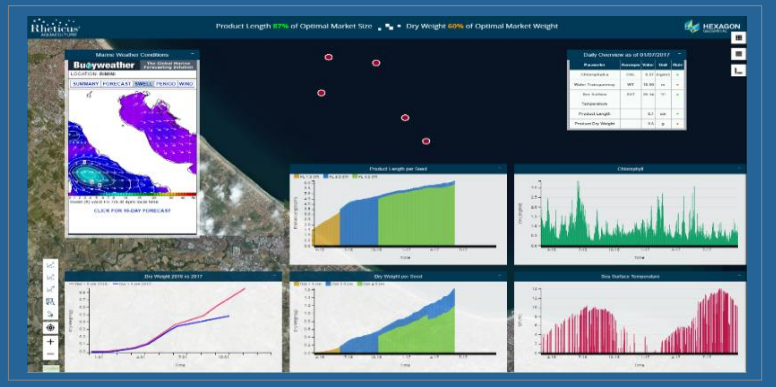
THE EUROPEAN BLUE ECONOMY

Aquaculture has been identified by the European Commission as a key component of both the Common Fisheries Policy and the Blue Growth Agenda, with high potential for sustainable jobs and growth. The aquaculture sector in Europe is highly competitive. Companies face many costs and challenges, which represent a great effort for them as the aquaculture sector is mainly dominated by SMEs with limited funding capabilities. In this regard, aquaculture activities need to be optimized in order to maximize the profitability, fulfil constraints set by environmental legislation and avoid risky situations for the production activities and the marine environment.

THE RHETICUS® AQUACULTURE PROJECT

The Rheticus® Aquaculture project intends to **support aquaculture professionals through the exploitation of EO data for the optimization of their activities, the monitoring of production sites and the maximization of profitability. The project intends to provide aquaculture actors with information to:**

- **Identify the best harvesting and selling time;**
- Estimate product growth rates, days to market size, start of breeding season, and product values in comparison with market prices and profitability trends;
- Identify the best locations for new aquaculture farms;
- Monitor and forecast environmental conditions for operational aquaculture;
- Analyze and characterize the marine environment with an 'a posteriori' approach.



Examples of Rheticus® Aquaculture Dashboards (Source: Planetek Italia)

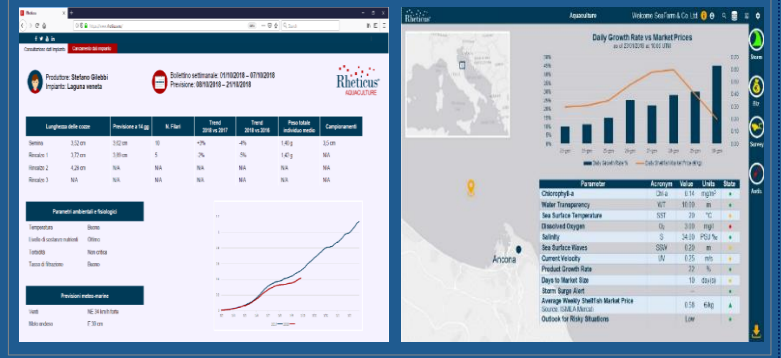
COPERNICUS CONTRIBUTION TO AQUAFARMING ACTIVITIES

USE OF COPERNICUS TO SUPPORT AQUAFARMS

Copernicus Marine Environment Monitoring Service (CMEMS) products and Sentinel-3 imagery regularly provide synoptic and useful information on the coastal environment; however, to boost their usefulness, the project has to combine such data with simulation models of finfish and/or shellfish growing rate together with other relevant information, such as records of in-situ measurements done by some involved mussel producers of the Adriatic sea or records of harvesting and market trends, to help aquafarmers make critical and informed decisions.

Due to peculiar climate conditions, in 2017 there was an early breeding season over the production sites of the involved mussel farmers (central Adriatic Sea). After the breeding season, mussels started losing most of their mass. When eventually farmers harvested them, the mass reduction was so great that it led to an economic loss of more than 20% with respect to the year before. Ultimately, farmers were not aware of the early climate conditions suitable for the breeding season and this caused the aforementioned economic disadvantages.

The results obtained by Rheticus® Aquaculture were able to give precious suggestions about the early breeding season. If farmers had had this information, they would have harvested mussels earlier than they actually did, reducing the economic loss of more than 50%.



Examples of Rheticus® Aquaculture Dashboards (Source: Planetek Italia)

COASTAL AND MARINE EXPLOITATION AND PRESERVATION / CASE STUDY

Copernicus helps to fill gaps in knowledge of the world's coastal zone

TCarta

NEEDS AND CHALLENGES OF COASTAL MONITORING

THE OCEAN ECONOMY

The ocean-economy is estimated to have a value between USD 3 and 6 trillion per year. And with 40% of the world's population estimated to live in coastal communities, the importance of having an up-to-date and clear understanding of this region is critical. Ocean depth data is used for a myriad of applications, including marine spatial planning, environmental impact assessments and aiding navigation. Less than 10% of the shallow waters of the world's oceans are charted to modern standards. In many instances, where charts do exist these are based upon information captured in the 1800s using lead-line techniques involving lowering a line from the side of a boat until the sea bottom is reached. This data gap is prohibiting decision making, resource planning and sustainable development.

OCEAN WATER DEPTHS ANALYSIS

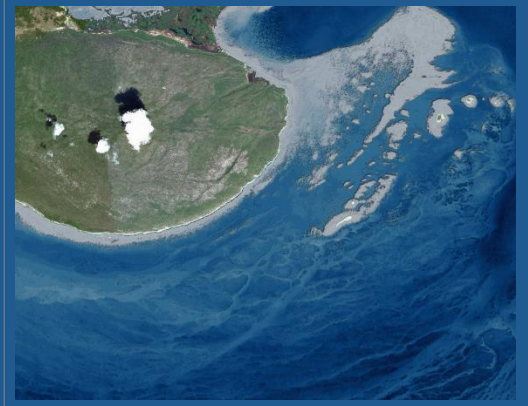
Earth Observation satellites, combined with Remote Sensing algorithms allow accurate depth data to be calculated for shallow waters. The technique is known as satellite derived bathymetry. Satellite Earth Observation methods allow large swathes of the world's shallow waters to be mapped quickly and remotely. Satellite derived bathymetry is up to 20 times cheaper than boat surveys, meaning that data becomes affordable to a larger user base. Although satellites do not offer the same level of accuracy as boat surveys, the output data is suitable for many end uses. Whether data is needed for reconnaissance work, ahead of more detailed data gathering, or is used stand alone to develop a clear picture of coastal change, satellite derived bathymetry is a now a proven tool that is providing critical understanding of the ocean environment. TCarta have been collating ocean depth data since 2008 from many data sources. This data is provided to end users in standardised and easily digestible formats that are ready for implementation within Geographic Information Systems (GIS). TCarta have a satellite derived production facility that is continually, speculatively producing satellite derived bathymetry data throughout the world.

COPERNICUS CONTRIBUTION TO COASTAL MONITORING

USE OF COPERNICUS TO SUPPORT BATHYMETRY

The Copernicus programme, and specifically the Sentinel-2 satellites, have provided the source inputs to create bathymetry at 10m resolution in clear waters to depths of up to 20m. The launch of the Sentinel-2 satellites (2015 and 2017) has provided a vital data source for bathymetry production that is readily accessible and frequently updated. The Sentinel-2 satellite imagery archive (now over 3 years old in many locations) has allowed multiple images to be processed and trends and changes in coastal geomorphology to be clearly understood. Prior to the launch of the Sentinel-2 constellation, satellite derived bathymetry was restricted to either utilising imagery from commercial operators (at very high resolution, and increased costs), or from USGS LandSat satellites (at a coarse resolution). TCarta are now using Sentinel-2 satellites to provide bathymetry that is in the mid-range of these 2 approaches.

Projects that have specifically utilised Copernicus Sentinel-2 satellites have been commissioned by oil and gas companies with a focus on hydrocarbon exploration, as well as governments who are undergoing large marine spatial planning exercises. Better knowledge of shallow water depths is key to improving these activities also reduces environmental impacts as there is a reduced need for deploying boats and aircraft to a region.



10m resolution Satellite Derived Bathymetry created from Sentinel-2 in Jamaica (Source: TCarta)

COASTAL AND MARINE EXPLOITATION AND PRESERVATION / CASE STUDY

Using Copernicus data to support water quality monitoring

SYKE

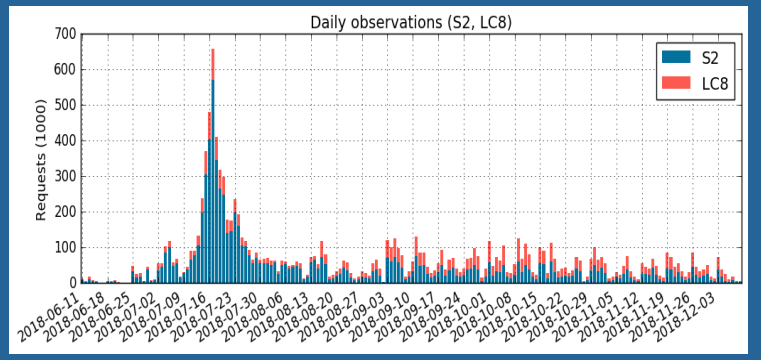
NEEDS AND CHALLENGES OF ENSURING WATER QUALITY

ALGAL BLOOMS

Cyanobacteria, blue - green algae, are of high interest to the public and the press in all Baltic countries, as they form toxic surface floating blooms during the summer holiday periods. In the Northern Baltic Sea, the cyanobacteria bloom season typically starts when the waters warm up by the end of June and continues to September. In 2018, the blooms were especially intensive in certain parts of the Baltic Sea, namely in the Gulf of Finland and in the Northern Baltic Proper. During a two-week period in July, extensive cyanobacterial blooms were packed tightly in the coastal waters of Finland, and were of serious and intensive concern to the public, authorities and press. As an organization responsible to this national concern, SYKE formed a special group to provide information on the algae and its toxins.

SYKE SERVICES

The Finnish Environment Institute (SYKE) has over twenty years of experience in utilizing satellite observations for monitoring surface algal blooms in the Baltic Sea. SYKE's EO services and methods are notably supporting the H2020 EOMORES project (eomores-h2020.eu). For distributing EO products as images, SYKE utilizes web map interfaces TARKKA (www.syke.fi/tarkka/en) and PINTA (www.syke.fi/pinta/en). EO data is also condensed as periodical statistics, histograms and time series in the web interface STATUS. During the intensive algal bloom weeks of July, the EO services of SYKE provided daily information on the extent of surface blooms. As a result, EO images of algal blooms were widely displayed in newspapers and TV. During the intensive phase of cyanobacteria bloom in summer 2018, SYKE's algae monitoring was mentioned in the media daily.



Number of service requests to SYKEs true color data interface during summer and fall 2018 (Source: SYKE)

COPERNICUS CONTRIBUTION TO WATER QUALITY MONITORING

USE OF COPERNICUS TO SUPPORT WATER QUALITY MONITORING

The algae bloom service of SYKE covers the whole Baltic Sea with medium resolution instruments - such as Sentinel-3 OLCIs - for generating the surface algal bloom maps and daily RGB images visualizing the cyanobacteria features in water. However, the coastal waters of Finland in the northern Baltic Sea are characterized by fragmented coastline and thousands of islands of various sizes. Thus, in 2018, the algal bloom monitoring was upgraded with high resolution data from Sentinel-2 MSI and USGS Landsat-8 (LC8) OLI. OLCI and S2/MSI captured the most intensive blooming days with almost no cloud over the Gulf of Finland and the central Baltic Sea.

In Finland, the reporting obligations set by the EU as part of the Water Framework Directive (WFD) concern about 4500 lakes and more than 250 coastal water bodies. In the currently ongoing WFD status assessment for 2011 – 2017, SYKE has effectively exploited the Sentinel satellite series instruments MSI and OLCI complemented with Landsat-8 OLI over numerous lakes and coastal water bodies. The authorities responsible for the assessment now have access to EO water quality products from approximately 40% of Finnish lakes and practically all coastal water bodies. The rest of the Finnish lakes are either too small or too shallow for monitoring with EO instruments. Naturally, this helps to diminish the enormous costs usually linked to monitoring activities.

S3 OLCI true color image taken on July 16, 2018 showing extensive algal blooms (Source: SYKE)

COASTAL AND MARINE EXPLOITATION AND PRESERVATION / CASE STUDY

Characterisation of natural water turbidity to support sustainable maritime projects

I-Sea

NEEDS AND CHALLENGES OF MONITORING WATER TURBIDITY

THE OCEAN ECONOMY

For Europe, maritime regions have long been drivers for economic development and prosperity. Nowadays, extraction of non-living resources, maritime transport, port operations and marine-based renewable energy represent, altogether, an estimated gross added value of about EUR 215 billion and employ at least 3.5 million people. The continuous growth of these industrial activities around coastal areas constantly raises new challenges for local authorities in charge of the maintenance and the improvement of the overall water quality and the related protection of natural habitats.

I-SEA SERVICES

Since the risks and severity of impacts from sediment disturbances on biological species are primarily related to the intensity, duration and frequency of exposure to increased turbidity and sedimentation, knowledge on natural patterns of turbidity is needed to support the prevention and mitigation of environmental damages to natural resources and thereby to achieve sustainable use of the marine environment.

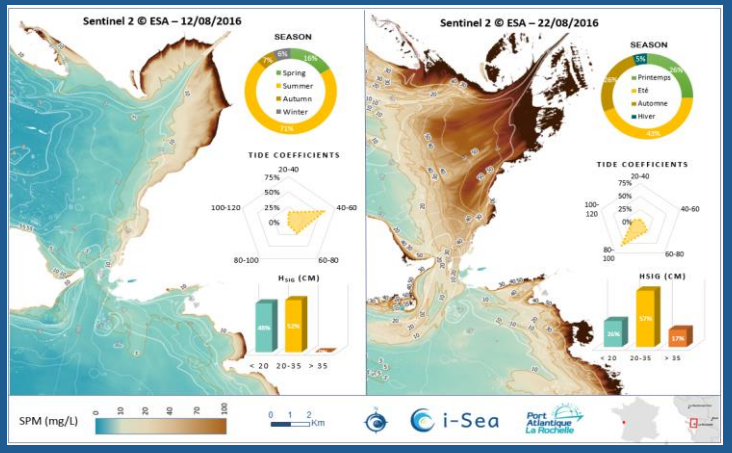
Turbidity image (Source: ESA)

COPERNICUS CONTRIBUTION TO WATER TURBIDITY MONITORING

USE OF COPERNICUS TO SUPPORT CHARACTERISATION OF WATER TURBIDITY

Medium to high-resolution optical satellite sensors are ideal providers of long-term observations on large coastal regions. The French company I-SEA provides dedicated services based on the statistical analysis of long historical time series to help in the definition of thresholds to be respected during marine construction works, in order to protect marine life. Sentinel-2 and Sentinel-3 are among the most consistent image sources feeding this service.

With uncertainties on turbidity retrieval below 40%, the remotely-sensed turbidity regimes allow the identification of locations and periods of time to favor, in order to prevent the impact of maritime works. Fish or shellfish farming, coastal fisheries and natural mollusk bed exploitation represent an estimated gross value added EUR 5 billion, employ more than 300,000 people and feed all coastal regions in the world, including the most vulnerable segments of the population. Monitoring coastal regions with Copernicus constellation can significantly contribute to the sustainability and safety of maritime projects and helps in maintaining healthy oceans for populations relying on it for jobs and food.



i-Sea dashboards (Source: i-Sea)

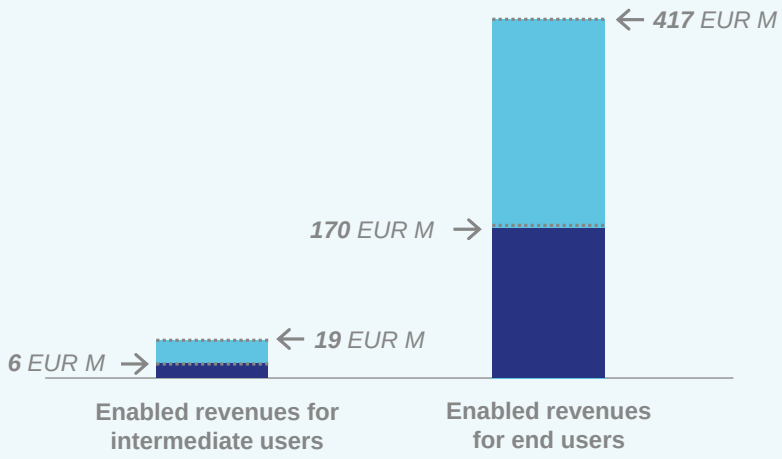
OIL AND GAS

KEY TAKEAWAYS

- The Oil and Gas (O&G) value chain is the most private sector-oriented value chain, where the value chain targets private end users from the upstream O&G industry.
- The upstream O&G industry is heavily impacted by the fall in oil price, which negatively impacts the dissemination of EO in general, including Copernicus data and products, since the O&G industry is very traditional and risk averse when it comes to new products such as Copernicus.
- The usage of EO data within the O&G upstream industry varies a lot from one actor to another, but in general the use of EO is widely spread among upstream O&G end users when compared to other private sector value-chains.
- The O&G upstream industry is heavily consolidated, with very large players involved in most of the supply chain and who dominate the market.
- Environmental legislation requires O&G companies to ensure compliance with policies and reduce risks to the environment. Hence, EO solutions are a useful tool for monitoring the effects of activities.
- Most of the industry has already switched to Geographic Information System (GIS) products and services. Upstream O&G players are in most cases using imagery incorporated into more complex GIS products, including EO (all resolutions), Remotely Piloted Aircraft Systems (RPAS) data, in-situ data, internal data and statistics, etc.

Copernicus economic impact (2018)

(Source: PwC)



COPERNICUS APPLICATIONS

- Maps and processes to support exploration and drilling activities
- Procedures for environmental monitoring (e.g. coastal ecosystems, marine habitats, pollution at sea, etc.)
- Maps and methods to prevent risk of disasters (e.g. maps of flooding, detection of hurricanes and typhoons, underwater currents, etc.)
- Maps and processes to support infrastructure construction and safety (e.g. maps to monitor construction and buildings, climate series of large waves, ocean current forecasts, measures to monitor oil rigs and flares, etc.)

KEY COPERNICUS PRODUCTS

- Real-time global sub-surface current forecasts, wave product, including the Significant Wave Height (SWH), Global ocean wind observations climatology (CMEMS)
- Global and regional ocean 1/12° 1/36° physics analysis and forecast - updated daily
- SAR oil pollution observations

OIL AND GAS

A RECOVERING SECTOR WITH CHALLENGES STILL LYING AHEAD

Between mid-2014 and early 2016, the global economy experienced a shocking decline in oil prices, tumbling from a peak of $115 per barrel in June 2014 to under $35 by the end of February 2016, caused by a combination of declining supply as well as a drop in demand. Several years later however, and production has picked up again, especially in the US, with the industry appearing more stable than it did a year ago. The price of oil has begun to increase once more, with a prediction by JP Morgan that Brent Crude Prices will average $73 a barrel in 2019.

There is, however, a risk of a supply shortage in upcoming years, where oil demand is growing and yet investment in major projects has still not recovered from stalling due to the downturn, and oil supply growth has also eased. Hence, oil companies will have to find a way to boost production.

The North American market is driving an uptick in oil and gas rig activity levels, and recovery of the sector can be seen in new projects being approved. For example, Shell approved a decision to invest in the Penguins field redevelopment, which will be its first new staffed installation within the northern North Sea in nearly 30 years. There has also been a rise in exploration activities.

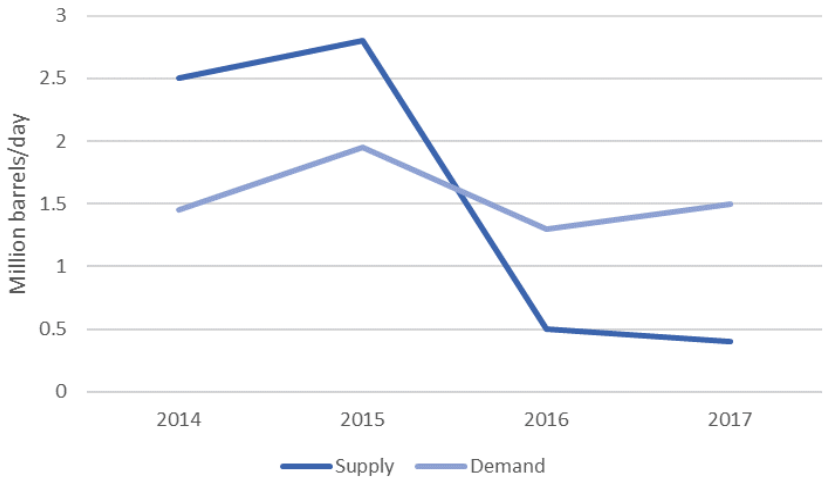
Sources: CNBC, PwC

However, challenges still lie ahead for the sector, above all in relation to supply:

1. There is a decline in new discoveries – only 3.5 billion barrels of liquids (crude, condensate and natural gas liquids) were discover in 2017, meeting only 10% of demand.
2. Exploration spending has been slow to rise after the downturn of 2014-2016. It fell from around US$153 billion in 2014 to around US$58 billion in 2017, with a modest recovery rate.
3. Supplies are being disrupted, which can often be linked to geopolitical issues.
4. Maintenance has been deferred, and now there is a rise in aging asset infrastructure.
5. There is an overall momentum towards a lower-carbon world.

Growth in world oil supply and demand

(Source: IEA Oil Market Report; PwC analysis)



OIL AND GAS

COMPANIES CAN BENEFIT FROM EO SOLUTIONS PRIMARILY THROUGH EXPLORATION AND MONITORING

The importance of EO data in business models for oil and gas companies varies extensively from one company to another. For some actors, EO is one of several tools to help with their activities, whilst for others it plays a more integral part of their competitive advantage in the market. Some of the large oil companies have their own in-house remote sensing capabilities, especially for on-going activities. For smaller companies or for general sporadic activities, it is more likely to be outsourced to a third party service provider.

EO in the oil and gas industry requires a variety of very different temporal and spatial imagery resolutions. Very high resolution data is required for extremely specific and local applications, whilst low/medium data and high resolution data can be used also for large area monitoring or mapping. EO is for supporting and calibrating existing activities, and helping improve planning activities, and is not a substitute for traditional techniques such as ground surveying.

Digitalization is also a trend within the O&G upstream industry, with GIS products and services being very popular. Digital platforms with integrated solutions can provide added-value business intelligence.

Exploration

As seen in the overall sector, there is a rise in the demand for supply in oil and gas, and yet there has also been a decrease in discoveries of new reservoirs. EO can provide solutions such as planning surveys and determining position of seismic equipment, helping produce topographical maps to confirm/correct sub-surface structures derived from seismic activities, or even detecting small oil leaks that are not located near current operations (natural reservoirs can also emit leaks).

EO allows for large scale prospecting in a more efficient manner for offshore and onshore exploration, and allows for more confidentiality than sending helicopters or boats over specific areas of interest.

Monitoring

Monitoring solutions using Earth Observation are useful in a variety of ways for the oil and gas sector.

Firstly, environmental legislation and policy has obliged O&G companies to conduct environmental assessments of their work, and ensure compliance in their activities. EO monitoring can detect oil spills and leaks, or track water quality levels during infrastructure installation such as underwater pipelines.

Secondly, it can help in the protection of rig/platform workers, by assessing extreme weather events and hazards such as ice floes in offshore locations.

Finally, it can help with decommissioning purposes, by ensuring there are no leaks/spills as the rigs/platforms are decommissioned.

WHY EARTH OBSERVATION?	APPLICATIONS	BENEFITS	END USERS
EXPLORATION	• Detection of oil seeps from deep-water petroleum reservoirs • Topographical maps can help confirm/correct the sub-surface structure derived from seismic data	• Better confidentiality than sending helicopters or boats • Cost efficient method for large scale prospecting • Allows preliminary exploration in remote areas without sending in workers	• Survey companies • Oil and gas companies
MONITORING	• Detecting oil spills/leaks during operations • Detecting oils spills/leaks from malfunctioning/aging infrastructure (which may be remote, e.g. pipelines) • Detecting hazards to workers and the platforms/rigs, e.g. ice floes • Monitoring of dangerous sub-surface currents	• Ensuring compliance with environmental legislation • Protecting workers from natural hazards • Protecting infrastructure from damage	• Oil and gas companies • Environmental consultancy/research firms • Decision makers (e.g. national public authorities, international bodies)

OIL AND GAS

DRIVERS AND CHALLENGES FOR THE ADOPTION OF EO FOR OIL AND GAS

Environmental legislation continues to be a key driver in the O&G industry in seeking EO-based solutions, especially for those conducting offshore production. The European Union has set out the Safety of Offshore Oil and Gas Operations Directive, which states that companies are fully liable for environmental damages caused to protected marine species and natural habitats, with a geographical zone covering all EU marine waters, including exclusive economic zones and continental shelves. O&G companies are therefore seeking new ways in which to monitor environmental factors when undergoing operations such as extractions or pipeline installations.

As the demand for oil grows, and the sector improves with the rise of oil prices again, companies are beginning to turn their attention back towards exploration. With this comes an interest in investing in new technology to support exploration activities, including EO-based solutions.

EO solutions have also been able to support O&G companies in assessing the risk to operations, especially through the monitoring of hazards such as encroaching ice, where large ice floes and other extreme ice features can damage offshore platforms and rigs, as well as endanger the workers. It also supports the monitoring of extreme weather events that will impact offshore oil and gas infrastructure.

DRIVER 1

Environmental responsibility driven by environmental legislation means that O&G companies are seeking ways to help monitor the environment as operations are undertaken.

DRIVER 2

Increase in oil demand means exploration activities may require new technological solutions

DRIVER 3

EO solutions are able to support risk assessments, such as the risk from floating ice to offshore platforms.

CHALLENGE 1

The oil and gas sector faces a volatile and cyclical market, meaning that the willingness to invest in new solutions changes depending on market strength.

CHALLENGE 2

Oil and gas actors are rational and traditional, and are hence unwilling to take too much risk on new technologies

CHALLENGE 3

Oil and gas companies remain reactive rather than proactive, so it can be challenging to persuade them to invest a share of their budget into these solutions

The oil and gas sector tends to be cyclical in nature, with rising and falling prices. The uptake of new technology is hence connected closely with the pricing. High price of the barrel for oil correlates directly to higher investments in the upstream and an increase in drilling activities, and of course the opposite is also true. Investments in technologies, methods or products, such as ones based on EO data, are dependent therefore on the Brent Crude Daily Price (indicator representing the price of oil on the stock exchange market).

Historically, oil and gas companies have been very rational and traditional. Actors are often unwilling to take too much risk, and are cost-oriented. Therefore, investment into new technologies need to be supported by some form of assurance of return.

It can be challenging for service providers to persuade oil and gas companies to dedicate some of their budget towards investing in EO solutions to support activities such as exploration or ongoing monitoring, since they remain reactive actors rather than proactive ones. If something goes wrong, such as an oil leak/spill, then they are willing to invest in a solution to find the cause of the issue, but they may not be so encouraged to invest in solutions for preventative measures.

OIL AND GAS

THE VALUE CHAIN OF EO DATA FOR OIL AND GAS

ACQUIRING EO DATA

Overall data needs

- Open source data (Sentinel, Landsat, MODIS) for low and medium resolution data to monitor infrastructure, spills/leaks, the environment, and hazards
- Sentinel-1 data is especially useful, above all for offshore activities, whilst Sentinel-2 is increasingly used for onshore activities
- Commercial data can also be required, for more specific or high resolution focus on certain areas
- Other sources of data besides EO are used also, including: Remotely Piloted Aircraft Systems (RPAS) data, internal data from the oil and gas company, ground data, marine data, meteorological data
- Other services include: ocean and wave forecasts, and long time series - surface and sub-surface, and ice conditions

PROCESSING NEEDS AND CAPABILITIES

Data format and in-house capabilities

- Data processing required to turn satellite images into a product that can offer information and decision-making support to oil and gas companies
- Large oil and gas companies often have their own internal capabilities for remote sensing and its utilization
- Copernicus data and other open source EO providers have allowed value added services companies to develop more off-the-shelf products
- There is an interest in digital platforms to access EO data, products and services
- Geographic Information Systems (GIS) are already utilized by many actors in the oil and gas sector
- EO data is often fused with other sources of data, both GIS and non-GIS. It is rarely the only data source/solution
- Some trends observed towards introducing automation and machine learning capabilities into the products

USERS & NEEDS

Non exhaustive list

- Supporting surveys (onshore and off) – EO allows for large scale prospecting in an efficient way. Topographical maps may be used to reconfirm/correct the sub-surface structure derived from seismic data
- GIS (including EO data) can help integrate data for different geological analyses, e.g. prospect analysis, land management, field geology maps, basin analysis
- Surveillance of production and pipelines – especially pipelines/infrastructure in remote areas
- Environmental impact and assessment of activities – ensuring no spills/leaks, as well as construction of infrastructure in an environmentally-friendly manner
- Safety of workers – ensuring extreme weather and hazards such as ice floes don't endanger the workers. EO in early exploration also ensures workers are less likely to have to go into remote locations for ground surveys with no purpose
- Transport and logistics planning
- Decommissioning monitoring

OIL AND GAS

EO PROVIDES USEFUL INSIGHT TO OIL & GAS, BUT OFTEN AS ADDED-VALUE RATHER THAN SUBSTITUTES

Solutions utilizing EO data are already wide-spread within the oil and gas industry, and a majority of large O&G actors have their own in-house activities related to remote sensing. Hence, the dissemination and integration of Copernicus products will be easier to facilitate. Geographic Information System (GIS) products especially are widely used. Indeed, a lot of the geospatial data utilized in the O&G sector will be through the implementation of GIS systems. Therefore, the more Copernicus data/products are integrated within GIS systems, the more it will be utilized by O&G actors.

Copernicus data/products are not supposed to be perceived as substitutes for traditional methods in the O&G sector; for example, ground surveying in exploration will still have to be carried out. However, it can act as a complementary tool that can bring a competitive advantage to its users, by adding efficiency to exploration activities, and covering a much larger area via satellite imagery than could be obtained by other, more traditional methods (helicopters, for example).

The open access data policy has been critical in allowing service providers to develop more off-the-shelf tools, enabling them to develop solutions and approach customers with results and information.

		Copernicus strengths / Copernicus weaknesses
Copernicus data/products are **not perceived as substitutes for more traditional methods** used in the O&G upstream industry, for example ground surveying. Rather, they are **complementary** tools for helping to bring **added value and efficiency** to the activities, and bring cost reduction thanks to the large coverage area offered by satellite imagery.	*COPERNICUS DATA SUPPORTS MORE TRADITIONAL METHODS, AND CAN HELP COST REDUCTION*	
	THE EASE OF ACCESS OF DATA HAS ALLOWED COMPETITION TO GROW	The **transparency, consistency, and stability** over time of the Copernicus project, as well as the **large volume** and **easy access** to data that it provides, means that it has **encouraged competition** to grow amongst companies providing EO solutions for oil and gas. Hence, there are more options on the market for EO companies to choose from.
Sentinel data can be provided **quickly** and **reliably, thanks to its revisit time,** for a **large area,** which is often what is required when monitoring a situation undergoing changes such as oil spills. The availability of **Sentinel-1 radar data** is a key advantage for offshore activities, whilst **Sentinel-2** is starting to be used more and more in onshore activities.	*SENTINELS OFFER RELIABLE SURVEILLANCE FOR A LARGE AREA*	
	THERE ARE SOME LIMITATIONS TO THE DATA, E.G. GEOGRAPHICAL COVERAGE VS REVIST TIME	In certain areas of the world, especially non-European, offshore regions, Sentinel-1 is not able to provide as efficient a revisit time as other locations, since the demand for imagery is not as significant as in populated or busier areas. However, since oil and gas activities can occur in these remote areas, it can limit solutions.
Accessing Copernicus data and services easily and without high data acquisition fees has allowed some companies to develop solutions for the market that can then be taken to prospective customers and used as a demonstrator to prove potential return. This can help encourage investment by traditionally conservative actors within the sector.	*OPEN & FREE DATA ALLOWS COMPANIES TO DEVELOP NEW SOLUTIONS*	
	COPERNICUS DATA CAN BE SLOWER AND MORE COSTLY THAN TRADITIONAL METHODS	Whilst remote sensing helps remove the risk to human life, it can also be **slower and more costly**. Human eyes from an airplane/ helicopter can be better at detecting leaks from pipelines or proxy, rather than ensuring sensors can do the task. No data processing is required after the fact either, meaning faster results.

OIL AND GAS

COPERNICUS BENEFITS FOR OIL AND GAS

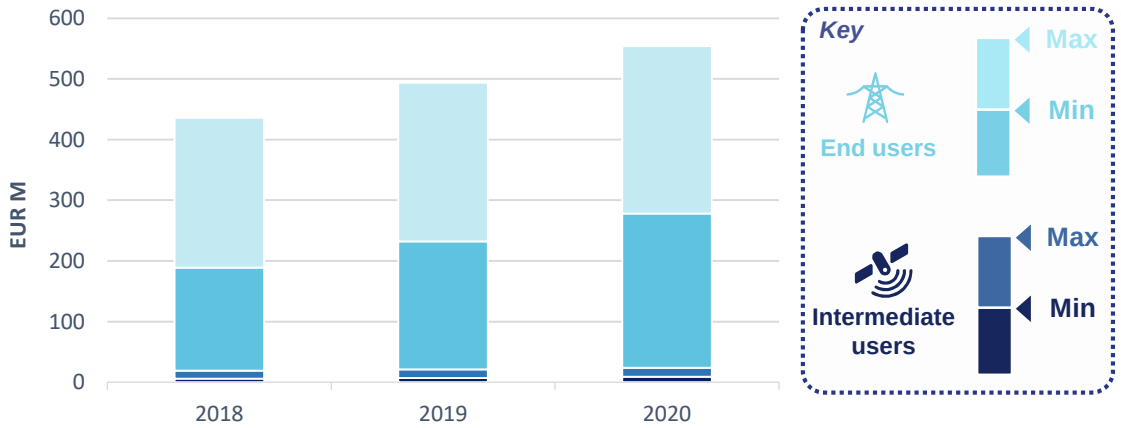
Revenues enabled by Copernicus for the oil and gas upstream industry is estimated as being already as high as EUR 170-417 million, with a steady increase up to a projected EUR 254-520 million by 2020. Benefits are predominantly felt by the end users (oil and gas companies themselves). Copernicus-based solutions help the oil and gas industry save costs, which in turn makes it cheaper for the companies to supply oil and gas. Conversely for intermediate users, the revenues are estimated as being EUR 6-9 million, rising to a projected 9-24 million by 2020.

The environmental monitoring sector is expected to grow, offering new business opportunities in the upcoming years. However, no market figures were specifically found for this sector yet. Instead, these figures include the EO intermediate players, integrated players and those actors involved in the oilfields.

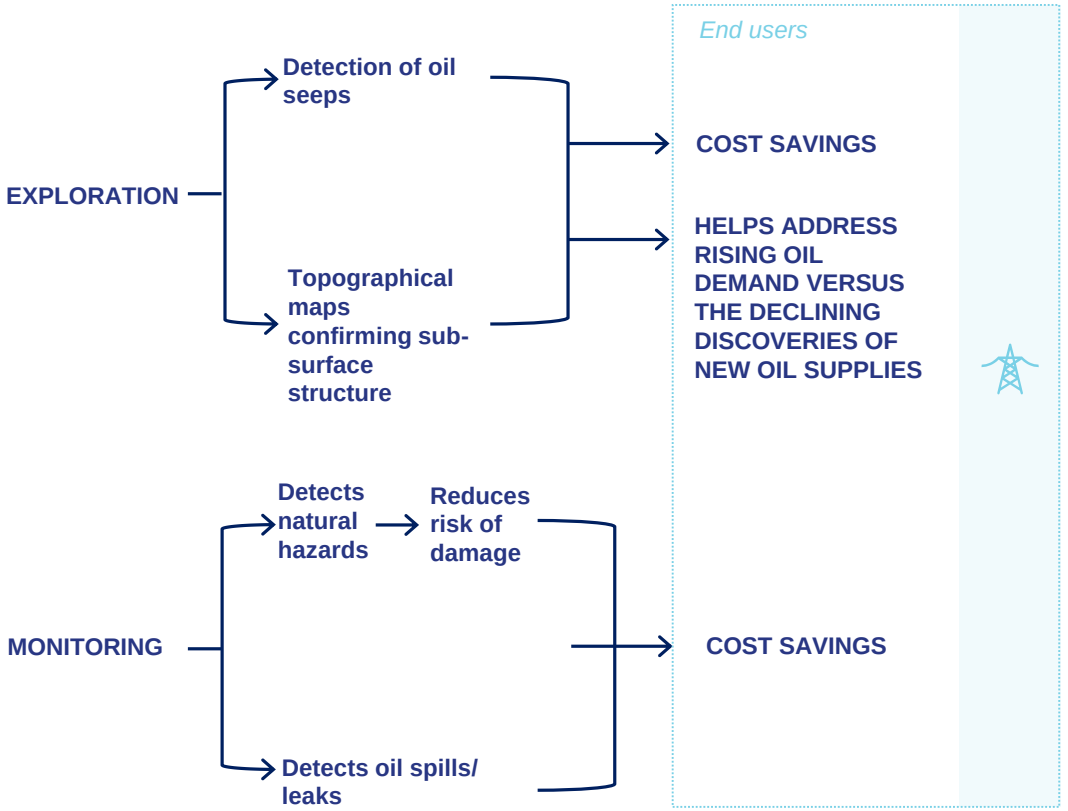
The projected increase in market value can be connected to the expected rise in oil prices in the next few years, as the sector continues to recover from the 2014-2016 collapse, as well as the growing concern of increase in supply demand in the face of a decline in new discoveries. Added to this is the fact that whilst Copernicus products are not considered as substitutes for ground surveys and other traditional methods, they can help add value compared to other exploration methods; for example, EO data covers much larger areas compared to airborne instruments, helicopters, etc.

Economic benefits of Copernicus through its contribution to oil and gas sector

(Source: PwC)



Economic impacts



OIL AND GAS

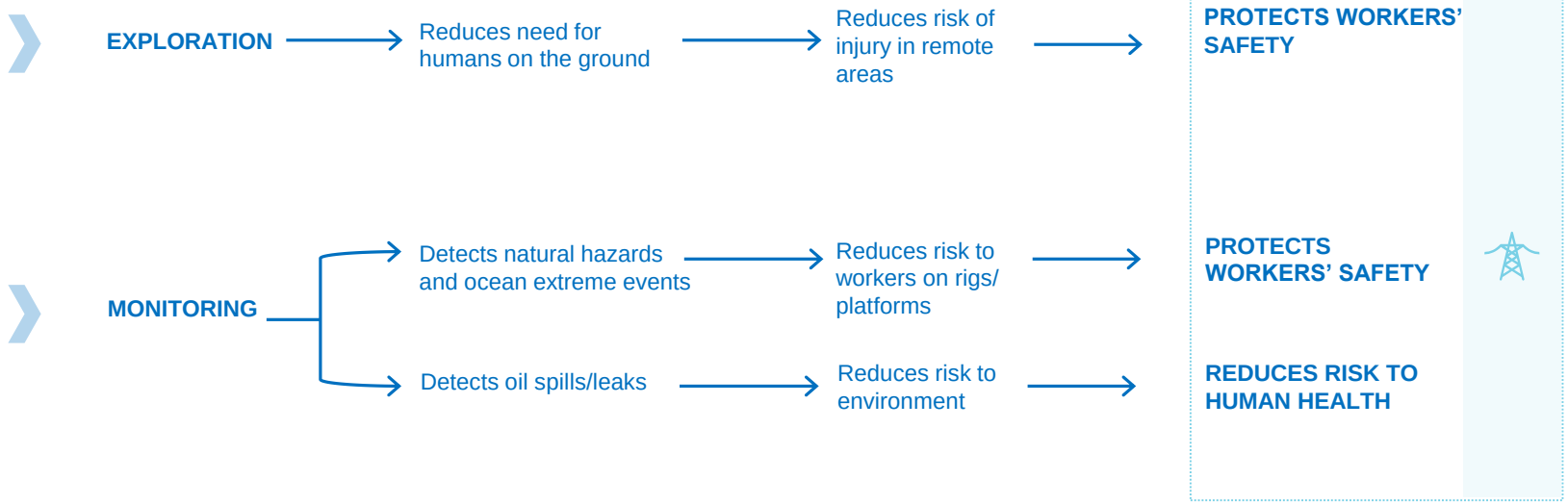
COPERNICUS BENEFITS FOR OIL AND GAS

Social impacts

Infrastructure monitoring, extreme weather monitoring and other risk assessment activities help ensure the workers are better protected when working on rigs/platforms.

Utilizing EO data for preliminary exploration measures can also ensure workers do not have to go into remote and potentially dangerous areas for ground surveys where there may be no purpose.

By decreasing the risk of pollution in the environment, it will also ensure protection to the health of citizens who could be affected.



OIL AND GAS

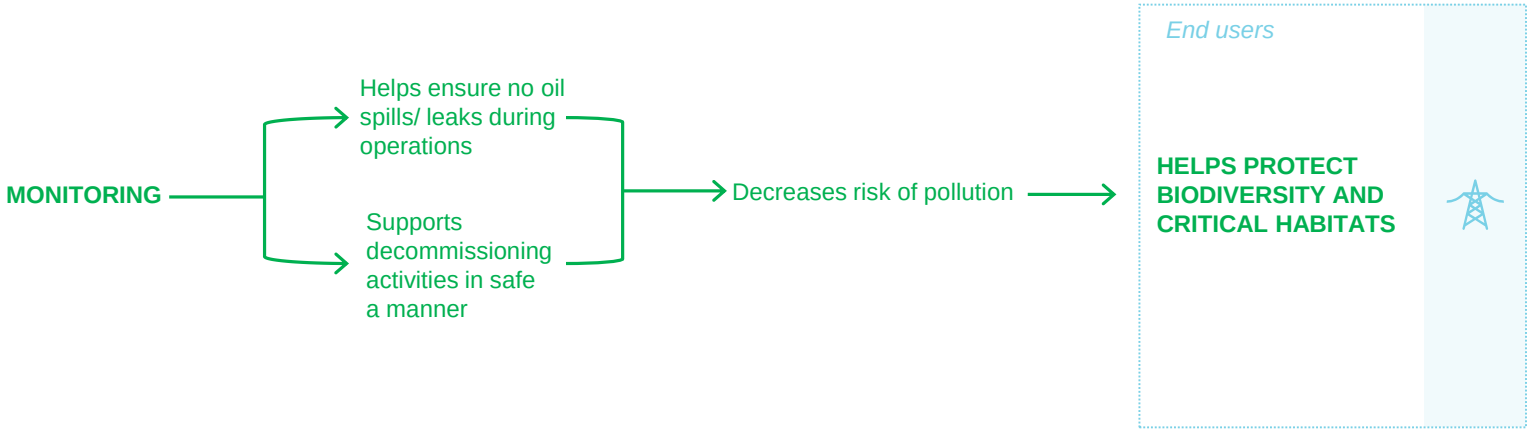
COPERNICUS BENEFITS FOR OIL AND GAS

Environmental impacts

Monitoring of infrastructure can give produce early warnings if there is a leak or spill at the site of operation. This in turn reduces pollution of the soil, water or air. In a similar manner, monitoring the surrounding environment at extraction sites, both onshore and off, will also help ensure that there is not an on-going pollution issue.

Decommissioning activities also run the risk of polluting the environment, so ongoing monitoring activities during decommissioning will ensure preventative measures.

Ensuring less risk of pollution helps protect the biodiversity and ecosystem within the water bodies and land, and EO can also provide critical habitat monitoring in potentially affected areas.



Strategic impacts

By implementing EO solutions for monitoring and protecting the environment, the company highlights that it is acting responsibly. This in turn feeds their corporate social responsibility (CSR) as well as the company perception, in a world where sustainability is becoming ever more important for its clients.

Environmental monitoring also supports the implementation of EU environmental policies.

ACTING ENVIRONMENTALLY RESPONSIBLE SUPPORTS A COMPANY'S CSR AND PUBLIC PERCEPTION

SUPPORTS THE IMPLEMENTATION OF EU ENVIRONMENTAL POLICIES

OIL AND GAS/ CASE STUDY

The detection of newly active oil seeps
NPA Satellite Mapping – CGG

OIL SEEPS FROM SATELLITES

THE CHALLENGE OF DETECTING OIL SEEPAGE

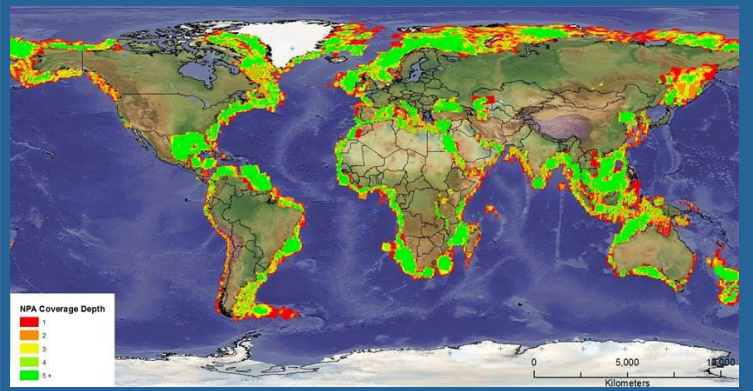
An oil seep, as opposed to an oil spill, is a naturally occurring leak of crude oil and gas that is released from fractures in the seafloor and rises up to the surface. Globally, oil seepage is the largest source of oil entering oceans. However, it can be a challenge to differentiate between oil polluting the environment from a spill, and naturally-occurring oil on the ocean surface.

Synthetic Aperture Radar (SAR) satellites, such as the Copernicus Sentinel-1 satellites, provide the ability to detect oil films on the surface of water, under favourable weather conditions. Using these images as a base, rules can then be applied concerning the oil slick shape and size, the local geology, the geographic setting and the anthropological activity, with the resulting information making it possible to characterise the source of oil as natural or pollution.

THE ROLE OF THE GLOBAL OFFSHORE SEEPS DATABASE (GOSD)

CGG's NPA Satellite Mapping business unit has developed an offshore seepage detection technique, utilising satellite SAR imagery to detect offshore sites of naturally-occurring oil seepage, including deep and ultra-deep waters, as well as untested offshore frontier basins. These oil slicks are organised into a number of confidence categories, and compiled within their world-leading Global Offshore Seeps Database (GOSD).

GOSD acts as a low cost and non-invasive method for first indication that a mature source rock is present. By establishing the presence of a mature source, and hence the inference of oil and gas accumulation, it reduces exploration risk for a company seeking a new location for operations.



Global Offshore Seeps Database coverage map
(Source: NPA Satellite Mapping)

COPERNICUS CONTRIBUTION TO OIL SEEP DETECTION IN THE GULF OF ADEN

USE OF COPERNICUS IN THE DETECTION OF OIL SEEPAGE IN THE GULF OF ADEN

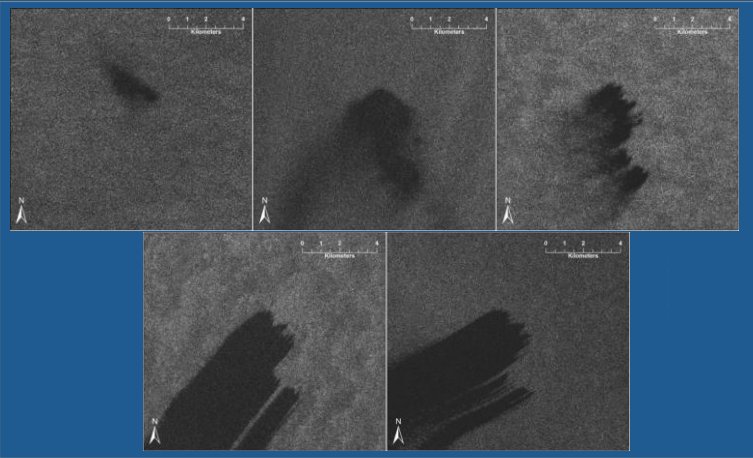
GOSD was originally formed predominantly of SAR data from the long-running ERS and Envisat satellites. However, the introduction of the Copernicus twin Sentinel-1A and -1B satellites has enabled NPA Satellite Mapping not only to continue recording sea surface oil slicks, but also to evolve their detection technique further, especially as the Sentinel imagery archive continues to expand.

One of the main challenges in utilising SAR data is that atmospheric and oceanic forces are the key drivers for slick formation and observations, and hence only a fraction of all available SAR data falls within the strict weather compliance guidelines. However, Sentinels regularly capture imagery of an area four times larger than historical missions, providing two significant benefits:

1. Larger areas are observed in advantageous weather conditions for the formation of oil slicks
2. Increased temporal repetition opportunities are observed with fewer images

Overall, the Sentinel-1 satellites can provide a higher quantity of imagery than was possible with previous SAR satellites, with better revisit time over a given area.

An example of the benefits that the Sentinel satellites have provided can be observed in the Gulf of Aden, where the Sentinel-1 satellites were the first to highlight seepage activity in a new frontier area in 2016, occurring over 100km away from the nearest exploration wells. 19 satellite images acquired across this site between 1997 and 2005 showed no prior indication of this seepage activity.



Seepage activity in the Gulf of Aden in 2016 and 2017
(Source: Sentinel-1 data processed by NPA Satellite Mapping)

OIL & GAS / CASE STUDY

Monitoring infrastructure in the case of natural gas storage e-Geos

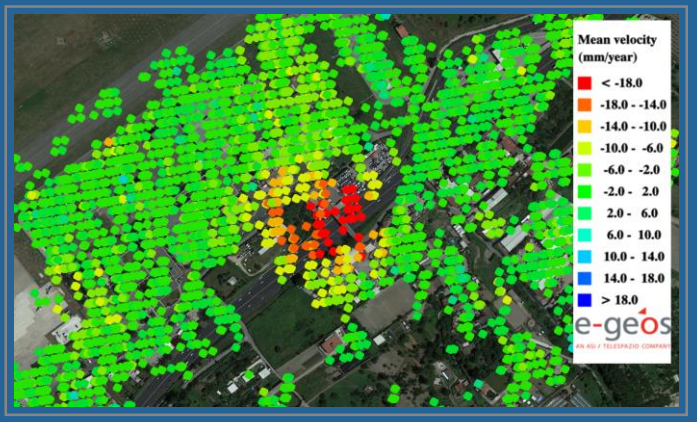
MONITORING OF NATURAL GAS STORAGE

CHALLENGES FOR THE NATURAL GAS SECTOR

Natural gas consumption is subjected to seasonal strong fluctuations. In fact, as it is used predominantly for heating, its natural production in warm seasons is usually higher than what the market requires. On the contrary, the demand for this resource in cold seasons is usually higher then the production. In this context, it is therefore important to store this resource properly. One of the methods is to store the gas into natural underground hollows, where the gas is injected in warm seasons, and extracted again in cold seasons. According to the terrain, this may have an effect on the surface that has to be monitored. These natural hollows usually cover very wide areas, and hence satellite InSAR technology, with its characteristics of high accuracy and wide coverage, can support these monitoring activities.

HOW COPERNICUS CONTRIBUTES TO INFRASTRUCTURE MONITORING

Stacks of Sentinel-1 data have been used as input for the interferometric analysis. Sentinel-1 SAR data allows the detection of slow deformations over wide areas, where buildings and other infrastructures are located. It means that, with respect to infrastructures, interferometric analysis obtained by Sentinel data can be used to identify areas subjected to major deformations, in order to then focus more detailed analysis (interferometric analysis with commercial high resolution sensors, or in situ real time monitoring with standard instruments).



InSAR analysis derived by Sentinel-1 data. Red points represents movements with velocity higher than 18 mm/year (Source: e-Geos)

USE OF COPERNICUS FOR NATURAL GAS STORAGE MONITORING

USE OF COPERNICUS IN THE CASE OF NATURAL GAS STORAGE MONITORING

One of the strongest points for the use of Copernicus data is the affordability of the acquisitions. For interferometric analysis, long stacks of interferometric acquisitions (same acquisition parameters) are needed: Copernicus Sentinel-1 acquisition plans ensure this continuity. The Sentinel-1 data are used to generate interferometric analysis of the area subjected to the injection/extraction process provide more understanding of the area impacted by it. The InSAR analysis helps to extract the evolution of the deformation and, consequently, to measure the amplitude of the displacement of the terrain. Sometimes natural phenomena may influence the terrain fluctuation; it is possible to subtract those seasonal deformation components to obtain correlation and deformation parameters highlighting the area most affected by the gas injection or extraction.

IMPACTS OF MONITORING

Thanks to the use of satellite InSAR technology, it is possible to monitor slow deformations with very high accuracy (millimetre measurements) over very wide areas. This is very useful in case major deformations are detected - in fact it allows the analysis of the overall area, and provides understanding of where it could be more useful to install sensors, saving absolute costs, maintenance costs and reducing the use of people in the field (which has always a certain level of risk).

Correlation among gas injected volumes and measured deformation by the use InSAR analysis derived from Sentinel-1. Red points have higher correlation. Graph compares gas volume I/E with INSAR measures (Source: e-Geos)

OIL & GAS / CASE STUDY

Preventing and managing oil spills
ATHENA

PREVENTION/MANAGEMENT OF MARINE POLLUTION FROM OIL OPERATIONS

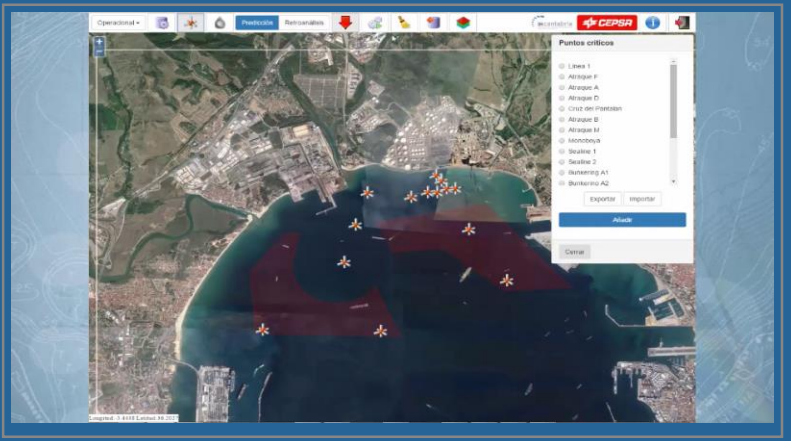
RISK OF MARINE POLLUTION FROM OIL OPERATIONS

Thanks to new legislation, oil companies are often legally responsible for ensuring their operations do not contaminate the surrounding environment, especially since oil spills can have disastrous environmental, social and economic consequences.

When working in offshore locations or in ports, it is therefore essential for the companies to monitor for leaks, especially when performing loading and unloading operations. If a leak does occur, it is also important for the company to be able to manage the fallout and understand where and how the oil spill may impact.

ATHENA PREVENTION AND RESPONSE SYSTEM

Athena is a system for the prevention and management of marine pollution caused by oil operations in both offshore and port environments. It has three different modules. Module 1 is an oil spill forecast and backtracking system with real time short-term oil spill trajectories and weather forecasting and backtracking using oil spill model TESEO. Module 2 meanwhile is a decision support system with operability conditions in real time, including warning criteria regarding the necessity of whether to halt or continue operations, and recommendation measures to reduce risk of contamination, as well as increasing security in operations. Finally, Module 3 is a planning system providing the probability of contamination from the critical scenarios identified. These are presented in a web service.



ATHENA
(Source: IH Cantabria, CEPSA)

USE OF COPERNICUS IN PREVENTION OF MARINE OIL POLLUTION

USE OF COPERNICUS IN THE PREVENTION/ MANAGEMENT OF MARINE POLLUTION FROM OIL OPERATIONS

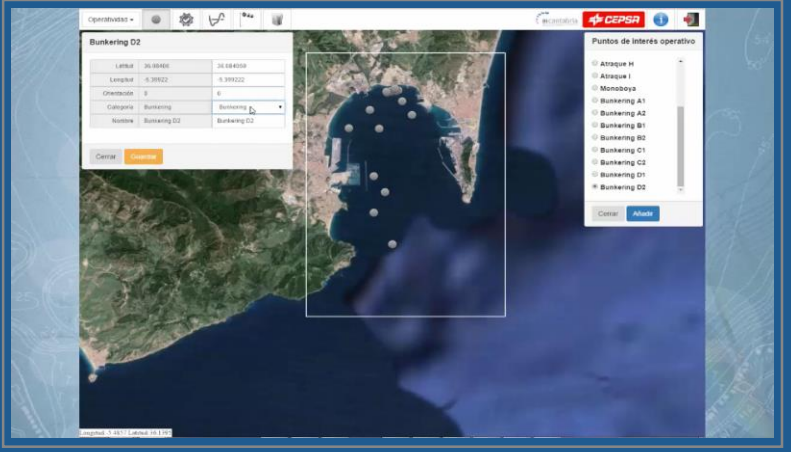
The ATHENA system was developed by the Environmental Hydraulics Institute “IHCantabria”, which is a joint research center that carries out research, knowledge transfer and training of specialists in the fields of fresh and saltwater.

Compañia Española de Petróleos (CEPSA), a Spanish multinational oil and gas company, had ATHENA installed at three CEPSA refineries, in Gibraltar, Tenerife and Huelva. First implemented in 2015, it has now provided more than 3,000 reports, with daily metocean reports for CEPSA operations. The web application allows ports to run the system in a way that is easy to use and obtain rapid information for efficient oil spill prevention and response.

The ATHENA system utilizes the Copernicus Marine Service Iberian Biscay Irish Ocean model for a near-real-time short-term (5-day) forecast for currents, waves and other oceanographic variables. It then utilizes the variable currents to strengthen the modelling of the spill trajectory for Module 1. The two products used are the physics analysis and forecast, and the ocean wave analysis and forecast.

ATHENA is beneficial for its users in a variety of ways, including:

- Providing the operating system with assistance in loading and unloading operations
- Providing the probability of arrival of pollution at the coast
- Providing the prediction of trajectories of possible spills during the loading and unloading operations and their inverse trajectory



ATHENA
(Source: IH Cantabria, CEPSA)

MONITORING OF RENEWABLE ENERGY

KEY TAKEAWAYS

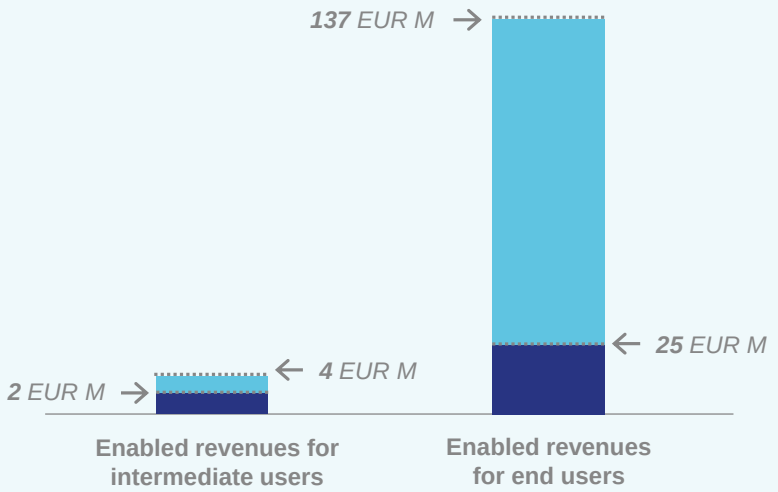
- This value chain focuses mostly on the main domains where Copernicus can provide crucial support, namely solar power, wind power and hydropower
- The global renewable energy market has been growing steadily in recent years, from representing 8.6% of the global energy mix in 2010 to a foreseen 22.5% in 2020.
- EO data are in most cases associated with meteorological data to support renewable energy activities.
- Environmental benefits resulting from the use of EO data and information in the renewable energy sector are significant and even bigger than economic benefits.
- Several Copernicus services can prove useful depending on the type of renewable energy supported. Both products from Copernicus services and raw Sentinel data are currently used by actors in the renewable energy sector.

COPERNICUS APPLICATIONS

- Siting plants and facilities (energy potential, environmental and social impacts)
- Optimised design
- Output estimates (e. g. based on plant characteristics coupled with forecasts)
- Production of forecasts (e. g. irradiance forecasts)
- Comparisons of actual output with the estimates

Copernicus economic impact (2018)

(Source: PwC)



KEY COPERNICUS PRODUCTS

- Raw data from Sentinel-1
- C3S ERA4 reanalysis
- CAMS aerosol, ozone, solar irradiance
- CMEMS ocean climatology and forecasts

MONITORING OF RENEWABLE ENERGY

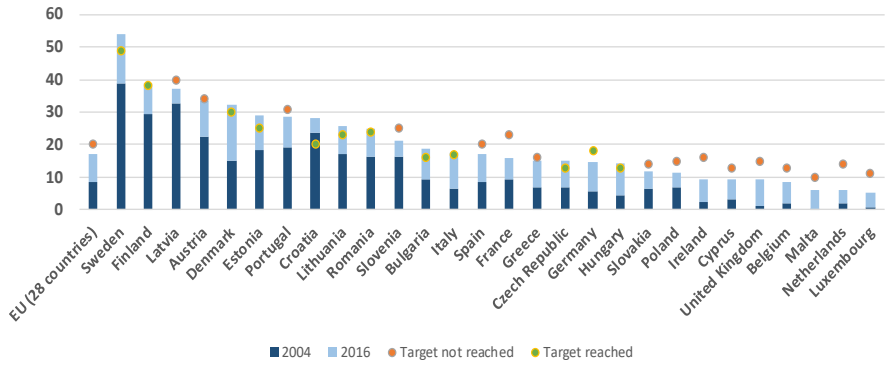
THE GROWING MARKET OF RENEWABLE ENERGIES

The current assessment evaluates the support renewable energy growth can receive from the use of Earth Observation data. Though renewable energy encompasses several types of energies (solar, wind, geothermal, tidal, wave, hydropower, biomass etc.), this report will only focus on the most developed ones currently utilized in Europe, which are wind and solar energy and hydropower, and will complement it with information on the other renewable energy sources. A particular focus will be given to renewable electricity, since this is one of the domains where Copernicus can contribute the most.

In 2009, the EU set within its renewable energy directive a binding target of 20% of final energy consumption from renewable sources by 2020, which varies in different targets among EU countries, the highest being the 49% renewable energy target of Sweden. In order to reach these, EU Member States have issued national renewable energy action plans detailing what they intended to do to achieve their targets. The objectives of this directive were further extended in 2014 as part of the EU's energy and climate goals for 2030, with EU Member States agreeing on a target of at least 27% of final energy consumption from renewable sources by 2030.

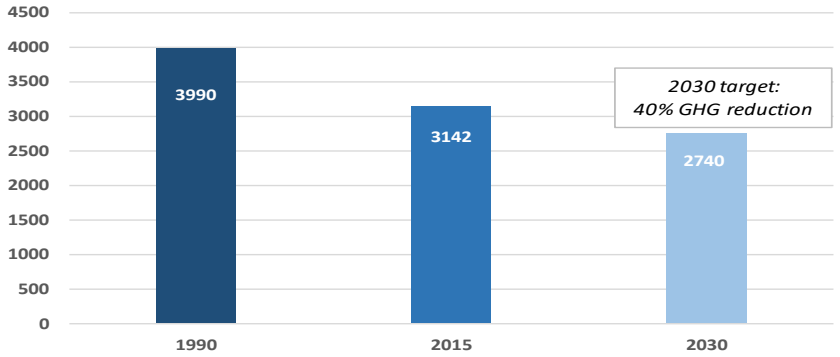
Sources: European Commission, IRENA

Share of energy from renewable sources in EU Member States in 2016 (in % of gross final energy consumption) (Source: Eurostat)



EU energy-related CO2 emissions (Mt CO2/year) – 1990, 2015, 2030

(Source: IRENA - Renewable Energy Prospects for the European Union, 2018)



Results from these measures already started to materialize, as using more renewables resulted in EUR 16 B saving in fossil fuel imports in 2015, projected to rise up to EUR 58 B in 2030. This ultimately leads to reduced CO2 emissions thanks to the transfer from a polluting energy source to a non-polluting one.

Solar and wind energy as well as hydropower are the biggest contributors to the targets for electricity and should continue to be so in the future. In recent years, these renewable energies have faced major cost reductions, in particular solar PV infrastructure and offshore wind energy, and these lower costs can push towards a bigger focus on these renewable energies to achieve the intended targets. In 2015, hydropower represented 38% of the renewable electricity production in the EU (compared to 70% in 2005, since this number has decreased due to the importance of solar and wind energy for electricity production), wind accounted for 31% (compared with 14% in 2005) and solar for 11% (compared with 0.3% in 2005).

Sources: European Commission, European Environmental Agency

MONITORING OF RENEWABLE ENERGY

EO DATA IS USED FOR HINDCAST, NOWCAST AND FORECAST OF RENEWABLE ENERGY PRODUCTION

Use of EO data for solar energy

EO data, and more specifically atmospheric (aerosol, ozone, irradiance) and meteorological (cloud, ozone) data can support both site selection, efficiency monitoring and production of solar power plants. Site selection is particularly key, as it is not only about determining the irradiance on a site, but is also about ensuring no dirt will affect solar panels (e.g. dust) and that sky conditions will be clear the majority of the time. As for energy monitoring and forecasting, the main interest of EO is to reduce uncertainties and ensure reliability of the estimations whose errors can lead to unforeseen costs.

Use of EO data for wind energy

EO data can support both onshore and offshore wind power plan site selection by providing information on wind conditions (past) that are key to power plant owners but also to researchers. As for forecasting, EO data can be useful; however, the final products that can currently be developed are often unable to address all end user requirements. EO data is mostly used as inputs in reanalysis models for onshore activities or in wind observations for offshore activities. In both case, EO data is needed at global level, considering wind has no boundaries. The wind energy market is, however, not very mature yet, and intermediate actors in this sector remain predominantly research centres, and research and development units of major VAS companies.

Use of EO data for hydropower

Combined with in-situ data, EO data can be key in the business of hydropower. The data used ranges from temperature data, to precipitation and meteorological data, land cover and land change, and water flow models. The data is mostly free but can be complemented by commercial data for applications specific to localized areas. EO is notably used to analyse the volume and distribution of snow, as well as its melting, but also to understand current water resource availability on the market. All this enables the provision of crucial information to managers of dams.

WHY EARTH OBSERVATION?	APPLICATIONS	BENEFITS	END USERS
RENEWABLE ENERGY MONITORING	• Site selection and design of plants or facilities • Production efficiency monitoring • Energy production forecasting • Energy production surveying • Environment monitoring • Tracing biomass and monitoring production	• Selection of the most productive energy production site • Competitive advantage • Understanding of the causes of productivity losses • Reduced negative impact of a plant or piece of infrastructure on the environment and health • Compliance with regulations	• Suppliers to energy providers • Energy providers • Electricity grid managers • Public authorities • State and local decision makers • Biomass producers • Dam managers
RENEWABLE ENERGY EXPLOITATION	• Energy trading • Environment monitoring • Enhancement of energy production	• Environmental and social impacts • Gain in competitiveness • Early and cost-effective detection of failure • Improved integration of the produced electricity on the grid • Optimized trading revenues • Compliance with regulations	• Utilities • Energy providers • Electricity grid managers • Energy and carbon traders • Public authorities • State and local decision makers • Biomass producers • Dam managers • Citizens

MONITORING OF RENEWABLE ENERGY

DRIVERS AND CHALLENGES FOR THE UPTAKE OF EO FOR RENEWABLE ENERGY MONITORING

Renewable energy development appears as one of the targets found in most policies, directives and agreements aimed at fighting global warming or fostering clean energy. EO has the potential to support the growth of renewable energy by providing information that can reduce production costs, improve profitability and thus lead to a competitive advantage.

One of the major costs linked to renewable energy power plants are O&M (operation and maintenance) activities. EO images have the ability to provide information to help avoid failures of power plants by anticipating damaged infrastructure but also to avoid unnecessary preventative repair and maintenance activities.

Fewer failures would enable an increased productivity of the power plants. This increased productivity is linked both to an improved site selection, by choosing the location that should enable the greatest yield, and to better forecasting.

As a result, bigger reliance on renewable energy activities thanks to the provision of key inputs by EO data can support the goal of reducing greenhouse gas (GHG) emissions.

DRIVER 1

There is an increasing demand for renewable energy over the globe and in Europe, considering directives such as EUROPE 2020 strategy or the COP21 agreement

DRIVER 2

The potential scarcity of fossil energies makes it easy for renewable to appear as a reliable and sustainable energy source from a long-term perspective

DRIVER 3

EO is an interesting tool from the perspective of increasing the share of renewable energy, as it enables optimization of the production

CHALLENGE 1

Renewable energy sources are particularly sensitive to environmental conditions (e.g. clouds for solar energy) and satellite images cannot always help anticipate these

CHALLENGE 2

The accuracy provided by EO data does not make errors fully disappear

Environment conditions are key for efficient functioning of renewable energy power plants and the production of the expected amount of energy. For instance, a solar photovoltaic (PV) power plant subject to desert dust or dirt will not be able to work at full efficiency, leading to energy losses. As such, elements such as dust winds or air pollution need to be monitored precisely through EO data to ensure forecasts are done precisely. However, irradiance products are often only efficient under clear sky conditions, and hence not all of the time. Considering errors in forecasts can have significant economic consequences, EO is still facing challenges in that field.

Indeed, errors in forecasts or nowcasts can have two consequences: first, it can lead the power plant owner to think there is a problem in the infrastructure and to engage in costly repair and maintenance activities for nothing; second, on the energy trade side, penalties can be given in order to enable the energy buyer to compensate for what he was expected to receive (this is particularly true for solar PV electricity). As such, EO data used as inputs for production prevision need to be as accurate as possible.

MONITORING OF RENEWABLE ENERGY

THE VALUE CHAIN OF EO DATA FOR THE RENEWABLE ENERGY SECTOR

ACQUIRING EO DATA

EO Data

- Copernicus
  - CAMS (Aerosol analysis, ozone, dust, water vapour, solar irradiance, clear sky products such as McClear, near-real time parameters) notably for solar
  - CLMS (digital elevation models, land cover type and change data, land surface temperature data, snow cover information) for wind and solar
  - CMEMS (wind, current, tides, sea surface temperature climatologies and forecast) for marine renewables
  - C3S (ERA5 reanalysis) notably for wind
  - Sentinel-1 notably for hydropower and high resolution winds
  - *Sentinel-4 notably for solar (future mission)*
  - *Polar mission for hydropower (potential future mission)*
- National missions (NOAA, JAXA)
- Meteorological satellites
- ECMWF data (reanalysis products) notably for wind
- NASA data (MERRA2)
- MODIS

Historical information

- ENVISAT
- Climate aerosol mean models notably for wind

In situ data

- Measured output

PROCESSING NEEDS AND CAPABILITIES

Data processing platforms

- ESA Urban TEP, PEPS

Systems and data logging devices

- Area-specific

In-house capabilities

- Data assimilation
- High-end climate modeling and computing
- Area-specific knowledge
- SAR expertise

Plant characteristics

Socio-economic data

USERS & NEEDS

Non exhaustive list

Site selection

- Siting plants and facilities (energy potential, environmental and social impacts)
- Optimized design
- Output estimates (e. g. based on plant characteristics coupled with forecasts)
- Mappings and elevation maps (e.g. wind farms, biomass)
- On demand maintenance

Plant output forecasting

- Production of forecasts (e. g. irradiance forecasts)
- Economic analyses of investment

Efficiency monitoring

- Comparisons of actual output with the estimates
- Better integration into the grid

Carbon sequestration estimation

Risks management

MONITORING OF RENEWABLE ENERGY

DEPENDING ON THE FIELD OF ACTIVITY, DIFFERENT TYPES OF COPERNICUS DATA ARE USED

Solar PV

Actors involved in solar energy and using EO are mostly relying on CAMS products through aerosol analysis and forecasts, global solar irradiance, ozone and water vapours. Raw Sentinel data is currently barely being used in this field. Without Copernicus services, an alternative would be aerosol climatological averages that are not as high quality or accuracy.

Wind energy

Several Copernicus services are key to the wind energy sector. First, CLMS provides global observation of wind characteristics, CORINE Land cover (used for positioning wind turbines) or the Digital Elevation Model (used to study the relief). Second, the C3S ERA5 reanalysis product is key to deriving wind information. Finally, CMEMS offers a product dedicated to sea surface winds (essential for offshore wind turbines).

Hydropower

In the hydropower sector, it is rather raw Sentinel-1 data that raise interest and are key to forecasting water evolution. Raw data is preferred to the currently available Copernicus products because they serve as inputs to existing models and leave more flexibility for the service developer to adapt to the specific needs of its clients. Indeed, products can strongly vary from one region to another, as well as between clients. Copernicus usually only represents about 20-25% of the final product delivered.

	Copernicus strengths	*Copernicus weaknesses*
The global coverage provided by Copernicus is key to all renewable energy sectors. Indeed it implies that final models, once developed, can be sold anywhere in the world. Moreover, wind, solar or water are domains that are transboundary, hence the need to survey them on a large scale.	*GLOBAL COVERAGE*	
Before the availability of Copernicus, the renewable energy sector was reliant on climatological averages that were not renewed regularly, thus increasing the uncertainty of their models. Copernicus reinforces the reliability of the models built on it.	*PROVISION OF HIGH QUALITY DATA*	
		PARTIAL ACCESS TO INPUT DATA USED IN PRODUCTS — The reluctance to use some Copernicus products often lies in the fact that the user lacks precise information on the input data that feed a product, and hence do not always have confidence in the results. This is often due to the fact that this input data come from Contributing Missions and are not available as such for free.
		SENTINEL RESOLUTION NOT SUITABLE FOR SOME APPLICATIONS — Even if users are globally satisfied with the resolution provided by Copernicus for applications in the field of renewable energy, it does not enable users to study the area at the level of a dam or a wind turbine. That implies that there is still a need for costly commercial data to compensate for this.
		FREQUENCY OF UPDATES — In the case of hydropower, clients would expect daily updates whereas Copernicus data provides only 2 to 3 updates per week.

MONITORING OF RENEWABLE ENERGY

COPERNICUS BENEFITS FOR THE RENEWABLE ENERGY SECTOR

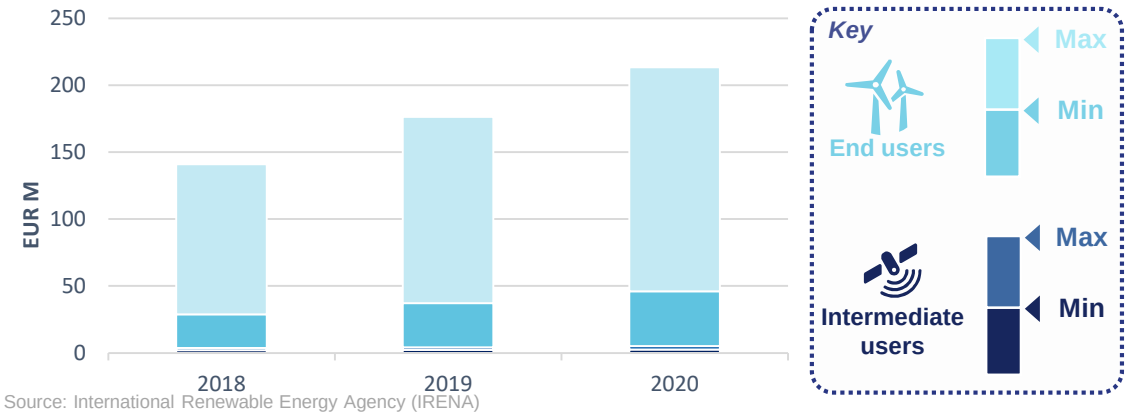
Out of the 10.3 million people employed in the renewable energy sector in 2017, 1.268 million were in Europe, compared to 1.16 million in 2015. 27% of these jobs are in the wind power sector, 6% in hydropower and 11% in solar energy. The availability of Copernicus data to support site selection and production forecasting should further increase job creation in this field, in particular for solar PV, which is the renewable sector that has faced the biggest employment increase in the last 5 years. This job creation will result from the extension of the renewable energy farms, from the creation of new types of jobs linked to the management of the intermittency of renewable energies, and from the rising need of smart cities management.

Economic benefits for intermediate users are linked to site selection and management (cost reduction on maintenance) and production forecasting (linked to a decrease in penalties). In 2018, it amounted to between EUR 2 M and EUR 3.6 M.

End user benefits are larger and encompass both economic impacts such as increased profitability from renewable energy production, as well as environmental and social impacts such as reduced GHG emissions and saved water. In 2018, it amounted to between EUR 25.3 M and EUR 137.3 M

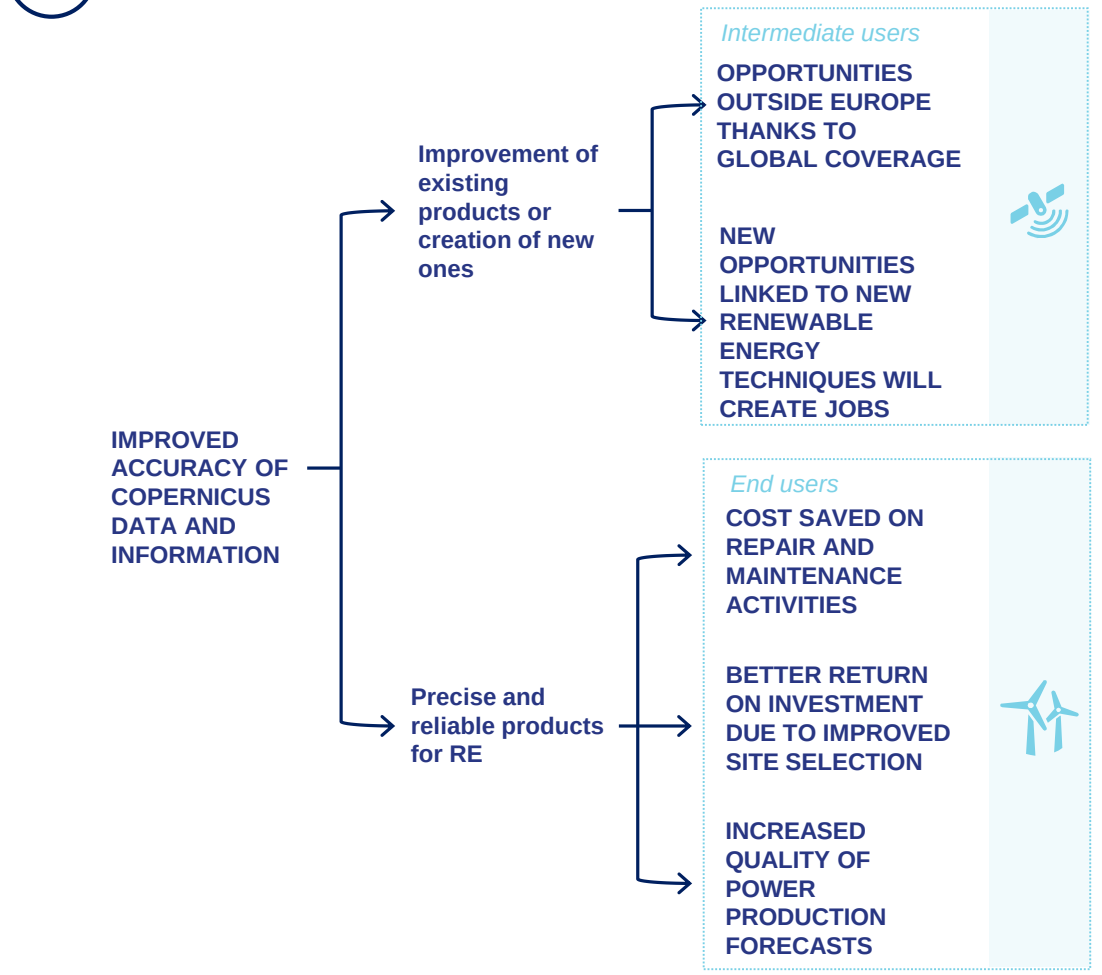
Economic benefits of Copernicus through its contribution to renewable energy monitoring

(Source: PwC)



Source: International Renewable Energy Agency (IRENA)

Economic impacts

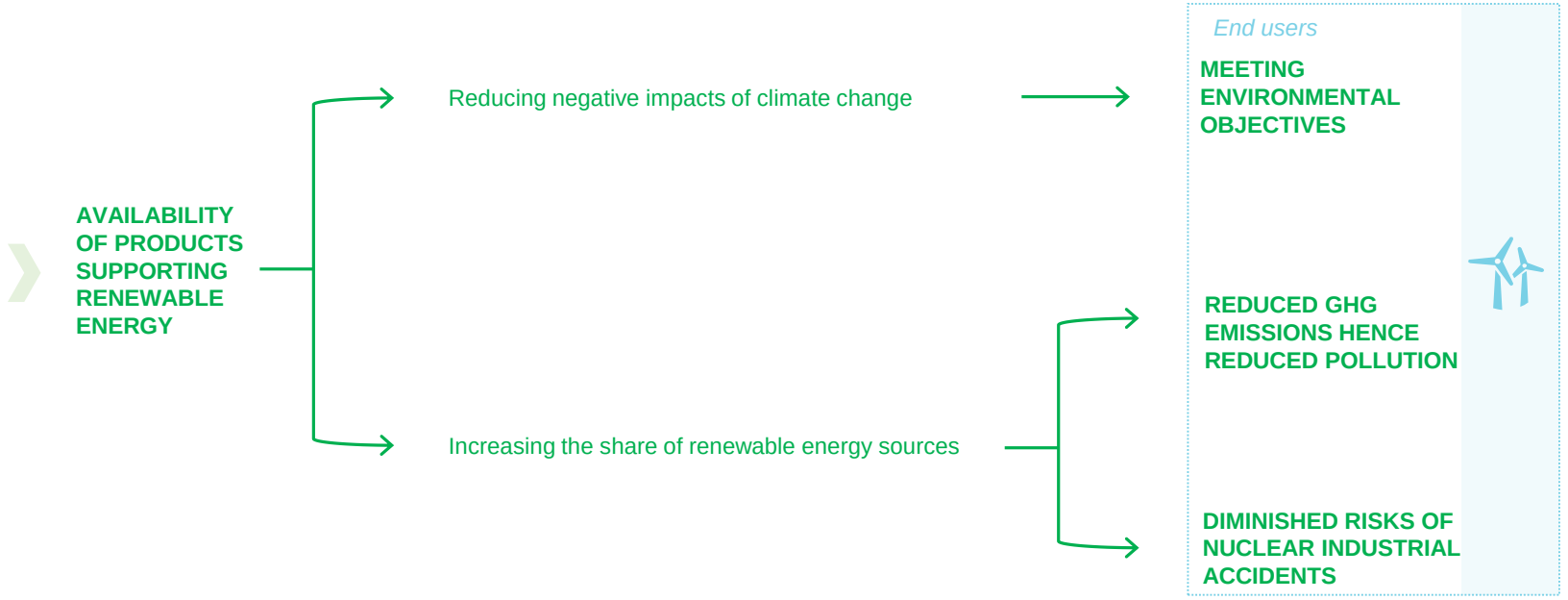


MONITORING OF RENEWABLE ENERGY

COPERNICUS BENEFITS FOR THE RENEWABLE ENERGY SECTOR

Environmental impacts

The availability of Copernicus data and products that support the fostering of renewable energy is key for the environment, as it will help to decrease the reliance on fossil energies and thus the emissions of GHG resulting from the use of such polluting energies, as well as on nuclear energy, hence diminishing the risk of industrial accidents and the impact of radioactive waste. This should also contribute to the targets fixed as part of environmental directives such as the COP 21.



MONITORING OF RENEWABLE ENERGY

COPERNICUS BENEFITS FOR THE RENEWABLE ENERGY SECTOR

Social impacts

The use of renewable energy helps to save water that is usually used for cooling purposes during fuel combustion of fossil energies. Considering how important water is today, this impact is non-negligible. Copernicus can also indirectly have social impacts on end users as the bigger the share of renewable energy sources, the less GHG emissions (toxic for human beings) there will be. Thus, improved public health and smaller health expenditures should occur.

INPUTS DATA FOR GREATER RENEWABLE ENERGY PRODUCTION MODELLING → Decreasing the share of fossil fuel energy sources →

End users

- **IMPROVED AIR QUALITY**
- **SAVED WATER**

Strategic impacts

By supporting the development of renewable energies, Copernicus will ultimately favour the security of energy supply. First, because it enables the diversification of the energy mix by installing renewable energy power plants and second by helping to ensure the amount of energy that can be produced thanks to more accurate forecasting. This aspect is all the more strategic as some fossil energies will be scarce in the near future and the others are highly volatile in terms of price. Being able to accurately determine the location and future production of a renewable energy site is thus key to avoid the negative impact scarcity and imports have on energy prices

Bigger accuracy on energy production →

Decreased default production →

End users

- **HELPING MATCH NATIONAL STRATEGIC CHOICES THAT PUSH TOWARDS RENEWABLE**
- **POSITIVE IMAGE AND PRESTIGE WORLDWIDE FOR EUROPE AS A LEADER IN THE FIELD OF EO**
- **IMPROVED SECURITY OF ENERGY SUPPLY**
- **SMALLER FINANCIAL BURDEN**

MONITORING OF RENEWABLE ENERGY / CASE STUDY

Using Copernicus to support solar PV forecasting
Steadysun

NEEDS AND CHALLENGES AROUND THE RENEWABLE ENERGY SECTOR

SOLAR PRODUCTION CHALLENGES

The European Union has recently established a policy aimed at reaching a **32% target of energy coming from renewable energy sources** in the final energy consumption by 2030. Among these renewable energy sources, solar energy (and in particular solar PV) is expected to play a growing role. However, **forecasting solar production is a significant challenge** as it requires the anticipation of the down-welling surface solar radiation variability - which is mainly driven by clouds and the atmospheric composition (aerosols, ozone, water vapor, etc.).

STEADYSUN'S WORK ON SOLAR PV

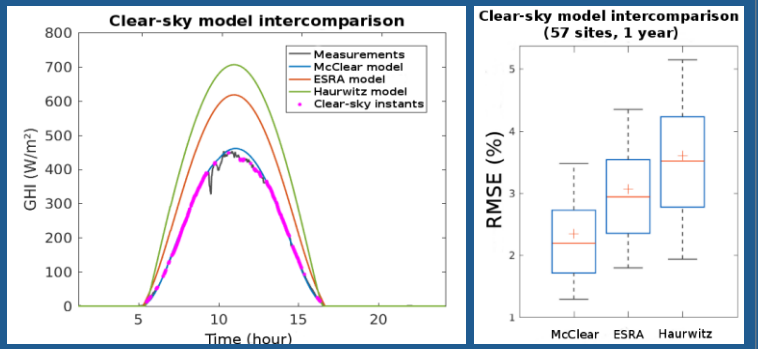
Steadysun is a leading French solar production forecasting provider. Their business solutions are designed to anticipate the solar energy injection variability into the electrical networks (transmission and distribution), to reduce power plant operation costs, to optimize portfolio asset management, to maximize self-consumption and, at the end, to allow an efficient integration of the solar energy in the grids. Steadysun's solar production forecasting services cover all types of solar technology, any size of installation and aggregation (from a few kW to a whole country), and a worldwide geographic area. They deliver high accuracy forecasts at horizons spanning from 1 minute to several days ahead using Numerical Weather Prediction (NWP) models, satellite imagery and ground-based sky images. For instance, Steadysun's services can anticipate the impact of dust daily variability, which may reduce the Direct Normal Irradiance (DNI) by 40-50% in extreme cases, with a strong impact on solar production. This is especially true for Concentrated Solar Power (CSP) technologies located in Northern Africa and Middle East region.

COPERNICUS CONTRIBUTION TO SOLAR PV

USE OF COPERNICUS TO SUPPORT SOLAR PV

In order to estimate the solar resource in cloudless conditions, Steadysun's forecasting solutions rely on the McClear clear-sky model. The model ingests aerosols and ozone concentrations from the CAMS real-time forecast up to 5 days ahead. This helps, amongst others, to correct the down-welling surface solar radiation from NWP models that only take into account normal atmospheric aerosols concentrations through climatologies.

Steadysun has conducted a clear-sky model inter-comparison study in order to quantify the benefits from using the McClear-CAMS clear-sky model compared to the use of classical models that are based on climatologies of Linke turbidity factor (ESRA) or on the sun position only (Haurwitz). The figure at left shows an example over one day for a site in China during an extreme air pollution event, where only the McClear-CAMS model was able to estimate accurately the Global Horizontal Irradiance (GHI). Steadysun shows that the forecasting errors due to aerosol-radiation interactions reduce significantly using a state-of-the-art clear-sky model combined with real-time forecast of the atmospheric composition provided by CAMS. The observed accuracy improvements compared to a standard model without CAMS data is about +20% and +30% regarding the GHI and DNI components respectively, based on Root Mean Square Error over clear-sky instants on average over 57 sites during one year under different climate conditions worldwide (figure on the right).



Clear-sky model inter-comparison over one day for one site (left) and for 57 sites worldwide (right) (Source: Steadysun)

MONITORING OF RENEWABLE ENERGY / **CASE STUDY**

Reducing wind project feasibility uncertainty and boosting site screening

Vortex

NEEDS AND CHALLENGES AROUND THE WIND ENERGY SECTOR

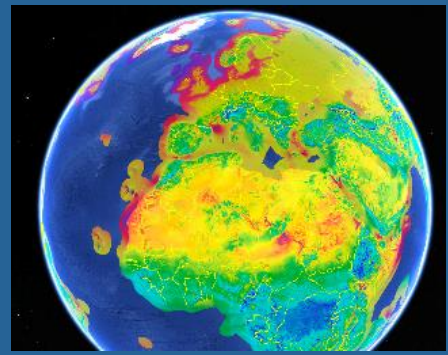
WIND ENERGY CHALLENGES

12% of EU power demand is provided by wind today – corresponding to 173 GW. The wind industry is a European industry: European wind turbine manufacturers represent 46% of the global market. The full supply chain represents 263,000 jobs, EUR 5 billion fossil fuel savings and EUR 22 billion investments in 2017. Wind will become the largest power source in the EU, reaching 32% by 2040 according to the International Energy Agency. Wind energy is a global market which is expanding rapidly to new regions; therefore, the need for global and local accurate model information where no other sources are available is a must to boost project develop and to scale-up wind energy across different markets.

VORTEX'S ACTIVITIES

Long-term uncertainty is one the main drivers of wind project feasibility uncertainty. Virtual wind time series have been adopted by the industry as a reliable source of information to calibrate energy estimation in the long-term. The lower the uncertainty in the project feasibility, the higher the return on investment and the profitability of the project.

Vortex delivers information and solutions for the wind industry which fulfill users' demands for accurate resource information at any stage in the project lifecycle and for any location in the world. Vortex wind resource data production is based on a multiscale downscaling model driven by hindcast data provided by Copernicus ERA5 Reanalysis. Vortex provides on-demand regional mapping products, site-specific assessments and long-term virtual series through a user-friendly online interface: interface.vortexfdc.com.



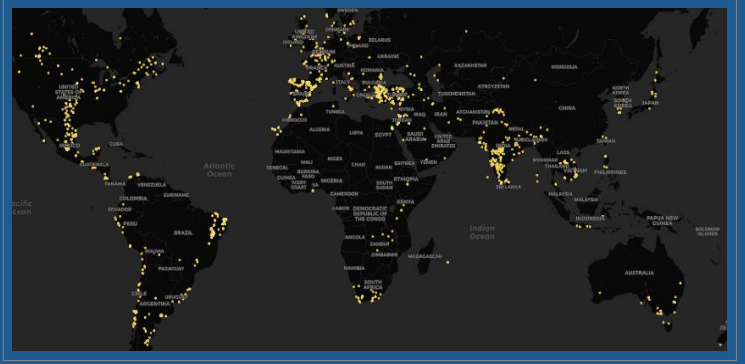
World Bank Global Wind Atlas layer produced by Vortex modeling system using ERA5 as input dataset (Source: Vortex)

COPERNICUS CONTRIBUTION TO WIND ENERGY

USE OF COPERNICUS TO SUPPORT WIND ENERGY

Copernicus ERA5 data stream has been implemented in the Vortex system since mid 2017. Vortex has carried out an intensive validation program to assess the performance of the wind resource virtual using ERA5 and based on measurements shared by Vortex users for more than 1500 sites across the world. Results from the validation exercise confirm the added value of ERA5 as input data. In particular, a reduction of 3% of global average wind speed bias and increase in correlation of ~ 0.1 for more that 75% of the sites have been found. As rule of thumb, a reduction of 1% in the project uncertainty implies an increase of the project feasibility by EUR 1 million for a typical 100MW windfarm project. Vortex provides information for more than 50 wind farm project developments per day.

The implementation of ERA5 as part of the Vortex system can be estimated to have an impact of a net average reduction of uncertainty of 1-3 %, depending on the regions of the world, which can thus be translated into EUR 1-3 million per 100 MW project return. Copernicus ERA5 has been proved to reduce substantially uncertainty in the Vortex modeling stream and, as by product, increased the project feasibility robustness which facilitates the profitability of funded projects.



Sites employed in the validation of Vortex virtual time series, using ERA5 data (Source: Vortex)

MONITORING OF RENEWABLE ENERGY / **CASE STUDY**

Photovoltaic power production forecast using CAMS
Reuniwatt

Reuniwatt

NEEDS AND CHALLENGES AROUND THE SOLAR ENERGY SECTOR

SOLAR PV MARKET

Once a solar PV power plant central is operational, the power plant owner sells the PV electricity to the local network manager and the production is then bought by a utility. Network managers have specific requirements for PV production forecasts:

- Day-ahead forecasts need to be sent each day at 9:00 and 21:00 (local time)
- The 9:00 forecast covers the hours from 9:00 to 0:00 (time horizon of 15h)
- The 21:00 forecast covers the hours from midnight until 9:00 of the next day (time horizon of 9h)
- Forecasts are delivered under the form of hourly time series

These forecasts are key: if the daily production represents less than the forecast, the utility will buy what has been produced, but if the daily production exceeds the forecast, the utility will buy the lowest value between the effective daily production and an additional 8% to the forecasted PV power. If the error between the forecast and the production is greater than 8%, the power plant owner will receive penalties that results in the energy output that the utility is obtaining but not purchasing from the producer (daily production minus 108% of the PV energy forecast).

REUNIWATT FORECASTING TECHNIQUES

The main variable to the forecasts is the GHI (Global Horizontal Irradiance), that is derived by multiplying a cloud cover index with the GHIcs (i.e. the GHI under clear sky). It is forecasted and converted into power according to PV plant characteristics (capacity, PV technology, PV panels orientation, thermal capacity of PV panel).

Two inputs are used by Reuniwatt for GHI forecasting techniques:

- Satellite data for short-term forecasts (up to 6 hours)
- Weather models for long-term forecasts (from 6 hours)

Forecasts are delivered as a time series mixing both technologies with weighted smoothing between satellite forecast and weather models.

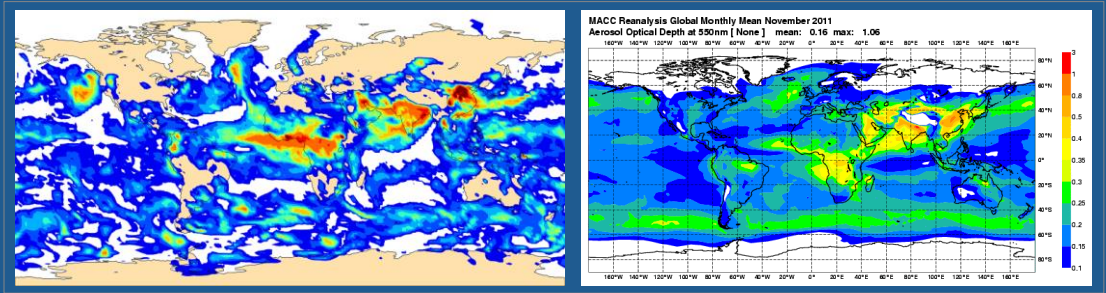
COPERNICUS CONTRIBUTION TO SOLAR ENERGY

USE OF COPERNICUS TO SUPPORT SOLAR PV FORECASTING

Copernicus is key to obtaining an accurate GHIcs. GHIcs necessitates three components: the solar zenith angle (which is perfectly known with astronomical computation); the ground albedo (which is available through open source databases and depends on ground color of the surrounding area); and atmospheric components (e.g. water vapor (delivered by CAMS after 2 days or by regular weather services), aerosol concentration (delivered by CAMS both in real-time and forecast), ozone concentration).

Should Copernicus not be available, the alternative to obtaining aerosol concentration would be to use monthly climatology averages. The advantage of this technique is that it is operationally easy to use. However, the drawback lies in the fact that if aerosol concentration suddenly increases (because of remote dust storm, heavy pollution, volcano eruption, high sea waves, etc.) or decreases, the climatology provides wrong values. Generally, the forecasts without CAMS impact the instantaneous GHIcs value of 7% in relative error.

For a power plant located in a savanna tropical climate with a capacity of 50MWpeak, 1 MWh costs USD 80. The annual production is of 105 885 MWh per year and the relative penalty with CAMS is of 1.51% whereas it is of 1.61% without CAMS. This represents respectively 1602.7 MWh and 1708.2 MWh, hence a gain with CAMS of 105.5 MWh less in penalties. This would represent for such a power plan USD 8,440 saved per year.



Forecasts of total aerosol optical depth (left) and monthly mean of total aerosol optical depth (right). The map of the monthly mean shows a smooth pattern neglecting higher temporal variations which are better taken into account by forecasts data (Source: CAMS)

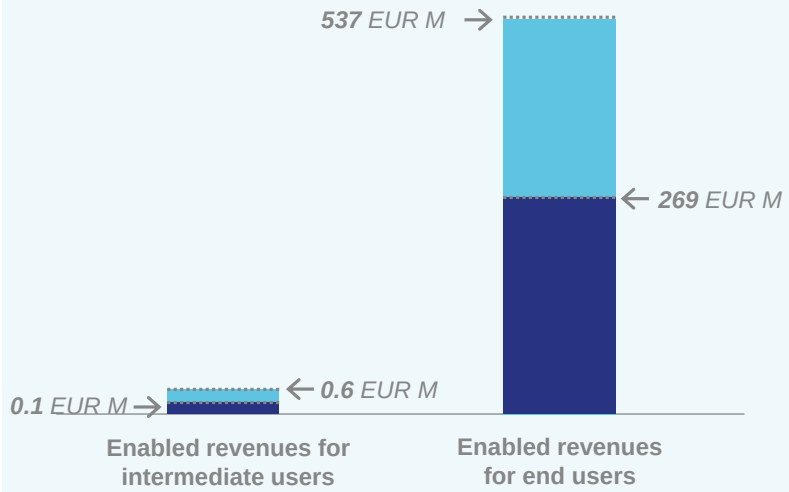
MONITORING OF AIR QUALITY

KEY TAKEAWAYS

- EO data on atmospheric composition has only recently started to contribute to air quality models, which used to rely mostly on meteorological data, air composition statistical data and measurements, and on ground measurements.
- Intermediate users remain mostly public actors (public authorities, meteorological and environmental agencies, research centres, etc.); however, a market is starting to develop among private companies. As of 2018, it remains a niche but is expected to expand with the improved accuracy and quality of EO input data in models.
- End users can be any citizen (as emphasised by the applications and services freely available to inhabitants of a city or tourists). Besides this, public authorities tend also to pay attention to air quality products in order to implement the right policies on pollution, as well as to provide advice to citizens on potential allergy risks.
- There is still a reluctance from end users to pay for air quality information, though this is slightly changing with the improvement of the services offered. Some categories of the population are more willing to invest in such a service than others, notably families with children and the elderly.
- CAMS is the Copernicus service that can best support activities in the field of air quality thanks to its near-real time analyses and forecasts provided, such as the global and regional air quality models

Copernicus economic impact (2018)

(Source: PwC)



COPERNICUS APPLICATIONS

- Support to policy making related to environment
- Estimation of policy efficiency and target achievement
- Development of maps providing air quality information, enabling conscious decisions to be taken
- Monitoring of compliance with limit values set for private companies

KEY COPERNICUS PRODUCTS

- CAMS global and regional air quality analysis

MONITORING OF AIR QUALITY

AIR QUALITY: A PUBLIC HEALTH MATTER

The current assessment looks at the monitoring of air quality for different purposes (pollution, allergies, etc.) that can all have an impact on public health.

Indeed, exposure to polluted air affects everyone (though the type of pollution may differ from one region to another): young and old people, all parts of the world, whether urban or rural areas, High-Income Countries (HICs) as well as Low and Medium Income Countries (LMICs), etc. Of course, among these categories, some are more affected by air pollution than others. For instance, 98% of all children under 5 years in LMICs are exposed to levels of fine particulate matter (PM2.5) higher than the World Health Organisation (WHO) air quality guideline levels whereas it is the case for only 52% of all children under 5 years in HICs.

As a result, each year 7 million people die because of polluted air, which makes air pollution the world's largest environmental threat to public health. Bad air quality can not only be the direct cause of these deaths but it can also exacerbate existing diseases in an individual (e.g. cancer, asthma, heart problems, pulmonary issues). The main substances found in the air and affecting the health are nitrogen oxides (NOx), sulphur oxides (SOx), ozone and particulate matter (especially those below 2.5 microns (PM 2.5)). Even though air quality has improved significantly in past decades, notably in Europe, air pollution concentrations remain high and a large proportion of Europe's population lives in areas with air pollution above EU limits. For instance, in Europe, 90% of the citizens are exposed to annual levels of outdoor fine particulate matter that are above WHO air quality guidelines.

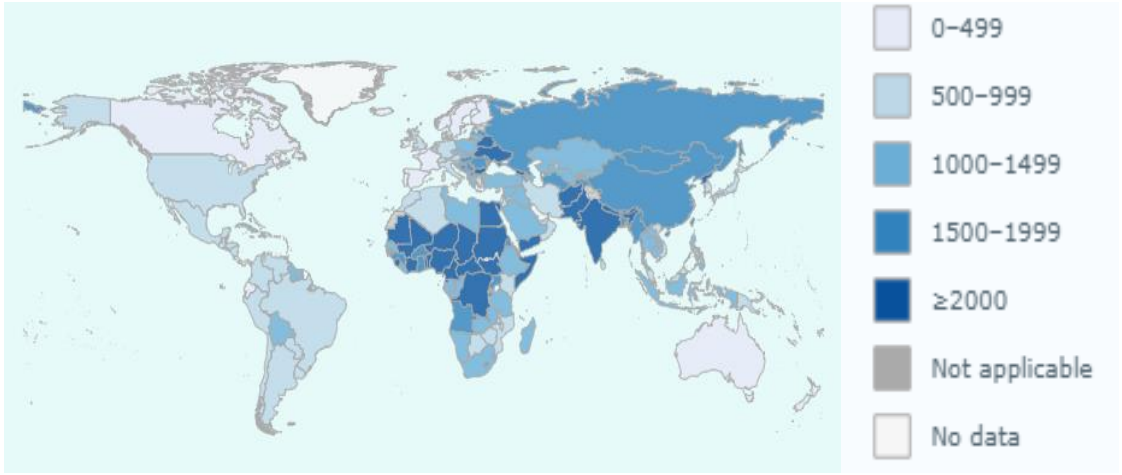
Air quality information is useful for both individual matters, as every citizen disposing of information on the air quality in his/her environment can decide to knowingly take actions (e.g. avoiding doing sport when the pollution rate is too high, not going in specific areas when there are risks of allergies due to significant pollen rate) and for collective matters, as public authorities and policymakers can use air quality data to propose policies aimed at reducing pollution and meeting the EU air quality targets. If it appears that near-real time information is key for individual use, forecasts and hindcasts are also necessary to take longer term actions.

Besides a direct impact on public health, air quality information is also a good indicator of climate evolution and an incentive to take action to protect the environment.

Sources: World Health Organisation, United Nations Economic Commission for Europe, European Environmental Agency

DALYs* attributable to ambient air pollution (per 100 000 population) in 2016

(Source: WHO – Global Health Observatory (GHO) data)



** One DALY (Disability-Adjusted Life Year) can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.*

MONITORING OF AIR QUALITY

EO DATA CAN BE A SUPPLEMENTARY TOOL IN THE RETRIEVAL OF AIR QUALITY INFORMATION

Air quality has a cost that EO can help diminish

In 2015, the cost of premature deaths from APMP (Ambient Particular Matter Pollution) and AOP (Ambient Ozone Pollution) in Europe represented about EUR 750 M in Europe, which is 4.5% of its GDP, and health expenditure related to pollution amounted to about EUR 580 M in 2016. Considering the importance of the economic impact of air pollution, the improvement of air quality models accuracy is key and there is room for services as the air quality monitoring market is growing. Indeed, the air quality monitoring market is expected to grow at a rate of 4.6% per annum from 2017 to 2022, reaching EUR 430 B by 2022.

Sources: OECD ; A.L. Preker et al. "Helath Care Expenditures Associated with Pollution: Exploratory Methods and findings ; MarketsAndMarkets

Satellite data combined with on-ground measurements for improved products

In the early-2000s, there was only one satellite able to provide information to support the monitoring of air quality: ENVISAT. Since then, several satellites have been launched (and some are planned to be launched, such as Sentinel-5) and are able to provide measurements of carbon emissions, ozone concentrations, and several other pollutants emissions such as particulate matters. As a result, satellite data on atmospheric composition has recently been incorporated into air quality models. Before, on-ground measurements were the basis of air quality models, but satellite data provides the advantage of being able to cover large areas, and therefore to anticipate trends by comparing regions. The combination of satellite data and on-ground measurements is key to the improvement of the accuracy of air quality models.

Use of EO data in the air quality monitoring sector

The main reasons why EO data has been incorporated in air quality products is that these products contribute to policy and regulations by helping set limit values and control whether they are met, and also that there has been a growing demand from the population to distribute applications enabling them to take actions when there is a pollution peak for instance.

WHY EARTH OBSERVATION?	APPLICATIONS	BENEFITS	END USERS
AIR POLLUTION	• Urban air nowcasting and forecasting • Pollutant fluxes tracking • Local scale air quality analysis • Hot spots detection	• Provision of inputs for local public health and climate change policies • Transparency with the citizens • Identification of polluters • Scientific research • Local environmental impact assessment • Identification of critical areas in a region • Stimulate tourism for people with health issues	• Citizens • Municipalities • Public authorities • Research centres • Companies such as industries, airports, waste management companies etc. • Institutions
ALLERGY MONITORING	• Pollen fluxes tracking • Environmental health issues mapping • Pollen trend forecasting	• Local environmental impact assessment • Ability to decrease risks linked to allergies • Decision of public authorities to issue allergies alerts • Identification of allergy causes	• Citizens • Medical institutes • Research centres • Public authorities

MONITORING OF AIR QUALITY

DRIVERS AND CHALLENGES FOR THE UPTAKE OF EO FOR AIR QUALITY MONITORING ACTIVITIES

According to the European Association of Remote Sensing Companies (EARSC) 2017 Industry Survey, out of all of Copernicus' six services, the interest in the atmosphere service represented 8% of the interest of the companies surveyed, which made this service the 4th most interesting one to users, slightly behind the emergency service (9%) and the marine service (13%). This represents an improvement compared to the EARSC 2015 Industry Survey, where atmosphere was the service industries were least interested in. The growing interest of the industry sector for air quality matters represents an opportunity for the EO sector, as EO data presents some advantages over on-ground measurements in the development of an operational service: the ability to provide a global coverage (which is key in a domain where there are no borders), the ease of downloading data on specific areas without having to engage with local in-situ data owners, and the ensured provision of continuous data availability.

This growing interest from the industry also takes form in the increased willingness of citizens to become aware of decisions for their activities. For instance, tourists, and more specifically elderly and families with young children, are more and more willing to pick a travel location that would cause minimum health risk to them, hence a bigger market for air quality applications.

DRIVER 1

Industry starts to become interested in being involved in air quality matters, which used to be mainly dealt by public sector bodies

DRIVER 2

Citizens pay bigger attention to air quality and how pollution affects them

CHALLENGE 1

Key users are often public authorities who do not have the necessary budget to turn to the commercial data they need for their project

CHALLENGE 2

The lack of willingness of end users to pay for air quality services implies specific attention should be paid by industries on the investment made into data

Air quality is a topic that has traditionally been dealt with by public authorities and was thus under the burden of the availability of public funding. Public authorities were working jointly with research centres that made use of local in-situ data through partnerships with dedicated providers. The availability of free EO data proves to be a supplementary source of information; however, even if air quality is a global issue, the product that is interesting to the user is a local one. This implies that high to very high resolution data is needed and this data is most of the time fee-based. This represents a major hurdle, notably for public authorities or for starting businesses with variable revenues.

Moreover, if interest from citizens on air quality products and services is growing, they are still reluctant to pay a significant price to access such products. That implies free EO data will be massively used but commercial data will be carefully used.

MONITORING OF AIR QUALITY

THE VALUE CHAIN OF EO DATA FOR AIR QUALITY ACTIVITIES

ACQUIRING EO DATA

Raw EO data

- Copernicus (current (Sentinel-3 & 5p) and future Sentinels (Sentinel-4 & 5))
- CAMS & CLMS to a lesser extent
- Aura, Aqua, Terra (MOPITT)
- EUMETSAT
- MODIS Aerosol
- AIRS CO (total column) and Sulfur Dioxide (day and night)
- OMI
- NOAA
- ENVISAT (Schiamachy)
- Japanese Space agency
- Chinese Space agency

Other type of data

- In-situ
- Background stations
- UAVs
- Ground sensors

PROCESSING NEEDS AND CAPABILITIES

Capabilities

Nowcast
- Near-real time maps of specific air pollutants or overall air quality at a global, regional or urban scale.

Forecast
- Forecasts of specific air pollutants or overall air quality at a global, regional or urban scale.

Hindcast
- Simulation of past air fluxes

Needs

Data processing platforms
- CAMS
- CLMS
- Space agencies warehouses
- Services of specialized companies

Data combining methods
- Data integration
- Data fusion
- Data assimilation

Required skills
- EO data processing
- Mathematical models
- Atmosphere physics
- Meteorology
- Health

USERS & NEEDS

Non exhaustive list

Public authorities

- Support to policy making related to environment
- Estimation of policy efficiency and target achievement
- Identification of best measures to adopt in case of air pollution peak
- Improved understanding of climate change
- Ability to inform citizens on air quality
- Survey pollutants flow over large areas

Private companies

- Monitoring of compliance with limit values set for private companies

Citizens

- Development of maps providing air quality information enabling conscious decisions to be taken

MONITORING OF AIR QUALITY

THE AVAILABILITY OF MODELS THROUGH THE COPERNICUS ATMOSPHERE MONITORING SERVICE IS KEY TO USERS

Two types of air quality product developers can be distinguished:

- Users that have launched their business or research projects thanks to the availability of models as part of CAMS: their activities often rely about 50-80% on the availability of CAMS products, and more precisely on the global and regional air quality models, which are comprised of EO data, in-situ data, and meteorological data. They usually do not make use of raw data from Sentinels.
- Users involved in air quality activities before Copernicus and for whom alternatives to Copernicus could be found. In this case, CAMS data and products are mostly used as inputs for transboundary conditions to existing models they have developed and represent about 10-30% of their inputs. The availability of Copernicus has enabled them to improve the quality of their final product. Indeed, CAMS products have seen their quality improved in the last two years with the integration of Sentinel-3 and Sentinel-5p data, (which respectively provide additional data on dust aerosol, particulate matters and water vapour and on pollutants fluxes), and the quality should keep on improving after Sentinel-4 and 5.

Another Copernicus service, the Copernicus Land Monitoring Service (CLMS), is also used for the development of air quality maps though its CORINE Land Cover product. It notably enables the development of urban or street level air quality models.

	Copernicus strengths	*Copernicus weaknesses*
Copernicus enables its users to have both a global and regional coverage, which is key in the air quality domain as pollution has no borders. It represents a major opportunity for companies considering the product is operational, reliable and encompasses an interesting range of pollutants information. However, the global coverage is not available for everything, for instance not for pollens.	*REGIONAL AND GLOBAL COVERAGE*	
The web interface has been updated recently to smooth user access, notably for heavy archives. Quality of data has also improved while the products remained free, which is a key aspect for users.	*OPEN AND EASY ACCESS*	
As one of the flagship European programmes, Copernicus gives trust to both users of CAMS data and of final products relying on Copernicus in terms of continuity of the programme and of reliability of the data provided. The free, full and open strategy seems sustainable and users can confidently build business or products on it.	*REFERENCE THAT GIVES TRUST TO USERS*	
		VARIETY OF DATA — Through CAMS service, users are able to download in near real time, and forecasts air quality information as well as archives.
		EXTENSION OF DATASETS FURTHER BACK IN TIME — Today, CAMS archives go back to a few decades ago. However, extended datasets would be useful to users as the more data you have, the easier it is to build trends.
		HIGHER SPATIAL RESOLUTION — CAMS global and regional air quality models provide a resolution of 10km and many users would like this resolution to be improved, in order to provide data at street or house level. Moreover, documentation on the inputs of the models are difficult to access and not exhaustive enough.

MONITORING OF AIR QUALITY

COPERNICUS BENEFITS FOR AIR QUALITY ACTIVITIES

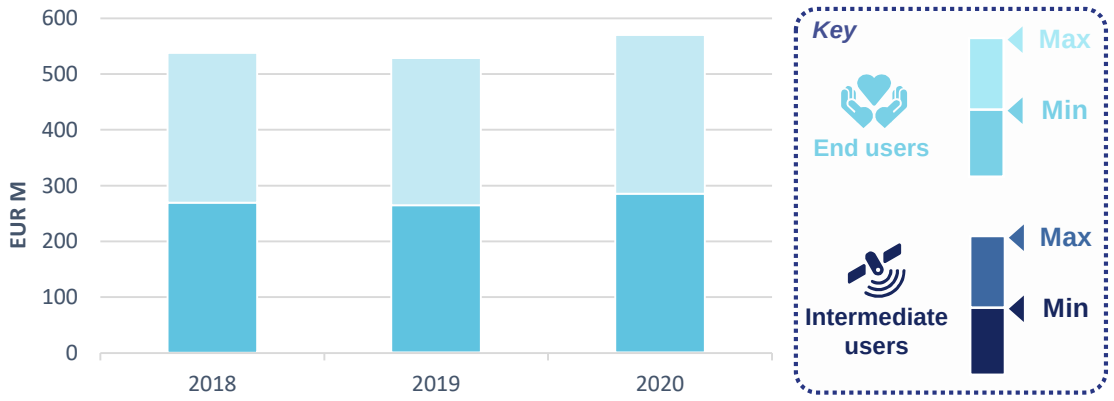
Copernicus, through the availability of CAMS products that combine EO data, in-situ data and meteorological data into modelling systems, creates a lot of new opportunities to deal with air quality at a global scale, especially because products are available openly and for free, and the programme is operational today and for the years to come.

Economic return of intermediate users due to the use of Copernicus for air quality, and more globally in the air quality monitoring sector, remains quite low. This is due to the fact that air quality is still a niche market mostly handled by public authorities. However, the provision of increased accuracy and data quality should bring potential for bigger revenues. For instance, when air quality variations at street level will be measurable, economic revenues will be generated as most citizens live in urban areas, so that is where the demand will come from. In 2018, economic benefits for intermediate users represented between EUR 0.1 M and EUR 0.6 M for 2018.

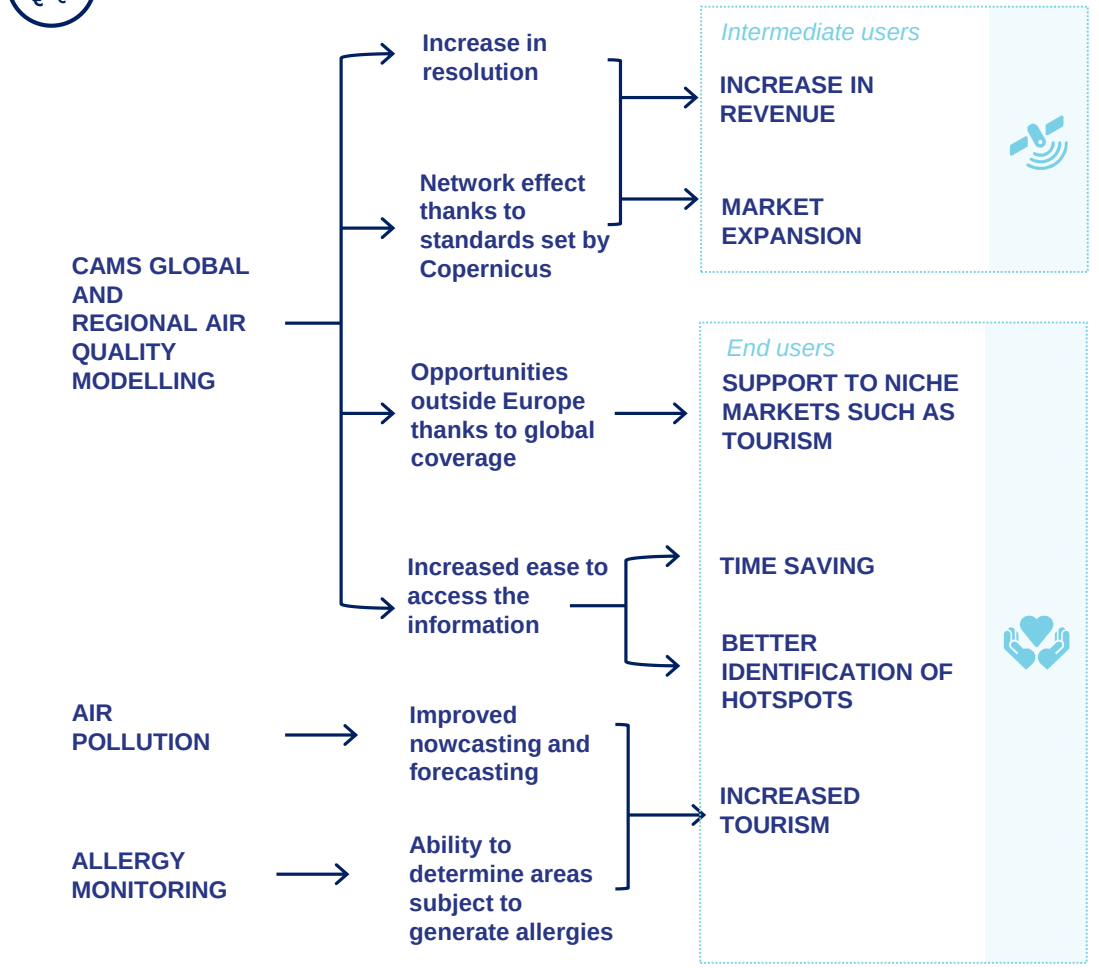
There is no direct economic impact on end users; however, the social impact, notably on improved visibility in cities and on health can be monetized and is significant. Indeed, economic benefits of end users represent between EUR 269 M and EUR 537 M for 2018.

Economic benefits of Copernicus through its contribution to air quality monitoring

(Source: PwC)



Economic impacts

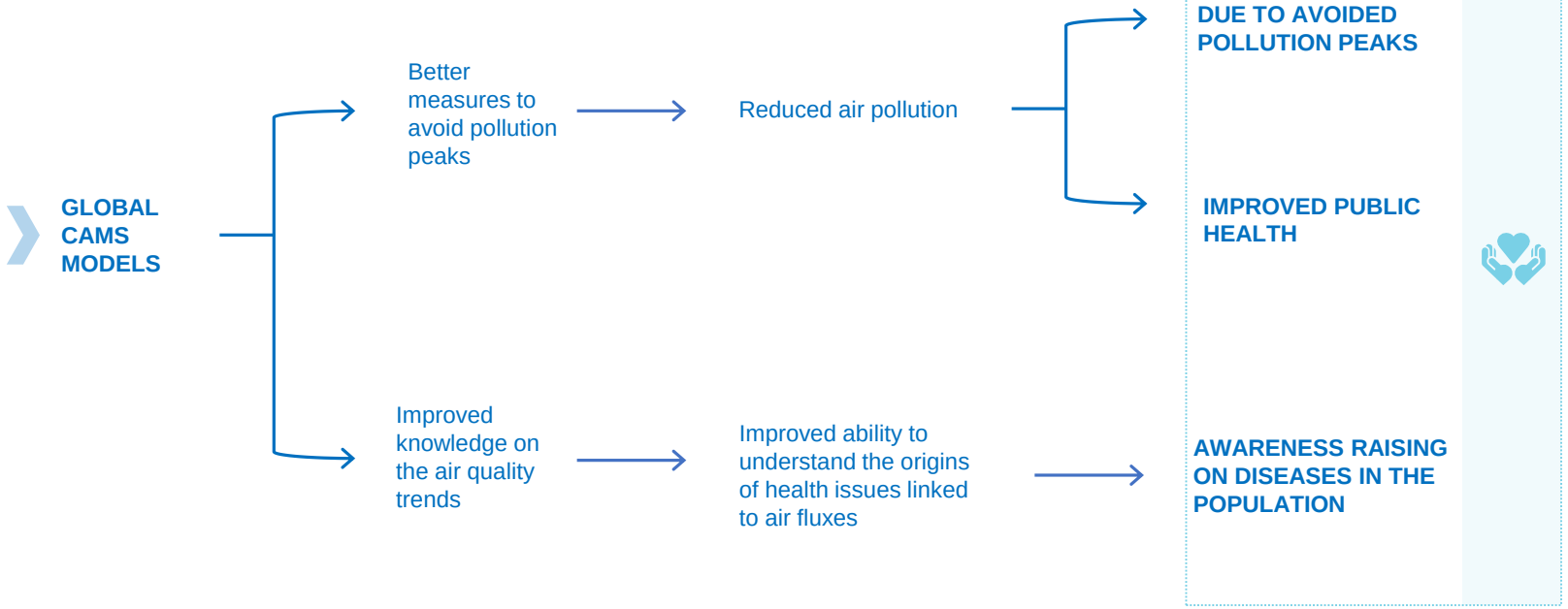


MONITORING OF AIR QUALITY

COPERNICUS BENEFITS FOR AIR QUALITY ACTIVITIES

Social impacts

Copernicus provides the necessary datasets to develop tools that are able to raise awareness on environmental health (e.g. on pollen dispersion or UV index). This matches with the current trend of citizens of paying attention to lifestyle/healthy applications. In the end, it should help to positively impact health expenditures and society as a whole.



MONITORING OF AIR QUALITY

COPERNICUS BENEFITS FOR AIR QUALITY ACTIVITIES

Environmental impacts

If health represents the biggest impact of all from bad air quality, it should not be forgotten that the pollutants or other fluxes also impact the state of our environment. The ability to trace carbon or other emissions contributes to the level of knowledge scientists have on our environment and to the understanding of the cause of global warming. Thanks to such information over a long period of time, the cause of emissions can be tackled.

GLOBAL CAMS MODELS → Increased knowledge for climate change monitoring →

End users

DIMINISHED IMPACT OF POLLUTION ON ECOSYSTEMS, INFRASTRUCTURE, BIODIVERSITY OR ANIMALS

Strategic impacts

In a context of global warming induced by climate changes and pollution, local and global actions need to be taken. Copernicus provides a tool for air quality analysis and forecasts, both to help set targets of emissions and to ensure that European countries are staying within the requested limits. This improves transparency between countries whereas, before, ground measurements not available outside the borders were used.

Improved transparency on results of European countries on the state of their air quality

End users

EASE OF COLLECTIVE ACTION FROM CITIZENS AT EUROPEAN LEVEL

DEFINITION OF PRECISE AND REACHABLE AIR QUALITY TARGETS

MONITORING OF AIR QUALITY / CASE STUDY

Forecasting personal allergy symptoms thanks to CAMS PASYFO

NEEDS AND CHALLENGES AROUND POLLEN ALLERGIES

AN IMPORTANT SHARE OF THE POPULATION IS FACED WITH SEASONAL ALLERGIES AND ASTHMA

Asthma and seasonal allergies can be a real burden for the people affected. Today, about 10-30% of the global population is afflicted by allergic rhinitis. In Europe, asthma and allergies linked to airborne particles have drastically increased in the last decades and pollen is one of the airborne particles responsible for the most chronic diseases. Sharing accurate knowledge on the presence of the pollen allergen enables allergic people to plan their outside activities accordingly and improve their quality of life.

PASYFO

PASYFO (Personal Allergy Symptom Forecasting System) is a service designed for pollen allergy sufferers, which is currently available in Lithuania and Latvia but could be extended further to the rest of Europe. It is split into 3 products, including a mobile app on which generalized allergy symptom forecasts are provided. People can also fill out their eyes, nose or lungs allergy symptoms on a daily basis and gather personalized overall symptom forecasts. Indeed different people respond differently to different varieties of pollen and PASYFO enables correlation between specific symptoms and air particles. Information on symptom forecasts, pollen forecasts and air quality forecasts are available for the next three days.

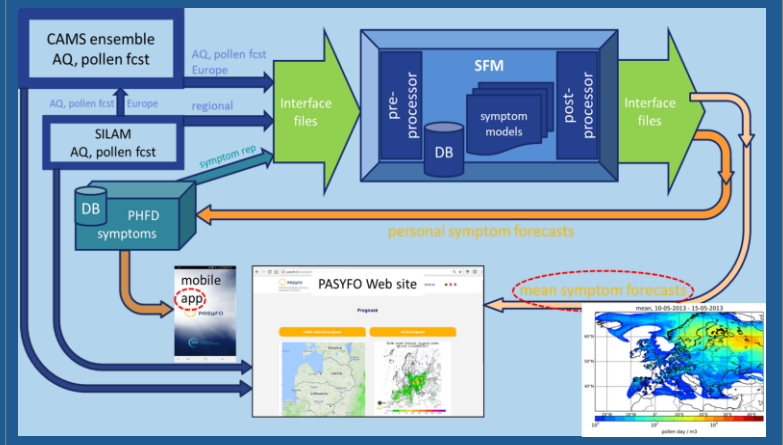
Examples of PASYFO Dashboards
(Source: PASYFO)

COPERNICUS CONTRIBUTION TO ALLERGY MONITORING

USE OF COPERNICUS TO SUPPORT ALLERGY MONITORING

The main input dataflow for PASYFO are CAMS pollen and air quality forecasts and are complemented by meteorological conditions. These are downloaded on a daily basis. The use of the CAMS data vary depending on the availability of the downscaling high-resolution SILAM (System for Integrated modeLling of Atmospheric composition) forecasts for Northern Europe, which have no guaranteed availability, timeliness, and completeness. If the high-resolution forecasts are not available, symptom predictions for +1 and +2 days use CAMS data. Days +3 and +4 of the symptom forecasts are always computed with CAMS input because the high-resolution forecasts do not reach beyond +54 hours. Additional pollen taxa computed within both SILAM high-resolution and the CAMS operational suites conclude the input-preparation steps.

Users of PASYFO are the allergy sufferers themselves or parents of allergic children. It can also support allergy doctors that could recommend the app to their patients. PASYFO is a unique product that currently has no equivalent. User feedback shows that the Personalized Allergy Symptoms Forecast has facilitated planning of outdoor activities for families, especially during the weekends and on holidays. It also paves the way to the future of "personalised medicine".



Principal scheme of PASYFO
(Source: PASYFO)

MONITORING OF AIR QUALITY / CASE STUDY

Planning ahead and organizing a stay in Greece DiscovAir

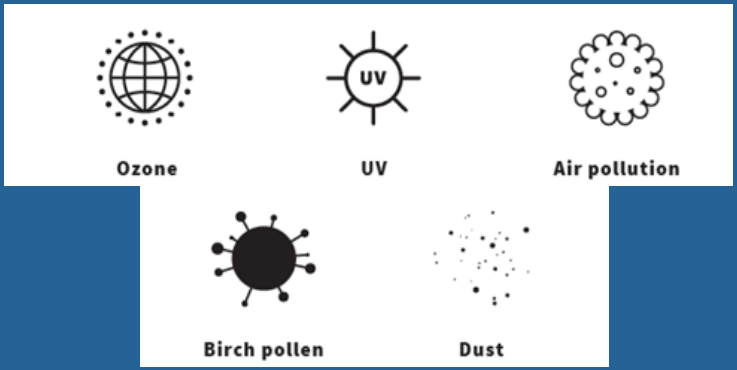
NEEDS AND CHALLENGES AROUND AIR QUALITY

BIGGER HABITS AROUND HEALTHY LIFESTYLES FOR EUROPEANS

Tourists and citizens pay higher attention than before on their lifestyle and their environment. This translates into an increased willingness to dispose of accurate services on weather (e.g. to avoid sunburn) and air quality conditions (e.g. to prevent breathing difficulties or allergies being triggered) that helps to make conscious decision on where to travel and when to plan outdoor activities.

DISCOVAIR

DiscovAir is an hybrid mobile application in-between generic weather applications and tourism applications. It is targeted to tourists, tourism operators and citizens in Greece and Cyprus. It provides information about environmental health and comfort conditions for tourists and citizens (UV index, pollen, Ozone concentration, Air quality (PM10, PM2.5)); up-to-date, location-specific and personalized indices and alerts; and personalized advice on protection measures. The provided air quality and weather-related information, forecasts and alerts, are tailored to meet the personal needs of the users at their specific location. For instances, the application provides the optimum time to visit a location for a specific person (e.g. children or elderly) as they do not face the same risks.



Parameters monitored by DiscovAir
(Source: DiscovAir)

COPERNICUS CONTRIBUTION TO AIR QUALITY MONITORING

USE OF COPERNICUS TO SUPPORT AIR QUALITY MONITORING

To make the user as comfortable as possible, DiscovAir provides air quality information taking into account the user's personal preferences and current location. To do so, DiscovAir makes use of the Copernicus Atmosphere Monitoring Service (CAMS) data. The service is fed and updated hourly by CAMS atmospheric composition data related, for example, to ozone (O3), atmospheric pollution (PM2.5 and PM10) and birch pollen. Additionally, CAMS data helps DiscovAir provide comfort suggestions based on weather conditions such as air temperature, relative humidity, total cloud cover, wind speed, dust aerosols and UV index.

Through the provision of personalized advice, DiscovAir and CAMS contribute to improve the travelling experience of the users, by reducing risk of health issues such as allergies or breathing difficulties due to polluted air or by enabling a better protection of the environment. As such, the final result is improved comfort and health of citizens staying in Greece or Cyprus.

Examples of DiscovAir dashboards
(Source: DiscovAir)

MONITORING OF AIR QUALITY / **CASE STUDY**

QualeAria: from Copernicus to city scale air quality forecast ARIANET

NEEDS AND CHALLENGES AROUND THE STUDY OF AIR QUALITY

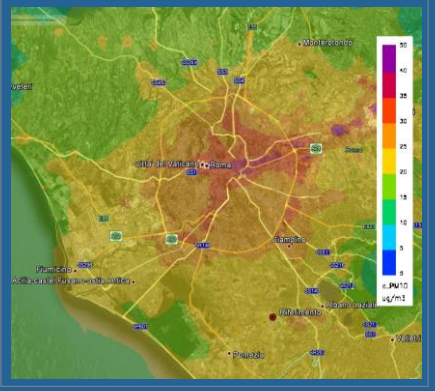
AIR QUALITY IN EUROPE

Several stakeholders, including regional air quality agencies, are interested in the availability of air quality forecasts to support their activities. ARIANET, an environmental consulting company focused on atmospheric modelling and developing and implementing air quality forecast systems, provides national tools such as Qualearia (http://www.qualearia.eu/) that can be key for these stakeholders.

QUALEARIA

Since 2007, QualeAria has provided an operational forecast over Italy and a large portion of Europe for the forthcoming 5 days, and feeds high resolution local scale forecast systems. QualeAria provides boundary conditions to local/urban scale air quality forecast systems, matching long range pollutants transport with local emissions to better resolve geographic and atmospheric circulation features. Its data is presently delivered to seven Italian regional air quality agencies. Downstream services include the Rome city air quality forecast and the early warning system for Taranto city, located besides the largest steel factory in Europe

Local scale air quality forecast systems (red boxes) linked to QualeAria (Source: ARIANET)



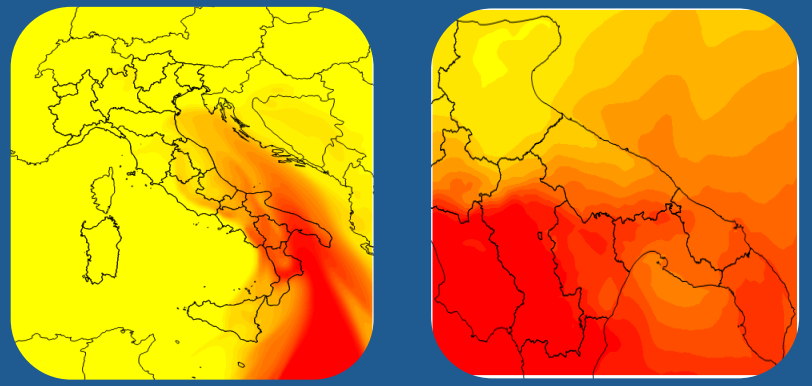
Rome city local air quality forecast fed by QualeAria (Source: ARIANET)

COPERNICUS CONTRIBUTION TO AIR QUALITY MONITORING

USE OF COPERNICUS TO SUPPORT AIR QUALITY MONITORING

CAMS is the reference system in Europe for air quality forecast at global and regional scales, which guarantees reliable input for smaller scale air quality forecast and assessment systems. Providing information free of charge, it enables SMEs like ARIANET to develop competitive downstream tools and services possibly applicable worldwide without being conditioned by the burden of information fees. QualeAria is fed by boundary conditions from the global scale chemical weather forecast produced by CAMS. Those also include the contribution of Sahara dust, allowing to account for its advection across the Mediterranean and its contribution on air quality in Italian areas. Anthropogenic emissions are assigned as a combination of data coming from the Italian national emission inventory and CAMS emissions for Europe.

QualeAria fostered the development of F-Air (ARIANET Integrated Forecast System Manager), a software environment where data sources, modelling components and data delivery tasks are connected and scheduled according to users needs. This notably enabled to effectively implement forecast systems integrating local sources' knowledge with wider context on a regional scale. The connection with CAMS services improved the air quality forecast of ozone and particulate matter in Mediterranean areas exposed to desert dust.



Sahara dust on local scale modelled through injection of CAMS boundary conditions (Source: ARIANET)

MANAGEMENT OF NATURAL DISASTERS

KEY TAKEAWAYS

Response to natural disasters

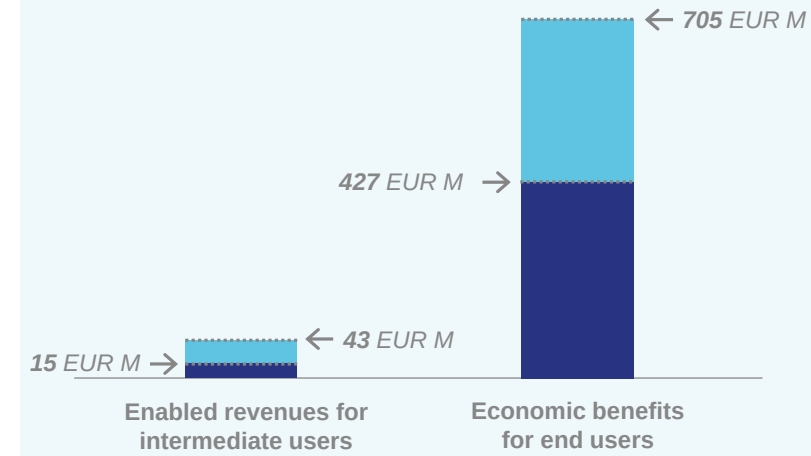
- Satellites images are used not only for emergency responses but also for risks forecasts and early warning operations.
- Because anticipation measures are the most efficient to mitigate disasters effects, early warning and forecasts have the biggest impact on the response to natural disasters.
- The Copernicus Emergency Management Service (CEMS) is a crucial asset for civil security teams in Europe as the unique and central interlocutor for all types of Earth Observation (EO) requests.

Insurance

- EO still has a limited contribution to the traditional insurance and reinsurance policies for natural catastrophes.
- Parametric insurance, although still marginal in terms of market size, relies more extensively on EO and tends to expand its insurance policies portfolio beyond the agricultural market.
- The slow increase of adoption rate reflects a mix of challenge to meet operational needs with current EO capabilities and traditionally conservative mind-set in the insurance industry.

Copernicus economic impact (2018)

(Source: PwC)



COPERNICUS APPLICATIONS

- Floods forecasts at short term and long term for riverine floods and fast floods
- Early Warning and alerts to national authorities
- Fire Risk Index at short and long term, assessing the risk of fire ignition and the difficulty to control it
- Rapid Mapping of disasters in emergency and in the following days
- Computation of indexes for parametric insurance products, mostly for agriculture

KEY COPERNICUS PRODUCTS

- CEMS European Flood Awareness System (EFAS) - Early Warning System
- CEMS European Forest Fire Information System (EFFIS) - Fire Risk Index
- CEMS Rapid Mapping Service

MANAGEMENT OF NATURAL DISASTERS

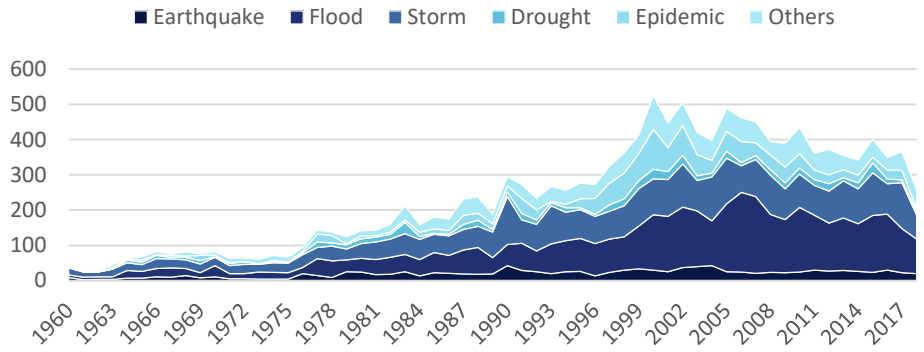
A RISK FOR CITIZENS AND FOR THEIR GOODS, AT GLOBAL SCALE

The current assessment looks at the management of natural disasters from the perspective of both civil protection and of insurance of properties. In both cases, the access in a timely manner to the right information on the events is crucial to be able to take to best measures for the protection of citizen.

Between 350 and 500 disasters occur every year globally, with a clear increasing trend over the past century, but which can be associated partly to the improvement of the reporting. The most common disasters over time are floods followed by storms, totalling together about 75% of the reported events. In terms of people affected by the events however, droughts, although representing less than 5% of the reported events, have the largest footprint, due to their impact on agriculture and water management. As a consequence of this, Asia concentrates the vast majority of the number of people affected by these catastrophes, in particular in the case of the severe droughts in 1987, 2002 and 2015, where more than 350 million people were affected each time.

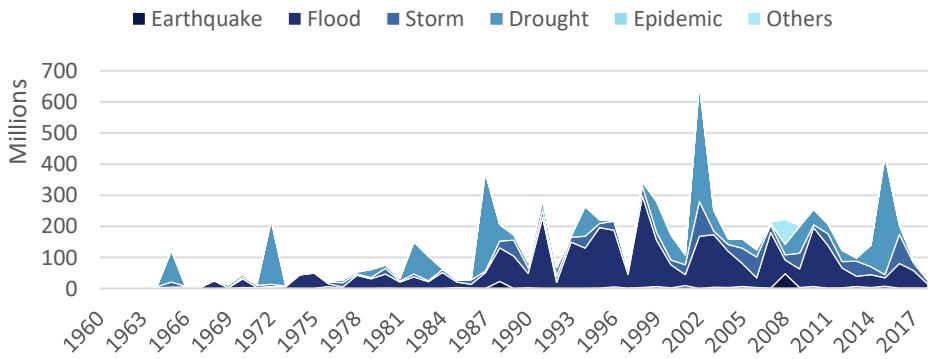
Number of disasters per disaster type at global scale

(Source: Centre for Research on the Epidemiology of Disasters (CRED), International Disaster Database EM-DAT)



Number of people affected by natural disasters at global scale

(Source: Centre for Research on the Epidemiology of Disasters (CRED), International Disaster Database EM-DAT)

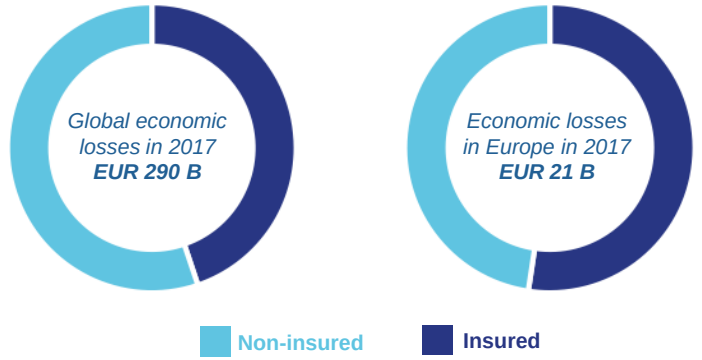


The high records witnessed in recent years are unfortunately expected to set the trend for the coming decades. The frequency of various events have shown an increase (such as hurricanes and wildfires), and climate change – in particular temperatures rising – is likely to also contribute to more frequent extreme weather conditions.

In 2017 the global claims for losses from natural disasters reached their highest value ever recorded, at nearly EUR 130 billion. Most of the losses covered by insurance policies were attributed to tropical cyclones and hurricanes (in particular the trio Harvey, Irma and Maria in North Atlantic for more than EUR 80 billion), while wildfires reached a new record of insured losses at more than EUR 12 billion.
Europe constituted about 8% of the global insured losses in 2017, representing EUR 11 billion of insured losses. The agriculture sector has been severely affected by a sequence of warm conditions, cold wave and drought, leading to more than EUR 3.5 billion economic losses.

Economic losses and share insured at global scale and European scale in 2017

(Source: Swiss Re)



INSURANCE FOR NATURAL DISASTERS

3 TYPES OF ACTIVITIES BASED ON EARTH OBSERVATION CAN BENEFIT INSURERS

Risk modelling

Insurance core activity relies on evaluating the levels of risk exposure, using probabilistic approaches of the events, exploiting historical data and performing climate reanalyses over hundreds to thousands of years.
Satellite images have been recently exploited as a complementary source of data to traditional sources (hydrological, meteorological, atmospheric, seismological etc.). Their main contribution to risk modelling is the analysis of post-event images to calibrate the models, assessing which ones are more accurate and refining the different hypotheses. In some cases they can also be exploited as inputs to digital models, for instance for digital elevation maps (useful for the assessment of floods exposure risks) and for ground assets mapping.

Event footprint

The availability of satellite images right after a natural catastrophe can also be an efficient way for (re)insurance companies to obtain a comprehensive view of the situation and of the distribution of damages in the area. The aim is not to remotely assess the indemnities claims from the images, and a ground presence of insurers agents and experts is always required. However this information enables appropriate planning and organisation of the operations for insurance companies in terms of sizing of the workforce, and ground deployment of the experts. The benefits of such anticipation is both for the (re)insurance companies and for the policies owners who benefit from a better customer service.

Parametric products

Since the 1990s, an alternative type of insurance policy has emerged using parametric products, largely driven by agriculture insurance, and by emerging markets in Asia, South America and Africa. The payment of indemnities is correlated to the computation of a numerical index, which triggers the payment when it exceeds a pre-defined threshold. As the index targets the state of the production directly (yield-based), the insurance policies are multi-perils, covering potentially any source of disaster (droughts, diseases, heavy rains etc.). Largely driven by agriculture insurance, the challenge for these products is the accuracy of the index (basis risk), which should reflect as much as possible the reality of the situation to be trustworthy. For this reason, the indexes require an expertise of the lines of business for which they are designed, for instance agronomists for crops insurance, in order to link the reading of EO data with local knowledge and local parameters. Today, index products still represent a marginal market compared to the rest of the market for natural catastrophes.

WHY EARTH OBSERVATION?	APPLICATIONS	BENEFITS	END USERS
RISK MODELLING	• Calibration of risk models and refinement of hypotheses • Inputs for digital models such as elevation maps	• Higher accuracy of risk models, higher accuracy of exposure risk • Better control of financial risk	• Reinsurers • Insurers • Catastrophe modelling companies
EVENT FOOTPRINT	• Comprehensive vision of the affected area • First estimates of the extent of the damages	• Improved customer service through better sizing of the workforce during crises • Costs savings through optimised ground intervention for field agents and experts	• Reinsurers • Insurers • Insured people • Emergency services
INDEX PRODUCTS	• Computation of indexes based on image analyses • Provision of informative maps for farmers	• New markets accessible in remote areas • Access to insurance products for new populations	• Reinsurers • Insurers • Farmers or local authorities

INSURANCE FOR NATURAL DISASTERS

DRIVERS AND CHALLENGES FOR THE ADOPTION OF EARTH OBSERVATION BY INSURERS

Traditional insurance policies are difficult to implement on some markets due to the limited presence of local sensors for data gathering. Parametric products offer a good potential for remote areas, in particular for agriculture. Earth Observation data enables a wide coverage, recurrent fly-by and data stability. Droughts are one of the main types of event that can be addressed for crops, but other potential markets are also envisaged, such as forestry, fisheries, and renewable energies.

The vision of the event footprint on large areas and the ability to have estimates of the damages in the few days following the catastrophe enable better planning of resources for crisis cells of insurance companies (hotline teams, indemnities management, field experts, etc.), which can last for weeks. In addition to the cost efficiency, the better responsiveness of their service has an impact on customer satisfaction, which has larger and longer term impacts on insurers business.

Insurers, as non-EO experts, need products tailored to their risk modelling activities. There is an opportunity for specialized companies at the interface of EO technical aspects and insurance technical aspects. There remain a substantial margin for improvement for the accuracy of both post event analyses and parametric indexes (reduction of the basis risk).

DRIVER 1

Although still a niche, index products offer a steady approach for insurance policies

DRIVER 2

Post event images allow insurers to anticipate crises management, improving customer service

DRIVER 3

Opportunities for intermediate market to fill the gap between required Earth Observation expertise and insurers business

CHALLENGE 1

Contribution of Earth Observation data curbed by the statistical nature of insurers needs for risk models

CHALLENGE 2

Many insurers are derivative users of Earth Observation products, with limited internal expertise

CHALLENGE 3

Basis risk is improving but still far from being accurate

Insurers rely extensively on statistical models for risk modelling, and use long historical datasets to simulate thousands of years of events. The data from satellites can be used for calibration or marginal improvement on some inputs, but is not able to replace these stochastics approaches.

Investing in EO capabilities is subject to prior demonstration of the added value to their business. Apart from large reinsurance groups, initial experiments are conducted with limited means, with challenges to acquire and manipulate satellite images, hindering the potential for initial investments in this direction. The limited improvements expected from EO do not justify the required investments, especially in a risk-averse industry.

Overall, despite some challenges and a moderate potential in terms of maximum uptake, insurers tend to show optimism on the trends for satellite data adoption. Most of them have noted a clear improvement of awareness in the past 5 to 10 years, a generalisation of EO data presence within insurance companies, and in particular a clear take-off of parametric products, starting from zero a decade ago.

INSURANCE FOR NATURAL DISASTERS

THE VALUE CHAIN OF EO DATA FOR INSURANCE COMPANIES

	ACQUIRING EO DATA	PROCESSING NEEDS AND CAPABILITIES	USERS & NEEDS
	Overall data needs • Landsat and MODIS satellites are prevalent sources • Sentinel data emerging, though on niche markets (parametric insurance) • Raw data not exploitable by insurers, needs to be tailored	**Data format and in-house capabilities** • Data processing to turn satellite images into insurance-friendly inputs • Large (re)insurance companies tend to have internal capabilities, and are able to ingest varied types of data • Other insurance companies require packaged data	*Non exhaustive list*
Risk modelling	• EO used mostly by Value Added Services (VAS) companies, and few large (re)insurance groups • In best cases, EO constitutes about 10% of the input data, mostly for wind modelling and floods • Few cases where High Resolution data is used for buildings models	• EO data mixed with both other Geographic Information Systems (GIS) and non-GIS: hydrological, meteorological, rain gauges and river gauges measurements, seismologic, administrative information etc.	• Calibration of risks models (both internal and outsourced) • Digital elevation models • Winds analysis for surface roughness • Grounds assets mapping
Event footprint	• Satellite source driven by first availability • Hectare scale to 10m-scale resolution sufficient • High Resolution data for roofs damages assessment • Data expected to be freely available • Procured from public entities or reinsurers	• Gap remains between intermediate user offers and insurers' needs • Improvements observed on the algorithms and machine learning capacities in the past years	• Impact sizing prior to event • Assessment of event geographical extent • Estimates of total damages and per area
Index products	• Landsat and MODIS satellites largely used • Sentinel 1 and 2 constitute more than 50% of the data for some Value Added Services companies • Open source data is paramount • Revisiting time of few days of Sentinels is suitable	• Externalized service: strong EO and machine learning expertise required • Available archives important parameter • Satellite data mixed with industry-specific data: agronomy, high precision meteorology, in-situ sensors, and farmers experience	• Normalised Difference Vegetation Index (NDVI) for meadow and crops insurance • Biomass index for livestock insurance • Other indexes for forestry, or renewable energies

INSURANCE FOR NATURAL DISASTERS

COPERNICUS MAKES A DIFFERENCE WITH ITS OPEN DATA POLICY AND DATA RELIABILITY, BUT STILL FACES ISSUES OF AWARENESS AND ACCESSIBILITY OF DATA

Besides the case of parametric products, for which experts acknowledge an improvement of the user uptake for Sentinel 1 and 2 data in the past 3 years, there remains strong discrepancies between insurers in the uptake of Copernicus data.

It is estimated that for insurance companies owning in-house capabilities, Copernicus images are used in no more than 5% of the cases.

For post disasters analysis, the choice of the source of data is not possible, but many cases of images provided by the Copernicus Emergency Management Service have been mentioned.

For risk modelling the impact of Copernicus remains anecdotal, and the few traditional sources such as MODIS are still used today, largely for simplicity and continuity issues.

	Copernicus strengths	Copernicus weaknesses
The open data policy allows for initial exploration projects before developing deeper EO skills. It also enables an affordable pricing of index products and free post event images in a market with limited willingness to pay.	***FREE EO DATA IS CRUCIAL TO SUPPORT BOTH INITIAL UPTAKE AND MATURE PRODUCTS***	
Copernicus is a first choice option for many index products for its transparency, consistency, stability over time (trustable providers), and its higher resolution than Landsat and MODIS satellites.	***SENTINEL DATA IS VERY SUITABLE FOR INDEX PRODUCTS***	
The improvement of spatial resolution of Sentinels over previous open source satellite data is a strong differentiator for event footprint assessment and preliminary damages assessment. The availability of Sentinel-1 radar data is also a key advantage, especially for floods and storms.	***SENTINELS RESOLUTION OFFERS AN ADVANTAGE OVER OTHER OPEN SOURCES***	
		LACK OF ASSURANCE ON THE TIMELINESS TO RECEIVE THE FIRST POST EVENT IMAGE
The delay between the catastrophe and the availability of the images is crucial. For quick events such as heavy rains, the uncertainty on the response timeliness curbs the interest for Copernicus.		
		AWARENESS OF THE DATA IS STILL LOW AND ACCESS TO THE DATA IS NOT INTUITIVE
The access to the data hubs and the channels to download it are complex to find for non-experts and insurers with limited resources. In some cases, commercial arrangements are more attractive as they are tailored and allow for automated data delivery		

INSURANCE FOR NATURAL DISASTERS

COPERNICUS BENEFITS FOR INSURANCE AGAINST NATURAL DISASTERS

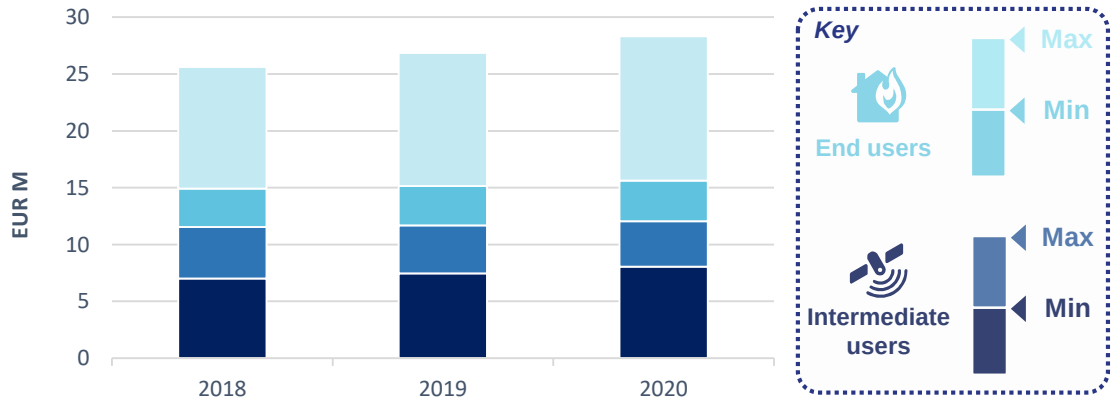
As of 2018, the economic benefits of Copernicus for the insurance sector concentrates on the niche market of parametric products, driven by agriculture insurance (meadows and crops).

At global scale, the revenues for intermediate users (Value Added Services companies) that can be associated to Copernicus data in 2018 are estimated between EUR 7 M and EUR 12 M. The early stage of the market and the confidentiality of insurers makes challenging the forecasts of the market growth. Based on the expected growth of EO information products and the experts feedback, it can be expected that the market, will grow at an average annual growth rate around 5% up to 2020.

The benefits for end users (insurance and reinsurance companies) materialise in different ways. The market for parametric products is a niche market compared to the overall Natural Catastrophes market, but the sizeable contribution of Copernicus in the index generation leads to revenues for insurers up to EUR 11 M in 2018, and foreseen to grow to EUR 13 M in 2020. The growth, which is expected by the many of the insurers consulted, remains dependent on the general uptake of Copernicus data and on the improvement of parametric products as the indexes become more accurate and reliable. The other applications of Copernicus data for insurers also have economic consequences, but in a lower range of values, estimated to not exceed EUR 3 M per year.

Economic benefits of Copernicus in Europe for the insurance market

(Source: PwC)



Economic impacts

PARAMETRIC PRODUCTS → **Production of indexes** → *Intermediate users*: **REVENUES FOR INDEX PROVIDERS**

End users:

- **RISK MODELLING** → **Greater model accuracy** → **LOWER FINANCIAL RISK**
- **EVENT FOOTPRINT** → **Optimisation of crisis workforce** → **COSTS REDUCTION**
- **EVENT FOOTPRINT** → **Optimisation of crisis workforce** → **CUSTOMER SATISFACTION**
- **PARAMETRIC PRODUCTS** → **Index-based policies** → **ADDITIONAL REVENUES**

RESPONSE TO NATURAL DISASTERS

CIVIL PROTECTION ACTIVITIES RELY ON ANTICIPATION AND QUICK RESPONSE

Risk analysis

Civil protection action begins before the actual disasters, through anticipation of events and regular monitoring of the risks.

In the case of floods, the European Flood Awareness System (EFAS) component of the Copernicus Emergency Management Service (CEMS) provides short term (between 1 day and 10 days) and long term (up to 4 months) forecasts of floods risks, looking at river levels and rain intensity. The data is made available to the Emergency Response Coordination Centre (ERCC) or directly to national authorised users such as civil protection authorities, and the EFAS issues alerts to its users in order to warn them when a flood risk is detected, allowing for confirmation and subsequent measures by local authorities. At a global scale, the Global Floods Awareness System (GLOFAS) is also operational as a CEMS since 2018.

Almost equivalent to EFAS for fires within CEMS is the European Forest Fires Information System (EFFIS), which provides a regular analysis of the fire risk (Fire Risk Index), describing how dangerous the conditions are if a fire is ignited and how it would be to control, based on statistical anomalies of rain. EFFIS provides short term (up to 10 days) and long term (up to 6 months) forecasts, however with no alert mode as for floods. The EFFIS data is freely accessible and can be displayed on a dedicated viewer. At global scale, the Global Wildfire Information System (GWIS) is a joint initiative of the Group on Earth Observations (GEO) and CEMS, building partially on the EFFIS data.

The risk analysis phase also includes a post event analysis (after the crisis), during which recovery mapping allows for a deeper investigation of the events. Spatial extent of past events can be used to identify areas exposed to certain types of disasters, subject to mitigation measures, or qualified as non-buildable.

Urgent response after the event

Representing about 80% of the requests of CEMS, rapid mapping of the situation just after or during a disaster is of high interest for civil protection authorities, which require information of the event extent and levels of damages (status of bridges, blocked roads, grading maps etc.) to organise their field intervention accordingly. Flood mapping lead to delineation maps, while fire fighting operations rely on burnt areas, and fire origin, type of land etc. European and international entities can request the support of ERCC, through activations triggering a mapping request, which can includes regular maps provision in the following days, depending on, the event.

WHY EARTH OBSERVATION?	APPLICATIONS	BENEFITS	END USERS
RISK FORECASTS	• Floods risk forecasts • Fires risk forecasts • Flood alerts (EFAS), including Early Warning	• Better preparedness for disasters • Better planning of field operations • Warning of areas at risks for local action	• Civil protection authorities • Hydrological institutes • Meteorological institutes
POST EVENT RISK ANALYSIS	• Delineation maps of past events • Analysis of historical data of similar events	• Understanding of risk exposure for urban infrastructures and population • Implementation of mitigation measures • Appropriate financial protection schemes	• Local authorities • Urban monitoring authorities and companies • Banks and insurers
RAPID MAPPING	• Provision of situation maps immediately after the event • Provision of analysis layers on the images	• Quick overview of the event extent and infrastructures affected • Better planning of field interventions	• Civil protection teams • Local authorities

RESPONSE TO NATURAL DISASTERS

DRIVERS AND CHALLENGES FOR THE ADOPTION OF EO FOR CIVIL PROTECTION

Satellite images benefit from a large swath, offering a wide view of the scene in a single delivery. The various analytics layers that can be applied to the images allows for information on the situation that are tailored to the event (earthquake, floods, fires etc.). This is applicable to all the potential disasters locations on the globe, regardless of local in-situ sensors' availability.

The Emergency Response Coordination Centre (ERCC) of the European Commission (DG ECHO), by constituting a unique contact point for civil protection authorities, greatly simplifies the process to acquire images by operational units. As non-EO experts, this optimize the efforts required and enables them to remain focused on field operations planning and management.

Satellites are also valuable for the forecasts phase, in which in-situ sensors are efficient only during the very short term. In the case of floods and heavy rains, satellites allow for about 1 week of anticipation. Based on these images, civil protection teams can anticipate their intervention plans, warning of local authorities and taking mitigation measures. In the case of absence of satellite data available, it would be considerably more difficult and less efficient for rescue teams to spot the most urgent areas.

DRIVER 1

Satellite data is the only means to obtain an exhaustive vision of the situation in many types of disasters

DRIVER 2

Emergency Response Coordination Centre acts as a common point of contact for data requests

DRIVER 3

Satellite images allow for longer term forecasts and anticipation of some events, such as floods

CHALLENGE 1

Civil protection teams are not EO professionals and few are familiar with EO data

CHALLENGE 2

The delay to obtain post-disaster images can curb the overall contribution of satellites

The main contribution and expertise of civil protection entities is on ground operations management. Very few individuals are knowledgeable on how to manipulate satellite data and how to extract information out of it, with a risk of misinterpreting the data if not appropriately trained. As a consequence, civil protection units are strongly dependent on data delivery and interpretation services. Local initiatives to develop EO capabilities usually depend on the personnel's' own motivation and own skills, and on local political will to support it.

Post-event responsiveness of mapping services is a crucial parameter for civil protection teams, as the potential to prevent casualties quickly decreases as hours pass. Although satellite data is always helpful for overall rescue operations, receiving interpreted images a day after the activation of Copernicus Emergency Management Service substantially reduces their added value. This aspect is relevant in particular for international partners requesting European support.

RESPONSE TO NATURAL DISASTERS

THE VALUE CHAIN OF EO DATA FOR EMERGENCY RESPONSE TO NATURAL DISASTERS

	ACQUIRING EO DATA	PROCESSING NEEDS AND CAPABILITIES	USERS & NEEDS
	Overall data needs • Disaster risk reduction (floods, landslides, earthquakes etc.): largely based on Sentinel, completed with higher resolution data in some cases • Longer term past analysis: MODIS, Radarsat and Landsat satellites • Data completed with in-situ and aerial • Data potentially provided by national partners (cartography services, space agencies)	**Data format and in-house capabilities** • Analytics largely performed by CEMS, based on needs expressed by national civil protection authorities • Few civil protection teams have EO capabilities. • Disaster risk reduction subcontracted to intermediate market companies (Value Added Services companies) • Analytics performed offline, but online interfaces include visualisation of data	**Non exhaustive list**
Floods	• Forecasts: no use of Copernicus, mostly EUMETSAT satellites, and national weather services • Fast floods: based on in-situ sensors • Post event images: extensively relying on radar data	• Forecasts from EFAS: checked and re-analysed by national hydrological or meteorological institutes	• >70 EFAS authorized users – From EU Member States, Balkan region and neighbouring countries • Partners are hydrological institutes, meteorological services, and 3rd parties (research and scientists) • For GLOFAS, users also include development agencies, Non Governmental Organisations, insurance sector
Fires	• Fire danger forecasts: meteorological satellites • Fires detection: MODIS, VIIRS and SEVIRI sensors • Mapping of burnt areas: MODIS, VIIRS, progressive incorporation of Sentinel 2	• Fire Risk Index maps: produced every day superposed with active fires and burnt areas maps	• Main user of CEMS is DG ECHO (ERCC) • National services are also users

RESPONSE TO NATURAL DISASTERS

CEMS IS A GAME CHANGER AS THE SYSTEMATIC INTERLOCUTOR FOR DATA REQUESTS AND PROVIDER OF READY-TO-USE INFORMATION PRODUCTS

The strengths of the Copernicus Emergency Management Service lie in its ability to provide Geographic Information Systems (GIS) products tailored to civil protection needs, that can directly be exploited by the operational planners, who are, for the most part, not experts in satellite data reading or manipulation.

The main challenge remaining, on the delay to deliver the images, is incumbent to the nature of satellite orbits, and is partly addressed through early warning and risk forecasts.

		Copernicus strengths	Copernicus weaknesses	
The professional interpretation of images is a crucial feature of CEMS, as no expertise is available among operational agents. The quality of interpretation strongly improved over time to extract intelligible information out of the images, with no need to re-process it afterwards.	***PROVISION OF END PRODUCTS TAILORED TO END USERS NEEDS***	***CEMS IS SUSTAINABLE***		The announced sustainability of the CEMS is an incentive for civil protection authorities to rely on it, and to anticipate long term collaboration
CEMS has demonstrated over time that it delivers high-end data and products. This is crucial in time constraint contexts where trust in the inputs allows users to focus on the operations. Copernicus brought significant added value over previously used sources such as aerial, which were not always available nor relevant.	***DATA AND PRODUCTS PROVIDED ARE RELIABLE***	***SINGLE INTERFACE WITH CEMS, WITH UNIQUE POINT OF CONTACT FOR ALL REQUESTS***		Sending data requests to ERCC for all events through a unique national relay greatly simplifies and streamlines the administrative process. It saves a lot of iterations and discussions, supporting Copernicus uptake in a context where people are not experts of EO networks or data formats, and can focus on emergency operations.
The fact that the service is free supports the uptake, in particular by local civil protection units with constrained budgets. Commercial data would not be affordable or a regular use basis, and so as a MS-funded initiative, governmental authorities find valuable return in using CEMS.	***DATA AND PRODUCTS PROVIDED ARE FREE***		***DELAYS TO RECEIVE PRODUCTS CAN IMPEDE THE IMMEDIATE RESPONSE***	As for satellite images in general, CEMS mapping service delivery time from the request is dependent on satellite orbit, downlink window, and data processing time. For events exploiting radar data only, such as floods, the reduced satellite options increase the risk of higher delays.

RESPONSE TO NATURAL DISASTERS

COPERNICUS BENEFITS FOR THE RESPONSE TO NATURAL DISASTERS

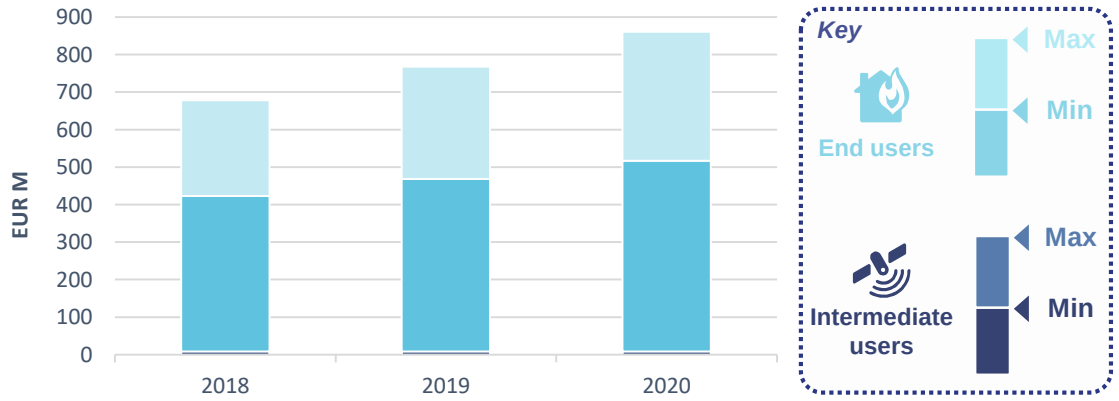
The revenues for the intermediate users are the sales of data used by the Service for its activities. Although other internal expenditures can be expected, the total amount is capped by the budget of the CEMS, representing EUR 8.5 M in 2018.

Regarding end users, the monetisation of the civil protection activities can be performed for fires and floods. The burnt areas are estimated to be reduced by about 230,000 ha per year thanks to civil protection actions. CEMS have provided its services for about 25% of the area, and its contribution to the results (through EFFIS and mapping services) is estimated between 10% to 15%. Reduced environmental damages based on a valuation coefficient represent between EUR 30 M and EUR 40 M of prevented environmental damages in 2018. Economic damages based on losses for the wood industry of around EUR 9 K per hectare amount to between EUR 225 M and EUR 335 M in 2018. The number of avoided fatalities raised too much uncertainty, hence could not be quantified.

Early warning for floods reduces by up to 33% the economic damages, for about EUR 2 B in 2018, considering the CEMS forecast success rate of 55% and the fact that other sources exist for floods forecasts, leads to a total of between EUR 135 M and EUR 270 M. In addition, the improvement of ground response by 1% in the 80% of floods mapped by CEMS leads to a total of EUR 25 M in 2018.

Economic benefits of Copernicus through its contribution to civil protection

(Source: PwC)



Economic impacts

- RISK ANALYSIS
- EARLY WARNING
- MAPPING

→ Purchase of data by CEMS to satellite operators →

Intermediate users

REVENUES FOR DATA PROVIDERS

- REDUCED BURNT AREAS
  - → Value of land for the ecosystem → REDUCED ENVIRONMENTAL DAMAGES
  - → Value of land for wood industry → REDUCED ECONOMIC DAMAGES
- EARLY WARNING FOR FLOODS → Anticipation of measures
- MAPPING OF FLOODS DURING THE EVENT → Better response strategy for remote areas

→ REDUCED MATERIAL LOSSES

End users

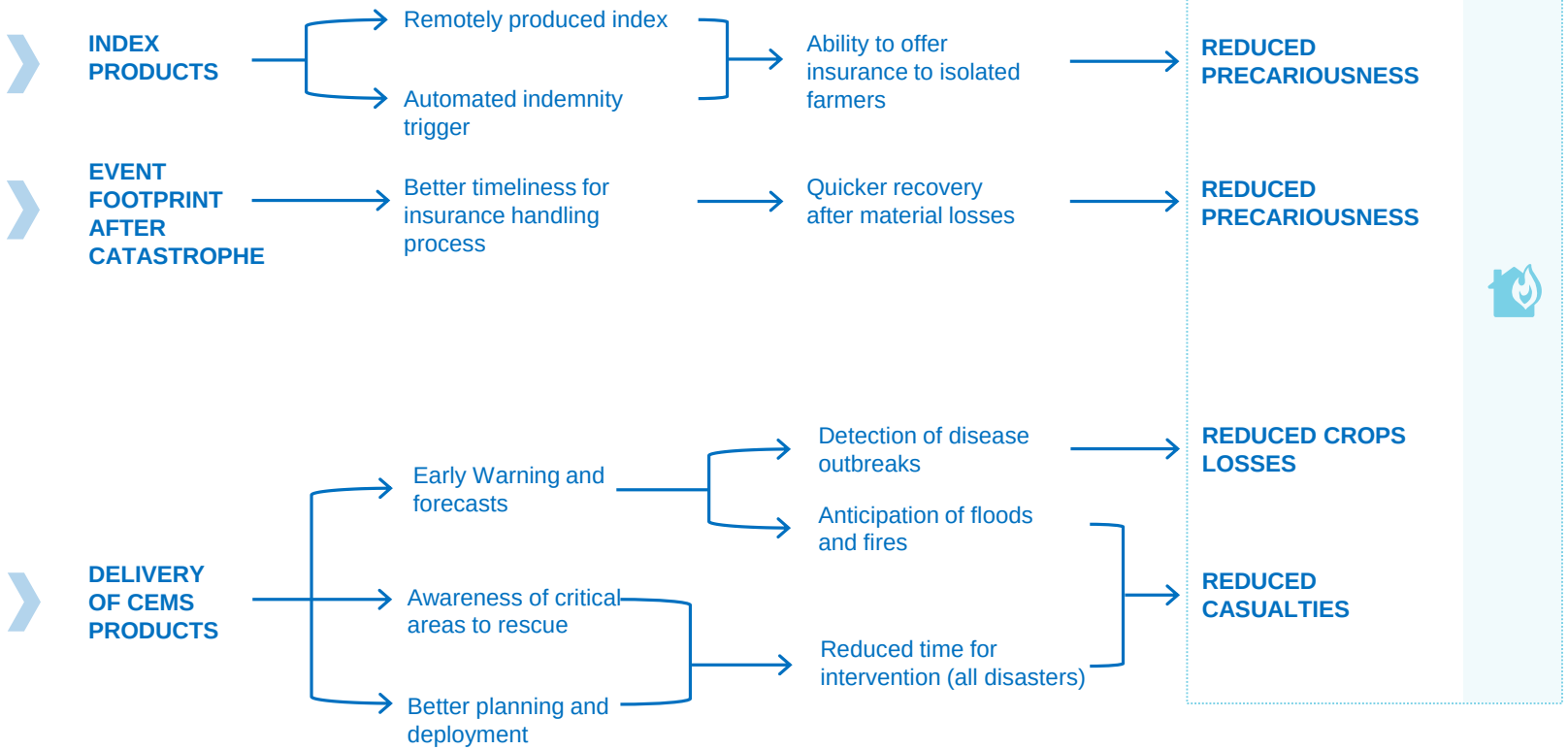
MANAGEMENT OF NATURAL DISASTERS

COPERNICUS BENEFITS FOR THE RESPONSE TO NATURAL DISASTERS

Social impacts

Through index products, Copernicus financially supports farmers in remote areas. These products are well suited for emerging countries where there is no or few alternatives to be insured. By protecting the livestock and crops of farmers, Copernicus helps them strengthen their business and envisage a better future. Although its contribution is more limited for post event assessment, Copernicus, by improving the claims management timeliness, also reduces the exposure of customers after natural catastrophe events.

The activation of the CEMS by civil protection organisations and rescue teams gives them access to crucial information improving the field interventions, to analyse the extent of the catastrophe, identify the critical areas to be rescued or the state of infrastructures such as roads and bridges. This goes beyond the fires and floods, and includes other disaster response managed by the CEMS, such as earthquakes, storms or epidemics.



MANAGEMENT OF NATURAL DISASTERS

COPERNICUS BENEFITS FOR THE RESPONSE TO NATURAL DISASTERS

Environmental impacts

Forest fires release CO2 in the atmosphere, with around 28 tons of CO2 emitted for each hectare of forest burnt (contributing to negative impacts on the environment such as the green house effect). Based on the contribution of CEMS to the reduction of burnt areas, it represents a total reduction of around 150,000 tons of CO2 per year.

DELIVERY OF CEMS PRODUCTS

- Awareness of critical areas to rescue
- Better planning of means and deployment

→ Reduced burnt area → **REDUCED CO2 EMISSIONS**

Strategic impacts

CEMS products enable MS with no or limited national capabilities to access appropriate tools for disaster resilience and to strengthen their vulnerabilities. Through its global coverage, CEMS also provides strategic information to rescue teams in all affected areas in the world and helping to protect populations on all continents, and Copernicus strengthens the bonds with international partners in critical situations.

Increase of the share of European capabilities in strategic operations for EU MS, providing civil protection support to European states with limited national capabilities. → **SUPPORT TO STATES WITH LIMITED CAPABILITIES**

Contribution of Europe to global initiatives for civil protection, on an open access mode, strengthening the bonds with international partners. → **CONTRIBUTION ON THE GLOBAL SCENE**

End users

NATURAL DISASTERS / CASE STUDY

Improving the delay for image delivery after floods
The European Flood Awareness System (EFAS)

EARLY WARNING SYSTEM WITHIN EFAS

THE CHALLENGE FACED BY THE EFAS

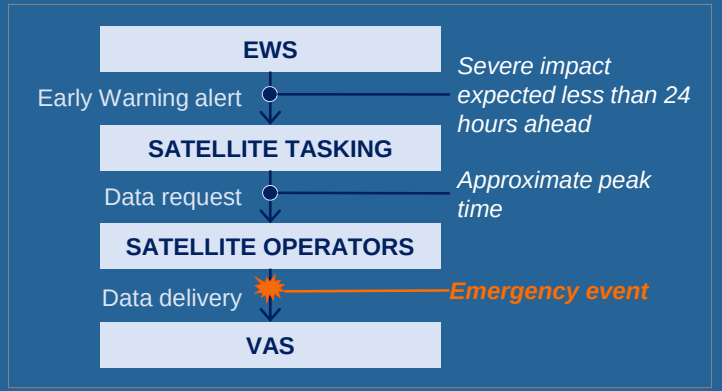
One of the key issues faced by emergency services when a catastrophic event occurs is the need to receive the maps and spatial analyses for situational awareness as fast as possible.
The rapid mapping workflow can be broken down into 4 phases:

- The decision to trigger or activate a mapping
- The remote sensing data acquisition process
- The downlinking and data acquisition procedures
- The production of crisis geo-information.

The data acquisition phase is the most time consuming, representing about 2 days on average for the Copernicus Emergency Management Service (CEMS) in 2017, or between 70% and 90% of the total time to deliver the final products.

THE ROLE OF THE EARLY WARNING SYSTEM OF EFAS

A part of the solution to improve the time to deliver the image is the use of Early Warning Systems (EWS) to pre-emptively trigger image acquisitions, as soon as an event is predicted or detected. Hydro-meteorological events, since they can be forecasted few days ahead, are well suited for EWS, and they represent the most frequent activations of the International Charter for disasters and of the CEMS in the past 20 years. The EWS of EFAS provides maps of flood probabilities, and in particular some risk forecasts, enabling to identify Areas of Interest for satellite tasking. Alerts above a certain level trigger the Rapid Mapping pre-tasking of satellites.



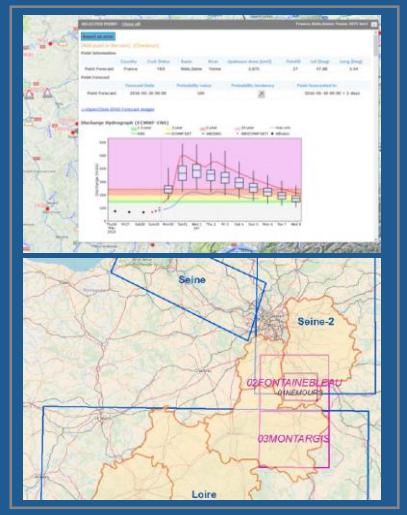
CEMS workflow for floods Early Warning Systems
(Source: EFAS)

COPERNICUS CONTRIBUTION TO THE RESPONSE TO FLOODS IN FRANCE

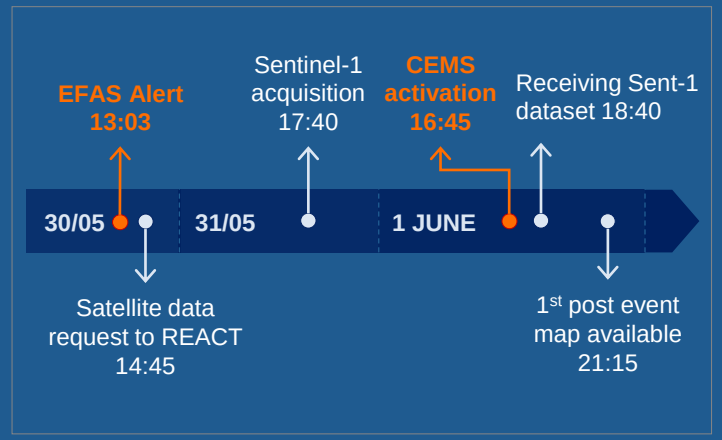
CONTRIBUTION OF EFAS TO FLOODS IN FRANCE (2016)

Some pre-tasking operational applications have been demonstrated, such as during the floods in the Loiret (France) in 2016. A early warning alert was sent on the 30th May for a high flood risk for the 31st May onward for the Seine and Loire river basins, forecasting a 20-year return period event.

A pre-emptive programming of satellite data and Rapid Mapping value added products was requested, enabling, on the 1st June, to receive the first acquired data less than 2 hours after the official activation of the CEMS. This represents a gain of about 14 hours, and the first cartographic products were delivered about 5 hours after the activation. The EWS not only ensured rapid availability of satellite images, but also enabled the value added service provider to be already focused on the event and to deliver the products in less than 3 hours after the images' reception.



EFAS alert message and AOI for rapid maps produced
(Source: EFAS)



Timeline of the EWS and data delivery during the floods
(Source: EFAS)

NATURAL DISASTERS / CASE STUDY

Supporting fire fighting operations through informative maps
The European Forest Fires Information System (EFFIS)

DANGER FORECASTS AND CURRENT SITUATION ASSESSMENT BY EFFIS

THE ROLE OF EFFIS

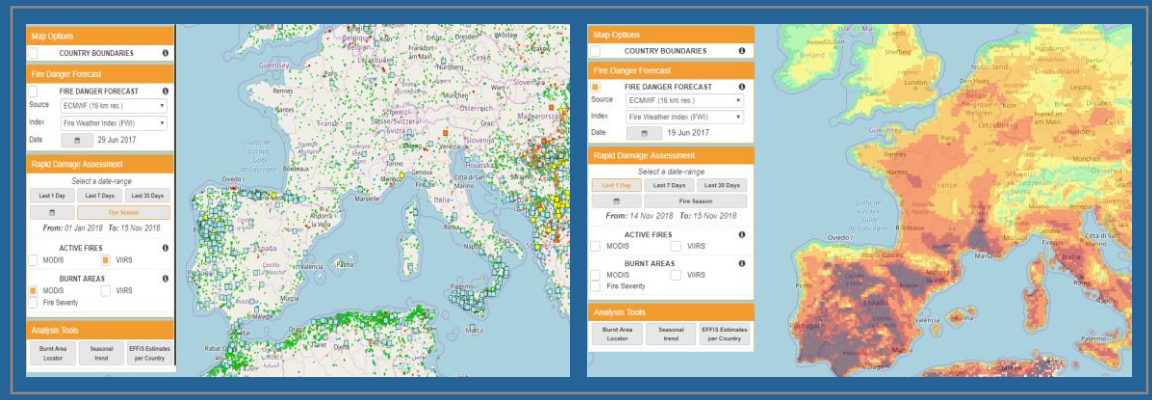
The European Forest Fires Information System (EFFIS) is a component of the Copernicus Emergency Management Service. EFFIS provides 2 types of products to support civil protection teams in fire fighting.

1 – The forecasts of fire danger provides maps of the area with a 6-grades scale (very low to extreme), with forecasts between 1-day up to 6 days upfront.

2 – After the beginning of the fires, the Rapid Damage Assessment (RDA) module of EFFIS delivers:

- Maps of burnt areas, showing the perimeters of burnt areas for fires larger than 30 ha. These maps are updated twice a day, exploiting MODIS images.
- Since 2016, maps of active fires ("hot spots") are also available, which are generated once per day, using images from the VIIRS sensor.

The fire danger forecasts and the RDA module are used by fire fighting teams to plan for their operations (sizing of the teams per location, deployment of equipment, monitoring of the evolution of the situation).



Left: Fire danger forecast map, 19 June 2017
Right: Active fires and burnt areas map, 2018 fire season
(Source: EFFIS)

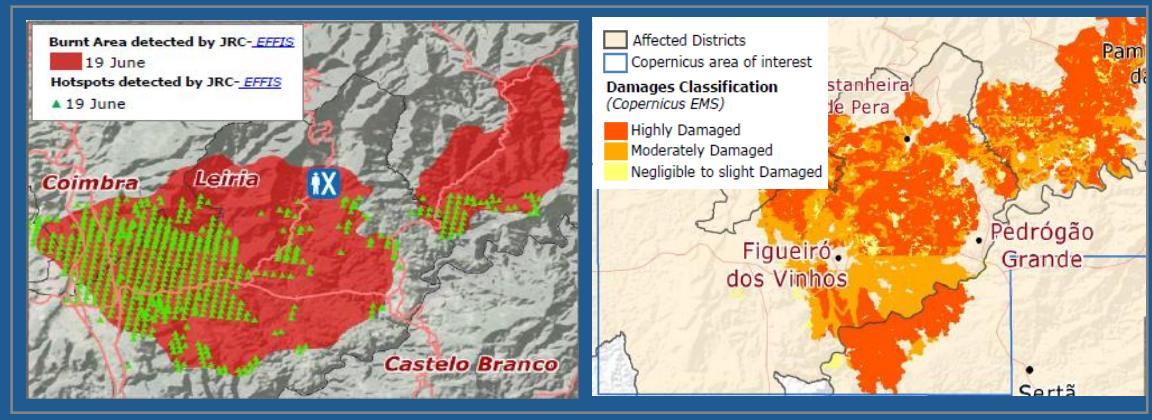
COPERNICUS CONTRIBUTION TO THE RESPONSE TO FIRES IN PORTUGAL

SITUATION OF PORTUGAL IN 2017

In 2017, Portugal faced highly dangerous meteorological conditions for fires, with a large share of the country assessed by the EFFIS as facing "Extreme" danger (6/6). It resulted in numerous fire outbreaks on the 17th June, of which 2 large fires burnt over 16,700 ha in the district of Coimbra. Throughout Portugal, 64 fatalities and 251 injured people were reported by the 22th June, and the National Authority for Civil Protection (ANPC) requested aerial and terrestrial support, which was provided by France, Italy and Spain.

CONTRIBUTION OF COPERNICUS TO GROUND OPERATIONS

On the 18th June, the ANPC activated the Copernicus Emergency Management Service, and the maps produced by EFFIS and the mapping service were analysed by Joint Research Centre (JRC) for the Emergency Response Coordination Centre (ERCC).
By the 18th June, EFFIS provided maps on the evolution of the ongoing fires and by the 22nd June, maps of burnt and damaged areas were available. In total, 42 maps based on Copernicus satellite images had been provided to the ANPC, helping to fight about 580 fires between the 15th June and 21st June.



Left: Burnt areas (red) and hotspots (green) mapped by the EFFIS for the ANPC, 19 June 2017
Right: Damaged areas (negligible to high) mapped by the CEMS Mapping Service for the ANPC, 22 June 2017
(Source: EFFIS)

NATURAL DISASTERS / CASE STUDY

Response to large wildfires in Germany
German Federal Agency for Technical Relief (THW)

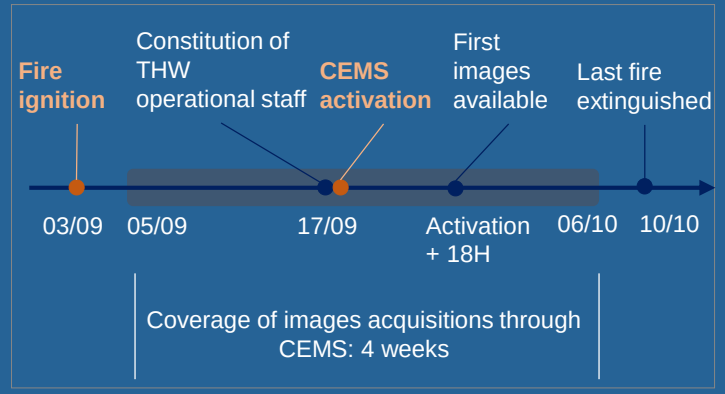
CONTEXT OF THE CATASTROPHE AND ROLE OF THW

CONTEXT

2018 was the driest year in Germany since weather records began. On September 3rd a wildfire broke in the Emsland region, which took over one month to be fully extinguished, burning about 1,200 hectares and mobilising at some times over 2,000 emergency operatives simultaneously on the field. The challenge in fighting this fire was its spread over several contaminated sites, which were not accessible by emergency teams.

ROLE OF THE THW

The Federal Agency for Technical Relief (THW) is a partner in civil protection in Germany, providing assistance after catastrophes, both in Germany and at international level. During this event, THW units were mobilised along with operatives from fire stations and the military.
Large amounts of equipment and personnel were required for the event, and the headquarters of THW started to build up their operations staff on September 18th.
Among the first activities undertaken by the teams was the activation of the Copernicus Emergency Management Service (CEMS), in order to acquire satellite imagery of the scene. During the operations, the satellite images were completed with airborne infrared images from military forces.



Timeline of the event and of CEMS contribution (Source: THW)

COPERNICUS CONTRIBUTION TO THE WORK OF EMERGENCY OPERATIVES

COPERNICUS PRODUCTS ACQUIRED

The first images received were the extent of the burnt areas, based on visual interpretation of Sentinel-2 data. On top of it, a map of the active fires was superposed.
After removing the non-exploitable acquisitions due to clouds, 7 successful snapshots of the fire spreading were obtained, covering more than 4 weeks.

CONTRIBUTION TO THE FIELD OPERATIONS

The images received from CEMS served multiple purposes:

- Overview of the fire extent and development
- Verification of the accessibility of areas and key infrastructures, planning of the staff deployment and assurance of their safety
- Estimates of the flame front movement based on prevailing winds
- Planning of potential evacuation plans for villages at threat
- Identification of areas for supply stations, accommodations and standby operatives
- Monitoring of active fires and success of fire-fighting operations
- Inform the politicians, medias and Federal Ministry

CEMS products therefore enabled time saving, increased safety, and more effective coordination by emergency managers.

Spreading of the fire: 5th September (red), 18th September (orange) 26th September (green) based on CEMS products (Source: THW)

Burnt area on the 6th October, based on Pléiades-1A images (Source: THW)

SECURITY / CASE STUDY

Support to response after an earthquake and tsunami in Indonesia
Asian Institute of Technology (AIT)

CONTEXT OF THE CATASTROPHE AND ROLE OF AIT

CONTEXT

On 28th September 2018, a 7.5 magnitude earthquake struck in the Minahasa peninsula in Indonesia. Following the earthquake, a localised tsunami hit the coast of Sulawesi island, affecting in particular the city of Palu.

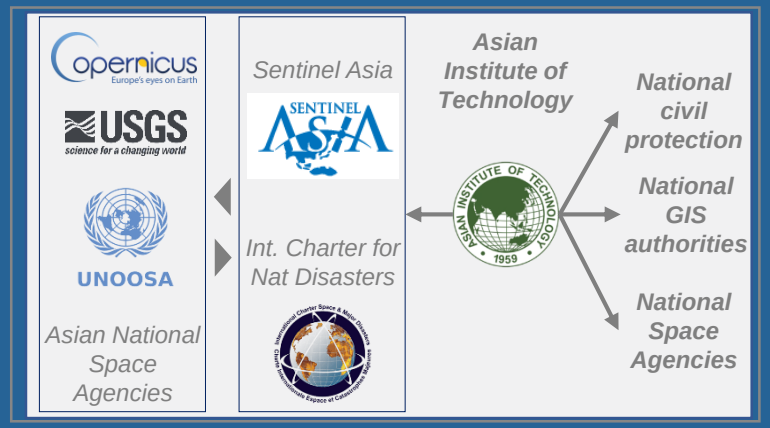
Although earthquakes are rather frequent in this area due to high tectonic plates activity, the twin effect of the seism and the tsunami increases the potential damages to the population and infrastructures.

The event led to over 2,000 casualties, 10,000 injured and more than 70,000 persons evacuated.

ROLE OF THE ASIAN INSTITUE OF TECHNOLOGY

The Asian Institute of Technology (AIT), and more specifically its Geo-informatics Centre, ensures the relay between data providers and national civil protection organisations in South-East Asia, acting as a single access point for satellite data.

Depending on the situation, they use their EO data analysis capabilities, sometimes in collaboration with national space agencies, to translate images received from satellite operators into intelligible and relevant maps for the local authorities. On top of their images processing, the AIT exploits web information to provide a more exhaustive vision of the situation.



Typical role of the AIT within civil protection action loop
(Source: AIT)

COPERNICUS CONTRIBUTION TO THE OPERATIONS IN SULAWESI

EXPLOITATION OF SATALLITE IMAGES TO SUPPORT OPERATIONS IN SULAWESI

The scale of the disaster in Sulawesi led to escalation of Sentinel Asia to the International Disasters Charter. Being the Project Manager, AIT received images from CNES, DLR, CNSA, ESA, JAXA, KARI, ROSCOSMOS, USGS and ABAE.

The first images, received from a Pleiades satellite (50cm resolution), arrived one day after the activation of the Charter.

The analysis of the images was performed in collaboration with the Indonesian National Institute of Aeronautics and Space (LAPAN) and local universities in order to tailor the information products to the local needs for field intervention by civil protection teams. It enabled governments and the army to plan the rescue operations, and to provide a first estimate of the damages in the city with around 5,000 buildings damaged (final estimated around 8,000).

Based on the images received, AIT also provided an analysis of the state of critical infrastructures, enabling for instance to identify alternative routes to damaged roads.

Optical view of the area affected by the tsunami (left) and analysis of building damages in the area affected by the earthquake and the tsunami (right)
(Source: AIT)

NATURAL DISASTERS/ CASE STUDY

Developing river ice satellite monitoring services in remote areas

C-CORE

MONITORING OF RIVER ICE COVERS AGAINST FLOODING

THE DANGERS OF RIVER ICE

During the winter season, rivers throughout Canada experience the development of ice covers from freezing over. These ice covers can become “ice jams”, blocking the river and causing water levels upstream to rise, which in turn can spill over and flood the adjacent land.

The economic impact of ice-jam floods is estimated to be in the hundreds of millions annually. The overall severity is exacerbated by the risk of post-flooding freeze-up.

Key factors to assess in regards to the danger of ice-jam flooding include location, extent and structure of ice field; however, accurate monitoring of these is difficult to achieve over large areas using conventional, field-based or aerial surveillance methods. Therefore, in remote and difficult-to-access areas, surveillance can often be cost-prohibitive.

C-CORE’S RIVER ICE MONITORING SERVICE

C-CORE is a Canadian not-for-profit corporation that conducts applied research, develops technology and delivers services to improve safety, efficiency and cost-effectiveness for clients operating in challenging environments. With core technical expertise in Earth Observation (EO), Ice Engineering and Geotechnical Engineering, C-CORE has more than 40 years experience in the advancement of satellite remote sensing, navigational and communication technologies for environmental and industrial monitoring.

C-CORE’s EO-based river ice monitoring service uses methods of visual interpretation, automated image classification and change detection to generate information related to location of the ice front, ice type and changes to the ice cover. Its project offers advanced prediction and delineation of ice-related flooding, offering reliable and consistent assessments of ice-related flood risk.

Image of typical rough river ice
(Source: C-CORE)

USE OF COPERNICUS FOR RIVER ICE MONITORING SERVICES

USE OF COPERNICUS FOR RIVER ICE MONITORING

The monitoring of river ice covers, with particular emphasis on the freeze-up and break-up periods, is an integral part of flood forecasting for many northern rivers.

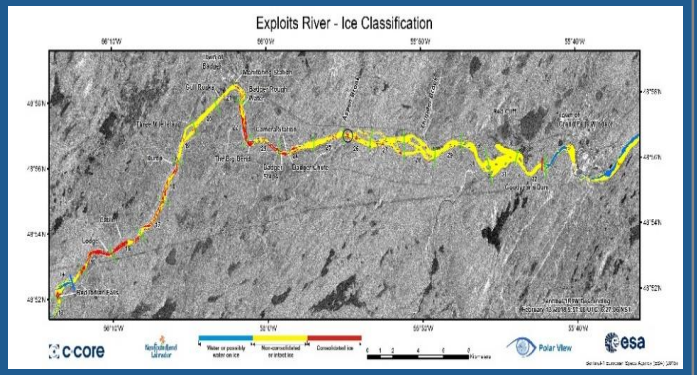
C-CORE relies on Sentinel-1 and Sentinel-2 imagery, together with field-based reference data and hydro-meteorological observations, to deliver time-critical, operational satellite-based river ice monitoring services.

The reliability and quality of Copernicus data has been instrumental in achieving the desired spatial and temporal coverage and guaranteeing satisfactory service levels.

The severity and economic impact of floods related to ice jams has been proven to be significant. In February, 2003 the Town of Badger on the Exploits River, NL (a remote area in eastern Canada) was flooded as a result of a collapsing ice dam. Damages ran to $10 M, with significant negative impact for both residents and the Canadian insurance industry.

Hence, responding to the need for accurate and reliable ice observations, C-CORE is using Copernicus imagery to deliver satellite-based river ice monitoring services across Canada, and in turn this helps:

- Prevent or plan for flooding, to alleviate social and economic impacts in northern communities (e.g. cost of flood damage, loss of human life)
- Share critical information with local stakeholders
- Execute a cost-effective and reliable surveillance program



Example of a river classification on Exploits River using Sentinel-1
(Source: C-CORE)

EMERGENCY RESPONSE/ CASE STUDY

Rapid Mapping services after flooding events in the USA
e-Geos

CONTEXT AND CONTRIBUTION TO THE EMERGENCY MANAGEMENT

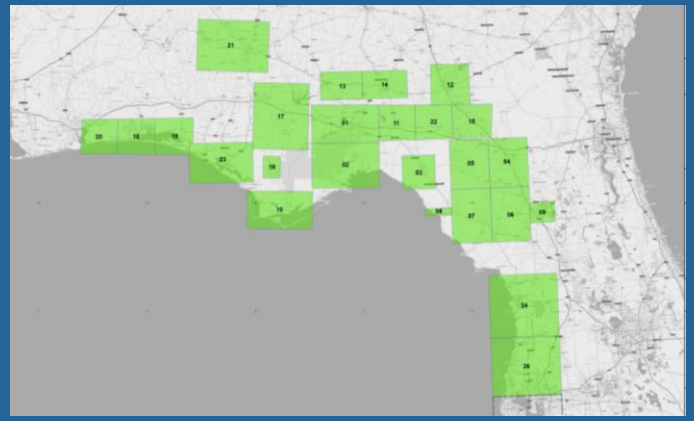
NATURAL DISASTERS: AN INCREASING CHALLENGE

In the past few years the climate change is amplifying the impact of extreme weather events in Europe and worldwide. Tropical cyclones are severely affecting the EU outermost regions and the European overseas territories. Over one million hectares of wildland areas were destroyed during summer 2017 by wildfires in Europe, an area four times the size of Luxembourg.

Natural disasters imply loss of properties and major impacts on the economy including to network infrastructure, businesses, agricultural and forestry activities. In this challenging context it is of outmost importance to grant fast access to fresh information over disater areas to the authorities involved in the emergency management: the more informed humanitarians are, the better they can react

COPERNICUS CONTRIBUTION TO THE EMERGENCY MANAGEMENT

The Copernicus EMS (Emergency Management Service) Rapid provides maps of damage assessment and reference pre-event situation maps based on satellite images, to support civil protection and humanitarian aid operators in their tasks related to the reaction to natural/man made disasters. Access to the service is centrally coordinated at European Commission level by the European Response Coordination Centre (ERCC) at DG ECHO. It is made available free of charge to all Authorized Users operating in Civil Protection and Humanitarian Aids sectors, both for European Member States and international organizations such as the United Nations, the World bank or other NGOs. The results of the service in near real time are published on the Copernicus portal, and are made publicly and openly available in accordance with the Copernicus policy on free and open data.



Areas of interest identified for the post disaster analysis following hurricane Michael (USA) – October 2018 (Source: e-geos)

OPERATIONAL USE OF COPERNICUS EMS

BENEFITS OF COPERNICUS EMS DURING THE HURRICANE SEASON

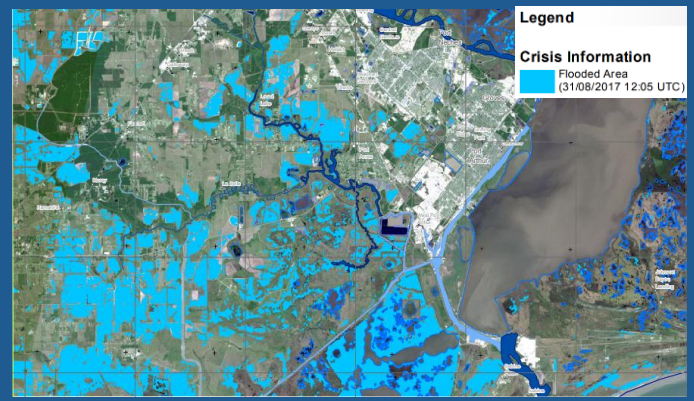
e-GEOS has been involved in the satellite based map production within Copernicus EMS during a number of seasonal hurricanes and typhoons that rage in the Atlantic and Pacific sea.

In 2017 Harvey caused prolonged heavy rains, flooding and storm surge along the Texas coast. President Donald J. Trump issued a Major Disaster Declaration for the state of Texas, making federal funding available for emergency work and to affected individuals and businesses owners who sustain damage as a result of the storm.

The EMS was activated for Harvey, producing 17 post event maps over six areas spread along the US east cost: Houston, Austin, San Antonio, Mathis, Beaumont/Orange (all in Texas) and Lake Charles (Louisiana).

In 2018 the EMS was activated to support the US on three occasions: for hurricane Michael, hurricane Florence that hit the Carolinas and Typhoon Mangkhut that made landfall in Guam (a U.S. island territory in Micronesia). A total of 54 maps were delivered to FEMA and helped the coordination structures as well as local emergency managers to assess the extent of flooding and the magnitude of damage inflicted to buildings and infrastructure after the cyclonic episodes.

"U.S. emergency managers have found great value in the near-real-time, geospatial analytical products prepared by the Copernicus operation centres in Europe. As the 2018 hurricane season ends this month, U.S. emergency management agencies are grateful for Europe's "full, free, and open" data policy.", US Department of State.



Flooded areas identified in the area of Beaumont Orange (USA) after the Hurricane Harvey (Source: e-geos)

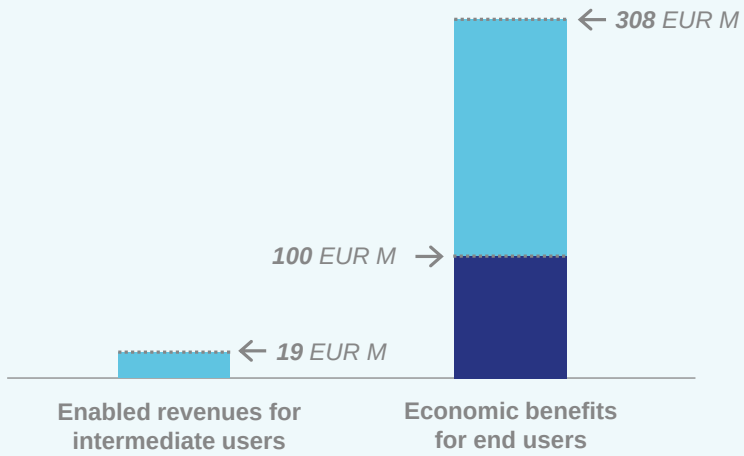
SECURITY

KEY TAKEAWAYS

- Security actors in Europe cover a wide range of applications, on land and on the sea, from border surveillance to vessel detection, oil spill detection, support to police forces and customs, monitoring of illegal fishing or support to European Union (EU) citizens in foreign countries.
- Satellite data offers the strong advantage of providing monitoring capabilities over large areas , especially at sea, which would not be possible with other means such as aircraft, drones or ships.
- Earth Observation (EO) is mostly used to detect behaviours or objects that require further investigation, hence it enables the optimization of the use of EU Member States capacities (aircraft, drones, vessels, human resources).
- The provision of EO services by Frontex, EMSA and SatCen is a clear stimulant for the adoption of EO by end users, since they can directly access services serving their day-to-day operations rather than spending resources in EO capacity.
- For some applications EO is not suitable due to the high reactivity required, in the case of quick movements (e.g. go-fasts) or border crossing on short distances (e.g. between Morocco and Spain).

Copernicus economic impact (2018)

(Source: PwC)



COPERNICUS APPLICATIONS

- Risk analysis on EU external land borders
- Vessel detection and identification
- Detection of abnormal behaviour
- Oil spill detection
- Monitoring of ship traffic
- Detection of icebergs

KEY COPERNICUS PRODUCTS

- Maritime Surveillance – Vessel detection
- Oil spills detection and support to pollution response

SECURITY

SECURITY OPERATIONS ADDRESS A VARIETY OF STRATEGIC GOALS

The scope of Security operations covered in this report covers all the civil applications under responsibility of governmental authorities aiming at ensuring European Union (EU) citizen security and safety. It typically includes the mandates of police forces, customs, Maritime Rescue Coordination Centres (MRCC), Fisheries authorities or military forces involved in civil actions. Such operations can take place both on land and on the seas.

By nature, security operations are strategic for EU Member States, as described in EU regulations such as the Global EU strategy, the EU Space Strategy and the European Defence Action Plan. The ability for governments to protect citizens and to have sovereign capabilities to do so are among key concerns in these regulations.

Services provided by Frontex, EMSA and SatCen as part of the Copernicus Security Service (Source: European Commission, Frontex, EMSA, SatCen)

Coastal Monitoring	Cross-border crime surveillance	Vessel Detection
Pre-frontier monitoring		Vessel tracking and reporting
Reference mapping	FRONTEX	Vessel anomaly detection
Large area pre-frontier monitoring		Environmental assessment
Maritime Surveillance of an AoI	Multi-sensor monitoring	Earth Observation recon

	Fisheries control	
Law enforcement	EMSA	Maritime Safety and Security
Maritime environment (pollution monitoring)		Other uses (support to international organisations)
	Customs	

Critical infrastructure analysis	Conflict damage assessment	Support to evacuation plan
Road Network Status Assessment	SatCen	Non-EU borders map
		Camp Analysis
Reference Map	Activity report	Crisis situation picture

In Europe, although practices vary between MS, the satellite data exploited for civil security operations is largely procured through the 3 entrusted entities of the Copernicus Security Service.

The European Border and Coast Guard agency (Frontex) is responsible for the management of EU external borders. Frontex provides support to national authorities of EU Member States and Schengen Associated Countries in fighting irregular migration and cross-border criminality. Copernicus services, provided in the framework of *EUROSUR Fusion Services*, enhance the situational awareness at the EU external borders and strengthen the risk analysis component of Frontex activities.

The European Maritime Safety Agency (EMSA) was established in 2002 with the mission to ensure a high, uniform and effective level of maritime safety, maritime security, prevention of and response to pollution caused by ships and installations. EMSA became the entrusted entity for the Copernicus Maritime Surveillance (CMS) service in 2015, which enhanced existing EMSA services by offering new and extended access to maritime Earth Observation (EO) data. CMS provides services to European maritime authorities with operational tasks in areas such as fisheries control, maritime safety, law enforcement, customs and environmental monitoring. EO products are combined with other data from EMSA systems (e.g. vessel information) and delivered through a dedicated user interface.

The third entrusted entity, the European Satellite Centre (SatCen), supports Frontex and EMSA by providing data and analytics, and also coordinates the Copernicus Security Service in support to the EU External Action (SEA). As such SatCen assists the EU representatives and citizen dealing with crises or emergency situations in third countries. It supports for instance the monitoring of political and armed conflicts, provides situational awareness, and support humanitarian operations or border surveys.

SECURITY

SITUATIONAL AWARENESS IS A CRUCIAL NEED ACROSS USER COMMUNITIES

Although land and sea environments follow different dynamics, the effectiveness of Security operations is largely supported by having access to an exhaustive understanding of the situation, or "situational awareness".

SECURITY ON LAND

The regular monitoring of EU external land borders by Frontex, supported by SatCen for the provision of some images, provides vulnerability assessment and risk analysis for land operations, exploited for intelligence needs. To a smaller extent, Frontex provides EU Member States with the last available analyses to support planning in the frame of joint operations, both on land and at sea.

SECURITY AT SEA

Besides the border operations managed by Frontex, sea operations encompass a wide range of activities, for which EMSA provides EO products and analyses.

Law enforcement operations through maritime surveillance includes activities such as:

- Detection of illicit activities by non-reporting vessels
- Border surveillance for illegal immigration (in particular in the Mediterranean Sea)
- Support to customs operations
- Monitoring of illegal fishing activities

Oil spills monitoring and mitigation is also a crucial area of contribution for satellite images and in particular Sentinel-1, as illustrated by the wide uptake of the CleanSeaNet service provided by EMSA.

Maritime safety is a strategic activity for EU governments, where satellite data can support Search and Rescue operations (typically by analysing currents and waves) and can improve ships routes safety through monitoring of the traffic and, in polar regions, of icebergs.

These operations are performed by different authorities from EU MS, each with their specific needs, but remain interconnected, typically from the command chain perspective, creating potential synergies on EO data requirements.

WHY EARTH OBSERVATION?	APPLICATIONS	BENEFITS	END USERS
LAND BORDER SURVEILLANCE	• Vulnerability assessment • Risk analysis • Near-real time analysis for joint operations	• Intelligence on critical infrastructures in pre-frontier areas • Better informed operations planning and coordination	• Frontex • Coast guards • Police and law enforcement authorities
MARITIME SURVEILLANCE	• Vessel detection and identification • Anomaly and abnormal behaviour detection • Search & Rescue	• Detection of suspect activities over large EEZ • Initial insights to commission in-situ means • Evidence support to prosecutions	• Frontex • Coast guards and law enforcement authorities • EFCA and national fisheries agencies
POLLUTION COMBAT	• Detection of oil spills • Drift models for oil spill development and origin	• Recurrent monitoring over large areas • Better informed planning for mitigation operations • Evidence support to trace back the origin	• Maritime Rescue Coordination Centres • EMSA
MARITIME SAFETY	• Monitoring of ship traffic • Icebergs detection • Drift models for Search & Rescue	• Reduced risk of traffic incidents • Improved efficiency of Search & Rescue operations	• Maritime Rescue Coordination Centres • Commercial vessels companies • NGOs

SECURITY

DRIVERS AND CHALLENGES FOR THE ADOPTION OF EO FOR SECURITY OPERATIONS

The first benefit of the availability of satellite images for security actors is undoubtedly the large swath offered at each fly-by, in particular for sea operations as the Exclusive Economic Zones (EEZ) of EU Member States can be extremely wide, and also extremely remote around the globe. Satellite monitoring is a game changer in the approach for surveillance, as an initial scan of the area of interest, enabling the identification of regions where to commission aerial means, official vessels, drones, or which vessel of opportunity to contact for confirmation.

Similarly to many end user communities, EO capabilities and manipulation skills tend to be limited within law enforcement authorities, coast guards, fishing authorities or rescue centres. The role of EU agencies Frontex and EMSA is a key driver as providers of not just EO data but analysed products and intelligible inputs for operational units. This allows EO to be smoothly integrated in the decision chain.

The improvement of data resolution contributes to expanding the base of targets that can be detected and identified (such as vehicles and boats below 10m length), stimulating the interest of authorities for satellite images.

DRIVER 1

Seas and Exclusive Economic Zones (EEZ) are wide areas where satellites are the only effective approach for surveillance

DRIVER 2

Provision of professional services by Frontex and EMSA stimulate EU Member States to adopt EO services

DRIVER 3

Increasing need for Very High Resolution data at sea, when targeting small boats

CHALLENGE 1

Persistent monitoring is crucial at sea, for it is a permanently evolving environment

CHALLENGE 2

High reactivity required for border surveillance

Seas and oceans are constantly moving environments, where the analysis of historical data is not relevant and where movements and changes are furtive. The effectiveness of surveillance activities is closely related to their persistence, raising barriers to the contribution of satellites, which are constrained by orbital geometry.

In addition, operations at EU borders sometimes require a high reactivity, when cross-border movements need to be monitored, due to the proximity of the non-EU territories. This can be the case for both land borders (in eastern Europe and around Turkey) and sea borders (Gibraltar strait, North Africa and Malta or Italy). Provided an image can be quickly acquired, the processing time is another constraint that can obviate EO products in these situations.

This also illustrates how user requirements for EO data vary with the situation and context, inevitably with cases where it contributes less than in others.

SECURITY

THE VALUE CHAIN OF EO DATA FOR SECURITY APPLICATIONS

	ACQUIRING EO DATA	PROCESSING NEEDS AND CAPABILITIES	USERS & NEEDS
	Overall data needs • Security applications characterized by large needs for high resolution data, procured from Copernicus contributing missions • EO data complemented with aerial observations • In the future, expectations to integrate other sources such as Remotely Piloted Aircraft Systems (RPAS) and High Altitude Pseudo Satellites (HAPS)	**Data format and in-house capabilities** • Beside image analysis, EO data requires fusion with other data sources to become meaningful • EMSA, Frontex and SatCen all partly rely on consortiums of private service providers • Integration of commercial images with Sentinel data done by EU entities	*Non exhaustive list*
Land	• Data for Frontex operations on land obtained through the Copernicus Space Data Access System (CSDAS) and through SatCen • Drones start to be used as a complement to satellites for emergencies	• EO data merged with other sources such as open sources (OSINT) and Human Intelligence (HUMINT) • Use of in-situ data for internal calibration and validation	• Law enforcement forces of EU MS in the frame of Joint Operations • EU Member States authorities for their own national needs
Sea	• Radar is the main type of EO images used • Historically, use of Envisat and Radarsat-2, with Sentinel-1 now replacing Envisat • EMSA acquires EO data for its own needs as well as for Frontex (for sea operations) • Size vs. resolution dilemma: low resolution enables larger swath but difficult to distinguish targets (e.g. ships vs. vessels) while higher resolution creates more noise • Images can also be provided by national services (e.g. iceberg detections, oil spills detection) • New types of sensors such as infra-red expected to be integrated in the future	• For maritime surveillance, EO data merged with satellite and terrestrial Automatic Identification System (AIS), Long Range Identification and Tracking (LRIT) and Vessel Monitoring System (VMS) • Multi-sources intelligence required for some applications (e.g. smuggling) • Currents models, waves models and ice conditions provided by CMEMS • Oil detection services in the EU largely rely on CleanSeaNet (EMSA) largely using Sentinel-1 images, completed by national services for the few Member States equipped	• Frontex for sea operations • Law enforcement authorities • Fisheries agencies and the European Fisheries Control Agency (EFCA) • Maritime Rescue Coordination Centres (Search & Rescue) • Non Governmental Organisations, in particular for Search & Rescue operations • Commercial vessels companies

SECURITY

THE COPERNICUS SECURITY SERVICE ENABLES MORE USERS AND PROVIDES VALUABLE LEADS ON GROUND OPERATIONS TARGETS

The surveillance services provided by Copernicus differentiate from traditional commercial providers as they give access to affordable monitoring of the large areas under security actors jurisdiction, allowing the use of local capabilities more efficiently.

This occurs in a context where many EU Member States face increasing pressure on the budgets and resources available to conduct the operations, and where detection services on hundred-km scales are mandatory to be able to have an impact on illicit activities.

On top of it, the provision of security products tailored to EU authorities enables the uptake of satellite-based inputs by non-expert users.

		Copernicus strengths	*Copernicus weaknesses*
By providing free products to its customers, the entrusted entities of the Copernicus Security Services ensure the affordability of surveillance means over the large areas under security actors' jurisdiction. Based on it, national authorities can greatly improve the efficiency of use of their local capabilities (ships, aircraft, etc.) and human resources.	***COPERNICUS IS A GAME CHANGER FOR EFFICIENCY OF SURVEILLANCE MEANS***	***COPERNICUS EXPANDS THE ALLOWED USER BASE FOR SECURITY PRODUCTS***	Historically, security products and analyses performed by EU entities are restricted in terms of dissemination. The Copernicus Security Services increase the eligible user base (such as for the European Fisheries Control Agencies), expanding the scope of mandate of the Entrusted Entities.
As for many end users, the expertise and skills required to manipulate and interpret EO data is a barrier. The access to end products through the Copernicus Security service saves time and effort, encouraging the users to adopt satellite data. As an illustration, the user uptake greatly increased since such services have been provided by EMSA and Frontex.	***COPERNICUS USERS CAN FOCUS THEIR EFFORT ON SURVEILLANCE***		
For some applications, routine monitoring is valuable, typically over geographically defined areas such as Exclusive Economical Zones. Where commercial services quickly become too expensive, the Copernicus Security Service provides an affordable answer, boosting the maritime awareness over these areas.	***ROUTINE MONITORING BECOMES ACCESSIBLE TO USERS***	***SENTINEL RESOLUTION IS NOT ENOUGH FOR SOME MARITIME SURVEILLANCE APPLICATIONS***	Vessel detection requires the ability to spot ships with a size down to a few meters, for which Sentinel-1 resolution is not always suited. When complemented with optical images, Very High Resolution is required for identification. In such cases, commercial satellites are better adapted.

SECURITY

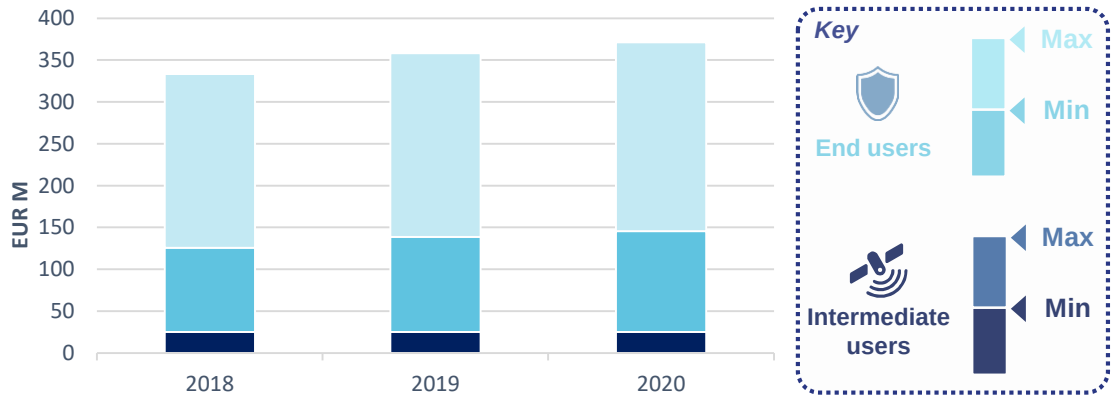
COPERNICUS BENEFITS FOR SECURITY OPERATIONS

The enabled revenues for the intermediate users are the sales of data to EU agencies (SatCen, Frontex, EMSA). The budgets of Frontex, EMSA and SatCen for the provision of the Copernicus Security service represent a total of EUR 25.2 M in 2018.

Combatting illegal fishing improves the revenues of the fishing industry, supports the preservation of fish stocks in the long term, and enables prosecution and fines by the EU Member States. Current estimates of illegal fishing catches amount to about 17,700 tons per year, representing combined benefits between EUR 30 K and EUR 90 K in 2018 for Copernicus*.
Oil pollution monitoring also leads to both a direct economic impact (fishing industry losses, tourism, maritime transport, cost of cleaning operations) and an ecological impact (destruction of marine and bird ecosystems) quantified through a valuation factor. The contribution of Copernicus to the reduction of these impacts is estimated in 2018 between EUR 30 M and EUR 50 M*.
Law enforcement benefits are quantified based on the value of illegal goods seized at EU borders (drugs and counterfeit goods), and the reduced treatment costs in Europe, assuming an impact on drugs consumption. The yearly value of counterfeit goods intercepted stands between EUR 600 M and EUR 700 M, while the value for drugs vary between EUR 1.8 B and EUR 3.5 B. Out of this, the benefits from Copernicus are estimated between EUR 70 M and EUR 250 M in 2018*.

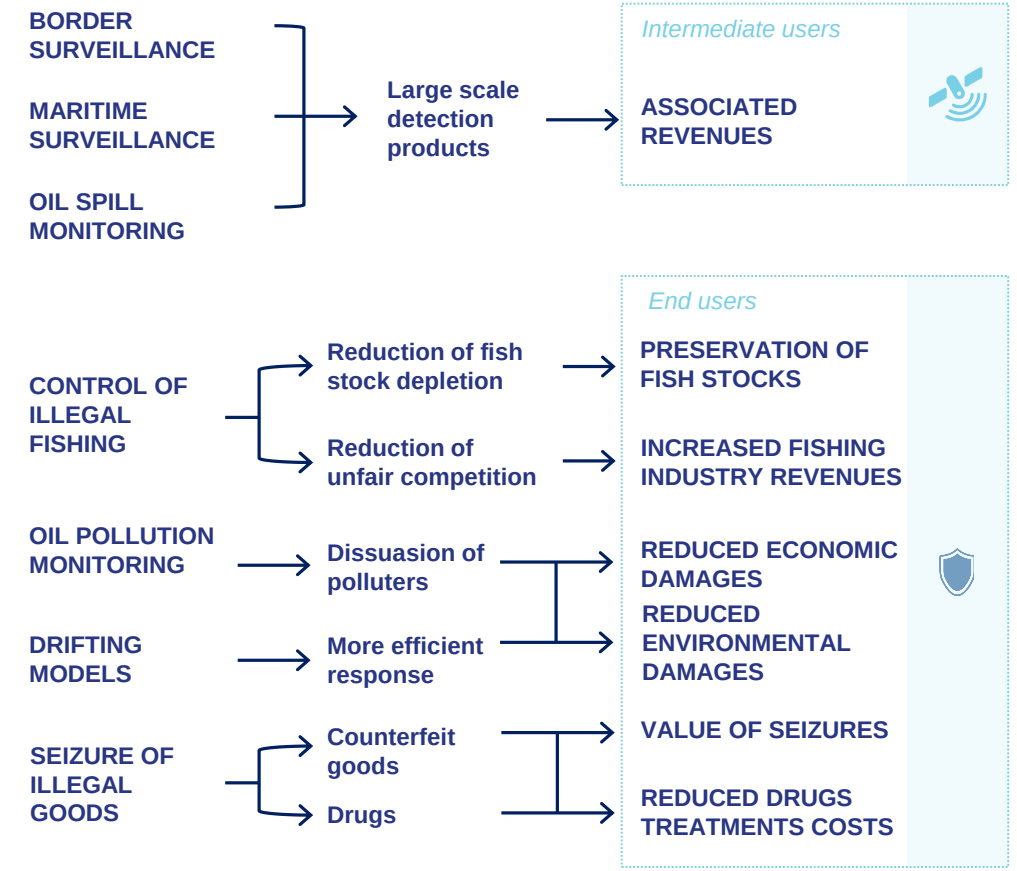
Economic benefits of Copernicus through its contribution to security operations

(Source: PwC)



** Source: PwC, 2017, Copernicus ex-ante societal impact assessment*

Economic impacts



SECURITY

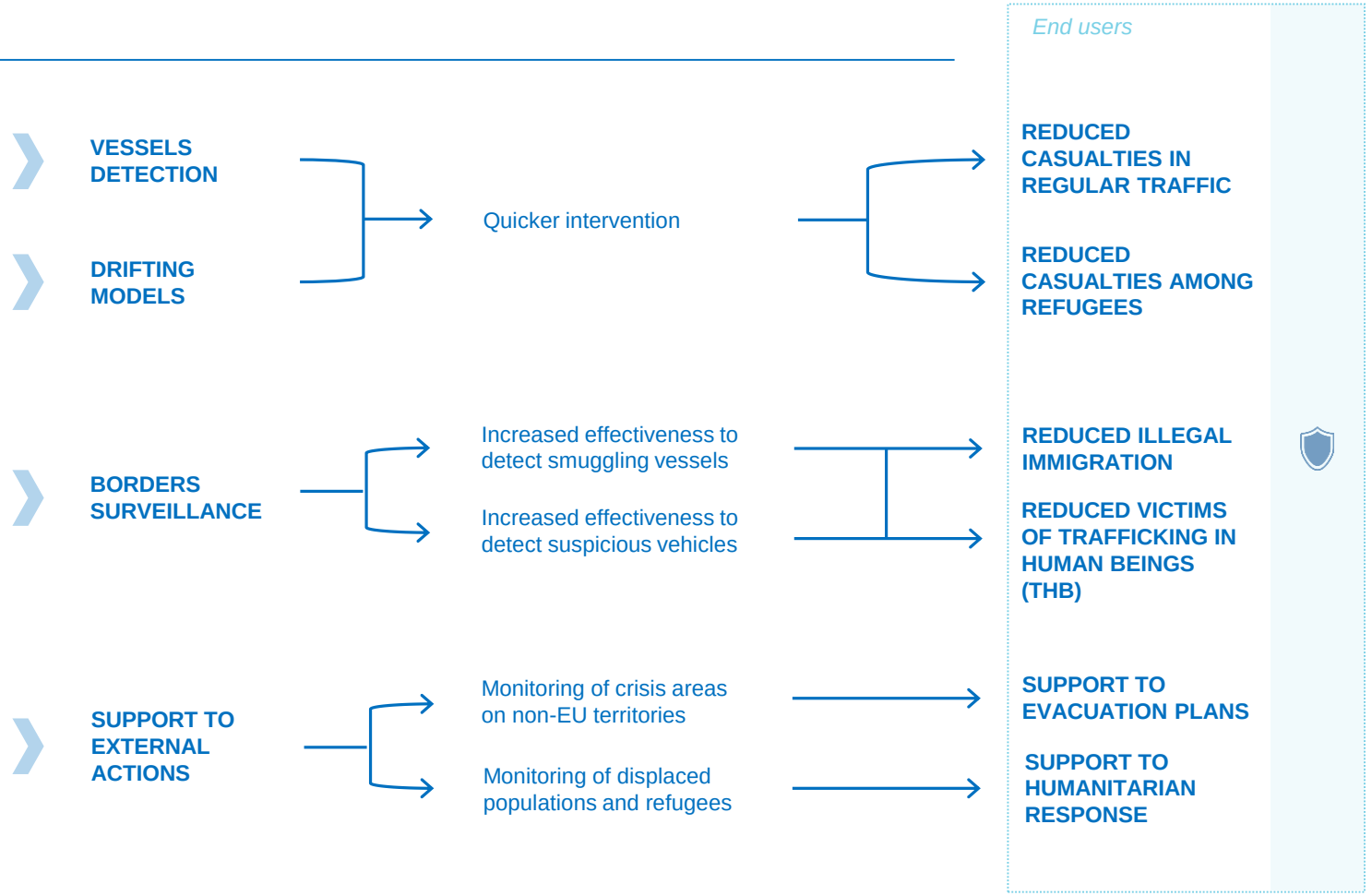
COPERNICUS BENEFITS FOR SECURITY OPERATIONS

Social impacts

The detection of vessels also contributes to Search & Rescue operations, mainly through 2 modes. For reported incidents, authorities can benefit from a more precise location of the boat based on satellite images combined with drifting models, depending on the delay between the signal and the image acquisition. In the case of refugees boats, which is a major concern in the Mediterranean Sea at the moment, boats that cannot signal their position can also be spotted as uncorrelated vessels, triggering further investigation before sending field support.

In the frame of border surveillance activities, suspicious vehicles or vessels based on satellite images can be targeted more precisely by border police forces and customs (on the same model as for illegal goods), helping preventing some cases of human trafficking or other illegal entry on EU territory.

In the cases of crisis situations in foreign countries, the monitoring of the situation by Copernicus enables EU authorities to build appropriate evacuation plans for their citizens, ensuring the right timing and access through understanding of the local movements and dynamics. Such monitoring is also an important contribution to humanitarian operations, as it provides awareness on the movements and location of displaced populations and refugees, anticipating influxes in certain areas and risk of accumulation of precarious populations.



SECURITY

COPERNICUS BENEFITS FOR SECURITY OPERATIONS

Environmental impacts

Through their action to detect and mitigate oil spills, EU authorities have a direct impact on the reduction of damages on local ecosystems, mainly fishes but also birds and the littoral wildlife.

Control of illegal fishing also supports the renewal of fish stocks and species by reducing the risks of depletion, both when illegal anglers are caught in action, and in the longer term as their surveillance and action becomes more effective, dissuading the anglers and reducing the attempts of illegal fishing.

OIL POLLUTION MONITORING

DRIFTING MODELS

→ Better timeliness for mitigation response → **REDUCED IMPACT ON ECOSYSTEMS**

CONTROL OF IUU FISHING

→ Reduction of fish stock depletion → **PRESERVATION OF MARINE ECOSYSTEMS**

→ Dissuasion of illegal activities

Strategic impacts

The monitoring and awareness of strategic areas such as the EU pre-frontiers (Russia and eastern Europe, Turkey, Middle-East and North Africa) enables EU governments to remain aware of the situation evolution with regards to critical infrastructures (ways of circulation, airports and ports, energy and nuclear plants, weapon sites etc.). It provides valuable information to adapt diplomatic relations for instance. The aim is to be able to avoid potential conflicts, as better anticipation gives time to build dialogue and appropriate solutions.

Better understanding of pre-frontier areas at risks, to anticipate potential crises and conflicts → **DEFUSING OF POTENTIAL CRISES**

Intelligence for critical infrastructures and movements of military troops → **BETTER PREPAREDENESS TO CONFLICTS**

End users

SECURITY / CASE STUDY

Supporting customs activities at sea
European Maritime Safety Agency (EMSA)

CUSTOMS ACTIVITIES AND ROLE OF SATELLITE IMAGES

THE ROLE OF CUSTOMS FORCES AT SEA

The role of European customs authorities at sea is to ensure the smooth flow of trade activities, and the prevention of illegal imports of goods into the EU. Sensitive goods under scrutiny include counterfeit goods, drugs, weapons, medicines and sometimes protected wildlife species.

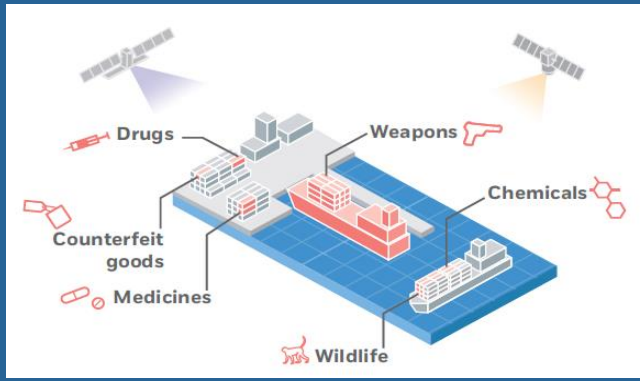
With around 16% of the worldwide trade transiting by the EU every year, the large quantity of goods to be controlled is a challenge for customs. Most of these goods are transported by sea, representing about 1,800 million tonnes of ship cargo every year.

THE CONTRIBUTION OF SATELLITES TO CUSTOMS ACTIVITIES

Satellites constitute valuable assets for the customs mandate, as they allow the monitoring of the wide areas under their authority, and provide an oversight of the traffic at sea. Using satellite images, customs can detect suspicious activities and intervene to investigate potential criminal activity.

In this context, the Copernicus Maritime Surveillance (CMS) service provides

- Vessel detection to monitor ships suspected to be involved in trafficking or smuggling
- Monitoring of abnormal behaviours such as ship-to-ship transfers at sea
- Early warning and identification for criminal vessels



Main targets of customs for prevention of illegal goods trafficking
(Source: EMSA)

CONTRIBUTION OF COPERNICUS TO VESSEL APPREHENSION IN SPAIN

TRAFFICKING RISKS IN SPAIN AND PORTUGAL

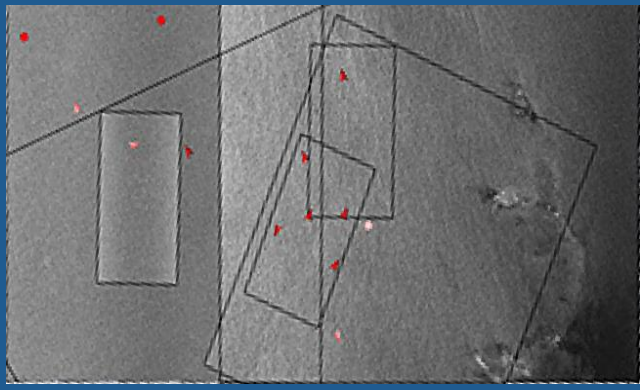
Spain and Portugal, by their geographic location, constitute key entry points in Europe for ships crossing the Atlantic. Routes from South America or from West Africa are closely monitored by anti-drug-trafficking authorities and lead to frequent detection of suspect vessels and field operations to investigate.

In this context, the Spanish Directorate of Customs Surveillance makes routine requests to CMS service, both for regular monitoring and for short notice requests in order to complement needs based on other sources of intelligence. The CMS service is provided by the European Maritime Safety Agency (EMSA), as part of the Copernicus Security Service.

CMS ACTIVATION FOR INTERCEPTION OF DRUG SMUGGLING VESSEL

In May 2017, the Spanish Customs Surveillance, in cooperation with the Portuguese Authorities, the US Drug Enforcement Agency and the UK National Crime Agency had identified a suspect vessel, based on combined intelligence from several organisations. The vessel, suspected of transporting large quantities of cocaine, was searched for between South America and Europe.

The Spanish Authorities requested the CMS services to monitor the vessel. Combining radar images and vessel detection, the Venezuelan-flagged fishing vessel Ali Primera was located and identified, enabling Spanish Authorities to intercept it South West of the Canary Islands. After investigation and search, around 2.4 tons of cocaine were seized by the customs, worth about 100 M€, and 7 crew members were arrested.



TerraSAR-X image provided through CMS in support to the operation
(Source: EMSA)

SECURITY / CASE STUDY

Support to interception of smuggling vessel in Greece Frontex

FRONTEX

THE COPERNICUS BORDER SURVEILLANCE SERVICE

SCOPE OF THE COPERNICUS BORDER SURVEILLANCE SERVICE

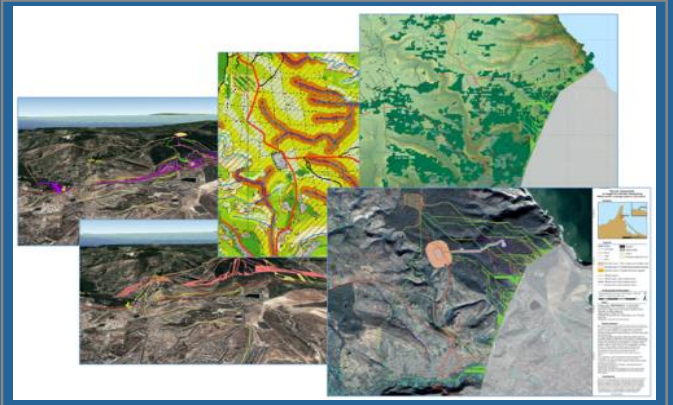
The Copernicus Border Surveillance Service implemented by the European Border and Coast Guard Agency (Frontex) improves the situational awareness at the EU's external borders, contributing to saving lives at sea and tackling cross-border crime.

The Copernicus Border Surveillance Service includes automated vessel tracking and detection capabilities, software functionalities allowing complex calculations for detecting anomalies and predicting vessel positions, as well as precise weather and oceanographic forecasts. Services use optical and radar satellite technology to locate vessels requiring search and rescue operations or those that are suspected of being engaged in criminal activities, such as drug or weapon smuggling.

LEVEL OF ACTIVITY OF THE BORDER SURVEILLANCE SERVICE

In 2018, under the Copernicus Border Surveillance Service, Frontex has delivered 2208 radar images, which were used for the Vessel Detection activities, and 1787 optical images for surveillance and analytical purposes.

In comparison to 2017, there was a significant increase in delivery of Earth Observation imagery. In case of SAR imagery it was due to the migratory pressure in the central Mediterranean area; as for optical imagery, it was linked to the enhancement of surveillance of ports of departures for activities related to cross-border crime.



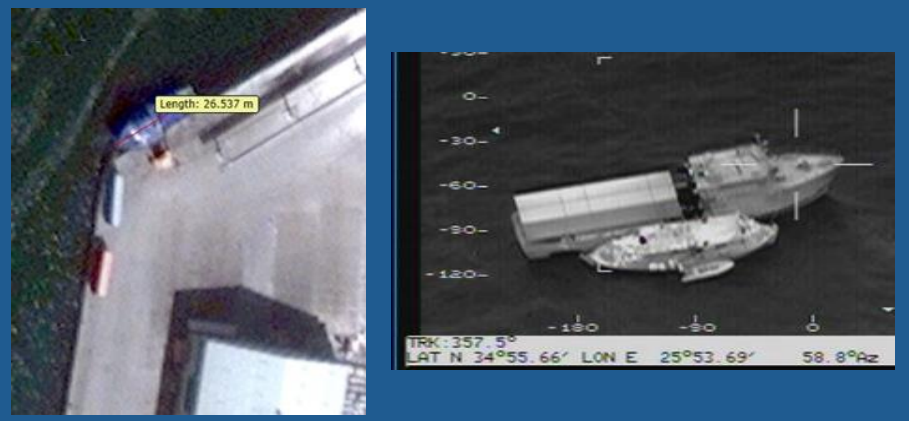
Land border surveillance analytical products
(Source: Frontex)

SUPPORT TO VESSEL INTERCEPTION IN GREECE

SUPPORT TO A VESSEL INTERCEPTION IN GREECE

A vessel was of interest after being intercepted in 2015 for tobacco smuggling. In 2018, following the detection of a rendezvous and cargo transfer at sea, the vessel was identified, and was located in the port of Beirut, still based on satellite images.

After its departure from Beirut, the ship was tracked using the Copernicus Border Surveillance service. When reaching Greece, she was intercepted by the authorities, in March 2018.



Ship identification in the port of Beirut and images of the cargo loading at sea
(Source: Frontex)

Maritime surveillance picture in Greek seas
(Source: Frontex)

SECURITY / CASE STUDY

Supporting combat of illegal immigration in Indian Ocean French Coast Guard (COFGC)

CONTEXT AND CONTRIBUTION OF SATELLITE IMAGES

CONTEXT

The French maritime area in the South Indian Ocean includes the territorial waters around the island of Mayotte. Located half-way between Madagascar and the Mozambique in East Africa, Mayotte is less than 70 km away from the island of Anjouan, part of the Union of the Comoros. This proximity fosters the illegal migratory flow through seas, in particular in the context of extreme poverty of the Union of Comoros. As a consequence, Mayotte has been facing a persistent migratory pressure in the past years.

In order to rally Mayotte, Comorian migrants use light traditional fishing vessels (about 7m long), called kwassa-kwassa. These motored vessels usually have no pavilion, no matriculation nor safety equipment.

CONTRIBUTION OF SATELLITE IMAGES

The challenge for satellite monitoring is that kwassa-kwassa have a very low radar signature (by their size and construction), and perform the transit between the islands in about 3 hours.

The combined use of multiple sources of information must allow for detection as upstream as possible of vessels with potential migrants on-board, in order to be able to intervene on time.

Optical images constitute a preliminary support for visual detection confirming or not the departure of the vessels, their transit or their arrival at Mayotte. The users of the images, the French Coast Guard authorities in the case of Mayotte, use these images and analyse them in order to potentially trigger the commissioning of operational means in the area.

Example of a kwassa-kwassa used to transport migrants
(Source: French Coast Guard Authority)

EXPERIMENTATION OF THE EUROSUR SERVICES

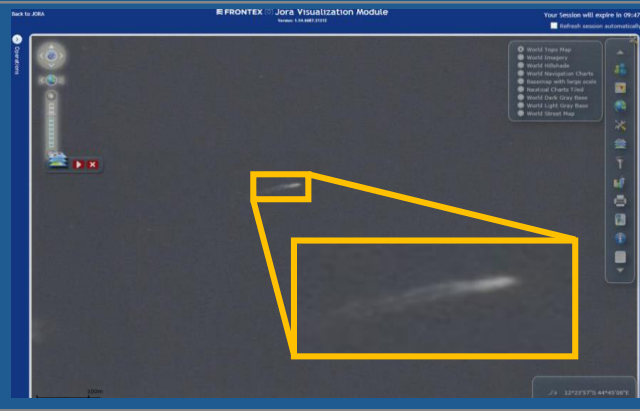
USE OF EUROSUR SERVICES TO DETECT KWASSA-KWASSA

In an attempt to offer support to the fight against illegal immigration in Mayotte, an experiment of 3 services provided by the European Border and Coast Guard Agency (FRONTEX) in the frame of the European Border Surveillance system (EUROSUR) has been conducted between May and July 2018 in the area of Mayotte.

The experimented services included optical satellite imagery (service 8) and vessels detection based on radar images (service 4). The purpose of using satellite images was to detect kwassa-kwassa in migrant departure areas in Comoros, then to monitor their displacement before their arrival near Mayotte departure using the satellite-based services. This information was then exploited to commission intercepting vessels in charge of meeting the ships at sea and apprehending them.

USE OF SENTINEL IMAGES

In the frame of EUROSUR services, Frontex provides the satellite images to the Member States, using data potentially coming from various sources and various satellites. This enables the adaptation of the types of images (resolution, revisiting time) to the users needs. In the frame of the experiment in Mayotte, the resolution of Sentinel images appeared to be too low to discriminate between regular fishing vessels and the boats used by the migrants.



Detection of a kwassa-kwassa through EUROSUR services experiment conducted in Mayotte
(Source: French Coast Guard Authority)

SECURITY / CASE STUDY

Detection of illegal activities on the seas
Icelandic Coast Guard

COAST GUARDS MISSIONS AND CHALLENGES FACED

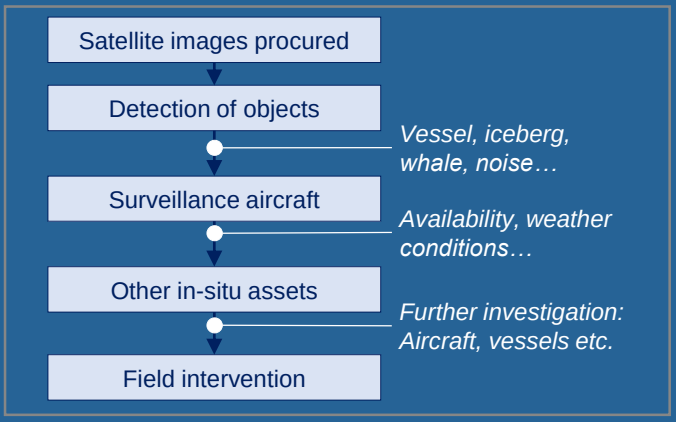
THE CHALLENGES FACED BY ICELANDIC COAST GUARD

Among the various missions of coast guards, the maritime surveillance serves multiple purposes, spanning from law enforcement at sea, the management of traffic safety, or of fishing activities or oil spills monitoring. The areas of responsibility of Icelandic Coast Guard extend well beyond the territorial waters (12 nautical miles from the coast), and include the entire Exclusive Economic Zone (EEZ, 200 nautical miles from the coast) and a Search & Rescue region of 1.9 million km².

In this context, satellite images are a crucial source of information to complement aerial means and vessels, providing a more exhaustive vision of the events of interest occurring in these different areas.

PURPOSE OF DETECTING NON-REPORTING VESSELS

A number of illicit activities carried out at sea are correlated to the presence of vessels not reporting their position through maritime systems such as the Automatic Identification System (AIS), or the Vessel Monitoring System (VMS) for fishing boats. Satellite images are used to detect objects on the surface of the sea, and can identify non-reporting vessels when compared with the picture provided by ships reporting systems. This triggers further investigation and the commissioning of local means in-situ, such as aerial vehicles or vessels.



Chain of action or detecting non-reporting vessels by Icelandic Coast Guard (Source: Icelandic Coast Guard)

COPERNICUS CONTRIBUTION TO THE IUU FISHING DETECTION IN ICELAND

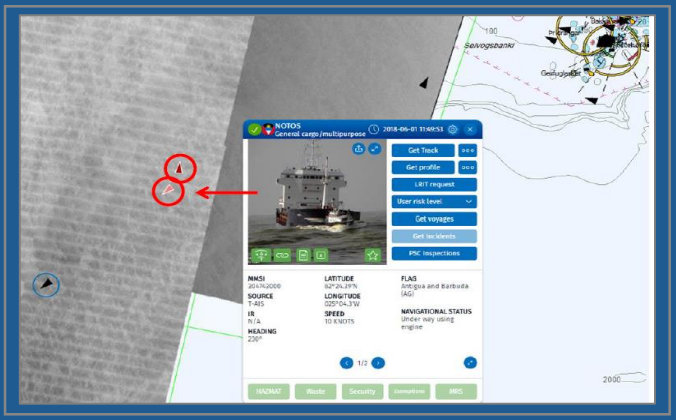
CONTRIBUTION OF COPERNICUS TO COAST GUARDS SURVEILLANCE OPERATIONS

As part of their EO sources, the Icelandic Coast Guards use the Copernicus Maritime Surveillance service provided by the European Maritime Safety Agency (EMSA). The service provides maritime situational awareness using Sentinel-1 data and Radarsat-2 data, as one of the contributing missions to Copernicus. Both satellites provide radar data, which is particularly suitable to detect objects on the surface of the seas.

CONTRIBUTION TO ILLEGAL FISHING DETECTION

On the 1st June 2018, the Icelandic Coast Guard received an image from the Copernicus service, showing an uncorrelated target of about 63m length, with a high confidence level in the interpretation. As a first verification, a nearby vessel was contacted, which was able to provide information on the activities of the detected target. A surveillance aircraft was then diverted to perform an in-situ investigation, and it identified the target as a foreign state fishing survey vessel (exact length 76m). Although legally acting in the area, the ship was operating without shining its AIS. When notified by the coast guard's maritime surveillance aircraft, the ship turned on its transmitter.

The event demonstrated the benefit of large area coverage by satellites, the usefulness of image analysing services, and enabled Iceland authorities to be more effective in their law enforcement activities at sea.



Radarsat-2 images showing the vessel detected (Source: Icelandic Coast Guard)

SECURITY / CASE STUDY

Supporting interception of "Go-Fast" boats
Airbus Defence & Space

AIRBUS

CONTEXT OF THE CAMPAIGN IN THE CARIBBEAN SEA

PRINCIPLE OF GO-FAST ON THE SEAS

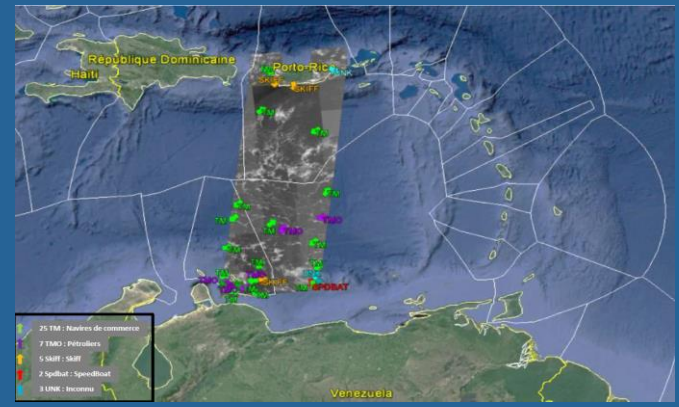
Among the vessels of interest for law enforcement authorities, some consist of small embarkations moving at very high speed, also called "speedboats". Similarly to the high speed cars targeted on roads, such vessels are sometimes used to transport illicit goods (often drugs), in which case they are labelled as "Go Fast". The purpose for smugglers is use their velocity and short travelling time as a mean to avoid interception and controls by the authorities.

These boats usually do not exceed few meters in length, hence are challenging to detect using satellite images; however, they also have a specific wake that eases their detection.

SITUATION IN THE CARRIBEAN SEAS

During the month of February 2018, an observation campaign has been conducted in the Caribbean Sea in the frame of the Trimaran II service. The objective was to detect and identify speedboats coming from the Venezuelan coast and aiming for the north-west or north-east, as they constitute potential go-fast vessels.

This campaign has been performed using Sentinel-2 images (optical data) with a 10-m spatial resolution. The aim was to demonstrate to the French Armed Forces of the Antilles (FAA) the feasibility of Go-Fast detection during the day using Sentinel data.



Situation in the Caribbean Sea (22nd February 2018)
(Source: Airbus Defence & Space)

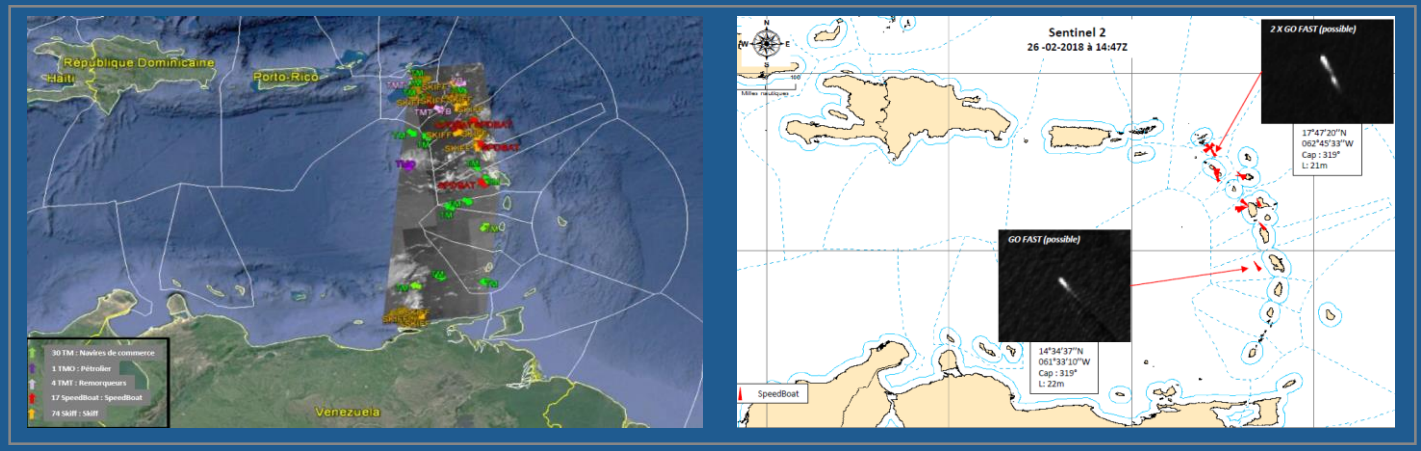
CAMPAIGN RESULTS

DETECTION OF SPEEDBOATS

There were a total of 35 speedboats detected within the area of interest over the 5 day period of the campaign.

Out of the 35 detected vessels, five have been tagged as 'Go-Fast'. In addition, three further objects have been located west of the Antilles Arc, out of territorial waters and two others have been observed leaving the coast of Venezuela within the southern part of the observation area.

To conclude, the satellite image and related value-added products reinforces custom authorities' capacity to maintain oversight of goods that are transported at sea. In particular, to detect and intervene when criminal activity is suspected, customs and other anti-drug-trafficking authorities frequently use intelligence information based on satellite images to detect and intercept suspicious vessels.



Detection of vessels and identification of potential Go-Fast (26th February 2018)
(Source: Airbus Defence & Space)

APPENDICES

© ESA – Processed image of Sentinel-2

METHODOLOGY FOR THE STUDY

OVERALL APPROACH

The Copernicus Market Report 2019 is an update of the previous Copernicus Market Report, published in 2016.

- The assessment of the GDP impact, based on the investments in the industry carried out by the European Commission and the European Space Agency, has been updated considering the expected overall spending up to 2020.
- The update relies on the re-assessment of the 8 value chains characterised in the previous report, and includes 2 additional value chains on the Response to natural disasters and Security.

The characterisation of the value chains relied on a mix of bibliography review and stakeholder consultation across the industrial sectors of interest.

The different steps to calibrate, prepare and conduct the consultation are the following:

Characterisation of the additional value chains	• Understanding and characterising the value chain stages • Based on past experience with these sectors and discussions with Copernicus experts
Mapping of the main players in the value chains	• Identification of the relevant players involved in each stage of the value chain • Screening of companies and organisations involved
Select company samples	• Sizing of samples to be representative, based on players stages, country and profile (private/institutional) • Targeting of large samples to anticipate response rate
Engage organisations in direct interviews	• Acquisition of qualitative data: scope of activities, types of products, usage of EO and of Copernicus, drivers and barriers for users uptake, alternative solutions and substitutes, impact of Copernicus data and services • Acquisition of quantitative data: revenues distribution, contribution of EO, distribution of satellite sources, dependence of operations on EO data, investments made to support business
Extrapolate the results to the whole value chain	• Extrapolation of sample to the overall value chain • Consideration of sample profiles, expertise and representativeness

Copernicus Market Report 2016

GDP impact Assessment
2016 estimates of the total investments in the Copernicus Programme up to 2020

Impact Assessment per Value Chain
Agriculture
Forestry
Urban Monitoring
Ocean monitoring
Oil & Gas
Renewable Energies
Air Quality
Insurance for Natural Disasters

Copernicus Market Report 2019

GDP Impact Assessment
2018 estimates of the total investments in the Copernicus Programme up to 2020

Impact Assessment per Value Chain
Agriculture
Forestry
Urban Monitoring
Coastal and marine exploitation and preservation
Oil & Gas
Renewable Energies
Air Quality
Insurance for Natural Disasters

+ Response to natural disasters
+ Security

METHODOLOGY FOR THE STUDY

CONSULTATION OVERVIEW

To support this impact assessment, the following organisations have been consulted. **Not all the companies are cited, as some of them preferred to remain anonymous.**

Institutional stakeholders

Asian Development Bank (ADB)
Asian Institute of Technology (AIT)
Bantry Marine Research Station Ltd
Copernicus User Forum Members
Center for International Forestry Research (CIFOR), UN
DiscovAir
DTU Space
ECMWF
European Association of Remote Sensing Companies (EARSC)
European Broder Surveillance and Coast Guard Agency (Frontex)
European Commission – DG for European Civil Protection and Humanitarian Aid Operations (ECHO)
European Commission Joint Research Centre (JRC)
European Maritime Safety Agency (EMSA)
European Topic Centre on Urban, Land and Soil Systems
Finnish Environment Institute (SYKE)
FRONTEX
French Coast Guard (COCGC)
Geoscience Australia
German Federal Agency for Technical Relief (THW)
German Federal Office of Civil Protection and Disaster Assistance (BBK)
German Space Agency (DLR)
Global Forest Watch
Icelandic Coast Guard
Institute of Geography and Spatial Planning
LEGOS
Mercator Ocean International
National Land Survey of Iceland
NILU
Ocean Energy Europe
PASYFO
SKYE Sustainable Urbanisation Programme
Swedish Agency for Marine and Water Management
Swedish Meteorological Hydrological Institute (SMHI)
Switzerland Federal Customs Administration
Turkish Disaster and Emergency Management Presidency (AFAD)
WindEurope
WEM

82 entities interviewed

Commercial companies

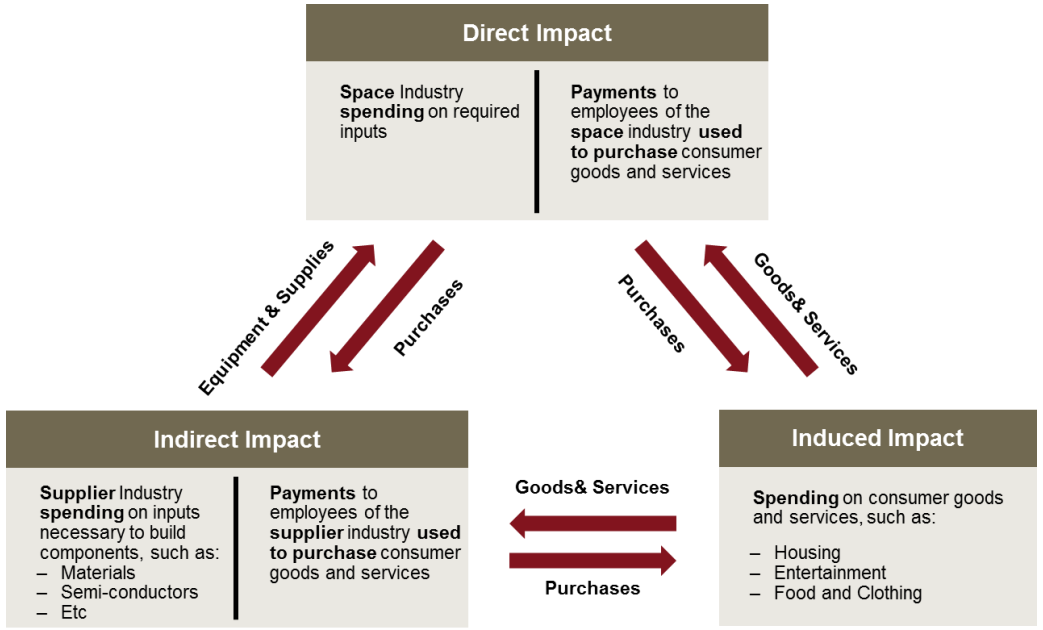
Airbus Defence & Space
Arcadis
Arianet
AXA
Beach & Associates
C-Core
CatInsight
CGG NPA Satellite Mapping
Copa Cogeca
Covea
Deimos Imaging
e-Geos
Earth-i
Edinsights
Environment Systems
Generali
Geo Smart Decision
Green Triangle
i-Sea
JBA Consulting
Mission Risque Naturel
NEXT INGEGNERIA DEI SISTEMI S.P.A
Oasis Loss Modelling Framework
Penta Technologies
Planetek Italia
Plumelabs
Rezatec
Reuniwatt
Satellio
SCOR
Sinergise
Space4environment
SteadySun
Swiss Re
TCarta
Terramonitor
TerraNIS
TRE Europa
Unifly
Vortex
Willis Towers Watson

METHODOLOGY FOR THE STUDY

GDP IMPACT ASSESSMENT

Principle of the GDP impact

The GDP impact represents the straight economic impact derived from an injection of spending into the economy. In the space sector specifically, spending that is injected in the upstream industry leads to a cascade of spending and economic activity through the supply chain. The space industry spends a portion of the funding through its suppliers (e.g., for components or subsystems) which, in turn, spend a part of those funds further down the supply chain (e.g., for raw materials). Meanwhile, all companies within the supply chain pay their employees' salaries. These salaries, in turn, provide consumer spending in the wider economy. The compounded effect of all the spending originated from the initial upstream spending constitutes the GDP impact associated to the initial investment. As part of the generally accepted best practices, the GDP impact is calculated by combining these three components.



The total GDP impact is then the sum of the three types of impacts (direct + indirect + induced).

Methodology

The methodology applied is standard in order to produce results that are comparable with similar studies carried out in for other space programmes and in non-space sectors.
The approach chosen uses a General Equilibrium Matrix, modelled by Cambridge Econometrics. The resulting E3ME model enables to compute the wider knock-on effects on the European economy. Cambridge Econometrics performed a dedicated modelling of the space supply chain in order to provide the E3M3 model with spending inputs associated to non-space industrial sectors.

Spending in Copernicus

Modelling of the space upstream

This step takes as input the institutional spending in the programme, and produces as output the space Gross Value Added (equal to labour plus profit) and the spending into a number of non-space industrial sectors that are modelled in the E3ME.

- Input spending decomposed by company, by country and by year
- The cost structure is retrieved for each company (labour, profit, imports, untracked spending in other industrial sectors of the E3ME model

Spending into non-space sectors

The spending into non-space industrial sectors is fed into the E3ME model, producing as output the overall GDP impact (total GVA), employment impact and government revenues.

E3ME model

Gross Value Added | **Employment** | **Government taxes**

METHODOLOGY FOR THE STUDY

INTERMEDIATE AND END USERS ASSESSMENT

Catalytic impacts - Copernicus enabled revenues

Most of the economic impacts on value chains are computed as revenues enabled by the use of Copernicus data and services (also called Copernicus enabled revenues).
These enabled revenues are computed for

- The intermediate users of all the value chains (revenues of the EO downstream companies)
- The revenues of end users for commercial value chains, which are the 8 value chains from the previous market report.

These revenues are computed using a microeconomic approach inspired from the BETA methodology. Such an approach allows dealing with a complex phenomenon that differs strongly from one end user to another. This methodology is able to catch the diversity and the complexity of effects derived from the use of EO data and requires direct interviews with a representative sample of end users in the different value chains under scrutiny.

Micro-economic approach for quantifying the enabled revenues

1. Picking a representative sample of organisations

2. Defining with them the impact of Copernicus on their business

- **Market effect:** the availability of Copernicus data enables an innovative offer for the users by increasing sales of existing products; increasing sales of new products on existing markets; and creating a new department/company on a new market.
- **Commercial effect:** the availability of Copernicus data enables the development of a new or better commercial network for the users by developing new networks and partnerships.
- **Organisational effect:** the availability of Copernicus data enables organisational improvements within the organisation.

3. Assessing the dependence of their businesses on Copernicus data and services

A range of dependence on Copernicus is estimated. On this range, the smallest figure is taken in order to provide the most robust estimation of the dependence on Copernicus data. The aim of this methodology is indeed to show the existence of the phenomenon rather than providing an exact figure, to prevent overestimation of benefits

4. Extrapolating the enabled revenues to the rest of the sector

For the intermediate/downstream users, the reference sector is the EO sector (minimal estimation) or the Geographic Information Systems (GIS) sector (maximum estimation)

Catalytic impacts - Economic impacts for non-commercial value chains

For the end users of the Civil Protection and Security value chains, the economic impacts do not materialise as revenues. By their institutional profile, civil protection forces and security authorities have economic impacts through:

- The reduction of damages caused by natural disasters
- The improvement of law enforcement and rescue operations effectiveness

The methodologies to quantify these economic impacts are tailored to each use cases, based on a how the operational consequences can be translated into economic values

Quantification of economic benefits for civil protection for natural disasters

1. Quantifying benefits of forest fires mitigation

The assessment of the reduced burnt area relies on dedicated studies, assessing the avoided burnt areas and the recovery time of lands depending on the types of vegetation. To these areas, a value for each hectare is associated based on the ecosystem value (valuation coefficient) and on the cost for the wood industry, independently assessed by experts. The statistics from EFFIS provide a quantification of its contribution to European fires.

2. Quantifying benefits of floods mitigation

Mitigation of floods enable cost savings, mostly through their anticipation (thanks to Early Warning Systems), as estimated by independent studies. Where the floods cannot be avoided, better response also reduce the damages, taken at a fraction of the cost savings enabled by anticipation.

3. Assessing the dependence on Copernicus to mitigation operations

Consultation with experts and end users helps to provide a range of the contribution of satellite data to civil protection operations:

- For fire prevention (EFFIS)
- For preparedness for field operations through mapping of the fires (CEMS)
- For floods prevention (Early Warning Systems)
- For floods response logistics through mapping of the events (CEMS)

4. Extrapolating to the overall disasters in Europe

Statistics on Copernicus Emergency Service and overall disasters in Europe enable to scale the benefits to the average situation in Europe each year

METHODOLOGY FOR THE STUDY

INTERMEDIATE AND END USERS ASSESSMENT

Quantification of economic benefits for security and safety

1. Quantification of benefits for combatting illegal fishing
Fighting Illegal, Unreported and Unregulated (IUU) fishing activities captures the commercial impact (value of fish stock at sale), the environmental impact (valuation factor for the ecosystems in the sea, based on independent studies) and the economic value of associated sanctions against criminals (perceived by Member States).

2. Quantification of benefits for law enforcement
The value of law enforcement reflect the value of seized illegal goods at EU borders (counterfeit goods, drugs, weapons and stolen vehicles), the reduced on healthcare costs based on the reduced drug consumption (based on independent studies), and the reduced revenues for traffickers of human beings (for each victim intercepted).

3. Quantification of benefits for oil pollution combat
Based on the oil spills released from ships (either by accident or voluntarily) and from offshore platforms, economic damages take into account the losses for the fishing, tourism and maritime transport industries, and the cost of cleaning operations. On top of it, environmental damages are based on a valuation factor per ton of oil, reflecting the destruction of marine and bird ecosystems. Both are based on independent dedicated studies.

4. Assessment of the dependence on Copernicus
Consultation with experts and end users helps to provide a range of the contribution of satellite data to the different field operations, considering the contribution of satellite data and the share of such data provided through Copernicus.

5. Extrapolating to the overall security operations in Europe
The benefits for each unitary mitigation (ton of IUU fishing, ton of seized drugs, ton of oil, etc.) are extrapolated to the overall extent of operations at EU borders and within EU territories.

The analysis for the sizing of economic impacts for Civil Protection and Security relies on a substantial and thorough analysis that was conducted shortly before the issue of this Copernicus Market Report, published in a study prepared by PwC France (PwC, 2017, Copernicus ex-ante societal impact assessment) for the European Commission.
Additional details can be found on the quantification methodologies in this study.

Societal and wider impacts analysis

In addition to the monetary impacts (GDP and catalytic), societal and wider impacts include all socio-economic impacts that are quantifiable but not monetary in nature. Examples are increased safety and security, national prestige, environmental impacts, outreach impacts (for example, impact on university enrolment in science-related disciplines), etc. Those impacts are extremely important to assess. It's worth noting that although there have been attempts to attribute monetary values to these sorts of impacts, the task is quite difficult to achieve due to the lack of generally-accepted methodology.

Assessment of societal and wider impacts

1. Categorisation of the impacts
In the frame of this report, societal and wider impacts have been segmented in 3 categories. Besides the presentation of the results, this allows a systematic approach for their identification.

Social impacts	Environmental impacts	Strategic impacts
Effects on the quality of life of people, their day-to-day environment, their health, safety and security	Effects on the land, water and atmospheric natural characteristics and ecosystem sustainability	Stakes for Europe and its Member States in a global context, both to maintain sovereignty and foster international cooperation

2. Consultation of stakeholders
This assessment was carried out based on the consultation with relevant stakeholders through phone interviews and face-to-face meetings as appropriate and needed.

3. Characterisation of the impacts
Since no proper methodology is perfectly suitable neither transversal to the impacts or value chains, a mix of qualitative and quantitative approach had to be used.

Quantitative impacts (examples)	Qualitative impacts (examples)
• Reduced CO_2 emissions • Reduced number of casualties	• Forests and ecosystem sustainability • European contribution to global civil protection

ABOUT THE AUTHORS

The European Commission

The European Commission (EC) is responsible for the management of the European satellite Earth Observation programme Copernicus, including:

- Management of funds allocated to the programme,
- Supervising the implementation of all activities related to the programme,
- Ensuring clear division of responsibilities and tasks in particular with the European Space Agency and the delegated entities,
- Ensuring proper reporting on the programme to the Member States of the EU, to the European Parliament and to the Council of European Union

The Copernicus programme is entirely financed by the European Union.

PwC Advisory France

PwC is a world leading firm in audit, legal services and advisory.
With a team dedicated to advisory for the space sector, PwC Advisory France built a strong expertise covering space-specific strategy studies, socio-economic impact assessments, programme management and operations implementation.

PwC Advisory France is a privileged partner of the European Commission on different assessments and studies on the Copernicus programme.

To find more about our offer and expertise: www.pwc.com and www.pwc.fr/space

ET-04-19-024-EN-N

Publications Office

ISBN 978-92-79-98973-5