CURRENT EO CAPABILITIES REPORT (FINAL)

EO-FIN

Prepared by:	GMV: Rahman Momeni, Enes Hisam, and Ana Sebastian Lopez London Economics: Tom Goulding
Approved by:	Rahman Momeni
Authorized by:	Rahman Momeni

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0.1	27/02/2023	34	
1.0	29/010/2023	145	Completed Section 1: Executive Summary. Expanded Section 3: Introduction. Completed Subsection 2.3: EARSC portal. Improved Section 3: Summary of user requirements. Improved Section 4: Catalogue of currently available EO datasets. Added Section 5: Current EO capabilities and use responding to geo-information needs of the financial management sector. Added Section 6: Current EO capabilities and use responding to geo-information needs of the financial management sector. Completed and Improved Section 7: EO products portfolio. Added Acknowledgement Section. Table1, Table 2, Table 3, Table 4, and Table 5 moved to Annex A. Table 6, Table 7, Table 8, and Table 9 moved to Annex B. Added Annex C.

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Reference Documents

The following documents, although not part of this document, amplify or clarify its contents. Reference documents are those not applicable and referenced within this document.

Table 1. Reference Documents

Ref.	Document ID.	Title	Rev.
[RD1]	Proposal	Proposal "EO-FIN Best Practice for Financial Management Support"	
[RD2]	PMP	The project management plan	
[RD3]	D1.1	Workshop-1 report	1
[RD4]	D1.2	EO-FIN-Geoinformation requirements report (draft)	0.1
[RD5]	D1.2	EO-FIN-Geoinformation requirements report (final)	1
[RD6]	D2.1	EO-FIN Current EO Capabilities Report (draft)	0.1

Acronyms

Table 2. List of acronyms

Acronym	Definition
AGB	Above-Ground Biomass
AFME	Association for Financial Markets in Europe
AIS	Automatic Identification System
CDI	Combined Drought Index
CNN	Convolutional Neural Network
CGLS	Copernicus Land Services
EARSC	European Association of Remote Sensing Companies
EO	Earth Observation
ESA	European Space Agency
ESG	Environment, Social, and Governance factors
EUSPA	European Union Agency for the Space Programme
DInSAR	Differential SAR Interferometry
dNBR	delta Normalized Burn Ratio
DSM	Digital Surface Models
DTM	Digital Terrain Model
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FM	Financial Management
GGIM	Global Geospatial Information Management
LAI	Leaf Area Index
IDI	Integrated Drought Index
InSAR	Interferometric Synthetic Aperture Radar
LOS	Length of the Season
LSP	Land Surface Phenology
LST	Land Surface Temperature
MAP	Malaria Atlas Project

MWR	Microwave Radiometer
NBR	Normalized Burn Ratio
NDCI	Normalized Difference Chlorophyll Index
NDMI	Normalized Difference Moisture Index
NDVI	Normalized Difference Vegetation Index
NDWI	Difference Water Index
OLCI	Ocean and Land Colour Instrument
OSM	Open Street Map
POS	Peak of the Season
SDB	Satellite-derived bathymetry
SFI	Standardised Streamflow Index
SOS	Start of the Season
SPEI	Standardized Precipitation Evapotranspiration Index
SWI	Short-Wave Infrared
UCS	Union of Concerned Scientists

1. EXECUTIVE SUMMARY

Following, gathering key User Needs (UNs), challenges, and geo-information requirements of the FM sector (described in the D1.2 Ge-information requirements report), this report summarises the process of identification and characterization of EO-based products and services, in response to the Geo-information needs of the Financial Management (FM) sectors. The aim of this report is to consolidate the current EO capabilities that are mature and fit for the purpose of supporting the business processes of four domains of the FM sector including, investment management, green finance, risk analysis, and insurance management.

This report targets audiences from both Earth Observation (EO) communities such as service and data providers and the FM sector. This report describes a detailed current and near-future EO dataset including optical, RADAR, and satellite-based and reanalysis products. A series of practices was conducted to identify and consolidate EO capabilities including desk-based research (1, 2), online survey, group discussions during Workshop 2, and EO capability questionnaires (versions 1, 2). After the consolidation of all EO capabilities findings, the EO-FIN team derived 38 EO products and 18 EO services that highly respond to the needs of the FM sector. In the end, 38 EO use cases describe product specifications including a description of each EO product, technical information, limitations, and the User's level of knowledge and skills to extract information and perform further analysis on the EO products.

2. INTRODUCTION

Geospatial data combines information about the objects' position, attributes, and behaviours. The UN estimates that up to 80% of all information exchanged today has a spatial component – 'everything happens somewhere' [1]. In recent decades geospatial data has become widely available and some financial institutions are beginning to exploit its potential. The concept of spatial finance has emerged and refers to the integration and analysis of geoinformation by financial theory and practice[2].

With technological advances, many devices now generate location information at scale, for example, satellites. With recent advances in data processing, such as increases in computing power and availability of cloud-computing and AI methods, large amounts of these data can now be easily analysed. These advances in the collection, computer processing, and analytics support services have democratised the use of geospatial data.

Satellite Earth Observation is an essential source of geospatial data and, with the free and open policy of Copernicus data and services, an increasingly proliferated source of geospatial information. The availability of a growing number of satellites gathering Earth Observation (EO) data flying more diverse instruments allows innovative solutions to be delivered, tackling an increasing breadth of markets and customers. This development is further supported by better data processing facilities and providers of analytics services (e.g., from Amazon AWS). To put this in perspective, in 2022, there were 1,030 EO satellites according to the Union of Concerned Scientists (UCS), which is 22% of all satellites[3]. The UK Centre for Greening Finance's 2021 report on emerging developments within the space, including emerging and mature applications, provided a useful starting point in understanding the 'art of the possible' enriching financial with spatial data.

The value of the global civil EO services market now stands at 2.8 billion Euros according to the European Union Agency for the Space Programme (EUSPA)[4]. The value of EO services is forecast to nearly double to 5.5 billion Euros within the next decade, though other forecasts put these numbers higher. In the civil economy, the five most important purchasers of EO services today are found in the urban development and cultural heritage, agriculture, climate services, energy and raw materials and infrastructure fields. By comparison, demand from the Finance and Insurance sector for EO services is relatively small, ranking 11th of 14 segments. Nonetheless, EUSPA classifies this EO segment (insurance and finance), as an "emerging market". This organization estimates that the finance and insurance segment purchases EO services valued at 145 million Euros in 2021, rising to 1 billion by 2031. Alternative estimates put this value at more than double. For this reason, Insurance and Finance are expected to increase in relative importance. Its forecasted CAGR of 20% over the next ten years exceeds all other segments of the market.

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[1] UN-GGIM. (2020) Future trends in geospatial information management: the five to ten year vision. Third edition, Lead author Christin Walter from Ordnance Survey of Great Britain, Available at: https://ggim.un.org/meetings/GGIM-committee/10th-Session/documents/Future_Trends_Report_THIRD_EDITION_digital_accessible.pdf (Accessed: 12/10/2023).

[2] UK Centre for Greening Finance. (2021). 'State and Trends of Spatial Finance'

[3] UCS (2020) How Many Satellites are Orbiting Around Earth in 2022?. Available at: https://www.geospatialworld.net/ prime/business-and-industry-trends/how-many-satellites-orbiting-earth/ (Accessed: 12/10/2023).

[4] EUSPA (2023) Earth Observation market. Available at: https://www.euspa.europa.eu/european-space/euspace-market/earth-observation-market (Accessed: 12/10/2023).

[5] Alternative Data for Alpha (2017) Alternative Data for Alpha. Available at: https://www.greenwich.com/press-release/alternative-data-alpha (Accessed: 12/10/2023) (Accessed: 12/10/2023).

The forecasted growth rate of EO services in the Insurance and Finance sector suggest there is a latent demand ready to be captured. In fact, many executives in the financial sector are keen to explore alternative data sources. In a 2017 survey, Greenwich Associates found that "80% of investors wanted access to alternative data sources in their search for alpha"[5]. Based on a survey among stakeholders of the financial sector, the World Economic Forum found that satellite imagery was the least used data type among alternative data. However, satellite-based EO is considered to have relative strength in data collection over other types of Geospatial datasets like aerial or ground-based methods. These advantages include:

- Regular frequency of acquiring data over the same region.
- Data collection over large areas with lower cost compared to other methods.
- Long-term observation and monitoring with access to historical data.
- Gathering Geospatial data over remote and potentially hazardous areas regions.
- Fast turnaround of data. (Rapid processing and tasking of data)
- Potential of efficient automatic process of large datasets.
- Flexibility and adaptability in processing (including by AI) to be easily used for a wide range of applications and scenarios.

Yet, the above-listed characteristics of satellite-based EO can help address the many challenges existing in the Financial Management sector such as unprecedented recent shifts in risk profiles, the increased intensity of physical hazards, the implications of climate change on financial stability, and rising costs in collecting data and regularly monitoring assets using traditional approaches (like field surveys).

2.1. EO CAPABILITIES IMPACT ON FINANCIAL MANAGEMENT:

There are many key areas where the EO capabilities play a crucial role in the FM sector. In cases of monitoring and analysing physical assets and infrastructure, satellite imagery can provide real-time data on construction projects, transportation networks, energy facilities, and other critical infrastructure. This information enables financial institutions and investors to gauge the progress of large-scale projects, assess potential risks, and make more accurate investment decisions.

In the realm of risk assessment, EO capabilities offer insights into environmental factors that can impact businesses and financial assets. For instance, monitoring natural disasters, climate change effects, and environmental regulations helps financial institutions assess the physical risks their investments might face. This data can guide the development of risk models and influence lending, insurance, and investment strategies. Another FM domain is Geopolitical risk assessment where EO capabilities can better anticipate market volatility and potential investment opportunities or threats can contribute. In fact, EO capabilities could monitor political events, social unrest, and infrastructure development in various regions, and financial analysts.

EO capabilities can provide valuable information to supply chain management and commodity trading for industries heavily reliant on commodity prices, such as agriculture, energy, and mining. In particular, the EO capabilities can track agricultural activities, land use changes, and weather patterns, financial professionals can anticipate crop yields, assess potential disruptions, and make informed decisions about commodity investments. Additionally, EO products contribute to the evaluation of real estate markets. Satellite imagery and geospatial data provide information about urban development, property value trends, and population growth. This aids in property valuation, urban planning, and mortgage lending decisions.

In summary, EO capabilities have become essential tools in the FM sector due to their ability to provide accurate, timely, and objective information about a wide range of economic, environmental, and geopolitical factors. By harnessing the power of satellite imagery and remote sensing processing and analysis techniques, financial professionals can make more informed decisions, manage risks effectively, and adapt to the dynamic and interconnected nature of today's global markets.

2.2. PROJECT OVERVIEW

The activity **"Best Earth Observation (EO) practices to support financial management (EO-FIN)"** is an ESA fully funded project aiming to understand the current, and short-term future, **EO capabilities** that can support the **Financial Management (FM)** sector. This project studies EO best practices meeting the best responses to the FM sector's needs and requirements. The best EO practices are expected to lead to better products, greater trust from the customers, and a more competitive position in the market. For the purpose of this activity, the FM sector will be represented by stakeholders operating in the following four FM markets: **Investment Management, Risk Analysis, Insurance Management, and Green Finance.**

2.2.1.PURPOSE

The goal of this activity can be broken down into the following objectives:

1. Identify and consolidate the geoinformation needs and priorities within the domains of concern.
2. Identify and characterise EO-based products and services meeting the needs of the domains of concern, now and in the future.
3. Implement and test on a Virtual Platform at least one prototype of an identified EO-based service.
4. Define a roadmap for building EO industry guidelines for the commonly accepted best-practice use of EO-based information by companies within the Financial Management sector.
5. Disseminate the analysis results via key international associations and bodies representing the sector, like EARSC (on the EO side) or the Association for Financial Markets in Europe (AFME).

Box 1 Key terminology

Earth Observation (EO): the gathering of information about the planet's physical, chemical, and biological systems via remote sensing technology including data and processing tools.

EO practice: A service is developed using EO data and technology to respond to the needs of specific applications.

Geospatial data/geoinformation: information about where observations are in relation to one another – any data tagged with a geographic reference is (geo)spatial data. Insights obtained from the analysis of spatial data are referred to as 'geoinformation'.

Spatial Finance: the integration of geospatial data and analysis into financial theory and practice

2.2.2.PROJECT BREAKDOWN STRUCTURE

Figure 1 shows the EO-FIN project breakdown structure by describing the entire scope of the EO-FIN project, and the distribution of the work among the three teams that form part of the consortium: GMV-NSL, London Economics, and GMV AD. Overall, there are five WPs defined, namely:

- WP1. Collection of geoinformation requirements and associated constraints (corresponding to Task 1 in the SoW).
- WP2. Definition of current EO capabilities and use (corresponding to Task 2 in the SoW).
- WP3. Development of a service prototype (corresponding to Task 3 in the SoW).
- WP4. Development of a best practice roadmap (corresponding to Task 4 in the SoW).
- WP5. Overall management.

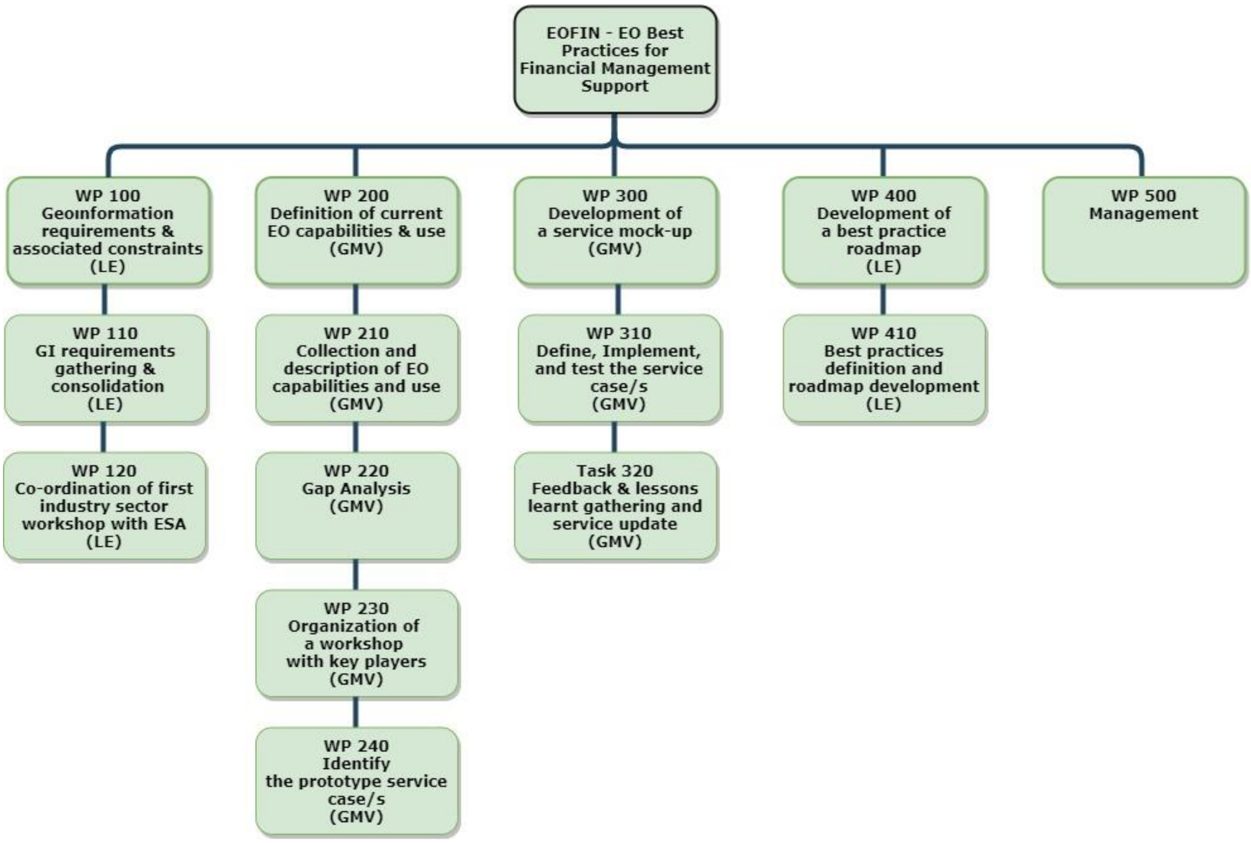


Figure 1. EO-FIN work breakdown structure.

2.2.3.SCOPE OF THE PRESENT REPORT AND TARGET AUDIENCE

This document presents the final version of Deliverable D2.1 "Current EO Capabilities" responding to the consolidated user needs (UNs) previously documented in the "Geo-information requirements report" (D1.2) report. The target audience of this report is the EO service and data providers and Financial Management stakeholders.

This report provides a depth overview of the current EO technology mostly responding to FM needs. It describes detailed EO datasets, satellite-based and reanalysis products, and EO products that can benefit the stakeholders of the financial sector. The findings of this report resulted from a wide range of activities from desk-based research to workshop group discussions, an online survey, and online questionnaires. The present report will be made public and subject to review by the EO community through the EARSC portal.

2.3. EARSC PORTAL

About EARSC: The European Association of Remote Sensing Companies (EARSC) is a non-profit, membership-driven organization dedicated to promoting and coordinating the activities of European EO products/services providers. EARSC boasts a diverse and growing membership, comprising a wide spectrum of companies engaged in EO-related activities. These member organizations range from small and innovative startups to well-established industry leaders, creating a dynamic network of expertise, innovation, and collaboration. EARSC serves as a hub for information dissemination, sharing insights, market trends, and developments within the EO sector.

The EARSC portal will play an important role in the EO-FIN project by hosting the outcomes of the project including financial management stakeholders' requirements and the corresponding EO capabilities. Further, the stakeholders shall be able to use the EARSC portal to provide feedback during the development of the EO prototype. Thus, the information will be shared and disseminated with the Financial Management (FM) sector and the EO downstream industry. This dissemination will play a crucial role in bridging the gap between the EO industry and financial management stakeholders, ensuring that EO technologies contribute effectively to addressing their actual needs and challenges.

EOFIN's content on EARSC portal: The EO-FIN project will have a website which is hosted by EARSC, this website will contain all the findings and outcomes of the project including:

- The financial management stakeholder's requirements which obtained in the first phase of the project.
- The EO products/services that correspond to the financial sector's needs.
- Gap analysis report.
- Prototype service description.
- Best practice road map.

On the website, a user interface will be built to link the user requirements to the corresponding EO products/services. Therefore, the reader will be easily able to have a good understanding of how EO products/services can be used to address each financial management requirement. In addition, for each EO product, it will be a product specification which includes a description of the product, with the main processing steps to be developed, and the technical information such as the resolutions, maturity level, and the level of knowledge and skills required by the end users to extract information and perform further analysis on the EO products.

3. SUMMARY OF THE USER REQUIREMENTS

Before describing the EO capabilities, this section provides a summary and key points of the user requirements from the 'Geo-information requirement report' (D1.2). It highlights gathering and consolidating key user needs, challenges, and geo-information requirements for four domains of the FM sector (Investment Management, Risk Analysis, Green Finance, and Insurance Management) which have a reliance on geo-information.

The growing demand for geo-information data in the FM sector is driven by the increasing prominence of regulations linked to climate change, sustainable development, preserving natural capital, and the attainment of Environmental, Social, and Governance (ESG) objectives, as well as the increased reliance on comprehensive disclosure frameworks for loan portfolios and investments. This makes it crucial for FM sector organisations to leverage EO products to monitor asset and sub-asset levels to understand the specific climate, nature, and ESG characteristics of their investment or loan portfolios. The consistent spatial and temporal coverage offered by EO data can offer valuable insight into physical climate risks, vulnerability to hazards, deforestation, and biodiversity information.

The latest and relevant information was acquired directly from experts in the FM sector through four separate activities: comprehensive desk-based research, a workshop, a series of semi-structured individuals' interviews with FM stakeholders, and a synthesis task to consolidate and improve the gathered information. **Error! Reference source not found.** shows the overview of t he "observation need" and "specific product" geo-information needs acquired across four FM domains.

Below is a list of the FM users' needs at four sub-domains that were collected during the preparation of the D1.2 report:

- **Investment Management:**
  - Analyse market signals: e.g., monitoring supply chain and stock changes in oil tanks.
  - Track macroeconomic trends: e.g., urban expansion and nighttime lights monitoring.
  - Monitor opaque markets: e.g., monitoring very /large/remote areas or markets where there is political unrest.
  - Due diligence and monitoring assets: e.g., monitoring the productivity of
  - physical investments and monitoring ESG.
- **Green Finance:**
  - Monitoring green finance: e.g., monitoring the sustainability of projects.
  - Monitoring carbon offsetting: e.g., monitoring reforestation projects and solar panel installations.
  - Environmental due diligence: e.g., surveillance of green finance projects and increased reliability of ESG ratings.
- **Risk Analysis:**
  - Measure physical risk: e.g., monitor slow-moving subsidence and coastal erosion.
  - Climate stress-testing: e.g., monitoring vulnerability to flooding, sea level rise, wildfires, and other natural hazards.
  - Forecasting to manage volatility: e.g., yield estimation and market risk (e.g., electronics and automotive supply chains affected in Thailand due to flooding).
  - Socioeconomic risk measurement: e.g., terrorism hotspot tracking
- **Insurance Management:**
  - Validating self-reports: e.g., acreage reporting.
  - Assess claims against policies: e.g., analysis of damage following insured events.

- Parametric insurance products: e.g., higher temporal resolution speeds up flood claim processes

Table 3. Geo-information needs classified as observation need and specific product, across four FM domains.

NO	UN ID	Financial domain	User's Expression
1	UN9	Investment management	Understanding stock levels and monitoring supply chains.
2	UN10		Need to understand population density when making investment decisions.
3	UN11		Realistic assessment of accessibility to assets.
4	UN12		Analysis of potential risks in specific regions.
5	UN13		Need to geo-map clients.
6	UN14		Need to screen the feasibility of projects against different hazard criteria.
7	UN15		Need to monitor carbon intensity of portfolio assets
8	UN16		Nighttime light monitoring
9	UN17		Need near real-time tracking of marine vessels to understand their routes and estimate fuel usage.
10	UN18		Need to monitor crop productivity.
11	UN19		Identifying types of crops being grown is essential.
12	UN26	Green finance	Need to monitor GHG emissions of projects funded.
13	UN27		Need to assess historical trends and baseline of natural assets.
14	UN28		Need to classify the types of crops being grown to assess the sustainability and environmental impact of agricultural investments.
15	UN29		Need to accurately measure the planted area for crops
16	UN30		Need for monitoring with accurate measurements of the growth and health of trees.
17	UN31		Need to link tree planting parcels to estimate the number of trees planted
18	UN32		Need to periodically estimate the growth of above-ground carbon stocks (in forests).
19	UN38	Risk analysis	Need for trustworthy time series of reliable data on assets.
20	UN39		Need to assess the potential impact of business activities or investments on ecosystems and biodiversity.
21	UN40		Need to monitor the risk of sea level rise threatening coastal property, infrastructure, and supply chains.
22	UN41		Need to monitor the impact of increased temperatures on assets.
23	UN42		Need to monitor the impact of droughts on assets.
24	UN43		Need to monitor changing precipitation patterns and flood risk in the vicinity of vulnerable assets.
25	UN44		Need to measure the area vulnerable to wildfires before events.
26	UN45		Need to measure the area affected by wildfires after the fact.
27	UN46		Need to measure the intensity of wildfires (level of damage to assets).
28	UN47		Need up-to-date geospatial data on residential and industrial infrastructures' locations.
29	UN38		Need for trustworthy time series of reliable data on assets.
30	UN54	Insurance management	Detecting crop damage at the level of individual farms/fields.
31	UN55		Need to detect changes in land use (at the level of individual buildings).

32	UN56		Automatically update changes in population density estimates based on observable land use changes.

During the first workshop, participants across all domains pointed out that geospatial data would be most promising in monitoring portfolio assets for investment management, identifying physical risk to assets in risk management, and for parametric insurance products in insurance.

Furthermore, there were some barriers to the use of geospatial datasets in the four FM domains. One of the main barriers to using spatial data in finance management sectors is a lack of awareness, understanding, technical knowledge, and uniformity in terms of products. Also, interviewees pointed out that one of the barriers to the wider use of geo-information for FM is the start-up costs of training staff, purchasing, or collecting the geo-information data itself, and developing new methodologies to utilise the data. Also, regulation and reporting requirements (or lack thereof at present) were thought to be key blockers of geospatial data use across multiple domains. For more detailed information on the geo-information user requirements, you can refer to D1.2-Geoinformation requirements report (final version).

The following sections describe the details of the EO capabilities including EO datasets and products to address the needs of the FM sector.

4. CATALOGUE OF CURRENTLY AVAILABLE EO DATASETS

Satellite EO sensors are sophisticated instruments mounted on orbiting satellites, capable of capturing a wealth of information about our planet's surface, atmosphere, and oceans. From their vantage point high above Earth, satellite EO sensors utilize a range of technologies, including remote sensing and imaging systems, to collect data across different parts of the electromagnetic spectrum. Through processing and analysing EO datasets using different techniques such as image analysis, computer vision, artificial intelligence, and data fusion, these data can be transformed into actionable insights, maps, and models that are invaluable for industries, governments, researchers, and organizations around the world.

In recent times there has been a huge advance in terms of these characteristics, which in turn enhances the ability of these sensors to provide more valuable information which can be used to develop EO-based products with great benefit for the FM sector. The section of the report provides an overview of the main types of EO datasets including optical, radar satellite data, and satellite-based and reanalysis products. These EO datasets are currently available and well-suited to be used to develop EO products for the FM sector. The section below describes in-depth insight into some of the highly used EO datasets including examples of the sensors and reanalysis products.

4.1. OPTICAL SENSORS

The Optical EO datasets are widely used in EO practices, but they come with certain limitations including their dependence on sunlight or external light sources for illumination; being highly affected by cloud coverage and atmospheric conditions; and inability to provide data during nighttime hours without adequate artificial lighting. Despite these limitations, advances in sensor technology (especially high revisit time), data processing techniques, and the integration of multiple data sources have helped mitigate some of these issues and expand the utility of optical sensors in diverse applications. A summary of some of the most popular and commonly used optical EO satellite sensors is as follows:

Sentinel-2: The Sentinel-2 mission is a vital component of the ESA's Copernicus program, aimed at providing global and frequent high-resolution optical imagery of the Earth's surface. Comprising a pair of identical satellites, Sentinel-2A (launched in 2015) and Sentinel-2B (launched in 2017), this mission is specifically designed to offer systematic and reliable Earth Observation data for a multitude of applications, including land monitoring, agriculture, forestry, environmental management, and disaster response.

Equipped with an array of advanced multispectral imaging instruments, each Sentinel-2 satellite captures data across 13 different spectral bands, ranging from visible light to shortwave infrared. This broad spectral coverage enables the satellites to discern fine details about land cover, vegetation health, urban expansion, and natural resources. Sentinel-2's primary features include its high spatial resolution, with imagery acquired at 10, 20, or 60 meters per pixel, depending on the specific spectral band. This allows for precise monitoring and analysis of changes occurring on the Earth's surface. Furthermore, the mission's revisit frequency is exceptionally high, with a global coverage rate of approximately every 5 days, enabling rapid response to dynamic events and changes.

Sentinel-3: The Sentinel-3 mission is a cornerstone of the ESA's Copernicus program, designed to provide comprehensive and precise ocean and land monitoring data to support environmental and climate-related research. Sentinel-3 satellites (Sentinel-3A, launch: 2016, and Sentinel-3B, launch: 2018) are equipped with advanced sensors that enable the mission to fulfil its objectives. These sensors include Ocean and Land Colour Instrument (OLCI), Sea and Land Surface Temperature Radiometer (SLSTR), Synthetic Aperture Radar Altimeter (SRAL), and Microwave Radiometer (MWR). Through its multi-instrument approach, the Sentinel-3 mission provides a holistic view of Earth's oceans, land, and atmosphere, ultimately aiding in the development of strategies to address climate change, support sustainable resource management, and enhance disaster resilience. Sentinel-3 provides a moderate spatial resolution (300m, 500m, and 1km) with a revisit time range between 1-2 days at the equator with more frequent revisit time at higher latitudes. These moderate spatial resolution and highly frequent data facilitate agile data acquisition and enable swift responsiveness to dynamic shifts and occurrences.

The Sentinel-2 and Sentinel-3 missions exemplify a commitment to open data sharing and accessibility. All data collected by the satellites are made freely available to the public, fostering collaboration, research, and informed decision-making on a global scale.

Pléiades: Pléiades 1A and Pléiades 1B are a pair of high-resolution optical imaging satellites, which are operated and owned by Airbus Defence and Space. Pléiades 1A was launched on December 17, 2011, followed by Pléiades 1B on December 2, 2012. Pléiades satellites excel in providing an extraordinary level of detail by offering imagery products with a high spatial resolution of 50cm with a daily revisit and a wide swath of 20 kilometres.

In 2021, two new identical satellites Pléiades Neo 3 and Pléiades Neo 4 were launched to provide a continuity of the Pléiades mission with improved precision, responsiveness, and frequency compared to its predecessors. They provide VHR satellite imagery at 30 cm spatial resolution with a revisit of twice a day and 14 km swath width. The precision of Pléiades data, coupled with its exceptional revisit frequency, allows for the monitoring of dynamic changes, both natural and human-induced, across various applications and in diverse fields including cartography, urban planning, agriculture, forestry, hydrology, and geological prospecting. For more detailed information on different types of optical datasets with associated characteristics please refer to Table 17, Table 18, Table 19, Table 20, and Table 21 in the Annex A. to this report.

4.2. RADAR SENSORS

The concept of radar sensing is based on radiation transmission and uses the measured return to infer properties of the ground features including dielectric constant and geometrical structure. Radar sensors can be categorised into three groups: Scatterometers, Altimeters, and SARs. Scatterometers provide data on the speed and direction of winds over the ocean; altimeters measure several important geophysical quantities like the topography of the ocean surface and its variation, ocean currents, significant wave height, and the mass balance and dynamics of the major ice sheets. Altimeters calculate the distance between the satellite platform and ground features to centimetric accuracy. The third and most versatile radar instrument is Synthetic Aperture Radar (SAR). Using interferometry SAR instruments can provide precise measurements of surface displacement. This capability, together with the fine spatial resolution of the images and the provision of long temporal sequences undisturbed by cloud, has led to SAR being applied in numerous fields, from topographic mapping to oceanography.

Similarly, to optical datasets, this information can help the selection of the right radar dataset(s) for future application(s) development on the next step of the work. A summary of some of the most popular and commonly used radar EO satellite sensors are as follows:

Sentinel-1: The Sentinel-1 mission, a cornerstone of the European Space Agency's Copernicus program, is an advanced radar imaging initiative designed to provide all-weather, day-and-night surveillance of the Earth's surface. Comprising a pair of satellites, Sentinel-1A (launched in 2014) and Sentinel-1B (launched in 2016), this mission carries a C-band synthetic aperture radar (SAR) technology and supports single and dual polarization mapping (HH, VV, VH, HV) to capture high-resolution images (starts from 20 m resolution) of the planet’s terrain, oceans, and polar regions with a revisit time of about 5 days. Sentinel-1's radar imaging prowess allows it to penetrate cloud cover, darkness, and adverse weather conditions, providing an unobstructed view of Earth's dynamic features. This unique capability is pivotal for various applications, including maritime surveillance, disaster monitoring, and land subsidence assessment. In essence, the Sentinel-1 mission leverages radar technology to overcome traditional limitations of optical sensors, empowering comprehensive and reliable Earth observation for a multitude of purposes, from environmental monitoring to disaster management and beyond.

TerraSAR-X and TanDEM-X: TerraSAR-X and TanDEM-X stand as remarkable radar satellites hailing from the German Aerospace Center (DLR). TerraSAR-X took to the skies in 2007, followed by the launch of TanDEM-X in 2010, and both satellites are still operational and provide a daily revisit. These twin satellites boast an exceptional geometric precision that outpaces most of the sensors in space, setting them apart as pioneers in radar technology.

The central payload aboard the TerraSAR-X and TanDEM-X satellites is an X-band radar sensor. This tool empowers the satellites to capture images with varying swath widths, resolutions, and polarizations. They have different operational modes which enable the acquisition of high-resolution imagery (≤ 3 m) as well as wide-swath imagery (30 km or more). With the ability to customize swath widths, resolutions, and polarizations, these satellites cater to diverse user needs. These capabilities enable them to be of great benefit for a range of applications including Digital Surface and terrain Models (DSM & DTM), maritime monitoring, change detection, and surface movement monitoring. For more detailed information on different types of radar satellites with key details and properties please refer to the annexes (Table 22. List of Radar satellite part 1 (level 1).Table 23, Table 24, and Table 25 in Annex B.).

4.3. SATELLITE-BASED AND REANALYSIS PRODUCTS

The satellite-based and reanalysis products are two other formats of EO data that provide valuable information about various atmospheric and surface variables. They are widely used as input data in a wide range of studies including meteorology, climate research, and environmental studies. Below, several examples of popular satellite-based and reanalysis products describes in detail. For more detailed information on different types of satellite-based reanalysis products with key details and properties please refer to the Annex C. (Table 26).

Satellite-based products: Satellite-based products involve collecting data from various sensors onboard satellites such as visible light, infrared, and microwave radiation. These sensors can measure a wide range of variables, including temperature, humidity, cloud cover, precipitation, sea surface temperature, land surface temperature, and more. These products offer a global perspective and are especially useful for monitoring dynamic and rapidly changing phenomena.

Reanalysis products: Reanalysis products involve using observations from various sources, including satellites, surface weather stations, and more, and combining them with mathematical models and applying physics law to create consistent and comprehensive datasets that describe the state of the atmosphere and other related variables over time. ERA5-land stands out as one of the most important and popular reanalysis products that is being used for several applications. The following section provides more information about ERA5-land and Copernicus Global Land Services (CGLS) as popular products in the EO field.

ERA5-land: ERA5-Land is a specialized dataset developed by re-examining the land-based segment of the ECMWF ERA5 climate reanalysis. This dataset offers an intricate and refined perspective of various land-related climate variables, spanning factors such as temperature, precipitation, soil moisture, and vegetation dynamics. By utilizing advanced modelling techniques, ERA5-Land provides a comprehensive and accurate portrayal of historical climate and environmental conditions over the land areas, enhancing our understanding of long-term weather trends and their impacts on ecosystems and societies.

Copernicus Global Land Services (CGLS): CGLS is an integral component of the broader Copernicus Earth Observation Program. This service focuses on delivering precise and up-to-date geospatial information related to land and its various attributes. Leveraging a combination of satellite observations, ground-based data, and advanced processing techniques, CGLS offers a wealth of information about land cover, land use, changes in vegetation, soil moisture, and other essential parameters. With a commitment to providing high-quality, reliable, and accessible data, CGLS supports a wide range of applications across diverse sectors such as environmental monitoring, agriculture, urban planning, and disaster management.

5. IDENTIFICATION AND CONSOLIDATION OF CURRENT EO CAPABILITIES

This section describes the process of identification and consolidation of the EO capabilities in response to the FM stakeholders' requirements. Before looking to identify the EO capabilities, the consolidated Geoinformation requirements (i.e. D1.2 final) were classified into three main definition levels:

- Generic need: this category addresses service boundary conditions enabling users to effectively use geoinformation products (e.g., Lower cost of integration of geo-information into existing systems and data processes). However, it does not refer to any specific observation need, nor to any product requirement,
- Observation need: a relatively general requirement expressed by the user with little specification, using non-technical terms and without requesting any specific product. It could also be a desired outcome (e.g., "Need to understand population density when making investment decisions").
- Specific product: specific geospatial needs indicate the requirement for new product products and services (e.g., "Identifying types of crops being grown").

From a total of 56 User Needs ('UNs'), 24 UNs are classified as generic needs. While generic needs help us understand the protocols underneath the business processes, they do not refer to any specific observation need, nor to any product requirement. As a result, the remaining 32 UNs from observation needs and specific products were considered as the scope of current EO capabilities practices.

An EO product serves as a building block, working in conjunction with other EO products and other sources of data, contributing to solutions catering for the geo-information requirements across the four domains of the FM sector outlined in the prior report: investment management, green finance, risk analysis, and insurance management. EO products play a crucial role in connecting the existing EO data availability with the development of diverse applications that offer valuable insights within the FM sector. EO products refer to the resulting form of EO datasets (including optical, radar, satellite-based and reanalysis products) and visualisation as primary or secondary sources derived using remote sensing's processing and analysis techniques.

Following the identification of the EO products in the draft version of the current EO capabilities report, the EO-FIN team conducted a series of practices to further identify EO capabilities and consolidate them to address the consolidated UNs reported in D2.1 Geo-information requirements report (Figure 2).

Figure 2. Overview of the identification and consolidation process of the current EO capabilities and use.

5.1.1.DESK-BASED RESEARCH

The primary task of identifying the EO products involved desk-based research carried out by the GMV team. It was aimed to identify at least one EO product for each user requirement, and in certain instances, there are multiple EO products identified for specific user needs. Additionally, several EO products could address or contribute to multiple user requirements simultaneously. An exhaustive search conducted to identify EO products could potentially contribute to addressing each of 32 FM's UNs (as observation needs and specific products). As a result of the first version of the desk-based research, thirty unique EO products were identified. You can find their specifications in the 'EO products portfolio' section of this report. The second stage of the desk-based reach was conducted after finding potential new EO products from an online survey and group discussion in Workshop 2. As a result of the second version of the desk-based research, nine additional EO products were identified. Similarly, you can find their specifications in the 'EO products portfolio' section of this report.

5.1.2.ONLINE SURVEY

In parallel with desk-based research activity, the EO-FIN team constructed an online survey to gather information from the EO service and data providers on the EO products can respond to the UNs. This survey was designed as a spreadsheet over the Google Forms platform by providing details of each 32 UNs along with their technical information. It has sections asking EO service/data providers to suggest the EO product fits well with each UN and their technical specifications. Besides asking the name of the EO product, there were parts to be filled about the specifications of each suggested EO product including the resolutions, latency, and maturity level. The online survey was disseminated directly to more than 100 EO service and data providers across Europe. There was only one response received from EarthBlox company in total, that was way below our expectations. However, . However, it provided an extensive list of products that greatly contributed to our effort in consolidating EO capabilities for the financial sector.

5.1.3.WORKSHOP DISCUSSIONS

During this exercise, in-person attendees were divided into four groups, each focusing on discussing Earth EO products that could address the user needs within one of the four financial domains: Investment Management, Green Finance, Risk Analysis, and Insurance Management. Within each of these groups, there were representatives from EO product and data providers and at least one representative from the relevant financial sector to enrich the discussion by having the provider and end user in the same group discussion. Each of four groups was given UNs of each domain with technical details and then ask them to identify the EO products (with their specifications) responding to these specified needs. After identifying the EO products, they were subjected to a feedback evaluation process. Their findings and feedback were recorded and shown over an online canvas. You can find detailed findings of the workshop 2 in the D2.3 Workshop 2 summary report.

5.1.4.EO CAPABILITIES QUESTIONNAIRE

After identifying EO products in previous steps, the EO-FIN Team designed an EO capability questionnaire to acquire feedback from the EO community. This feedback enables evaluation of the identified EO products and further consolidation of the current EO capabilities for the FM sector. The Team used the Google Forms platform for the EO capabilities questionnaire. The EO capability questionnaire targets the EO service/data providers as the audience by asking two questions product EO products. The first question is about the maturity level of the EO product regardless of its capability in contributing to meet the user needs. The maturity levels were defined and categorised into three categories: Mature, partially mature, and immature. **Error! Not a valid bookmark self-reference.** describes the maturity levels with their description providing a common understanding and uniform interpretation of these terms.

Table 4. Maturity levels definition.

Maturity level	Description
Immature	■ The technology/methodology is in the design/research phase. ■ User feedback and customization options may be limited or underdeveloped. ■ Minimally validated and may still contain significant errors.
Partially mature	■ The technology/methodology has been demonstrated in different domains. ■ The product is partially validated, user feedback and customization options are ongoing and there is room for enhancements and updates.
Mature	■ The service offers comprehensive and sophisticated functionalities for various applications and domains. ■ Integration with diverse data sources, such as ground observations, enriches the service's capabilities and accuracy. ■ The service has a large user base, and widespread adoption, and plays a critical role in supporting decision-making, planning, and operational activities across multiple sectors.

Subsequently, respondents were given information about the corresponding UNs for the EO product. The second question was about the level at which the EO product responds to the UNs. The response levels were categorized into four levels (i.e., highly respond, moderately respond, partially respond, and not at all responding). This standardized framework enables participants to respond consistently, resulting in enhancing the reliability and comparability of the collected data.

Table 5. Definitions of the response levels of each EO product to UNs.

Level	Description
Not at all Respond	The EO product cannot respond to the Financial Management User Requirements.
Partially Respond	EO products can only address the User Requirements in a limited way (e.g., new sensors required).
Moderately Respond	EO products can often fulfil the demand, but there are some thematic content, accuracy, or delivery limitations to address the challenges and needs. In other cases, new sensors that are being developed should improve the product to meet the User Requirements.
Highly Respond	EO products can meet the current and anticipated User Requirements of the Financial Management sector. Initiatives such as standards, training, and integration tools can still benefit the EO solution.

The questionnaire focuses on the high level of the EO product rather than a specific EO product with unique predefined parameters. There can be several types of similar EO products available in the EO community and each of them is developed differently according to specifications and requirements. For example, there are different types of crop map products and instead of asking for a specific crop map product, the questionnaire asked the EO community to provide their feedback on their view of this product.

Acquiring feedback on the EO products' maturity level can indicate the development and reliability levels of these EO products and if used technology is ready and reliable. Further, finding the response level of EO products meeting UNS can suggest how realistically these EO products are beneficial in the real world. These responses show how well the current EO technology addresses the FM users' expectations, particularly in terms of practicality and reliability. This information can help users from the FM sector to better decisions on using EO products. Also, the EO community can identify gaps to further improve the remote sensing technology effectively.

Note: There was an option as 'I am not sure' for both questions in case respondents were not confident in their answers. This can potentially increase the reliability of findings.

Note: For the question on the response level, if respondents chose any of these three choices (i.e., not all respond, partially respond, or moderately respond), they asked two further questions including:

- What are the main factors preventing this EO product from fully responding to the above-mentioned User Requirement(s)?
- What are the main factors preventing this EO product from fully responding to the above-mentioned User Requirement(s)?

The answers to these two questions describe in the D2.2 Gap analysis report.

The EO-FIN Team designed two different versions of the EO capability questionnaires. The first version of the EO capability questionnaire was conducted during the workshop 2 event. The Team asked online participants about the maturity and response levels of 30 EO products. These 30 EO products were identified through desk-based research-1.

The second EO capability questionnaire was conducted after desk-based research 2 by asking about maturity and response levels for 9 new EO products (in total covering 39 EO products). The EO capability questionnaire 2 was disseminated internally at GMV and externally through EARSC and Space4Climate channels.

6. CURRENT EO CAPABILITIES AND USE RESPONDING TO GEO-INFORMATION NEEDS OF THE FINANCIAL MANAGEMENT SECTOR

This section presents the EO capabilities identified and consolidated responding into four FM domains (Figure 2). You can find the detailed findings of the EO capability questionnaires and the final list of EO products including their EO application field. Then, the final EO capabilities with associated EO application field will be presented and it followed by the introducing the EO services.

6.1. EO CAPABILITIES IDENTIFIED

This section presents those EO capabilities gathered during desk-based research, online survey, and workshop discussions, shown in Table 7, Table 8, Table 9, and Table 10 that respond to UNs of investment management, green finance, risk analysis, and insurance management, respectively.

To prioritise the EO capabilities, all identified EO capabilities are classified into five categories (Table 7). The EO capabilities in category A (shown in green colour) are highly relevant to UNs and will be explained in the current EO capabilities portfolio section. Several EO capabilities in categories B and D (shown as amber and red colours, respectively) are similar to the EO capabilities in category A. As the study aims to have at least one EO product per UN, the EO capabilities with similar applications were discarded to be described in the current EO capabilities portfolio section. The EO capabilities in category C (shown in cream colour) are "satellite-based and reanalysis products" and are presented in the annexes section. The EO capabilities with cantaloupe colour (category E) are too general and often don't refer directly to a specific EO product.

Table 6. Definition of the EO capabilities were identified during desk-based research, online survey, and workshop discussions.

Category	Colour	Description
A		• They are highly relevant EO products and are selected to be presented.
B		• They are EO products but discarded to be presented in the current EO capabilities portfolio. Because there are similar EO products from category A have already been considered. • They are EO-derived products and are included in the current EO capabilities portfolio as EO-derived products were used to develop EO products from category A.
C		• They are "satellite-based and reanalysis products" and are presented in the annexes.
D		• They are EO products but discarded to be presented in the current EO capabilities portfolio. Because there are similar EO products from category A have already been considered. • They are not relevant to EO.
E		• They are too general.

Table 7. EO capabilities were identified during desk-based research (1,2), online survey, and workshop discussions in response to UNs of the investment management domain.

NO	ID: User Expression	EO Products from desk-based research	EO Products from online survey	EO Products from workshop discussions
1	UN9: Understanding stock levels and monitoring supply chains	Green biomass and yield estimation	Worldpop	Measure the capacity of oil storage with daily monitoring
		Monitoring changes in port activity patterns		Traceability using EO technology
		Stock changes in oil tanks with floating roofs		Scan mine surfaces and get spectral data
		Milk and cattle (in weight) productivity estimation		
2	UN10: Need to understand population density when making investment decisions	Land use maps		
		Building Inventory		
		In situ data (Census/Worldpop)		
		Nightlight		
		Building Inventory		
		In situ data (Census/Worldpop)		
		Nightlight		
3	UN11: Realistic assessment of accessibility to assets		Surface Friction dataset (travel time)	VHR SAR and optical imagery
			Land Classification around assets	DEM data, for topography
				Thermal, Lidar to identify energy transformation
4	UN12: Analysis of potential risks in specific regions	Satellite-derived bathymetry for port and coastal monitoring	Fire risk	Climate risk
		Identification of flood hazard areas	Drought risk	
		Identification of trends related to shifts in rainfall patterns	Flood risk	
		Monitoring reforestation and deforestation activities	NEX-GDDP-CMIP6: NASA Earth Exchange Global Daily Climate Projections (to 2100)	
		Monitor slow-moving subsidence		
		Drought monitoring at the assets level		
		Wildfires danger forecasting		

		Coastal erosion		
		Predicting terrorism hotspots		
5	UN13: Need to geo-map clients	Land use maps	Earth Blox - Climate and environmental risk: use building footprints and postcode locators.	Mapping clients to their assets
		Political stability map		
		Economic conditions		
		Identification of flood hazard areas		
		Identification of trends related to shifts in rainfall patterns		
		Monitoring reforestation and deforestation activities		
		Monitor slow-moving subsidence		
		Drought monitoring at the assets level		
		Wildfires danger forecasting		
6	UN14: Need to screen the feasibility of projects against different hazard criteria	Drought monitoring at the assets level	Using geographic/historic risk criteria to evaluate risk factors for asset locations	Flood risk mapping
		Identification of flood hazard		Drought monitoring
		Identification of trends related to shifts in rainfall patterns	NEX-GDDP-CMIP6: NASA Earth exchange global daily climate projections (to 2100)	Land subsidence monitoring (i.e., EGMS from ESA)
		Sea level rising map		
		Heat hazard map		
7	UN15: Need to monitor carbon intensity of portfolio assets	GHG emissions monitoring	Carbon monitoring	
			Biomass estimation	
			Deforestation monitoring	
			Land cover change	
8	UN16: Nighttime light monitoring	Nighttime light monitoring	Nighttime light monitoring	Nighttime light monitoring (i.e., VIIRS from NASA)
		Land use maps		

9	UN17: Need near real-time tracking of marine vessels to understand their routes and estimate fuel usage			
10	UN18: Need to monitor crop productivity	Crop Type and Acreage Mapping	Land cover change	
		Crop phenology, rotation, number of seasons, tillage, and crop residue cover practices		
		Green biomass and yield estimation		
11	UN19: Identifying types of crops being grown is essential	Crop type and acreage mapping	Crop type mapping using a combination of imaging systems and classification. Field data for training required	

Table 8. EO capabilities were identified during desk-based research (1,2), online survey, and workshop discussions in response to UNs in the green finance domain.

NO	ID: User Expression	EO Products from desk-based research	EO Products from online questionnaire	EO Products from workshop discussions
1	UN26: Need to monitor GHG emissions of projects funded	GHG emissions monitoring	Land cover change	
2	UN27:Need to assess historical trends and baseline of natural assets	Land use maps	Deforestation monitoring	
		Monitoring reforestation and deforestation Activities	Land cover change	
			land cover change	
3	UN28: Need to classify the types of crops being grown in order to assess the Sustainability and Environmental impact of agricultural investments	Crop type and acreage mapping		
4	UN29: Need to accurately measure the planted area for crops.	Crop type and acreage mapping	Land cover Change	
		Green biomass and yield estimation		

5	UN30: Need for monitoring with accurate measurements of the growth and health of trees and verifying the sustainability of forest management practices.	Vegetation height estimation	Deforestation monitoring	Tree inventory
		Crop health (diseases and pests' detection)	Carbon monitoring	Trees count
			Biomass estimation	Tree height estimation
6	UN31: Need to link tree planting parcels to estimate the number of trees planted		Carbon monitoring	
			Biomass estimation	
7	UN32: Need to periodically estimate the growth of above-ground and soil carbon stocks (in forests).	Estimation of above-ground carbon stocks in forests	Carbon monitoring	
			Biomass estimation	

Table 9. EO capabilities were identified during desk-based research (1,2), online survey, and workshop discussions in response to UNs in the risk analysis domain.

NO	User Expression	EO Products from desk-based research	EO Products from online survey	EO Products from workshop discussions
1	UN37: Projection of risk to portfolio assets into the future	Crop health (diseases and pests' detection)	NEX-GDDP-CMIP6: NASA Earth Exchange Global Daily Climate Projections (to 2100)	ML for prediction by using historical data like MODIS
		Vegetation height estimation		
		Surveillance of oil and gas pipelines for geohazard and ground subsidence vulnerabilities		
		Monitoring highway and railway networks		
		Monitoring reforestation and deforestation activities		
		Monitor slow-moving subsidence		
		Coastal erosion		
		Dams' safety		
		Identification of flood hazard areas		
		Identification of trends related to shifts in rainfall patterns		
		Predicting terrorism hotspots		
2	UN38: Need for trustworthy time series of reliable data on assets	Green biomass and yield estimation		
		Monitoring reforestation and deforestation activities		

3	UN39: Need to assess the potential impact of business activities or investments on ecosystems and biodiversity	Oil spill detection	Deforestation	EASOS from Catapult
			Land cover change	
			Biodiversity (using a combination of data layers (intactness, IBAT, etc)	
4	UN40: Need to monitor the risk of sea level rise threatening coastal property, infrastructure, and supply chains	Coastal erosion	Aqueduct Water Risk Atlas (AWRA)	Coastal storms activity
			NASA Earth Exchange Global Daily Climate Projections (to 2100)	Digital elevation model
				Land use and land cover boundaries
				Sea level rise monitoring programs from NOAA-NASA
5	UN41: Need to monitor the impact of increased temperatures on assets	Heat hazard maps	NASA Earth Exchange Global Daily Climate Projections (to 2100)	
		Impact of increased temperatures on soil moisture and vegetation condition		
6	UN42: Need to monitor the impact of droughts on assets	Drought monitoring at the assets level		Vegetation indices
7	UN43: Need to monitor changing precipitation patterns and flood risk in the vicinity of vulnerable assets	Identification of flood hazard areas	Aqueduct Water Risk Atlas (AWRA)	Flood risk maps
		Identification of trends related to shifts in rainfall patterns	NASA Earth Exchange Global Daily Climate Projections (to 2100)	Precipitation estimation
8	UN44: Need to measure the area vulnerable to wildfires before events	Wildfires danger forecasting		Wildfire detection & monitoring from space from Orora
9	UN45: Need to measure the area affected by wildfires after the fact	Post wildfires monitoring (area and severity)		
10	UN46: Need to measure the intensity of wildfires (level of damage to assets)	Post wildfires monitoring (area and severity)		Wildfire behaviour assessment using information like fuel availability
11	UN47: Need up-to-date geospatial data on residential and industrial infrastructure locations	Land use maps		
		Building inventory		

Table 10. EO capabilities were identified during desk-based research (1,2), online survey, and workshop discussions in response to UNs in the insurance management domain.

NO	ID: User Expression	EO Products from desk-based research	EO Products from online questionnaire	EO Products from workshop discussions
1	UN55: Detecting crop damage at the level of individual farms/fields	Crop health (diseases and pests' detection)	Land cover change	Land use at the building level
				Catchment hydrological modelling
				Flood maps
				Landslides monitoring
2	UN56: Need to detect changes in land use (at the level of individual buildings)	Land use maps		
3	UN57: Automatically update changes in population density estimates based on observable land use changes	Building inventory		Worldpop

6.2. EVALUATION OF IDENTIFIED EO CAPABILITIES

In total, 39 EO products (shown in green colour in Table 7, Table 8, Table 9, and Table 10) selected as the most relevant EO capabilities to the FM UNs. At this stage, the Team conducted two sets of questionnaires (as explained in the EO Capabilities Questionnaire section 5.1.4) to understand how well these EO products respond to their UNs by asking the EO community on the maturity level of those EO product at a high level.

Five responses were received for the EO capability questionnaire 1, whereas we received ten responses for the second questionnaire. Therefore, certain products got a cumulative total of fifteen responses, combining input from both questionnaires. This also means others, which were exclusively included in the second questionnaire, obtained ten responses.

Table 11 presents responses received on the product's response level to UNs and maturity level. The percentage of four response levels (i.e., not at all respond, partially respond, moderately respond, and highly respond) were calculated by the number of participants per each response level to the total number of responses, excluding those selected 'I am not sure' option. Please refer to Table 5 for a definition of the response levels of each EO product to UNs.

In addition to the percentages of response level, a response score is computed as the mean and standard deviation of the scores derived from the responses. The mean provides insights into the average response level of each product, while the standard deviation offers an indication of the variability in answers for the same product. Furthermore, among products with similar means, those with lower standard deviations are positioned ahead of those with higher standard deviations. The higher standard deviations can indicate a greater degree of uncertainty regarding the maturity/response levels of the products. The EO products in Table 11 ordered based on the response score from highest 4 to lowest 2.4. To distinguish the response scores better visually, the responses were scores categorised into three levels 3.5 to 4; 3 to 3.49; and below 2.99, shown as green, orange, and red, respectively.

Next, the percentage of three maturity levels (i.e., immature, partially mature, and mature) was calculated by a number of participants per each level to the total number of responses, excluding those who selected 'I am not sure' option. In addition to presenting the percentages, similarly to response level, a maturity score computed for each EO product as the mean and standard deviation. Please refer to After identifying EO products in previous steps, the EO-FIN Team designed an EO capability questionnaire to acquire feedback from the EO community. This feedback enables evaluation of the identified EO products and further consolidation of the current EO capabilities for the FM sector. The Team used the Google Forms platform for the EO capabilities questionnaire. The EO capability questionnaire targets the EO service/data providers as the audience by asking two questions product EO products. The first question is about the maturity level of the EO product regardless of its capability in contributing to meet the user needs. The maturity levels were defined and categorised into three categories: Mature, partially mature, and immature. Table 4 describes the maturity levels with their description providing a common understanding and uniform interpretation of these terms. The maturity score categorised into three levels 2.5 to 3; 2 to 2.49; and below 1.99 shown as green, orange, and red, respectively (Table 11).

Compared to the response level, questionnaires ask about the maturity level at high level without associating them with UNs. For instance, the description for the EO product 'Crop type and acreage mapping' was stated as follows: "Maps provide detailed information about the agricultural species present in a specific area, including their extent." As a result, the variability in responses can be attributed to the diverse range of specific products falling under the same high-level product category, each employing distinct algorithms and datasets. In other words, each participant may possess differing experiences with the same high-level product based on the specific product they have used or are aware of. It's worth noting again that we received a maximum of 15 responses from experts in the field of EO. Consequently, the results may not serve as an exhaustive representation of the entire EO community. This limitation made it challenging to come up with a concrete decision about the maturity/response level of each product.

Comparing the maturity score and response score suggests that the EO product with a higher response is more likely to have a higher maturity level. There are several EO products for which 'I am not sure' were selected by 50% or more of the participants including: Satellite-Derived Bathymetry for Port and Coastal Monitoring, Lithology and Surficial Geology Mapping, Dams' Safety, Predicting Terrorism Hotspots, Monitoring Green House Gases (GHG) emissions from marine vessels, Fish Stock Assessment, and Milk and Cattle (in weight) Productivity Estimation. One reason for that could be these products are newer or not commonly used in the EO field, therefore, the participants were not fully aware of them. More comprehensive insights into the gaps hindering EO products from meeting the financial sector's requirements will be elaborated upon and discussed in the upcoming gap analysis report.

Statistical Significance of the Results

The survey data generated by the EO-FIN survey comes from human test-takers who we know to be making deliberate decisions. For all cases that were relevant to the survey-taker's experience, they scored the EO product on a scale of 1-3. We therefore present the average response per question, using the arithmetic mean, to summarise the strength of feeling among all test-takers who responded to that particular product.

These average values should be interpreted cautiously – different survey takers have different experiences and interests and hence may score the same product very differently. With that being said, some clear trends do emerge, with some EO products receiving generally high scores which mark them as a highly relevant product.

Other statistical measures of the importance or significance of survey results were investigated but deemed to be inappropriate in this instance. For example, while student t-tests can theoretically be applied to the data to investigate whether the results are statistically significantly different from random data, we know that the input data was not random – it was generated by human survey takers. Testing this is therefore not necessary to deem the results statistically significant. Further complications arise when considering various statistical tests due to the small sample size available for each question – the maximum number of responses for a product was 15, and the mean was 9.2. This leads to low test power and hence a likely inability to find meaningful results, no matter what test is applied.

Table 11. Analysis of responses to EO capability questionnaires (versions one and two).

		Response level of the EO product to associated UNs								Maturity level the of EO product					
No	Product name	Total No of participants	NO of participants answered maturity as ' I am not sure'	% of participants selected response level as:				Response score		NO of participants answered maturity as	% of participants selected maturity level as:			Maturity score	
				Not at all Respond	Partially Respond	Moderately Respond	Highly Respond	Mean	Standard deviation		Immature	Partially mature	Mature	Mean	Standard deviation
1	Land Cover Maps	10	0	0	0	0	100	4	0	0	0	0	100	3.0	0.00
2	Mapping Travel Times to Assets	10	7	0	0	0	100	4	0	8	0	0	100	3.0	0.00
3	Monitoring Reforestation and Deforestation Activities	15	1	0	0	7	93	3.9	0.26	1	0	7	93	2.9	0.26
4	Post Wildfires Monitoring (Area and Severity)	15	3	0	8	0	92	3.8	0.55	3	0	17	83	2.8	0.37
5	Coastal Erosion	15	5	0	0	30	70	3.7	0.46	4	9	18	73	2.6	0.64
6	Land Use Maps	15	0	0	0	33	67	3.7	0.47	0	0	13	87	2.9	0.34
7	Lithology and Surficial Geology Mapping	10	7	0	0	33	67	3.7	0.47	6	0	0	100	3.0	0.00
8	Crop Phenology, Rotation, and Number of Seasons	10	0	0	10	10	80	3.7	0.64	0	0	10	90	2.9	0.30
9	Trees Counting	10	2	0	0	38	63	3.6	0.48	2	13	38	50	2.4	0.70
10	WorldPop – Population Counts	10	5	0	0	40	60	3.6	0.49	4	33	17	50	2.2	0.90
11	Stock Changes in Oil Tanks with Floating Roof	15	5	0	10	20	70	3.6	0.66	7	0	50	50	2.5	0.50
12	Building Inventory	15	4	0	18	0	82	3.6	0.77	4	9	18	73	2.6	0.64
13	Crop Type and Acreage Mapping	15	1	0	0	50	50	3.5	0.5	1	0	50	50	2.5	0.50
14	Satellite-Derived Bathymetry for Port and Coastal Monitoring	15	11	0	0	50	50	3.5	0.5	10	0	80	20	2.2	0.40

15	Surveillance of Oil and Gas Pipelines for Geohazard and Ground Subsidence Vulnerabilities	15	7	0	13	25	63	3.5	0.71	7	13	13	75	2.6	0.70
16	Ship Detection and Categorization	10	4	0	17	17	67	3.5	0.76	4	0	33	67	2.7	0.47
17	Identification of Flood Hazard Areas	15	2	8	0	23	69	3.5	0.84	2	8	15	77	2.7	0.61
18	Wildfires Danger Forecasting	15	3	8	0	25	67	3.5	0.87	1	8	31	62	2.5	0.63
19	Nighttime Light Monitoring	15	5	10	10	0	80	3.5	1.02	4	9	27	64	2.5	0.66
20	Drought Monitoring at the Assets Level	15	1	0	7	43	50	3.4	0.62	1	7	29	64	2.6	0.62
21	Oil Spill Detection	15	5	0	20	20	60	3.4	0.8	5	0	0	100	3.0	0.00
22	Monitoring Highway and Railway Networks	15	7	13	0	25	63	3.4	0.99	6	0	33	67	2.7	0.47
23	Monitor Slow-Moving Subsidence	15	6	11	11	0	78	3.4	1.07	4	9	27	64	2.5	0.66
24	Dams' Safety	15	11	0	25	25	50	3.3	0.83	10	20	20	60	2.4	0.80
25	Monitoring Changes in Port Activity Patterns	15	5	0	30	10	60	3.3	0.9	5	10	40	50	2.4	0.66
6	Estimation of Above-ground Carbon Stocks in Forests	15	4	9	9	27	55	3.3	0.96	3	8	42	50	2.4	0.64
27	Heat Hazard Map	10	4	17	0	17	67	3.3	1.11	5	20	0	80	2.6	0.80
28	Crop Health (Diseases and Pests detection)	15	0	0	13	53	33	3.2	0.65	0	0	40	60	2.6	0.49
29	Green Biomass and Yield estimation	15	2	8	0	62	31	3.2	0.77	2	8	62	31	2.2	0.58
30	Vegetation Height Estimation	15	3	8	17	25	50	3.2	0.99	3	8	33	58	2.5	0.65
31	Impact of increased temperatures on soil moisture and vegetation condition	10	4	17	17	0	67	3.2	1.21	4	17	33	50	2.3	0.75
32	Identification of Trends Related to Shifts in Rainfall Patterns	15	6	11	11	33	44	3.1	0.99	7	13	38	50	2.4	0.70
33	Tillage, and Crop Residue Cover Practices	10	3	0	29	43	29	3	0.76	3	29	29	43	2.1	0.83
34	Predicting Terrorism Hotspots	15	9	0	33	33	33	3	0.82	8	43	43	14	1.7	0.70
35	Green House Gases (GHG) Emissions Monitoring	15	4	10	30	20	40	2.9	1.04	5	20	30	50	2.3	0.78
36	Milk and Cattle (in weight) Productivity Estimation	15	9	17	17	33	33	2.8	1.07	8	29	57	14	1.9	0.64
37	Monitoring Solar Panel Installations	15	6	11	44	0	44	2.8	1.13	6	33	33	33	2.0	0.82
38	Fish Stock Assessment	15	10	20	20	20	40	2.8	1.17	11	0	100	0	2.0	0.00

39	Monitoring Green House Gases (GHG) emissions from marine vessels	10	6	0	50	50	0	2.5	0.5	6	0	100	0	2.0	0.00

6.3. OVERVIEW OF THE CURRENT EO CAPABILITIES AND USE

From 39 EO products selected for the questionnaire, only 'Monitoring Green House Gases (GHG) emissions from marine vessels' was removed from the list of final EO products. This was done because there is no such an EO product currently found in the EO market, plus this product received poor response and maturity scores. Table 12 describes the final list of the consolidated current EO capabilities and their associated EO application field.

Table 12. List of final 38 Consolidated EO products.

Product ID	Product name	EO application field
P01	Land Use Map	Land use
P02	Crop Type and Acreage Mapping	
P03	Crop Phenology, Rotation, and Number of Seasons	
P04	Tillage, and Crop Residue Cover Practices	
P05	Green Biomass and Yield estimation	
P06	Milk and Cattle (in weight) Productivity Estimation	
P07	Monitoring Reforestation and Deforestation Activities	
P08	Trees Counting	
P09	Building Inventory	
P10	Mapping Travel Times to Assets	
P11	WorldPop – Population Counts	
P12	Monitoring Solar Panel Installations	
P13	Monitoring Changes in Port Activity Patterns	
P14	Stock Changes in Oil Tanks	
P15	Lithology and Surficial Geology Mapping	
P16	Predicting Terrorism Hotspots	
P17	Land Cover Maps	Land cover
P18	Crop Health (Diseases and Pests detection)	
P19	Vegetation Height Estimation	
P20	Nighttime Light Monitoring	
P21	Drought Monitoring at the Assets Level	Natural disaster
P22	Post Wildfires Monitoring (Area and Severity)	
P23	Wildfires Danger Forecasting	
P24	Identification of Flood Hazard Areas	
P25	Identification of Trends Related to Shifts in Rainfall Patterns	
P26	GHG Emissions Monitoring	Climate change
P27	Estimation of Above-Ground Carbon Stocks in Forests	
P28	Impact of increased temperatures on soil moisture and vegetation condition	
P29	Heat Hazard Map	
P30	Satellite-Derived Bathymetry for Port and Coastal Monitoring	Coast management
P31	Coastal Erosion	
P32	Fish Stock Assessment	Marine
P33	Oil Spill Detection	

P34	Ship Detection and Categorization	
P35	Monitoring Highway and Railway Networks	Earth's surface motion
P36	Dams' Safety	
P37	Surveillance of Oil and Gas Pipelines for Geohazard and Ground Subsidence Vulnerabilities	
P38	Monitor Slow-Moving Subsidence	

6.4. CURRENT EO CAPABILITIES AND FINANCIAL MANAGEMENT IN SUBDOMAIN

This part describes the relationship between the 38 EO products with FM sector at the subdomain level. Each FM domain divided into several subdomains including:

Investment Management subdomains: analyse market signals, track macroeconomic trends, monitor opaque markets, and due diligence and monitoring assets.

Green Finance subdomains: monitoring green finance, carbon offsetting, and environmental due diligence.

Risk Analysis subdomains: measure physical risk, climate stress-testing, forecasting to manage volatility, and socioeconomic risk measurement.

Insurance Management subdomains: validating self-reports, assessing claims against policies, parametric insurance products.

Table 1Table 13 describes the EO capabilities response level to FM subdomains. This information collected during the first phase of this work (Geo-information requirements) and desk-based research in the current stage of work.

Table 13. Relation between the consolidated EO products and FM sector at subdomain level.

EO capabilities		Investment Management Subdomain				Green Finance Subdomain			Risk Analysis Subdomain				Insurance Management Subdomain		
NO	Product ID: Product name	Analyse Market Signals	Track Macro Economic Trend	Monitor Opaque Markets	Due Diligence and Monitoring Assets	Monitoring Green Finance	Carbon Offsetting	Environmental Due Diligence	Measure Physical Risk	Climate Stress-Testing	Forecasting to Manage Volatility	Socioeconomic Risk Measurement	Validating Self Reports	Assessing Claims Against Policies	Parametric Insurance Products
1	P01: Land Use Map				■	■									
2	P02: Crop Type and Acreage Mapping				■								■		
3	P03: Crop Phenology, Rotation, and Number of Seasons			■	■								■		
4	P04: Tillage, and Crop Residue Cover Practices			■	■								■		
5	P05: Green Biomass and Yield estimation				■						■				
6	P06: Milk and Cattle (in weight) Productivity Estimation				■										
7	P07: Monitoring Reforestation and Deforestation Activities						■	■	■						
8	P08: Trees Counting				■	■	■			■					■
9	P09: Building Inventory			■											
10	P10: Mapping Travel Times to Assets				■							■			
11	P11: WorldPop – Population Counts	■		■		■									

12	P12: Monitoring Solar Panel Installations														
13	P13: Monitoring Changes in Port Activity Patterns														
14	P14: Stock Changes in Oil Tanks														
15	P15: Lithology and Surficial Geology Mapping														
16	P16: Predicting Terrorism Hotspots														
17	P17: Land Cover Maps														
18	P18: Crop Health (Diseases and Pests detection)														
19	P19: Vegetation Height Estimation														
20	P20: Nighttime Light Monitoring														
21	P21: Drought Monitoring at the Assets Level														
22	P22: Post Wildfires Monitoring (Area and Severity)														
23	P23: Wildfires Danger Forecasting														
24	P24: Identification of Flood Hazard Areas														
25	P25: Identification of Trends Related to Shifts in Rainfall Patterns														
26	P26: GHG Emissions Monitoring														
27	P27: Estimation of Above-Ground Carbon Stocks in Forests														
28	P28: Impact of increased temperatures on soil moisture and vegetation condition														
29	P29: Heat Hazard Map														
30	P30: Satellite-Derived Bathymetry for Port and Coastal Monitoring														
31	P31: Coastal Erosion														
32	P32: Fish Stock Assessment														
33	P33: Oil Spill Detection														
34	P34: Ship Detection and Categorization														
35	P35: Monitoring Highway and Railway Networks														

36	P36: Dams' Safety														
37	P37: Surveillance of Oil and Gas Pipelines for Geohazard and Ground Subsidence Vulnerabilities														
38	P38: Monitor Slow-Moving Subsidence														

6.5. EO SERVICES IDENTIFIED FOR FINANCIAL MANAGEMENT SECTOR

This report section explains the relationship between UNs and consolidated EO capabilities. Upon the identification and consolidation of EO capabilities, the relation between the UNs and associated EO capabilities can be categorised into three groups.

Group A: An individual EO product could fulfil a UN. For example, UN15 pertains to 'Need to monitor carbon intensity of portfolio assets' can be addressed by the EO product 'Green House Gases (GHG) emissions monitoring' (P22). Another example is UN19 pertains to 'Identifying types of crops being grown is essential' which can be addressed by the EO product 'Crop type and acreage mapping' (P02).

Table 14. Individual EO products can fulfil a UN.

EO product ID	EO product name	Corresponding UNs
Investment Management domain		
P11	WorldPop – population counts	UN10: Need to understand population density when making investment decisions.
P26	Green House Gases (GHG) emissions monitoring	UN15: Need to monitor carbon intensity of portfolio assets.
P20	Nighttime light monitoring	UN16: nighttime light monitoring.
P02	Crop type and acreage mapping	UN19: Identifying types of crops being grown is essential
Green Finance domain		
P26	GHG emissions monitoring	UN26: Need to monitor GHG emissions of projects funded.
P08	Trees counting	UN31: Need to link tree planting parcels to estimate the number of trees planted.
Risk Analysis domain		
P21	Drought Monitoring at Assets Level	UN42: Need to monitor the impact of droughts on assets.
P23	Wildfires Danger Forecasting	UN44: Need to measure the area vulnerable to wildfires before events.
P22	Post Wildfires Monitoring (Area and Severity)	UN45: Need to measure the area affected by wildfires after the fact. UN46: Need to measure the intensity of wildfires (level of damage to assets).
Insurance Management domain		
P01	Detailed land use change maps	UN56: Need to detect changes in land use (at the level of individual buildings).
P11	WorldPop – population counts	UN57: Automatically update changes in population density estimates based on observable land use changes.

Group B: Several EO products across multiple sectors potentially fulfil this UN (only one UN available is this group). For example, UN9 pertains to 'Understanding stock levels and monitoring supply chains'. This need is extensive and shared across multiple application fields including agriculture, energy, and mining. For instance, 'Green biomass and yield estimation' (P04) EO product responds to UN9 in the agriculture sector by monitoring the agricultural supply chain. Whereas the 'Stock changes in oil tanks with floating roof' (P22) EO product, responds to UN9 in the petroleum sector monitoring the oil and gas supply chain (please refer Table 7).

Group C: A combination of EO products in a specific sector potentially fulfils these UNs. This group is about the types of UNs that can be addressed by an EO service. The EO service is formed by a combination of a series of EO products in a specific application field.

For instance, UN12 pertains to the 'Analysis of potential risks in specific regions'. This requirement is broad without mentioning a specific risk type. Therefore, the EO service suits well for this UN by combining a series of relevant EO products including 'Drought Monitoring at Assets Level' (P15), 'Wildfires Danger Forecasting' (P17), and 'Identification of Flood Hazard Areas' (P20).

Another example, UN18 pertains to: 'Need to monitor crop productivity' and can be fulfilled by an EO service forming by a combination of Crop type and acreage mapping' (P02), 'Crop phenology, rotation, and number of seasons' (P03), 'Tillage, and crop residue cover practices' (P04), and 'Green biomass and yield estimation' (P05).

Table 15 introduces 18 EO services that fulfil 18 UNs. It contains the ID and name of the service plus the EO products and ancillary data that can be integrated (all or part of them upon the user's request) to generate that service. It should be noted that the ancillary data that is being used to develop each EO product is not added to the table, you can find this information in EO products portfolio section 7.

Table 15. List of the EO services derived addressing 18 UNs.

N	Service ID: name	EO products forming the service	Ancillary data for the service	User needs addressed by the service	Service description
	Investment Management domain				
1	**S01:Asset Accessibility Assessment**	• Land use maps (P01) • Mapping travel times to assets (P10) • Digital Elevation Model (DEM)		UN11: Realistic assessment of accessibility to assets.	
2	**S02: Natural hazard risk analysis**	• Drought monitoring at assets level (P21) • Wildfires danger forecasting (P23) • Identification of flood hazard areas (P24) • Identification of trends related to shifts in rainfall patterns (P25)		UN12: Analysis of potential risks in specific regions. UN14: Need to screen the feasibility of projects against different hazards criteria.	
3	**S03: Security risk analysis**	• Predicting terrorism hotspots (P16)	• The Armed Conflict Location & Event Data Project (ACLED) • Uppsala Conflict Data Program (UCDP) • IB Global Politics - Conflict Analysis Data Sheet	UN12: Analysis of potential risks in specific regions.	
4	**S04: Client risk mapping**	• Land use maps (P01) • Drought monitoring at assets level (P21) • Wildfires danger forecasting (P23) • Identification of flood hazard areas (P24) • Identification of trends related to shifts in rainfall patterns (P25)	• The Armed Conflict Location & Event Data Project (ACLED) • Uppsala Conflict Data Program (UCDP) • IB Global Politics - Conflict Analysis Data Sheet	UN13: Need to geo-map clients.	
5	**S05: Monitoring crop productivity**	• Crop type and acreage mapping (P02) • Crop phenology, rotation, and number of seasons (P03) • Tillage, and crop residue cover practices (P04) • Green biomass and yield estimation (P05)		UN18: Need to monitor crop productivity.	
	Green Finance domain				
6	**S06: Natural assets time series analysis**	• Land cover maps (P17) • Land use maps (P02) • Vegetation indices • Monitoring reforestation and deforestation activities (P07)		UN27: Need to assess historical trends and baseline of natural assets.	
7	**S07: Assessing crop types' of**	• Crop type and acreage mapping (P02) • Deforestation activities (part of P07)		UN28: Need to classify the types of crops being grown	

	impact on sustainable and environmental investments	• Land degradation • Carbon sequestration in soil		to assess the Sustainability and Environmental impact of agricultural investments. UN29: Need to accurately measure the planted area for crops.	
8	**S08: Assessing trees health condition and forest carbon sequestration**	• Estimation of Above-Ground Carbon Stocks in Forests (P27) • Deforestation and reforestation monitoring (P07) • Carbon Sequestration in Soil • Vegetation Indices		UN30: Need for monitoring with accurate measurements of the growth and health of trees and verifying the sustainability of forest management practices.	
9	**S09: Measuring the growth of carbon stocks: in forests**	• Estimation of Above-Ground Carbon Stocks in Forests • Carbon Sequestration in Soil		UN32: Need to periodically estimate the growth of above-ground and soil carbon stocks (in forests).	
	Risk Analysis domain				
10	**S10: Natural hazard prediction**	• Wildfire danger forecasting (P23) • Identification of Flood Hazard Areas (P24) • NEX-GDDP-CMIP6: NASA Earth Exchange Global Daily Climate Projections (to 2100) • Copernicus seasonal forecast program	• Historical drought maps	UN37: Need to assess historical trend and baseline of natural assets.	Potential machine learning model can be used for prediction of risks using historical data of drought, floods, wildfires, extreme precipitation events etc.
11	**S11: Geohazards prediction**	• Surveillance of Oil and Gas Pipelines for Geohazard and Ground Subsidence Vulnerabilities (P37) • Monitoring Highway and Railway Networks (P35) • Monitor Slow-Moving Subsidence (P38) • Coastal erosion (P31) • Dams' Safety (P36)		UN37: Need to assess historical trend and baseline of natural assets.	These layers can be used to know the vertical /horizontal displacement rate of the ground per year, which enables the prediction of any potential risk in the future for the infrastructure.
S12	**S12: Historical asset data analysis**	• NEX-GDDP-CMIP6: NASA Earth Exchange Global Daily Climate Projections • ERA5-land data (Table 26 in the Annex C.) • Copernicus Land Services data (Table 26 in the Annex C.)		UN38: Need for trustworthy time series of reliable data on assets.	

		• Land use change (P01) • Land cover change (P17) • SPEI • FAPAR anomaly • Vegetation indices anomalies • Soil moisture anomaly			
13	**S13: Business activities' impact on ecosystems and biodiversity**	• Deforestation activities (part of P07) • Land cover change (P11) • Land use change (P12) • Vegetation indices • Water quality monitoring • Wetland extent mapping	• Biodiversity Intactness Index (BII) • Integrated Biodiversity Assessment Tool (IBAT)	• UN39: Need to assess the potential impact of business activities or investments on ecosystems and biodiversity.	
14	**S14: Sea level risk monitoring**	• DEM • Land cover change (P17) • Land use change (P01) • Dams' Safety (P36)	• Building footprint dataset such as Bing maps or World Settlement Footprint (WSF)	• UN40: Need to monitor the risk of sea level rise threatening coastal property, infrastructure, and supply chains.	
15	**S15: Monitor temperature increase on assets**	• Heat hazard maps (P29) • Impact of increased temperatures on soil moisture and vegetation condition (P28)		• UN41: Need to monitor the impact of increased temperatures on assets.	
16	**S16: Climate resilient flood management**	• Land cover maps (P17) • Land use maps (P01) • Identification of flood hazard areas (P24) • Identification of trends related to shifts in rainfall patterns (P25)		• UN43: Need to monitor changing precipitation patterns and flood risk in vicinity of vulnerable assets.	
17	**S17: Urban properties geolocations map**	• Land use maps (P01) • Building inventory (P09)		• UN47: Need up-to-date geospatial data on residential and industrial infrastructures' locations.	
	Insurance Management domain				
18	**S18: Crop damage map**	• Crop Type and acreage Mapping (P02) • Changes and anomalies of multiple vegetation indices		• UN55: Detecting crop damage at the level of individual farms/fields.	

7. EO PRODUCTS PORTFOLIO

It worth to remind readers that the identified EO capabilities were consolidated based on high level EO products rather than a specific EO products that developed by a certain organisation or company. For the purpose of this report, This section presents a portfolio containing 38 EO use cases responding to 38 EO capabilities identified for FM (section:6.5 EO services identified for financial management sector). These EO use cases selected since they are currently available and well-validated with known, documented performances and constraints shall be within the scope of this activity.

Each EO use cases describe on the same product sheet template that you can find the details in below:

The first part of the product sheets includes the product category, the financial domain that can benefit from the product, and the consolidated FM user requirements that can be addressed by the product, followed by a description of the product, spatial coverage target, and data throughput which can be characterized as follows:

- 'Description': Describe product overview and give information on how a service can respond to the user requirement.
- 'Spatial Coverage Target': Emphasize the spatial coverage of the product.
- 'Data Throughput': Represents the need for time and effort from requesting to receiving the products. The definition of it is based on 'Rapid Tasking' and 'Data availability'.
    - 'Rapid tasking': the process of quickly requesting and obtaining EO products.
    - 'Data availability': it indicates the availability of satellite data in terms of its temporal, and spatial coverage. It is not related to the resolution of the product but is most relevant for User Needs where data for a very specific time or region is required.

This second part of the product sheets gives technical details about the input data to develop each EO product like the sensors, accessibility, spatial resolution, frequency, etc. It also provides additional detail where applicable about the product accuracy, constraints, maturity level, and level of skills required by users to use the EO service. Explanation of most of the technical information about the EO products are as follows:

<u>'Main Processing Steps':</u> Summary of the methodology developed for a service and main step from obtaining the data to develop the product.

<u>'Input Data sources':</u> The names of Satellite sensors used to develop the products such as Sentinel-1&2&3, Worldview2&3, etc.

<u>'Accessibility':</u> If the input data sources are publicly available (e.g., Sentinel1&2&3 are available from ESA) or commercially available (e.g., WorldView-2&3).

<u>'Spatial Resolution':</u> Spatial Resolution of the input data sources.

<u>'Frequency':</u> The frequency of your product like daily, dekadal, monthly, etc.

<u>'Latency':</u> The time delay between data acquisition and its availability for users.

<u>'Geographical Scale Coverage':</u> Describe the geographical scale of the product like local, national, regional, and global.

<u>'Delivery Output Format':</u> The format in which your service is available to be used like Raster (tiff, netCDF, etc.) – Vector (shp, etc.).

<u>'Accuracies':</u> The quantitative metric represents the accuracy of your product like thematic accuracy as percentage and spatial accuracy as pixels.

<u>'Constraints and Limitations'</u>: What are the identified constraints and limitations of the products?

<u>'Availability'</u>: The status of the availability of the EO service. It is classified into three categories:

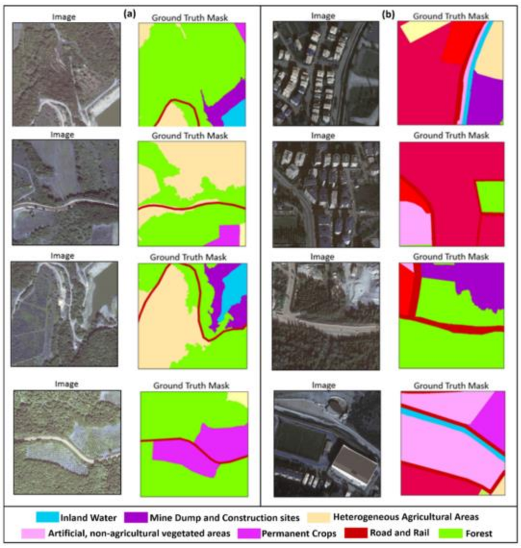
- Currently Available
- Available in 5 years
- Not available now and in 5 years

'User's level of knowledge and skills to extract information and perform further analysis on the EO products.': The level of skills and knowledge required by the end-users for understanding the product – extracting information – basic post-processing. We have classified the skills and knowledge to level 'essential' and 'ample' as follows:

Table 16. Classification of skills and knowledge into essential and ample.

	Essential	Ample
Skills	• Rasterization • Vectorization • Map projection • Image interpretation • Clipping raster data • Cartographical annotations • Vector processing tools (merge-clip-buffer- etc) • Exporting Subsets of the Data	• Geometric calculations • Merging/mosaicking • Resampling • Temporal composites • Spatial query • Zonal statistics • Spatial interpolation • Raster calculator
Knowledge	• Vector and raster data types • Data Formats such as "tiff" and "shp" • Thematic maps • Coordinate systems • Electromagnetic spectrum • Spectral indices • Spatial, spectral, and temporal resolutions	• Understanding terrain analysis • Hyperspectral remote sensing • SAR (Synthetic Aperture Radar) • LIDAR

Land Use Maps



Sample image patches and their corresponding ground truth land use masks in Turkey using Worldview-3 images (0.3m) (Source: Sertel, E., Ekim, B., Ettehadi Osgouei, P. and Kabadayi, M.E., 2022. Land use and land cover mapping using deep learning based segmentation approaches and vhr worldview-3 images. Remote Sensing, 14(18), p.4558.)

Product Category

■ Land Use ☐ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion

☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

■ Investment management ■ Risk analysis ■ Insurance management ■ Green finance

User requirements

UN10: Need to understand population density when making investment decisions.
UN11: Realistic assessment of accessibility to assets.
UN13: Need to geo-map clients.
UN27: Need to assess historical trends and baseline of natural assets.
UN43: Need to monitor changing precipitation patterns and flood risk in the vicinity of vulnerable assets.
UN47: Need up-to-date geospatial data on residential and industrial infrastructures' locations.
UN56: Need to detect changes in land use (at the level of individual buildings).

Description

Land use maps provide information not only about the physical attributes of the Earth's surface, such as land cover but also detail the human activities and utilization of the land. These maps distinguish primary land cover categories, like urban areas, into various subcategories representing specific anthropogenic uses, such as residential zones, industrial areas, transportation networks, structures, and agricultural lands. By providing crucial insights into the spatial distribution of land cover types and anthropogenic activities, these maps enable informed decision-making in real estate development, market analysis, and infrastructure planning. New technologies like deep learning-based-image segmentation algorithms such as Convolutional Neural Network (CNN) have shown impressive accuracy in segmenting complex images with intricate boundaries. Using such techniques gives promising results in land use classification even for complex areas with multiple land use classes.
Land use change map is a form of LU map and it is derived from a time series of LU maps and identifies the changes between maps. Similar to the LU map, the LU change map is important for many applications.

Spatial Coverage Target

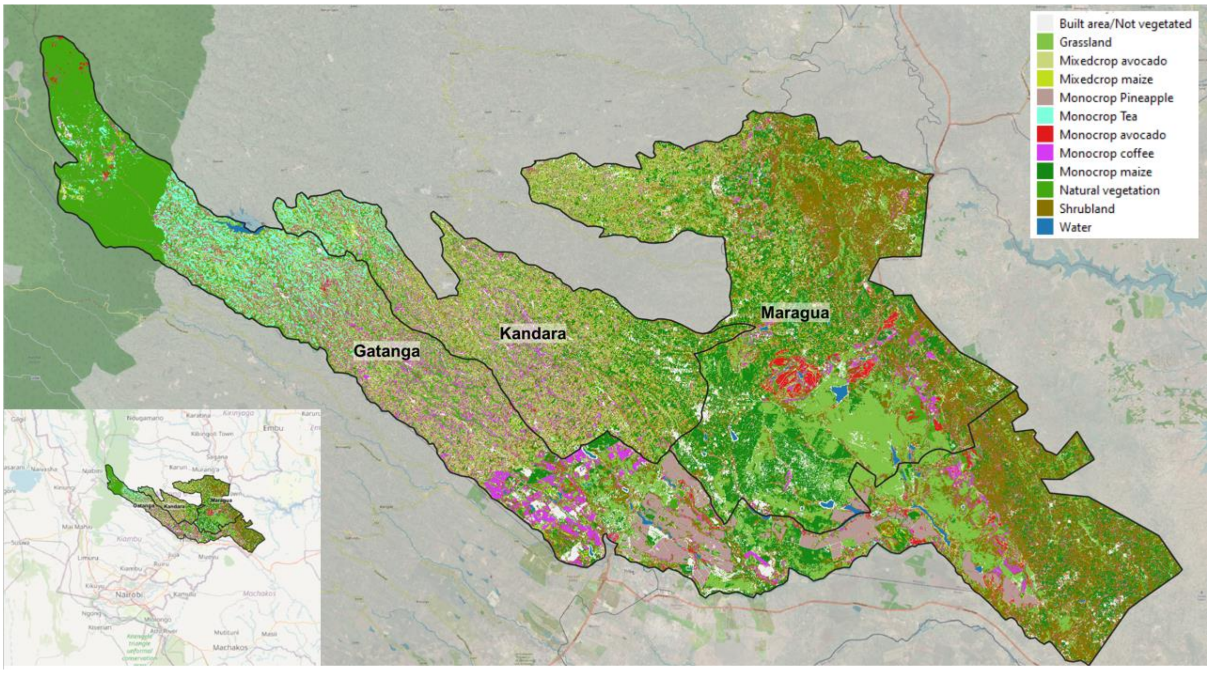
Asset level

Data Throughput

Rapid tasking	☐ High	■ Low	
Data availability	☐ High	■ Low	

Product specifications	
Main processing steps	It can ingest high-resolution EO data, such as satellite imagery or aerial photographs. Then, pre-preprocess the data by performing the atmospheric correction, radiometric calibration, and geometric alignment, as necessary. Split the data into training, validation, and testing sets. Manually label the training data to create a ground-truth dataset. This involves identifying and marking different land cover classes in the images. Land cover data can be used to segment land covers which makes it easier to classify the land use classes based on corresponding land cover. The labelled data will be used to train the deep learning model. To enhance the training process and improve model generalization, data augmentation techniques can be applied, followed by choosing an appropriate deep learning model like U-Net.
Input data sources	Optical: VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: N.A Satellite-based products: N.A Supporting data: Land cover data such as ESA CCI Land cover (20m resolution)
Accessibility	Optical VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Optical VHR: ≤ 1 m
Frequency (Temporal resolution)	Optical VHR: Sub-daily to Daily
Latency	< 1 Day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Cloud presence ▪ Creating high-quality and diverse labelled data for land use mapping can be challenging for specific land cover classes.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Crop Type and Acreage Mapping



1-year Crop Type map in Kenya based on monthly products from Sentinel1&2 (Source: GMV).

Product Category

■ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

■ Investment management ☐ Risk analysis ■ Insurance management ■ Green finance

User requirements

UN18: Need to monitor crop productivity.
UN19: Identifying types of crops being grown is essential.
UN28: Need to classify the types of crops being grown in order to assess the sustainability and environmental impact of agricultural investments.
UN29: Need to accurately measure the planted area for crops.

Description

Crop type and acreage mapping play a crucial role in monitoring agricultural land use and making estimations of crop production. These maps provide detailed information about the agricultural species present in a specific area, including their extent, and growth stage at a particular point in time. Satellite images capture detailed data about agricultural areas, allowing for the identification and classification of different crops based on their spectral characteristics. By leveraging advanced image processing algorithms and machine learning models, crop types can be accurately determined.

Spatial Coverage Target

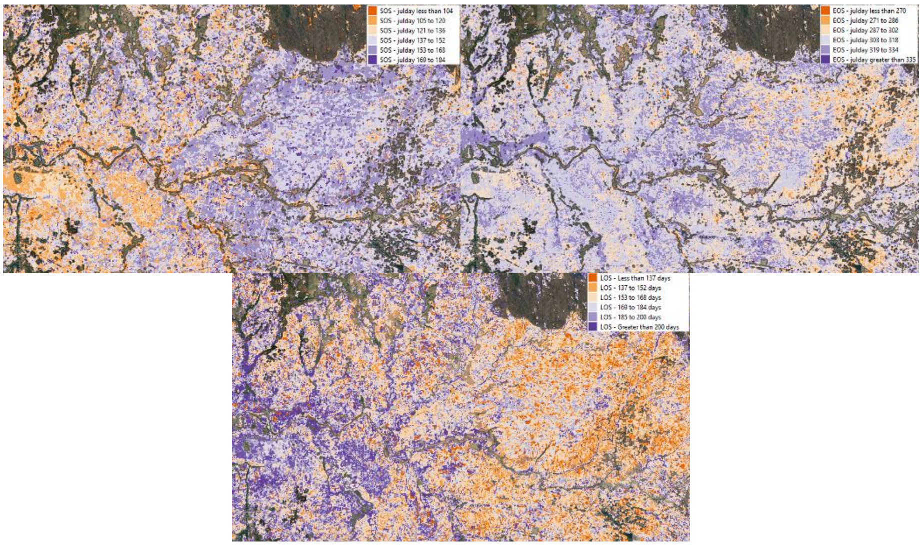
Individual farm level

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	Before creating crop type and acreage maps, the initial step involves mapping the location of crops. This process utilizes machine learning-based classification models, incorporating inputs from various Earth Observation (EO) data sources such as vegetation and backscatter indices. In addition to EO data, non-EO data like local in-situ data and land use land cover maps are also incorporated. The resulting crop location maps are then combined with vegetation and backscatter indices, Digital Surface Models, existing crop type maps like ESA WorldCereal, and ground truth data. These combined inputs are then fed into machine learning models for the classification of different crop types.
Input data sources	Optical: Sentinel-2, VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: Sentinel-1 Supporting data: In-situ crop type data, ESA's WorldCover layer, ESA WorldCereal, ALOS Global Digital Surface Model
Accessibility	Sentinel-1&2: freely and publicly available from ESA. Optical VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel-2: 10 m Optical VHR: ≤ 1 m Sentinel-1: 20 m
Frequency (Temporal resolution)	Sentinel-2: 6 days Optical VHR: Sub-daily to Daily Sentinel-1: 6 days
Latency	< 1 Day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster, Vector File format: GeoTIFF, Shapefile
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ The lack of local in-situ data ■ Cloud presence ■ Differentiating between certain crop types with similar spectral signatures can be challenging. Field heterogeneity with different crop types intermixed or crop rotations occurring within the same area.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Crop Phenology, Rotation, and Number of Seasons



LSP metrics: start of season (SOS), end of season (EOS), and length of season (LOS) in Nigeria using Sentinel-2 (Source: GMV).

Product Category

■ Land Use ☐ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion

☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

■ Investment management ☐ Risk analysis ■ Insurance management ☐ Green finance

User requirements

UN18: Need to monitor crop productivity.

Description

Crop phenology refers to the study and observation of the timing and sequence of distinct stages in the life cycle of a crop from germination to the final maturity and senescence. Phenological stages are anticipated to happen consistently at the same time every year within a particular bioclimatic region. Nevertheless, it is important to acknowledge that certain advancements or delays (measured in weeks) might be observed due to varying climatic conditions. Understanding the seasonal patterns in satellite time-series data and their correlation with dynamic vegetation characteristics, like phenology (growth stages) and temporal growth patterns, is a crucial process for developing more advanced crop-specific products. These products may include information related to crop rotation, the number of growing seasons, tillage practices, green biomass, and yield estimation. Crop type and acreage maps, along with vegetation indices, serve as the primary inputs for calculating land surface phenology (LSP) metrics, including the start of the season (SOS), end of the season (EOS), length of the season (LOS), and the peak of the season (POS). Additionally, local observations of crop phenology can be utilised for calibration purposes.

Spatial Coverage Target

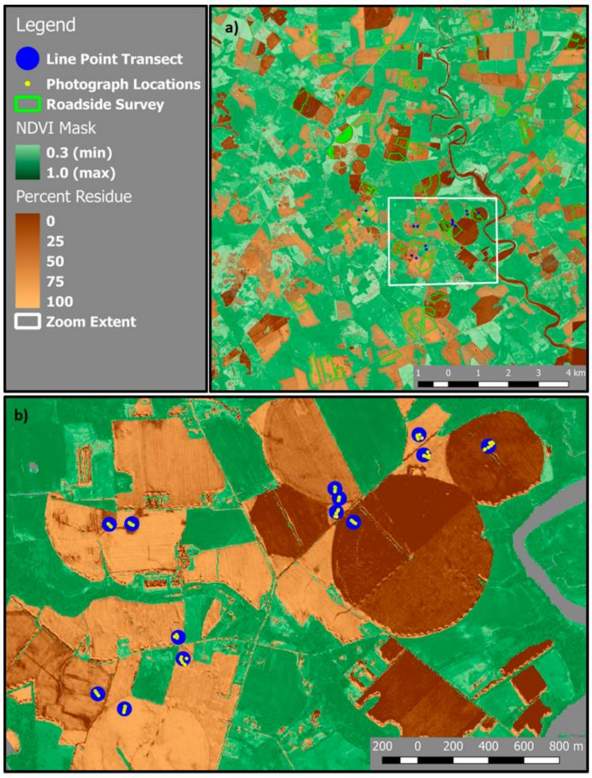
Individual farm level

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	After generating the vegetation indices, linear interpolation will be used to fill in the gaps in the time series of vegetation indices. Afterwards, a temporal smoothing algorithm is employed to average matched images that fall within a predetermined time window. Then LSP metrics will be calculated based on the concept and methodology behind the Timesat software which has been used widely for phenological analysis and was applied to the generation of European high-resolution vegetation phenology and productivity data for Copernicus (HR-VPP).
Input data sources	Optical: Sentinel-2, VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: Sentinel-1 Supporting data: Crop phenology observations
Accessibility	Sentinel-1&2: freely and publicly available from ESA. Optical VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel-2: 10 m Optical VHR: ≤ 1 m Sentinel-1: 20 m
Frequency (Temporal resolution)	Sentinel-2: 6 days Optical VHR: Sub-daily to Daily Sentinel-1: 6 days
Latency	< 1 Day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ The lack of local in-situ data ▪ Cloud presence ▪ The limited temporal resolution can make it challenging to capture specific phenological changes or detect short-duration crops accurately. ▪ Capture complex phenological events. ▪ May not directly capture the underlying physiological processes driving phenological stages, limiting the understanding of crop responses to environmental stressors.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Tillage and Crop Residue Cover Practices



Map of calculated percent residue cover on non-vegetated fields within (a) the WorldView-3 (WV3) shortwave infrared (SWIR) imagery extent and (b) the extent of on-farm sampling. Green shading represents levels of vegetation measured by the Normalized Difference Vegetation Index (NDVI), and tan shading represents mapped levels of crop residue on non-vegetated fields. Legend identifies line-point transect locations (blue dots), photo sampling locations (yellow points), and roadside survey boundaries (green polygons). (Source: Hively, W.D., Lamb, B.T., Daughtry, C.S., Shermeyer, J., McCarty, G.W. and Quemada, M., 2018. Mapping crop residue and tillage intensity using WorldView-3 satellite shortwave infrared residue indices. Remote Sensing, 10(10), p.1657.)

Product Category

■ Land Use ☐ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion

☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

■ Investment management ☐ Risk analysis ■ Insurance management ☐ Green finance

User requirements

UN18: Need to monitor crop productivity.

Description

An EO product designed for monitoring tillage and crop residue cover practices involves the use of remote sensing technology to assess the extent and intensity of tillage operations, as well as the amount of crop residue left on agricultural fields. This product provides valuable insights into sustainable farming practices and their relation to crop productivity. Tracking tillage and residue cover, enables farmers and agricultural policymakers to optimize land management strategies, reducing soil erosion and conserving moisture. The maintenance of crop residues on fields can improve soil health, reduce weed growth, and enhance nutrient retention, ultimately promoting higher crop yields and increased agricultural sustainability.

Spatial Coverage Target

Individual farm level

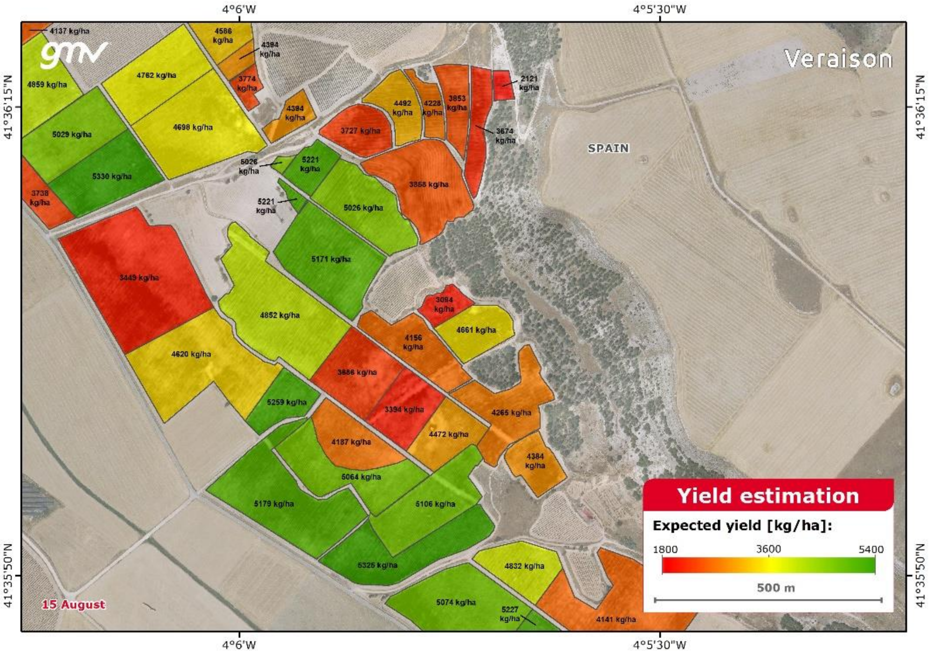
Data Throughput

Rapid tasking ☐ High ■ Low

Data availability ☐ High ■ Low

Product specifications	
Main processing steps	Based on calculating phenology metrics, monitoring activities following the conclusion of the first growing season, such as ploughing and residue management, can be accomplished by utilizing soil, senescence, and tillage indices. Soil indices can help determine if the soil remains fallow or is being actively managed. Additionally, the use of senescence and tillage indices allows for distinguishing between different levels of intensity in ploughing and residue management scenarios. To achieve this, it is essential to have sampling points with known tillage practices and residue management to train and validate the modelling process.
Input data sources	Optical: Sentinel-2, VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: Sentinel-1 Supporting data: Crop phenology observations, ground truth tillage and crop residue practices
Accessibility	Sentinel-1&2: freely and publicly available from ESA. Optical VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel-2: 10 m Optical VHR: ≤ 1 m Sentinel-1: 20 m
Frequency (Temporal resolution)	Sentinel-2: 6 days Optical VHR: Sub-daily to Daily Sentinel-1: 6 days
Latency	< 1 Day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ The lack of local in-situ data ■ Cloud presence ■ The effectiveness of the product can be affected by environmental conditions such as heavy rain, snow cover, or flooding, which can obscure the view of the land surface or modify tillage and residue patterns. ■ Different crops and crop varieties may have varying residue cover practices, making it challenging to establish a one-size-fits-all monitoring system.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Green Biomass and Yield estimation



Yield estimation map in Spain using Sentinel-2 (Source: GMV).

Product Category

■ Land Use ☐ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion
☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

■ Investment management ■ Risk analysis ■ Insurance management ■ Green finance

User requirements

UN9: Understanding stock levels and monitoring supply chains.
UN18: Need to monitor crop productivity.
UN29: Need to accurately measure the planted area for crops.
UN38: Need for trustworthy time series of reliable data on assets.

Description

Green biomass is a crucial parameter for various applications and a key input for yield estimation. Multiple methods exist to calculate green biomass using satellite imagery. One approach relies on LSP metrics, which discussed briefly earlier. Green biomass is determined at the peak and end of the season using the Leaf Area Index (LAI) rather than NDVI due to LAI's correlation with the leaf's life stage. Yield estimation is a complex indicator and can be achieved using machine learning algorithms that are trained with EO data (such as vegetation indices like FAPAR), climate data (temperature and precipitation), crop type and acreage maps, LSP metrics, biomass, and ground truth yield samples. By integrating these data sources, accurate yield predictions can be obtained, aiding in effective agricultural planning and management.

Spatial Coverage Target

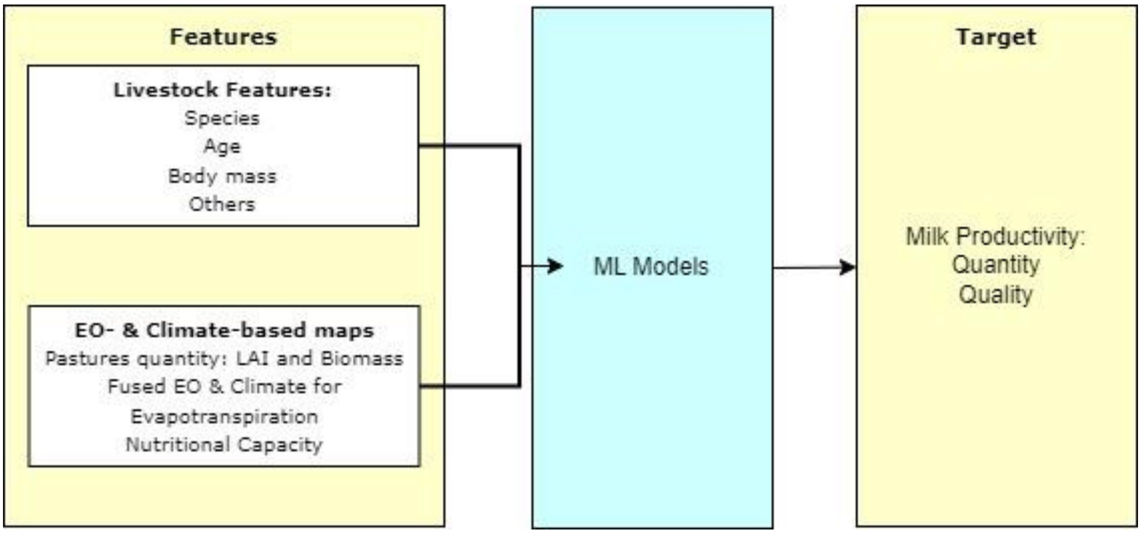
Individual farm level

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	Green biomass can be computed using optical and/or SAR imagery through various algorithms, which may involve the use of vegetation and soil indicators. Alternatively, commercially available products like Planet Biomass Proxy can be utilized to estimate green biomass. Subsequently, the green biomass data is combined with other EO data, such as vegetation indices like FAPAR, climate data (temperature and precipitation), crop type and acreage maps, LSP metrics, and ground truth yield samples. These combined datasets are then used to train machine learning models for accurate yield estimation.
Input data sources	Optical: Sentinel-2, VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: Sentinel-1 Reanalysis products: ERA5 land Supporting data: crop type and acreage maps, LSP metrics, and ground truth yield samples.
Accessibility	Sentinel-1&2: freely and publicly available from ESA. Optical VHR imagery: commercially available on demand from EO service providers. ERA5 land: freely and publicly available from ECMWF
Spatial resolution	Sentinel-2: 10 m Optical VHR: ≤ 1 m Sentinel-1: 20 m ERA5 land: 0.1°
Frequency (Temporal resolution)	Sentinel-2: 6 days Optical VHR: Sub-daily to Daily Sentinel-1: 6 days ERA5 land: Hourly
Latency	< 1 Day
Geographical scale coverage	Globally
Delivery / output format	Data type: Raster File format: GeoTIFF. NetCDF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ The lack of local in-situ data ▪ Cloud presence ▪ The accuracy of Biomass and Yield estimation relies on the accuracies of their inputs like crop type and acreage maps, LSP metrics, and climate data. ▪ Machine learning model uncertainty
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential
Similar Products	**Planet Biomass Proxy** (link) Spatial resolution: 10 m Frequency (Temporal resolution): Daily Latency: 1 Day Geographical scale coverage: Globally with gaps over some major agricultural areas of the world, due to the discontinuity of Sentinel-1B in December 2021 Delivery / output format: GeoTIFF, NetCDF (Raster), CSV (Time series) Accuracies: 80-90% Accessibility: Commercially available from Planet

Milk and Cattle (in weight) Productivity Estimation



Machine learning model to predict milk productivity based on EO data

Product Category

■ Land Use ☐ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion
☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

■ **Investment management** ☐ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN9: Understanding stock levels and monitoring supply chains

Description

Milk and cattle (in weight) productivity have a very strong correlation with multiple factors including pasture quantity and climate data. EO can provide continuous spatial and temporal climatic data such as precipitation, temperature, wind, and evapotranspiration. Also, vegetation indices and biophysical variables derived from satellite data can be used as indicators for pasture quantity. Using machine learning algorithms, EO data can be correlated with historical milk and cattle productivity. Subsequently, these models can be used to predict and estimate productivity using EO data as predictors.

Spatial Coverage Target

Individual farm level

Data Throughput

Rapid tasking ☐ High ■ Low
Data availability ■ High ☐ Low

Product specifications	
Main processing steps	Climate data such as precipitation, temperature, wind speed and direction, pressure, and humidity can be derived from ERA5-land. Potential evapotranspiration can be calculated from data obtained from ERA5-land. Vegetation indices (such as NDVI, REPO, NDMI, NDCI, and PSRI), biophysical variables (such as LAI), and albedo can be derived from Sentinel-2 or Sentinel-3 based on the application. Green biomass data can be derived from LAI and phenology stages as described previously. By using feature selection algorithms, we can identify and select the most correlated features to milk and cattle productivity to be used as inputs to different machine learning models. After training and validation of different models, we can choose the models with the best

Product specifications	
	performance to estimate and predict milk and cattle productivity based on input EO data.
Input data sources	Optical: Sentinel-2&3 Radar: N.A Reanalysis products: ERA5-land Supporting data: Historical milk and cattle (in weight) productivity
Accessibility	Sentinel-2&3: freely and publicly available from ESA. ERA5-land: freely and publicly available from EMCWF.
Spatial resolution	Sentinel-2: 10 m Sentinel-3: 300 m ERA5-land: 0.1°
Frequency (Temporal resolution)	Sentinel-2: 6 days Sentinel-3: Daily ERA5-land: Daily
Latency	Daily
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: N.A Spatial accuracy: N.A
Constraints and limitations	▪ Cloud presence ▪ Low spatial resolution of ERA5-land ▪ Lack of historical milk and cattle (in weight) productivity data ▪ Creating universally applicable methods are challenging due to the variation of livestock and climate conditions.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Monitoring Reforestation and Deforestation Activities

Comparison of Pléiades imagery of 0.5-meter of a forest restoration site in 2018 and 2020 (Source: blog.explorer.land).

Product Category

■ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ■ **Green finance**

User requirements

UN27: Need to assess historical trends and baseline of natural assets.
UN28: Need to classify the types of crops being grown in order to assess the sustainability and environmental impact of agricultural investments.
UN30: Need for monitoring with accurate measurements of the growth and health of trees.
UN39: Need to assess the potential impact of business activities or investments on ecosystems and biodiversity.

Description

Earth Observation helps establish baseline data by providing detailed information about the current state of forests and land cover. It enables the identification of areas suitable for reforestation and helps estimate the extent of deforestation or degradation that has taken place. Optical and SAR sensors allow for the continuous monitoring of reforestation efforts. It enables the assessment of tree planting activities, including the extent, density, and spatial distribution of newly planted trees. Satellite imagery can be used to estimate tree survival rates, monitor the growth and health of planted trees, and track changes in vegetation cover over time. Also, earth observation helps in detecting and monitoring instances of deforestation or illegal logging within reforested areas. Satellite imagery can identify changes in land cover and detect signs of forest clearance or encroachment. Early detection of deforestation enables prompt action to protect reforested areas and implement mitigation measures.

Spatial Coverage Target

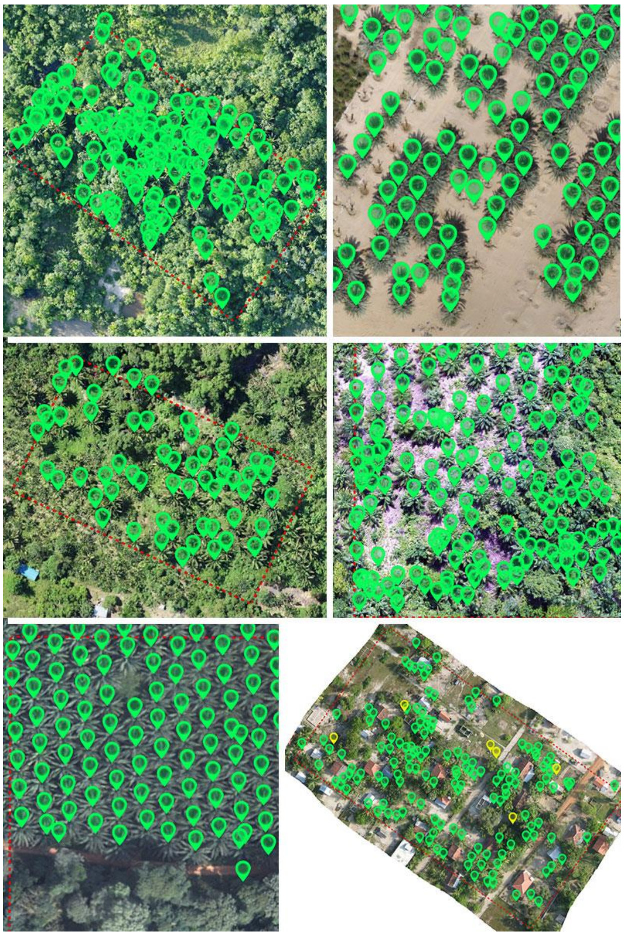
Forests

Data Throughput

Rapid tasking	☐	High	■	Low
Data availability	■	High	☐	Low

Product specifications	
Main processing steps	Medium resolution or VHR optical/SAR satellite imagery can be used to monitor reforestation and deforestation activities. The selection of the appropriate resolution is based on different factors such as area to monitor, cost, and level of accuracy required. The procedure commences with determining the study's timeframe, followed by the selection of base line data serving as a reference for detecting reforestation or deforestation activities. Forest areas within the images can be identified by either land cover data or employing vegetation indices. By comparing each image within the designated timeframe with the reference image using change detection techniques, regions attributed to reforestation or deforestation activities can be distinguished. Moreover, incorporating supplementary data such as tree height, diameter at breast height, and species types can provide further understanding of the implications of deforestation actions.
Input data sources	Optical: Sentinel-2, VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: Sentinel-1, VHR images from different sources like ICEYE, Capella space, Umbra, and TerraSAR-X Supporting data: land cover data, in-situ data like height, diameter at breast height, species types
Accessibility	Sentinel-1&2: freely and publicly available from ESA. VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel-2: 10 m Optical VHR: ≤ 1 m Sentinel-1: 10 m SAR VHR: ≤ 3 m
Frequency (Temporal resolution)	Sentinel-2:6 days Optical VHR: Daily Sentinel-1:6 days SAR VHR: Daily
Latency	≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Cloud presence ▪ By using medium resolution imagery for large forests, distinguishing reforestation, or deforestation activities from other land uses, such as agriculture or natural disturbances, can be challenging due to similar visual characteristics. ▪ The accuracy of land cover data used for classification can impact the precision of change detection results. ▪ Availability of historical satellite imagery may be limited. ▪ Changes in vegetation cover due to natural seasonal cycles can impact the accuracy of change detection, potentially leading to false positives or negatives.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Trees Counting



Palm trees counting over different countries (Ghana, Indonesia, Papua, Sri Lanka, and Brazil) (Source: https://feds.ae/saving-time-and-effort-training-an-ai-to-count-palm-trees/)

Product Category

■ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

☐ **Investment management** ☐ **Risk analysis** ☐ **Insurance management** ■ **Green finance**

User requirements

User requirements

UN31: Need to link tree planting parcels to estimate the number of trees planted

Description

Tree counting require VHR satellite imagery to accurately and efficiently determine the number of trees within a specified area. This approach offers significant advantages over traditional ground-based methods, as it enables rapid, cost-effective, and large-scale tree counting without the need for time-consuming field surveys. This data, coupled with the ability to monitor changes over time, aids in assessing the value of forestry assets, estimating timber volume for investment or insurance purposes, and evaluating the environmental impact of forestry investments.

Spatial coverage target

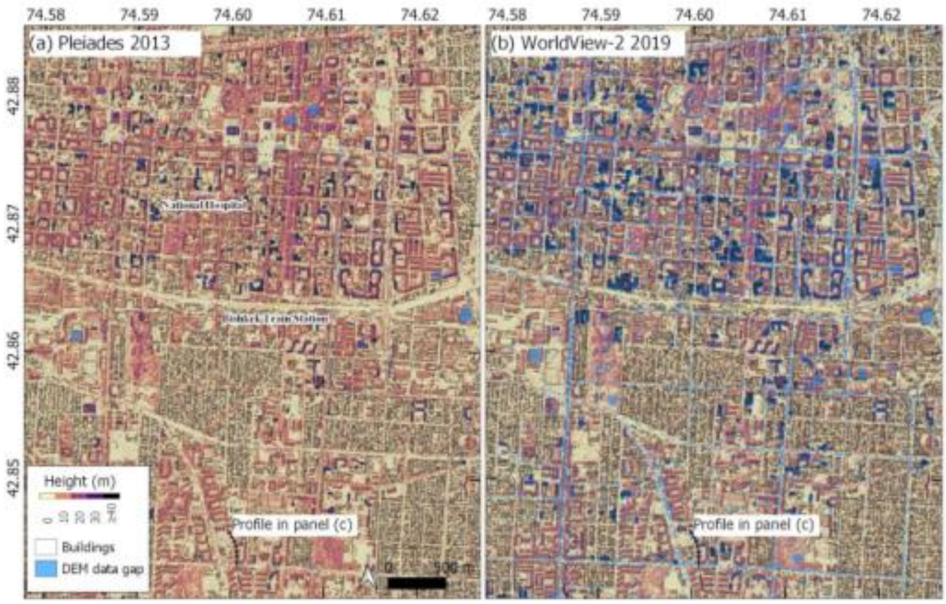
Asset level

Data throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	The process starts by inspecting optical VHR imagery (≤ 0.5 m) to identify a sample of individual trees to build a training dataset for a deep learning model. Then a deep learning model to be trained in optimoum way to detect the individual tree and, subsequently, identify the number of trees.
Input data sources	Optical: VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: N.A Supporting data: N.A
Accessibility	Optical VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Optical VHR: ≤ 0.5 m
Frequency (Temporal resolution)	Optical VHR: Sub-daily to Daily
Latency	< 1 Day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 70-80% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ Cloud presence ■ Cost of VHR imagery ■ Lack of training data ■ Global inconsistency due to the diversity of tree species. ■ Limitations in homogeneous forests where the trees are connected.
Level of skills required by users to use the EO service	Skills: Essential Knowledge: Essential

Building Inventory



Example hillshaded DSMs for Pleiades (a) and WorldView-2 (b) over central Bishkek, Kyrgyzstan (Source: Watson, C.S., Elliott, J.R., Amey, R.M. and Abdrakhmatov, K.E., 2022. Analyzing Satellite-Derived 3D Building Inventories and Quantifying Urban Growth towards Active Faults: A Case Study of Bishkek, Kyrgyzstan. Remote Sensing, 14(22), p.5790.).

Product Category

■ Land Use ☐ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion
☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN47: Need up-to-date geospatial data on residential and industrial infrastructures' locations

Description

Detecting structures and associated details like their heights can provide insights into urban population density and enable the tracking of construction activities. Such data is valuable for formulating investment strategies and overseeing construction advancements, facilitating both investment planning and project monitoring. Due to the progress in sophisticated deep learning methods, it is now possible to identify buildings from VHR optical satellite pictures. Additionally, stereo and tri-stereo satellite visuals can be employed to gauge building heights through the creation of digital surface and terrain models (DSM and DTM). These techniques can be utilised to generate various maps about building footprint, building count, building area, building density, and even an approximate count of stories and floor area. These insights are instrumental in deducing details about the density of the population.

Spatial Coverage Target

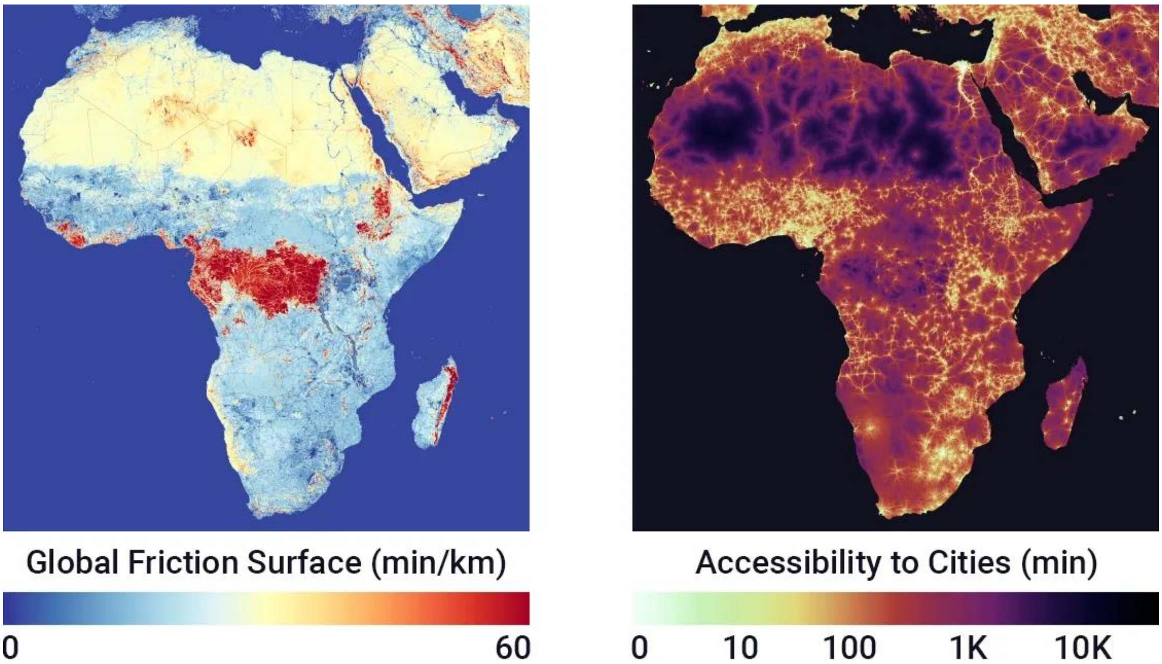
Building Level

Data Throughput

Rapid tasking ☐ High ■ Low
Data availability ☐ High ■ Low

Product specifications	
Main processing steps	Built-up areas can be identified using high-resolution land cover data such as the world settlement footprint (WSF) (10 m resolution). Alternatively, we can classify cloud-free Sentinel-2 images into Corine 2018 land-cover classes using a pre-trained U-net deep learning. Subsequently, VHR stereo images (such as Worldview-2&3) and tri-stereo images (such as Pleiades) can be orthorectified and pansharpened, then fed to a deep learning based semantic segmentation model for building extraction, by using available building datasets. The stereo and tri stereo image would also be used to derive point cloud and DSM using software such as Agisoft Metashape. All DSMs should be coregistered to TanDEM-X DSM. In addition, DTM which represents the surface features after the removal of vegetation and building can be generated using LAStools. By clipping the DSMs and DTMs to the building footprint, building heights can be calculated by subtracting DTMs from DSMs.
Input data sources	Optical: VHR stereo and tri-stereo images from commercial sources such as Worldview-2&3 and Pleiades, Sentinel-2 (for built-up regions identifying) Radar: N.A Supporting data: high resolution land cover data such as WSF, building detection training datasets for deep learning models
Accessibility	Sentinel-2: freely and publicly available from ESA. Stereo and tri-stereo VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Optical VHR: <1m Sentinel-2: 10m
Frequency (Temporal resolution)	Optical VHR: Daily Sentinel-2: 6 days
Latency	≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 60-70% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ Cloud presence ■ Urban areas across the world can have different building styles, densities, and layouts, which can make creating universally applicable methods challenging. ■ Tall buildings or structures can cast shadows making it challenging to accurately identify their characteristics, and occlusion might hinder the detection of buildings behind vegetation or other structures. ■ Estimating precise building heights from satellite imagery can be complex due to variations in terrain, building shapes, and local conditions. ■ Cost of VHR images ■ Using satellite imagery for building inventory might raise legal and privacy concerns, especially when dealing with sensitive areas or personal property.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Ample Knowledge: Ample

Mapping Travel Times to Assets



Example of friction surface (left) and accessibility to cities represented in how many minutes needed to access the nearest city (right) (Source: MAP (university of Oxford))

Product Category

■ Land Use ☐ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion
☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

■ **Investment management** ☐ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN11: Realistic assessment of accessibility to assets

Description

Global Friction Surface is a map produced through a collaboration between the Malaria Atlas Project (MAP) (University of Oxford), Telethon Kids Institute (Perth, Australia), Google, and the University of Twente, Netherlands. Friction surface is a map relative measures how "hard" it is to cross a grid cell, based on whether the cell contains good roads, worse roads, railroads, rivers, various water bodies, or terrain with some slope. These maps quantify the time required to traverse each pixel within a ~1 km × 1 km gridded representation of the Earth's surface. Using this map, we can generate travel times maps from any place to another. The importance of these comes come from that places a longer distance away may take less time to reach physically closer places.

Spatial coverage target

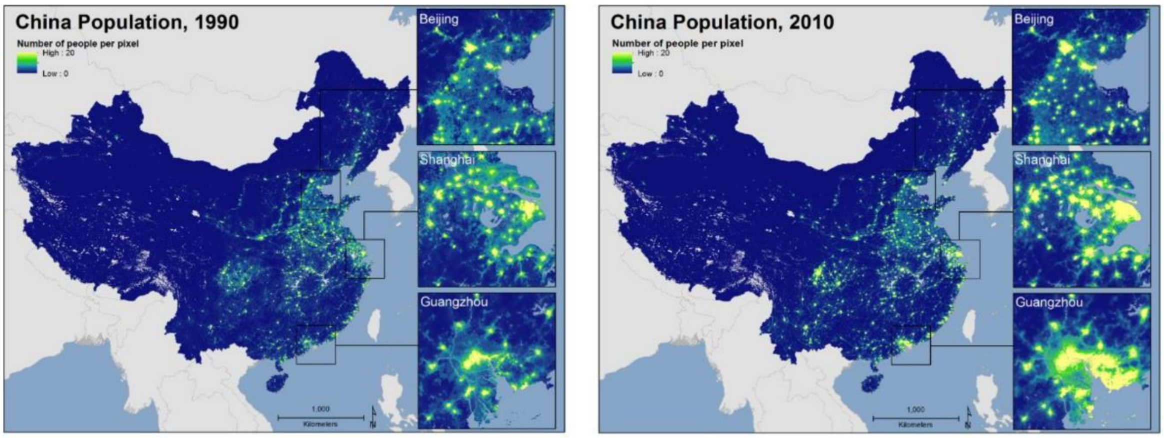
Asset Level

Data throughput

Rapid tasking ☐ High ■ Low
Data availability ☐ High ■ Low

Product specifications	
Main processing steps	The process starts by clipping the Global Friction Surface 2019 to the surrounding area of the asset. Knowing that each pixel (~ 1 km x 1km) of these maps represents a value of a time in minutes needed to cross one meter of that pixel walking only and using motorized means. Using these maps by identifying a line representing the way to the asset, it is possible to calculate the travel time by accumulating the pixels' values of the friction surface map. The way from a pixel to the asset can be the nearest distance (using algorithms) or any way identified by the asset's owner.
Input data sources	Optical: Land cover data derived from optical sensors Radar: N.A Grid-based data: Global Friction Surface 2019 Supporting data: DEM, road input layer consisted of vector data extracted from the OSM database, road data from the Google distance to roads surface, and the Global Human Settlement (GHS)
Accessibility	Freely and publicly available through MAP (university of Oxford)
Spatial resolution	~ 1 km
Frequency (Temporal resolution)	Annually only for 2019
Latency	N.A
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: N.A
Constraints and limitations	▪ The relatively coarse spatial resolution (~ 1 km) ▪ It is static and may not account for dynamic factors like traffic congestion, seasonal changes, or road closures, which can impact travel times. ▪ It represents the travel time of using motorized means without considering the type of vehicle.
Level of skills required by users to use the EO service	Skills: Essential Knowledge: Essential

WorldPop – Population Counts



WorldPop population change mapping for China, showing predicted population density for each 100m x 100m grid square for (left) 1990 and (right) 2010 (Source: WorldPop)

Product Category

■ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

■ **Investment management** ☐ **Risk analysis** ■ **Insurance management** ☐ **Green finance**

User requirements

UN10: Need to understand population density when making investment decisions
UN57: Automatically update changes in population density estimates based on observable land use changes

Description

Investment managers must consider population density at a localized level when formulating investment strategies. Analysing population density within smaller geographical areas provides valuable insights into consumer demand, market opportunities, and growth prospects for particular regions or sectors. This data aids in evaluating the feasibility and potential profitability of their investment choices. Conventional data sources for population density are often outdated and lack the granularity required for precise targeted interventions. Moreover, continuously tracking populations can pose difficulties, especially in low- and middle-income nations facing resource constraints, conflict, or dealing with terrain landscapes. WorldPop, a project based on the University of Southampton, and dedicated to mapping global populations. It complements conventional population data sources by incorporating dynamic data spanning from 2000 to 2020, with a high spatial resolution of 100 meters, to map the distribution of human populations. The overarching objective is to guarantee that every individual, regardless of their location, is included in the decision-making process. One important layer of these is the confidence level which gives information about the error interval associated with each grid cell.

Spatial coverage target

Districts within a city

Data throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	WorldPop generates high resolution global population density maps by using machine learning algorithms to correlate available census surveys for certain years with many other sources of data including geospatial data. The idea is to generate population grid maps which are continuous in time and space. The geospatial data used to generate these maps is categorised into raster and vector data. The raster data includes EO data such as elevation, slope, vegetation types, accessibility to major cities, land use and land cover maps, nighttime light, temperature, and precipitation data. The population maps are generated using two different techniques called bottom-up and top-down, each of these techniques has advantages and disadvantages and the investment manager can choose any of them based on their needs. For more information about these techniques and how the maps are generated, you can open this link https://www.worldpop.org/methods/populations/. In addition to the EO data, the population maps are generated using geospatial data like Open Street Map (OSM) to calculate the distance to important features such as roads water bodies, hospitals, etc.
Input data sources	Optical: land use and land cover maps, vegetation types, temperature and precipitation maps. Radar: Elevation, Slope Supporting data: Census data, settlement data, OSM
Accessibility	Optical and SAR VHR imagery: commercially available on WorldPop – population count is publicly and freely available through the University of Southampton.
Spatial resolution	100 m & 1 km
Frequency (Temporal resolution)	Annual
Latency	N.A
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: varies by the region. Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ WorldPop data is available at a relatively high spatial resolution (often 100 meters) and is dynamic from 2000 to 2020. However, for some applications, even higher resolution and more recent data may be required. ▪ The accuracy of population estimates relies on multiple factors, including the quality of input data, the assumptions made in modelling, and validation against ground truth data. Errors can occur, especially in areas with limited ground data for validation. ▪ There can be a lag between the actual population changes and the availability of updated WorldPop data, as it is not real-time information. However, this can be overcome by calculating the maps by an EO provider with the same methodology as WorldPop.
Level of skills required by users to use the EO service	Skills: Essential Knowledge: Essential

Monitoring Solar Panel Installations

Ground truth for solar panels bounding boxes (Left) and prediction using deep learning-based object detection model (Right) using Worldview-3 images (0.3 m)over southern Germany (Source: Maxar).

Product Category

■ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN37: Projection of risk to portfolio assets into the future

Description

VHR satellite imagery can assess the condition of solar panels, detect anomalies or defects, and evaluate the overall energy generation of the installation. By comparing historical data, it becomes possible to identify changes in performance over time and address maintenance or operational issues promptly. In addition, satellite imagery can be used to evaluate land use changes that affect the performance of solar panels such as shadows from tall buildings and vegetation cover.

Spatial Coverage Target

Asset level

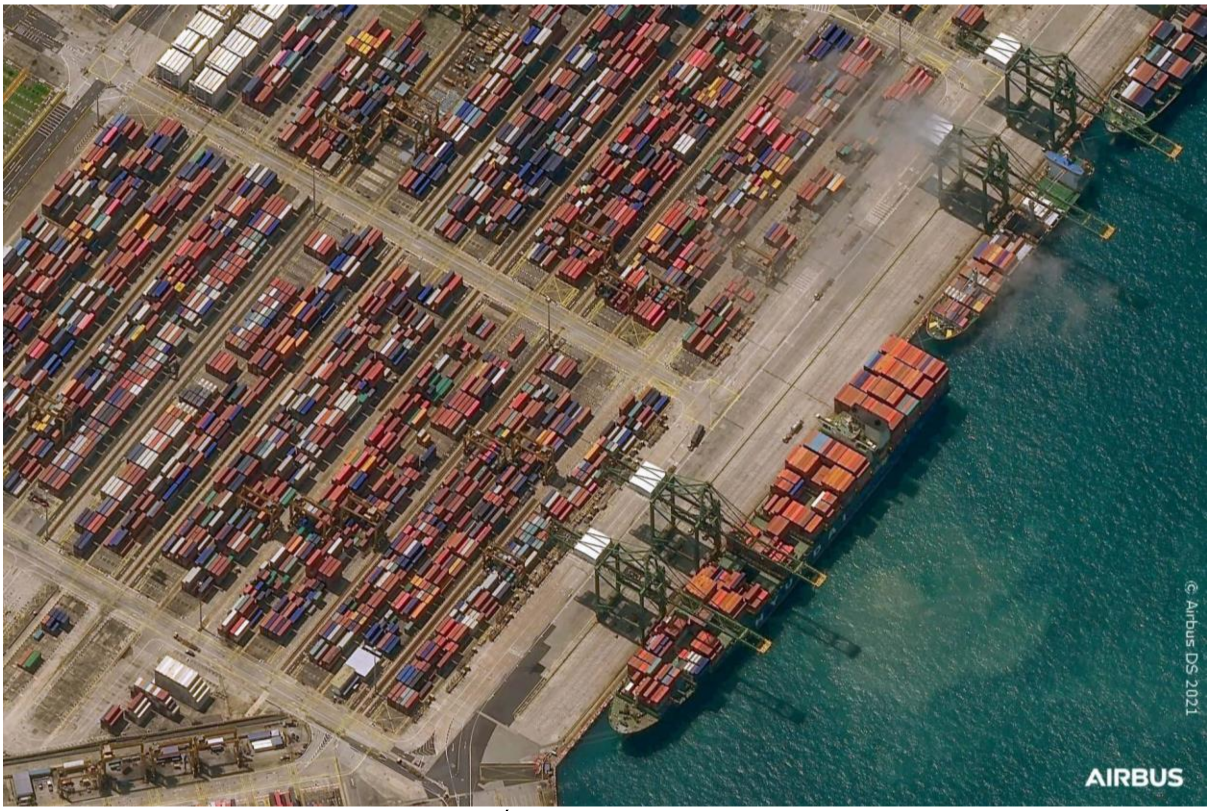
Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	After the acquisition and preprocessing of the optical VHR (< 0.5 m), deep learning-based object detection algorithms such as YOLO can be used to detect solar panels. First, the dataset of the VHR images would be divided into training, validation, and test datasets. Training and validation will be used to train and optimize the deep learning model, which would be used then for inference to detect solar panels in the test data (our interest). Subsequently, temporal image pairing and image registration would be applied to analyse changes in the solar panels. Then, change detection techniques should be applied to the detected solar panels to identify changes over time. In terms of monitoring vegetation cover over the solar panels, vegetation indices can be used with change detection techniques.
Input data sources	Optical: VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: N.A Supporting data: Solar panel datasets for deep learning models (if any)

Product specifications	
Accessibility	VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Optical VHR: ≤ 0.5 m
Frequency (Temporal resolution)	Optical VHR: Daily
Latency	Daily
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Cloud presence. ▪ The availability and size of solar panels dataset to train the deep learning model. ▪ Cost as balancing higher spatial resolution (to detect small panels) with broader coverage (to monitor larger installations) can be challenging due to cost constraints. ▪ The exact timing of solar panel installations might be a challenge due to cost constraints. ▪ Panels integrated into complex rooftop configurations can be harder to identify due to varying angles and orientations.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Monitoring Changes in Port Activity Patterns



VHR image of Pléiades Neo (0.3m) (Source: Airbus)

Product Category

■ Land Use ☐ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion
☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

■ **Investment management** ☐ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN9: Understanding stock levels and monitoring supply chains.

Description

The EO data enables the financial management sector to regularly track changes in port activity patterns including cargo volumes, vessel traffic, and infrastructure development. By analysing these changes, financial managers can make informed investment decisions, assess the financial health of companies engaged in port operations, and identify emerging market trends.

Spatial Coverage Target

Ports

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	■ High	☐ Low

Product specifications	
Main processing steps	Monitoring changes in port activities over time is applicable by using VHR images with suitable temporal frequency. Then we can perform change detection analysis on the acquired satellite images to identify and quantify changes in the port's infrastructure, cargo volume, vessel traffic, and other relevant parameters. This analysis involves comparing two or more images taken at different times and highlighting the differences between them. The change detection analysis becomes more informative when we possess labelled data of the port. In addition to conventional change detection techniques, automated change detection methods using machine learning algorithms can be advantageous in this context.
Input data sources	Optical: VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: N.A Satellite-based products: N.A Supporting data: AIS
Accessibility	Optical VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Optical VHR: ≤ 0.5 m
Frequency (Temporal resolution)	Optical VHR: Sub-daily to Daily
Latency	< 1 Day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ Cloud presence near large water bodies ■ Limited available labelled data of port activities. ■ Temporal resolution and Cloud presence of the satellite data can limit the frequency of monitoring and timely detection of rapid changes in port activities. ■ Discerning fine-scale details of port activities. ■ Access to high-quality EO data, especially from commercial satellite providers, can be costly. ■ Limited nighttime observations
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Stock Changes in Oil Tanks with Floating Roof

(Left) Oil tanks with floating roof (Right) Floating oil tank roofs in the Port of Rotterdam, Netherlands using ICEYE's Daily Coherent Ground Track Repeat (GTR) imagery (0.5 m) (Source: ICEYE).

Product Category

■ Land Use ☐ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion
☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

■ **Investment management** ☐ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN9: Understanding stock levels and monitoring supply chains.

Description

The condition of crude oil reserves holds significant significance for the oil market and is a vital determinant in worldwide economic progress. Oil inventory reflects the balance between market supply and demand, directly impacting pricing Therefore, regular, and precise updates regarding the levels of reserves are of utmost importance. High frequent SAR VHR imagery (daily) can be utilized for daily assessments of oil production. SAR imagery is preferable as it provides a continuous time series regardless of weather conditions, day, and night. However, remote sensing sensors cannot penetrate walls and roofs. Therefore, they are only capable of measuring the volume of oil in storage tanks that are above ground and equipped with an external floating roof. The roof sits on the oil and goes up and down as the oil level changes in the tanks. This helps to make less space above the oil and reduce the vapour in that space. By measuring how tall and wide the floating tanks are, along with some other tank measurements, we can accurately figure out how much oil they can hold.

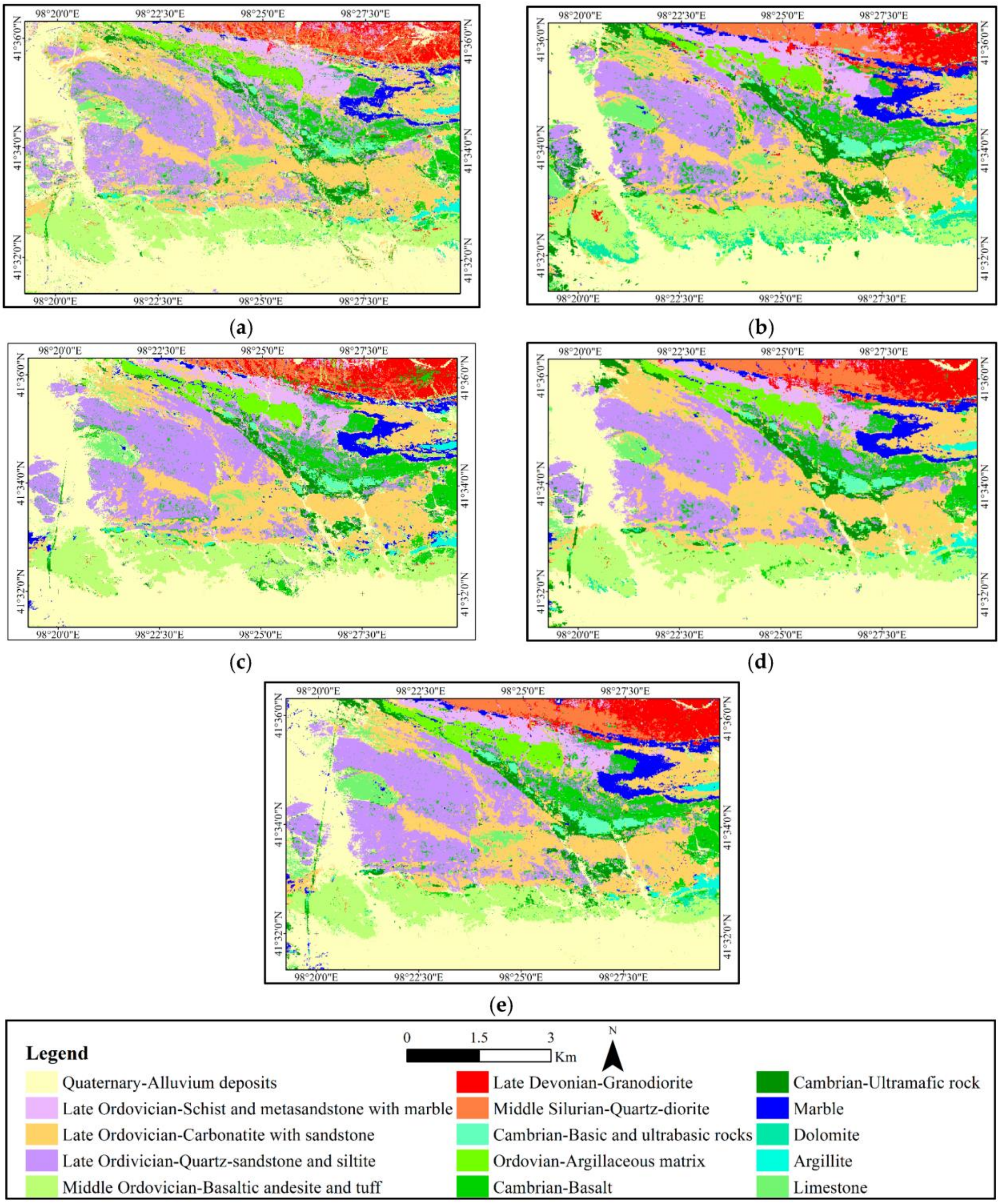
Spatial Coverage Target

Oil storage tanks with floating roof

Data Throughput

Rapid tasking	■ High	☐ Low
Data availability	■ High	☐ Low

Product specifications	
Main processing steps	By using a time series of daily or weekly VHR SAR imagery for the same region, it becomes feasible to detect the change that is occurring in an object (floating roof oil tanks). Objects that haven't changed while being observed will appear identical every day. Objects that have undergone changes can be recognized and studied. With the VHR imagery, the change in height and area can be calculated enabling the volume of oil on a daily or weekly basis.
Input data sources	Optical: N.A Radar: VHR images from different sources like ICEYE and Capella space Supporting data: N.A
Accessibility	SAR VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	SAR VHR: ≤ 0.5 m
Frequency (Temporal resolution)	SAR VHR: sub-daily to daily
Latency	≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Cost of time series of VHR images ▪ While VHR imagery provides detailed views, there might still be limitations in identifying very small details
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Ample Knowledge: Ample



Lithological classification in the Shibanjing Ophiolite Complex in Inner Mongolia, China using Sentinel-2 and DEM using machine learning methods. (a) k-nearest neighbour (k-NN); (b) random forest classifier (RFC); (c) artificial neural network (ANN); (d) support vector machine (SVM); (e) maximum likelihood classification (MLC) (Source: Ge, W., Cheng, Q., Tang, Y., Jing, L. and Gao, C., 2018. Lithological classification using Sentinel-2A data in the Shibanjing ophiolite complex in Inner Mongolia, China. Remote Sensing, 10(4), p.638.).

Product Category			
■ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

■ **Investment management** ☐ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN9: Understanding stock levels and monitoring supply chains.

Description

This product provides a spatial characterization of surface rock and soil types based on satellite imagery. These maps can be used by mining exploration companies to know the mineral composition of the area they are exploring. Litho-types can be distinguished based on their spectral signatures, as well as their associations with topographical and geomorphological features, in particular surface texture (roughness) and patterns (including drainage patterns).

Spatial coverage target

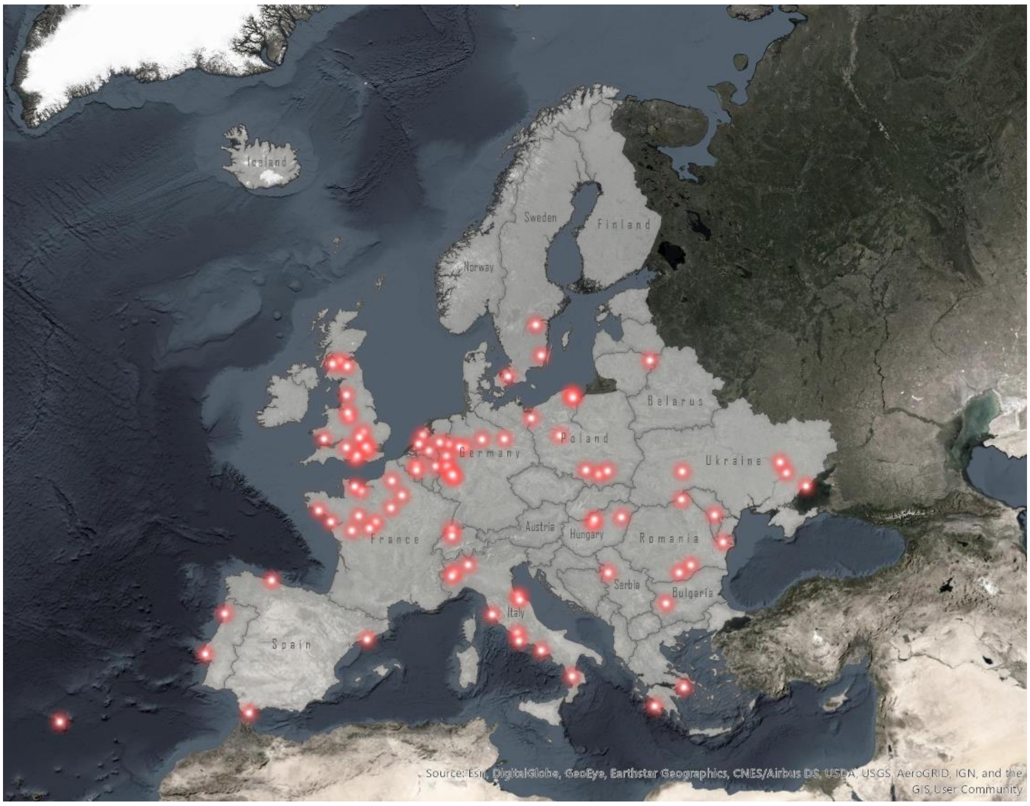
Mining area

Data throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	Lithology and surficial geology maps are produced based on supervised classification techniques. These maps are produced by applying supervised classification algorithms (e.g., machine learning based algorithms) using data from multispectral imagery like Sentinel-2 and other ancillary EO data like DEM. These models should be trained by using reference maps which were generated by in-field surveys.
Input data sources	Optical: Sentinel-2 Radar: N.A Supporting data: DEM
Accessibility	Sentinel-2: is freely and publicly available through ESA.
Spatial resolution	Sentinel-2: 10 m
Frequency (Temporal resolution)	Sentinel-2: ~ 6 days
Latency	Sentinel-2: ≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTiff
Accuracies	Thematic accuracy: 75-85% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ Mapping lithology is most effective in arid and semi-arid regions. ■ It becomes more difficult and less accurate in temperate and tropical areas where weathering is extensive, and dense vegetation cover is prevalent. ■ Cloud presence. ■ Rely on reference data.
Level of skills required by users to use the EO service	Skills: Essential Knowledge: Essential

Predicting Terrorism Hotspots



Map illustrates the regions thatthe ML model has predicted at-risk in Europe based on previous terrorism attacks (1970-2018). (Source: Buffa, C.M., 2021. Predicting Terrorism in Europe with Remote Sensing, Machine Learning, and Spatial Statistics (Doctoral dissertation, Saint Louis University).).

Product Category

■ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

■ Investment management ■ Risk analysis ☐ Insurance management ☐ Green finance

User requirements

UN12: Analysis of potential risks in specific regions
UN37: Projection of risk to portfolio assets into the future

Description

Terrorism poses significant risks to economies and financial systems. Identifying terrorist hotspots allows financial institutions to assess the potential impact of terrorism-related disruptions on their investments, portfolios, and operations. Using satellite imagery, socio-economic data and historical terroristic activity with machine learning models, we can predict terroristic hotspots from spatial and geographical perspectives. Remote sensing data such as DEM, land cover, and nighttime lights can be used as predictors with open-source socio-economic data including civil unrest data, socio-political interactions, and population features such as distance to major waterways, inland water, major road intersections, roadways, the population counts, population densities, built settlement growth, and demographics.

Spatial coverage target

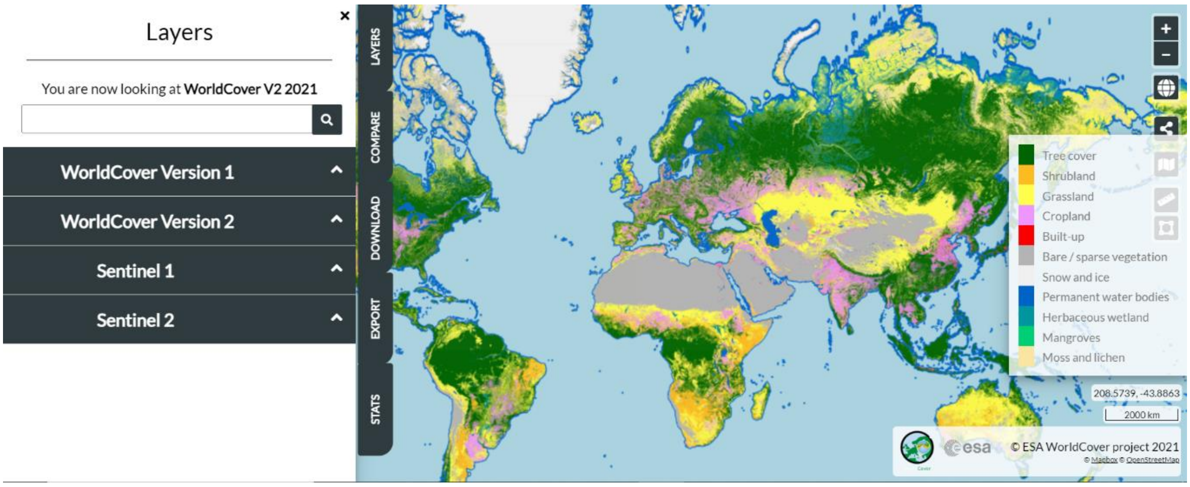
Regional

Data throughput

Rapid tasking	☐ High	■ Low
Data availability	■ High	☐ Low

Product specifications	
Main processing steps	Remote sensing data needs to be sourced from suitable providers. DEMs can be acquired from various sources including Copernicus DEM, ASTER, ACE-2, and others. Land cover information can be obtained from diverse sources like Copernicus land cover datasets. Nighttime light data can be accessed from VIIRS DNB. Past instances of terrorist attacks in the vicinity can be retrieved from the Global Terrorism Database (GTD), while geospatial and population features can be gathered from Worldpop. Civil unrest data can be calculated using the Armed Conflict Location and Event Data set (ACLED), while sociopolitical interactions can be derived from the Integrated Crisis Early Warning System (ICEWS). All of this data should be interpolated to generate raster data in the form of grids. Employing a feature selection algorithm is essential to pinpoint the pertinent factors for predicting the locations of terrorist hotspots. Subsequently, the chosen features will be input into various machine learning models to evaluate their predictive capabilities. The model demonstrating the most optimal performance will be employed for forecasting regions prone to terrorist hotspots.
Input data sources	Optical: VIIRS DNB Radar: N.A Supporting data: DEM, land cover data, GTD, Worldpop, ACLED, ICEWS
Accessibility	VIIRS DNB: are publicly available from NASA.
Spatial resolution	VIIRS: 750 m DMSP OLS: 2700 m
Frequency (Temporal resolution)	VIIRS: Daily
Latency	1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: N.A Spatial accuracy: N.A
Constraints and limitations	▪ The complexity of terrorism which related to plenty and complex factors. ▪ Some of the factors are not directly correlated with terroristic activity which may lead to false predictions. ▪ Cloud presence for nighttime light data.
Level of skills required by users to use the EO service	Skills: Essential Knowledge: Essential

Land Cover Maps



ESA Worldcover V2 global map for 2021 (Source: ESA)

Product Category

☐ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
■ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

■ **Investment management** ■ **Risk analysis** ■ **Insurance management** ■ **Green finance**

User requirements

UN11: Realistic assessment of accessibility to assets.
UN27: Need to assess historical trends and baseline of natural assets.
UN38: Need for trustworthy time series of reliable data on assets.
UN39: Need to assess the potential impact of business activities or investments on ecosystems and biodiversity.
UN40: Need to monitor the risk of sea level rise threatening coastal property, infrastructure, and supply chains.
UN43: Need to monitor changing precipitation patterns and flood risk in the vicinity of vulnerable assets.

Description

Land cover maps are geographical representations that depict the various types of surfaces and features present on the Earth's surface, categorizing them into different categories based on the physical and biological characteristics of the terrain. Common land cover classes include forests, agricultural land, urban areas, water bodies, wetlands, barren land, and more. These maps are typically represented through colour-coded legends or thematic symbols that make it easy to visualize and interpret the distribution of land cover across a specific geographic area.
Land cover change map is a form of LC map and it is derived from a time series of LC maps and identifies the changes between maps. Similar to the LC map, the LC change map is important for many applications.

Spatial coverage target

Asset Level

Data throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	There are many freely available land cover maps with different spatial resolutions, temporal coverages, and number of land cover classes. The highest freely available spatial resolution of land cover is 10 m and is provided by ESA. However, for some applications there might be a need to generate land cover maps at very high resolution, these maps can be generated by supervised machine learning algorithms. These models should be trained using ground truth land cover data.
Input data sources	Optical: Sentinel2, VHR imagery based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7. Radar: Sentinel-1, VHR images from different sources like ICEYE, Capella space, Umbra, and TerraSAR-X. Supporting data: ground truth land cover data.
Accessibility	Sentinel-1&2: freely and publicly available from ESA. VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel-2: 10 m Optical VHR: ≤ 1 m Sentinel-1: 20 m SAR VHR: ≤ 3 m
Frequency (Temporal resolution)	Sentinel-1&2: 6 days Optical and SAR VHR: Daily
Latency	< 1 Day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Lack of ground truth data ▪ Cloud presence ▪ Limited spectral resolution for some optical VHR imagery. ▪ Seasonal variability ▪ Topographic effects ▪ In some cases, pixels may represent a mix of multiple land cover classes
Level of skills required by users to use the EO service	Skills: Essential Knowledge: Essential
Similar Products	Name of the Product: ▪ ESA WorldCover (link) ▪ Copernicus Land cover classification gridded maps from 1992 to present (link) ▪ Corine Land Cover (CLC) (link) Spatial resolution: ▪ ESA WorldCover: 10 m ▪ Copernicus Land cover classification gridded maps from 1992 to present: 300 m ▪ Corine Land Cover (CLC): 100 m Frequency (Temporal resolution): Annual Temporal coverage: ▪ ESA WorldCover: 2020, and 2021 ▪ Copernicus Land cover classification gridded maps from 1992 to present: 1992 to present. ▪ Corine Land Cover (CLC): 1990, 2000, 2006, 2012, and 2018 Geographical scale coverage:

Product specifications	
	■ ESA WorldCover: Globally ■ Copernicus Land cover classification gridded maps from 1992 to present: Globally. ■ Corine Land Cover (CLC): Europe Delivery / output format: GeoTIFF (Raster), Shape files (Vector) Accessibility: Freely and publicly available from ESA

Crop Health (Diseases and Pests detection)

Sentinel-2 NDVI image of land along the Milk River in Alberta (Source: USGS).

Product Category

☐ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
■ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ■ **Insurance management** ■ **Green finance**

User requirements

UN30: Need for monitoring with accurate measurements of the growth and health of trees.
UN37: Projection of risk to portfolio assets into the future.
UN55: Detecting crop damage at the level of individual farms/fields.

Description

Crop health monitoring with EO involves analysing the distinctive energy absorption and reflection patterns of healthy and stressed plants. Stressed plants exhibit reduced energy reflection in the near-infrared (NIR) spectrum compared to healthy plants. This enables NIR to identify stressed plants, often before visible signs of stress are noticeable to farmers. Additionally, various vegetation indices like NDVI, NDWI, EVI, LAI, and FAPAR, derived from the relative reflectance of visible, NIR, and SWIR light, can be utilized to monitor stressed vegetation. These indices capture altered reflectance patterns caused by factors such as water stress, nutrient deficiencies, pests, diseases, or extreme temperatures. However, multispectral sensors used for these indicators lack the ability to differentiate specific disease types due to limited spectral discrimination. The use of hyperspectral sensors overcomes this limitation but introduces challenges such as spectral complexity and interpretation, data volume and processing requirements, coarse spatial resolution, and data pre-processing challenges.

Spatial Coverage Target

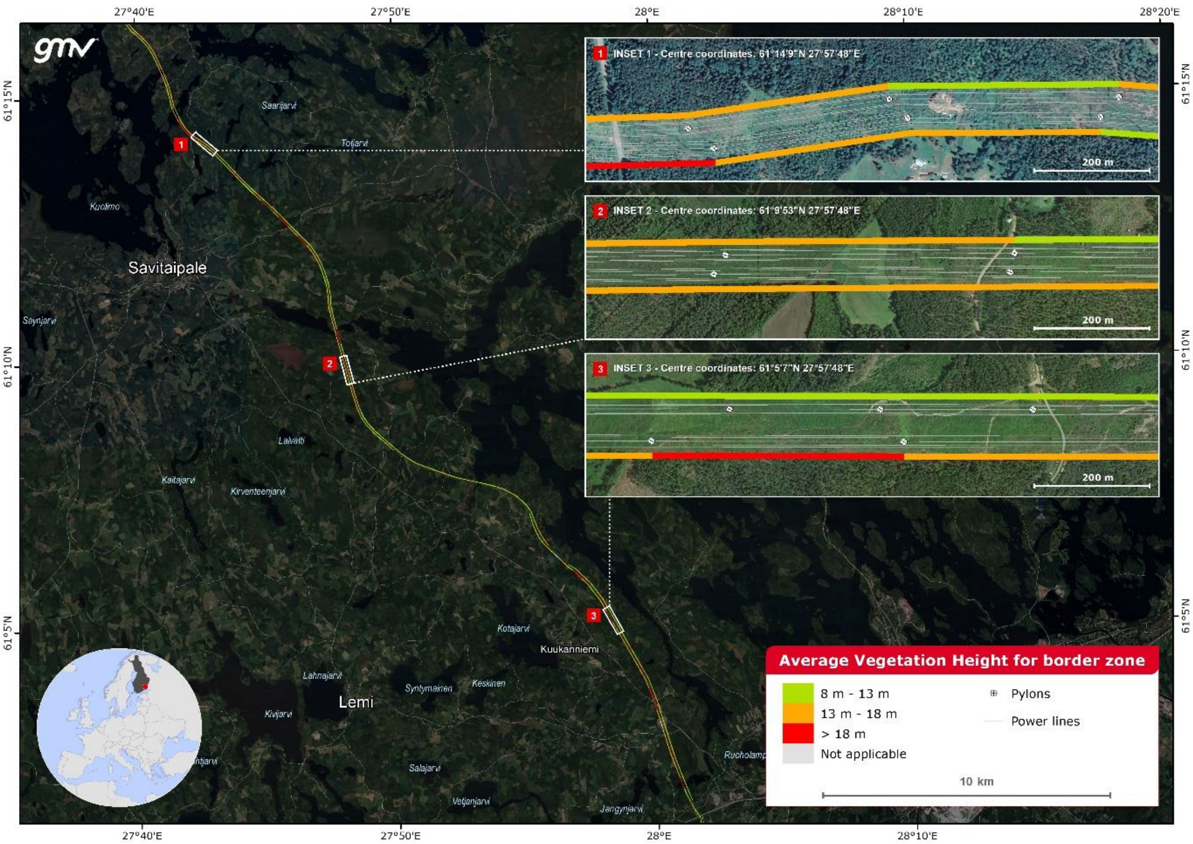
Individual farm level

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	The crop health monitoring process begins with the acquisition of optical satellite imagery that includes near-infrared (NIR) bands, and sometimes short-wave infrared (SWIR) bands, as well as SAR imagery to provide consistent monitoring, regardless of weather conditions. Both optical and SAR imagery should be with appropriate spatial resolution for the target monitoring area. Subsequently, the process entails computing various vegetation indices, utilizing thresholding or classification methods to classify health conditions, examining temporal changes to identify variations, and finally visualizing the outcomes through thematic maps.
Input data sources	Optical: Sentinel-2, VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: Sentinel-1 Supporting data: N.A
Accessibility	Sentinel-1&2: freely and publicly available from ESA. Optical VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel-2: 10 m Optical VHR: ≤ 1 m Sentinel-1: 20 m
Frequency (Temporal resolution)	Sentinel-2: 6 days Optical VHR: Sub-daily to Daily Sentinel-1: 6 days
Latency	< 1 Day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Cloud presence ▪ Challenges in fields with mixed land cover (multiple crops, bare soil, vegetation). ▪ Lacking the ability to differentiate specific disease types due to limited spectral discrimination.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Vegetation Height Estimation



Average vegetation height for border zone of electrical power lines in Finland using Worldview-2&3 (0.5m) (Source: GMV)

Product Category

☐ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth’s Surface Motion
■ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN37: Projection of risk to portfolio assets into future

Description

Vegetation height estimation is important for many aspects of the financial management sector. In sectors like construction and infrastructure development, accurate vegetation height estimation is vital for assessing potential risks related to buildings, power lines, and transportation projects. Overgrown vegetation near critical infrastructure can lead to safety hazards and increased maintenance costs. For industries focusing on renewable energy, such as solar and wind farms, knowing vegetation height is crucial. Tall vegetation around these facilities can obstruct sunlight and wind flow, affecting energy production and efficiency. In forestry and natural resource management, understanding vegetation height aids in estimating timber volume, planning harvest rotations, and assessing forest health. These factors directly influence revenue generation and sustainable resource utilization. Vegetation height can be estimated using VHR satellite images and machine learning models. To train these models, it is essential to have ground truth data such as in-situ or LIDAR data.

Spatial Coverage Target

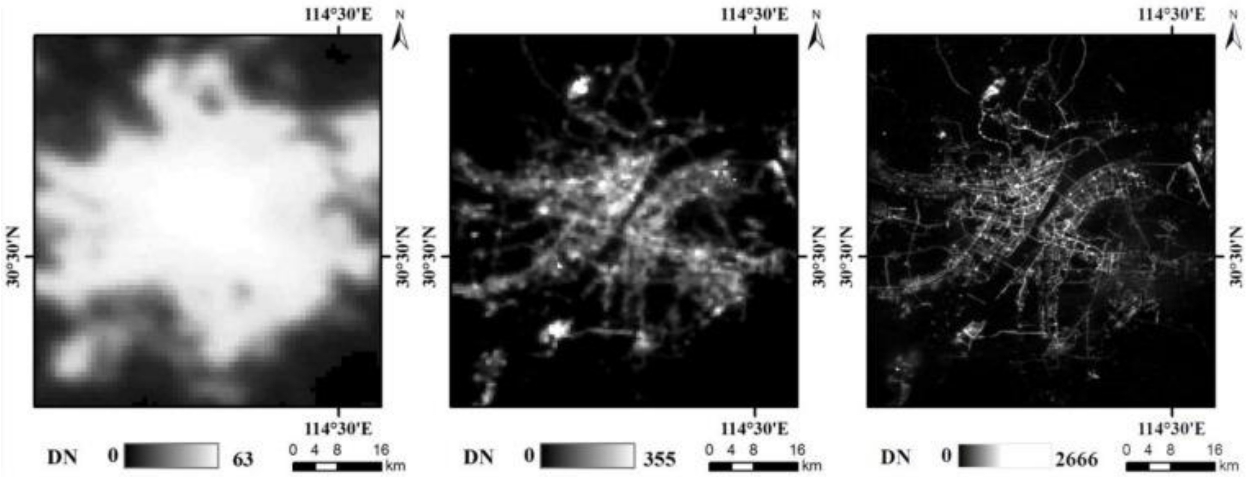
Asset level

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	■ High	☐ Low

Product specifications	
Main processing steps	The vegetation height machine learning model can be a regression-based deep learning approach that utilizes a Convolutional Neural Network (CNN), particularly an auto-encoder architecture such as DenseNet, ResNet, and SENet. Its primary objective is to predict the height of vegetation in a high-resolution satellite image that contains RGB channels. The model aims to create a canopy height map based on this single input image. When the ground truth data is LIDAR, the initial steps involve converting LIDAR point clouds into canopy height models. Then, the vegetation in the VHR satellite image is masked using vegetation indices and supervised machine learning models. The deep learning model is subsequently trained using VHR images timely aligned with the LIDAR data (ground truth data). After successful training and validation, the model can be deployed to estimate vegetation height in any desired image.
Input data sources	Optical: VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: N.A Satellite-based products: N.A Supporting data: Ground truth data such as LIDAR
Accessibility	Optical VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	≤ 1m
Frequency (Temporal resolution)	Daily
Latency	Daily
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-85% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Lack of ground truth data (LIDAR) ▪ The cost of the VHR satellite images ▪ Cloud presence ▪ The machine learning model is limited to regions with similar vegetation characteristics where it was trained.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Nighttime Light Monitoring



Nighttime imagery from DMSP-OLS, NPP-VIIRS and Luojia 1-01 in Wuhan, China: (a) is DMSP-OLS in 2013, (b) is NPP-VIIRS in May 2018; (c) is Luojia 1-01 on 13 June 2018. (Source: Jiang, W., He, G., Long, T., Guo, H., Yin, R., Leng, W., Liu, H. and Wang, G., 2018. Potentiality of using Luojia 1-01 nighttime light imagery to investigate artificial light pollution. Sensors, 18(9), p.2900.

Product Category

- ☐ Land Use
- ■ Land Cover
- ☐ Natural Disaster
- ☐ Climate Change
- ☐ Coast Management
- ☐ Marine
- ☐ Earth's Surface Motion

Financial Domain(s)

■ **Investment management** ☐ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN16: Nighttime light monitoring.

Description

Nighttime light plays a crucial role in various Earth science studies and practical applications. By filtering out unwanted sources like moonlight and other interferences, we can effectively track and analyse artificial lights from human activities, such as street and building lighting. Hence, monitoring nighttime lights can serve various purposes, including measuring the extent and characteristics of urbanization processes, estimating economic growth at both national and subnational scales, mapping global poverty, and population density, and evaluating access to electricity and electrification. Generally, there are three remote sensing sensors for nighttime light, and each of them has advantages and disadvantages. DMSP OLS provides long-term data from the early 1970s until 2011, however, it has low spatial (2.7km) and radiometric (6bits) resolutions. The VIIRS Day/Night Band (DNB) represents an enhancement over the previous DMSP OLS system, offering improved spatial and radiometric resolution. VIIRS provides spatial resolutions of 375 and 750 meters (depending on the band), and daily temporal resolution, and delivers more comprehensive global coverage with higher-quality data. In addition, there is NASA's Black Marble product which is an enhancement product of DNB by applying atmospheric and angular corrections and applying an algorithm to remove moonlight contribution. One of the advantages of using DMSP-OLS and VIIRS-DNB is that the World Bank provides a data archive called The Light Every Night dataset that is published on Amazon Web Services including tutorials about using the dataset. The last product is Luojia 1-01 which was produced by Wuhan University in 2018 and has the advantage of higher spatial resolution (130m) but it lacks the high temporal resolution of DNB by having data every 15 days. Furthermore, there is inconsistency in the data available on the portal, as the most recent observations are only up to March 2019, and in certain regions of the world, the data is even earlier. Finally, using land cover data can be useful to concentrate the service for urban areas only.

Spatial Coverage Target

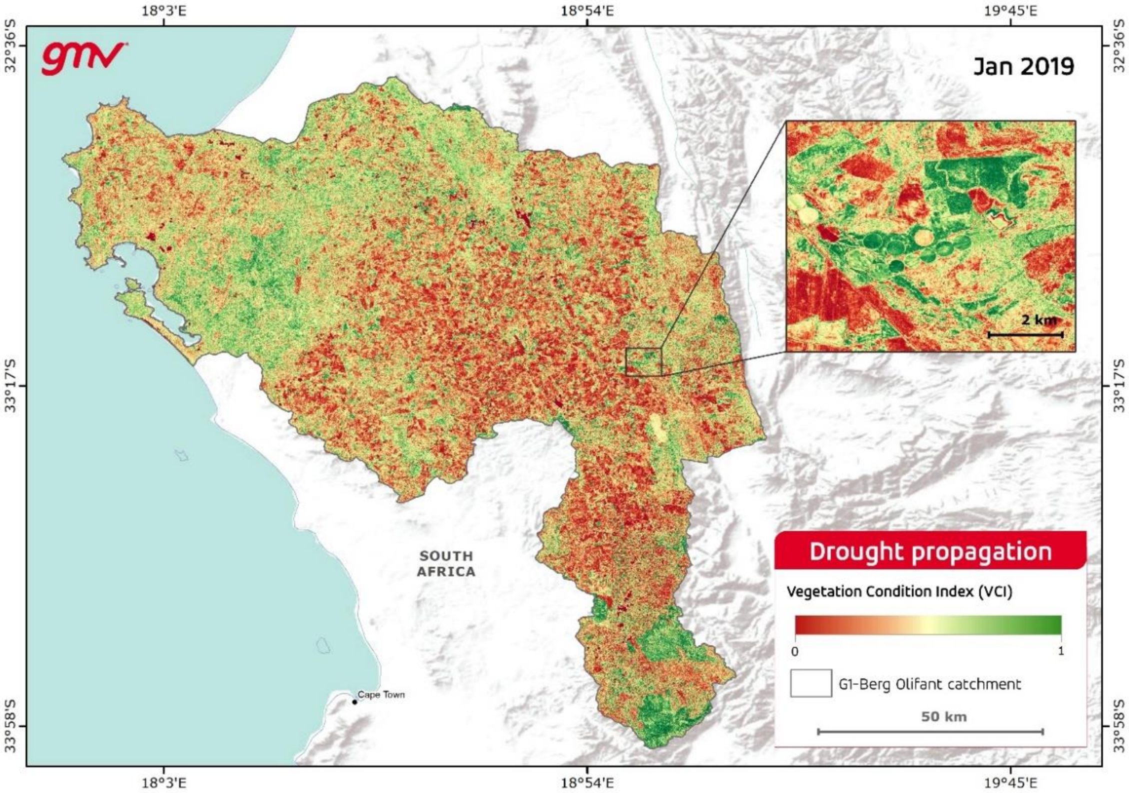
Regional

Data Throughput

Rapid tasking	☐	High	■	Low
Data availability	☐	High	■	Low

Product specifications	
Main processing steps	The dynamic change of nighttime light is the main indicator of the change in human activities. Therefore, time series nighttime light data is essential for related applications. Apply masks and filters to remove unwanted data or sources of interference. This may involve masking out areas with heavy cloud cover or masking out natural sources of light, such as moonlight, to focus on artificial light sources. Conduct calibration processes to convert the digital numbers in the nighttime light imagery to radiance or reflectance values, making the data suitable for quantitative analysis. Generate time series data by compiling and comparing nighttime light data over various periods. This enables the monitoring of changes in artificial light patterns over time. Conduct statistical and spatial analyses to interpret the data and derive insights related to urbanization, economic activities, energy consumption, and other factors. Create visualizations and maps to present the nighttime light data in a clear and informative manner.
Input data sources	Optical: DMSP OLS, VIIRS DNB, Luojia 1-01 Radar: N.A Satellite-based products: N.A Supporting data: Land cover data such as ESA CCI Land cover (20m resolution)
Accessibility	DMSP OLS, VIIRS DNB: freely and publicly available from NASA. Luojia 1-01: available from Wuhan university
Spatial resolution	Luojia 1-01: 130m VIIRS DNB: 750m DMSP OLS: 2700m
Frequency (Temporal resolution)	Luojia 1-01: 15 days VIIRS DNB: Daily DMSP OLS: Annual
Latency	Luojia 1-01: NA VIIRS DNB: Daily DMSP OLS: Archive
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster/Vector/Charts File format: GeoTIFF/Shapefile /PDF
Accuracies	Thematic accuracy: N.A Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Cloud presence ▪ The lower spatial resolution of the products ▪ Natural light sources like moonlight can interfere with the detection of artificial nighttime light. ▪ May not be sensitive enough to detect low-intensity light sources accurately, which can lead to underestimation of nighttime light in less densely populated areas.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Ample Knowledge: Ample

Drought Monitoring at Assets Level



VCI at 10m resolution based on Sentinel-2 data over a secondary catchment in South Africa (Source: GMV)

Product Category

☐ Land Use	■ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

■ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN12: Analysis of potential risks in specific regions.
UN13: Need to geo-map clients.
UN14: Need to screen the feasibility of projects against different hazards criteria.
UN37: Projection of risk to portfolio assets into future.
UN42: Need to monitor the impact of droughts on assets.

Description

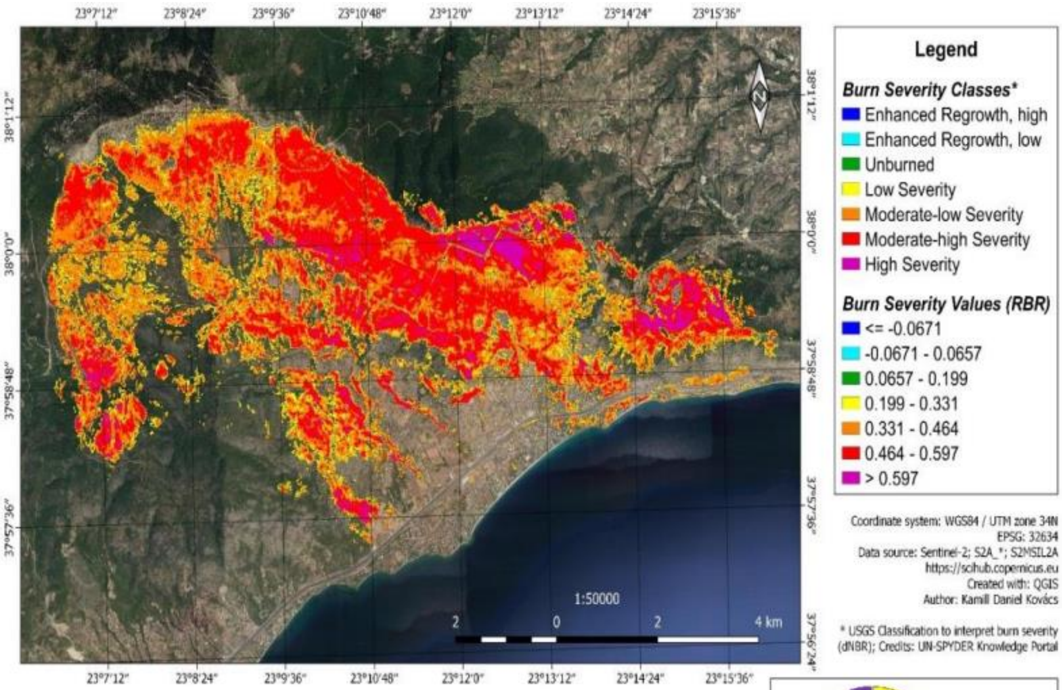
Drought is a natural disaster or climatic phenomenon characterized by an extended period of abnormally low precipitation, resulting in a significant water deficit in a particular region. It leads to reduced water availability, soil moisture depletion, and a range of negative impacts on agriculture, ecosystems, water resources, and human communities. Considering the extensive range of factors that can cause and effects that can result from droughts, droughts are classifies into four main categories 1) Meteorological Drought 2) Agricultural Drought 3) Hydrological Drought 4) Socioeconomic Drought. As drought has complex environmental impacts and can affect numerous ecosystems components in parallel, it is important to monitor droughts using different indicators which correspond to each type of droughts. Standardised Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) can be used as indicators for Meteorological Drought. Vegetation Condition Index (VCI) and Combined Drought Index (CDI), which is based on FAPAR anomaly, soil moisture anomaly, and SPI can be used to monitor Agricultural Droughts. For hydrological drought, indices such as Standardised Groundwater Index (SGI), Standardised Streamflow Index (SFI), and Integrated Drought Index (IDI) can be used.

Beside using such indicators for drought monitoring and drought damage assessment, seasonal forecast of some of these indices can be generated.
Spatial Coverage Target
Asset level
Data Throughput
Rapid tasking ☐ High ■ Low Data availability ■ High ☐ Low

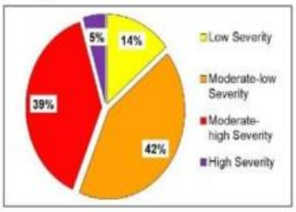
Product specifications	
Main processing steps	Meteorological Drought: SPI is generated based on precipitation data which can be obtained from satellite-based precipitation products such as CHIRPS pr reanalysis products such as ERA5-Land. The SPI is calculated by comparing the accumulation of precipitation on a location over a period, to the same period through the historical precipitation data at that location. SPEI differs from SPI by calculating precipitation and Evapotranspiration to indicate the severity of drought based on water demand besides the amount of precipitation. Therefore, it is essential to calculate potential evapotranspiration (POT) which requires a lot of data such as precipitation, land temperature, wind speed and direction, and surface pressure. Such information can be acquired from ERA5-Land. Agricultural Drought: VCI evaluates the current NDVI about the range of values seen during the same period in preceding years. The VCI provides a sense of where the observed value falls about the extreme values (minimum and maximum) from prior years. NDVI data can be obtained based on the desired spatial coverage. Moderate spatial resolution NDVI (300m) based on Sentinel-3 can be obtained directly from Copernicus Land Service, on the other hand, high spatial resolution NDVI (10m) can be calculated from Sentinel-2. CDI is calculated based on SPI, FAPAR anomaly, and Soil moisture anomaly. FAPAR anomaly can be calculated based on FAPAR data from Copernicus Land Services, and Soil moisture anomaly can be calculated also using Soil Water Index data from Copernicus Land Service. Hydrological Drought: SGI and SFI can be calculated using in-situ data. IDI combines data from various sources (some of them are described above) and uses statistical methods or models to produce a single index value that represents the overall drought situation.
Input data sources	Optical: Sentinel-2 Radar: N.A Reanalysis products: ERA5-Land Satellite-based products: CHIRPS, Copernicus Global Land Service, MODIS. Supporting data: Stream flow and groundwater in-situ data.
Accessibility	Sentinel-2 & Copernicus Global Land Service: freely and publicly available from ESA. CHIRPS: freely and publicly available from the Climate Hazard Centre in the University of Santa Barbara. ERA5-land: freely and publicly available from ECMWF. MODIS: freely and publicly available from NASA.
Spatial resolution	Sentinel-2: 10 m Copernicus Global Land Service: 300 m CHIRPS: 0.05° ERA5-land: 0.1° MODIS: 250 m
Frequency (Temporal resolution)	Sentinel-2: 6 days Copernicus Global Land Service: 10 days CHIRPS: Daily ERA5-land: Hourly MODIS: 16 days

Product specifications	
Latency	Sentinel-2: ≤ Day Copernicus Global Land Service: ~ 3 days CHIRPS: ~ 45 days ERA5-land: ≤ Day MODIS: 1-2 days
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF, NetCDF, HDF
Accuracies	Thematic accuracy: 70-90% (depends on the input data sources) Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Low spatial resolution of precipitation data ▪ Lack of in-situ data for stream flow and groundwater data ▪ Lack of validation due to the lack of in-situ data
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Post Wildfires Monitoring (Area and Severity)



Colour	Fire Severity	Number of pixels	area (m2)	area (ha)	area (ha) %
	Low Severity	9365	4931005	493	14%
	Moderate-low Severity	2319	14834377	1483	42%
	Moderate-high Severity	1477	13701737	1370	39%
	High Severity	654	1643389	164	5%
	TOTAL	13815	35110508	3511	100%



Burned area size and burn severity levels, Kineta-Greece July 2018 using Sentinel-2. (Source: Kovács, K.D., 2019. Evaluation of burned areas with Sentinel-2 using SNAP. Geographia Technica, 14(2), pp.20-38.)

Product Category

☐ Land Use ■ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion
☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN45: Need to measure the area affected by wildfires after the fact.
UN46: Need to measure the intensity of wildfires (level of damage to assets).

Description

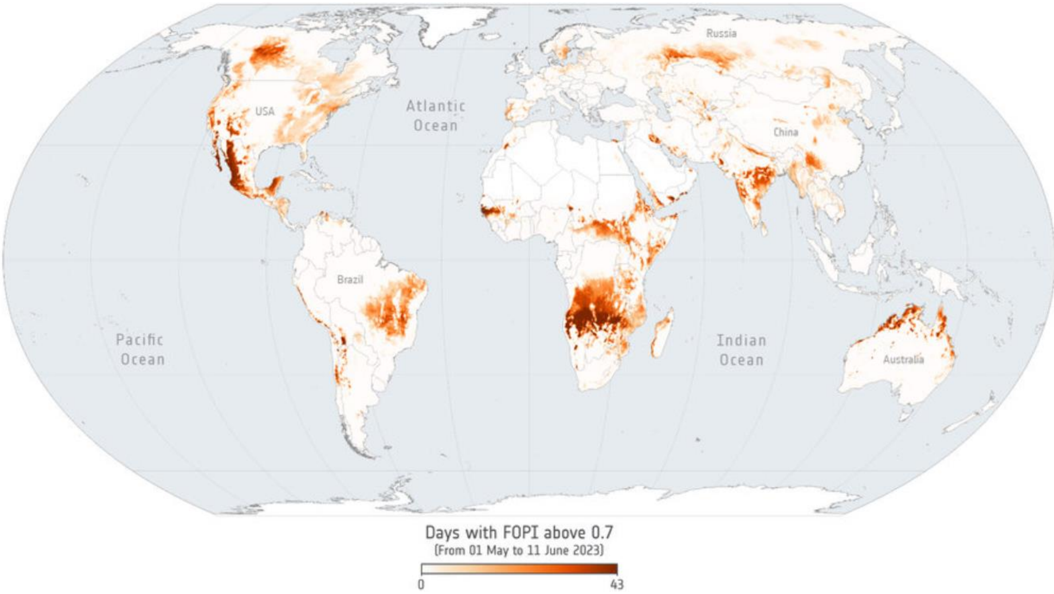
The Normalized Burn Ratio (NBR) is an index utilized to assess burn severity by identifying areas that have experienced significant changes in their spectral properties following a wildfire. It is derived from the energy intensity observed in the Near-Infrared (NIR) and Shortwave Infrared (SWIR) wavelength bands in satellite imagery. The formula for NBR is similar to the widely used Normalized Difference Vegetation Index (NDVI), which assesses vegetation health based on the NIR and red wavelength bands. However, NBR focuses on the NIR-SWIR ratio. High NBR values indicate regions with thriving vegetation, while low values represent bare ground or recently burned areas. Near-zero NBR values signify locations unaffected by the fire event. By calculating NBR from satellite data, we can gain insights into the severity of the wildfire's impact on vegetation and the landscape, aiding in post-fire assessment and ecological recovery efforts.
Burn severity refers to the extent of impact a wildfire has on an ecosystem. It is assessed by comparing pre-fire and post-fire Normalized Burn Ratio (NBR) values derived from satellite images. To distinguish recently burned areas from bare soil and non-vegetated regions, we use the delta Normalized Burn Ratio (dNBR) index, which calculates the difference between pre-fire and

post-fire NBR values. Higher dNBR values indicate a more severe level of damage caused by the fire. On the other hand, lower dNBR values indicate areas that were not affected by the fire or have experienced regrowth of vegetation following the wildfire event.

Spatial Coverage Target		
Asset level and its surrounding		
Data Throughput		
Rapid tasking	■ High	☐ Low
Data availability	■ High	☐ Low

Product specifications	
Main processing steps	Two satellite images of the area of interest should be acquired, one pre and one post the wildfire event. The satellite images should have NIR and SWIR bands to be able to calculate NBR. One important step is to mask clouds and water bodies because these pixels may be misclassified later. After calculating NBR and masking clouds and water bodies of both images, dNBR is calculated by subtracting the post fire image from the pre fire image. Nevertheless, using dNBR as an absolute measure of change can pose challenges in regions with low pre-fire vegetation cover, where the difference may be minimal or insignificant. To address this concern, the relativized burn ratio is employed as an alternative approach. Then, we classify the areas that are burned based on the magnitude of RBR to seven classed as proposed by USGS as follows: Enhanced regrowth (high), Enhanced regrowth (low), Unburned, Moderate-low severity, Moderate-high severity, and High severity. Then, the area of each class can be easily calculated by multiplying the number of pixels of each class by the resolution of the satellite imagery.
Input data sources	Optical: Sentinel-2, VHR with SWIR bands based on the availability like Worldview-3 Radar: N.A Satellite-based products: N.A Supporting data: N.A
Accessibility	Sentinel-2: freely and publicly available from ESA. Optical VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sebtinel-2: 10m Optical VHR: <1m
Frequency (Temporal resolution)	Sentinel-2: 6 days Optical VHR: Sub-daily to Daily
Latency	Sentinel -2: ≤ 1 day Optical VHR: ≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ Availability of pre- and post-fire event images due to cloud presence ■ Lack of VHR imagery that has SWIR bands. ■ Smoke and haze from the wildfire can affect the quality of satellite images.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential
Similar products	Wildfire detection & monitoring from space from ORORA technologies

Wildfires Danger Forecasting: the Fire Occurrence Probability Index (FOPI)



Global Fire Occurrence Probability Index (Source: ESA)

Product Category

☐ Land Use ■ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion
☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

■ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN12: Analysis of potential risks in specific regions.
UN13: Need to geo-map clients.
UN14: Need to screen the feasibility of projects against different hazard criteria.
UN44: Need to measure the area vulnerable to wildfires before events.

Description

Pre-wildfire conditions are too complex and rely on multiple factors including weather conditions such as precipitation, temperature, humidity, and winds o, landscape conditions such as elevation, slope and aspect and vegetation conditions such as type, extent, health, and moisture content. Generally, four factors have a significant impact on wildfire activity: fuels, climate/weather, ignition agents, and human influence. FOPI seeks to enhance the accuracy of fire danger predictions by taking into account landscape flammability. It is calculated using either Vegetation Optical Depth (VOD) or Leaf Area Index (LAI) as a substitute for fuel load and incorporates the fire weather index (FWI) to gauge fire weather conditions. When derived from the FWI and equipped with a dynamic fuel mask, FOPI significantly boosts the correlation between FWI and observed fire activity in areas where fuel is limited.

Spatial coverage demand

Asset level and its surrounding

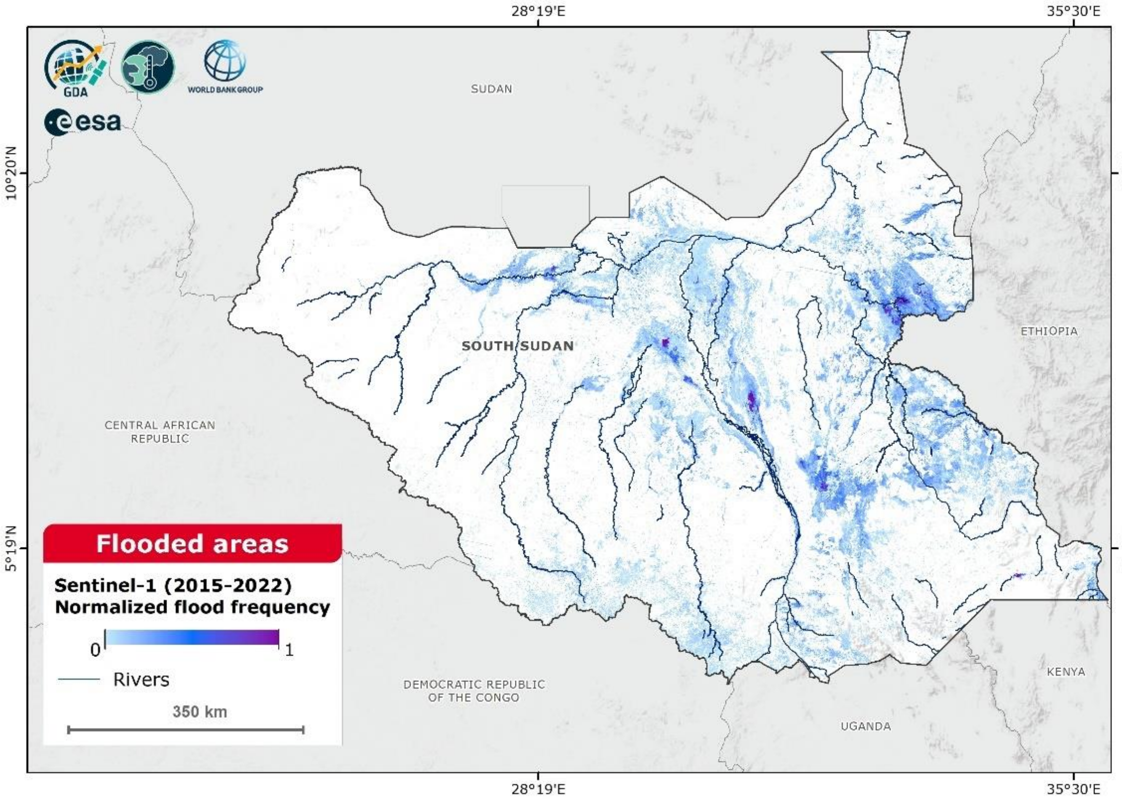
Data throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	To establish the relationship between fuel, weather, and fire incidents, a data cube is generated for the year 2020, aligning fuel indicators, fire weather indices (FWIs), and records of fire occurrences. This dataset is then divided into an 80% training set and a 20% testing set through a random sampling generator. The training set is utilized to analyze the conditions

Product specifications	
	under which fire activity was observed, leading to the derivation of the analytical formulation for FOPI. On the other hand, the independent testing dataset is employed to evaluate the performance of the new flammability index in predicting fire activity. The training set comprises over 9 million data points, while the validation set includes 3 million points. The dataset includes collocated information on FWI, Vegetation Optical Depth (VOD), Leaf Area Index (LAI), and metrics of fire activities, represented by burned areas (BAs) and active fires (AFs).
Input data sources	Optical: • LAI from the product MOD15A2 of MODIS • AFs are from Collection 6 MODIS MOD/MYD14 products. BAs are from a multisensor product provided by the ESA Climate Change Initiative (CCI)Passive microwave: VOD retrievals are from the 2LSM product of the ESA's SMOS mission. Reanalysis products: Global FWI daily values for 2020 are calculated from weather forecasts using the ECMWF operational prediction system.
Accessibility	The product will also be accessible through the ECMWF open charts in 2024
Spatial resolution	FOPI: 9 km
Frequency (Temporal resolution)	Daily with a medium-range forecast (one to five days in advance)
Latency	1 day
Geographical scale coverage	Globally
Delivery/ output format	Grib/NetCDF
Accuracies	Thematic accuracy: N.A Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ Low spatial resolution (9km). ■ The use of the ten-day running mean VOD implies only up to 5days of forecasting.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Identification of Flood Hazard Areas



Normalized flood frequency (Jan 2015- Dec 2022) derived from Sentinel -1 data over South Sudan. (Source: GMV)

Product Category

☐ Land Use ■ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion

☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

■ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN12: Analysis of potential risks in specific regions.
UN13: Need to geo-map clients.
UN14: Need to screen the feasibility of projects against different hazard criteria.
UN37: Projection of risk to portfolio assets into the future.
UN43: Need to monitor changing precipitation patterns and flood risk in the vicinity of vulnerable assets.

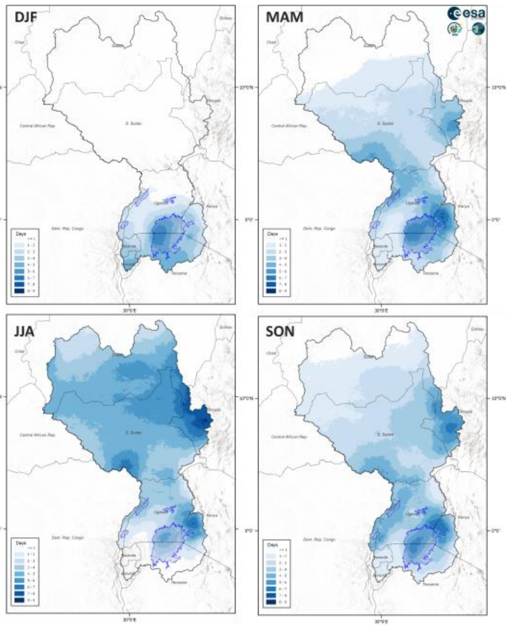
Description

The identification of flood hazard areas refers to the process of assessing and determining the regions that are susceptible to flooding. Flood hazard maps can be generated by analysing historical flood data to determine the frequency of flood events within a specific region over a given time period. The identification of flood hazard areas offers several important advantages for the financial management sector including risk mitigation and planning, for example, avoiding construction in high-risk zones and insurance management to set appropriate premiums based on the level of flood risk. The concept of calculating flood hazard maps involves comparing a temporal composite image representing dry conditions with multiple composites of available images over a specific period. The goal is to detect flooded pixels and subsequently determine the flood frequency for each pixel based on the number of occurrences it was susceptible to flooding. SAR sensors are preferred for flood hazard mapping due to their ability for cloud penetration, which is an important factor to consider for monitoring flood events because they commonly occur during hurricane-related flooding or periods of extended rainfall.

Spatial Coverage Target		
Asset level and its surrounding		
Data Throughput		
Rapid tasking	☐ High	■ Low
Data availability	■ High	☐ Low

Product specifications	
Main processing steps	The process starts by downloading Sentinel-1 images and covers an appropriate time period, it is suggested to use all available images since the launch of Sentinel-1 (2014) and determine the dates with available data. Apply temporal composites within an appropriate number of days. It is recommended to use a time window of two days to avoid the loss of information in a larger time window. If there is more than one image in the time window, the last image is selected. Then it is crucial and critical to select a composite that represents the reference dry condition. The identification of flooded pixels for each composite can be conducted by implementing an UN-recommended practice by comparing each composite to the reference dry condition composite resulting in a different image for each composite. Subsequently, a threshold should be applied to highlight the flooded pixels. Then we should exclude permanent water bodies, areas with higher slopes, and pixels with few flooded neighbours. At this point, the flooded maps for each temporal composite are generated, and a normalized flood frequency map is generated by normalizing the number of times each pixel was identified as flooded using the total number of observations.
Input data sources	Optical: N.A Radar: Sentinel-1, VHR images from different sources like ICEYE, Capella space, Umbra, and TerraSAR-X Satellite-based products: N.A Supporting data: DEM, Permanent water shape file
Accessibility	Sentinel-1: freely and publicly available from ESA. SAR VHR imagery: commercially available on demand from EO providers.
Spatial resolution	Sentinel-1: 20 m SAR VHR: ≤ 3 m
Frequency (Temporal resolution)	Sentinel-1: 6 days SAR VHR: Daily
Latency	Sentinel-1: ≤ 1 day SAR VHR: ≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ False positives from changes on the land surface, not caused by flooding. ▪ Difficulties of detecting flood in urban or densely vegetated areas. ▪ No capturing of flood peak due to the Sentinel-1 acquisition frequency. ▪ False positives caused by differences in relative orbits of Sentinel-1.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Ample Knowledge: Ample

Identification of Trends Related to Shifts in Rainfall Patterns



Seasonal distribution of average number of days with precipitation above 90th percentile of the reference (1983-2022) over South Sudan. (Source: GMV)

Product Category

☐ Land Use	■ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

■ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN12: Analysis of potential risks in specific regions.
UN13: Need to geo-map clients.
UN14: Need to screen the feasibility of projects against different hazards criteria.
UN43: Need to monitor changing precipitation patterns and flood risk in vicinity of vulnerable assets.

Description

Amidst climate change, the importance of identifying trends related to shifts in rainfall patterns becomes even more crucial due to the severe impact of extreme precipitation events, leading to a multitude of natural disasters like landslides and flash floods. Knowing the extreme precipitation trends is important for crop productivity by helping agricultural companies to adapt their cropping patterns, irrigation practices, and water management techniques. In addition, the benefits of analysing extreme precipitation events are not only limited to the agricultural sector but also important for risk analysis and insurance management for other sectors such as real estate, infrastructure planning, and Tourism. To determine the probability of occurrence of extreme rainfall events, the return period (a measure of the rareness of extreme events), and frequency of extreme precipitation events are computed through a statistical analysis of historical time series data. For precipitation estimation, satellite-based precipitation and reanalysis products offer significant advantages over traditional in-situ observations. These methods provide continuous spatial and temporal coverage, which is particularly beneficial for remote regions and developing countries where traditional in-situ observations may have limitations in terms of both spatial and temporal coverage.

Spatial Coverage Target

Asset level and its surrounding

Data Throughput

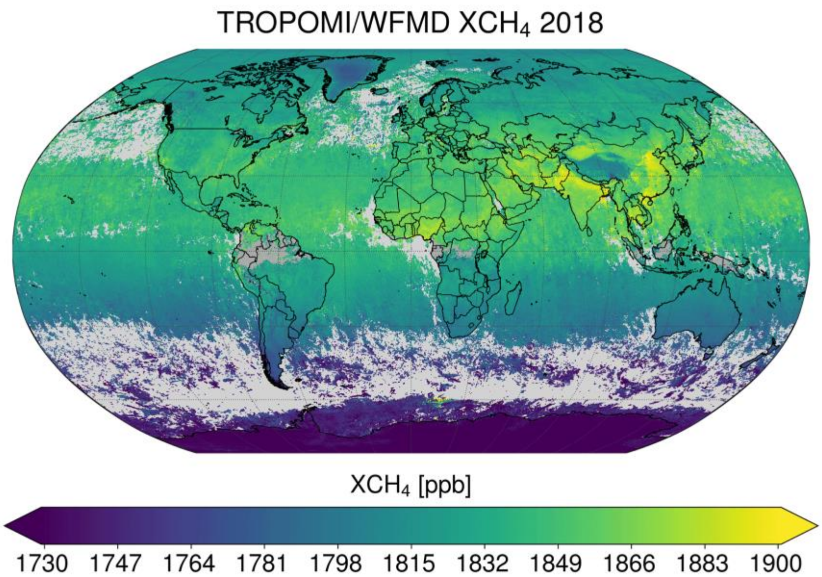
Rapid tasking ☐ High ■ Low

Data availability	☐ High	■ Low

Product specifications	
Main processing steps	Long-time series of historical precipitation data should be acquired through validated sources with long periods of observations and appropriate spatial resolution such as ERA5-land, CHIRPS, and TAMSAT. The performance of these products can be evaluated over the study area to select the most appropriate product for the region. The return level is calculated for the return periods for multiple sampling sizes, based on the study, such as 1-day, 5-day, and 30-day maximum precipitation. One way to analyse the general precipitation trend is to generate the Simple precipitation intensity index (SDII). This index is used to indicate the average daily rainfall on wet days (with daily precipitation > 1mm) for a period. It is calculated by dividing the total amount of precipitation in wet days over the number of wet days. The trend can be analysed by plotting the time series of SDII, the analysis can be seasonally and annually or any time interval. Besides SDII, we can calculate the annual total precipitation on wet days (PRCPTOT). Combining information from both SDII and PRCPTOT, we can have an overview of the mean and amount of precipitation on wet days. To further assess the spatio-temporal variation of precipitation, we can perform a frequency analysis based on the number of days where the daily precipitation is above the 90th percentile (may change) of the reference period. Thus, we can have a comprehensive insight into the trend of extreme precipitation events over a long period over the study area.
Input data sources	Optical: N.A Radar: N.A Reanalysis products: ERA5-land Satellite-based products: CHIRPS, TAMSAT Supporting data: In-situ precipitation data
Spatial resolution	ERA5-land: 0.1° CHIRPS: 0.05° TAMSAT: 0.0375°
Accessibility	ERA5-land: freely and publicly available from ECMWF. CHIRPS: freely and publicly available from Climate Hazard Centre in University of Santa Barbara. TAMSAT: freely and publicly available, it was developed by the University of Reading.
Frequency (Temporal resolution)	ERA5-land: Hourly CHIRPS: Daily TAMSAT: Daily
Latency	ERA5-land: ≤ 1 day CHIRPS: ~ 45 days TAMSAT: 5-6 days
Geographical scale coverage	ERA5-land & CHIRPS: Globally TAMSAT: Africa
Delivery/ output format	Data type: Raster File format: GeoTIFF, NetCDF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ Low spatial resolutions of the precipitation products. ■ Uncertainties related to precipitation estimation of the products due to the sensors, or the methodology to calculation precipitation amount. ■ Lack of in-situ data to evaluate the products.

Product specifications	
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

GHG Emissions Monitoring



Global yearly average of TROPOMI/WFMD XCH4 for 2018 (Source: Schneising, O., Buchwitz, M., Reuter, M., Bovensmann, H., Burrows, J.P., Borsdorff, T., Deutscher, N.M., Feist, D.G., Griffith, D.W., Hase, F. and Hermans, C., 2019. A scientific algorithm to simultaneously retrieve carbon monoxide and methane from TROPOMI onboard Sentinel-5 Precursor. Atmospheric Measurement Techniques, 12(12), pp.6771-6802.).

Product Category

☐ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	■ Climate Change	☐ Marine	

Financial Domain(s)

■ **Investment management** ☐ **Risk analysis** ☐ **Insurance management** ■ **Green finance**

User requirements

UN15: Need to monitor carbon intensity of portfolio assets.
UN26: Need to monitor GHG emissions of projects funded.

Description

Accurate and continuous monitoring of Green House Gases (GHG) such as Co2, No2, and CH4 is crucial for making informed decisions about green finance investments. It enables financial institutions to assess the environmental impact of projects, identify emission reduction opportunities, and prioritize funding for sustainable initiatives. Following the approval of loans and/or investments for projects supporting environmentally friendly activities, it is crucial to monitor these projects to ensure that the funds are effectively utilized to achieve their environmental objectives. EO data offers valuable oversight for specific types of projects. There are several validated and mature EO products (most of them use SWIR and TIR bands) that provide comprehensive monitoring of GHG emissions with global coverage and appropriate spatial and temporal resolutions. In this document, we will focus on products used to monitor three important GHGs which are Co2, No2, and CH4.

Spatial Coverage Target

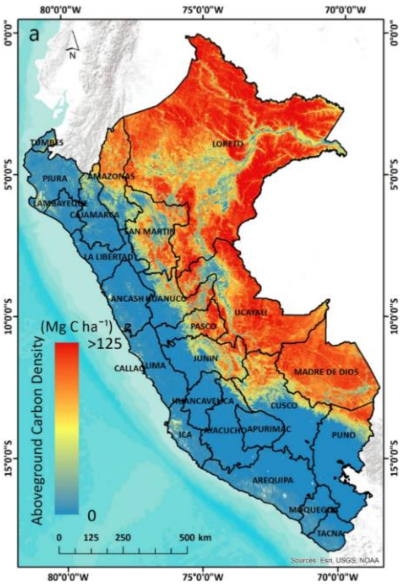
Asset and Project level

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	Data for GHG emissions can be easily accessed through many satellite-based products. These data can be used directly or with simple preprocessing.
Input data sources	Satellite-based products (Optical): GHG. Sentinel-5P (TROPOMI): Co2, No2, and CH4 Metop-A/B/C (IASI): Co2, No2, and CH4 GEOSAT-2: Co2 and CH4 OCO-2: Co2 OCO-3: Co2
Accessibility	Sentinel-5P (TROPOMI): freely and publicly available from European Commission, ESA, Netherlands Space Office (NSO). Metop-A/B/C (IASI): freely and publicly available from EUMETSAT GEOSAT-2: freely and publicly available from JAXA, MOE Japan, National Institute for Environmental Studies of Japan (NIES). OCO-2: freely and publicly available from NASA. OCO-3: freely and publicly available from NASA.
Spatial resolution	Sentinel-5P (TROPOMI): 7 km x 3.5 km Metop-A/B/C (IASI): 100 km GEOSAT-2: 460 m OCO-2: 2.25 km x 1.29 km OCO-3: 2.25 km x 0.7 km
Frequency (Temporal resolution)	Sentinel-5P (TROPOMI): Daily Metop-A/B/C (IASI): Daily GEOSAT-2: 2 days OCO-2: 16 days OCO-3: 1-3 days
Latency	N.A
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF, NetCDF, HDF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Satellite sensors may have limitations in spatial resolution, making it challenging to capture emissions from small sources or accurately distinguish between localized emissions and background levels. ▪ Cloud presence ▪ Vertical sensitivity as satellite measurements generally provides information on total column concentrations of GHGs. While this is useful for many applications, it may not provide a complete understanding of vertical distributions, which are essential for certain scientific studies and policy decisions. ▪ Distinguishing between anthropogenic (human caused) GHG emissions and natural sources (e.g., wetlands, volcanic activity) can be complex. ▪ Low spatial resolution
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Estimation of Above-Ground Carbon Stocks in Forests



High-resolution ACD map of Peru at 1-ha resolution expressed in Mg C ha−1 using Planet Dove satellite imagery and LIDAR data (Source: Csillik, O., Kumar, P., Mascaro, J., O'Shea, T. and Asner, G.P., 2019. Monitoring tropical forest carbon stocks and emissions using Planet satellite data. Scientific reports, 9(1), p.17831.).

Product Category

☐ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	■ Climate Change	☐ Marine	

Financial Domain(s)

☐ **Investment management** ☐ **Risk analysis** ☐ **Insurance management** ■ **Green finance**

User requirements

UN30: Need for monitoring with accurate measurements the growth and health of trees
UN32: Need to periodically estimate the growth of above-ground carbon stocks (in forests).

Description

Calculating aboveground carbon stock on forests is crucial as they store a significant portion of Earth's carbon. Accurate measurement of gains and losses of carbon associated with forest growth, loss, and degradation. aids in designing effective conservation strategies, sustainable land-use planning, and informed policy decisions. Calculation of Aboveground Carbon Density (ACD) starts by measuring the Above Ground Biomass (AGB) due to the strong correlation between both. AGB is calculated based on the height and structure of trees in forests. While field data collection is possible, it encounters geographical constraints within forests. Conversely, LiDAR data, providing valuable information on canopy heights and forest structure, emerges as a more viable option for encompassing broader geographical extents. Although LiDAR enables the expansion of analysis to more extensive regions, its geographic scope is constrained by the financial implications and logistical challenges linked to aircraft deployment. To address this challenge, LiDAR or even field tree inventory data are frequently coupled with remote sensing data possessing diverse spectral and spatial characteristics, facilitating the transition to comprehensive coverage using satellite-based platforms.

Spatial Coverage Target

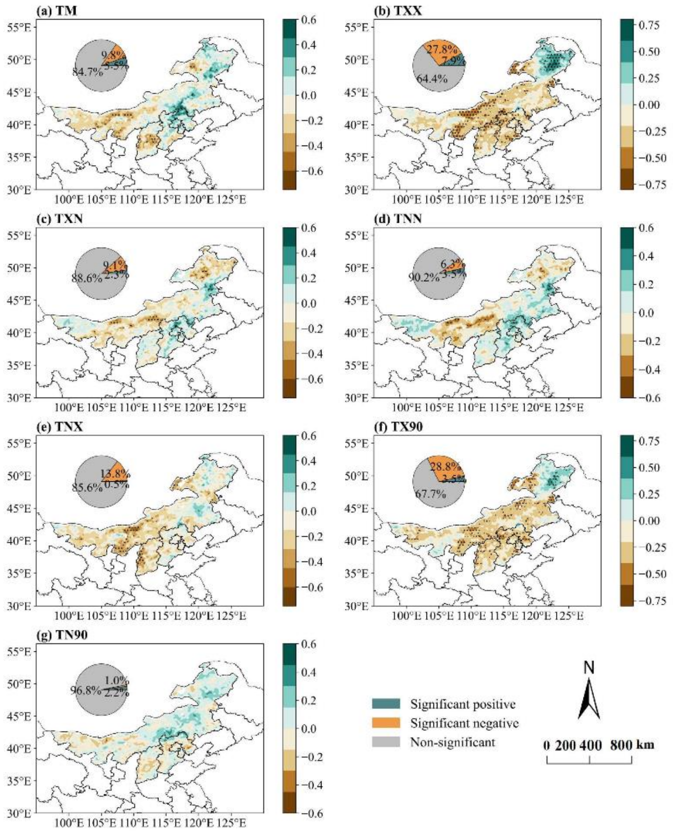
Forests

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	Information about the height and structure of the forest should be gathered through fieldwork or LIDAR. In the fieldwork method, measurements of tree height and diameter at breast height (DBH) are collected from select trees, forming inputs for allometric equations. These equations are then utilized to compute Above-Ground Biomass (AGB), which would be multiplied by a factor (based on the type of the forest) to calculate ACD. In the case of using LIDAR, the top of the canopy height is used as an indicator of the height and structure of the trees. This value serves as the basis for AGB estimation through calibrated equations derived from the earlier allometric model. These data serve as ground truth for training machine learning models using satellite-based data. These datasets comprise optical information from sensors like Sentinel-2 or VHR sensors, along with SAR data from sensors like Sentinel-1 or VHR sources. Predictors for the machine learning models encompass spectral reflectance, vegetation indices, and biophysical variables from optical sensors, as well as SAR backscatter data, image textures computed via techniques like the grey-level co-occurrence matrix, and DEM data. Before training the machine learning model for AGB or top-of-canopy height prediction, applying feature selection algorithms is vital to identify impactful input features. The chosen features are then employed to train the model. Following training and validation, the model is deployed to estimate AGB or top-of-canopy height across the study area, which is subsequently input into the allometric or calibrated equations for ACD computation.
Input data sources	Optical: Sentinel-2, VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: Sentinel-1, VHR images from different sources like ICEYE, Capella space, Umbra, and TerraSAR-X Supporting data: Ground truth data for tree inventory like LIDAR
Accessibility	Sentinel-1&2: freely and publicly available from ESA. SAR and optical VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel-2: 10m Optical VHR: < 0.5m Sentinel1: 20m SAR VHR: < 3m
Frequency (Temporal resolution)	Sentinel-2: 6 days Optical VHR: daily Sentinel1: 6 days SAR VHR: daily
Latency	≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 70-80% (based on input data) Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ Lack of ground truth data about trees height and structures obtained from filed work or LIDAR. ■ Cloud presence ■ Satellite data might not provide direct measurements of biomass, requiring the use of models and assumptions that can introduce uncertainties.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Ample Knowledge: Essential

Impact of Increased Temperatures on Soil Moisture and Vegetation Condition



Spatial patterns of the correlations between the NDVI and the extreme-high-temperature indices in North China from 1982 to 2015 (Source: Yang, Q., Jiang, C. and Ding, T., 2023. Impacts of Extreme-High-Temperature Events on Vegetation in North China. Remote Sensing, 15(18), p.4542.).

Product Category

☐ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	■ Climate Change	☐ Marine	

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN41: Need to monitor the impact of increased temperatures on assets.

Description

This product offers a comprehensive understanding of how temperature changes affect soil moisture levels and the overall health of vegetation. Such information is invaluable for financial institutions, investors, and insurers as it enables them to evaluate climate-related risks associated with agricultural investments, land portfolios, and insurance underwriting. This product is generated by analysing the correlation between temperature maps, soil moisture data and vegetation indices that have been generated through the EO dataset.

Spatial coverage target

Asset level

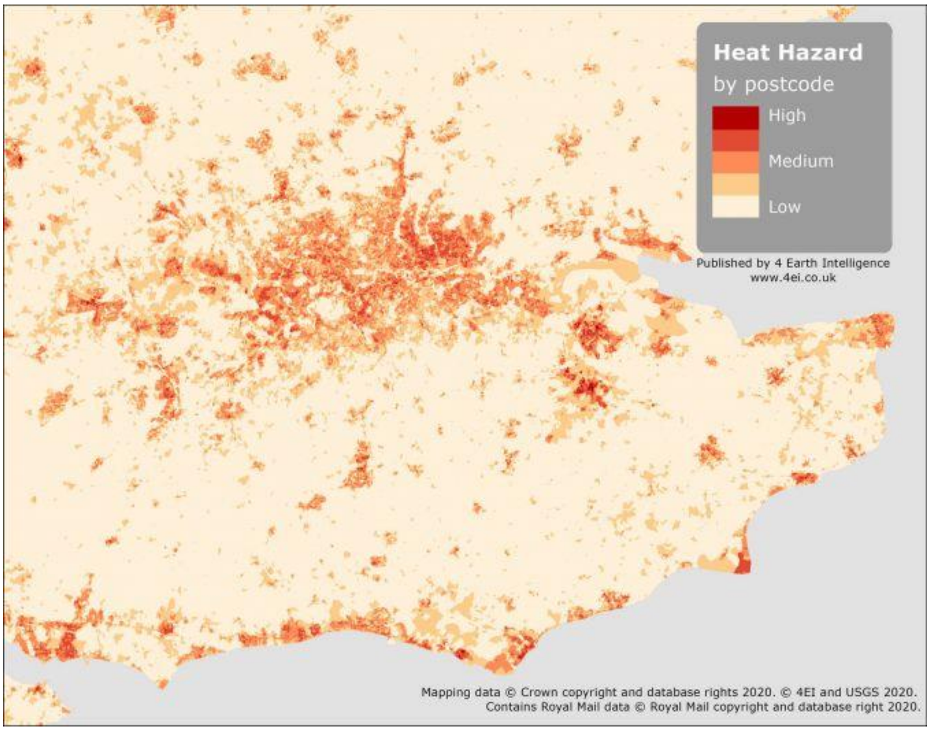
Data throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	The first stage is to generate time series maps of the temperature, soil moisture, and vegetation indices over the asset. These data can be downloaded directly from open access sources such as those provided by Copernicus, MODIS, or EUMETSAT. Subsequently, time series analysis would be applied to gain insight into the correlation between the variables.
Input data sources	Optical: Sentinel-2&3 to calculate vegetation indices. Radar: N.A Satellite-based products: for soil moisture: ESA C3S SSM, SMOS L2 SSM, H SAF ASCAT SSM, SMAP L4 RZSM, VanderSat, and Soil Water Index (SWI) from Copernicus Land Services. Reanalysis products: Temperature data from ERA5 land Supporting data: N.A
Accessibility	Sentinel-2&3, ESA C3S SSM, SMOS L2 SSM, SWI, and ERA5 land are freely and publicly available through ESA. H SAF ASCAT SSM: is publicly and freely available from EUMETSAT. SMAP L4 RZSM: is publicly and freely available from NASA. VanderSat is commercially available through VanderSat.
Spatial resolution	Sentinel-2: 10 m Sentinel-3: 300 m ESA C3S SSM: 0.25° SMOS L2 SSM: 36 km SWI: 0.1° globally and 1 km over Europe H SAF ASCAT SSM: 6.25 km & 12.5 km SMAP L4 RZSM: 9 km VanderSat: 100m ERA5 land: 0.1°
Frequency (Temporal resolution)	Sentinel-2: ~ 6 days Sentinel-3: 1-2 days ESA C3S SSM: Daily SMOS L2 SSM: 1-2 days SWI: daily H SAF ASCAT SSM: 1-2 days SMAP L4 RZSM: Daily VanderSat: Daily ERA5 land: Hourly
Latency	Sentinel-2: ≤ 1 day Sentinel-3: ≤ 1 day ESA C3S SSM: ~ 10 days SMOS L2 SSM: 1 day SWI: 1-2 days H SAF ASCAT SSM: 1 day SMAP L4 RZSM: 7 days VanderSat: N.A ERA5: ≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Low spatial resolution of products for temperature and soil moisture ▪ Cloud presence

Product specifications	
	▪ Ground truth data is important for validation purposes
Level of skills required by users to use the EO service	Skills: Essential Knowledge: Essential

Heat Hazard Maps



South East England heat hazard map by postcode (Source: 4 Earth Intelligence company).

Product Category

☐ Land Use ☐ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion
☐ Land Cover ■ Climate Change ☐ Marine

Financial Domain(s)

■ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN12: Analysis of potential risks in specific regions.
UN14: Need to screen the feasibility of projects against different hazards criteria.
UN41: Need to monitor the impact of increased temperatures on assets.

Description

financial management sector by identifying areas prone to extreme heat events. These maps utilize satellite imagery to visualize temperature variations and heatwave patterns across a region. By highlighting regions with high heat risk, financial institutions, insurers, and investors can assess potential impacts on various assets, such as real estate, infrastructure, and agricultural holdings. Heat hazard maps are based on Land Surface Temperature (LST) that can be calculated based on the data from thermal sensors on satellites. By comparing LST with its historical record, it is possible to generate heat hazard maps that categorize levels ranging from minimal to severe.

Spatial coverage target

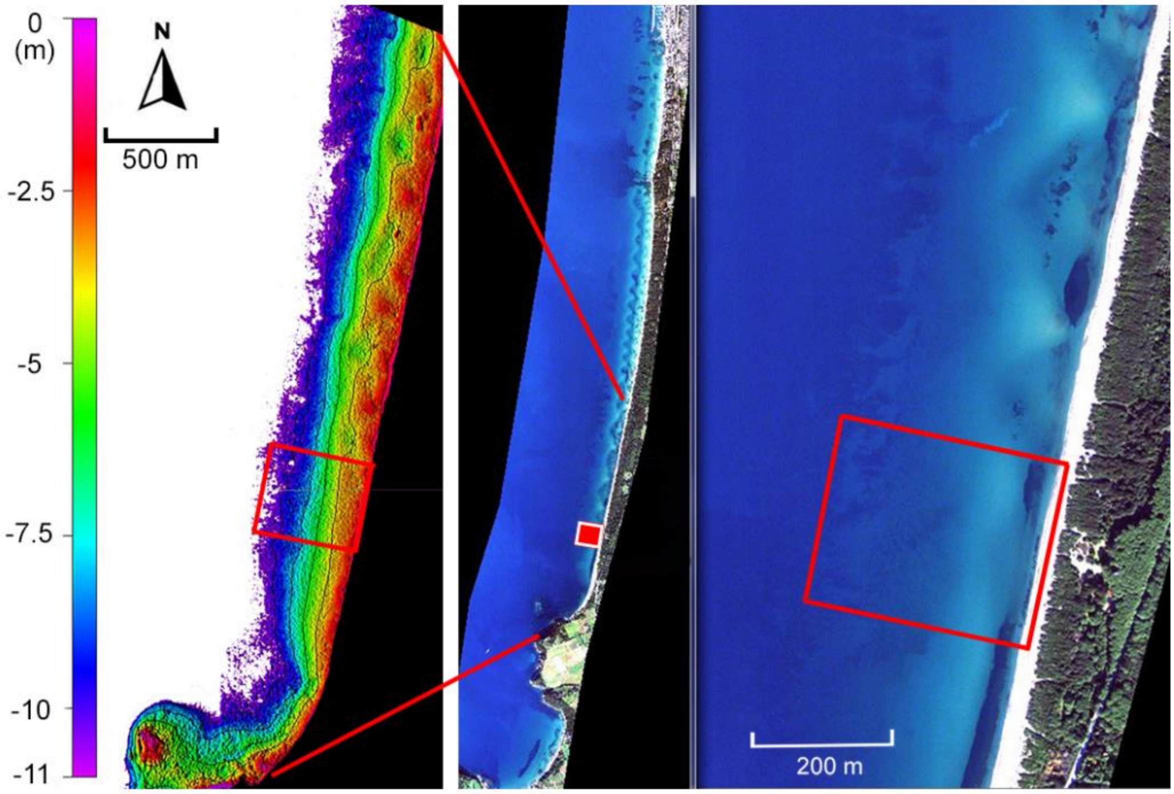
Asset level

Data throughput

Rapid tasking ☐ High ■ Low
Data availability ☐ High ■ Low

Product specifications	
Main processing steps	LST can be calculated at a relatively high spatial resolution (30 m) through equations based on the thermal bands from Landsat. Otherwise, there are some publicly available LST data from Copernicus at lower spatial resolution (5 km), but with very high temporal frequency (~ 1 hour). Afterwards, by comparing LST data with its historical record, it is possible to generate heat hazard maps.
Input data sources	Optical: Landsat series Radar: N.A Satellite-based products: LST from Copernicus Land Services Supporting data: N.A
Accessibility	Landsat series: is freely and publicly available through NASA. LST is from Copernicus Land Services: is publicly and freely available from Copernicus
Spatial resolution	Landsat series: 30 m LST is from Copernicus Land Services: ~ 5km
Frequency (Temporal resolution)	Landsat series: 16 days LST is from Copernicus Land Services: hourly
Latency	Landsat series: ≤ 1 day LST is from Copernicus Land Services: ~ 4 hours
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ The unavailability of higher spatial resolution thermal sensors. ■ Low temporal frequency of Landsat data (16 days). ■ LST data can be influenced by atmospheric conditions, such as clouds, aerosols, and water vapor. These factors can introduce inaccuracies in temperature measurements, especially in cloudy regions.
Level of skills required by users to use the EO service	Skills: Essential Knowledge: Essential
Similar Products	Name of the Product: Heat Hazard Map over Great Britain (link) EO provider: 4 Earth Intelligence Spatial resolution: 30 m Temporal coverage: they used Landsat 8 data for summers of 2017, 2018, an 2019. Geographical scale coverage: Great Britain Accessibility: contact 4 Earth Intelligence company to discuss eligibility, coverage, and data access.

Satellite-Derived Bathymetry for Port and Coastal Monitoring



Satellite-Derived Bathymetry (SDB) and the WorldView-2 (WV2) RGB image showing an area located on the coast on the Tyrrhenian Sea in the south of San Vincenzo town (LI) in Italy (Source: Rossi, L., Mammi, I. and Pelliccia, F., 2020. UAV-derived multispectral bathymetry. Remote Sensing, 12(23), p.3897.)

Product Category

☐ Land Use ☐ Natural Disaster ■ Coast Management ☐ Earth's Surface Motion
☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN12: Analysis of potential risks in specific regions.

Description

Shallow water zones are dynamic, so it is important to be monitored regularly. Satellite-derived bathymetry (SDB) is preferable due to the low cost and near real-time monitoring. Therefore, SDB can help assess the vulnerability of critical infrastructure like shipping lanes, ports, and canals to potential blockages or accidents. By having accurate and up-to-date information on water depths, authorities and stakeholders can identify areas that may be at risk of blockages or accidents and take preventive measures to avoid costly disruptions. For example, the blockage of the Suez Canal stands out as one of the most significant and compelling demonstrations of the importance of SDB in this context. In addition, such information can be used to adjust insurance plans and make informed decisions about the most cost-effective and safe shipping routes.

Spatial Coverage Target

Ports, canals, and coastal areas (with max depth 20m)

Data Throughput

Rapid tasking ■ High ☐ Low
Data availability ■ High ☐ Low

Product specifications	
Main processing steps	Shallow water zones are dynamic, so it is important to be monitored regularly. Satellite-derived bathymetry (SDB) is preferable due to the low cost and near real-time monitoring. Therefore, SDB can help assess the vulnerability of critical infrastructure like shipping lanes, ports, and canals to potential blockages or accidents. By having accurate and up-to-date information on water depths, authorities and stakeholders can identify areas that may be at risk of blockages or accidents and take preventive measures to avoid costly disruptions. For example, the blockage of the Suez Canal stands out as one of the most significant and compelling demonstrations of the importance of SDB in this context. In addition, such information can be used to adjust insurance plans and make informed decisions about the most cost-effective and safe shipping routes.
Input data sources	Optical: Sentinel-2, VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: N.A Supporting data: Ground truth water depth data like LIDAR, single or multi beam Echo-Sounder data.
Accessibility	Sentinel-1&2: freely and publicly available from ESA. Optical VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel-2: 10 m Optical VHR: ≤ 1 m
Frequency (Temporal resolution)	Sentinel-2: 6 days Optical VHR: Sub-daily to Daily
Latency	< 1 Day
Geographical scale coverage	Globally
Delivery/output formats	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ The lack of local in-situ data like LIDAR or Echo-Sounder data ▪ Cloud presence ▪ Limited to estimate water depth up to max 20m
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Ample Knowledge: Essential
Similar Products	Name of the Product: Planet Biomass Proxy (link) Spatial resolution: 2 m,10 m,15 m, and 30 m Frequency (Temporal resolution): Daily Latency: Few weeks Geographical scale coverage: Globally Delivery / output format: ASCII XYZQ files (Point clouds), GeoTIFF (Raster), KMZ overlays for Google Earth, PDF maps and contour lines (Shape files) Accuracies: 80-90% Accessibility: Commercially available from EOMAP

Coastal Erosion

Shoreline changes along the coast of Malgrat de Mar, Spain. The 1994 coastline data is extracted from US Landsat data while the 2019 data is from the Copernicus Sentinel-2 mission. (Source: ESA).

Product Category

☐ Land Use	☐ Natural Disaster	■ Coast Management	☐ Earth's Surface Motion
☐ Land Cover	☐ Climate Change	☐ Marine	

Financial Domain(s)

■ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN12: Analysis of potential risks in specific regions
UN14: Need to screen the feasibility of projects against different hazard criteria.
UN37: Projection of risk to portfolio assets into future
UN40: Need to monitor the risk of sea level rise threatening coastal property, infrastructure, and supply chains

Description

Coastal erosion poses significant risks to properties, developments, and investments in coastal areas. Monitoring erosion enables financial institutions to identify high-risk properties, estimate potential losses, and make informed decisions about lending, insurance, and investment activities' paraphrase. Earth observation data allows for the comparison of optical images acquired at different times to detect changes along the coastline. By analysing these images, it is possible to identify erosional hotspots, quantify shoreline retreat, and assess the magnitude of coastal erosion.

Spatial Coverage Target

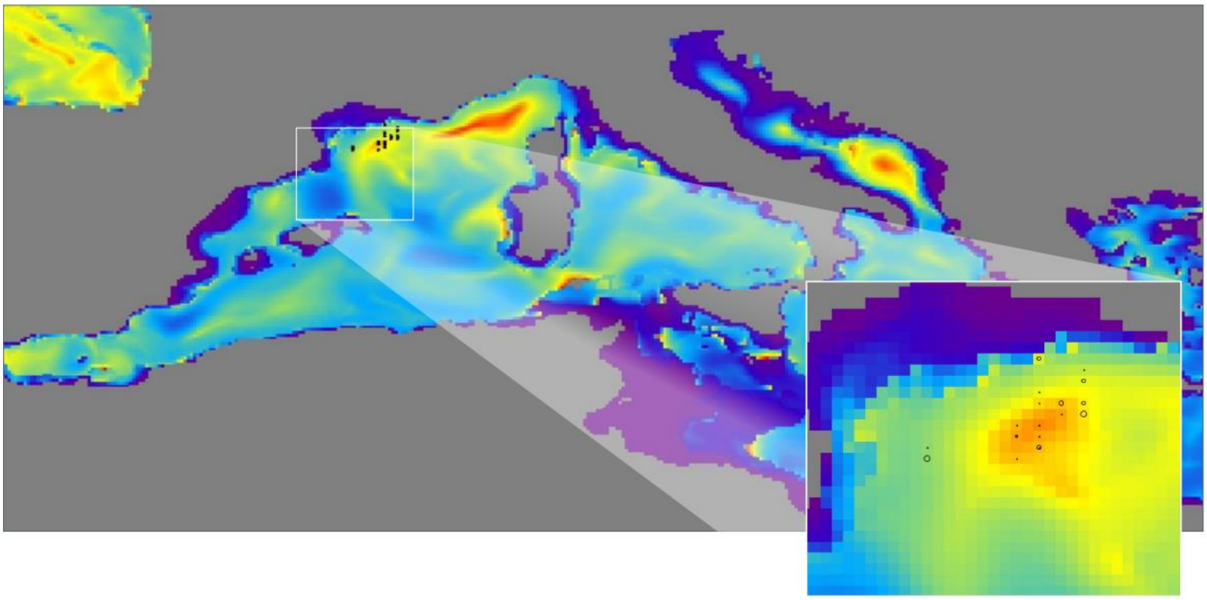
Coasts

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	Coastal erosion monitoring involves tracking changes in shoreline dynamics over time. This approach can be developed using medium-resolution optical satellite imagery like Sentinel-2 and Landsat (for long-term coastal erosion monitoring). The fundamental concept is to establish a reference dataset representing the normal shoreline and then compare it with images from various time periods. This process identifies regions experiencing erosion or accretion and quantifies the rate of change over the years. To accurately differentiate between water and land areas and identify the shoreline, spectral indices like the Normalized Difference Water Index (NDWI) or Modified NDWI can be utilized, applying a threshold to distinguish these regions. To estimate the rate of coastline change, a transect-based method can be employed. This involves calculating the distance between a user-defined reference baseline and multitemporal coastlines using transects generated along the baseline at specified intervals.
Input data sources	Optical: Sentine-2, Landsat Radar: N.A Supporting data: N.A
Accessibility	Sentinel-2: freely and publicly available from ESA. Landsat: freely and publicly available from NASA.
Spatial resolution	Sentinel-2: 10 m Landsat: 30 m
Frequency (Temporal resolution)	Sentinel-2: 6 days Landsat: 16 days
Latency	≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Cloud presence ▪ Variability in sea level due to tides, storm surges, and other factors can introduce noise and uncertainty in detecting shoreline shifts. ▪ Subpixel changes in shoreline positions might be challenging to detect and measure accurately, impacting erosion rate calculations. ▪ Availability of high spatial and temporal resolution historical satellite imagery might be limited.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Essential

Fish Stock Assessment



The image shows conditions for Bluefin tuna feeding, ranging from unfavourable (blue) to favourable (red) in the Mediterranean Sea (Source: ESA)

Product Category

- ☐ Land Use
- ☐ Land Cover
- ☐ Natural Disaster
- ☐ Climate Change
- ☐ Coast Management
- ■ Marine
- ☐ Earth's Surface Motion

Financial Domain(s)

■ **Investment management** ☐ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN9: Understanding stock levels and monitoring supply chains

Description

The EO data can be employed to estimate fish stocks by analysing ocean conditions, temperature, and chlorophyll concentrations, helping in making informed decisions on fishing quotas and seasons. Data on water surface temperature, which exhibits a strong correlation with the presence of certain fish species, and ocean colour, characterized by distinct spectral signatures indicating chlorophyll pigments' concentration linked to phytoplankton biomass (the main food source in the sea), can assist in selecting optimal fishing locations. The combination of two fundamental factors—knowing the marine environment and knowing where fishing takes place—can be powerful: leading to more productive, better-managed, and more sustainable fisheries. Financial planners and investors can use this information to identify regions with the potential for profitable fishing operations.

Spatial Coverage Target

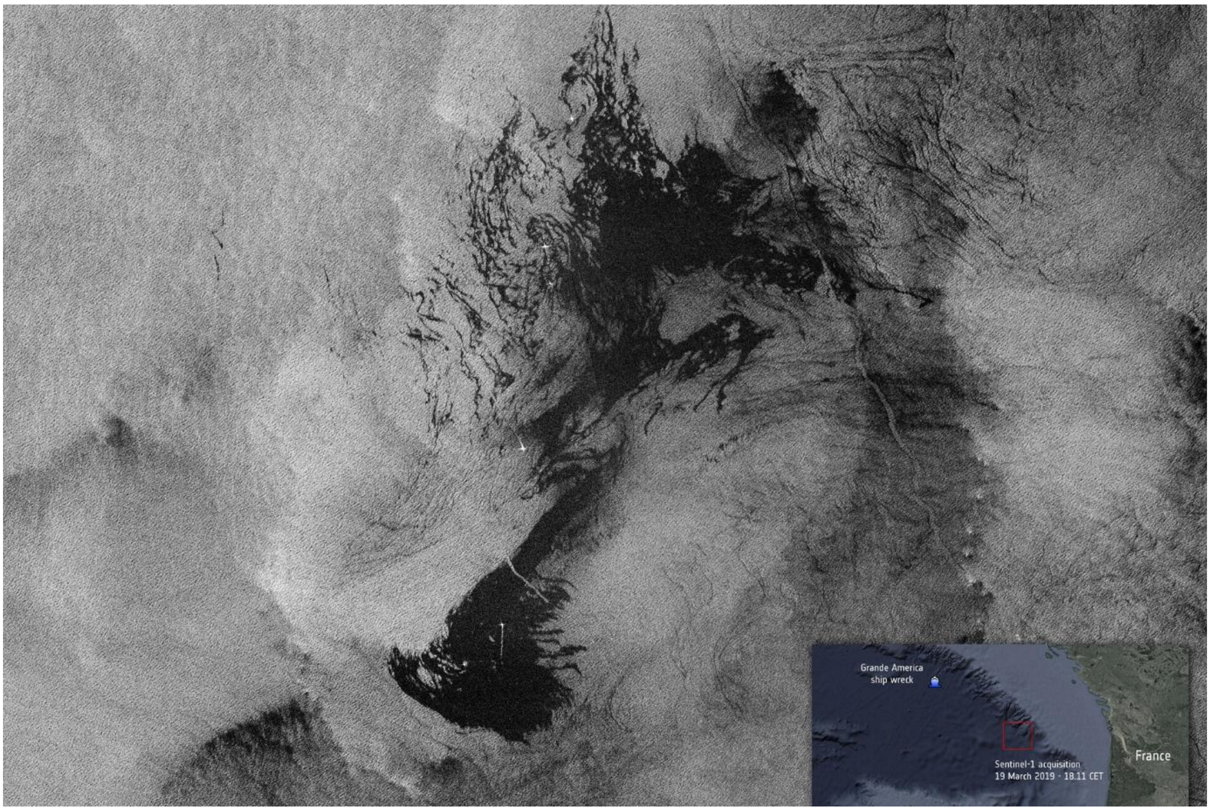
Seas and Oceans

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	Remote sensing data from Sentinel-3 like Sea surface temperature and ocean/sea reflectance can be used to generate easy-to-read maps. These maps can be delivered to fishing companies to have a good idea about the most susceptible regions of fish stocks. As water surface temperature exhibits a strong correlation with the presence of certain fish species, and ocean colour, characterized by distinct spectral signatures indicating chlorophyll pigments' concentration linked to phytoplankton biomass (the main food source in the sea).
Input data sources	Optical: Sentinel-3 Radar: N.A Satellite-based products: Sea surface temperature of Sentinel-3 Supporting data: AIS
Accessibility	Sentinel-3: freely and publicly available from ESA.
Spatial resolution	Sentinel-3: 300 m
Frequency (Temporal resolution)	Sentinel-3: 1-2 days
Latency	Sentinel-3: ≤ Day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: NA Spatial accuracy: NA
Constraints and limitations	▪ Cloud presence ▪ Sentinel-3 data primarily focus on the sea surface, which may not provide information about fish species that inhabit deeper waters. ▪ The data may not distinguish between mixed species
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Ample Knowledge: Essential

Oil Spill Detection



Copernicus Sentinel-1 acquired this radar image of the oil slick, the large, dark patch visible in the centre of the image, stretching about 50 km in Atlantic, about 300 km off the French coast on 12 March 2019 (Source: ESA)

Product Category

☐ Land Use	☐ Natural Disaster	☐ Coast Management	☐ Earth’s Surface Motion
☐ Land Cover	☐ Climate Change	■ Marine	

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN39: Need to assess the potential impact of business activities or investments on ecosystems and biodiversity

Description

Satellite-based oil spill detection monitoring allows for the surveillance of significantly large areas while being much more cost-effective compared to using aircraft, drones, vessels, buoys, fluorescence sensors or platform radars for monitoring purposes. SAR imagery is preferred for oil spill detection and size determination due to its ability to capture images even in challenging conditions such as clouds, darkness, smoke, or other obstructions. This guarantees extensive coverage possibilities for any location worldwide. SAR images can detect oil spills on the water's surface as dark patches. Oil has a dampening effect on the water's surface, making it look smoother and less reflective in SAR images, creating a noticeable contrast with the surrounding water. In addition, SAR images can be used to track the expansion and movement of oil spills over time. Also, following an oil spill incident, SAR images serve for post-spill assessment, enabling the evaluation of the impacted area's extent and facilitating continuous monitoring of the recovery process.

Spatial Coverage Target

Seas and Oceans

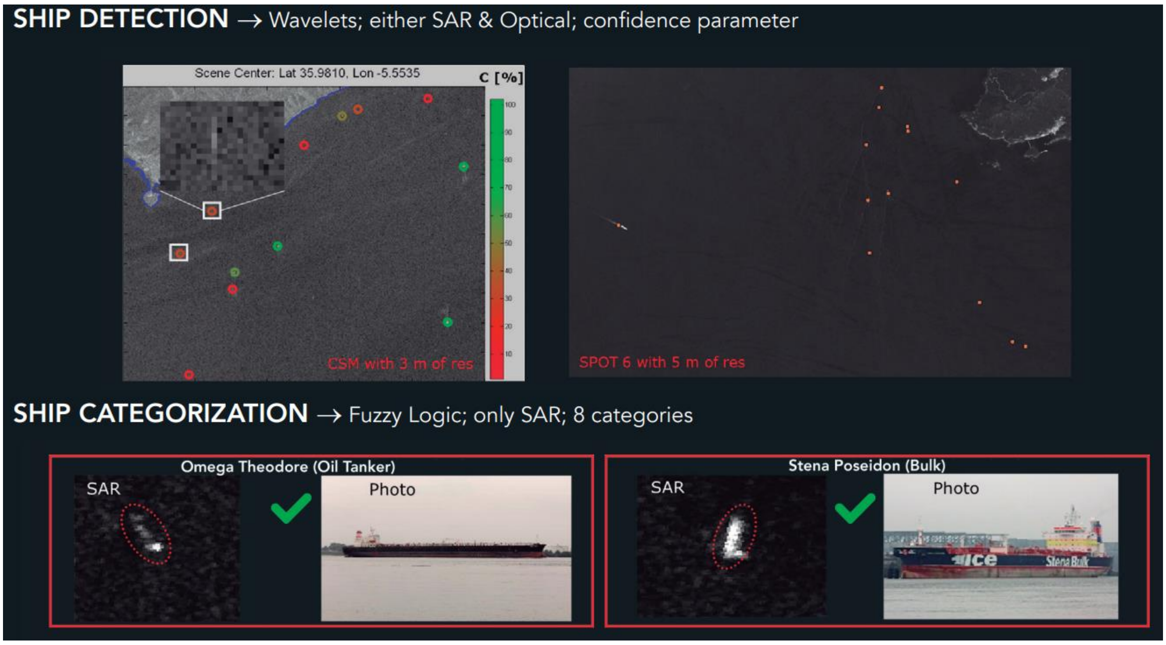
Data Throughput

Rapid tasking ■ High ☐ Low

Data availability	■ High	☐ Low

Product specifications	
Main processing steps	The main processing steps for using Synthetic Aperture Radar (SAR) for oil spill detection include data acquisition from SAR satellites and pre-processing steps to improve the visibility of oil spills such as De-bursting, Radiometric calibration, multi-looking, Speckle filtering, Edge enhancement, Texture analysis, and shape analysis techniques. Then, oil spills on the water's surface can be observed as dark patches. Using AIS data to identify the locations of marine accidents can be useful information for oil spill detection. Moreover, emerging technologies like machine learning can be employed, with the limitation of requiring substantial amounts of data for training. However, they can prove beneficial in distinguishing oil spills from similar-looking substances or features on the water's surface.
Input data sources	Optical: N.A Radar: Sentinel-1, VHR images from different sources like ICEYE, Capella space, Umbra, and TerraSAR-X Supporting data: AIS
Accessibility	Sentinel-1: freely and publicly available from ESA. SAR VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel-1: 20 m SAR VHR: ≤ 3 m
Frequency (Temporal resolution)	Sentinel-1: 6 days SAR VHR: Daily
Latency	< 1 Day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ Radar detection of oil is difficult in low or high wind areas. Due to low difference between backscattering between oil and surrounding water in low wind conditions, and the strong backscatter of water's surface in high wind conditions overwhelming the weak signals from the oil spill. ■ Thin oil films may not produce strong enough signals to be easily distinguishable from the surrounding water. ■ SAR may have limitations in detecting small or localized oil spills, especially when the slick size is below the resolution capability of the radar
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Essential Knowledge: Ample
Similar Products	CleanSeaNet Service from European Maritime Safety Agency (EMSA) (Commercial) OIL SPILL DETECTION Service from Kongsberg Satellite Services (KSAT) (Commercial) OIL SPILL DETECTION Service from ICEYE (Commercial) Earth and Sea Observation System from Catapult (Commercial)

Ship Detection and Categorization



Example of ship detection and categorization from SHIP MONITORING SUITE (SIMON) project (Source: GMV)

Product Category

☐ Land Use ☐ Natural Disaster ☐ Coast Management ☐ Earth's Surface Motion
☐ Land Cover ☐ Climate Change ■ Marine

Financial Domain(s)

■ **Investment management** ☐ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN17: Need near real-time tracking of marine vessels to understand their routes and estimate fuel usage

Description

Ships detection and categorization using EO data involves the use of satellite imagery to identify and classify ships on water bodies. This technology employs advanced image processing and machine learning techniques to distinguish between different types of vessels, such as cargo ships, fishing boats, or naval vessels, and track their movements. For investment management, this capability is invaluable as it offers real-time insights into maritime traffic, trade routes, and shipping activities, enabling investors to make data-driven decisions related to shipping and logistics sectors.

Spatial coverage target

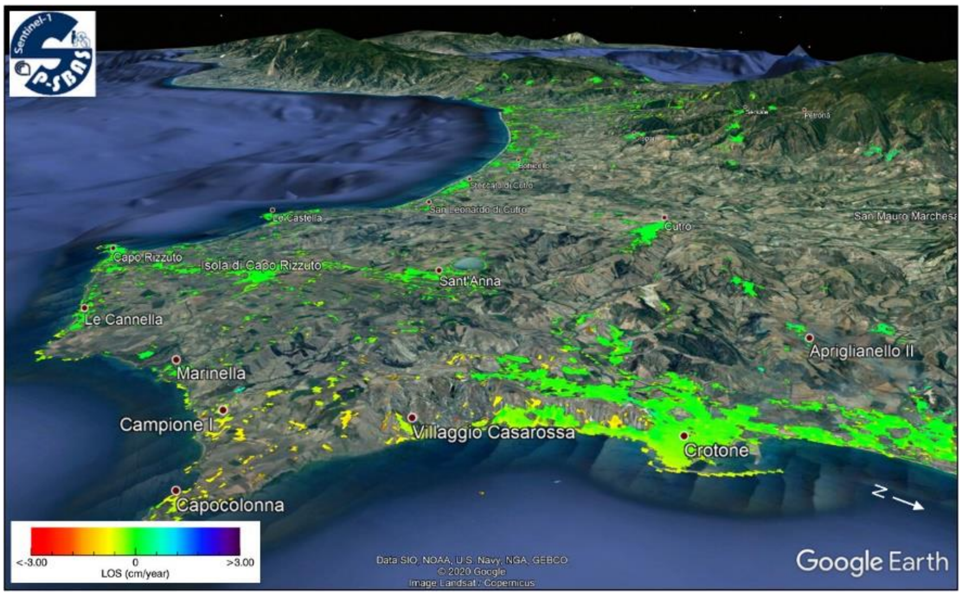
Water bodies extent

Data throughput

Rapid tasking	■ High	☐ Low
Data availability	■ High	☐ Low

Product specifications	
Main processing steps	The process starts by obtaining various training samples from optical and SAR VHR imagery (≤ 3 m) to be used for training of machine learning models for ship detection and categorization. Then we apply the model for any type of ship over any type of water body to detect and categorize ships.
Input data sources	Optical: VHR based on the availability like Pleiades 1A/1B & NEO, WorldView2&3, and SPOT6/7 Radar: VHR images from different sources like ICEYE, Capella space, and TerraSAR-X Supporting data: AIS
Accessibility	Optical and SAR VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	≤ 3 m
Frequency (Temporal resolution)	Daily
Latency	< 1 Day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	■ Smaller vessels and low-profile ships may be challenging to detect or classify. ■ Cloud presence but it can be overcome by using SAR imagery. ■ Challenging to separate individual vessels over-crowded ports or regions with high maritime traffic. ■ Cost of VHR imagery
Level of skills required by users to use the EO service	Skills: Essential Knowledge: Essential

Monitor Slow-Moving Subsidence



Google Earth output file obtained after P-SBAS InSAR processing of the 2014–2020 Sentinel-1 IW SAR ascending mode stack: detail over the area of Crotone province, southern Italy. (Source: Cigna, F. and Tapete, D., 2021. Sentinel-1 big data processing with P-SBAS InSAR in the geohazards exploitation platform: An experiment on coastal land subsidence and landslides in Italy. Remote Sensing, 13(5), p.885.).

Product Category

☐ Land Use ☐ Natural Disaster ☐ Coast Management ■ Earth's Surface Motion
☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN37: Projection of risk to portfolio assets into future

Description

Slow-moving subsidence can pose substantial risks to properties and investments. Monitoring enables financial institutions to identify properties at risk, assess potential losses, and make informed decisions about lending, insurance, and investment activities. SAR interferometry, specifically the technique called Interferometric Synthetic Aperture Radar (InSAR), is widely used for subsidence monitoring. InSAR uses multiple SAR images acquired over time to measure small changes in the Earth's surface (vertical and horizontal displacements). It can detect millimetre-scale ground deformation, making it suitable for monitoring slow-moving subsidence. In addition, Differential SAR Interferometry (DInSAR) compares two or more SAR images taken at different times to generate an interferogram, which highlights surface displacement. By subtracting two interferograms, DInSAR can detect and quantify slow subsidence rates, even in areas where ground deformation is challenging to observe visually.

Spatial Coverage Target

Asset level

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	Time series SAR data covers the extension of the asset can be obtained from different sources such as Copernicus Sentinel-1 or commercial providers such as TerraSAR-X with the selection based on factors like spatial and temporal resolutions required for the application. When dealing with known vulnerable locations that can be covered by a few images, VHR SAR imagery is suggested. However, for monitoring large areas, the use of Sentinel-1 data is recommended due to its free availability, larger swath width, and lower spatial resolution compared to commercial SAR imagery. Additionally, after detecting failures using Sentinel-1, utilizing VHR SAR imagery is advised to ensure higher accuracies. Then, SAR data should be pre-processed to correct for various artifacts and errors. This step includes calibration, atmospheric corrections, and removing noise caused by factors like topography and vegetation. By comparing the phase components of at least two SAR images captured in different times by using different PSI techniques (based on the application and area of interest) such as PS-InSAR and SBAS, it is possible to calculate ground deformations which had occurred between sensing periods.
Input data sources	Optical: N.A Radar: Sentinel-1, VHR images from different sources like ICEYE, Capella space, Umbra, and TerraSAR-X Supporting data: N.A
Accessibility	Sentinel-1&2: freely and publicly available from ESA. VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel-1: 20 m SAR VHR: ≤ 3 m
Frequency (Temporal resolution)	Sentinel-1: 6 days SAR VHR: Daily
Latency	≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 80-90% Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ In areas with varied topography and dense vegetation cover, analysing subsidence can be challenging due to the influence of terrain on measurements. ▪ Local factors like soil composition, water table fluctuations, and geologic conditions can influence subsidence rates, leading to complexities in interpretation.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Ample Knowledge: Ample
Similar products	European Ground Motion Service from ESA

Monitoring Highway and Railway Networks

Displacement and average velocity maps PSI Sentinel-1 for D18 highway in Rome (Source: Orellana, F., Delgado Blasco, J.M., Foumelis, M., D'Aranno, P.J., Marsella, M.A. and Di Mascio, P., 2020. Dinsar for road infrastructure monitoring: Case study highway network of Rome metropolitan (Italy). Remote Sensing, 12(22), p.3697.).

Product Category

- ☐ Land Use
- ☐ Land Cover
- ☐ Natural Disaster
- ☐ Climate Change
- ☐ Coast Management
- ☐ Marine
- ■ Earth's Surface Motion

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN37: Projection of risk to portfolio assets into future

Description

Ensuring the safety and efficiency of supply chains remains a top concern for ongoing monitoring and surveillance of transportation infrastructure, including highways and railways. This assures structural stability and operating safety, as well as preventing corrosion and degradation, which can lead to costly recovery, failures, and collapses. With a high temporal frequency at the network level, on-site survey activities might be demanding, costly and difficult to implement. To tackle these limitations, SAR techniques, such as the persistent scatterers interferometry methods can be used to monitor transportation assets and surrounding environment. This technique offers the advantage of covering vast areas, spanning thousands of square kilometres within a single footprint, while accurately detecting even minor changes in highways or railways infrastructure by measuring vertical and horizontal displacement of the ground.

Spatial Coverage Target

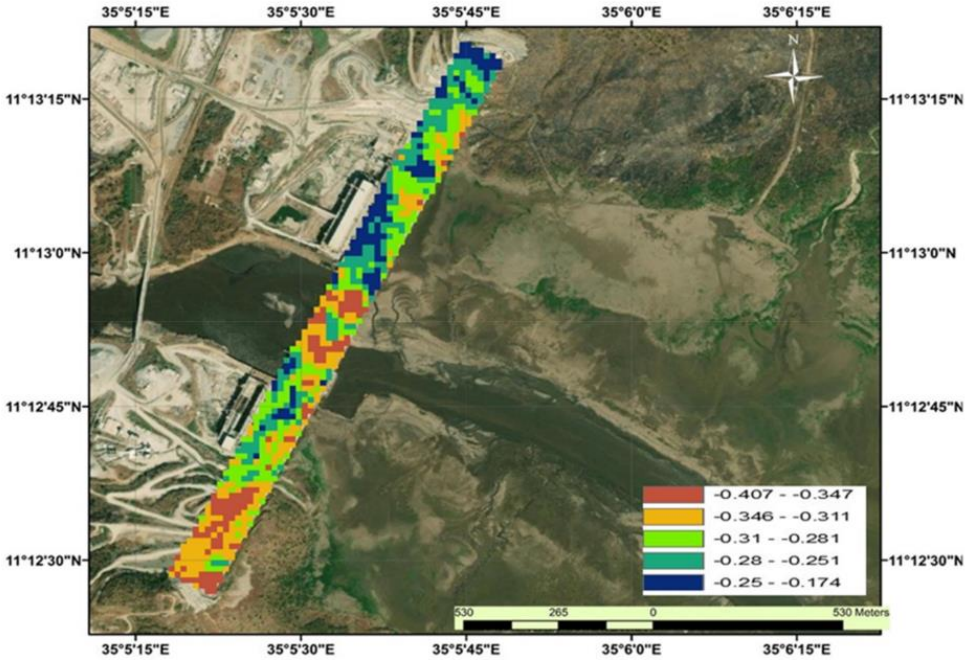
Highway and Railway Networks

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	☐ High	■ Low

Product specifications	
Main processing steps	Shape file of the highway or railway networks should be acquired. Time series SAR data covers the extension of the network can be obtained from different sources such as Copernicus Sentinel-1 or commercial providers such as TerraSAR-X with the selection based on factors like spatial and temporal resolutions required for the application. When dealing with known vulnerable locations that can be covered by a few images, VHR SAR imagery is suggested. However, for monitoring large areas, the use of Sentinel-1 data is recommended due to its free availability, larger swath width, and lower spatial resolution compared to commercial SAR imagery. Additionally, after detecting failures using Sentinel-1, utilizing VHR SAR imagery is advised to ensure higher accuracies. Then, SAR data should be pre-processed to correct for various artifacts and errors. This step includes calibration, atmospheric corrections, and removing noise caused by factors like topography and vegetation. By comparing the phase components of at least two SAR images captured in different times by using different PSI techniques (based on the application and area of interest) such as PS-InSAR and SBAS, it is possible to calculate ground deformations which had occurred between sensing periods.
Input data sources	Optical: N.A Radar: Sentinel-1, VHR images from different sources like ICEYE, Capella space, and TerraSAR-X Supporting data: N.A
Accessibility	Sentinel-1: freely and publicly available from ESA. SAR VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel1: 20m SAR VHR: < 3m
Frequency (Temporal resolution)	Sentinel1: 6 days SAR VHR: Daily
Latency	≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 1 to 5 mm Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Monitoring large highway or railway networks is challenging and using Sentinel-1 can miss some risk events. ▪ SAR signals have limited penetration through certain materials, which can obstruct the measurements of ground movement beneath these surfaces
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Ample Knowledge: Ample

Dams' Safety



Accumulated vertical displacement from January 2017 till July 2021 over The Grand Ethiopian Renaissance Dam in Ethiopia using Sentinel-1. (Source: El-Askary, H., Fawzy, A., Thomas, R., Li, W., LaHaye, N., Linstead, E., Piechota, T., Struppa, D. and Sayed, M.A., 2021. Assessing the vertical displacement of the grand Ethiopian renaissance dam during its filling using DInSAR technology and its potential acute consequences on the downstream countries. Remote Sensing, 13(21), p.4287.).

Product Category

- ☐ Land Use
- ☐ Natural Disaster
- ☐ Coast Management
- ■ Earth's Surface Motion
- ☐ Land Cover
- ☐ Climate Change
- ☐ Marine

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ☐ **Green finance**

User requirements

UN37: Projection of risk to portfolio assets into future

Description

Dams are significant infrastructure investments, which involve substantial financial commitments. Ensuring dam stability is crucial to safeguard these investments and prevent potential financial losses due to failure or costly repairs. Radar-based remote sensing like SAR can detect and monitor land subsidence near dam sites. SAR-related technologies like InSAR and DInSAR can identify and measure ground deformations over time (vertical and horizontal), enabling the identification of potential subsidence that may affect dam safety. Continuous monitoring of subsidence can help assess the stability of the surrounding area and detect any subsidence-related risks that could impact the dam's integrity.

Spatial Coverage Target

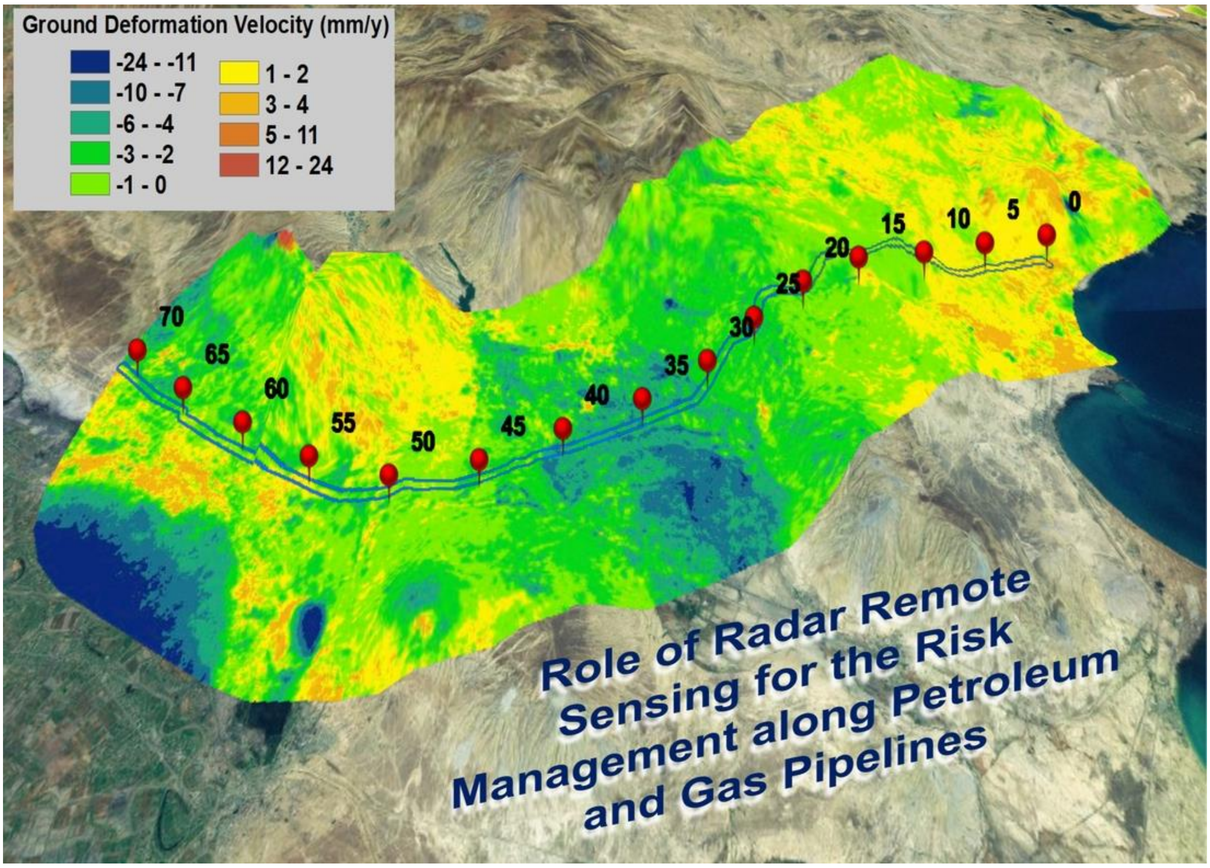
Dams' Surrounding Area

Data Throughput

Rapid tasking	☐ High	■ Low
Data availability	■ High	☐ Low

Product specifications	
Main processing steps	Time series SAR data covers the dam, and its surrounding area can be obtained from different sources such as Copernicus Sentinel-1 or commercial providers such as TerraSAR-X with the selection based on factors like cost, spatial and temporal resolutions required for the application. Then, SAR data should be pre-processed to correct for various artifacts and errors. This step includes calibration, atmospheric corrections, and removing noise caused by factors like topography and vegetation. By comparing the phase components of at least two SAR images captured in different times by using different DIn-SAR or PSI techniques, it is possible to calculate deformations which had occurred between sensing periods.
Input data sources	Optical: N.A Radar: Sentinel-1, VHR images from different sources like ICEYE, Capella space, Umbra, and TerraSAR-X Supporting data: N.A
Accessibility	Sentinel-1: freely and publicly available from ESA. VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel-1: 20 m SAR VHR: ≤ 3 m
Frequency (Temporal resolution)	Sentinel-1: 6 days SAR VHR: Daily
Latency	≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 1 to 5 mm Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ SAR signal coherence can be reduced in vegetated areas, making it challenging to monitor dam stability in regions with dense vegetation. ▪ Changes in the dam environment, such as construction activity or vegetation growth can cause temporal decorrelation, reducing the coherence needed for accurate deformation measurement. ▪ SAR data might not capture localized deformation patterns if the area of interest is smaller than the SAR pixel size.
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Ample Knowledge: Ample

Surveillance of Oil and Gas Pipelines for Geohazard and Ground Subsidence Vulnerabilities



InSAR technology based on Sentinel-1 to measure surface deformation along oil and gas pipelines in Azerbaijan (Source: Bayramov, E., Buchroithner, M. and Kada, M., 2020. Radar remote sensing to supplement pipeline surveillance programs through measurements of surface deformations and identification of geohazard risks. Remote Sensing, 12(23), p.3934.)

Product Category

☐ Land Use ☐ Natural Disaster ☐ Coast Management ■ Earth's Surface Motion
☐ Land Cover ☐ Climate Change ☐ Marine

Financial Domain(s)

☐ **Investment management** ■ **Risk analysis** ☐ **Insurance management** ■ **Green finance**

User requirements

UN37: Projection of risk to portfolio assets into future

Description

Oil and gas pipeline networks commonly extend across vast distances, covering hundreds or even thousands of kilometres. To safeguard pipelines from geohazards and ground movement, close monitoring is essential. Possible threats, such as landslides, seismic events, ground settlement, urban development, vegetation encroachment, and other factors, can lead to pipeline damage. Detecting and monitoring such displacements play a crucial role in cost-effective measures to prevent potential harm. In the past, risk monitoring primarily relied on ground-based systems, LIDAR, and aerial photographs. Although these methods are precise in measuring displacement, they become impractical for cost-effective coverage of entire pipeline networks. InSAR technology offers the advantage of covering vast areas, spanning thousands of square kilometres within a single footprint, while accurately detecting even minor changes in the structure, foundation, or surrounding terrain through repeated measurements to detect horizontal and vertical displacement in the ground. By utilizing multiple footprints, InSAR can effectively monitor entire pipeline networks, identifying thousands of potential hazards with precision ranging from millimetres to centimetres.

Spatial Coverage Target

Oil and Gas pipelines

Data Throughput

Rapid tasking	■ High	☐ Low
Data availability	■ High	☐ Low

Product specifications	
Main processing steps	A shape file of the oil and gas pipeline network should be acquired from the stakeholders. Time series SAR data covers the extension of the network and can be acquired from different sources such as Copernicus Sentinel-1 or commercial providers such as TerraSAR-X with the selection based on factors like spatial and temporal resolutions required for the application. When dealing with known vulnerable locations that can be covered by a few images, Very High-Resolution (VHR) SAR imagery is suggested. However, for monitoring large areas, the use of Sentinel-1 data is recommended due to its free availability, larger swath width, and lower spatial resolution compared to commercial SAR imagery. Additionally, after detecting pipeline failures using Sentinel-1, utilizing VHR SAR imagery is advised to ensure higher accuracies. Then, SAR data should be pre-processed to correct for various artefacts and errors. This step includes calibration, atmospheric corrections, and removing noise caused by factors like topography and vegetation. By comparing the phase components of at least two SAR images captured at different times by using different InSAR techniques (based on the application and area of interest), it is possible to calculate ground deformations which had occurred between sensing periods.
Input data sources	Optical: N.A Radar: Sentinel-1, VHR images from different sources like ICEYE, Capella space, and TerraSAR-X Satellite-based products: N.A Supporting data: shape file for the oil and gas pipelines network
Accessibility	Sentinel-1: freely and publicly available from ESA. SAR VHR imagery: commercially available on demand from EO service providers.
Spatial resolution	Sentinel-1: 20 m SAR VHR: ≤ 3 m
Frequency (Temporal resolution)	Sentinel-1: 6 days SAR VHR: Daily
Latency	Sentinel-1: ≤ 1 day SAR VHR: ≤ 1 day
Geographical scale coverage	Globally
Delivery/ output format	Data type: Raster File format: GeoTIFF
Accuracies	Thematic accuracy: 1 to 5 mm Spatial accuracy: 1.5-2 pixels of input data
Constraints and limitations	▪ Monitoring large pipeline networks is challenging and using Sentiel-1 can miss some risk events. ▪ SAR signals have limited penetration through certain materials, which can obstruct the measurements of ground movement beneath these surfaces
User's level of knowledge and skills to extract information and perform further analysis on the EO products.	Skills: Ample Knowledge: Ample

8. CONCLUSION

The report has provided a comprehensive exploration of the EO capabilities to meet the geo-information needs of the FM sector. By thoroughly assessing the consolidated user needs, challenges, and geo-information requirements (described in the D1.2 Ge-information requirements report), 38 EO products and 18 EO services were identified and characterized that are well-suited to support various facets of the FM sector, including investment management, green finance, risk analysis, and insurance management. Also, a detailed inventory of current and near-future EO datasets was provided encompassing optical, RADAR, and satellite-based and reanalysis products.

The collaborative effort involved desk-based research, online surveys, group discussions during Workshop 2, and EO capability questionnaires. These activities allowed us to collect and consolidate the EO products that can potentially contribute to fulfilling the geo-information needs of the FM sector.

For each of the consolidated 38 EO products, we described use cases that provide product specifications, technical details, limitations, and guidance on the user's level of knowledge and skills required to effectively extract information and conduct further analysis using the EO products. These use cases serve as valuable resources for both EO communities, including service and data providers, and the FM sector.

This report bridges the gap between EO capabilities and FM sector requirements, facilitating a smoother integration of EO-based products and services into financial management processes. It is expected that this consolidation of EO capabilities will enhance decision-making, risk assessment, and overall performance within the FM sector, while also offering opportunities for EO communities to develop and tailor their products to better meet industry needs. EO communities and the FM sector as the target audience of this report, are encouraged to engage with the identified EO products and services (which will be publicly available through the EARSC portal) to leverage the power of EO in addressing FM challenges and opportunities.

In the upcoming report, a gap analysis will be undertaken to compare the current EO capabilities against the FM geo-information requirements. This analysis promises to provide valuable insights and opportunities for further refining EO products and services to align more closely with the specific demands of the FM sector.

9. ACKNOWLEDGEMENTS

We would like to extend our sincere gratitude to the following individuals and organizations for their invaluable contributions to this report:

EO-FIN Stakeholder Board members: For their dedicated contributions and insights. Their input, feedback, and expertise have during Workshop 2 and meetings been invaluable in shaping the direction and scope of this report. We are deeply grateful for their unwavering support and commitment to this project.

EO-FIN Workshop 2 in-person and online attendants: For sharing their experience and knowledge on how EO can benefit the financial management sector. In addition, their contributions to the group's discussions on afternoon sessions of Workshop 2 and to those who responded to the EO capabilities questionnaire.

EO4I, EO4OG, and EO4RM projects: For serving as an essential reference throughout the development of this report. Their exemplary structure, informative tables, and product specifications template greatly informed our work and played a pivotal role in shaping the content and presentation of this document.

Earth Blox company: We acknowledge their willingness to participate in our survey regarding EO products that address financial management geo-information requirements. Their insights and expertise helped in the consolidation of the EO capabilities, and we are thankful for their collaboration.

The collaborative efforts of these individuals and organizations have been instrumental in the success of this report, and we acknowledge their significant contributions with the utmost gratitude.

ANNEX A.

Table 17. List of the optical multispectral sensors with spatial resolution less than 1 m.

Satellite name	Sensor types	Swath (km)	Spatial resolution at nadir	Temporal resolution	Radiometric resolution	Operational status	Launch date	Orbital distance (km)	Spectral bands	Panchromatic band spatial resolution	Commercial status
Eros-C	Optical-Multi spectral	11.5	0.6 m	TBD	12 bits	Not operational	cancelled			0.5 m	Commercial
WorldView-1	Optical-Panchromatic	17.6	0.5 m	1.7 days	11 bits	Operational	2007	496	Panchromatic	0.5 m	Commercial
Skysat (1-21)	Optical-Multi spectral	5.5-8	0.75 – 1 m	2.5-5 hrs	11 bits	Operational	2013	400-600	Vis/NIR	0.57 – 0.86 m	Commercial
GaoFen-7	Optical-Multi spectral	20	0.65 m	5 days	10 bits	Not operational	2014				Commercial
Eros-B	Optical-Panchromatic	7	0.5 m	4 days (repeat cycle)	10 bits	Operational	2006	500	Only PAN	0.70	Commercial
Dailyvision (JL1SP-3/4/5/6/7/8)	Optical-Video and/or night	19 X 4.5	0.92	Three times/day	8 bits	Operational	2017/2018	528-535	Video Mode: RGB	0.7 m	Commercial
Satellogic (Aleph-1)	Optical-Multispectral	5 or 125	0.99 m	<24 hrs	8 to 16 bits	Operational	2014	500	Vis/NIR	1 m	Commercial
BlackSky Global	Optical-Multispectral	6	1.00	Up to Sub-Daily	TBD	Operational	2016	500	Vis	1 m	Commercial

Table 18. List of the optical multispectral sensors with spatial resolution between 1 and 2 m.

Satellite name	Sensor types	Swath (km)	Spatial resolution at nadir	Temporal resolution	Radiometric resolution	Operational status	Launch date	Orbital distance (km)	Spectral bands	Panchromatic band spatial resolution	Commercial status
Pleiades NEO	Optical-Multi spectral	14	1.2 m	1 day	12 bits	Operational	2021	620	Deep Blue, Blue, Green, Red, Red Edge, Near-infrared, Panchromatic	0.3 m	Commercial
WorldView-2	Optical-Multi spectral	16.4	1.84 m	1.1 days	11 bits	Operational	2009	770	red, blue, green, near-IR), red edge, coastal, yellow, near-IR2	0.5 m	Commercial
Worldview-3	Optical-Multi spectral	13.2	1.24 m	<1 day	11 and 14 bits	Operational	2014	617	red, red edge, coastal, blue, green, yellow, near-IR1, and near-IR2)/8 SWIR	0.3 m	Commercial
Worldview-4,	Optical-Multi spectral	13.2	1.24 m	N/A (Archive Only)	11 bits	Not Operational	2016	617	Vis/NIR	0.3 m	Commercial
Superview 2nd gen	Optical-Multi spectral		1.2 m	Daily	TBD	Operational	2022	500	Vis/NIR	0.3 m	Commercial
GeoEye-1	Optical-Multi spectral	15.2	1.84 m	2.6 days	11 bits	Operational	2008	770	Vis/NIR	0.5 m	Commercial
JL1GF03C1/2/3	Optical-Video and/or night	TBD	1.21	Daily	8 bits	Operational	2020	535	Vis	NA	Commercial
Spot-6/7	Optical-Multispectral	60	1.5	2 days	12 bits	Operational	2012 - 2014	694	Vis/NIR	1.5 m	Commercial

Table 19. List of the optical multispectral sensors with spatial resolution between 1 and 2 m.

Sensor Name	Sensor types	Swath (km)	Spatial resolution at nadir	Temporal resolution	Radiometric resolution	Operational status	Launch date	Nominal altitude (km)	Spectral bands	Panchromatic band spatial resolution	Commercial status
Kompsat-3A	Optical-Multi spectral	12	2.2 m	1.4 days (with Kompsat-3)	14 bits	Operational	2015	528	Vis/NIR/MWIR	0.55 m	Commercial
Kompsat-3	Optical-Multi spectral	15	2.8 m	1.4 days (with Kompsat-3A)	14 bits	Operational	2012	685	Vis/NIR	0.7 m	Commercial
Earthscanner (JL1KF01)	Optical-Multi spectral	136	2 to 3 m	5 days	12 bits	Operational	2020/2021	482	Vis/NIR	0.5-0.75 m	Commercial
BJ3 (Beijing-3)	Optical-Multi spectral	24	2 m	4 days (40 degrees N)	12 bits	Operational	2021	500	Vis/NIR	0.5 m	Commercial
Pléiades 1A/1B	Optical-Multi spectral	5.5	2 m	1 day	12 bits	Operational	2011/2012	694	Vis/NIR	0.5 m	Commercial
Superview 1-4	Optical-Multi spectral	12	2 m	1 day	11 bits	Operational	2016/2018	530	Vis/NIR	0.5 m	Commercial
Quickbird, archive	Optical-Multi spectral	18	2.62 m	N/A (Archive Only)	11 bits	Not operational	2001	450	Vis/NIR	0.65	Commercial
Jilin-1 GXA/JL1GXA	Optical-Multi spectral	11.6	2.88 m	Daily	10 bits	Operational	2015	650	Vis/NIR	0.72	Commercial
Deimos-2	Optical-Multi spectral	12	3 - 4 m	2 days (average)	10 bits	Operational	2014	620	Vis/NIR	1.00	Commercial
Jilin-1 stereo JL1GF02A/B	Optical-Multi spectral	40	3 m	3 Days	12 bits	Operational	2019	535	Vis/NIR	0.75	Commercial

GaoFen-2	Optical-Multi spectral	45	3.2 m	5 Days	10 bits	Operational	2014	631	Vis/NIR	0.80	Commercial
TSC (Triplesat 1-3 (4))	Optical-Multi spectral	23	3.20	24 hours at equator	10 bits	Operational	2015	650	Vis/NIR	0.80	Commercial
Ikonos-2, archive	Optical-Multispectral	11.3	3.2 m	N/A (Archive Only)	11 bits	Not operational	1999	681	Vis/NIR	0.8 m	Commercial
Vision-1	Optical-Multispectral	20.8	3.5 m	1 to 8 days	10 bits	Operational (nominal)	2018	583	Vis/NIR	0.9 m	Commercial
Dailyvision (JL1 GF03B-1/2/3/4/5/6)	Optical-Multispectral	17	3.92 cm	Twice/day	16 bits	Operational	2020	535	Vis/NIR	0.98 m	Commercial
KazEOSat-1	Optical-Multispectral	77	4 m	24-48 hours at equator	12 bits	Operational	2014	759	Vis/NIR	1 m	Commercial
Kompsat-2	Optical-Multispectral	15	4 m	Daily (with degraded GSD)	10 bits	Operational	2006	685	Vis/NIR	1 m	Commercial
Pixxel constellation	Optical-Hyperspectral		4 m	1 day (2023)		Operational	2022	480-510	300 bands Vis/NIR and SWIR	NA	Commercial
HuanJing -1A/1B	Optical-Multispectral	30	4 m	4 days		Operational	2008	641		NA	Commercial
Planetscope SuperDoves	Optical-Multispectral	32.5 x 19.6	3.7 m	1-2 days	12 (scaled to 16)	Operational	2020	475-525	Coastal blue, Blue, Green1, Green, Yellow, Red, RedEdge, NIR	NA	Commercial

Table 20. List of the optical multispectral sensors with spatial resolution between 4 and 10 m.

Satellite name	Sensor types	Swath (km)	Spatial resolution	Temporal resolution	Radiometric resolution	Operational status	Launch date	Orbital distance (km)	Spectral bands	Panch resolution	Commercial status
Dailyvision (JL1GF3A)	Optical-Multispectral	18.5	4.24 m	Twice/day	12 bits	Operational	2019	572	Vis/NIR	1.06 m	Commercial
Formosat-2	Optical-Multispectral	24	8 m	N/A (Archive Only)	12 bits	Not operational	2004	888	Vis/NIR	2 m	Commercial
Formosat-5	Optical-Multispectral	24	4 m	2 days (average)	12 bits	Operational	2017	720	Vis/NIR	2 m	Commercial
NaturEye (GaoFen-1 A/B/C/D)	Optical-Multispectral	69	8 m	1 day	10 bits	Operational	2013	645	Vis/NIR	2 m	Commercial
GaoFen-6	Optical-Multispectral	90	8 m	1 day	12 bits	Operational	2018	640	Vis/NIR	2 m	Commercial
ZiYuan 3 (ZY3) – ½	Optical-Multispectral	51/52	6 m	5 days	10 bits	Operational	2016	500	Vis/NIR	2.1 m	Commercial
Planetscope Doves	Optical-Multispectral	24 x 8 – 24 x 16	4.1 m	1-2 days	12 bits	Not operational	2014/2019	475-525	Vis/NIR	3 m	Commercial
RapidEye, archive	Optical-Multispectral	77	5 m	N/A (Archive Only)	12 bits	Not operational	2008	622	blue, green, red, red edge, near infrared	NA	Commercial
KazEOSat-2	Optical-Multispectral	TBD	6.5 m	24-48 hours at equator	TBD	Operational	2014	630	blue, green, red, red edge, near infrared	NA	Commercial

Table 21. List of the optical multispectral sensors with spatial resolution of more than 10 m.

Satellite name	Sensor types	Swath (km)	Spatial resolution at nadir	Temporal resolution	Radio res	Operational status	Launch date	Nominal altitude (km)	Spectral bands	Panch res	Commercial status
OHS: 1-4	Optical-Hyperspectral	150	10 m	<1 day	TBD	Operational	2018	~ 500	32 spectral bands from 400-nm to 1,000-nm	NA	Commercial
Sentinel-2	Optical-Multispectral	290	10 – 20 m	5 days	12 bits	Operational	2015	786	Coastal aerosol, Vis, NIR, Narrow NIR, Vegetation red edge 1&2&3, water vapour, SWIR-cirrus, SWIR 1&2	NA	Non-commercial
UK-DMC2	Optical-Multispectral	600	22 m	1 day	12 bits	Mission complete	2009	650	Coastal Aerosol/Vis/NIR/SWIR	NA	Commercial
Landsat-7 ETM+	Optical-Multispectral	185	15 m	8 days (with Landsat-8)	8 bits	2022	1999	705	8 bands: Vis/NIR/SWIR/TIR/ Mid IR/PAN	15 m	Non-commercial
Landsat-8	Optical-Multispectral	185	15 m	8 days (with Landsat-7)	8 bits	Operational	2013	705	Coastal (Aerosol)/Vis/NIR/SWIR1&2/ TIR1&2/PAN/Cirrus	15 m	Non-commercial
Landsat-9	Optical-Multispectral	185	15 m	8 days (with Landsat-7)	8 bits	Operational	2021	705	Coastal (Aerosol)/Vis/NIR/SWIR1&2 /TIR1&2/PAN/Cirrus	15 m	Non-commercial
Deimos-1	Optical-Multispectral	660	22 m	3 days (average)	8 or 10 bits	Mission complete	2009	661	Green/Red/NIR	NA	Commercial

GaoFen-5	Optical-Hyperspectral	60	30 m	5 days	14 bits	Operational	2021	705	EMI, DPC, POSP, Absorbent Aerosol Detector	NA	Commercial
Landsat-4	Optical-Multispectral	185	30 m	N/A (Archive Only)	6 bits	Not Operational	1982	705	MSS 4 bands / TM 7 bands	NA	Non-commercial
Landsat-5	Optical-Multispectral	185	30 m	N/A (Archive Only)	6 bits	Not Operational	1984	705	MSS 4 bands / TM 7 bands	NA	Non-commercial
GaoFen-4	Optical-Video and/or night	400	50 m	20 seconds	16 bits	Operational	2015	36,000	Vis/NIR/Thermal	50 m	Commercial
Landsat-1	Optical-Multispectral	185	60 m	N/A (Archive Only)	6 bits	Not Operational	1972	917	RBV 3 bands, MSS 4 bands	NA	Non-commercial
Landsat-2	Optical-Multispectral	185	60 m	N/A (Archive Only)	6 bits	Not Operational	1975	917	RBV 3 bands, MSS 4 bands	NA	Non-commercial
Landsat-3	Optical-Multispectral	185	60 m	N/A (Archive Only)	6 bits	Not Operational	1978	917	RBV 3 bands, MSS 4 bands	NA	Non-commercial
Modis	Optical-Multispectral	2330	250 m – 500 m – 1000 m	1-2 days	Dec-14	Operational	1999/2002	705	36 Spectral bands	NA	Non-commercial
Sentinel-3	Optical-Multispectral	1270	300 m	<24 hrs	TBD	Operational	2016/2018	815	OLCI: 21 bands/ SLSTR: 9 bands	NA	Commercial

ANNEX B.

Table 22. List of Radar satellite part 1 (level 1).

Satellite Name	Wavelength Frequency	Polarisation	Mood types	Spatial resolution	Frame size (km)	Temporal resolution	Launch date	Nominal latitude
Radarsat-2	C-band λ = 05.6 cm	Single: HH, VV, HV, VH Dual: HH/HV, VV/VH Quad: HH/HV/VH/VV	Spotlight	1.5 m	18 x 8	24 days	COSMO 1: 2007 COSMO 2: 2007 COSMO 3: 2008 COSMO 4: 2010	798 km
			Stripmap	3 x 3 m to 25 x 25 m	20 to 17			
			ScanSAR	35 x 35 m to 100 x 100 m	300 x 300 - 500 x 500			
COSMO - SkyMed	X-band λ = 03.5 cm	Single: HH, VV, HV, VH Dual: HH/HV, HH/VV, VV/VH	Spotlight	< 1 m	10 x 10	Satellite: 16 days Constellation: ~hrs	2007	620 km
			Stripmap	3 to 15 m	40 x 40			
			ScanSAR	30 to 100 m	100 x 100 - 200 x 200			
ALOS-2 PALSAR-2	L-band λ = 24.6 cm	Single: HH, VV, HV, VH Dual: HH/HV, VV/VH Quad: HH/HV/VH/VV	Spotlight	1 x 3 m	25 x 25	14 days	2014	628 km
			Stripmap	3 to 10 m	55 x 70 - 70 x 70			
			ScanSAR	25 - 100 m	355 x 355			
Sentinel-1	C-band λ = 5.6 cm	Single: HH, W Dual: HH/HV, W/VH	Stripmap	5 x 5 m	375	12 days Constellation: 6 days	2014	693 km
			Interferometric Wide	5 x 20 m	250			

			Extra Wide Swath	20 to 40 m	400			
SAOCOM	L-band λ = 24.6cm	Single: HH, VV Dual: HH/HV, VV/VH Quad: HH/HV/VH/VV	Stripmap	10 x 10 m	>65	Satellite: 16 days Constellation: 8 days	1A: 2018 1B: 2020	620 km
			TopSAR	100 x 100 m	320			
RCM	C-band λ = 05.6cm	Single: HH, VV, VH, HV Dual: HH/HV, VV/VH, HH/VV	Stripmap	VH, H, M, VL resolutions from 3 to 100 m	20 x 20 m 500 x 500 km	Satellite: 12 days Constellation: ~hrs	2019	600 km
NISAR	L-band λ = 24.6cm	Single: HH, VV, VH, HV Dual: HH/HV, VV/VH, HH/VV		From 2 to 20 m	250 km	12 days	2021	747 km
BIOMASS	P-band λ = 70.0cm	Quad		≤ 60 x 50 m	160 km	17 days	2024	660 km
TanDEM-L	L-band λ = 24.6cm	Single Dual Quad	Stripmap ScanSAR / TOPS	12 x 12 m	350 km	Satellite: 16 days Constellation: 8 days	2024	745 km

Table 23. List of Radar satellite part 1 (level 2).

Satellite name	Space agency	Commercial status	Data format	Processing level	Descriptions
Radarsat-2	MacDonald Dettwiler Associates Ltd. of Richmond, BC	Commercial	GeoTIFF or NITF 2.1, with XML	SLC, Amplitude	Interferometry, visualization, mapping, change detection
COSMO - SkyMed	Agenzia Spaziale Italiana	Commercial; limited proposal-based scientific	HDF5	Raw, SLC, Amplitude	Interferometry, visualization, mapping, change detection
ALOS-2 PALSAR-2	Japan Aerospace Exploration Agency	Commercial; limited proposal-based scientific		SLC, Amplitude, Geocoded amplitude, Enhanced amplitude	Interferometry, visualization, mapping, change detection, monitoring disasters rapidly
Sentinel-1	ESA	Non- Commercial	SAFE, GeoTIFF		Interferometry, visualization, mapping, change detection and wide applications
SAOCOM	Italian Space Agency	Commercial	GeoTIFF		Agriculture, Hydrology-including floods and emergencies, Soil moisture
RCM	Canadian Space Agency	Commercial			Arctic sovereignty and conducting coastal surveillance
NISAR	NASA	Non- Commercial	HDF5		Scientific studies and a wide range of applications development, and disaster monitoring
BIOMASS	ESA	Non- Commercial	TBD	TBD	Forest monitoring and the role forests play in the carbon cycle
TanDEM-L	German Aerospace Center	Non- Commercial	TBD	TBD	investigate dynamic processes in the biosphere, cryosphere, geosphere, and hydrosphere

Table 24. List of Radar satellite part2 (level1).

Satellite name	Wavelength / Frequency	Polarisation	Mood types	Spatial resolution	Frame size	Temporal resolution	Launch date	End date	Nominal latitude
Seasat	L-band λ = 24.6 cm	HH	Az	25 m	100 km		1978	1978	800 km
			Rg						
ERS-1	C-band λ = 05.6 cm	W	Az	6 to 30 m	100 km	35 days	1991	2001	785 km
			Rg	26 m					
JERS-1	L-band λ = 24.6 cm	HH	Az	18.0	100 km	44 days	1995	1998	568 km
			Rg	18.0					
ERS-2	C-band λ = 5.6 cm	W	AZ	6 to 30 m	100km	35 days	1995	2011	780 km
			RG	26 m					
ENVISAT	C-band λ = 5.6 cm	Single: HH, W, W/HH	AZ	28 m	100km	35 days	2002	2012	800 km
		Dual: HH/HV, WW/VH	RG	28 m					
ALOS-1	L-band λ = 24.6cm	HH, VV	FBS	10 x 10 m	70 km	46 days	2006	2011	692 km
		HH/HV, HH/VH	FBD	20 x 10 m	70 km				
		HH/HV, VH /VV	PLR	30 x 10 m	30 km				
		HH, VV	ScanSAR	100 m	250 to 350 km				
Radarsat-1	C-band λ = 5.6 cm	HH	Standard	25 x 28m	100 km	24 days	1995	2013	798 km
			Fine	9 x 9 m	45 km				

			Wide 1	35 x 28 m	165 km				
			Wide 2	35 x 28 m	150 km				
			ScanSAR	50 x 5 m - 100 x 100 m	305 to 510 km				
TerraSAR-X TanDEM-X	X-band λ = 3.5 cm	Single: HH, VV Dual: HH/VV, HH/HV, VV/VH Twin: HH/VV, HH/VH, VV/VH	Spotligh	0.2 x 1.0 m - 1.7 x 3.5 m	3 to 10 km	11 days	2007	2010	514 km
			Stripmap	3 x 3 m	50 x 30 km				
			ScanSAR	18 - 40 m	150 x 100 km - 200 x 200 km				

Table 25. List of Radar satellite part 2 (level 2).

Sensor Name	Space agency	Commercial status	Data format	Processing level	Descriptions
Seasat	NASA	Non-Commercial	HDF5, GeoTIFF	Amplitude	Feasibility of global satellite monitoring of oceanographic phenomena on snow and ice
ERS-1	ESA	Non-Commercial	EOS	Raw, amplitude	Visualization, mapping, change detection, environmental monitoring
JERS-1	National Space Development Agency of Japan	Non-Commercial	EOS	Raw, amplitude	Visualization, mapping, change detection, environmental monitoring
ERS-2	ESA	Non-Commercial	EOS	Raw, amplitude	Visualization, mapping, change detection, environmental monitoring
ENVISAT	ESA	Non-Commercial	EOS	Raw, amplitude	Visualization, mapping, change detection, environmental monitoring
ALOS-1	ESA	Non-Commercial	CEOS	Raw, SLC, amplitude	Interferometry, visualization, mapping, change detection,
Radarsat-1	Canadian Space Agency and Canada Center for Remote Sensing	1995-2008: Restrained 2008-2013: Commercial	EOS	Raw, amplitude	Visualization, mapping, change detection, environmental monitoring
TerraSAR-X TanDEM-X	ESA	Application-dependent; restrained scientific, commercial	COSAR, GeoTIFF	SLC, amplitude	Interferometry, visualization, mapping, change detection, environmental monitoring

ANNEX C.

Table 26. List of satellite-based and reanalysis products.

Product Name	Provider	Data	Spatial Sampling	Minimum Temporal Frequency	Latency	Temporal archive	Spatial Coverage	Accessibility	Accessibility Website
CHIRPS	CHC	Precipitation	0.05°	Daily	~ 45 days	1981-present	50°S-50°N	Free	https://www.chc.ucsb.edu/data/chirps
GPM-IMERG	NASA	Precipitation	0.1°	30 min	~ 3.5 months	2000-present	Globally	Free	https://gpm.nasa.gov/data/imerg
PERCIANN CDR	CHRS	Precipitation	0.25°	Daily	~ 3 months	1983-present	Globally (60N-60S)	Free	https://chrsdata.eng.uci.edu/
GSMaP Gauge	JAXA	Precipitation	0.25°	1 hour	3 days	2014-present	Globally (60N-60S)	Free	https://sharaku.eorc.jaxa.jp/GSMaP/
TAMSAT	University of Reading	Precipitation	0.0375°	Daily	5-6 days	1983-present	Africa	Free	https://www.tamsat.org.uk/
ESA CCI SSM	ESA	Soil Moisture	0.25°	1-2 days	Year	1978-present	Global	Free	https://climate.esa.int/en/projects/soil-moisture/data/
ESA C3S SSM	Copernicus	Soil Moisture	0.25°	Daily	~ 10 days	1978-present	Global	Free	https://cds.climate.copernicus.eu/cdsapp#!/dataset/satellite-soil-moisture?tab=overview
H SAF ASCAT SSM CDR	EUROSTAT	Soil Moisture	6.25/12.5 km	1-2 days	Year	2007-present	Global	Free	https://hsaf.meteoam.it/Products/Detail?prod=H120
H SAF ASCAT SSM NRT	EUROSTAT	Soil Moisture	6.25/12.5 km	1-2 days	1 day	2007-present	Global	Free	https://hsaf.meteoam.it/Products/ProductsList?type=soil_moisture
SMOS L2 SSM	ESA	Soil Moisture	36 km	1-2 days	1 day	2010-present	Global	Free	https://earth.esa.int/eogateway/catalog/smos-science-products
SMAP L4 RZSM	NASA	Soil Moisture	9 km	Daily	7 days	2015-present	Global	Free	https://nsidc.org/data/spl4smlm/versions/4

VanderSat	VanderSat	Soil Moisture	100 m	Daily	N.A	2002-present	Request	Commercial	https://docs.vandersat.com/VanderSat_Data_Products.html
Sentinel-5P (TROPOMI)	European Commission, ESA, Netherlands Space Office (NSO)	Co2, No2, and CH4	7 km x 3.5 km	Daily	N.A	2018-present	Global	Free	https://sentinel.esa.int/web/sentinel/user-guides/sentinel-5p-tropomi
Metop-A/B/C (IASI)	EUMETSAT	Co2, No2, and CH4	100 km	Daily	N.A	2007-present	Global	Free	https://navigator.eumetsat.int/product/EO:EUM:DAT:METOP:IASIL1C-ALL
GEOSAT-2	JAXA, MOE Japan, National Institute for Environmental Studies of Japan (NIES)	Co2 and CH4	460 m	2 days	N.A	2014-present	Global	Free	https://geosat.space/
OCO-2	NASA	Co2	2.25 km x 1.29 km	16 days	N.A	2014-present	Global	Free	https://ocov2.jpl.nasa.gov/
OCO-3	NASA	Co2	2.25 km x 0.7 km	1-3 days	N.A	2019-present	Global	Free	https://www.jpl.nasa.gov/missions/orbiting-carbon-observatory-3-oco-3
ERA5-Land	European Commission, Copernicus, ECMWF, and Climate Change Service	Temperature, Snow, Soil Water, Radiation, Heat, Evaporation, Runoff, Wind, Pressure, Precipitation, and Leaf Area Index	0.1°	1 hour	ERA5-Land-T: ~ 5 days ERA5-Land: ~ 2 months	1950-present	Global	Free	https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-land?tab=overview

CGLS	Copernicus	NDVI	300 m	10 days	3 days	2014-present	Global	Free	https://land.copernicus.eu/global/products/ndvi
CGLS	Copernicus	Soil Water Index	Europe: 1 km Global: 0.1°	Daily	2-3 days	Europe: 2015-present Global: 2007-present	Europe Global	Free	https://land.copernicus.eu/global/products/swi
CGLS	Copernicus	Surface Soil Moisture	1 km	Daily	1-2 days	2014-present	Europe	Free	https://land.copernicus.eu/global/products/ssm
CGLS	Copernicus	Burnt Area	300 m	Daily	1-2 days	July 2023 onwards	Global	Free	https://land.copernicus.eu/global/products/ba
CGLS	Copernicus	Dry matter Productivity (DMP)& Gross DMP (GDMP)- Dry Biomass	1/3 km	10 days	5 days	2014-present	Global	Free	https://land.copernicus.eu/global/products/dmp
CGLS	Copernicus	FAPAR	1/3 km	10 days	5 days	2014-present	Global	Free	https://land.copernicus.eu/global/products/fapar
CGLS	Copernicus	Leaf Area Index (LAI)	1/3 km	10 days	5 days	2014-present	Global	Free	https://land.copernicus.eu/global/products/lai
CGLS	Copernicus	Land Surface Temperature (LST)	5 km	1 hour	4 hours	2010-present	Global	Free	https://land.copernicus.eu/global/products/lst
CGLS	Copernicus	Lake Surface Water Temperature (Sentinel-3)	1 km	10 days	~ 5 days	2016-present	Global	Free	https://land.copernicus.eu/global/products/lswt
CGLS	Copernicus	Lake Water Quality - Turbidity&Phytoplankton &Lake	100 m	10 days	~5days	2019-present	Europe & Africa	Free	https://land.copernicus.eu/global/products/lwq

		surface reflectance							
World Settlement Footprint (WSF)	ESA/DLR	Human Settlement	10 m	2015-2019	N.A	2015-2019	Global	Free	https://download.geoservice.dlr.de/WSF2015/
NEX-GDDP-CMIP6: NASA Earth Exchange Global Daily Climate Projections	NASA	humidity, precipitation, downwelling longwave radiation, surface downwelling shortwave radiation, wind speed, temperature,	0.25°	Daily	Archive	1950-2100	Global	Free	https://www.nccs.nasa.gov/services/data-collections/land-based-products/nex-gddp-cmip6
CGLS	Copernicus	Water Bodies Extend	60 m	Monthly	~5days	2020-present	Global	Free	https://land.copernicus.eu/global/products/wb
CGLS	Copernicus	Water level	River Virtual stations Lakes	N.A	4 days	2002-present	River Virtual stations Lakes	Free	https://land.copernicus.eu/global/products/wl
CGLS	Copernicus	Land Cover	100 m	Annual	Annual	2015-2019	Global	Free	https://land.copernicus.eu/global/products/lc
ESA CCI land cover	Copernicus, ECMWF, & Climate Change Service	Land Cover	300 m	Annual	Annual	1992-present	Global	Free	https://cds.climate.copernicus.eu/cdsapp#!/dataset/satellite-land-cover?tab=overview
Sentinel-2 10-Meter LU/LC	Esri	Land Cover	10 m	Annual	Annual	2017-present	Global	Free	https://livingatlas.arcgis.com/landcover/

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