FR - FINAL REPORT

EO-FIN BEST PRACTICE FINANCIAL MANAGEMENT SUPPORT

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1. EXECUTIVE SUMMARY REPORT

The EO-FIN project stands for the best Earth Observation (EO) practice for the Financial Management (FM) sector and aims to understand how, and under what conditions, the Financial Management sector can best benefit from geospatial data. This geospatial data, referred to more generally as 'geoinformation', includes satellite-derived EO data. The financial management (FM) sector was assessed across four markets including investment Management, green fiancé, risk analysis, and insurance management.

The user requirements gathering and consolidation phase aimed to gather up-to-date geoinformation directly from financial management professionals through four main activities. These included an extensive desktop review to explore geospatial data in finance, identify drivers of spatial finance demand, and pinpoint stakeholders. A workshop facilitated feedback and contacts from stakeholders, while semi-structured interviews with diverse sector representatives aimed to understand geospatial challenges, opportunities, and user requirements. A synthesis task consolidated findings, improved via stakeholder review, and publicly reported for further feedback. Findings highlighted that 28% of organizations currently use geospatial data in financial management, with 47% considering its adoption. Key barriers included awareness gaps and regulatory challenges. Geospatial data showed promise in asset monitoring, risk management, and sustainability, particularly in areas like ESG investing and climate resilience.

The study comprehensively evaluated 32 observation needs (UNs) and specific products within the current Earth Observation (EO) capabilities framework. This involved multiple methodologies such as desk-based research, online surveys, group discussions, and EO capability questionnaires. After consolidating these findings, the EO-FIN team identified 38 EO products and 18 services tailored to meet the financial management sector's requirements. Each EO uses case-detailed product specifications, including technical details, limitations, and user skill levels necessary for data extraction and analysis. Notably, the team excluded 'Monitoring Green House Gases (GHG) emissions from marine vessels' due to its absence in the current EO market and poor maturity scores. Table 4 1 presented 18 EO services corresponding to 18 UNs, outlining service names, associated EO products, and options for integrating ancillary data upon user request, with detailed data sources available in the EO products portfolio section. Specific interests included multi-physical risk observations and GHG emissions monitoring, prioritising historical data for risk assessment models. Recommended products included agricultural drought observations, wildfire assessments, flood event identification, rainfall pattern trends, heat hazard maps, and assessments of temperature impacts on soil and vegetation.

The gap analysis conducted between 32 geo-information needs specific to the financial management (FM) sector and 38 Earth Observation (EO) products revealed several critical insights through a blend of quantitative and qualitative methods. Methods included desk research, expert interviews, workshops, and online questionnaires. The analysis categorised gaps into guideline, utilisation, and R&D types, emphasising urgent actions required to address significant deficiencies. Quantitative assessments gauged demand, capability, and utilisation scores, while qualitative approaches provided deeper contextual understanding. As a result, a prototype EO service focusing on multi-physical risk observation was developed, highlighting priorities such as drought observation and wildfire mapping. This prototype was tested in Gauteng Province, South Africa, aimed at supporting non-technical users in making informed financial decisions within a high-risk, economically crucial region.

The EO use case service offers four primary products: agricultural drought observation, flood extent mapping, heat hazard mapping, and past wildfire observations, each detailing aspects like burned areas, vegetation impact, detection dates, confidence levels, and land cover. Financial users can access these products through a platform based on GMV Prodigi®, enabling registration, service selection, area definition, time range setting, parameter customisation, order review, confirmation without payment, and product download with scalability and temporary storage capabilities. A multi-physical risk observations service, identified as highly demanded and mature within the financial management sector, focuses on historical data for physical risk modelling by large institutions. They prioritise long-term data for their proprietary risk assessment models rather than relying on EO provider solutions. Key physical risk products of interest include agricultural drought observations for asset and real estate valuation, post-wildfire assessments crucial for wildfire-prone regions, flood event identification to assess vulnerability and aid in risk mitigation, analysis of rainfall pattern shifts to predict extreme events, heat hazard maps for identifying areas prone to extreme heat, and assessments of temperature impacts on soil moisture and vegetation conditions, crucial for agricultural sector assessments. The platform feedback underscores the need for flexible area selection, diverse data formats, detailed metadata, and pre-purchase visualisation capabilities. It aims to accommodate users with varying levels of geospatial expertise, offering outputs ranging from simple files for non-GIS users to raw data and APIs for advanced programming users. The project engaged extensively with stakeholders through workshops, interviews, and questionnaires, navigating sector-specific challenges like regulatory constraints and competition through strategies like the Chatham House Rule and consultancies to ensure alignment with market needs for a commercially viable EO prototype.

Key challenges in adopting EO services in the financial management sector include high costs associated with high-resolution, near-real-time EO products, which extend beyond data acquisition to processing and analysis, posing financial justification hurdles for institutions. Moreover, the lack of direct communication channels between EO providers and financial managers creates a disconnect, hindering tailored solutions and mutual understanding. The sector's traditional lack of geospatial expertise necessitates costly training efforts to effectively leverage EO data. Complex, regulated IT systems further complicate the integration of EO data, discouraging adoption. Additional barriers highlighted by the WWF include gaps in asset and environmental data, difficulties in company matching across systems, and legal complexities surrounding data sensitivity and usage. Despite these challenges, macro drivers such as underserved markets, ESG frameworks, and initiatives to promote environmental sustainability are motivating factors for increasing geospatial data use in financial applications.

The EO-FIN project actively engaged with the financial sector to gather and consolidate geospatial requirements, develop optimal EO services tailored for financial applications, and refine the characterization of these services for successful commercialization. Engagement methods included workshops, interviews, questionnaires, meetings with stakeholder board members, and webinars, tailored to the highly regulated and competitive financial environment. Given the sector's confidentiality norms, stakeholders were cautious about sharing insights and operational details, prompting the EO-FIN team to propose the Chatham House Rule to safeguard shared information. Continuous stakeholder outreach throughout the project lifecycle ensured ongoing engagement and the identification of new stakeholders, crucial for maintaining project momentum and benefitting from diverse perspectives. To address reluctance among private firms to share sensitive data, the EO-FIN team secured consultancies with key stakeholders from the board, enhancing their understanding of market dynamics and priorities. This approach aimed to develop a prototype closely aligned with market needs, poised for potential commercial success.

The commercialisation of EO services in the financial management (FM) sector promises transformative benefits in investment, risk, insurance management, and green finances. To realise this potential, EO services must cater to diverse user expertise, centralise risk hazard data, and provide multi-hazard assessments using historical, probabilistic, forecasting, and climate projection data. Key features of an ideal EO platform include compatibility with various data formats, product visualisation before purchase, detailed metadata, and expanded climate risk products. Overcoming barriers like high costs, lack of communication, limited geospatial skills, and complex IT systems is essential. Solutions include leveraging public-private partnerships, cloud computing, subscription models, training programs, and seamless IT integration. Demonstrating EO-derived solutions' value through case studies, pilot projects, and ROI metrics can encourage financial institutions to invest in and adopt these services.

2. INTRODUCTION

2.1. PURPOSE

This document corresponds to the deliverable of the final meeting of the ESA project AO/1-11083/21/I-DT: EO-FIN best practice financial management support.

The final report provides a complete description of all the work done during the EO-FIN activity and shall be self-standing, not requiring to be read in conjunction with reports previously issued. It shall cover the whole scope of the activity, i.e. a comprehensive introduction of the context, a description of the programme of work and a report on the activities performed and the main results achieved.

2.2. SCOPE

This document is structured according to the following sections:

- Section 1, (Executive summary report) concisely summarises the findings during the EO-FIN project.
- Section 2, (current chapter) defines the purpose of the document within the WP objectives and the overall purpose of WP deliverables. It also contains the definitions and acronyms used in this document.
- Section 3 includes the list of applicable documents and additional references to be taken into account during the project life cycle.
- Section 4 provides a comprehensive **background** of the study,
- Section 5 presents the result of user requirements, EO capabilities, gap analysis, and the EO use case service web platform.
- Section 6 discusses the key issues and challenges faced by both FM and EO sectors to promote using EO products in financial practices.
- Section 7 explains all findings of FM requirements, EO use case, engagement of FM users, future EO mission and their contribution to the FM practices, and steps to be performed towards the commercialisation of EO products in the FM sector.
- Section 8 acknowledges those who greatly contributed to the project.

2.3. DEFINITIONS AND ACRONYMS

2.3.1. DEFINITIONS

Concepts and terms used in this document and needing a definition are included in the following table:

Table 2-1 Definitions

Concept / Term	Definition
Earth Observation	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
User requirement	A User Requirement is a data and/or information need expressed by users in a specific thematic domain.

2.3.2. ACRONYMS

Acronyms used in this document and needing a definition are included in the following table:

Table 2-2 Acronyms

Acronym	Definition
AI	Artificial Intelligence
AoI	Area of Interest
AWRA	Aqueduct Water Risk Atlas
AWS	Amazon Web Services
DEM	Digital Elevation Model
DInSAR	Differential SAR Interferometry
dNBR	delta Normalized Burn Ratio
DSM	Digital Surface Model
DTM	Digital Terrain Model
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
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FM	Financial Management
FR	Final report
GHG	Green House Gases
GIS	Geographical Information Systems
GNSS	Global Navigation Satellite System
MCA	Multi-Criteria Assessment
NASA	National Aeronautics and Space Administration
SAR	Synthetic Aperture Radar
SOS	Start of the Season
SPEI	Standardized Precipitation Evapotranspiration Index
STD	Standard Deviation
SWI	Short-Wave Infrared
UCS	Union of Concerned Scientists
UN	United Nations
UNs	User needs
VHR	Very High Resolution
WP	Work Package
WWF	World Wide Fund for Nature

3. REFERENCES

3.1. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [ADx]:

Table 3-1 Applicable 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 summary 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
[RD7]	D2.2	EO-FIN-Current EO Capabilities Report (final)	1
[RD8]	D2.2	EO-FIN-Gap analysis report	1
[RD9]	D2.3	EO-FIN-Workshop-2 summary report	1
[RD10]	D3.1	EO-FIN-Prototype identification (draft)	0.1
[RD11]	D3.1	EO-FIN-Prototype identification (final)	1
[RD12]	D4.1	EO-FIN-Best practices roadmap	1

4. PROJECT BACKGROUND

EO-FIN, a European Space Agency (ESA) project seeking to understand how, and under what conditions, the Financial Management sector can best benefit from geospatial data. This geospatial data, referred to more generally as 'geoinformation', includes satellite-derived Earth Observation (EO) data.

The **financial management (FM) sector** was assessed across four markets:

- **Investment Management** as an industry is highly diversified, with a focus on the allocation of client capital across a wide range of asset classes and investment strategies. This capital is entrusted to investment managers who invest on a client's behalf to deliver a return on their client's capital, mitigate risk, or to deploy that capital in line with particular principles/ethical frameworks. Increasingly common are constraints which take into account ESG considerations, which may be accompanied by associated due diligence and reporting requirements.
- **Green Finance** is defined such that it includes structured financial activities, products, or services, that have been created to mitigate negative impacts that arise from environmental pollution and climate change. The funded interventions seek to foster the development of greener business practices, operating models, and a sustainable economy as a whole.
- **Risk Analysis** includes the process of identifying, assessing, and managing financial, legal, strategic and security risks to an organisation's capital, operations, and earnings. Financial Management businesses typically have a Risk Management function to ensure they identify risks to their operations and manage these risks, in order to mitigate exposure and impact.
- **Insurance Management** is defined as the section of the finance industry that provides risk management solutions in the form of insurance contracts. Insurance contracts serve as a hedge against uncertain or contingent losses to assets or occurrences which may impact business operations.

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].

Advances in technology have enabled devices like satellites to generate large-scale location data. With improved data processing capabilities, including increased computing power and access to cloud computing and AI, analysing this data has become more accessible. These advancements have democratised the use of geospatial data. Satellite EO is a key source of this data, with the Copernicus program providing free and open access to it. The growing number of satellites, equipped with diverse instruments, facilitates innovative solutions across various markets. Enhanced data processing and analytics services, such as those from Amazon AWS, further support this development. In 2022, there were 1,030 EO satellites, representing 22% of all satellites [3]. A 2021 report by the UK Centre for Greening Finance highlighted emerging and mature applications of geospatial data in enriching financial services.

The global civil EO services market is valued at 2.8 billion Euros and is expected to nearly double to 5.5 billion Euros within the next decade, with some forecasts predicting even higher values [4]. Currently, the primary purchasers of EO services are in urban development and cultural heritage, agriculture, climate services, energy and raw materials, and infrastructure. In contrast, the finance and insurance sector ranks lower in EO service demand, but it is considered an "emerging market" by the European Union Agency for the Space Programme

[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).

(EUSPA). In 2021, this sector purchased EO services worth 145 million Euros, with expectations to reach 1 billion Euros by 2031. Alternative estimates suggest even higher growth. With a projected compound annual growth rate (CAGR) of 20%, the finance and insurance sector are expected to become increasingly important in the EO market. 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]. 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.

4.1. PROJECT OVERVIEW

The activity "Best 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 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.

4.2. CARDINAL REQUIREMENTS

In total 63 user requirements were considered for the EO-FIN in which all have been addressed. Below are the cardinal requirements responded to during the EO-FIN.

- [RQ.12]: WHAT the geoinformation needs are in the concerned business processes.
- [RQ.13]: HOW geoinformation products and services should be combined with other data and embedded within the established working practices and regulatory constraints within the target market domain(s).
- [RQ.14]: HOW the requirements vary according to geographic regions and annual seasons.
- [RQ.15]: WHICH are the existing, mature, and available EO-based products relevant to the FM sector?
- [RQ.16]: TO WHAT extent do these products meet the identified stakeholder requirements?
- [RQ.17]: WHAT constraints must be complied with in the generation of the geoinformation products to ensure that these are accepted as fit for the intended purpose?
- [RQ.18]: WHAT the information content, availability and accuracy of these EO products are?
- [RQ.19]: WHAT gaps exist between the information requirements and current EO capabilities now, and can these gaps be addressed over the next 5 years (e.g., through already planned new EO missions)?

4.3. OBJECTIVES

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: Investment Management, Green Finance, Risk Analysis, and Insurance Management.
2. Identify and characterise EO-based products and services meeting the needs of the domains of concern by assessing the gaps between these and what EO can offer, now and in the near 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 FM sector.

[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).

5. Disseminate the analysis results via key international associations and bodies representing the sector, like EARSC (on the EO side).

4.4. PROJECT BREAKDOWN STRUCTURE

Error! Reference source not found. 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

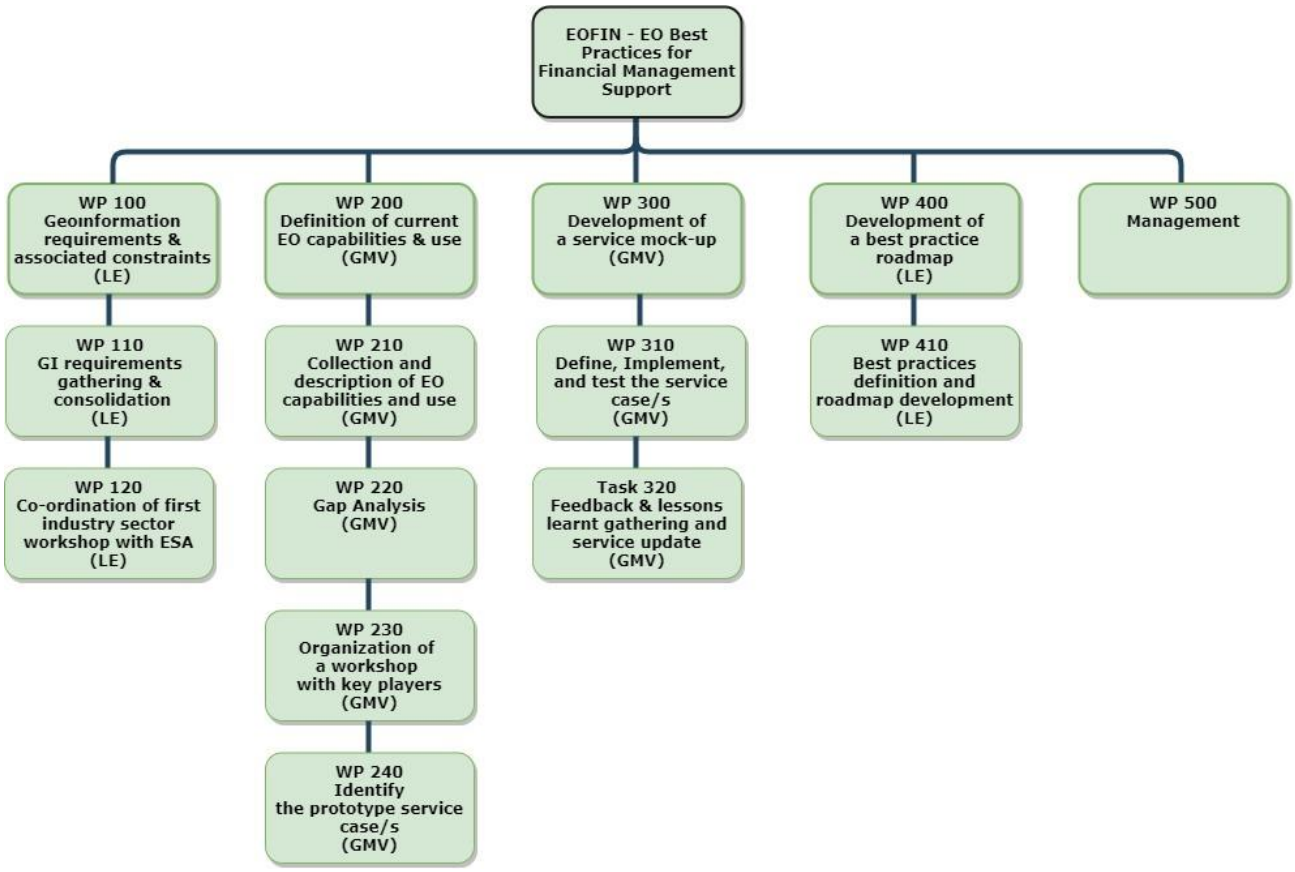


Figure 4-1 EO-FIN work breakdown structure.

5. PROJECT OUTCOMES

5.1. GEOINFORMATION REQUIREMENTS

To obtain the geoinformation needs most recent and relevant information directly from Financial Management professionals, four distinct activities were undertaken. Firstly, an extensive desktop review was conducted to examine geospatial data in the financial sector, identify the drivers behind the demand for spatial finance, and pinpoint potential stakeholders in this field. Secondly, a workshop was organised to gather feedback, thoughts, and valuable contacts from stakeholders operating within this space. Thirdly, a series of semi-structured one-to-one interviews were carried out with stakeholders from the private, public, and third sectors. The aim was to unravel and gain a deeper understanding of geospatial pain points, opportunities, as well as user needs and requirements. Finally, a synthesis task was carried out to consolidate this information, improve it via the review of a Stakeholder Board review process, and report it publicly for further comment and dissemination of useful findings.

The forecasted growth rate of EO services in the insurance and finance sector suggest there is a latent demand ready to be captured. Why this has not already been realised could have many explanations, including that the sector finds little utility in EO data.

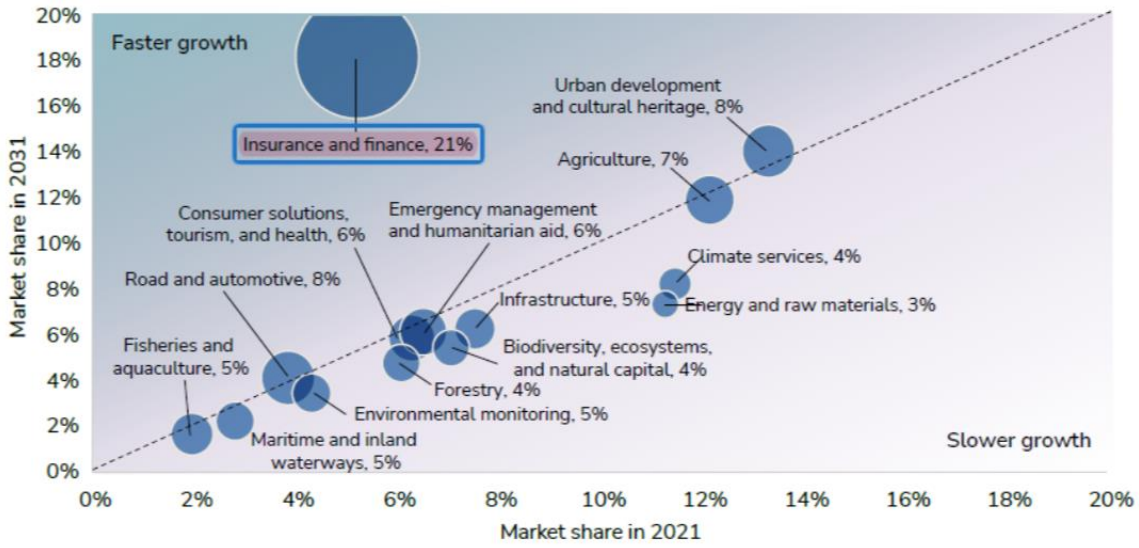


Figure 5-1 EO segment market shares over the next decade (Source: EUSPA. (2022). 'EO and GNSS Market Report').

However, surveys about the sector's data use and data needs tell a different story. In fact, many executives in the financial sector are keen to explore alternative data sources, generally. In a 2017 survey, Greenwich Associates found that 80% of investors wanted access to alternative data sources[6] in their search for alpha[7]. The World Economic Forum also found that satellite imagery was the least used data type among alternative data, based on a survey of the financial sector. The authors suggest cost, a lack of skill, and limited use cases are driving the lower adoption rates.

All four primary domains (including, investment management, risk analysis, green finance, and insurance management) are highly dependent on information to efficiently carry out their roles in the broader financial

[6] Cambridge Centre for Alternative Finance. (2020) 'Transforming Paradigms – A Global AI in Financial Services Survey'.

[7] Alpha refers to a measure in the finance sector of performance, indicating when a strategy, trader, or portfolio manager has managed to beat the market return or other benchmark over some period. It is often considered the active return on an investment.

ecosystem. Geoinformation is increasingly viewed as one source of alternate data to drive further improvements across these domains.

Users' requirements were classified into the following Definition Levels:

i. Generic Need

ii. Observation Need

iii. Specific Product

iv. Technical Requirement

Where:

- **Generic Need**

  This category does not refer to any specific observation need, nor to any product requirement, but to the service boundary conditions that make it possible for the user to utilize a geo-information product or optimize the use of it (e.g. a method of accessing the data).

  Additionally, if the user is not able to express the requirement as an Observation need or a Specific Product or a Technical Requirement, then his/her need will be a 'Generic Need'.

  Generic Needs help us understand the protocols underneath the business processes, that is: the stakeholders' 'jobs'.

- **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. "Better crop production monitoring").

  Observation Needs help us understand the need for geospatial data from the personal perspective of stakeholders.

- **Specific Product**

  This field is to indicate the requirement of a new product, e.g. "Annual cocoa tree plantation estimates", which has been specifically identified – as opposed to the broader needs expressed as Observation Needs. Despite this higher level of precision, no technical info is provided.

  Specific Products helps us understand the need for specific geospatial products and services.

- **Technical requirement**

  This field is to indicate requirements expressed with specific figures referring to technical aspects (e.g. spatial or temporal resolution). In contrast with previous examples, this field could be a "1-m resolution layer with annual olive trees counts within land parcels". Note the difference with the example above where no technical specification is provided by the user. This information will go in Block 3 (below).

  Technical Requirements help us understand whether satellite-based EO is a solution for the "pains" of a given stakeholder, or not, in which case there is gap between requirement and capability.

Table 5-1 describes 25 user needs as generic needs with associated financial domains and subdomains.

Table 5-1 User requirements: Generic needs.

ID	User's Expression	Financial domain	User Subdomain
UN1	Lower cost of integration of geo-information into existing systems and data processes	Investment management	Cost management

UN2	Easy-to-access complementary data layers	Investment management	Data integration
UN3	Independent validation for data accuracy	Investment management	
UN4	Less limited data disclosure from operators and owners	Investment management	
UN5	Skills to integrate/reconcile geo-information with existing systems and data processes	Investment management	Skills
UN6	Standardised annual or quarterly reporting	Investment management	Standardisation
UN7	Standardised data	Investment management	Standardisation
UN8	Due diligence process support	Investment management	
UN20	Lower cost of data onboarding and integration for high-resolution geo-information	Green finance	Cost management
UN21	Need to combine geoinformation with other relevant (non-geospatial) data sources	Green finance	Data integration
UN22	Need to consider the cost of acquiring data from providers	Green finance	Cost management
UN23	Need to upgrade the technical knowledge or skills within their organisations	Green finance	Skills
UN24	Need for awareness-raising campaigns	Green finance	Demonstrations
UN25	Need for easy-to-interpret EO products for would-be investors in Green Finance mechanisms to ensure efficient aggregation of information	Green finance	Standardisation
UN33	Need more in-house expert teams to analyse and use geo-information data	Risk analysis	Skills
UN34	Need a larger middle layer of companies able to generate ready-to-use data	Risk analysis	Data integration
UN35	Combination of in situ "ground truths" (data) with geo-information	Risk analysis	Data integration
UN36	Integration of climate risk models and 'value at risk' models	Risk analysis	Data integration
UN37	Projection of risk to portfolio assets into the future	Risk analysis	Risk screening
UN48	Regular assessment of risk pricing and policy portfolio	Insurance management	
UN49	Collecting field data to calibrate remote sensing geo-information	Insurance management	Data integration
UN50	Timely data to keep models useful	Insurance management	
UN51	Guidance to overcome regulatory barriers to the use of satellite-derived geoinformation in insurance	Insurance management	
UN52	Achieving high enough spatial resolution for asset location geoinformation	Insurance management	
UN53	Developing viable business models with cash flow sustained beyond pilot schemes	Insurance management	

Table 5-2 describes user needs as observation needs in detail in three sections preliminary information, traceability and characterisation, and technical requirements.

Table 5-2 User requirements: Observation needs.

ID	User's Expression	User Domain	User Subdomain	Area to monitor	Spatial resolution	Temporal Coverage and Resolution	Data throughput
UN9	Understanding stock levels and monitoring supply chains	Investment management	Stock level and supply chain analyses	Storage facilities and single-sites - 1km x 1km	10m x 10m	High refresh rate to understand the rate of change. The historical period to be covered is highly case-dependent.	Very quick tasking and data availability for analysis
UN10	Need to understand population density when making investment decisions	Investment management	Population analyses	Districts within a city - 1km x 1km	Building-level	Low refresh rate needed; multiple years of historical data useful for model calibration	Low need for rapid tasking or data availability
UN11	Realistic assessment of accessibility to assets	Investment management	Asset surroundings characterisation and mapping		Hundreds of metres - relevant pixels e.g. flood risk		
UN12	Analysis of potential risks in specific regions	Investment management	Asset surroundings characterisation and mapping	Project location	Project asset level	Dependent on risk level - length of coverage need is higher if determined in a high-risk situation	High need for rapid data availability
UN13	Need to geo-map clients	Investment management	Risk screening	Business operational geography	Building-level	Dependent on risk level - length of coverage the need is higher if determined in a high-risk situation	
UN14	Need to screen the feasibility of projects against different hazard criteria	Investment management	Project screening	Project location	Project asset level	Dependent on hazard risk level - length of coverage need is higher if determined in a high-risk situation	Tasking and data availability are required to be sufficient to feed into the screening and decision process
UN15	Need to monitor carbon intensity of portfolio assets	Investment management	Carbon-related analyses	Asset location	Asset level	Multi-year coverage, a high refresh rate to capture different phases of asset use	Data availability sufficient for regular reporting cycles
UN26	Need to monitor GHG emissions of projects funded	Green finance	Carbon-related analyses	Project location	Project asset level	Multi-year coverage, a high refresh rate to capture different phases of asset use	Data availability sufficient for regular reporting cycles
UN27	Need to assess historical trends and baseline of natural assets	Green finance	Project screening	Asset location	Asset level	Multi-year coverage, variable refresh rate depending on type of natural asset	Data availability sufficient for regular reporting cycles
UN38	Need for trustworthy time series of reliable data on assets	Risk analysis	Retrospective analyses	Asset location	Asset level	High need for historical data to calibrate predictive models	Low need for rapid tasking or data availability

UN39	Need to assess the potential impact of business activities or investments on ecosystems and biodiversity	Risk analysis	Biodiversity	A wide area around business assets	High requirement for precise spatial resolution	Annual coverage and medium refresh rate to ensure a full understanding of seasonal changes in the ecosystem monitored	
UN40	Need to monitor the risk of sea level rise threatening coastal property, infrastructure, and supply chains	Risk analysis	Climate change vulnerability	Asset location	Asset level	Low need for temporal resolution and, a high need for long-term coverage to understand trends	Low need for rapid tasking or data availability
UN41	Need to monitor the impact of increased temperatures on assets	Risk analysis	Climate change vulnerability	Asset location	Asset level	Low need for temporal resolution, a high need for long-term coverage to understand trends	High need for rapid tasking and data availability following damaging events
UN42	Need to monitor the impact of droughts on assets	Risk analysis	Climate change vulnerability	Asset location	Asset level	Low need for temporal resolution, a high need for long-term coverage to understand trends	High need for rapid tasking and data availability following damaging events
UN43	Need to monitor changing precipitation patterns and flood risk in the vicinity of vulnerable assets	Risk analysis	Climate change vulnerability	Asset location	Asset level	High need for historical data to calibrate predictive models	Low need for rapid tasking or data availability
UN44	Need to measure the area vulnerable to wildfires before events	Risk analysis	Climate change vulnerability	Asset location	Asset level	High need for historical data to calibrate predictive models	Low need for rapid tasking or data availability
UN45	Need to measure the area affected by wildfires after the fact	Risk analysis	Climate change vulnerability	Asset location	Asset level	High need for a small amount of historical data for pre-event comparisons	High need for rapid tasking and data availability following damaging events
UN46	Need to measure the intensity of wildfires (level of damage to assets)	Risk analysis	Climate change vulnerability	Asset location	Asset level	High need for a small amount of historical data for pre-event comparisons	High need for rapid tasking and data availability following damaging events
UN54	Detecting crop damage at the level of individual farms/fields	Insurance management	Crop analyses	Entire agricultural region - 100s of square km	Individual farm level	High need for a small amount of historical data for pre-event comparisons	High need for rapid tasking and data availability following damaging events

Table 5-3 describes user needs as specific products in detail in three sections preliminary information, traceability and characterisation, and technical requirements.

Table 5-3 User requirements: Specific products.

ID	User's Expression	User Domain	User Subdomain	Area to monitor	Spatial resolution	Temporal Coverage and Resolution	Data throughput
UN16	Nighttime light monitoring	Investment management	Economic activity and urban development analyses	Regions within a country	10s to 100s of meters	Low refresh rate needed; low temporal coverage needed	Low need for rapid tasking or data availability
UN17	Need near real-time tracking of marine vessels to understand their routes and estimate fuel usage	Investment management	Economic activity and urban development analyses	Entire shipping routes/seas likely to sail in	10s of meters	The high temporal resolution allows better route approximations. Constant coverage is required for the duration of the analysis.	Need real-time tracking but low data availability need
UN18	Need to monitor crop productivity	Investment management	Crop analyses	Entire agricultural region - 100s of square km	Individual farm level	Annual coverage, greater refresh rate at key planting/harvesting periods	High need for rapid tasking and data availability to onboard new fields
UN19	Identifying types of crops being grown is essential	Investment management	Crop analyses	Entire agricultural region - 100s of square km	Individual farm level	Annual coverage, higher refresh rate at key planting periods	High need for rapid tasking and data availability to onboard new fields
UN28	Need to classify the types of crops being grown in order to assess the sustainability and environmental impact of agricultural investments	Green finance	Crop analyses	Entire agricultural region - 100s of square km	Individual farm level	Annual coverage, greater refresh rate at key planting/harvesting periods	
UN29	Need to accurately measure the planted area for crops	Green finance	Crop analyses	Entire agricultural region - 100s of square km	Individual farm level	Annual coverage, higher refresh rate at key planting periods	High need for rapid tasking and data availability to onboard new fields
UN30	Need for monitoring with accurate measurements of the growth and health of trees	Green finance	Crop analyses	Entire forests - 1000s of square km	Individual farm level	Regular monitoring throughout the year with a low refresh rate	Low need for rapid tasking or data availability
UN31	Need to link tree planting parcels to estimate the number of trees planted	Green finance	Crop analyses	Entire forests - 1000s of square km	Tree level; a few metres	Regular monitoring throughout the year with a low refresh rate	Low need for rapid tasking or data availability

UN32	Need to periodically estimate the growth of above-ground carbon stocks (in forests).	Green finance	Carbon-related analyses	Entire forests - 1000s of square km	Tree level; a few metres	Higher refresh rate in regions of faster growth (e.g. tropics); quarterly in colder climates, monthly or more regular elsewhere	Low need for rapid tasking or data availability
UN47	Need up-to-date geospatial data on residential and industrial infrastructures' locations	Risk analysis	Asset surroundings characterisation and mapping	Business operational geography	Building-level	Low refresh rate needed; low temporal coverage needed (to match changes in asset locations)	Low need for rapid tasking or data availability
UN55	Need to detect changes in land use (at the level of individual buildings)	Insurance management	Economic activity and urban development analyses	Business operational geography	Building-level	Low refresh rate needed; multiple years of historical data useful for model calibration	Low need for rapid tasking or data availability
UN56	Automatically update changes in population density estimates based on observable land use changes	Insurance management	Economic activity and urban development analyses	Insured area	Building-level	Low refresh rate needed; multiple years of historical data useful for model calibration	

5.2. CURRENT EO CAPABILITIES RESPONDING TO GEOINFORMATION NEEDS OF THE FINANCIAL MANAGEMENT SECTOR

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.

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 (Figure 5-2). 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.

Figure 5-2 Overview of the identification and consolidation process of the current EO capabilities and use.

To prioritise the EO capabilities, all identified EO capabilities are classified into five categories (Table 5-4).

Table 5-4 The definition of the EO capabilities was identified during desk-based research, online surveys, 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.

Four tables below describe the current EO capabilities gathered during desk-based research, online surveys, and the workshop responding to the consolidated user requirements of four primary financial management domains.

Table 5-5 EO capabilities were identified during desk-based research (1,2), online surveys, 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 5-6 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		Vegetation height estimation	Deforestation monitoring	Tree inventory

	UN30: Need for monitoring with accurate measurements of the growth and health of trees and verifying the sustainability of forest management practices.	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 5-7 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 5-8 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

In total, 39 EO products (shown in green colour in Table 5-5, Table 5-6, Table 5-7, and Table 5-8) selected as the most relevant EO capabilities to the FM UNs. At this stage, the Team conducted two sets of questionnaires to understand how well these EO products respond to their UNs by asking the EO community about the maturity level of that EO product at a high level.

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 EO product currently found in the EO market, plus this product received poor response and maturity scores. Table 5-9 describes the final list of the consolidated current EO capabilities and their associated EO application field.

Table 5-9 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	

Table 5-10 List of the EO services derived addressing 18 UNs.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 **Error! Reference source not found.** section **Error! Reference source not found.**.

Table 5-10 List of the EO services derived addressing 18 UNs.

NO	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 the 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 hazard 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 the 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' impact on sustainable and environmental investments**	• Crop type and acreage mapping (P02) • Deforestation activities (part of P07) • Land degradation • Carbon sequestration in soil		UN28: Need to classify the types of crops being grown 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 trends and baseline of natural assets.	A potential machine learning model can be used for the 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 trends 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 (**Error! Reference source not found.** in the Annex C.) • Copernicus Land Services data (**Error! Reference source not found.** in the Annex C.) • Land use change (P01) • Land cover change (P17) • SPEI • FAPAR anomaly • Vegetation indices anomalies • Soil moisture anomaly		UN38: Need for trustworthy time series of reliable data on assets.	
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 datasets 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.	

5.3. GAP ANALYSIS TOWARDS FINANCIAL USERS WITH EO SERVICES

The gap analysis resulting from comparing the consolidated 32 Financial Management (FM) geo-information needs (documented in the D1.2 Geo-Information Requirements report) with the consolidated 38 Earth Observation (EO) products to address these needs (documented in D2.1 Current EO Capabilities report). The analysis combines both quantitative and qualitative assessments to provide a holistic understanding of the existing gaps.

To identify these gaps, a multi-faceted approach was undertaken. It included desk-based research conducted by the GMV team, interviews conducted by the London Economics team with experts in the financial sector, two workshops, and two separate online questionnaires. The first questionnaire was about the level of the utilisation of the EO products in the FM sector, and it was designed for experts in the FM sector. The second questionnaire focused on the capabilities of the EO products and was designed for experts in the EO industry. Three distinct types of gaps were identified during this analysis: Guideline gaps, Utilisation gaps, and Research and Development (R&D) gaps. Additionally, we have pinpointed certain critical gaps that deserve particular attention.

5.3.1. QUANTITATIVE ANALYSIS

A GGIM IDI NBR(MCA) was implemented for the consolidated 32 geo-information FM sector's needs (which were documented in the Geo-Information Requirements report (D1.2)) and the consolidated EO products (which were documented in the Current EO Capability report (D2.1)). The assessment of the FM sector's needs is based on the **demand** level criteria, while it was based on two criteria for EO products which are **capability** and **utilisation**. The demand and utilisation scores have been built up by experts in the FM sector, whereas the capability scores have been built up by experts in the EO industry.

Demand scores for each geo-information need were identified by London Economics based on a discussion with FM experts during the first workshop and a series of semi-structured one-to-one interviews that were carried out with FM stakeholders from the private, public, and third sectors. **Utilisation** scores for each EO product were identified through an online questionnaire disseminated to FM experts. **Capability** scores for each EO product were also identified via an online questionnaire shared with EO experts through the channels of GMV, the European Association of Remote Sensing Companies (EARSC), and Space for Climate.

correlation between the EO products and associated user needs:

Guideline Gap (If Capability > Demand):

Gap exist: If $0.5 \leq$ Capability - Demand < 1.

Critical Gap: If Capability - Demand ≥ 1.

Utilisation Gap (If Capability = Demand & Capability > Utilisation):

Gap exist: If $0.5 \leq$ Capability - Utilisation < 1.

Critical Gap: If Capability - Utilisation ≥ 1.

R&D Gap (If Capability < Demand):

The gap exists: If $0.5 \leq$ Demand - Capability < 1.

Critical Gap: If Demand - Capability ≥ 1.

In addition, we found that is important to identify **critical gaps**. Knowing the critical gaps will be greatly beneficial to the FM sector and EO industry to take urgent actions and decisions. We recognised a gap as critical when the difference between scores is more than or equal to one.

The user needs' ID and expression	The demand level of the need	Corresponding EO product(s)	Capability score		Utilisation score		Critical gaps
			Mean	STD	Mean	STD	
UN9: Understanding stock levels and monitoring supply chains	3	Fish Stock Assessment	2.80	1.17	1.40	0.49	
		Green Biomass and Yield estimation	3.15	0.77	2.40	0.80	
		Lithology and Surficial Geology Mapping	3.67	0.47	2.00	0.00	Utilisation
		Milk and Cattle (in weight) Productivity Estimation	2.83	1.07	2.00	0.71	
		Monitoring Changes in Port Activity Patterns	3.30	0.90	2.33	0.94	
		Stock Changes in Oil Tanks with Floating Roof	3.60	0.66	2.83	1.07	
UN10: Need to understand population density when making investment decisions	3	Land Use Maps	3.67	0.47	2.71	0.70	
		WorldPop – Population Counts	3.60	0.49	3.00	0.89	
UN11: Realistic assessment of accessibility to assets	2	Land Cover Maps	4.00	0.00	2.86	0.64	Guideline
		Land Use Maps	3.67	0.47	2.71	0.70	Guideline
		Mapping Travel Times to Assets	4.00	0.00	2.50	1.32	Guideline
UN12: Analysis of potential risks in specific regions	3	Coastal Erosion	3.70	0.46	2.17	1.07	Utilisation
		Drought Monitoring at the Assets Level	3.43	0.62	2.71	0.70	
		Heat Hazard Map	3.33	1.11	2.80	0.98	
		Identification of Flood Hazard Areas	3.54	0.84	3.13	0.60	
		Identification of Trends Related to Shifts in Rainfall Patterns	3.11	0.99	2.60	1.02	
		Predicting Terrorism Hotspots	3.00	0.82	2.50	1.12	

		Satellite-Derived Bathymetry for Port and Coastal Monitoring	3.50	0.50	2.50	0.87	Utilisation
		Wildfires Danger Forecasting	3.50	0.87	2.71	0.70	
UN13: Need to geo-map clients	4	Drought Monitoring at the Assets Level	3.43	0.62	2.71	0.70	
		Identification of Flood Hazard Areas	3.54	0.84	3.13	0.60	
		Identification of Trends Related to Shifts in Rainfall Patterns	3.11	0.99	2.60	1.02	
		Land Use Maps	3.67	0.47	2.71	0.70	
		Wildfires Danger Forecasting	3.50	0.87	2.71	0.70	
UN14: Need to screen the feasibility of projects against different hazards criteria	3	Coastal Erosion	3.70	0.46	2.17	1.07	Utilisation
		Drought Monitoring at the Assets Level	3.43	0.62	2.71	0.70	
		Heat Hazard Map	3.33	1.11	2.80	0.98	
		Identification of Flood Hazard Areas	3.54	0.84	3.13	0.60	
		Identification of Trends Related to Shifts in Rainfall Patterns	3.11	0.99	2.60	1.02	
		Wildfires Danger Forecasting	3.50	0.87	2.71	0.70	
UN15: Need to monitor carbon intensity of portfolio assets	4	GHG Emissions Monitoring	2.90	1.04	2.33	0.94	R&D
UN16: Nighttime light monitoring	3	Nighttime Light Monitoring	3.50	1.02	2.86	1.12	
UN17: Need near real-time tracking of marine vessels to understand their routes and estimate fuel usage	3	Ship Detection and Categorization	3.50	0.76	2.00	1.26	Utilisation
UN18: Need to monitor crop productivity	2	Crop Phenology, Rotation, and Number of Seasons	3.70	0.64	2.00	0.58	Guideline
		Crop Type and Acreage Mapping	3.50	0.50	2.60	1.02	Guideline
		Green Biomass and Yield estimation	3.15	0.77	2.40	0.80	Guideline
		Tillage, and Crop Residue Cover Practices	3.00	0.76	1.80	0.40	Guideline

UN19: Identifying types of crops being grown is essential	3	Crop Type and Acreage Mapping	3.50	0.50	2.60	1.02	

Table 5-11. Green Finance user needs demand scores with the capability and utilisation scores for the associated EO products.

The user needs' ID and expression	The demand level of the need	Corresponding EO product(s)	Capability score		Utilisation score		Critical gaps
			Mean	STD	Mean	STD	
UN26: Need to monitor GHG emissions of projects funded	3	Green House Gases (GHG) Emissions Monitoring	2.90	1.04	2.33	0.94	R&D
UN27: Need to assess historical trend and baseline of natural assets	3	Land Cover Maps	4.00	0.00	2.86	0.64	Guideline
		Land Use Maps	3.67	0.47	2.71	0.70	
		Monitoring Reforestation and Deforestation Activities	3.93	0.26	3.00	0.82	
UN28: Need to classify the types of crops being grown in order to assess the sustainability and environmental impact of agricultural investments	3	Crop Type and Acreage Mapping	3.50	0.50	2.60	1.02	
		Monitoring Reforestation and Deforestation Activities	3.93	0.26	3.00	0.82	
UN29: Need to accurately measure the planted area for crops	3	Crop Type and Acreage Mapping	3.50	0.50	2.60	1.02	
		Green Biomass and Yield estimation	3.15	0.77	2.40	0.80	
	3	Crop Health (Diseases and Pests detection)	3.20	0.65	2.20	0.75	Guideline
		Estimation of Above-ground Carbon Stocks in Forests	3.27	0.96	2.29	0.88	Utilisation

UN30: Need for monitoring with accurate measurements the growth and health of trees		Monitoring Reforestation and Deforestation Activities	3.93	0.26	3.00	0.82	
UN31: Need to link tree planting parcels to estimate the number of trees planted	3	Trees Counting	3.63	0.48	2.14	0.64	Utilisation
UN32: Need to periodically estimate the growth of above-ground carbon stocks (in forests).	3	Estimation of Above-ground Carbon Stocks in Forests	3.27	0.96	2.29	0.88	Utilisation

Table 5-12. Risk Analysis user needs demand scores with the capability and utilisation scores for the associated EO products.

The user needs' ID and expression	The demand level of the need	Corresponding EO product(s)	Capability score		Utilisation score		Critical gaps
			Mean	STD	Mean	STD	
UN37: Projection of risk to portfolio assets into the future	2	Monitoring Highway and Railway Networks	3.38	0.99	1.80	0.75	Guideline
		Coastal Erosion	3.70	0.46	2.17	1.07	Guideline
		Crop Health (Diseases and Pests detection)	3.20	0.65	2.20	0.75	Guideline
		Dams' Safety	3.25	0.83	2.50	0.50	Guideline
		Drought Monitoring at the Assets Level	3.43	0.62	2.71	0.70	Guideline
		Identification of Flood Hazard Areas	3.54	0.84	3.13	0.60	Guideline
		Monitor Slow-Moving Subsidence	3.44	1.07	2.00	0.82	Guideline
		Monitoring Solar Panel Installations	2.78	1.13	2.25	0.83	
		Predicting Terrorism Hotspots	3.00	0.82	2.50	1.12	
		Surveillance of Oil and Gas Pipelines for Geohazard and Ground Subsidence Vulnerabilities	3.50	0.71	2.25	1.09	Guideline
		Vegetation Height Estimation	3.17	0.99	2.40	0.49	Guideline

UN38: Need for trustworthy time series of reliable data on assets	4	Green Biomass and Yield estimation	3.15	0.77	2.40	0.80	
		Land Cover Maps	4.00	0.00	2.86	0.64	Utilisation
UN39: Need to assess the potential impact of business activities or investments on ecosystems and biodiversity	2	Land Cover Maps	4.00	0.00	2.86	0.64	
		Monitoring Reforestation and Deforestation Activities	3.93	0.26	3.00	0.82	Guideline
		Oil Spill Detection	3.40	0.80	2.25	0.83	Guideline
UN40: Need to monitor the risk of sea level rise threatening coastal property, infrastructure, and supply chains	3	Coastal Erosion	3.70	0.46	2.17	1.07	Utilisation
		Land Cover Maps	4.00	0.00	2.86	0.64	
UN41: Need to monitor the impact of increased temperatures on assets	2	Heat Hazard Map	3.33	1.11	2.80	0.98	Guideline
		Impact of increased temperatures on soil moisture and vegetation condition	3.17	1.21	2.20	0.75	Guideline
UN42: Need to monitor the impact of droughts on assets	2	Drought Monitoring at the Assets Level	3.43	0.62	2.71	0.70	Guideline
UN43: Need to monitor changing precipitation patterns and flood risk in the vicinity of vulnerable assets	3	Identification of Flood Hazard Areas	3.54	0.84	3.13	0.60	
		Identification of Trends Related to Shifts in Rainfall Patterns	3.11	0.99	2.60	1.02	
		Land Cover Maps	4.00	0.00	2.86	0.64	
		Land Use Maps	3.67	0.47	2.71	0.70	
UN44: Need to measure the area vulnerable to wildfires before events	3	Wildfires Danger Forecasting	3.50	0.87	2.71	0.70	
UN45: Need to measure the area affected by wildfires after the fact	2	Post Wildfires Monitoring (Area and Severity)	3.83	0.55	3.00	0.82	Guideline

UN46: Need to measure the intensity of wildfires (level of damage to assets)	2	Post Wildfires Monitoring (Area and Severity)	3.83	0.55	3.00	0.82	Guideline
UN47: Need up-to-date geospatial data on residential and industrial infrastructures' locations	4	Building Inventory	3.64	0.77	2.25	0.83	Utilisation
		Land Use Maps	3.67	0.47	2.71	0.70	

Table 5-13. Insurance Management user needs demand scores with the capability and utilisation scores for the associated EO products.

The user needs' ID and expression	The demand level of the need	Corresponding EO product(s)	Capability score		Utilisation score		Critical gaps
			Mean	STD	Mean	STD	
UN55: Detecting crop damage at the level of individual farms/fields	3	Crop Health (Diseases and Pests detection)	3.20	0.65	2.20	0.75	Utilisation
UN56: Need to detect changes in land use (at the level of individual buildings)	2	Land Use Maps	3.67	0.47	2.71	0.70	Guideline
UN57: Automatically update changes in population density estimates based on observable land use changes	2	WorldPop – Population Counts	3.60	0.49	3.00	0.89	Guideline

5.3.2. QUALITATIVE ANALYSIS

Quantitative analysis (which is described in the previous section), while valuable for providing numerical data and measurable insights, is not sufficient on its own for a complete understanding of the gaps. Quantitative data alone may oversimplify or miss important details. Therefore, qualitative analysis is crucial to complement quantitative data by providing insights about the reasons and factors that lead to certain quantitative results.

The qualitative analysis was carried out to give deep insights into the different types of gaps described previously, guideline, utilisation, and R&D gaps.

For guideline and utilisation gaps, the qualitative analysis was conducted via the online utilisation questionnaire which was described earlier. As we mentioned, based on the utilisation score selected by a participant, there was a question about the reason for the selected level of utilisation (see section 5 of [RD8]).

For R&D gaps, the qualitative analysis was carried out via three different activities: desk-based research conducted by the GMV team, workshop group discussions, and an online capability questionnaire. In the online questionnaire as mentioned earlier, if respondents chose any of these three choices (i.e., not all respond, partially respond, or moderately respond). The qualitative gap analysis was presented for each 38 EO products. It comes with Constraints and limitations, Relevant user needs, R&D gaps, Potential improvement drivers, and utilisation gaps in three criteria no utilisation, low utilisation, and medium utilisation. Please refer to 6.2.1.1 of [RD8].

5.4. EO USE CASE FOR THE FINANCIAL MANAGEMENT SECTOR

The selection of the prototype for the EO service case considers both the anticipated impact it will have on addressing the FM sector's geo-information needs and the effort required for its development. The approach to defining a fully fit-per-purpose prototype involves weighing the resources, time, and expertise dedicated to developing the prototype against the potential positive outcomes it is expected to deliver for FM stakeholders.

Different activities were conducted to evaluate both **impact and effort**.

The activities to evaluate the impact included:

- Analysis of the demand levels of the consolidated FM geo-information requirements which were documented in the D2.2 Gap Analysis report. The demand level describes the degree of interest, enthusiasm, and recognition expressed by stakeholders or potential users regarding a specific geospatial user need.
- Analysis of the utilization and capability levels of the consolidated EO products which were also documented in the D2.2 Gap Analysis report. Utilization level refers to the degree of utilization of the EO product by the FM sector. Capability level refers to the EO product's ability to meet the relevant FM user needs.
- Prioritise 38 consolidated EO products based on their impact on the Finance industry through members of the Stakeholder Board (SB) feedback.
- Conduct a series of one-to-one interviews with SB members to further assess the impacts of the EO products by considering the technical specifications of the products and the detailed functionalities expected on the virtual platform.

The activities to evaluate the effort included:

- The EO-FIN Team internally evaluated to determine the time and resources required to develop each of the potential mature EO products with high priority from the SB members.

Therefore, a multi-physical risk observation was identified to meet specific requirements of the FM sector, particularly large investment firms like banks. It addresses aspects of investment management such as risk assessment, mitigation, insurance strategies, and adherence to environmental, social, and governance (ESG) regulatory standards. The prototype features an EO multi-physical risks observation service, focusing on historical events and forming layers of various physical risks with the highest impact on the sector.

This EO use case service includes four EO products such as include agricultural drought observation, flood extent mapping, heat hazard mapping, and past wildfire observations with five sub-products (burned areas, burned area in vegetation, date of the first detection, confidence level, and land cover of burned area).

This EO use case service was developed based on a web platform owned by GMV (called Prodigi) with a user-friendly interface tailored for non-technical users, facilitating easy access to EO data and analysis tools. It has a GIS base map enabling users to select the Area of Interest (AoI). Also, users can select and order the types of desired EO products plus downloading features at the end.

Gauteng Province in South Africa was chosen as the study area for this prototype. Gauteng Province is home to Johannesburg City known as significance as the wealthiest province and the financial hub of the African continent. Its dense population, economic activity, and exposure to physical risks make it an ideal location for testing the prototype's effectiveness in supporting financial decision-making. The study area has been chosen in a developing country to demonstrate the advantage of EO datasets in relevance and accuracy compared to more developed counties with highly accurate in-situ datasets.

5.4.1. EO DERIVED PRODUCTS

This EO use case service includes four EO products such as include agricultural drought observation, flood extent mapping, heat hazard mapping, and past wildfire observations with five sub-products (burned areas, burned area in vegetation, date of the first detection, confidence level, and land cover of burned area). Please see the tables (Table 9-1, Table 9-2, Table 9-3, Table 9-4, Table 9-5, Table 9-6, Table 9-8, and Table 9-9).

5.4.2. THE SERVICE ON THE PLATFORM

The following high-level features for financial users have been identified below, classified by the user goal they fulfil.

- Register for the services and log in: To register in the EO-FIN portal, users can sign up themselves and use the credentials to log in.
- Enter the portal: To enter the portal, users will log in using the username and password provided by the operator.
  - Order products: To order products, users will:
  - Select the service by browsing the available services and descriptions.
  - Select the area of interest from a list of predefined areas.
  - Select the temporal range (start date and end date).
  - Set the options and parameters required to run the service and customise the results (for instance the geographical level of data aggregation).
  - Add the order to a ‘shopping cart’.
- Review the shopping cart: The shopping cart contents can be reviewed, and some orders can be removed from it. It is also possible to go back to the portal and continue the navigation.
- Checkout: From the shopping cart, it is possible to confirm the orders or cancel the confirmation and go back to review the cart. The prototype does not consider payments for the orders, they will be provided for free.
- Check the status of my orders: The user will be able to review the status of the orders and their details.
- Receive the ordered products: Once an order is ready it will be possible to download the product to the user’s computer.
- Log out: It will be possible to close the session manually or to be disconnected after a period of inactivity.
- The prototype inherits the scalability capabilities of GMV Prodigi®. It is possible to add more resources to the Kubernetes cluster and therefore increase the capabilities of the system. One single instance of the Customer Services is capable of being accessed in parallel by 1000 users, while one instance of the Processing Platform can trigger thousands of processing per minute. The processing capability is therefore restricted to the number of processing nodes available in the cluster.
- At the storage level, Prodigi can store temporarily (according to the configuration) the output products in an S3 storage, this kind of storage can easily scale without performance impact. Nevertheless, in EO-FIN the generated products are not stored permanently and therefore we do not expect a need to increase this capability.

6. KEY ISSUES AND CHALLENGES

Cost considerations: Cost is one of the key barriers to adopting the EO service in the financial management sector. Generating EO products in particular EO products that are derived from high-resolution and near-real-time data can be expensive. The costs of EO-derived products are not limited to data acquisition but also include expenses related to data processing, integration, and analysis, which can be substantial. Financial institutions may find it challenging to justify the investment required for EO products, especially when the return on investment is not immediately apparent.

Lack of direct communication channels: Effective collaboration between EO service providers and financial management professionals is hindered by the absence of direct communication channels. This lack of direct dialogue leads to a disconnect where EO products may not be tailored to the specific requirements of financial institutions. Financial managers might not be aware of the potential applications and benefits of EO data, while EO providers might not comprehend the financial sector's operational constraints and decision-making processes. One potential reason would be that financial experts often lack the technical knowledge to engage directly with EO specialists. Bridging this gap requires creating platforms or forums where both parties can interact, share insights, and address specific needs.

Lack of geospatial skills in the financial management sector: The financial management sector traditionally relies on economic data, market analysis, and risk assessment models that do not require expertise in geospatial technologies. The introduction of EO products necessitates a new set of technical skills, including data interpretation, spatial analysis, and integration of EO data with existing financial models. Many financial institutions lack the in-house expertise to effectively leverage EO data, creating a significant barrier to adoption. This skills gap requires substantial training and development efforts, which can be both time-consuming and costly.

In response to a poll question during the workshop, 54% of participants thought that a lack of technical knowledge or skills to analyse data was the main barrier to using geospatial data for Green Finance.

Complexity of IT systems: Financial institutions operate complex IT systems that are heavily regulated and designed to handle vast amounts of data. Integrating EO data into existing systems can be intricate and time-consuming. Compatibility issues, data formats, regulatory compliance, operational efficiency, and security protocols pose challenges. The complexity of achieving such integration, coupled with the risk of potential disruptions, discourages financial institutions from adopting EO technologies. Collaborative efforts between EO providers, IT experts, and financial managers are essential to streamline integration and ensure seamless data flow.

7. PROJECT FINDINGS

7.1. FINANCIAL MANAGEMENT'S REQUIREMENTS

7.1.1. DESK-BASED RESEARCH

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. In particular, further analysis of the use cases presented allowed for inference of high-level user requirements in different domains in terms of spatial and temporal resolution as well as information integration with other data sources.

Another valuable source of information on the uses and challenges of geoinformation within the Financial Management sector was the recent ESA 'Space for Green Finance' study.[8] This study noted that the three key challenges that spatial finance can provide solutions to are 1) data collection, 2) monitoring, and 3) verification. Each of these use-case areas is currently 'dominated' by 'indirect measurements and estimations'.[9]

A report from the WWF[10] identifies six 'major gaps to be resolved', highlighting core areas of emerging demand as the spatial finance sector develops. These major gaps are:

1. A lack of asset data, openly or commercially available, to enable spatial finance assessment of assets, companies, and portfolios.
2. Lack of robust climate and environmental data to use as observational datasets within spatial finance.
    a. Issues with format, frequency, relevance, accuracy, comparability, topic coverage, accessibility, saturation
3. Difficulty in accurately assigning subsidiaries to parent companies, and consistently matching parent companies across different systems.
4. Complexity around the establishment of benchmarked methods to define climate and environmental impact and risk across different industries.
5. Lack of robust supply chain data to use within spatial finance and high data sensitivities around the use of such data.
6. Legal issues and data challenges in the application and use of Tier 4 data in spatial finance in the future.

The desk-based review identified several macro drivers for geospatial data use cases across these financial services activities. The discussion of user requirements and use cases is therefore organised by macro driver. These macro drivers are 1) demand from un- and underserved markets, 2) the rise of voluntary and mandatory environment, social, and governance (ESG) frameworks and 3) initiatives to green the financial system. Within the sections on each macro driver user requirements and use cases are outlined, with boxes providing more in-depth discussions of specific use cases and highlighting any practitioner examples, where feasible.

7.1.2. WORKSHOP

Below are the key findings during the workshop on consolidation user requirements.

- Many participants' organisations use (28%) or consider incorporating (47%) geospatial data into their Financial Management decisions.

[8] ESA Commercialisation Gateway. (2022). 'Space for Green Finance'

[9] The report also noted the opportunity size: the estimated current size of the global impact investing market stands at US$715 billion.

[10] WWF. (2020). 'Spatial Finance: Challenges and Opportunities in a Changing World'.

- One of the main barriers to using spatial data in finance management sectors is a lack of awareness, understanding, and technical knowledge within this field.
- Regulation and reporting requirements (or lack thereof at present) were also thought to be key blockers of geospatial data use across multiple domains.
- Promising uses of spatial data include monitoring portfolio assets for investment management, identifying physical risk to assets in risk management, and parametric insurance products.
- Participants across all domains felt that spatial data had exciting possibilities in the areas of sustainability and climate, including areas such as ESG investing, climate stress testing, and monitoring green finance targets.
- Sustainable agriculture and reforestation were identified as the key use sectors for geoinformation for Green Finance, particularly for crop monitoring in developing nations. The use of geoinformation for carbon monitoring and to assess green credentials was also mentioned.

7.2. EO USE CASE FOR THE FINANCIAL MANAGEMENT SECTOR

Based on the prioritized EO products and the one-to-one interviews with financial end users, it has been noted that there are a series of EO products that are highly interesting, and they can be grouped into two services such as multi-physical risk observations and Green House Gas (GHG) emissions monitoring.

- **Multi-physical risk observations**. We realized that big financial institutions are very interested in having historical data on physical risks, they need those long-term data to be used as inputs for their statistical models to calculate risk factors. They prefer to have these historical data rather than have a risk factor product provided by EO providers. The reason is that they have their models which they trust and would not share with the EO providers. In addition, we found that financial institutions are struggling to access data on different physical risks. And it would be great for them to access different physical risk layers in one platform. The physical risk products that they were interested in included:
  - Agricultural drought observations at the asset level, which is very important for the agricultural sector as well as real estate for mortgage and estimation of house and land prices.
  - Post wildfires assessment (area and severity), which is important in regions prone to wildfires like southern Europe.
  - Identification of past flood events, which can be used for assessing and determining the regions that are susceptible to flooding. It was also crucial for the stakeholders to know the type of flood (like surface, river, sea, or groundwater floods), which helps the financial institutions with risk mitigation strategies.
  - Identification of trends related to shifts in rainfall patterns, which is used to determine the probability of occurrence of extreme rainfall events over a specific region.
  - Heat hazard maps, that are used to identify areas prone to extreme heat events. These maps utilize satellite imagery to visualize temperature variations and heatwave patterns across a region.
  - Impact of increased temperatures on soil moisture and vegetation condition, this product along with heat hazard maps is very useful to assess the impact of temperature increases on the agricultural sector, country GDP, and inflation.
- **Green House Gas (GHG) emissions monitoring** which is important for financial institutions to assess the impact of climate change mitigation/transition policies. They are also of great importance to validate self-reported disclosures of emissions. Those products include:
  - GHG emissions monitoring focuses on continuous monitoring of GHGs such as Co2, No2, and CH4.
  - Estimation of above-ground carbon stocks in forests which focuses on the measurement of gains and losses of carbon associated with forest growth, loss, and degradation.

According to demand, capability, and utilization scores, the current EO products for GHG emissions monitoring are not capable of responding to the FM needs mainly due to the low spatial resolution of existing products which cannot enable the monitoring of emissions over asset levels. This gap was classified as a critical R&D gap on the scope of the D2.2 Gap Analysis report. Also, the resources needed for developing the product of estimation of 'above-ground carbon stocks in forests' are not available within the EO-FIN project as it requires LIDAR data to train a machine learning model. Also, there was a higher interest from the FM stakeholders in the multi-physical risk observations service over the current EO products for GHG emissions.

Therefore, when it comes to choosing which services to select as the use case for the prototype service, the **multi-physical risks observations service** is more of interest to the FM sector by providing a comprehensive and holistic view of various physical risks, allowing financial institutions to assess and mitigate potential threats to their assets and investments. A multi-physical risk observation service is proposed for the selection of the EO-FIN use case service. According to feedback from FM stakeholders gathered through interviews, there is a recognised need for historical data on various hazards. Here are some important characteristics of the anticipated service that are provided in the following table.

Table 7-1 Characteristics of the anticipated prototype service.

Feature	Related information
Target audience	Big financial institutions
Targeted FM domain	Investment management firms
Regions of interest	Not region-specific: it is based on risk and opportunity.
Expected output	They prefer raw output that can be used as input to other statistical models.
Target time frame	Historical monitoring
Output format	The end users prefer to have different output formats and choose among them, like: • Geospatial formats: raster and vector files • Tabular data
Accuracy expectation	High accuracy is not crucial for investment management.
Functionalities on the platform	• Allow end users to upload information. • Integrate EO data with companies' information. • Download raw data based on area of interest and time range. • Aggregate data to different geographical levels such as districts, municipalities, cities, and country levels.
Visualization features on the platform	Downloading digital raw data is more appealing than visualization of the information platform.

7.3. EO SERVICE WEB PLATFORM

The overall feedback received on the EO multi-natural hazard web platform service was positive. Users found the EO-FIN web platform service easy to use and interact with, appreciating the ability to select different products and layers within the same interface. The process of ordering, purchasing, and downloading products is straightforward and designed to accommodate users' varying levels of experience, focusing on one decision at a time. However, users also provided feedback aimed at further improving the EO-FIN web platform service for successful commercialisation.

A user remarked on the goal of the EO-FIN web platform prototype:

"I just want EO-FIN to be the platform that has thought about all possible use cases and aggregated that information in the most scientifically robust way, so I feel confident about downloading it and using it as the starting point of my analysis".

This section describes lessons learned during project life and findings in seven sections including barriers, web platform features, a wider range of EO-derived products for natural hazard risks, the accuracy of EO-derived products, financial management sector, stakeholder engagement, and commercialisation.

Area of Interest (AoI) identification

The users emphasised the importance of the user interface to offer broader features for selecting the Area of Interest (AoI). This improvement aims to facilitate user interaction with the platform and expand the range of use cases. Here is the list of those features:

- Ability to select the AoI as points besides polygons.
- Ability to upload a shapefile (.shp) or "CSV" files of the AoI. Those files shall contain polygons or points of information.
- In the case of the AoI as points, there is a need to add a buffer (the buffer can be fixed or predefined by the user) to cover the actual region of the AoI or the surrounding areas which are important for many applications where monitoring the suspectable risks over the surrounding areas is crucial.

Formats of EO-derived products

To address the diverse needs of users with varying experience levels in geospatial data, it is crucial to offer Earth observation (EO) products in a wider range of formats. Consider the following formats based on user proficiency:

1) TIFF and SHP Formats (Advanced Users):
   - Users with expertise in geospatial data analysis prefer formats like TIFF (Tagged Image File Format) and SHP (Shapefile). These formats allow seamless ingestion into specialised tools for processing and analysis.
2) PDF, CSV, and PNG/JPG Formats (General Users): For FM professionals with limited geospatial knowledge, providing EO products in more accessible formats is essential. Consider offering:
   - PDF: Suitable for easy viewing and sharing of maps and reports.
   - CSV (Comma-Separated Values): High interest among users in exporting data to Excel sheets or extracting information over specific Areas of Interest (AoIs) as points.
   - PNG/JPG: Useful for visual representation and inclusion in presentations.
3) Advantages of the CSV Format: The CSV format is particularly valuable for:
   - Exporting Data: Users can export information from maps directly to Excel sheets for reporting purposes.
   - Point Information: EO data in CSV format provides detailed information on specific points, which is essential for disclosure and decision-making.
   - Asset Boundaries: Some users may require CSV files covering entire asset boundaries, not just point locations. This flexibility accommodates varying use cases.

By diversifying the available formats, FM platforms can better serve their user base, ensuring accessibility and usability across different skill levels.

Metadata:

User feedback highlights the critical role of detailed metadata during the EO product selection process. The metadata and a product sample should be available for the users during the selection of the products. Here are why providing detailed metadata is necessary.

1) Informed Decision-Making:
   - Metadata provides essential context about each EO product. Users can assess its suitability, accuracy, and relevance to their specific needs.
   - Product sheets offer concise summaries, highlighting key attributes, spatial coverage, and temporal resolution.
2) Comparative Analysis:
   - By comparing metadata across different EO products, users can make informed choices. They can evaluate advantages over alternative resources like Google Earth Engine, Sentinel Hub (ESA), or governmental datasets.
   - Understanding the unique benefits of derived EO products empowers users to select the most suitable data source.

3) Demonstrating Value:
   - Detailed metadata and product sheets allow users to showcase the advantages of EO data to stakeholders, clients, or decision-makers.
   - Highlighting specific features (e.g., higher resolution, specialised indices) reinforces the value of EO products.
4) Downloadable Documentation:
   - The EO web platform should include features for downloading metadata documentation alongside each product.
   - Users can access this information offline, share it with colleagues, or refer to it during project planning.

Visualization of EO products during ordering:

Users highlight the importance of being able to Visualise EO products before purchasing, even if it involves a subscription for membership to preview it beforehand. Ideally, a web-based GIS view is preferable for an interactive presentation of the EO products however, having EO products in "PNG" could be sufficient for their needs to decide the suitability of the products before purchase.

GIS-based visualisation:

For those users who prefer visualising EO products within GIS software like QGIS and ArcMap, providing specific GIS styles for each EO product is highly beneficial. Here's why:

1) Customized visualisation:
   - GIS styles (such as symbology, colour ramps, and labelling) allow users to tailor the visualisation of EO data to their preferences.
   - Users can apply predefined styles directly to the EO layers, enhancing clarity and making the data more interpretable.
2) Consistent Representation:
   - By offering standardised styles to ensure consistency across different EO products.
   - Users can easily compare and analyse various datasets through a common visual language.
3) Ease of Interpretation: Well-designed styles enhance comprehension, like colour scales, transparency, and labels.

An ideal EO service for the FM sector should offer comprehensive, reliable, and user-friendly access to EO data tailored to financial applications. Such services must provide historical risk data, multi-hazard assessments, and forecasting capabilities in formats accessible to both geospatial experts and general users. This report details these characteristics, emphasising the need for integration with existing financial systems, robust data validation processes, and flexible delivery formats.

EO-derived products:

Here is the list of other natural hazard products to be considered in the EO service web platform:

- Flood mapping is identified as an EO product with the highest natural hazard impact. It has been noted that there is a need to further advance flood information and mapping.
- Shifts in rainfall patterns can help to analyse trends related to changes in rainfall patterns by determining the likelihood of extreme rainfall events in specific regions. This information is crucial for disaster preparedness and risk assessment. Next, mathematical models and historical data can provide insights into how rainfall patterns are evolving.
- Soil moisture and heat hazard maps are very useful, particularly in agricultural applications.
- The impact of increased temperatures can affect soil moisture and vegetation conditions. Combining heat hazard maps with soil moisture data allows us to assess the impact of temperature increases on the agricultural sector, the country's GDP, and inflation.

The need for hazard products depends on whether the service targets private asset management or public investment strategies. For private asset management, the availability of asset data, specific locations, and finer resolution data are crucial. However, public investment strategies may require broader coverage across various

locations. Beyond the provided hazards, stakeholders showed interest in additional natural physical risk products such as frost risks, coastal erosion, and sea level rise.

Accuracy of EO-derived products:

The accuracy of EO-derived products plays a crucial role in demonstrating their reliability. Banks and larger financial institutions follow a strict policy of not deploying any data or model without validation. This validation process ensures that EO data/products meet the required standards. Inside banks, there is a dedicated validation process for EO data/products. Banks validate the delivered EO data themselves to ensure accuracy and reliability.

It has been noted that an accuracy level above 80% is considered satisfactory for historical and observed data, while for climate model projections the expected accuracy tends to be lower due to the inherent complexity of modelling climate dynamics.

7.4. FINANCIAL MANAGEMENT SECTOR

1) One of the features of an ideal EO web platform serving the FM sector is to adopt users' different expertise levels in using and processing geospatial datasets including EO-derived products. Below, you can see three different FM users' expertise levels with recommendations features for the EO web platform to address their needs.
   - Users without GIS expertise require simple outputs like CSV, PNG, or PDF files.
   - Users with basic GIS knowledge can handle more complex outputs.
   - Users proficient in programming languages can work with raw data and APIs.
2) Compared to the majority of financial institutions, insurance companies have varying levels of expertise in geospatial datasets using sophisticated algorithms to accurately assess and manage risks, leveraging EO datasets for natural disasters, climate change impacts, and asset vulnerabilities. These proprietary algorithms are kept confidential preventing the broader industry from benefiting from these innovations, potentially slowing the advancement of geospatial applications in the sector.
3) Compared to the smaller institutions with lack in-house forecasting teams for physical risk and may rely on external services, large banks and insurance companies have substantial forecasting teams.

7.5. FINANCIAL STAKEHOLDERS' ENGAGEMENT

The EO-FIN project was highly engaged with financial sectors to acquire and consolidate the geospatial needs; define and develop the financial sector's best EO service; and understand the ideal characterisation of the EO service for successful commercialisation applications. The EO-FIN Team engaged with financial stakeholders through two sets of workshops (online and hybrid), one-to-one interviews, questionnaires (online and through email), meetings with stakeholder board members, and a webinar to the EO and FM community.

Compared to other sectors, the financial management sector is highly regulated and competitive with a proportion of secrecy. These factors resulted in the stakeholders being limited to sharing their opinions and their business practice information. To ensure the confidentiality of information shared and discussed during engagement with stakeholders the EO-FIN Team proposed the Chatham House Rule.

The process of attracting new stakeholders shall continue across the project life and not be limited to the initial part of the project and those who signed the letter of interest. This ensures that there is adequate engagement in case any of the stakeholders leave the stakeholder board. Also, during the project life, there are huge opportunities to reach new stakeholders with strong interests who bring significant benefits to the project.

To overcome the private firms' reluctance to share information, and to truly get to know the market from the inside, the EO-FIN team allocated the resources to sign a consultancy with two stakeholders who are members of the stakeholder board. The feedback and information provided ensure the EO-FIN team has deep access to sector/market-specific data and, in general, to the necessary insights and priorities to design and develop a prototype close to market, able to have a real impact on the business processes with chances of entering a commercial phase.

7.6. FUTURE MISSIONS AND THEIR CONTRIBUTION TO THE FINANCIAL SECTOR'S NEEDS

Table 7-2 Contribution of future missions in the following 5 years to the financial management geo-information needs.

Mission	User needs that can benefit from the mission				Contribution of the mission to the user needs
	Investment Management	Green Finance	Risk Analysis	Insurance Management	
BIOMASS		**UN30:** Need for monitoring with accurate measurements of the growth and health of trees and verifying the sustainability of forest management practices. **UN32**: Need to periodically estimate the growth of above-ground and soil carbon stocks (in forests).	**UN39:** Need to assess the potential impact of business activities or investments on ecosystems and biodiversity		• BIOMASS provides global coverage of the tropics. • Frequent and consistent measurements over time • Easy access to the data without a need to obtain and analyse raw data, which reduces time and cost.
Flex	**UN18:** Need to monitor crop productivity	**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 and verifying the sustainability of forest management practices.	**UN39:** Need to assess the potential impact of business activities or investments on ecosystems and biodiversity.	**UN55:** Detecting crop damage at the level of individual farms/fields	• Complementary to Sentinel-2 by adding a new dimension by measuring fluorescence, which offers complementary information for agriculture, ecology, and land management. • FLEX data can enhance the monitoring of crop health and stress. • It aids in understanding the responses of different ecosystems to environmental changes and human impacts.
LSTM	**UN12:** Analysis of potential risks in specific regions		**UN41:** Need to monitor the impact of increased temperatures on assets		Higher spatial resolution and revisit time for land surface temperature compared to currently available data
CHIME	**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.	**UN39:** Need to assess the potential impact of business activities or investments on ecosystems and biodiversity.	**UN55:** Detecting crop damage at the level of individual farms/fields.	• Complementing Sentinel-2, as hyperspectral data at appropriate spatial resolution and revisit time will add value in agricultural activities. This will enhance crop type and disease classification. • It will add value to biodiversity management and the characterization of soil properties.
ROSE-L			**UN37:** Projection of risk to portfolio assets into the future.		ROSE-L will reinforce the capabilities of current Copernicus C-band SAR systems as it will improve imaging performance in regions densely covered by vegetation, thanks to its longer

					wavelength L-band radio that can penetrate through the canopy.
CO2M	**UN15:** Need to monitor carbon intensity of portfolio assets	**UN26:** Need to monitor GHG emissions of projects funded			Global Carbon Monitoring at appropriate spatial resolution (2 km) and revisit time (11 days) at a global scale.
Carbon mapper	**UN15:** Need to monitor carbon intensity of portfolio assets	**UN26:** Need to monitor GHG emissions of projects funded			The relatively high resolution (30 m) and revisit time (1-7 days) for GHG monitoring at a global scale.
MAIA			**UN37:** Projection of risk to portfolio assets into the future. **UN39:** Need to assess the potential impact of business activities or investments on ecosystems and biodiversity.		• Provides global information about the sizes, compositions, and quantities of particulate matter in air pollution with appropriate spatial resolution (1km, and 300 m over some regions) and revisit time (≤ 1 day). • Integrate MAIA data with population health records
NISAR			**UN37:** Projection of risk to portfolio assets into the future.		Using both L-band and S-band with appropriate spatial resolution and revisit time.

7.7. TOWARDS COMMERCIALISATION

The commercialisation of EO services in the financial management sector holds significant potential to revolutionise primary domains including investment management, risk management, insurance management and green finances. However, realising this potential requires EO service offering characteristics required for the ideal EO service, overcoming key barriers, and demonstrating the value of EO-derived solutions.

Characteristics of the ideal EO service for FM

It was noticed that historical risk data is valuable for specific risk events by helping stakeholders make informed decisions based on past occurrences. Further, stakeholders appreciate having all risk hazard data accessible from a single platform. This centralised approach streamlines decision-making and risk assessment.

The current platform is useful for insurance companies to verify location impacts after disasters. Stakeholders showed a preference for such multi-natural hazard EO service to serve a variety of use cases and scenarios, for EO-derived products to be related to risks such as historical data (past risk events and patterns), probability of occurrence (assessing likelihood), forecasting (predicting future risks), and climate change projection (considering long-term impacts).

Recommended features of the EO web platform

- Is compatible with a wide range of formats and types of definitions AoI.
- Offers a full package of natural hazard products.
- Offers product visualisation (e.g., in PNG format) before purchasing and ordering.
- Provides detailed metadata and samples of products.
- Offers Various Format of the products according to the level of users.
- Expands the EO products in the probability of occurrence, forecasting, and projection of specific climate risks (climate risk scenarios).
- Providing further statistics including pixel counting and maximum to the current features including mean, median, and standard deviation at district and province levels.

Overcoming the current barriers:

To commercialise the EO service to overcome the barriers (section 6. Key issues and challenges) including cost considerations, lack of direct communication channels, lack of geospatial skills in the financial management sector, and complexity of IT systems.

The high cost of data and imagery can be addressed by leveraging public-private partnerships and open data policies. Governments and space agencies like the European Space Agency (ESA) have increasingly adopted open data initiatives, making vast amounts of freely available EO data. By encouraging collaborations between the agencies and private companies, it is possible to reduce costs associated with data acquisition. The cost of computation and storage can be reduced by adopting cloud computing and processing can facilitate the efficient processing and storage of large EO datasets, further driving down operational expenses. Further, implementing subscription-based models or tiered pricing strategies can make EO products more affordable and accessible to smaller financial institutions and emerging markets. Ideally, this approach can encourage innovation and scalability in the development of tailored financial management solutions by enhancing the sector's ability to leverage EO insights for risk assessment, investment management, and strategic planning.

Opening robust communication channels between financial users and EO service providers is key to the effective commercialisation of EO services in the financial management sector. Regular workshops, webinars, and joint development initiatives can help translate complex EO data into actionable insights tailored for financial applications, such as risk management, investment management, and market forecasting. It is expected that the feedback and findings drive iterative improvements in EO services, fostering innovation and customisation. Further, by promoting transparency and mutual understanding, these channels can bridge the gap between EO capabilities and financial sector requirements, ultimately enhancing the relevance and adoption of EO-derived solutions in financial decision-making processes.

The lack of technical skills and knowledge of handling and processing geospatial datasets can be addressed by providing targeted training courses for FM users. Training programmes such as workshops and real-world case studies enable users to develop the practical skills required to leverage EO data effectively. The training

programmes can significantly enhance the integration of EO services into financial decision-making, thereby accelerating their commercialisation and adoption.

To overcome the complexity of IT systems in larger financial institutions and banks and facilitate the commercialisation of EO services, it is recommended to develop seamless integration solutions that align with existing banking infrastructure. This can be achieved through the use of standardised data formats, APIs, and interoperable platforms that allow EO data to be easily ingested within the current IT ecosystem. It is suggested that EO service providers collaborate with financial institutions' IT departments during the development process. This collaboration can ensure that derived-EO solutions meet security, compliance, and performance requirements specific to the financial sector. Further, adopting cloud-based EO services can reduce the burden on internal IT resources by providing scalable, flexible, and secure access to EO data. Finally, offering comprehensive technical support and user-friendly interfaces can further simplify the integration process, making it easier for financial institutions to incorporate EO insights into their workflows.

Demonstrating the value of EO-derived solutions

Adopting an EO-derived solution requires significant investment by financial intuition. This investment is not only limited to paying for service but also related to the cost of training and adopting EO-derived solutions in financial institutions. To encourage financial managers to have this investment, EO service providers should effectively demonstrate the value of EO-derived solutions by providing concrete examples and showcasing studies where EO-derived solutions have led to significant financial benefits. This could include instances where EO data improved risk assessment models for insurance companies, enhanced the accuracy of agricultural yield forecasts for investment portfolios, or identified environmental risks impacting real estate valuation. Further, EO service providers and financial institutions can develop pilot projects and collaborative research initiatives aiming to reach tangible proof-of-concept results. Finally, quantifying the return on investment through metrics including cost savings, improved decision accuracy, and reduced risk exposure can further highlight EO's practical benefits.

8. ACKNOWLEDGEMENTS

The EO-FIN consortium extends its heartfelt gratitude to the European Space Agency (ESA) for funding this project. Also, we would like to express our sincere appreciation to the financial management stakeholders (representing investment management, insurance management, green finance, and risk management) and EO service and data providers who provided invaluable insights throughout this project. Their expertise and guidance during various activities, meetings, interviews, responding to questionnaires, and workshop participation in-person and online, have been invaluable in shaping our approach and ensuring the success of our endeavours. Due to Chatham House Rules, the Consortium cannot name all names and affiliations of those stakeholders who collaborated, however here are the names of those who agreed their names and affiliations to be shared Laura Garcia Velez (from Lombard Odier), Carolien Samson (from Oxbury Bank), and Doyle Ray Oakey (from Parametrica).

9. ANNEXE

Table 9-1 Product specifications - Wildfires: Burned area.

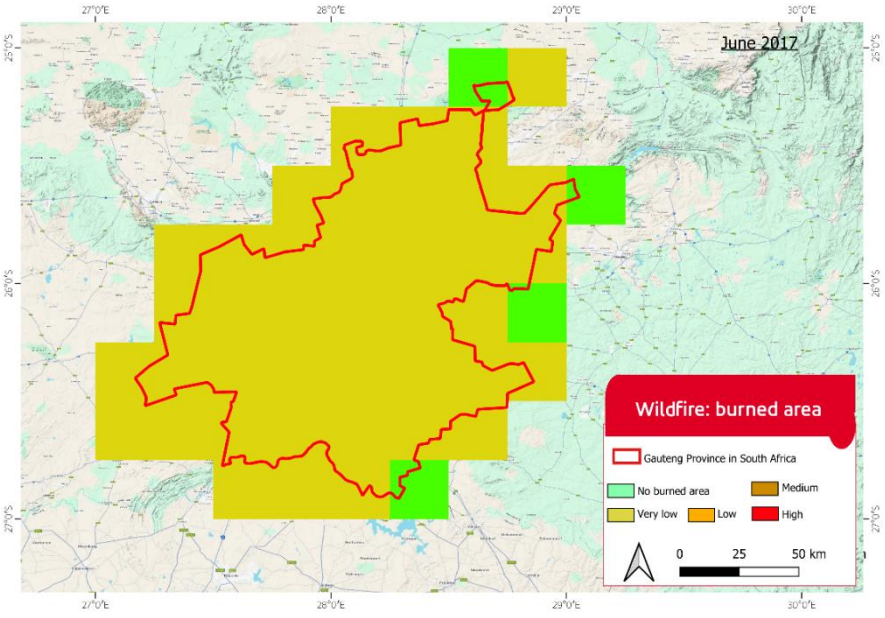
Product name	Wildfires: Burned area
Product Description	The Burned Area is from wildfire products from the climate Copernicus program with global coverage. It is generated as a grid scale and provides a monthly total area in m² of burned areas within the grid.
Main applications	Risk assessment; Environmental Impact Assessment; Post-fire Recovery
Format	Image with continuous data in raster format (.tiff) and metadata (.txt).
Input data	Medium-resolution sensors like Terra MODIS and Sentinel-3 OLCI, complemented by MODIS thermal information.
Spatial info	Spatial Reference: WGS 1984 --- Projection system: EPSG:4326 --- Spatial resolution:0.25°
Temporal info	01/01/2017 to 01/04/2022 --- Frequency: Monthly
Value Range	Between 0% and 100%
Postprocessing options	• Spatial aggregation (as Tiff raster format for AoI; a CSV spreadsheet format for district and province geographical levels).
Output style	No burned area (0%) Very low burned areas (0% to 25%) Low burned areas (25% to 50%) Medium burned areas (50% to 75%) High burned areas (75% to 100%)
Area of Study	Gauteng Province, South Africa with global coverage
Product Overview	

Table 9-2 Product specifications - Wildfires: Burned area in vegetation class.

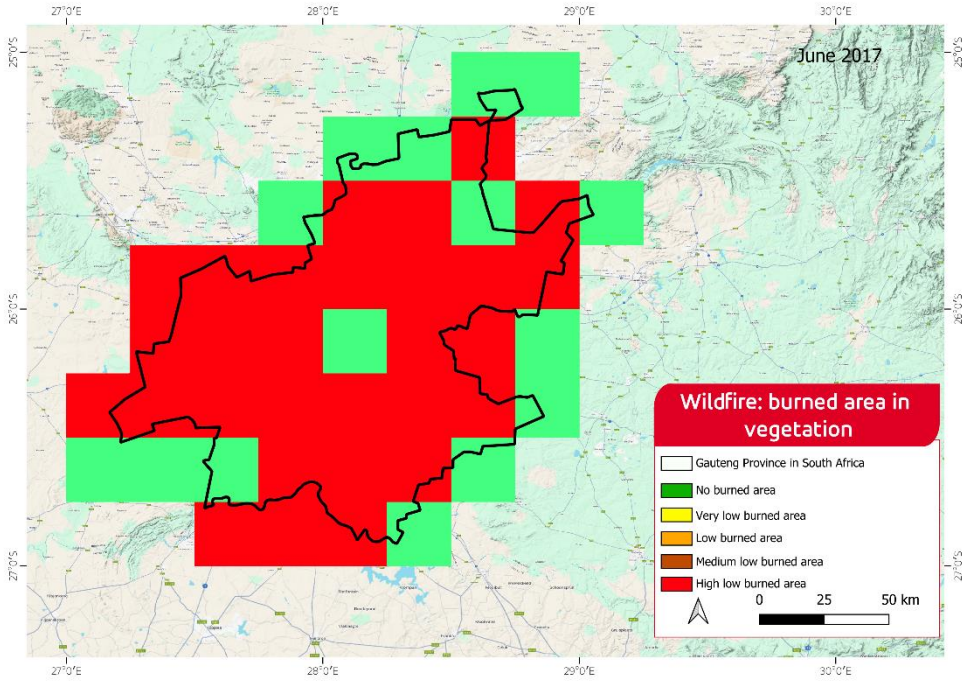
Product name	Wildfires: Burned area in vegetation class
Product Description	The Burned Area in the vegetation class is from a series of wildfire products from the climate Copernicus program with global coverage. It is generated as a grid-scale and provides a monthly total area in m² of burned areas within the grid for each land cover vegetation class of the Copernicus Climate Change Service (C3S) land cover dataset. The monthly product contains 18 layers that describe the total burnt area of each vegetation class which are: Cropland, rainfed; Cropland, irrigated or post-flooding; Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover)(<50%); Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) /cropland (<50%); Tree cover, broadleaved, evergreen, closed to open (>15%); Tree cover, broadleaved, deciduous, closed to open (>15%); Tree cover, needleleaved, evergreen, closed to open (>15%); Tree cover, needleleaved, deciduous, closed to open (>15%); Tree cover, mixed leaf type (broadleaved and needleleaved); Mosaic tree and shrub (>50%) / herbaceous cover (<50%); Mosaic herbaceous cover (>50%) / tree and shrub (<50%); Shrubland; Grassland; Lichens and mosses; Sparse vegetation (tree, shrub, herbaceous cover) (<15%); Tree cover, flooded, fresh or brackish water; Tree cover, flooded, saline water; Shrub or herbaceous cover, flooded, fresh/saline/brackish water.
Main applications	Risk assessment; Environmental Impact Assessment; Post-fire Recovery
Format	Image with continuous data in raster format (.tiff) and metadata (.txt).
Input data	Medium-resolution sensors like Terra MODIS and Sentinel-3 OLCI, complemented by MODIS thermal information, and the Copernicus Climate Change Service (C3S) land cover dataset.
Spatial info	Spatial Reference: WGS 1984 --- Projection system: EPSG:4326 --- Spatial resolution:0.25°
Temporal info	01/01/2017 to 01/04/2022 --- Frequency: Monthly
Postprocessing options	• Spatial aggregation (as Tiff raster format for AoI; a CSV spreadsheet format for district and province geographical levels).
Output style	No burned area (0 km^2) Very low burned areas (between 0 and 5 km^2) Low burned areas (between 5 and 20 km^2) Medium burned areas (between 20 and 50 km^2) High burned areas (more than 50 km^2)
Area of Study	Gauteng Province, South Africa with global coverage
Product Overview	

Table 9-3 Product specifications - Wildfires: Date of the first detection.

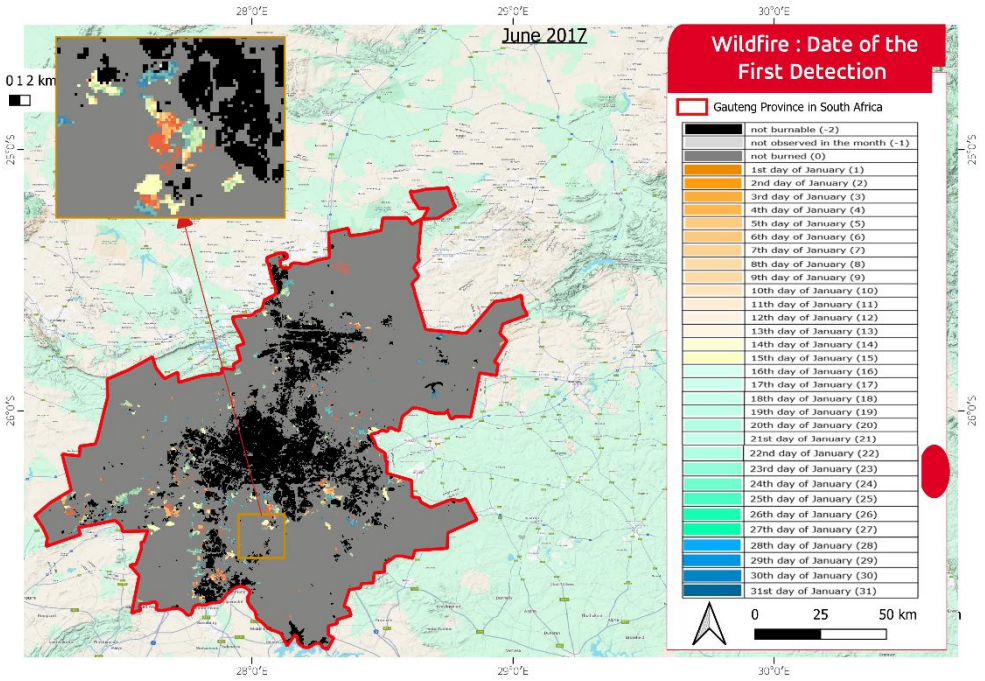
Product name	Wildfires: Date of the first detection
Product Description	The Burned Area products (https://cds.climate.copernicus.eu/portfolio/dataset/satellite-fire-burned-area) provide global data on the total burned area (BA) at both pixel and grid scales. BA date of first detection represents the day of the year in which it was the first detection of a burned area. Possible values: 0 when the pixel is not burned; 1 to 366 days of the first detection when the pixel is burned; -1 when the pixel is not observed in the month; -2 when a pixel is not burnable: water bodies, bare areas, urban areas, and permanent snow and ice.
Main applications	• Risk assessment • Environmental Impact Assessment • Post-fire Recovery
Format	Classification image in raster format (.tif) and metadata (.txt).
Input data	Medium-resolution sensors like Terra MODIS and Sentinel-3 OLCI, complemented by MODIS thermal information.
Spatial info	Spatial Reference: WGS 1984 --- Projection system: EPSG:4326 --- Spatial resolution:300
Projection info	EPSG:4326 with monthly frequency
Value Range	Between -2 and 366
Postprocessing options	• Spatial aggregation (as Tiff raster format for AoI; a CSV spreadsheet format for district and province geographical levels).
Area of Study	Gauteng Province, South Africa with global coverage
Product Overview	

Table 9-4 Product specifications - Wildfires: Land cover of burned pixels.

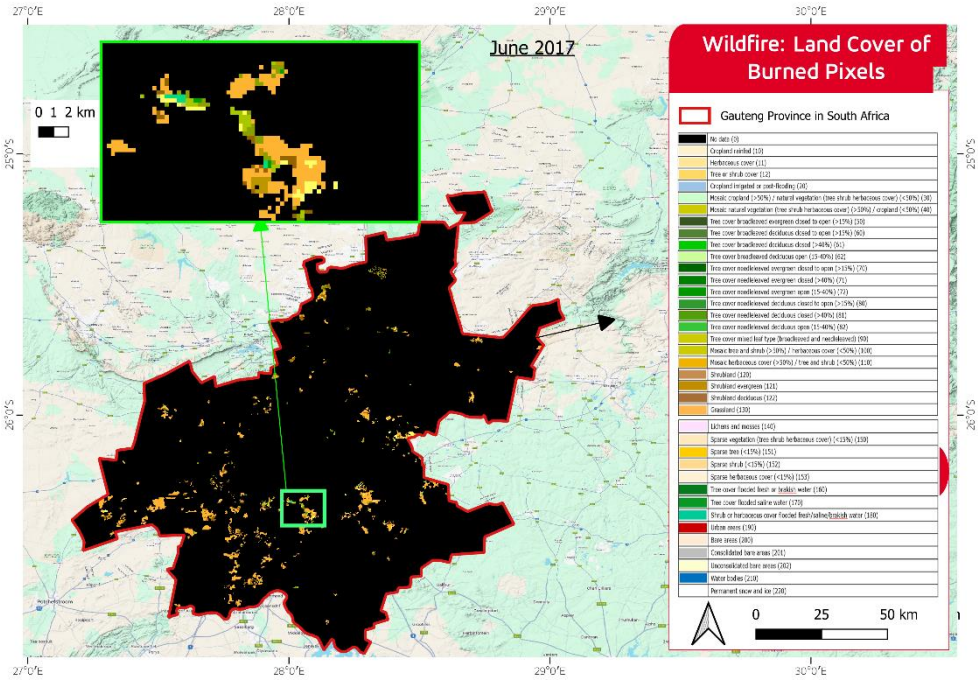
Product name	Wildfires: Land cover of burned pixels
Product Description	The Burned Area products (https://cds.climate.copernicus.eu/portfolio/dataset/satellite-fire-burned-area) provide global data on the total burned area (BA) at both pixel and grid scales. Land cover of the burned pixel, extracted from the CCI Land Cover v1.6.1 (LC). N is the number of the land cover category in the reference map. It is only valid when JD > 0. Pixel value is 0 to N under the following codes: 10 = Cropland, rainfed; 20 = Cropland, irrigated or post-flooding; 30 = Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover)(<50%); 40 = Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) /cropland (<50%); 50 = Tree cover, broadleaved, evergreen, closed to open (>15%); 60 = Tree cover, broadleaved, deciduous, closed to open (>15%); 70 = Tree cover , needleleaved, evergreen, closed to open (>15%); 80 = Tree cover, needleleaved, deciduous, closed to open (>15%); 90 = Tree cover, mixed leaf type (broadleaved and needleleaved); 100 = Mosaic tree and shrub (>50%) / herbaceous cover (<50%) ; 110 = Mosaic herbaceous cover (>50%) / tree and shrub (<50%); 120 = Shrubland; 130 = Grassland; 140 = Lichens and mosses; 150 = Sparse vegetation (tree, shrub, herbaceous cover) (<15%); 160 = Tree cover, flooded, fresh or brackish water; 170 = Tree cover, flooded, saline water; 180 = Shrub or herbaceous cover, flooded, fresh/saline/brackish water.
Main applications	Risk assessment; Environmental Impact Assessment; Post-fire Recovery
Format	Classification image in raster format (.tiff) and metadata (.txt).
Input data	The Copernicus Climate Change Service (C3S) land cover dataset.
Spatial info	Spatial Reference: WGS 1984 --- Projection system: EPSG:4326 --- Spatial resolution:300
Temporal info	01/01/2017 to 01/04/2022 with monthly frequency
Value Range	Between 0 and 220
Postprocessing options	Spatial aggregation (as Tiff raster format for AoI; a CSV spreadsheet format for district and province geographical levels).
Area of Study	Gauteng Province, South Africa with global coverage
Product Overview	

Table 9-5 Product specifications – Wildfires: Confidence level.

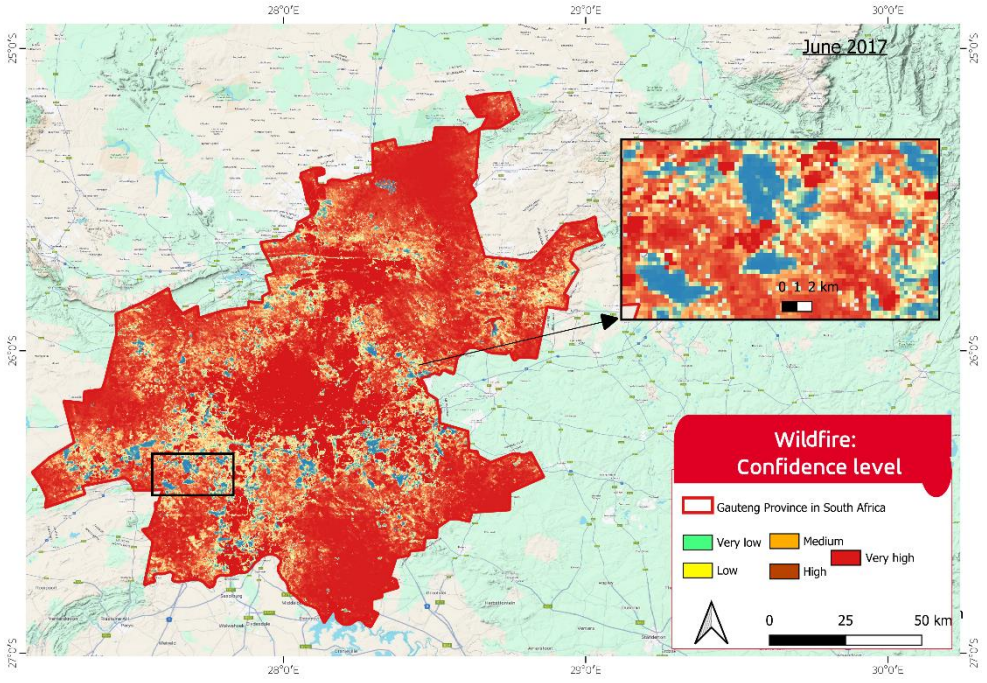
Product name	Wildfires: Confidence level
Product Description	The Burned Area is from a series of wildfire products from the climate Copernicus program (https://cds.climate.copernicus.eu/portfolio/dataset/satellite-fire-burned-area) with global coverage. It is generated as a grid scale and provides a monthly total area in m² of burned areas within the grid.
Main applications	Risk assessment; Environmental Impact Assessment; Post-fire Recovery
Format	Image with continuous data in raster format (.tiff) and metadata (.txt)
Input data	Medium-resolution sensors like Terra MODIS and Sentinel-3 OLCI, complemented by MODIS thermal information.
Spatial info	Spatial Reference: WGS 1984 --- Projection system: EPSG:4326 --- Spatial resolution:300
Temporal info	01/01/2017 to 01/04/2022 with monthly frequency
Value Range	Between 0% and 100%
Postprocessing options	Spatial aggregation (as Tiff raster format for AoI; a CSV spreadsheet format for district and province geographical levels).
Output style	Very low (0%) Low (0% to 25%) Medium (25% to 50%) High (50% to 75%) Very high(75% to 100%)
Area of Study	Gauteng Province, South Africa with global coverage
Product Overview	

Table 9-6 Product specifications - Flood extent mapping.

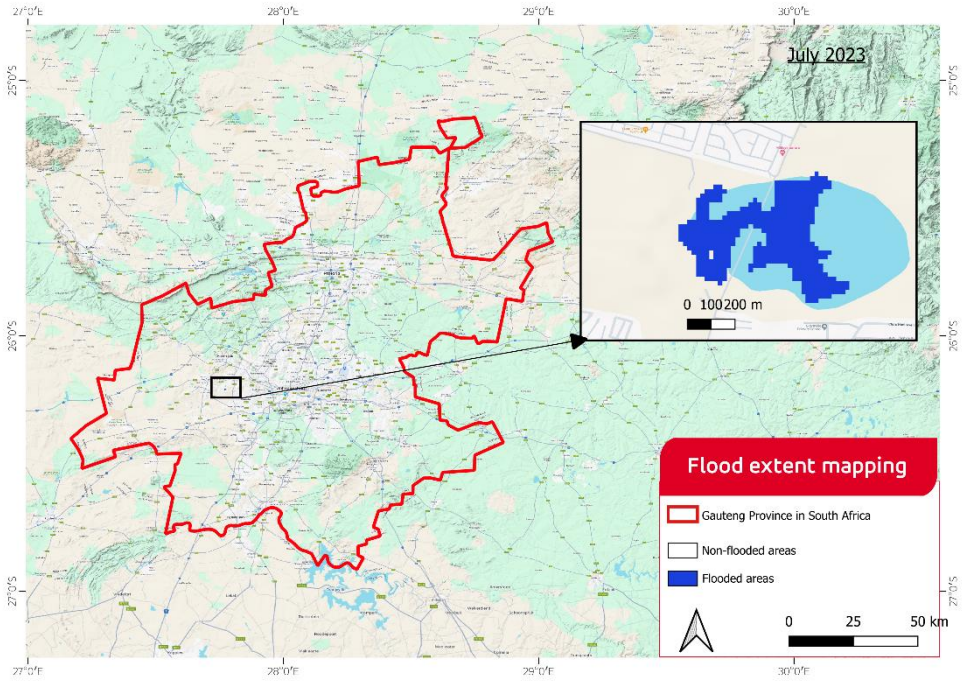
Product name	Flood extent mapping
Product Description	In the context of EO-FIN, the flood extent mapping product provided through GloFAS Global Flood Monitoring (GFM) has been used with some preprocessing and postprocessing stages. The product is generated using flood detection algorithms applied to Sentinel-1 satellite data, operating day and night with C-band synthetic aperture radar imaging for all-weather acquisition. Level-1 Sentinel-1 datasets undergo preprocessing before being fed into three parallel flood detection algorithms. The ensemble flood mapping combines results from these algorithms, attributing each pixel a ratio based on the agreement among algorithms.
Main applications	Early Warning Systems; Disaster Response and Management; Risk Assessment and Planning; Climate Risk Management
Format	Classification image in raster format (.tiff) and metadata (.txt).
Input data	Sentinel-1 imagery.
Spatial info	Spatial Reference: WGS 1984 --- Projection system: EPSG:4326 --- Spatial resolution:20
Temporal info	04/01/2023 to 08/12/2023 with 6 days or monthly frequency
Value Range	0 and 1
Postprocessing options	• Spatial aggregation (as Tiff raster format for AoI; a CSV spreadsheet format for district and province geographical levels). • Temporal monthly aggregation.
Area of Study	Gauteng Province, South Africa with global coverage
Product Overview	

Table 9-7 Description of the Agricultural Drought Observations (ADO) classes.

Level	CLASSIFICATION CONDITION	Interpretation
Watch	SPI-3 < -1	The amount of precipitation is lower than normal
Warning	SMA < -1 and SPI-3 < -1	Soil moisture deficit coexists with the precipitation deficit
Alert	FAPAR anomaly < -1 and SPI-3 < -1	Indicator of stress in the vegetation

Partial recovery	FAPAR anomaly < -1 and SPI-3(m-1) < -1 and SPI-3 > -1	The meteorological conditions have returned to normal following a period of drought, but vegetative growth has not
Full recovery	FAPAR anomaly > -1 and SPI-3(m-1) < -1 and SPI-3 > -1	The meteorological conditions and vegetation growth have returned to normal following a period of drought

Table 9-8 Product specifications - Agricultural Drought Observations.

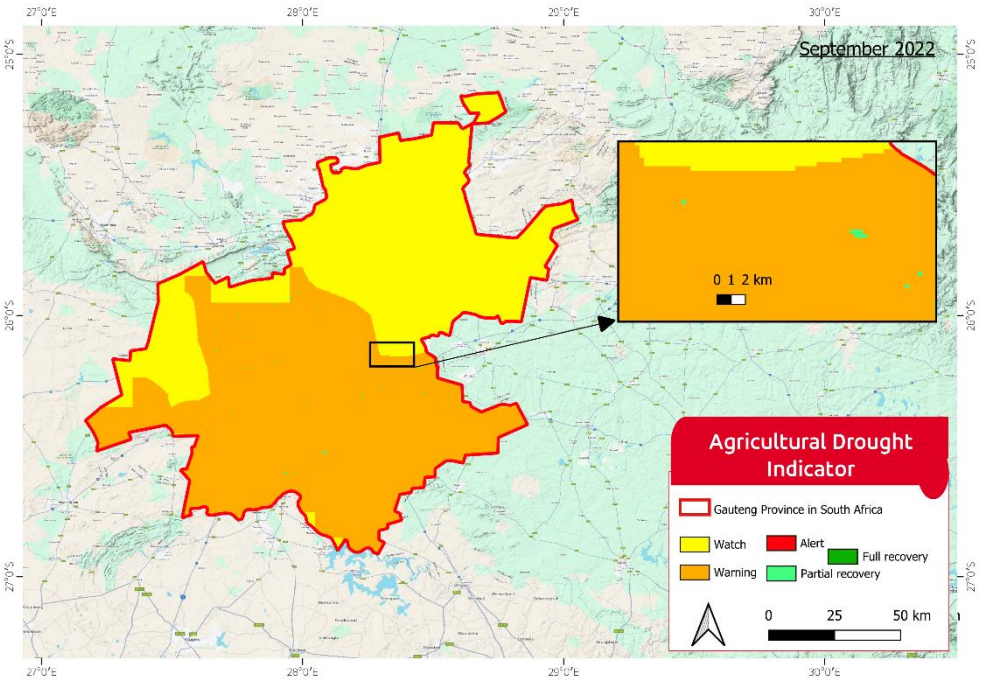
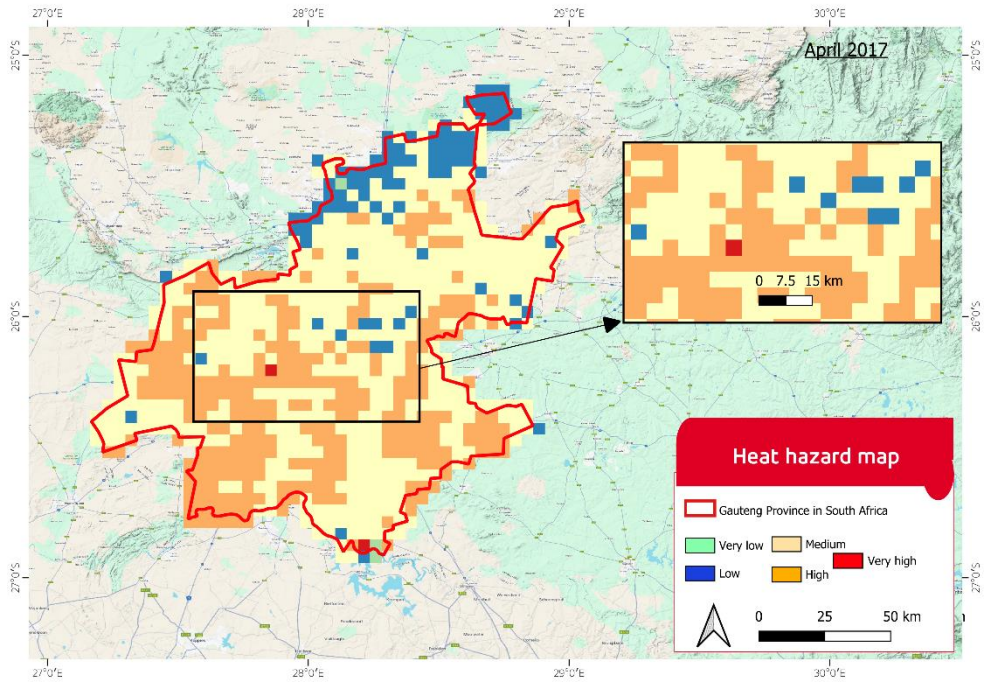
Product name	**Agricultural drought observations**
Product Description	The Combined Drought Indicator (CDI) is utilised to identify and monitor regions that are either experiencing or prone to agricultural drought. Using the combination of spatial patterns of precipitation, soil moisture, and greenness vegetation anomalies, the ADO identifies areas at risk of agricultural drought, regions in which the vegetation has already been impacted by drought, and areas that are returning to normal conditions.
Main applications	Agricultural Drought Monitoring; Early Warning Systems; Drought Assessment and Reporting Agricultural Planning; Environmental Impact Assessment
Format	Classification image in raster format (.tiff) and metadata (.txt).
Input data	FAPAR (GLASS & GCLS), SPI (ERA5 Land), Soil Moisture Index (Copernicus).
Spatial info	Spatial Reference: WGS 1984 --- Projection system: EPSG:4326 --- Spatial resolution:300 m
Temporal info	01/08/2020 to 31/01/2023 with monthly coverage
Value Range	Between 0 and 4
Postprocessing options	• Spatial aggregation (as Tiff raster format for AoI; a CSV spreadsheet format for district and province geographical levels).
Area of Study	Gauteng Province, South Africa with global coverage
Product Overview	

Table 9-9 Product specifications - Heat hazard maps.

Product name	Heat hazard maps
Product Description	Extreme temperature events, including heat waves, are becoming increasingly common across the world. 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. LST data used for the development of the prototype has been accessed through Copernicus Global Land Services (CGLS).
Main applications	Risk assessment; Early warning systems; Corporate Due Diligence; Environmental Impact Assessment
Format	Image with continuous data in raster format (.tiff) and metadata (.txt).
Input data	LST Daily Cycle from CGLS every 10-day
Spatial info	Spatial Reference: WGS 1984 --- Projection system: EPSG:4326 --- Spatial resolution:5 km
Temporal info	01/01/2017 to 01/12/2023 with 10 days frequency
Value Range	Between -1 and 1
Postprocessing options	• Spatial aggregation (as Tiff raster format for AoI; a CSV spreadsheet format for district and province geographical levels). • Temporal monthly aggregation.
Area of Study	Gauteng Province, South Africa with global coverage
Product Overview	

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