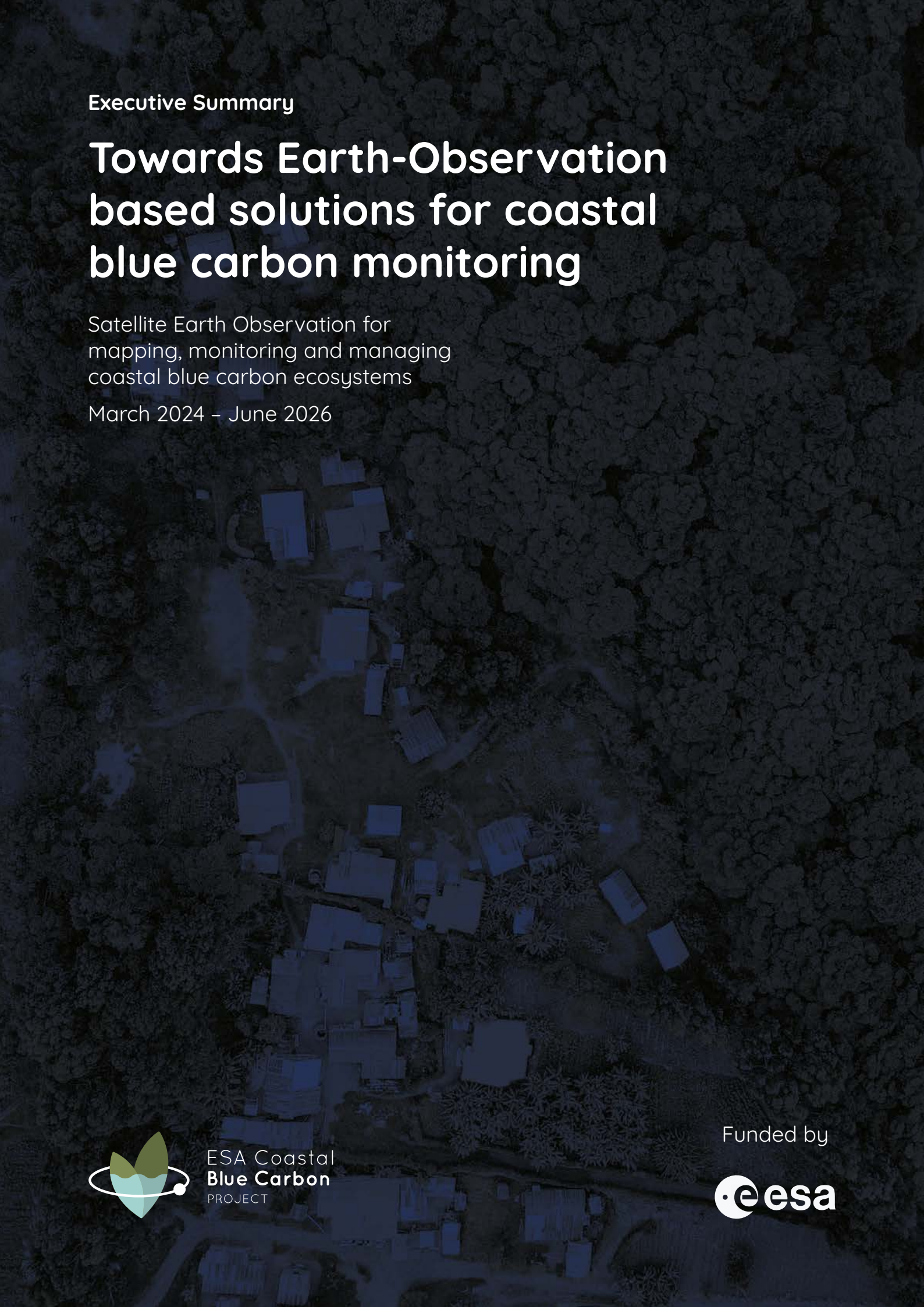
Executive Summary

Towards Earth-Observation based solutions for coastal blue carbon monitoring

Satellite Earth Observation for mapping, monitoring and managing coastal blue carbon ecosystems

March 2024 – June 2026



ESA Coastal **Blue Carbon** PROJECT

Funded by esa

Contents

Marie-Helene Rio

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Context

Coastal ecosystems — mangroves, seagrasses and tidal saltmarshes — store an estimated **50% of all carbon buried in marine sediments but cover only 0.2% of the ocean surface**.

Yet they remain poorly mapped and are largely absent from national greenhouse-gas inventories and Nationally Determined Contributions (NDCs).

Funded by the European Space Agency (ESA) and coordinated by i-Sea with five partner organisations — BlueSeeds, IRD, CEAB/CSIC, LIENSs–Université de La Rochelle, and Simon Fraser University — the ESA Coastal Blue Carbon (ESA CBC) project developed and demonstrated satellite-based Earth Observation (EO) products, indicators and methods to map, monitor, and support the conservation and restoration of Blue Carbon Ecosystems, co-designed with local practitioners, policymakers and scientific *Early Adopters*.

French Guiana's mangroves
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This summary details the project's objectives, methodology, key results and perspectives.

Objectives

The 24-month long project aimed to use remote sensing (RS) and machine learning (ML) to estimate carbon stock in the intertidal zones of salt marshes, seagrass and mangroves over three reference years (spanning 2015-2025) using 10m Sentinel-2 imagery.

The project focused on 5 pilot regions across 4 countries: The **French Atlantic and Mediterranean coasts**, the **Mediterranean coast of Spain** (salt marsh and seagrass); the **Atlantic and Pacific coasts of Canada** (salt marsh and seagrass); and the **French Guiana /** the **Guiana Shield** in South America (mangroves).

The project was split into two phases:

1. Establish user requirements and develop mapping methodologies on representative *Test Sites*;
2. Deploy these methods at scale across *Pilot Regions* and assess their impact on target users.

Canada

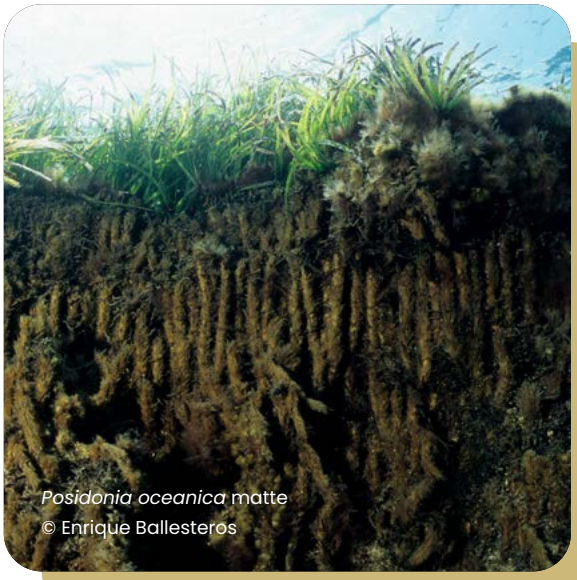
Guiana Shield

Europe

Stakeholder engagement and co-design

From its inception, the ESA CBC project was built user-centered, co-designed with ***Early Adopters***, local practitioners, policymakers and scientific institutions, expected to become its first operational users. Throughout the project, over 227 users were engaged through 25 interviews, 5 webinars, and questionnaires (39 responses) to identify their needs across multiple scales and regions, including those related to policy guidance and management.

Relationships with key users (the **French Biodiversity Agency** (OFB), the **Junta de Andalucía** in Spain, and the **Nature Conservancy of Canada**) were strengthened to develop concrete use cases and assess the usability and appropriateness of ESA CBC products.



Posidonia oceanica matte
© Enrique Ballesteros

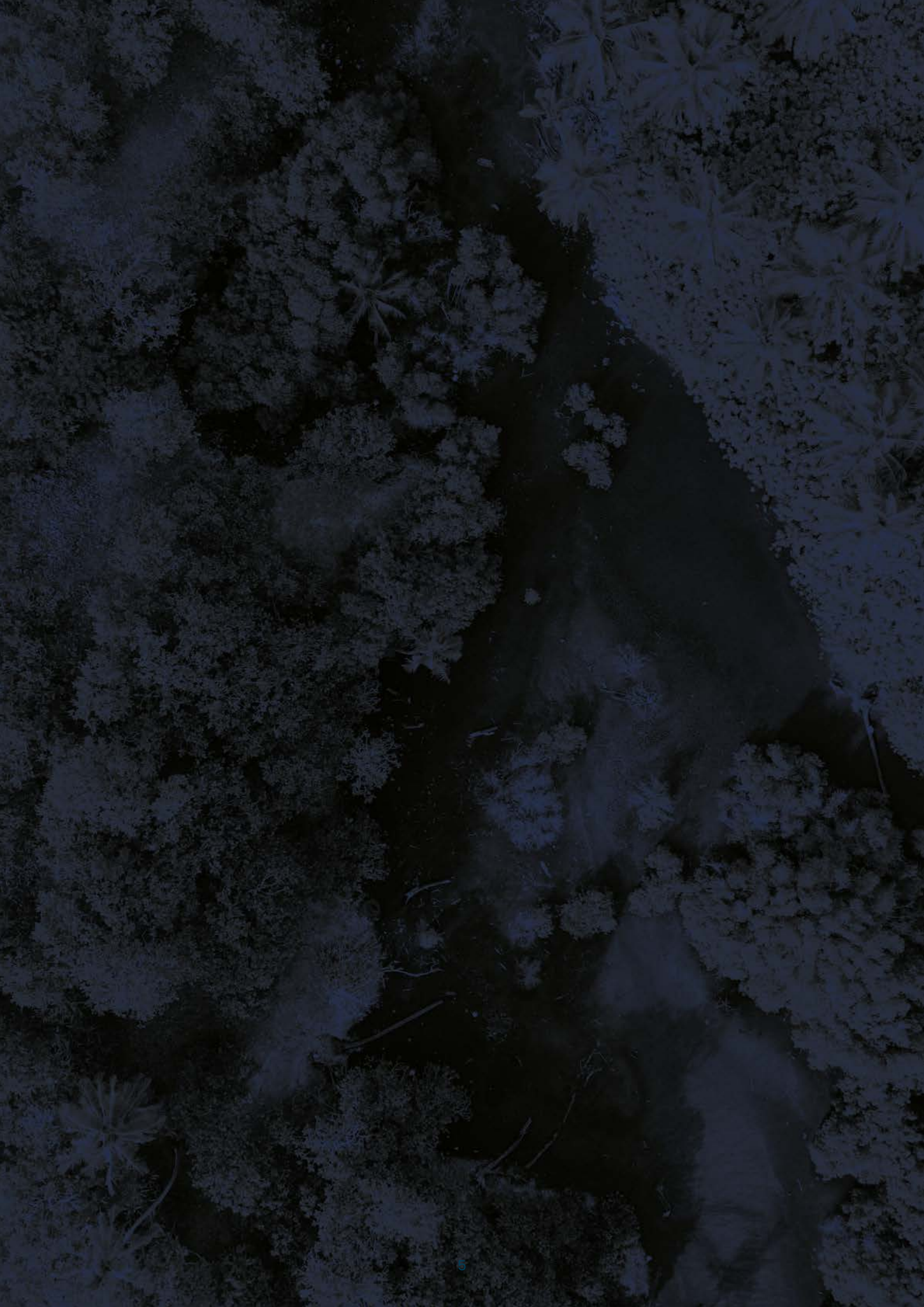
User Consultation Meeting,
Frascati, Italy, 2026

Laura Lorenzoni, Program Scientist, NASA
User Consultation Meeting,
Frascati, Italy, 2026

The user engagement culminated in The User Consultation Meeting convening more than 30 organisations — including **ESA**, **NASA**, the **European Commission's DG MARE** and **Joint Research Centre**, **JPI Oceans**, **The Nature Conservancy**, **WWF**, **Global Mangrove Watch** and **Wetlands International** — around plenary sessions and ecosystem-specific breakout workshops.

This meeting confirmed the community's enthusiasm around large scale CBC products but also the limits of the current products.

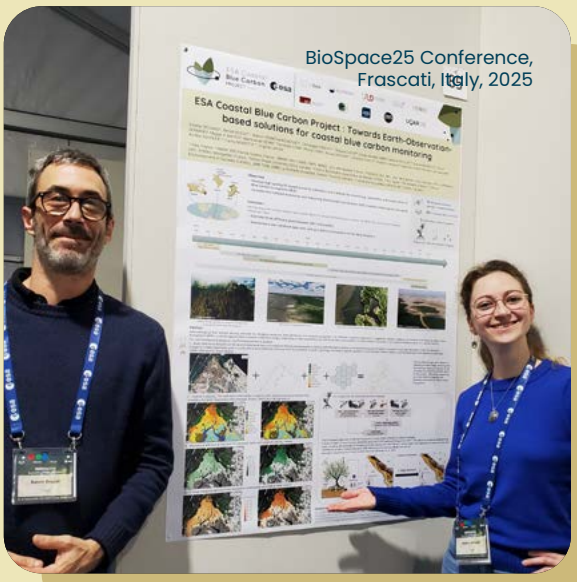
Discover the methodology behind this project



Methodology

The project followed a five-step pipeline:

1. **Gathering user needs and reference data;**
2. **Local calibration on Test Sites using in-situ sampling and very-high-resolution (VHR) imagery;**
3. **Large-scale mapping deployment on multi-temporal Sentinel-2 composites across *Pilot Regions*;**
4. **Independent validation against in-situ and VHR reference data;**
5. **Delivery of blue carbon stock maps with confidence indicators.**



BioSpace25 Conference, Frascati, Italy, 2025

In the northern hemisphere pilot regions, steps 2 through 4 of the pipeline were achieved by first predicting habitat extent maps using a **Random forest classifier**, followed by determining carbon stocks either through averaged in-situ carbon values, both acquired during the ESA Coastal Blue Carbon project (568 new vegetation and carbon samples) and outside the scope of the project, or large-scale BRT modelling (using *in-situ* carbon cores and external indicators).

In South America, mangrove structures were first determined using **Fourier Textural Ordination (FOTO)** analysis of canopy texture on Pléiades imagery subsequently upscaled with Sentinel-2 imagery; followed by age-based allometric equations for mangrove carbon using 125 mangrove forest inventory plots (acquired between 1997 and 2025).

In-situ sampling
© LIENSs / La Rochelle Université

All products are available through the **i-Sea Geoportal** (coastal-blue-carbon.i-sea.fr), with data downloadable as GeoTIFF, GeoPackage or Shapefile and via OGC web services (WMS/WCS/WFS/WMTS) for direct use in GIS software such as QGIS or ArcGIS.

VIEW PRODUCTS >

Study workflow

1

Study context

3 blue carbon ecosystems

They represent:

- 0.2% of the ocean surface
- 50% of sediment carbon

Objective: Help improve the monitoring, conservation and management of:

Seagrass
Subtidal and intertidal meadows

Saltmarsh
Intertidal vegetated wetlands

Mangroves
Coastal forested wetlands

Space agencies and research
ESA, NASA, universities

Conservation and NGOs
Managers, WWF, wetlands organisations

Scientific & mapping workflow
Iteratively refined with user feedback

Applicable use cases
Usability, interpretability & decision-support capability

Policy and public bodies
Ministries, EU, agencies

Local communities
Fisheries, port, citizens

2

User engagement

Iterative co-design

3

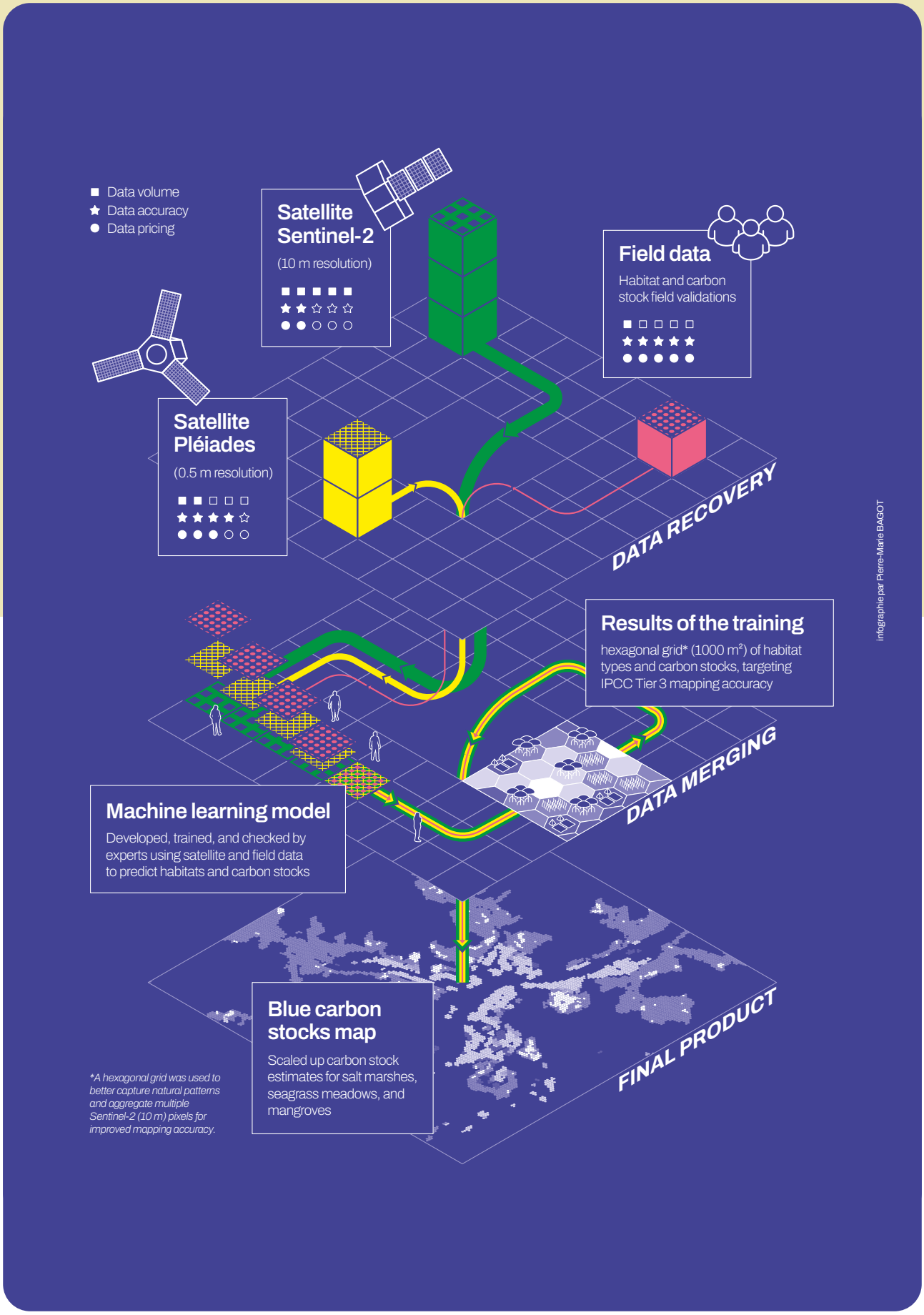
Remote sensing methodology

Ecosystem-specific pipeline

Sentinel-2 VHR imagery	Sentinel-2 time series VHR imagery	Pléiades VHR imagery	**DATA ACQUISITION**
Water-column Correction / Low-tide compositing	Low-tide compositing	FOTO texture analysis	**PRE-PROCESSING**
Random Forest Classifier + BRT carbon (Posidonia) / Averaged *in-situ*	RFC + Averaged *in-situ* carbon	Canopy age clustering	**MODELLING** (Habitat and carbon)
Habitat: Leave-one-out testing Carbon: field-calibrated		Allometric conversion	**VALIDATION**
			**PRODUCTS**

Habitat and carbon maps

Study workflow



Key results

The consortium produced the first multi-country, multi-ecosystem, multi-scale blue carbon mapping efforts.

A total of

114 Earth Observation products

were deployed on the geo-platform:

44 habitat maps

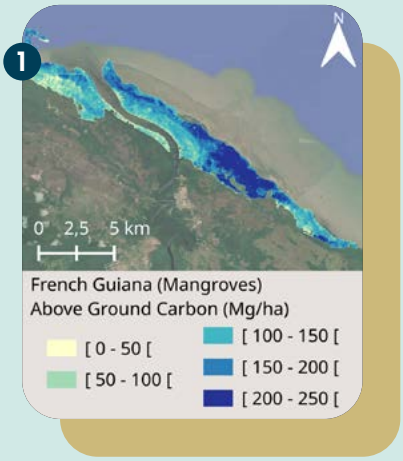
51 carbon-stock maps

14 reference / training datasets

5 experimental change-detection layers

Explore the results of the project:

Large-scale coastal blue carbon mapping across three ecosystems (salt marshes, seagrasses and mangroves); a first-generation product for carbon management, monitoring and policy.



At local scale,

where dense field data allowed fine calibration, mapping models perform strongly indicating a good product reliability:

The French Guiana mangrove habitat map reached

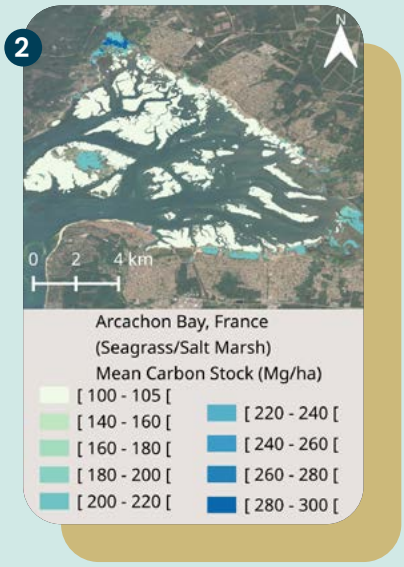
84% overall accuracy

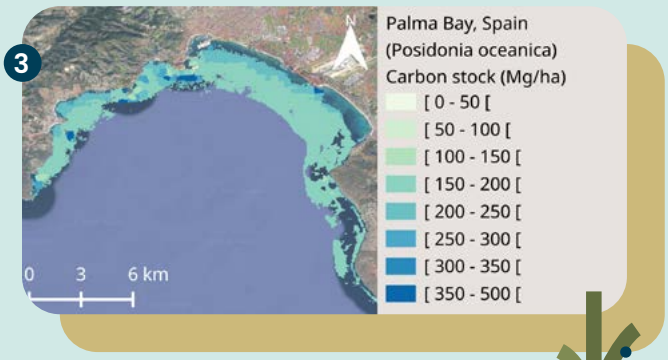
across three reference years, with a carbon-stock model achieving

$R^2 = 0.86$

The Aiguillon Bay (France) salt-marsh carbon-regression model achieved

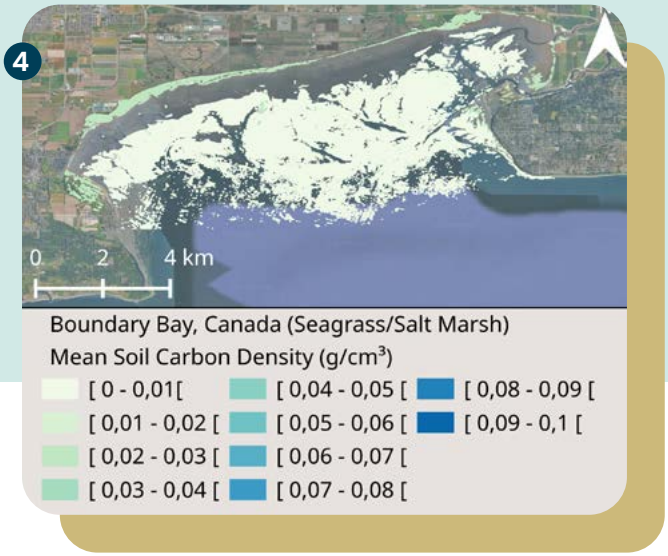
$R^2 = 0.95$





The Mediterranean seagrass soil-carbon model explains over

70% of regional variability



The Canadian carbon-stock mapping models achieved:

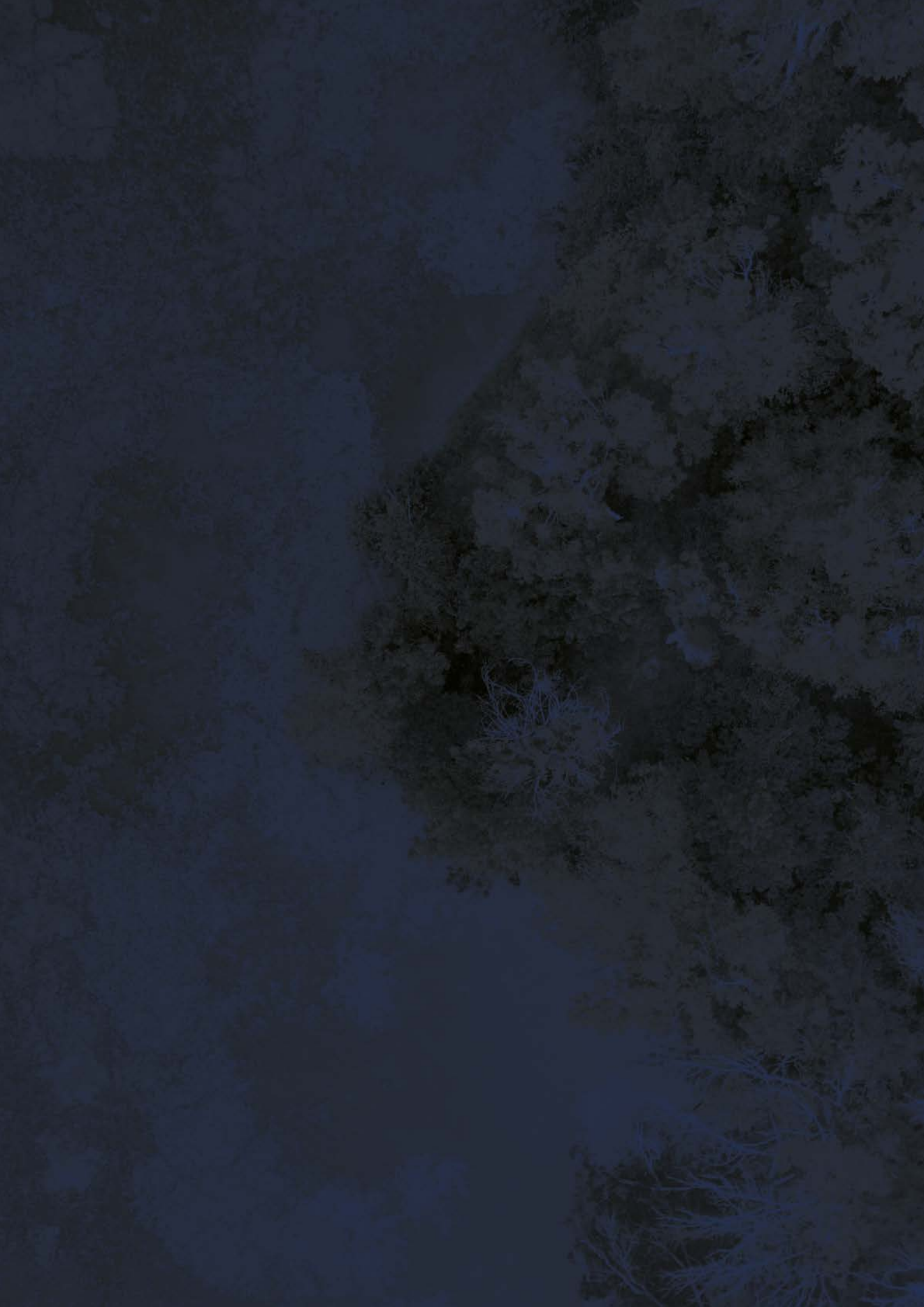
$R^2 = 0.77$
for the Pacific coast

$R^2 = 0.93$
for the Atlantic coast.

At regional scale,

the same models were extended using 10m satellite imagery (Sentinel-2), producing consistent, pilot region coverage of carbon stocks and habitat extents. These first generation regional products help users identify broad carbon hotspots and priority areas for conservation, restoration, and targeted field investigation, directly supporting their strategic planning and regional trend monitoring needs.

A striking example of the operational value at this scale: a traditional field based carbon MRV campaign for Spanish Posidonia oceanica costs about €193,000 initially plus €36,000 per five year revalidation, compared with an estimated €30,000–50,000 for an equivalent satellite based hybrid approach.



Conclusions and perspectives

Community feedback and the consortium's large scale production experience show that further development is needed to make Blue Carbon Ecosystem (BCE) products fully integrated into policy processes (NDC contribution, adaptation, restoration and coastal-protection planning) and for them to be recognised and sustained, in a community-anchored Decision-Support Capability.

Four main themes are proposed to achieve this long-term goal:

1. **Bolstering user and pilot use cases;**
2. **Improving the remote-sensing/technical pipeline;**
3. **Creating a long-lasting and trusted shared datahub for harvesting existing and new data;**
4. **Improving product interpretability and decision-usability**

This trajectory is reinforced by external momentum identified by the project: on the policy side, the EU Nature Restoration Law, the Paris Agreement NDC cycle, and the Taskforce on Nature-related Financial Disclosures (TNFD); and on the technical side, satellite missions — ESA's BIOMASS, CHIME, and the NASA/ISRO NISAR mission — expected to improve Tier 2–3 carbon-accounting capability for Blue Carbon Ecosystems.

The consortium concludes that the ESA Coastal Blue Carbon project "has the potential to generate lasting impact" across science, policy/territorial management, and business/finance, by producing high-resolution, multi-temporal, uncertainty-quantified carbon products across three continents.

Coastal Blue Carbon from Space Forum, Bern, Switzerland 2024

The consortium

esa · i-Sea · BLUE SEEDS · SFU Simon Fraser University · CEAB · CSIC Consejo Superior de Investigaciones Científicas · LIENSs Littoral Environnement et Sociétés · La Rochelle Université · IRD Institut de Recherche pour le Développement France · cnrs

www.esa-coastal-blue-carbon.eu