Global Development Assistance

Forest Management

May 2025

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Summary

This brochure for the ESA-funded Global Development Assistance Programme - Forest Management activity provides an overview of the global challenges facing forest management and presents use cases for applying satellite Earth Observation to address them. Examples include monitoring deforestation, managing forest resources, and supporting climate change mitigation.

Contents

What does ESA GDA thematic activity on Forest Management do?

What is the ESA GDA programme?

The European Space Agency's Global Development Assistance (GDA) Programme is a global partnership designed to accelerate the mainstreaming of Earth Observation (EO) into development operations. Implemented in collaboration with leading International Financial Institutions (IFIs), such as the World Bank (WB) and the Asian Development Bank, the ESA GDA programme aims to create operational services tailored to user needs and requirements. The Programme focuses on embedding these services within the operational frameworks of IFIs and Client State governments.

What is ESA GDA Forest Management?

The ESA GDA thematic activity on Forest Management consortium collects the operational needs of IFI projects and programmes to identify possible EO applications. These applications must:

1. **Be demand-driven:** The need for a particular service or product has been expressed by an IFI team or preferably several teams or departments with an interest in the same EO Information.
2. **Be customisable:** The request corresponds to services or products that require customisation and therefore are not already and readily available 'off-the-shelf' through commercial entities.
3. **Have potential for wider uptake:** The service or product requested has significant potential for operational uptake and adoption in Client States.

Who are the consortium members in ESA GDA Forest Management?

The activity is implemented by a consortium of six European companies leading in the field of EO, remote sensing, Geographic Information Systems (GIS), forest management, and the integration of technology into international development contexts.

GAF AG is an e-GEOS (Telespazio/ASI) company located in Munich and Neustrelitz, Germany – embedded in the Space Alliance of European high-tech leaders Leonardo and THALES. With almost 40 years of experience, GAF is one of Europe's forerunners and market leaders in satellite data reception and distribution, advanced analysis techniques, AI processes and the tailor-made development of geoinformation and software systems, platforms and consulting solutions.

IGN FI is internationally renowned in the field of geographic information. Since it was founded in 1986, IGN FI has established itself as a leader in geomatic projects, working with the predominant policy makers, both public and private. The company has provided indispensable support tools for decision-making, particularly in the fields of land planning, the environment, agriculture, land administration, civil security, risk management, transport, tourism and more.

Since its creation in 1997, ONF International has been promoting French forest management skills and expertise across the world. As a subsidiary of the French National Forest Office, ONFI's strength lies in its dual approach when carrying out its missions: an institutional body in matters of international cooperation projects on the one hand; a competitive player as an expertise consultancy firm on the other.

GISBOX is a Romanian company providing all range services for Photogrammetry and GIS. Based on their expertise, GISBOX can provide high-precision photogrammetric and remote sensing services, offered by a highly experienced team. The geospatial GISBOX team has designed and developed numerous projects in geomatics, GIS applications ranging from simple to complex GIS solutions at the scale of entire countries.

Unique was founded in 1998 and is headquartered in Freiburg, Germany. Since 2003, they have been developing climate protection projects in the land use sector: afforestation, agriculture and agroforestry systems, coastal protection and mangrove rehabilitation, and forest protection and sustainable forest management.

Caribou is a global consultancy working with ambitious foundations, companies, and governments to accelerate and deliver impact in a digital age. It applies deep technical expertise and rigor to strategy design, fund and program management, impact measurement, and actionable research. Caribou works towards a world in which digital economies are inclusive and sustainable, driven by secure livelihoods, innovative business models, and bold climate action.

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What are the challenges of forest management?

Forests play a vital role in the global ecosystem and economy, serving multiple functions as a critical resource. They provide habitats for two-thirds of all terrestrial animal and plant species, support the livelihoods of indigenous communities, and produce commodities essential to the global economy and food systems. In fact, in tropical countries, forest-adjacent communities derive around 25% of their income from forest resources.[1] Forests are a vital resource for rural populations, providing a "hidden harvest" that prevents extreme poverty. Globally, 4.2 billion people live within 5 km of a forest.[2] Forests are also integral to the global carbon cycle, absorbing and storing atmospheric carbon to regulate greenhouse gases. Additionally, they prevent soil erosion, reduce water run-off, and offer sustainable livelihoods for local populations. Resilient and sustainable forest management is critical for achieving broader development goals, such as economic growth, food security, and climate resilience. The global forestry sector faces significant challenges, particularly in low- and middle-income countries:

1. **Meeting the needs of growing populations and economies:** Growing populations and expanding economies, are placing immense pressure on forest ecosystems. The demand for agricultural land is rising, whilst the need for commodities such as timber, palm oil, and soy drives both legal and illegal deforestation, leading to habitat destruction and biodiversity loss. Overexploitation risks degrading these ecosystems and is jeopardising their ability to sustain future generations.
2. **Protecting the environment and combating climate change:** Forests are essential for mitigating climate change and maintaining global ecological balance. They sequester carbon, reduce greenhouse gas emissions, and support biodiversity. However, deforestation, forest degradation, uncontrolled wildfires, and climate change itself threaten these ecosystems. The loss of forests in turn contributes substantially to carbon emissions, exacerbating climate change, and depriving forest-dependent communities of their livelihoods.

To combat these challenges, sustainable forest management practices must prioritise restoration and conservation while enhancing forest resilience to climate impacts. Ambitious investments and coordinated global action are required. The WB has committed over US$8.6 billion to its forest and landscapes portfolio and supports several high-profile initiatives.[3] For example, PROGREEN is a WB Multi-Donor Trust Fund that supports countries in improving livelihoods, conserving forests and ecosystems, restoring landscapes, and addressing climate change.[4] Using an integrated landscape approach, PROGREEN helps achieve sustainable development goals, including poverty reduction, cost-effectively and at scale.

By balancing the urgent needs of growing populations with the imperative to protect and restore forest ecosystems, sustainable forest management can ensure forests continue to support both human well-being and environmental health. This requires innovative policies, cross-sectoral collaboration, and the scaling up of sustainable practices globally.

[1] FAO, In Brief to The State of the World's Forests 2022. Forest pathways for green recovery and building inclusive, resilient and sustainable economies, 2022, https://doi.org/10.4060/cb9363en

[2] Ibid.

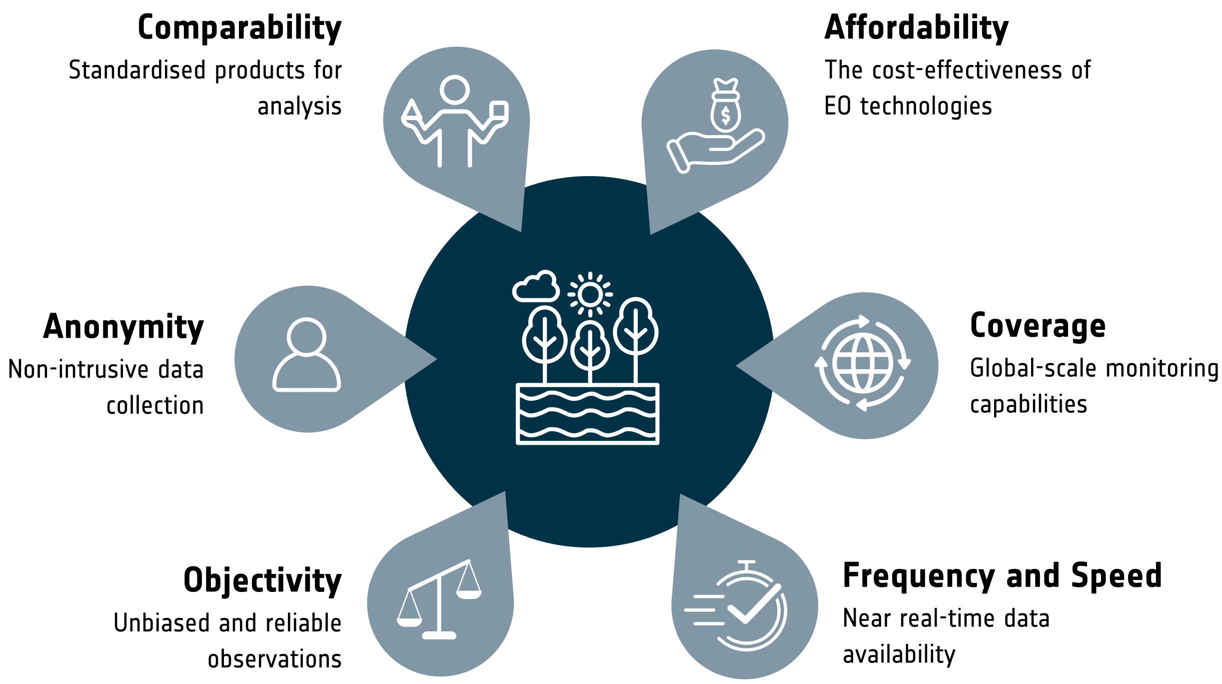
[3] World Bank Group (WBG), Forests and Landscapes, 2024, https://www.worldbank.org/en/topic/forests#2

[4] PROGREEN, Home, 2024, https://www.progreen.info/

What is the value proposition of satellite Earth Observation for Forest Management?

Earth Observation (EO) is transforming forest management by providing accurate, scalable, and cost-effective solutions to monitor and safeguard forest ecosystems. Leveraging advancements in satellite imaging, computing, and data analytics, EO offers unparalleled insights into forest health, productivity, and sustainability. Satellites equipped with radar and optical sensors provide consistent, repeatable observations, making it possible to monitor forests globally. The increased availability of EO data, coupled with analytical tools such as artificial intelligence and cloud computing, enables actionable insights that support decision-making, from tracking deforestation to optimising resource management. By reducing operational costs and enhancing compliance with environmental legislation, EO solutions help tackle global environmental challenges while improving sustainability and profitability within the forestry sector.

Figure 1: Aspects of the Value Proposition of EO for Forest Management



What are the use cases[5] of satellite Earth Observation for Forest Management?

Use case: Forest inventories

Problem to be addressed

Successful forest management, the protection of forest ecosystems and research to improve our understanding of their biodiversity and functioning requires detailed knowledge of the current state of the forest and its changes. Recording the current state of the forest is the main goal of forest structure monitoring. Forest inventories are central elements of forest monitoring carried out on national level, regional or enterprise or project level to assess the standing forest stocks and changes in these stocks, which is not only relevant for sustainable forest management but as well as to contribute to the national greenhouse gas emissions assessments. Traditional field-based approaches to forest inventories are resource-intensive and time-consuming, and very limited in geographic coverage, particularly in remote or inaccessible regions. Without accurate and up-to-date forest inventory data, it is difficult to monitor forest characteristics, detect changes, make informed decisions for forest management, and design effective conservation strategies. Moreover, the inability to efficiently disseminate inventory results to stakeholders, decision-makers, and the public undermines the transparency and utility of forest data in policy and planning.

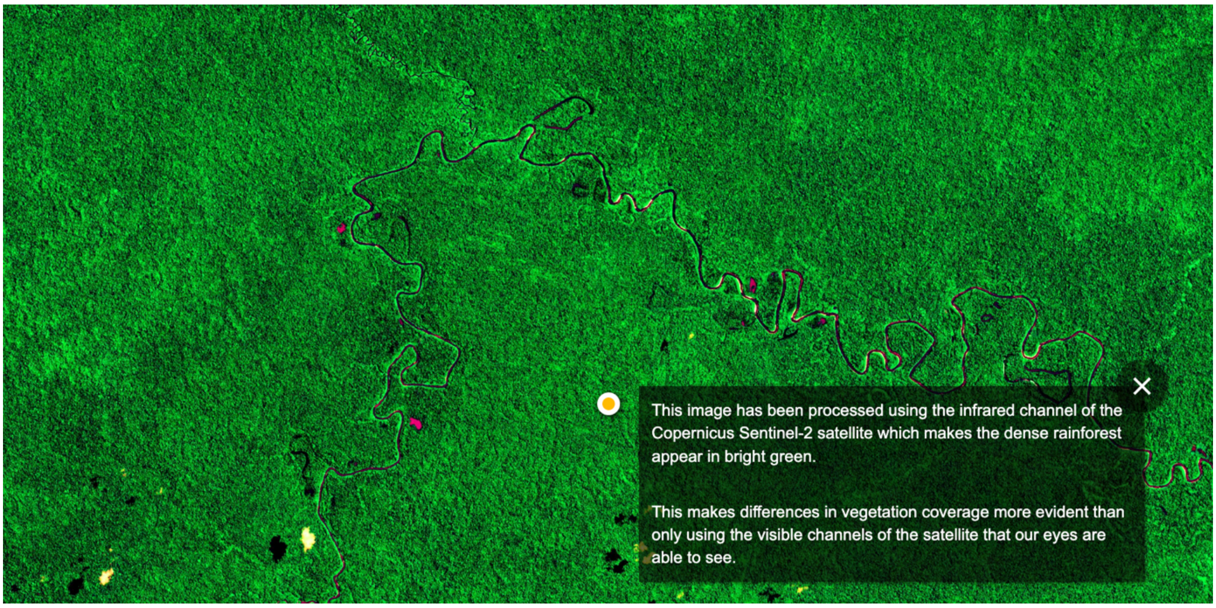
Example EO application

By integrating satellite data, such as Sentinel-1 or Sentinel-2 from the European Copernicus programme and other high-resolution imagery, EO can support Forest Inventories on all levels with provision of spatial information on forest area, forest types, biomass, carbon, other structural variables and their changes over time. Forest cover maps are very often used for masking forests and to stratify forests by forest types and to improve sampling strategies.

One application involves the combination of Sentinel-2 satellite data and plot data from terrestrial inventories to train models in order to provide country-wide, spatially explicit information on forest type classification, growing stock volume, biomass, carbon, or other relevant forest structural variables. This wall-to-wall coverage offers detailed insights into the distribution of forest types and land use changes. This information is essential for achieving high accuracy in monitoring forest dynamics, biodiversity and carbon reporting and supports decision making in forest management.

[5] ESA GDA defines a use case as a sub-topic/sub-challenge within a thematic area.

Figure 2: Vegetation Coverage in Amazon Forest[6]



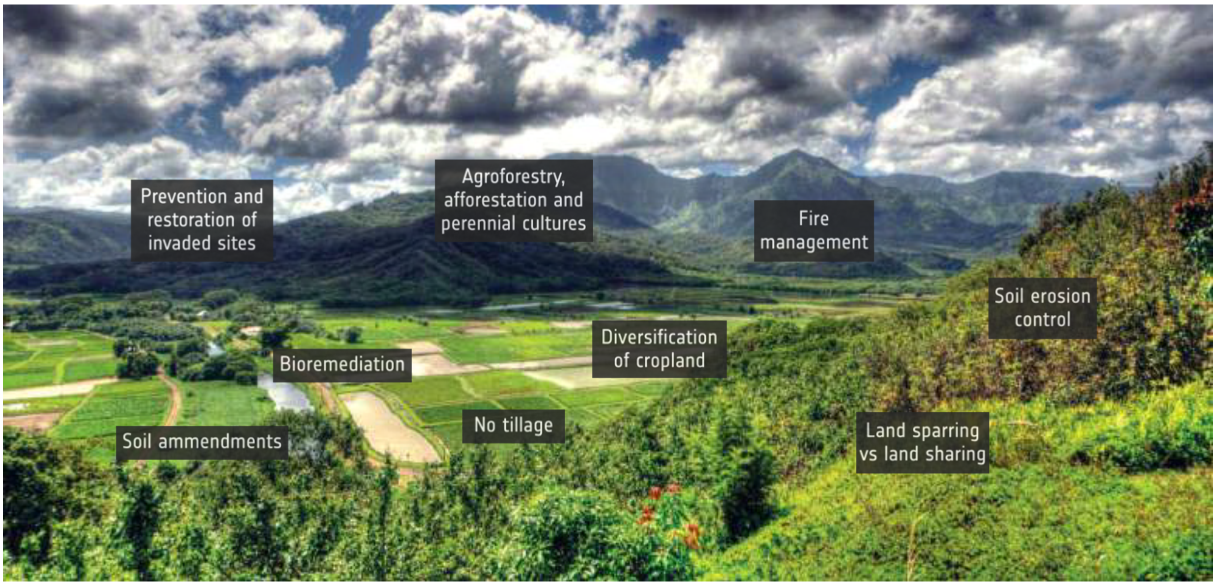
[6] Contains modified Copernicus Sentinel data (2019), processed by ESA. https://www.esa.int/ESA_Multimedia/Images/2021/03/Amazon_rainforest

Use case: Landscape spatial planning and sustainable management

Problem to be addressed

Landscape spatial planning is a systematic approach to organising land use to balance ecological, economic, and social priorities. "*Forest Landscape Restoration (FLR) is the ongoing process of regaining ecological functionality and enhancing human well-being across deforested or degraded forest landscapes. FLR is more than just planting trees – it is restoring a whole landscape to meet present and future needs and to offer multiple benefits and land uses over time*" (IUCN, 2019). See Figure 3, which presents the landscape concept behind FLR. Central to FLR is the restoration of deforested and/or degraded lands, and the assessment on the causes of deforestation and degradation.

Figure 3: The Landscape Aspect of FLR[7]



Effective landscape planning ensures sustainable management by identifying land-use patterns that support biodiversity, reduce resource conflicts, and enhance ecosystem services, particularly in regions vulnerable to climate change or overexploitation.

When planning a FLR programme the first step is to identify locations where deforestation and/or degradation have occurred, and a second step is to note priority landscapes and specific ecological and social goals; both these activities require geospatial data. After the FLR intervention the monitoring stage also requires spatial data on the developments of the reforestation and conservation activities.

Example EO application

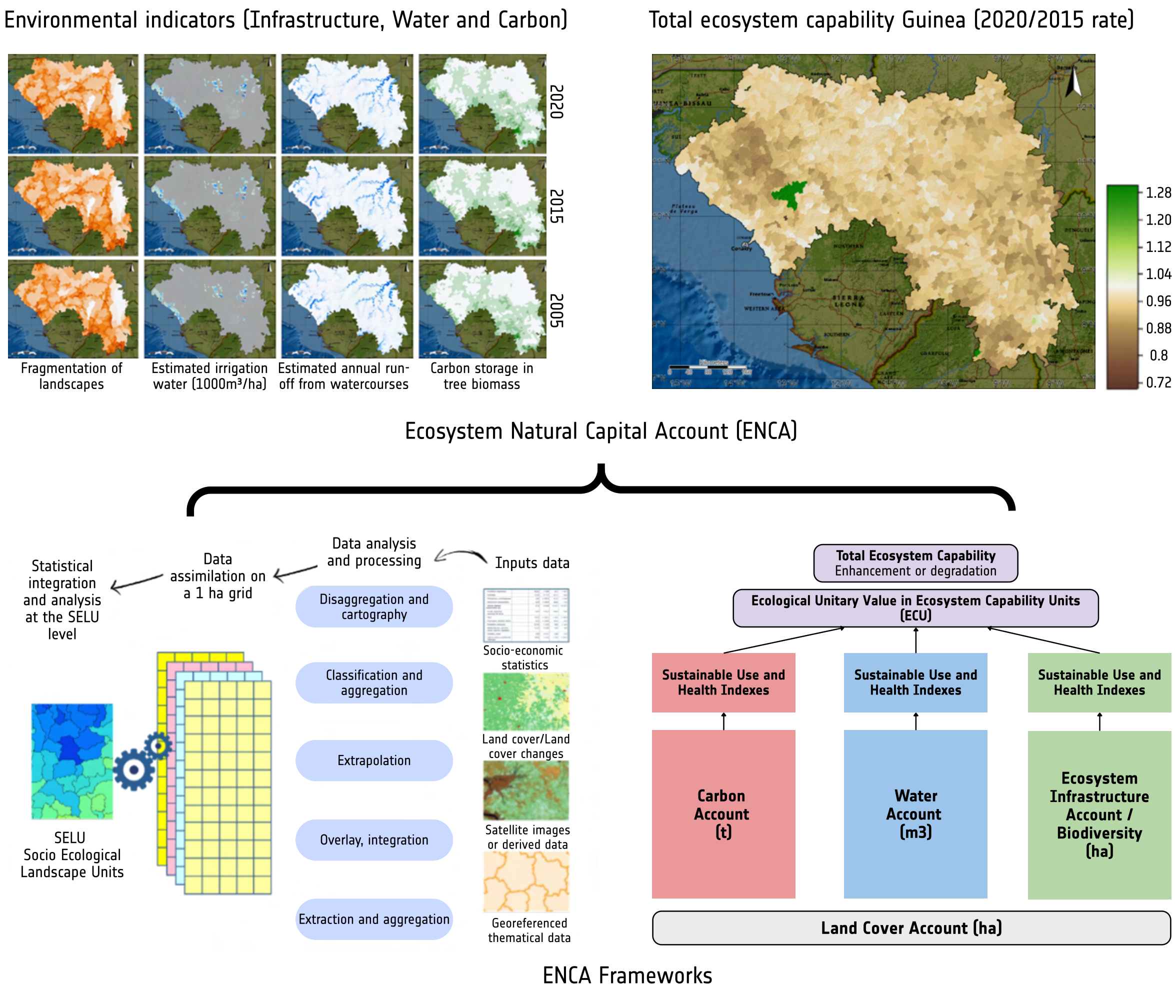
EO plays a critical role in supporting landscape spatial planning and sustainable management through accurate and scalable data products.

These EO developments include innovative methodologies like the Ecosystem Natural Capital Accounting (ENCA), integrating water, biomass, and land cover data to monitor ecosystem capacity and sustainability.

[7] Orgiazzi et al., Global Soil Biodiversity Atlas, 2019, https://esdac.jrc.ec.europa.eu/content/global-soil-biodiversity-atlas

Additionally, the production of atlases and tools for national planning enhances the accessibility and usability of spatial data for policymakers and stakeholders, fostering capacity building and enabling informed resource management at scale.

Figure 4: Ecosystem Natural Capital Account Framework © IGNFI



Use case: REDD+ workflows

Problem to be addressed

Deforestation and forest degradation are major contributors to global greenhouse gas emissions, necessitating robust frameworks for their monitoring and mitigation. The United Nations Framework Convention on Climate Change's Paris Agreement has a specific policy segment for reducing emissions from deforestation and degradation (REDD+) which aims to provide financial compensation to countries for their efforts in reducing deforestation/degradation. However, a key challenge lies in accurately tracking and verifying forest sector impacts and ensuring that emissions from forest and non-forest sectors are comprehensively accounted for. Additionally, elaborating precise Forest Reference Emissions Levels (FRELs) requires integrating advanced tools and methodologies, which can improve the accuracy of deforestation and carbon emission estimations.

Example EO application

EO has been instrumental in supporting REDD+ workflows by providing advanced tools and methodologies to monitor and manage forest resources effectively. A key application includes the use of high-resolution satellite imagery, such as SPOT and Sentinel-2 data, to develop forest and land cover maps. These maps serve as critical inputs for understanding forest dynamics, tracking deforestation, and assessing land-use changes over time. Historical and current forest maps have been used to establish baselines, monitor changes, and validate outputs in alignment with Intergovernmental Panel on Climate Change (IPCC) recommendations.

Another significant development is the creation of Tree Cover Density (TCD) products, which measure the proportional crown coverage of forests. These products serve as a basis for calculating forest extent and is a major input for deforestation assessment.

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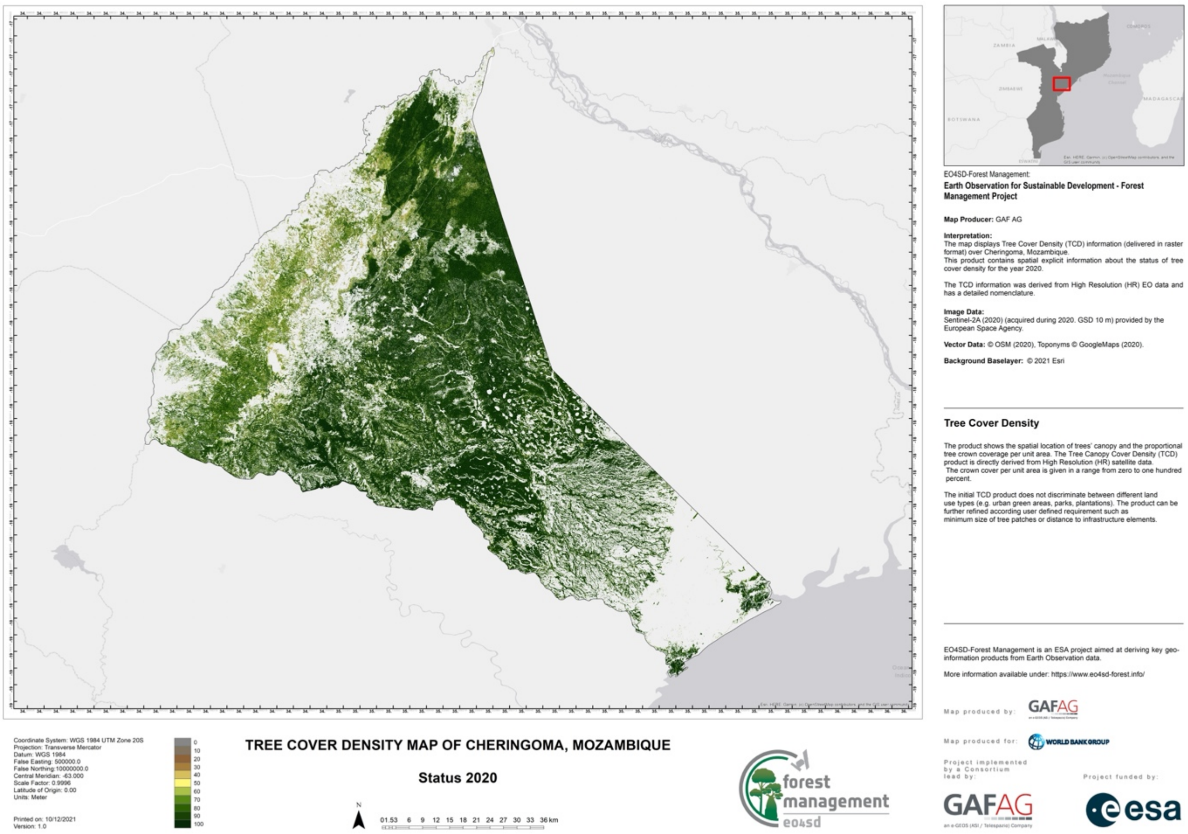
Figure 5: Tree Cover Density Product © GAF AG



Use case: Deforestation early-warning systems

Problem to be addressed

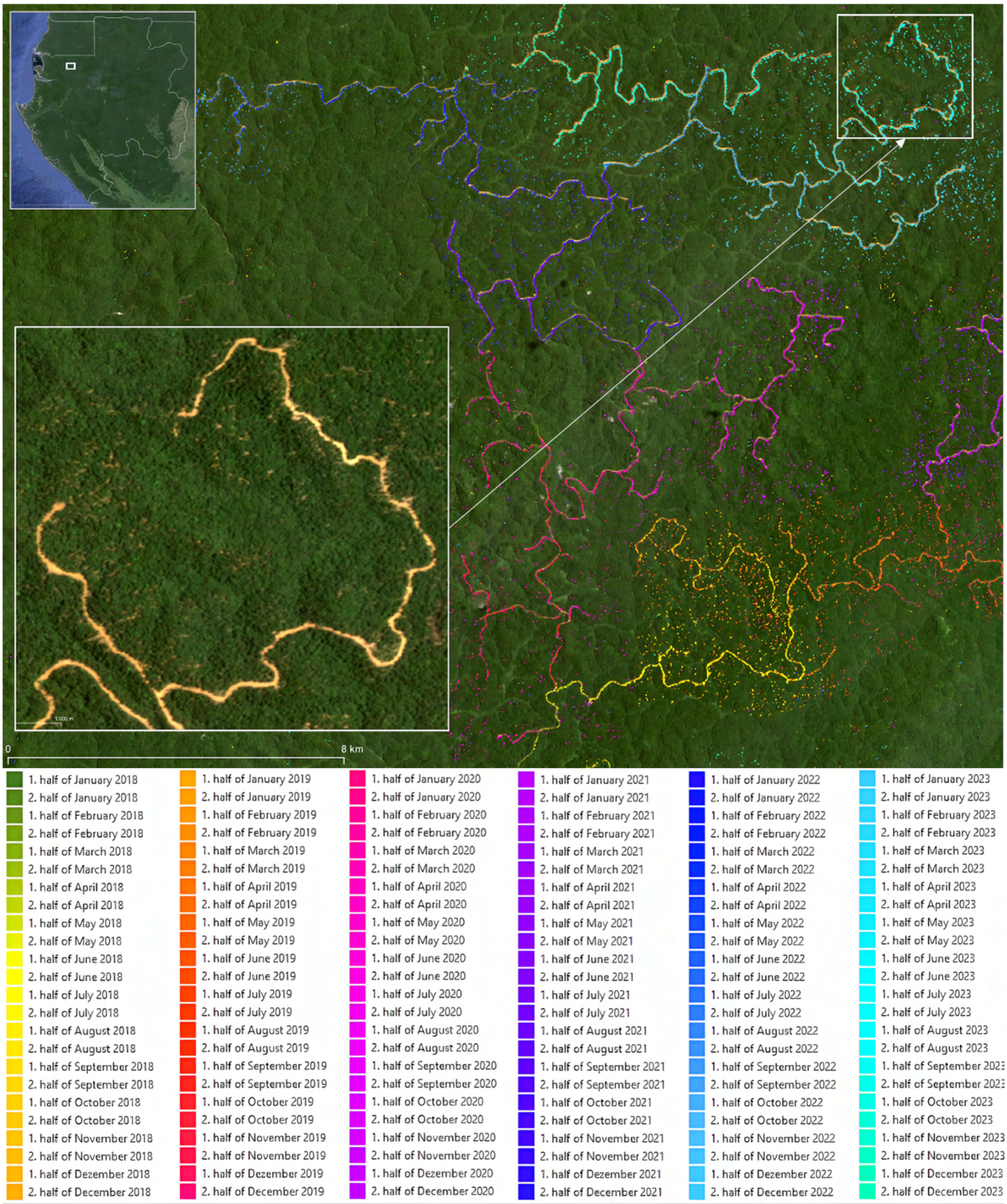
Deforestation and forest degradation are leading causes of biodiversity loss, carbon emissions, and ecosystem disruption worldwide. Early detection and monitoring of deforestation as well as degradation activities, including illegal logging and land conversion, are critical for mitigating these impacts. However, tracking forest cover disturbances in near real-time is challenging, particularly in regions with persistent cloud cover or topographically rough terrain. Moreover, understanding the underlying drivers of deforestation, such as agricultural expansion, urbanisation, and artisanal mining, requires integrated and scalable systems capable of identifying and analysing these pressures. Traditional monitoring methods often fail to provide timely and comprehensive data, limiting the effectiveness of interventions.

Example EO application

Deforestation early-warning systems leverage satellite EO data to monitor forest disturbances and detect deforestation events in near real-time. The 5-day repeat cycle for example of the Sentinel-2 system provides the frequent coverage required for near real time mapping. Due to frequent cloud coverage, in particular within the humid tropics, the integration of optical and radar data (e.g. Sentinel-1) sources for forest monitoring provides improved solutions. The methodology involves detecting changes in forest cover through time-series analyses, enabling the identification of deforestation hotspots and trends.

Digital platforms are commonly used to synthesise and visualise the results of these analyses, providing stakeholders with accessible dashboards and alerts that detail the location, magnitude, and potential causes of deforestation. These platforms integrate various data streams, including satellite-derived indicators of forest health and external socio-economic datasets, to enhance the accuracy of deforestation predictions and support proactive decision-making.

Figure 6: Disturbance Detections Based on Sentinel-1 Data (Colours Indicate the Bi-Weekly Detection Time of those Events) © GAF AG[8]



[8] Background imagery provided thru NICFI Planet licence, Imagery © 2023 Planet Labs Inc.

Use case: Monitoring of ecologically vulnerable areas

Problem to be addressed

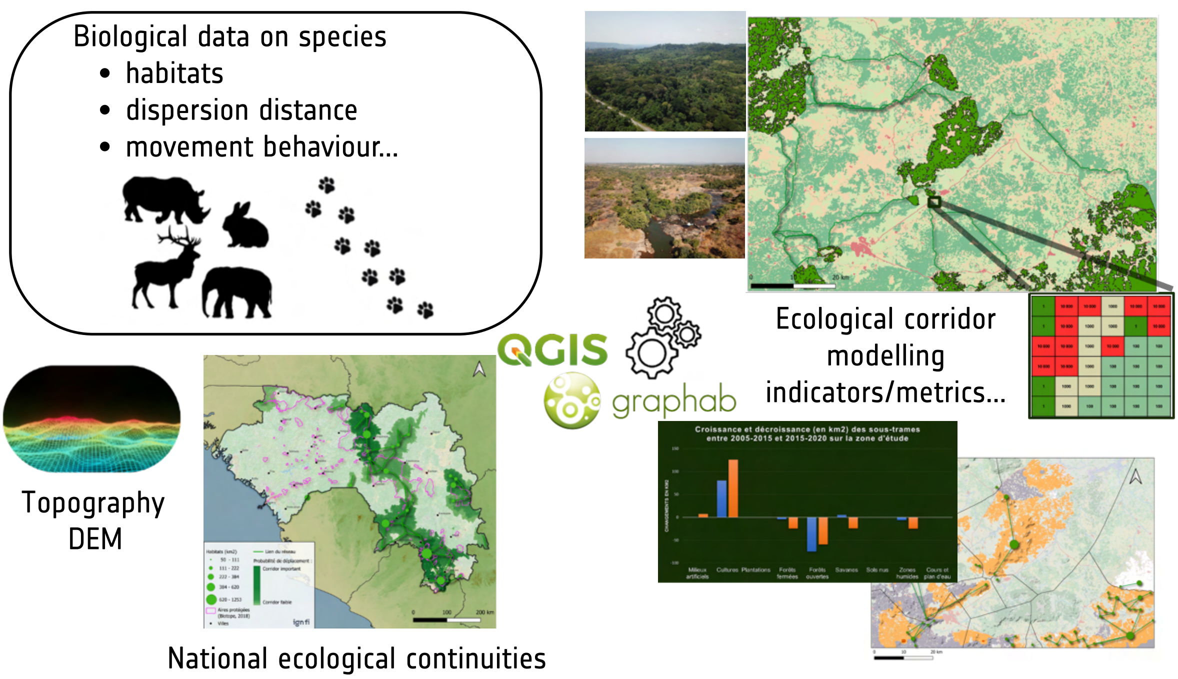
Ecologically vulnerable areas are under increasing threat from anthropogenic activities such as deforestation, land conversion, mining, and urbanisation, as well as natural hazards exacerbated by climate change. These threats compromise biodiversity, ecosystem services, and environmental stability. Effective conservation and management of these areas require robust monitoring systems to identify critical biodiversity hotspots, track ecological changes, and evaluate the impacts of interventions.

Example EO application

Monitoring ecologically vulnerable areas relies on the integration of EO data to identify, assess, and manage areas at risk. Key methodologies include the use of EO-derived land cover classifications to map natural habitats and evaluate their connectivity. By applying criteria such as the presence of undisturbed vegetation, the distribution of threatened species, and the ecological continuity of landscapes, EO tools support the identification of critical zones for biodiversity conservation.

Advanced spatial analysis algorithms are employed to model ecological corridors, which facilitate species movement and habitat connectivity between protected areas. These algorithms consider factors like “travel costs” across landscapes, using land cover data and other environmental parameters to optimise corridor routes. Such analyses enable the delineation of core zones, buffer areas, and steppingstone habitats essential for sustaining biodiversity. The outputs of these EO-based approaches, including maps of proposed ecological corridors and areas of vulnerability, serve as foundational tools for landscape planning and conservation policy.

Figure 7: Ecological Continuities Modelling © IGNFI



Use case: Deforestation-free supply chains

Problem to be addressed

A major driver of deforestation globally is agricultural expansion; large agri-businesses are increasingly under pressure by consumers to provide traceability of their supply chains in relation to reduced impact on the environment. Recent regulatory frameworks, such as the EU Deforestation Regulation (EUDR), mandate stringent monitoring and reporting, to ensure that commodities such as soy, cocoa, coffee, rubber, cattle and palm oil entering the EU market are not linked to deforestation since 2021. This presents a challenge for producers, traders, and governments in monitoring deforestation impacts and demonstrating compliance with regulations.

Example EO application

EO provides independent data at regular intervals with global coverage for creating robust monitoring systems, including the development of forest benchmark maps and recurrent forest degradation maps. These maps are generated using satellite data, such as Sentinel-2 high-resolution analysis, adapted to local conditions through rule-based classification schemes.

Advanced machine learning algorithms are applied to delineate forest vitality classes, distinguishing degraded areas from intact forests. Texture metrics and vegetation indices, including Normalised Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI), are used to assess forest conditions and identify the drivers of degradation, such as agricultural expansion. These analyses support the segmentation and classification of forest areas into degradation categories, providing actionable insights for supply chain interventions.

Figure 8: Deforestation in the Amazon Rainforest[9]

[9] ESA, The Amazon forest, 2021, https://www.esa.int/ESA_Multimedia/Images/2021/11/The_Amazon_rainforest

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Use case: Monitoring of mangrove areas

Problem to be addressed

Mangroves are remarkably diverse and important ecosystems providing critical services such as carbon sequestration, coastal protection, and habitat for thousands of species. However, mangroves are under increasing threat from agricultural expansion, urban development, and unsustainable land-use practices. These pressures result in the loss of mangrove coverage and degradation, leading to reduced ecosystem services and increased carbon emissions. Accurate, timely, and scalable monitoring of mangroves is necessary to quantify these changes, guide conservation efforts, and support initiatives such as carbon credit certification.

Example EO application

Mangrove monitoring utilises advanced EO technologies, such as Sentinel-1 radar and Sentinel-2 multispectral data, to create detailed status and change maps to assess mangrove ecosystems over time. These maps are typically produced at high resolutions of 10 metres supporting the assessment of human impacts, including agriculture and other land use changes, on mangroves. High-resolution satellite imagery and machine learning techniques are employed to develop scalable and adaptable classification models for mapping and tracking mangrove dynamics. These approaches utilise satellite data to analyse mangrove extent and condition over large areas and identify zones with favourable growth conditions. By comparing EO-derived maps over multiple years, trends in mangrove loss and gain can be observed, providing valuable insights for conservation and sustainable management. Localised and adapted methods complement global initiatives such as the Global Mangrove Watch (GMW) and serve as a powerful tool for monitoring coastal ecosystems and informing local decision-making.

Figure 9: Satellite Image of Coastal Mangrove Area © Copernicus Sentinel-2 Satellite 2025

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