Space for Shore

ESA EOEP-5

Coastal Erosion

Requirement Baseline

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Summary

Illustrations and Tables

1 INTRODUCTION

1.1 Scope of the document

The Requirement Baseline displays a comprehensive statement of the requirements expressed by coastal managers, in terms of tools and products that they are currently using to achieve their missions of coastline surveillance.

To support this document, its first section summarizes the necessary thematic backgrounds presented for the main coastal geomorphologies. The third section explains the method used to select our potential users, collect their needs and perform the analysis necessary to derive the Space for Shore Portfolio (addressed by section 4) and finally describe the product and service requirements as a function of families of products identified (detailed by section 5). A cross-tabulation of the products required as a function of the regions is synthetized in section 4. Finally, the section 6 details the validation data available by regions and families of product. This final section has been defined in order to organized the Proof of Concept phases.

Finally, individual forms collected are groups in a separate document, entitled User Requirement Document Book. With respect to the Directive on the protection of personal data, the names and contacts of the interviewees have been removed from the forms.

This document is a basis to finalise the EO Data Procurement Plan and achieve the Technical Specifications.

1.2 Reference documents

The Requirement Baseline is the first document produced in the framework of Space for Shore. The only reference documents are the bid submitted by our consortium in response to the EOEP-5 Coastal Erosion Tender, the scientific literature related to the thematic fields linked to the use of remote sensing, in particular satellite remote sensing, for coastal monitoring and the preliminary user needs collected prior to the bid submission.

2 COASTAL EROSION BACKGROUND

2.1 Introduction

Today, more than 200 million of European citizens live in coastal regions, representing 41% of Europe's total population, and 33% live within 50 km from the sea (Eurostats, 2013[1]). Coastal regions account for about 40% of European Union's Domestic Gross Product with the maritime economy, tourism and yachting being the main parts of the total gross value. In addition, in 2004, the estimate of the current total value of the economic assets located within 500 m from the EU's coastline, including beaches, agricultural land and industrial facilities, was 500 to 1,000 billion € (Eurosion, 2004[2]; EEA, 2013[3]).

According to the Eurosion project (Eurosion, 2004), 20 000 km of the coastline faced serious impacts in 2004 (Figure 1). Most of the impact zones are actively retreating, including 2900 km that are already protected, whilst 4700 km are artificially stabilized. Erosion rates of 2 m per year are frequently recorded all over Europe. Thus, about 25% of the European coastline for which data is available is currently retreating. The issue is not restricted to European coasts, but is a global, worldwide threat. In the context of global warming and sea level rise, coastal erosion issues will be even more relevant in future, as both the frequency and strength of storm events are likely to increase causing billions of Euros of damages. Unfortunately, this topic is not covered by any European directives (neither the Water nor the Marine Strategy); therefore, it is currently dealt with at the national levels (e.g. in France through the shoreline management policy) resulting in heterogeneous degrees of concern in different EU member States.

Dealing with coastal erosion implies to provide highly precise (sub-metric) geo-located information about shorelines on a yearly to decadal timescale. For this reason, the classical approach for coastal erosion assessment has been based on the analysis of historical aerial orthophotos (enabling the extraction of long-term trends), along with GPS field observations (short-term beach and shoreline changes at the timescale of storm events). Historical data sets allow accurately determining the erosion hazard and projecting from such hazards at various time horizons that are compatible with safe coastal planning for people and goods (Figure 2). This strategy, chosen by French Government in particular, is imposed to any regional authorities to develop local compulsory littoral risk prevention plans[4]. The use of both historical and present data of shoreline change is therefore crucial.

The use of new technologies for shoreline monitoring has significantly increased during the past 20 years (airborne lidar topographic surveys, photogrammetry, in situ laser scanning) but their definitive adoption still depends on their cost to effectiveness ratio. At the same time, previous work has shown high-resolution (Pleiades-like) optical satellite remote sensing to be adequate and relatively cost-effective for detecting and monitoring shorelines over wide sandy areas on a yearly timescale (Lafon et al., 2010[5][6]). Other high-resolution satellite sensors of lower resolution (Sentinel-1/2) may also be relevant for this issue, more likely over coastal areas evolving very rapidly, where the annual shoreline changes exceed

1 Eurostat (2013). Coastal regions: people living along the coastline, integration of NUTS 2010 and latest population grid Statistics in focus 30/2013; Author: Isabelle OLLET, Andries ENGELBERT. ISSN:2314-9647Catalogue number:KS-SF-13-030-EN-N

2 Eurosion (2004). Living with coastal erosion in Europe: sediment and space for sustainability. PART I – Major findings and policy recommendations of the EUROSION project (Maps and statistics). European Commission, Directorate General for the Environment, Brussels. http://wwww.eurosion.org/reports-online/part1.pdf.

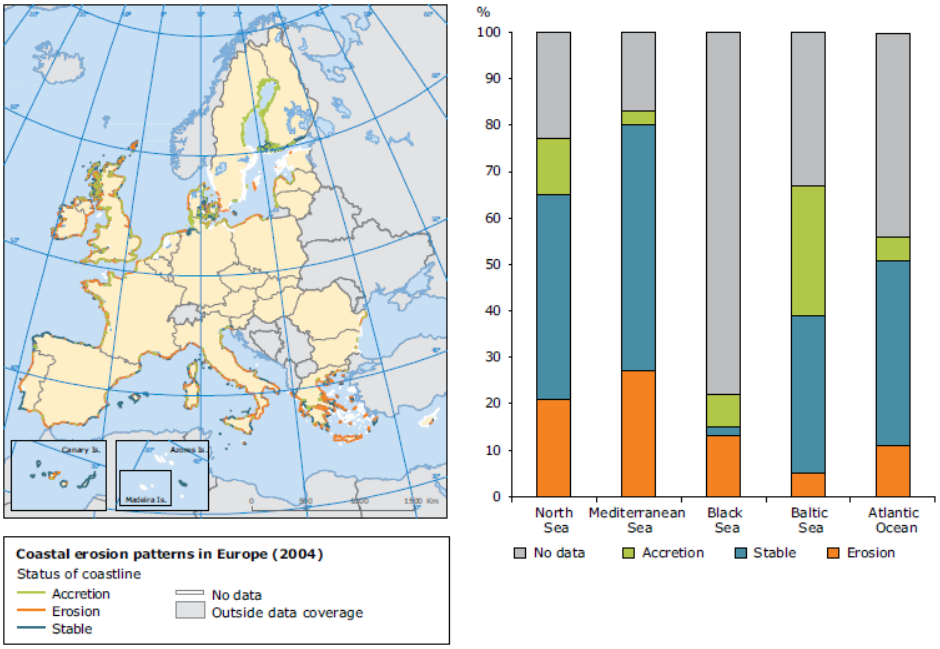
3 European Environment Agency (2013). Balancing the future of Europe's coasts—knowledge base for integrated management, 64 pp., ISBN 978-92-9213-414-3 doi:10.2800/99116

4 MEDDE, 2014. Guide méthodologique : Plan de prévention des risques littoraux. *Rapports, Direction Générale de la Prévention des Risques Service des Risques Naturels et Hydrauliques, 169 p*

5 Lafon, V., Maneux, E, Froidefond, J.-M. et Mallet, C. (2010). Coastline monitoring. In 25 Uses of GMES in the NEREUS regions. Prepared by the NEREUS Earth Observation / GMES Working Group, p. 25-26.

6 Lafon V., Hoareau A., Mallet C., Desprats J.-F. (2010) Suivi du trait de côte en Aquitaine par imagerie Formosat-2, Proceedings of 11e Conférence Génie Côtier Génie Civil, Les Sables d'Olonne, juin 2010, 497-504, available online at http://www.paralia.fr (in french)

several tens of meters, like at some places in western Africa or French Guyana. However, this is typically not the case for most European coastlines.



Source: Deduce project (44) (http://www.deduce.eu/IFS/IFS26.pdf).

Figure 1. Coastal erosion patterns in Europe (Eurosion, 2004)

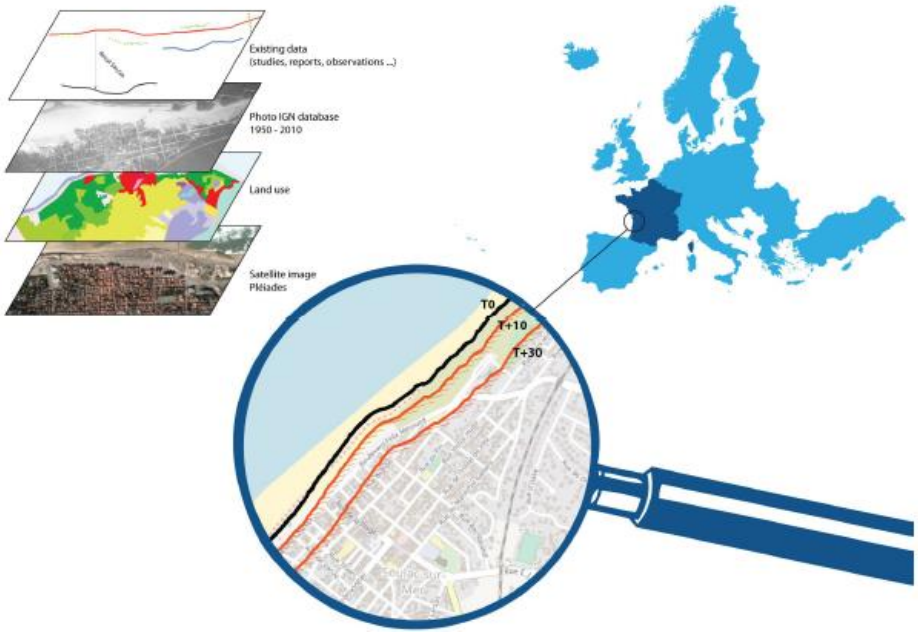


Figure 2. Projection of erosion hazard in Aquitaine (10-year and 30-year time horizons)

"Space for Shore" intends to unravel the remaining technical issues and to provide a large European end user community with prototyped products, that are based on the Copernicus Sentinel-1 and Sentinel-2 missions and, to a certain extent, on Third Party Missions.

2.2 Rocky cliffs

Main processes responsible for cliff erosion in the coastal zone are:

- The hydraulic action of waves, destabilizing the cliff over long periods of time,
- The repeated action of waves breaking (which power may be increased by the presence of and & shingle in the water) provoking corrasion and abrasion able to remove material from the cliff over time,
- Attrition,
- Corrosion that affects rocks vulnerable to acidic water (ex. limestones) that is formed in the atmosphere by carbon dioxide that is dissolved into water.

Cliff erosion rate varies with the strength of waves that is partly controlled by coastal bathymetry. Also, depending on their lithology, cliffs are more or less resistant to erosion. In addition, cliffs may be formed by alternating layers of hard and soft rock, and the angle the beds dip at affects how they are eroded and the profile of the resulting cliffs. Cliffs made of limestone, flysch rocks, clays, soft till deposits are amongst the most vulnerable observed throughout Europe (examples give in Figure 3). Although, low yearly erosion rates are reported (ex. in the French Basque country: 0.2 m/year to locally more than 0.5 m/year), erosion occurs as landslides and is therefore dramatic. Anticipation is required to protect people and goods, particularly in region where rocks are the most vulnerable.

Figure 3. Calcareous cliffs in Calvados, France (left, credit: S. Costa); Till cliff of the Baltic Sea, Germany (central picture, Photo © www.anglerforum-sh.de), Flysh cliffs of the Basque Country in Spain 5right)

2.3 Beaches

The state of the World's beaches has been recently published by Luijendijk et al. (2018)[7]. A global evaluation has been carried out based on satellite imagery in the framework of a work is funded by NatureCoast, a project of technology foundation STW (applied science division of NWO) and the Deltares Strategic Research Programme 'Coastal and Offshore Engineering'. This investigation provides a quantitative global distribution of sandy shorelines, determined by supervised (human-guided) classification applied to global cloud-free satellite Sentinel 2 images. The authors show that 31% of the ice-free world shoreline is sandy (Figure 4). The continent with the highest presence of sandy beaches is Africa (66%), while in Europe only 22% of the shoreline is sandy.

[7] *Luijendijk, A., Hagenaars, G., Ranasinghe, R., Baart, F., Donchyts, G and Aarninkhof, S. 2018. The State of the World's Beaches. SCIENTIFIC REPORTS | (2018) 8:6641 | DOI:10.1038/s41598-018-24630-6.*

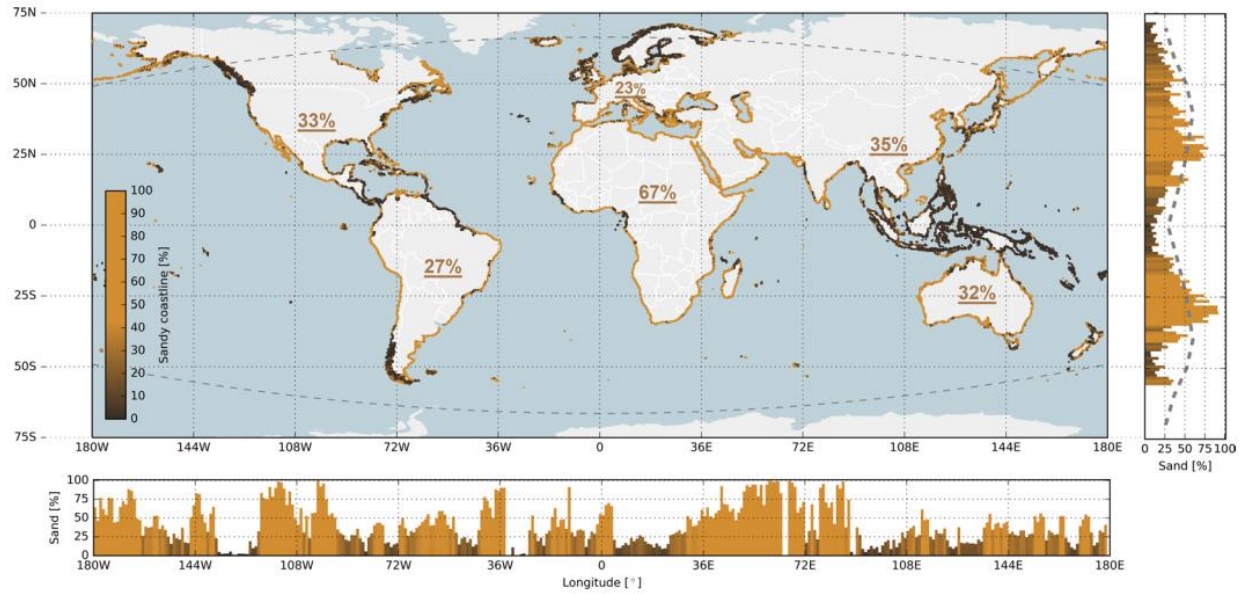


Figure 4. Global distribution of sandy shorelines (Luijendijk et al. (2018))

Sandy beach erosion is due to wave action. However, other causes such as the decrease of fluvial sediment supply caused by the construction of dams, the subsidence and the sea-level rise caused by climate change are increasingly important. However, the rapid disappearance of sandy beaches during the last 30 years in coasts and beaches worldwide cannot be solely explained by the above, and are, therefore, associated with human activities in coastal areas, such as the construction of new harbours[8]. In Europe, it is recognized that human-induced coastal erosion exceeds coastal erosion driven by natural factors[9,10].

Early evaluation[11] showed that at least 70% of sandy beaches around the world are recessional (Bird, 1985). Luijendijk et al. (2018) recently proposed a global map of main erosion and accretion hotspots (Figure 5). Remote sensing data are used for this recent analysis. The shoreline position is defined and the water / land interface, yearly global image composites are produced in a way that decreases the influence of the tidal stage. Then, erosion accretion trends are derived using a global transect system based on yearly coastlines extracted from 1986 to 2016. The analysis of global shorelines revealed significantly lower percentages for shoreline erosion than reported in the literature (24% as opposed to 70%).

Although this global assessment seems encouraging, it is based on Landsat imagery. Landsat space resolution is not adapted to slow erosion rate (< 2 m/year) over a period of 30 years, particularly in areas with high tidal range. From a local point of view, whatever the erosion rate, the erosion of populated sandy shore appears sometimes slow but inexorable with potential significant impact on the buildings to be considered over long-time scales (50 to 100 years ahead). In addition, coastal protection action is often counterproductive on a regional scale, inducing major erosion hotspots downdrift the built structures. Therefore, sandy coastline erosion must be addressed at large geographical and temporal

[8] *Tsoukala, V. K. , Katsardi, V., Hadjibiros, K. Moutzouris, C. I., 2015. Beach Erosion and Consequential Impacts Due to the Presence of Harbours in Sandy Beaches in Greece and Cyprus. Environmental Processes, November 2015, Volume 2, Supplement 1, pp 55–71.*

[9] *Eurosion (2004a) Coastal erosion – Evaluation of the need for action, Living with coastal erosion in Europe: Sediment and Space for Sustainability, PART IV: A guide to coastal erosion management practices in Europe Lessons Learned, B4-3301/2001/329175/MAR/B3, Directorate General Environment, European Commission*

[10] *Eurosion (2004b) Coastal erosion – Evaluation of the need for action, Living with coastal erosion in Europe: Sediment and Space for Sustainability, PART V: Guidelines for incorporating coastal erosion issues into Environmental Assessment (EA) procedures,B5-3301/2001/329175/MAR/B3, Directorate General Environment, European Commission.*

[11] *Bird, E. C. F.: 1985, Coastline Changes, Wiley & Sons, New York, 219 pp.*

scales far greater than those of political decision-making process. High resolution frequently refreshed data are therefore needed to support ambitious measures for sustainable development of the sandy shores.

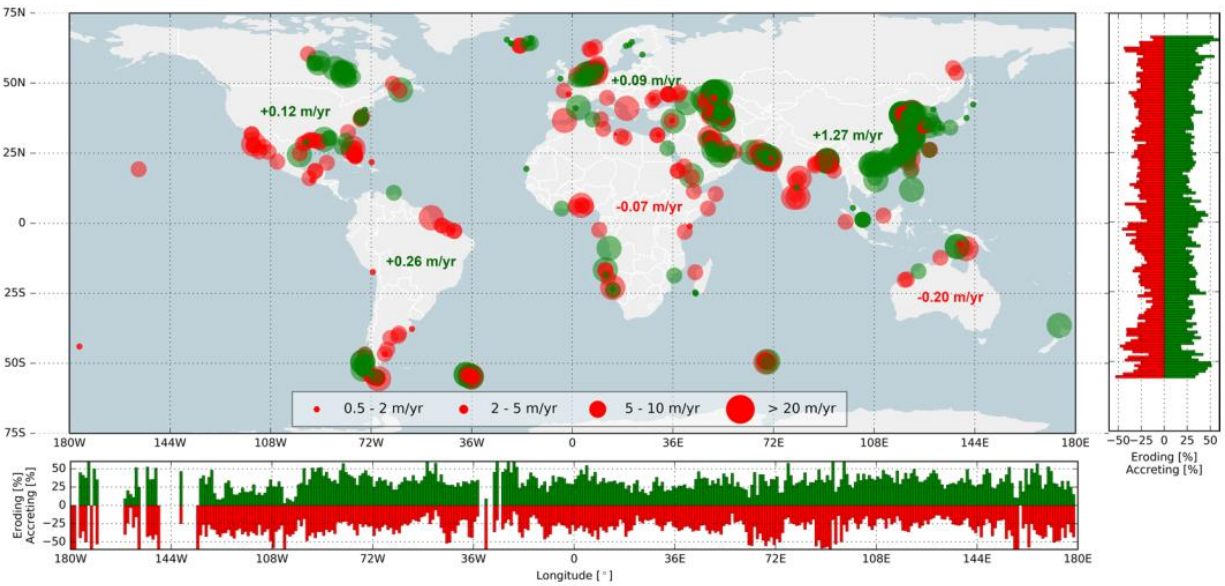


Figure 5. Global hotspots of beach erosion and accretion; the red (green) circles indicate erosion (accretion) (Luijendijk et al. (2018))

2.4 Tidal flats

Tidal flats form in low-lying sheltered areas (estuaries, lagoon) with sediment suppled by rivers and estuaries.

Alternately submerged and exposed to the air by changing tidal levels, tidal flats are important ecosystems. They usually support a large population of wildlife, and are among the most favorable habitat that allows tens of millions of migratory shorebirds to migrate from breeding sites in the northern hemisphere to non-breeding areas in the southern hemisphere.

Tidal flats are composed of cohesive or non-cohesive sediments, often mixed, supporting seagrass meadows in most sheltered areas sometimes competing with bivalve mollusks either farmed or wild. In environments more energetic, they protect the sea front from storm surges by breaking waves.

Over tidal flats, it has been demonstrated that waves is the main forcing involving erosion, whist tidal current are recognized as main forcing of accretion[12]: The authors found that for a bare flat under only tidal action, the model predicts a convex cross-shore profile. When wind waves are strong, the intertidal flat is highly eroded resulting in a concave profile near the high-water mark. In the presence of vegetation such a behavior is altered.

Loss of sediment over tidal flat may lead to lower its altitude and henceforth diminish its protection efficiency against flooding induced by storm surges. To mitigate sediment loss, there are essentially two main approaches: (i) retaining existing sediment on the foreshore/intertidal and (ii) restoring sediment to the foreshore/intertidal.

In flooded areas, anti-erosion measured of tidal flat is not extensively described in the literature. Indeed, wall building t is the main measure taken to limit submersion risks and protect costal populations. However, major programs of tidal flat restauration are undertaken since they contribute to prevent flooding events.

[12] *Zhou, Z., Ye, Q., Cocoa, G., 2016. A one-dimensional biomorphodynamic model of tidal flats: Sediment sorting, marsh distribution, and carbon accumulation under sea level rise. Advances in Water Resources, Volume 93, Part B, July 2016, Pages 288-302*

3 METHODS

3.1 Collection of the user's requirements

Collection of user's requirements followed a three-step method.

First, potential users were identified in France, Portugal, Romania, Germany and Greece.

With this aim, national to local responsible for coastal management were contacted.

In some cases, intermediate end-users (coastal experts) have been solicited to express coastal managers' needs, since they are considered by the managers as their referees with regards to coastal dynamics and erosion monitoring.

Second, meetings were organized with most of the end-users interested in participating in the development and evaluation of Space for Shore erosion monitoring service.

In France, Portugal and Germany, the forms have been filled during face-to-face meetings. The project and its ambitions were also exposed during these meetings.

In Romania, the project was presented to potential users during face-to-face meetings. Afterwards all the interviews were carried out by phone.

In Greece, presentation and the filling of forms was done through teleconferences.

In some case, end-users were not available or not enough mature to be involved during this first phase of requirement collection. We have therefore a second pool of potential users ready to integrate the project later. This second pool consisting of insurance companies and local managers is expected to grow up all along this first year of the project.

Third, the requirement forms filled during the interviews have been reworked by the regional coordinators and then send back to the end users for validation purposes. These last versions approved by the end users are enclosed in the End User Document Book.

3.2 Descriptive analysis of the sites, users and products

A first analysis of the form has been carried out by the regional coordinators in order to produce exhaustive listings of:

- the demonstration areas and suggested sites to perform Proof-Of-Concept (POC) activities,
- end users' communities,
- products.

With this aim, each regional partner performed extraction, identification and description of these information for their own end-users. This analysis is developed in section 4.

3.3 Requirement analysis

As a second step, an analysis of the information derived from the first analysis crossed with the original forms, was carried out with the objective to synthesize the needs in terms of accuracy, frequency of production and delivery time. This analysis was performed without considering countries or regions.

In order to synthetize this information, the products have been first classified in relevant families. Then precise needs have been summarized according to the product and the requirement of all end-users interested by the same product.

Then, major products have been identified, with regards to users' priorities and number of times the products were cited.

Based on users' requirements, an early critical analysis of the suggested products was made to confront the demand for quality with actual satellite capacities.

As a first step, the requirement analysis was performed by I-SEA's coastal experts. As a second step, it has been reviewed by the regional partners to insure the coherence of the analysis with their discussions with users.

This analysis is developed in section 5.

3.4 Validation data analysis

POC site suggestions must be further analyzed with regards to data availability in order to finalize the validation of the POC sites.

With this aim, the availability of satellite imagery and validation data must be confirmed for each suggested POC site.

An early analysis of available satellite imagery demonstrated that either SAR or optical data are available for the past 10 years over the demonstration areas. However, with regards to the users' requirements collected, the specific image products availability must be carefully check. This analysis is not developed in this document. It will be part of the EO Data Procurement Plan.

Since ground-truth surveys can be limiting to develop the Proof-of-Concept step, we decided to emphasize the analysis of available *in situ* relevant data for each region concerned.

The results of this analysis will contribute to the validation of the POC sites.

4 SPACE FOR SHORE PORTFOLIO

4.1 Test sites

The Space for Shore consortium focuses its actions on coastal areas of 5 countries: France, Germany, Greece, Portugal and Romania. Within each of these countries, specific areas (demonstration areas) have been identified where potential Space for Shore end-users were interviewed. Interested end-users designated smaller-scale sites on which the consortium will focus its efforts during phase 1 of the project in order to expose objectively its ability to answer end-user needs in terms of products and services for coastal erosion monitoring. These smaller-scale sites are hereafter referred to as suggested POC sites (POC = Proof Of Content). If phase 1 is successful, the project will enter in phase 2 during which products and services designed during phase 1 will be extended to the entire demonstration areas. Note that, not all the suggested POC sites will be addressed during phase 1 because of the following reasons. First, we must organize wisely the consortium production capacities to achieve phase 1 in due time. Second, some suggested POC sites present very similar environmental conditions and indicators requirements making relevant the indicator production for only a subset of these sites. Third, as stated in Section 4.3, the selected sites for POC activities will be the sites where enough validation datasets are available.

The following subsections present all the suggested POC sites per demonstration area.

4.1.1 France – Coast of the New Aquitaine (AQ)

The coast of the Nouvelle Aquitaine region (SW France) is a highly dynamic coastal area exposed to Atlantic swells, presents a meso to macrotidal range (3-5m) and exhibits a variety of coastal geomorphologies. The area of interest is made of two contiguous sub-areas in south-west Nouvelle Aquitaine: the Landes department and the Basque Country department. The Landes coast is dominated by sandy sediments with well-developed coastal dunes and is a quasi-rectilinear coast interrupted by estuary inlets and mixed-sediment lagoons. South of the Landes coast and extending up to the Spanish border is the Basque Country coast, which is essentially rocky and characterized by an alternance of embayed/pocket beaches and sediment-free foreshore both mostly backed by high coastal cliffs. Four sites of interest were targeted by end-users of this region as possible POC sites: the Biscarrosse beach, the Erretegia cliffs, the Bidart central beach and the Corniche Basque (cliffs). Synthetic description of the demonstration areas and suggested POC sites is provided in Table 1 and Table 2, respectively.

Table 1. Demonstration areas of New Aquitaine

Demonstration area	Geographical description	Geographical coordinates	Size (length / area)	Tidal range	Geomorphology
New Aquitaine – Landes	From the Arcachon Lagoon inlet to Adour estuary inlet	44.555°N, -1.244°E 43.529°N, -1.522°E	120 km	Meso to macro	Natural sandy beaches & coastal dunes disrupted by some river and tidal inlets
New Aquitaine – Basque Country	From Adour estuary inlet inlet to Henday embayment	43.529°N, -1.522°E 43.374°N, -1.788°E	30 km	Meso to macro	Alternance of sandy embayed/pocket beaches and rocky foreshore & rocky cliffs with alongshore varying rocky type

Table 2. Suggested POC sites for New Aquitaine

Suggested POC site	Geographical description and specificities	Geographical coordinates	Size (length / area)	Included in the demonstration area
Biscarrosse beach	The sandy beach of the Biscarrosse municipality	44.454°N, -1.255°E 44.436°N, -1.258°E	2 km	New Aquitaine – Landes
Erretegia cliffs	A calcareous marl cliff in the municipality of Bidart	43.445°N, -1.590°E 43.439°N, -1.595°E	0.6 km	New Aquitaine – Basque Country
Bidart central beach	A low-lying sandy beach over a rocky substratum (flysch) backed by boulder-made seawalls and cliffs	43.439°N, -1.595°E 43.435°N, -1.598°E	0.6 km	New Aquitaine – Basque Country
Corniche Basque	A flysch cliff extending from Ciboure to Hendaye municipalities	43.395°N, -1.684°E 43.380°N, -1.732°E	4.5 km	New Aquitaine – Basque Country

4.1.2 France – Coast of Normandy (NOR)

The coasts of the Normandy region (N France) are located in the English Channel, are exposed to moderate wave conditions and present a macro to mega tidal range. The area of interest is made of two contiguous sub-areas in north-east Normandy: the east coast of the Calvados department and the entire coast of the Seine-Maritime department. These two sub-areas are separated by the Seine estuary and present distinct geomorphological features. The east coast of the Calvados encompasses sandy beaches and rocky foreshore platforms alternatively backed by natural coastal dunes, seawalls and calcareous cliffs. The coast of the Seine-Maritime essentially exhibits shingle beaches and shingle and rocky foreshore backed by high limestone cliffs. For each of these demonstration areas, a smaller-scale stretch of coast was targeted by end-users of this region as possible POC site: the Calvados coast from Villers-sur-Mers to Ouistreham and the Seine-Maritime coast from Puys to Quiberville. Synthetic description of the demonstration areas and suggested POC sites is provided in Table 3 and Table 4, respectively.

Table 3. Demonstration areas of Normandy

Demonstration area	Geographical description	Geographical coordinates	Size (length or area)	Tidal range	Geomorphology
Normandy – East coast of Calvados department	From Saint-Aubin-Sur-Mer to Seine estuary	49.37°N, -0.40°E 49.43°N, 0.25°E 49.31°N, 0.25°E 49.25°N, -0.37°E	60 km	macro	Urbanized sandy beaches and rocky calcareous cliffs
Normandy – Entire coast of Seine-Maritime department	From Seine estuary to Mers-Les-Bains	49.51°N, -0.40°E 50.18°N, 1.30°E 49.96°N, 1.57°E 49.43°N, 0.26°E	150 km	macro	Shingle beaches and limestone cliffs

Table 4. Suggested POC sites for Normandy

Suggested POC site	Geographical description	Geographical coordinates	Size (length / area)	Included in the demonstration area
Calvados POC site	Calcareous cliffs from Villers-sur-Mers to Houlgate and Urbanized sandy beaches from Houlgate to Ouistreham	49.331°N, 0.012°E 49.297°N, -0.297°E	21 km (17+4)	Normandy - East coast of Calvados department
Seine-Maritime POC site	Shingle beaches and limestone cliffs from Puys to Quiberville	49.941°N, 1.117°E 49.901°N, 0.903°E	16 km	Normandy - Entire coast of Seine-Maritime department

4.1.3 France – Provence-Alpes-Côte d'Azur Region (PACA)

The coasts of the PACA region (SE France) are located in the Mediterranean Sea and exhibits a micro tidal range. The wave climate is on the average low-energetic, though occasional storms coming from the south can generate high-energy waves (mostly during winter). The area of interest is made of two subareas of very distinct geomorphology: the coast of Camargue which is a pretty natural, low-lying sandy environment next to a major estuary, and the coast of Côte d'Azur, which is an overall rocky coast including several sandy/shingle embayed/pocket beaches densely urbanized (Table 5). The end-user of this region suggested four POC sites (Table 6): the entire coast of Camargue, the entire bay of Hyères, the two adjacent embayments between Antibes and Nice and the bay of Saint-Raphaël.

Table 5. Demonstration areas of Provence-Alpes-Côte d'Azur Region

Demonstration area	Geographical description	Geographical coordinates	Size (length or area)	Tidal range	Geomorphology
PACA – Camargue	From the Rhone delta to the Espiguette sandspit	43.391°N, 4.911°E 43.509°N, 4.111° E	80 km	micro	Deltaic environment and surrounding low-lying sandy coasts
PACA – Côte d'Azur	From Hyères tombolo to Nice beach	43.079°N, 6.122°E 43.694°N, 7.278°E	200 km	micro	Rocky coasts with some urbanized sandy and shingle embayed/pocket beaches

Table 6. Suggested POC sites for Provence-Alpes-Côte d'Azur Region

Suggested POC site	Geographical description	Geographical coordinates	Size (length / area)	Included in the demonstration area
Camargue	Same as for the demonstration area	43.391°N, 4.911°E	80 km	PACA - Camargue

		43.509°N, 4.111° E		
Hyères bay	From the Hyères tombolo on the west to Cap Bénat on the east.	43.079°N, 6.122°E 43.110°N, 6.359°E	45 km	PACA - Côte d'Azur
Antibes-Nice embayments	Two successive embayed beaches: 1) Shingle beach from Nice to Saint Laurent du Var; 2) Mixed shingle-sandy beach from Saint Laurent du Var to Antibes	43.592°N, 7.125°E 43.690°N, 7.288°E	22 km	PACA - Côte d'Azur
Saint Raphaël bay	From Saint Aygulf (Fréjus district) to Santa Lucia harbour (Saint-Raphaël)	43.390°N, 6.732°E 43.408°N, 6.781°E	8 km	PACA - Côte d'Azur

4.1.4 Germany – North Sea (NS)

The Wadden Sea, a 450 km coastal wetland along the North Sea coasts of Denmark, Germany, and the Netherlands, is one of the largest wetlands in the world. It forms the transition zone between the North Sea and the mainland and is characterized by large changes in water coverage due to the semi-diurnal tides. The Wadden Sea is a highly dynamic area with habitats comprising tidal channels, sandbars, mudflats, and saltmarshes. The Wadden Sea with its extensive tidal flats and sands has great importance for the coastal protection of the mainland. It acts as a transformation of energy from waves and currents and therefore the protection and long-term stability of the intertidal flats is in the focus of coastal protection at the German North Sea Coast. (Table 7) The Northern Part of the Schleswig-Holstein Wadden Sea (North Frisian Wadden Sea) is characterized by a number island and halligen, while the southern part (Dithmarschen) is exposed to the North Sea. It is proposed to use parts of the entire Wadden Sea as POC sites (Table 8), the user proposed the Blauort, which is part of the Dithmarschen Wadden Sea and the Memengrund, which is the north of the Elbe Estuary.

In addition to the Wadden Sea areas, the southern part of Island Sylt has been proposed as POC sites (Sylt Odde). It is characterized by high coastal changes over the last years, and coastal protection measures (sand nourishment) in the adjacent areas.

Table 7. Demonstration areas of the North Sea

Demonstration area	Geographical description	Geographical coordinates	Size (length or area)	Tidal range	Geomorphology
Dithmarschen	Wadden Sea from Eiderstedt to Elbe Estuary	8.85E 54.3N 8.66E 54.3N 8.63E 53.94N 8.94E 53.88	500 km²	Meso to Macro	Intertidal flat area without barrier islands
Nordstrand	Wadden Sea North of Nordstrand Island	8.6E 54.5N 8.8E 54.5N 8.75E 54.68N 8.6E 54.6N	200 km²	Meso to Marcro	Interdidal flag, Halligenwatt, barrier islands
Sylt Odde	Southern part of Sylt Island	8.26E 54.79N 8.32E 54.79N 8.31E, 54.7N 8.25E, 54.7N	40 km²	Micro	Sandy beach and dunes, sublittoral sand banks

Table 8. Suggested POC sites for the North Sea

Suggested POC site	Geographical description	Geographical coordinates	Size (length / area)	Included in the demonstration area
Blauort	Wadden Sea north of Büsum	8.82E 54.19N 8.63E 54.18N 8.82E 54.125N	100 km²	Dithmarschen, mud flats with high sands
Medemgrund	River estuary with strong morphodymanics and changes of tidal creeks	8.94E 53.88N 8.97E 53.9N 8.68E 53.91N	150 km²	Southern Dithmarschen
Sylt Odde	Southern part of Sylt Island	8.26E 54.79N 8.32E 54.79N 8.31E, 54.7N 8.25E, 54.7N	40 km²	Sylt Odde

4.1.5 Germany – Baltic Sea (BW)

The Baltic Sea Coast of Germany is characterized by sandy beaches and cliffs (Table 9). Wave conditions and sediment transport in coastal waters depend on exposure to the predominant wind and wave direction. Dominant westerly winds cause an eastwardly moving sediment transport system. Strong and long-lasting easterly winds cause high level at the Western Baltic Coast as water is pushed towards the mainland. The POC sites (Table 10) contain both, beaches (Kiel/Probstei) as well as cliffs (Schönhagener Kliff, Bothener Ufer). The beaches are characterized by large areas with underwater sand banks that are of interest for detecting changes and movements.

Table 9. Demonstration areas of the Baltic Sea

Demonstration area	Geographical description	Geographical coordinates	Size (length or area)	Tidal range	Geomorphology
Schönhagener Kliff	Coast between mouth of Schlei and Eckernförder Bucht	10.03E 54.64N 10.03E 54.58N	23 km	micro	Exposed cliff with characteristic erosion
Kieler Förde	Laboe to Schönberger Seebrücke	10.218E 54.405N 10.329E 54.436N	10 km	micro	Sandy Beaches and sublittoral sand banks
Fehmarn Coast	Norst coast of Island Fehmarn	11.06E 54.534N 11.22E 54.50N	10 km	micro	Sandy beaches and sublittoral sand banks
Brothener Cliff	Bay of Lübeck; Niendorf to Travemünde	10.835E 53.992N 10.858E, 53.993N	5 km	micro	cliff

Table 10. Suggested POC sites for the Baltic Sea

Suggested POC site	Geographical description	Geographical coordinates	Size (length / area)	Included in the demonstration area
Schönhagener Kliff	Schönhagen to Damp	10.03E 54.63N 10.03E 54.319N	2 km	Schönhagener Kliff
Kiel/Probstei	Laboe to Schönberger Seebrücke	10.218E 54.405N 10.329E 54.436N 10.878E 53.986N 10.882E 54.97N	10 km	Kieler Förde
Brothener Ufer	Bay of Lübeck; Niendorf to Hermannshöhe	10.848E 54.992N 10.8688E 53.99N	2.5 km	Brothener Cliff

4.1.6 Greece – Eastern Macedonia & Thrace (EMT)

The Region of Eastern Macedonia & Thrace covers the northeastern edge of Greece and includes two major islands of the Thracian Sea, Thassos and Samothraki. It also includes the Regional Units of Drama, Kavala, Xanthi, Rodopi and Evros. Due to the climatic variations and the geomorphology of the terrain, Eastern Macedonia & Thrace has created a unique nature (Table 11). Vistonis and Evros Delta exhibits a microtidal range. The majority of the coastline area consists mainly of sandy and rocky beaches, deltas (Evros and Nestos) and lagoons. Two Areas of Interest (AOI) were targeted by end-users of this region to implement possible POC sites (Table 12). Vistonis-Maroneia and Evros Delta. The coastline of Vistonis-Maroneia extends from the port of Avdira to the port of Ag. Charalampos and consists a relatively straight coastline of red clay suffering from erosion and on the other hand, Evros Delta consists mainly of sandy and deltaic environments. Demonstration areas and suggested POC sites are shown in the table below.

Table 11. Demonstration areas of Eastern Macedonia and Thrace

Demonstration area	Geographical description	Geographical coordinates	Size (length or area)	Tidal range	Geomorphology
Vistonis	Coastline extending from the city of Kavala to the Delta area of Lissos River	40°58'05.1''N 24°30'17.2''E 40°55'04.2''N 25°22'47.2''E	100km	microtidal	Mainly sandy, locally rocky cliffs, the lake of Vistonis and the lake of Ismaris (natura areas) and deltaic environments of Nestos and Lissos Rivers. The city of Kavala (population 56,000 inhabitants) located on the coastline.
Evros Delta	Coastline extending from the city of Alexandroupolis to the Delta area of Evros River	40°51'03.4''N 25°49'39.5''E 40°41'13.9''N 26°03’41.3''E	50km	microtidal	Mainly sandy, locally rocky cliffs and deltaic environments. The city of Alexandroupolis (population 58,000 inhabitants) located on the coastline.

Table 12. Suggested POC sites for Eastern Macedonia and Thrace

Suggested POC site	Geographical description	Geographical coordinates	Size (length / area)	Included in the demonstration area
Vistonis-Maroneia	Coastline extending from the port of Avdira to the port of Ag. Charalampos.	40°56'01.2''N 24°57'34.6''E 40°52'44.2''N 25°30'42.2''E	60km	Mainly sandy, locally rocky cliffs, the lakes of Vistonis and Ismaris (natura areas) and Lissos deltaic environments. A relatively straight coastline of red clay suffering from erosion.
Evros Delta	An area covering the Delta of Evros River	40°50'49.1''N 25°54'47.8''E 40°43'19.6''N 26°02'58.3''E	20km	Mainly sandy and deltaic environments of Evros River.

4.1.7 Greece – Peloponnese (PEL)

The Region of Peloponnese is the largest peninsula in Greece and constitutes the southernmost of Greek mainland. It borders with the Aegean, Ionian Sea, Corinth Gulf and the Mediterranean Sea. The coasts of Xylokastro, Iria, Astros and the Gulf of Messinia are surrounded by the Corinth and the Argolis Gulf respectively. This region exhibits a microtidal range. The coastline geomorphology of Xylokastro, Iria and Gulf of Messinia consists mainly of sandy and locally rocky cliffs. Astros coastline extends from Palaiochano beach to the city of Paralio Astros and in the south extends the wetland of Moustos. Proof of Concept (POC) sites for the Region of Peloponnese are not retained. Demonstration areas are shown in Table 13.

Table 13. Demonstration areas of Peloponnese

Demonstration area	Geographical description	Geographical coordinates	Size (length or area)	Tidal range	Geomorphology
Xylokastro	Coastline extending from the city of Corinth to the city of Aigeira (Corinthian Gulf)	38°08'53.5''N 22°21'21.8''E 37°56'18.3''N 22°55'57.6''E	55	microtidal	Mainly sandy and locally rocky cliffs. Several small cities located on the coastline.
Iria	Coastline extending from Candia beach to Iria beach (Tolo Gulf)	37°31'20.6''N 22°56'17.9''E 37°28'20.5''N 23°01'04.4''E	15	microtidal	Mainly sandy and locally rocky cliffs

Astros	Coastline extending from Palaiochano beach to the city of Paralio Astros	37°26'56.8''N 22°44'57.8''E 37°22'41.7''N 22°45'06.9''E	10	microtidal	Mainly sandy, a lagoon (natura area) and locally rocky cliffs
Gulf of Messinia	Coastline within the Gulf of Messinia (eastern part), from the beach of Acrogiali to the inlet of Mezapos	36°57'29.2''N 22°08'30.4''E 36°31'52.1''N 22°21'54.2''E	65	microtidal	Mainly sandy and locally rocky cliffs

4.1.8 Portugal – Northwest coast (NWC)

The coasts of the Portugal are located in the northwest littoral, are exposed to high wave conditions and present a mesotidal range. The area of interest is made of three contiguous sub-areas: the sandy barrier of Aveiro lagoon, the Mondego region and the Leiria region.

These three sub-areas present distinct geomorphological features. The sandy barrier of Aveiro lagoon from Ovar to Quiaios correspond to a low sandy barrier and a sandy coast, in the Southern area, with a NNE-SSW orientation and exposed to one of the most energetic wave climate of the world. This coastal stretch presents extensive linear beaches bounded by coastal dunes and more recently by sandy dykes, which are only interrupted by the jetties of Aveiro lagoon inlet and by coastal engineering structures as groins and seawalls.

South of Quiaios the littoral is developed in cliffs that end at the Mondego cape, which constitutes a natural barrier to residual sediment transport. Beach–dune systems represent almost 90 % of this sector's total length.

Immediately south of Mondego Cape it is present a rocky coast, carved on cliffs and with the presence of an abrasion platform passing progressively to a sandy beach, extremely developed at the north of the Mondego inlet, by effect of retention against the north jetty of Figueira da Foz horbour. This retention induced the coastline retreat in the low, sandy and rectilinear coastal stretch of Cova Gala – Pedrogão which retaking the approximate direction NNE-SSW.

South of São Pedro de Moel, the coast develops in cliffs bordered by narrow beaches it develops upwards along a narrow beach, which widens in the vicinity of Nazaré by retention effects induced by the Nazaré promontory. The Nazaré canyon, works as a sedimentary sink where a significant amount of sand transported in the coastal drift was lost to the deep ocean. In this sector (Mondego Cape to Nazaré where 72 % of the beaches are backed by dunes), the erosion is mainly concentrated in its northern section, up to about 20 km to the south of the Mondego river mouth, in relation to harbour development works, including dredging and jetties.

For the sandy barrier of Aveiro Lagoon demonstration areas, two smaller-scale stretches of coast were targeted by end-users of this region as possible POC sites: The coastline extending from Praia de S. Pedro Maceda to Torrão Lameiro and the coastline extending from Praia da Costa Nova to Praia de Mira. Synthetic description of the demonstration areas and suggested POC sites is provided in Table 14 and Table 15, respectively.

Table 14. Demonstration areas of Northwest coast of Portugal

Demonstration area	Geographical description	Geographical coordinates	Size (length or area)	Tidal range	Geomorphology
Sandy barrier of Aveiro Lagoon	Coastline extending from Ovar to Quiaios	40º55'16.32''N 8º39'54.72''W 40º10'46.5''N 8º54'10.08''W	80 km	mesotidal	Sandy beaches backed by coastal dunes or sandy dykes

Mondego Cape	Coastline extending from Quiaios to Cabo Mondego	40º10'46.5''N 8º54'10.08''W 39º45'18''N 9º02'60''W	10 Km	mesotidal	Sandy beaches backed cliffs
Figueira da Foz region	Coastline extending from Mondego Cape to S. Pedro Moel	40º10'46.5''N 8º54'10.08''W 39º45'18''N 9º02'60''W	45 km	mesotidal	Sandy beaches over an abrasion platform between Mondego Cape and Mondego inlet and low, sandy beaches backed by coastal dunes south
Leiria region	Coastline extending from S. Pedro Muel to Nazaré	39º45'18''N 9º02'60''W 39º36'00 N 9º06' 00W	20 km	mesotidal	Sandy beaches backed by cliffs

Table 15. Suggested POC sites for of Northwest coast of Portugal

Suggested POC site	Geographical description	Geographical coordinates	Size (length / area)	Included in the demonstration area
North of Aveiro Lagoon	Coastline extending from Praia de S. Pedro Maceda to Torrão Lameiro	40º55´16.32''N 8º39'54.72''W 40º49'39.36''N 8º41'12.48''W	10 km	Included in the north part of Aveiro Lagoon North of Aveiro harbour
South of Aveiro Lagoon	Coastline extending from Praia da Costa Nova to Praia de Mira	40º37'7.68'' N 8º45'5.76''W 40º27'37.44''N 8º48'7.2''W	15 km	Included in the north part of Aveiro Lagoon South of Aveiro harbour

4.1.9 Romania – Romanian coast (RO)

The Romanian coastal area is unique and diverse, from geomorphological point of view, with two different shore sectors (Table 16). The northern one, approximately 158 km long, lies between Secondary Delta of Chilia Arm and Cape Midia and is characterized mainly by a low coastal relief, with extensive sandy beaches. The southern one, 85 km long, spreads between Cape Midia and Vama Veche (the border with Bulgaria) and, as going further away from the deltaic coast, the topography becomes more dynamic on the vertical plane, with the appearance of clay cliff areas, with heights generally not exceeding 15-20 m. All the area is under the direct influence of the Danube River, the most important one in terms of discharge rates (approximately 6000 m3/s, in average), out of the ones flowing into the Black Sea.

Based on the previous knowledge and collected user requirements, two areas were considered for the demonstration phase: (1) Sulina-Sfantu Gheorghe and (2) 2 Mai – Vama Veche sectors (Table 17).

The northern sector of the Romanian coast is mostly included in the Danube Delta Biosphere Reserve. The frontage between Sulina and Sfantu Gheorghe, approximately 30 kilometers long, is the most erosive sector on the Romanian coast. Although erosion in this area has naturally occurred before, the human impact accelerated it in the last one and a half

century. Hydrotechnical works on Danube and its tributaries led to a significant decrease in Danube sediment load. Moreover, building of Sulina Jetties and local characteristic of sea currents circulation make this area a vulnerable one.

The southern sector of Romanian coast suffered more artificial human intervention compared to the northern one. It is subject to erosion due to ineffective or poor condition of existing systems. There are a number of hotspots which have been identified as highly affected by coastal erosion. One of them is 2 Mai –Vame Veche area. The southern bay of 2 Mai, characterized by loess and clay cliffs above the water line and a lime stone layer below, has been affected by erosion and landslides since the 1980`s.

Table 16. Demonstration areas of the Romanian coast

Demonstration area	Geographical description	Geographical coordinates	Size (length or area)	Tidal range	Geomorphology
All Romanian coastline	From Musura Bay to Vama Veche	45.206660 29.671614 43.743112 28.579540	Size (km2): ≈4200 Length: ≈243 km	Microtidal	Deltaic coastline (Danube Delta) with low relief and sandy beaches. Clay cliffs with limestone shore platform in the south part.

Table 17. Suggested POC sites for the Romanian coast

Suggested POC site	Geographical description	Geographical coordinates	Size (length / area)	Included in the demonstration area
Sulina – Sfântu Gheorghe Sector	Coastal Area of Danube Delta between Sulina and Sfântu Gheorghe	45.150043 29.690542 44.881515 29.621743	30 km	Northern part of Romanian coastline: Deltaic coastline with low relief and sandy beaches.
2 Mai – Vama Veche Sector	Coastal area between 2 Mai and Vama Veche	43.788852 28.581050 43.743112 28.579540	6km	Southern part of the Romanian coastline: Clay cliffs with limestone shore platform

4.2 Space for Shore Users

The management of coastal erosion hazards within the European countries is relatively country-specific, which does not facilitate the implementation of universal end-user typology. The different types of organization identified within the Space for Shore end-user community are presented in Table 18, along with the number per country. Overall, we received formal and complete answers from 22 end-users, essentially from the public sector.

Table 18. Space for Shore end-user community description

Type of structure		France	Germany	Greece	Portugal	Romania	Total
Public	Ministry; National / governmental agency / authority				1	1	2
	Regional authority	3	1	2		1	7
	Intermunicipal cooperation	2					2
	Coastal municipality				2		2
	Natural site manager	2		2			4
	Research center					2	2
	Coastal observatory	2					2
	Other	0	1 (office state)				1
Private	Insurance company	0					
	Other	0					
Total		9	2	4	3	4	22

The following subsections briefly describe end-users interviewed during WP 1.1 per country. Complete descriptions are provided in the end-user forms provided in the User Requirement Document Book

4.2.1 France

In France, coastal erosion is the concern of many institutions, research organizations (universities), national public agencies (BRGM, ONF, Conservatoire du Littoral), public authorities at several territorial levels (departmental, regional, national) and of course of coastal cities and intermunicipal cooperation (details in Table 19).

Coastal observatories

Observers of coastal erosion (mostly academic scientists, BRGM, ONF, two national environmental agencies) are often structured in regional scientific coastal networks (ROLNP in Normandy, RRLA in Aquitaine) which provide a collaborative framework for fundamental and applied research cooperation and dissemination of their activities. Unfortunately, funds for research coastal monitoring actions are sparse and with no character of regularity, they come from national (mostly from the French National Research Agency) and European programs (INTERREG), regional partners often providing complementary support (regional councils, Water Agencies). As an indication, the University of Caen has benefited of about 500 k€ in the frame of their current research program for surveying actions (approx. budget of 100 k€ for coastal erosion). These activities being performed with the support of students and PhDs funded by the Ministry of Research and regional authorities.

Regional authorities are also part of the coastal erosion community, not being in front line, but providing guidance and funds for the structuration of public action and policy. The Aquitaine Coastal Observatory (OCA) is one of these examples,

technical operator for the Aquitaine region for more than 20 years (founded in 1996 by the Aquitaine regional council and associated departments, along with the GIP Littoral Aquitain). It is in charge of coastal erosion monitoring and provides some guidance to local stakeholders facing coastal erosion (BRGM and ONF being the major technical operators). In Normandy, the *Syndicat Mixte Littoral Normand* (SMLN) is in the same line and about to be converted in a public interest group (*Groupement d'Intérêt Public*). Both of them are involved in the project as end users.

French Ministry for Environment and its related local and regional governmental directorates (DDTM, DREAL)

In France, the ministry for Environment is in charge of the definition and implementation of national and European environmental policies (WFD, MSFD, …). Any of the European directives cover the topic of coastal hazards, but national policies started in 1995 to evoke coastal hazards in the frame of PPRN documents (*Plan de Prévention des Risques Naturels*). Then, with the Xynthia storm in 2010 which severally damaged the coastal areas in the south west of France, coastal hazard prevention plan (*Plan de Prévention des Risques Littoraux*) were more intensively generalized, now existing in every coastal hot spot in France. Assessment of coastal change and vulnerability in terms of both marine erosion and marine flooding is central in these official documents which aimed at defining adequate coastal land planning with regards to the knowledge of coastal hazards and considering also the impacts of climate change. Some local and regional offices of the French Ministry for Environment have been involved in the Space for Shore end user panel, DDTM 83 (local representation in the Var department) and DREAL PACA (regional representation in the South of France).

More recently, governmental authorities have been thinking to the definition of a **national coastline planning strategy (*stratégie nationale de gestion intégrée du trait de côte*)** that is now declined in an action plan. This is done with the total cooperation of the scientific coastal erosion community which is gathered in a **national coastal erosion network** (*Réseau national des Observatoires côtiers*). Stéphane Costa (Professor at Caen University, involved in the project) is the head of the scientific coastal erosion board, while Francois Sabatier (Aix-Marseille University) is the PACA regional representative. As far as we know, there is no national financial contribution other than research programs to pursue shoreline monitoring actions held by scientists.

The Ministry for Environment has decided in early 2000's to provide the community with a coastal reference DEM (Litto 3D®). This is an aerial topo-bathymetric lidar survey which is being implemented by the IGN / SHOM Agencies in every coastal region (each survey is around 2-3 M€) and paid by local and regional authorities. Almost every French region is now covered by Litto 3D (New Aquitaine will be soon in 2020), but once again, there is no regular monitoring of this kind, due to the value for money which is not in total adequation with the local and regional stakeholders' requirements.

Coastal cities and intermunicipal cooperation

They are the primary final end users for coastal erosion services being monitoring or consultancy services.

Coastal cities are facing directly coastal hazards and their consequences, with regards to many aspects that affect them, e.g. coastal land planning (damage to first-line houses and buildings), human safety (risk to lost lives during extreme storm or flooding events), coastal tourism (loss of beach width at high tide may lead to loss of attractivity). Mayors have the legal responsibility towards security of their citizens and goods. They are now due to consider in appropriate ways the coastal hazards their town is facing and to elaborate local shoreline management plans.

Furthermore, since 2018 in France, intermunicipal cooperations have gained new missions with regards to wetland management and inundation hazard prevention (GEMAPI for *GEstion des Milieux Aquatiques et Prévention des Inondations*), shoreline management being also in this perimeter. Two end users of this type have been involved among the french end users, in Aquitaine, the intermunicipal cooperation of the Basque County (covering 38 km of coastal linear from Anglet to Hendaye, close to the Spanish border) and "Great Lakes" (Biscarrosse city, 100 km northward in the Landes department), being POC areas. Some others would be able to join the end user panel in the course of project implementation, in particular in PACA (Hyères Bay and Frejus-Saint Raphael agglomeration). Annual budget devoted to coastal monitoring actions is highly dependent on the degree of awareness/maturity with the coastal erosion issue and

size of each coastal intermunicipal cooperation, in the range of 10-100 k€ (Basque Country intermunicipality has cited 200-300 k€ per year for the forthcoming period).

Table 19. Details about the end-user community in France

	End-user original name ***End-user translated name***	**Type**	**Description of their mission**	**Acronym**
New Aquitaine	Observatoire de la Côte Aquitaine *Aquitaine coastal observatory*	Coastal observatory	Provide scientific and technical supports within the region regarding management and prevention of coastal hazards and decision making	FR_OCA
	Communauté d'Agglomération du Pays-Basque *Intermunicipal cooperation of Basque Country*	Intermunicipal cooperation	…	FR_CAPB
	Communauté de Communes des Grands Lacs *Intermunicipal cooperation of Landes Great Lakes area*	Intermunicipal cooperation	…	FR_CCGL
Normandy	Syndicat Mixte Littoral Normand (Conservatoire du Littoral de Normandie) *Organization representing the coastline conservation authority for the Normandy region*	Natural site manager	…	FR_CLN
	Université de Caen – Réseau d'Observation Littoral Normand Picard *University of Caen – observatory network of Normandy and Picardy region coasts*	Coastal observatory		FR_UC
PACA	Conseil regional de Provence Alpes Côte d'Azur (PACA) *Regional Council of PACA*	Regional authority		FR_CRPACA
	Direction Régionale de l'Environnement, de l'Aménagement et du Logement de la region PACA (DREAL) *Regional Directorate for environment, land planning and housing of the PACA region*	Regional authority	…	FR_DREAL
	Direction Départementale des Territoires et de la Mer du Var (DDTM83) *Directorate of Territories and sea of Var department*	Regional authority	…	FR_DDTM
	Conservatoire du Littoral de PACA *PACA coastline conservation authority*	Natural site manager	…	FR_CLPACA

4.2.2 Germany

Coastal protection is in the responsibility of the Bundesländer (countries) in Germany. Thus, each Bundesland has its own Coastal Protection Plan (Generalplan Küstenschutz).

In Schlweswig-Holstein, where our main focus is within Space for Shore, the highest coastal protection authority is the Ministry of Agriculture, Environment and Rural Areas. As such, it sets the target dimensions to be met by the dikes in the first and second dyke lines to meet legal requirements. It is also responsible for planning decisions and planning permission for the construction, removal, strengthening or substantial modification of state defensive dikes and regional dikes in the country's support, safety dams and barrages.

On 01.01.2008, the Landesbetrieb für Küstenschutz, Nationalpark und Meeresschutz (LKN) was founded as the upper Country authority. The LNCC, as the Lower Coast Guard Authority, is responsible for monitoring the sound health of coastal defense facilities and conducting waterborne measurements both in coastal and inland waters. The LKN is responsible for the planning approval of facilities in the coastal area. In 1963, as a consequence of the catastrophic flood of 1962, the state government of Schleswig-Holstein passed a general plan for coastal protection for the first time. Already at that time, it was stated that this plan should be regularly updated to take account of new technical and scientific findings. The fourth update was now approved in a cabinet meeting by the state government. The 2012, an update was created to ensure the long-term safety of Schleswig-Holstein's coastal inhabitants from the attacks of the sea, in particular with regard to the expected sea-level rise. Among other things, the results of the regular safety review of the Landesschutzdeiche, new findings on climate change and its possible consequences as well as the 2007 EU Flood Risk Management Directive came into force. Significant innovations include the introduction of a nationwide uniform safety standard for Landesschutzdeiche and the concept of *Baureserve* for dike reinforcement. In the light of climate change, principles for structural uses on the coasts and in the coastal lowlands are being included in the update.

The State Agency for Agriculture, Environment and rural Areas (Landesamt für Landwirtschaft, Umwelt und ländliche Räume, LLUR) was founded in 2009 by merging several formerly independent state offices working on a variety of issues. Its work includes surveying, compiling and assessing a wide range of area-related data in the different sectors of nature protection and landscape conservation, forestry, technical aspects of nature protection, agriculture and water management, geology, fisheries and rural development. Thus, also the monitoring for coastal erosion is one of the topics for LLUR's monitoring programmes. Around 20 smaller and larger offices spread around Schleswig-Holstein enable it to carry out its varied duties locally. These duties include basic groundwork, execution of administrative initiatives, consultation and advisory services as well as public relations work and education.

The department "Water Management" is also responsible for the implementation of water related EU-Directives like WFD, MSFD and the environmental monitoring for the Habitat Directive. Monitoring data for coastal erosion and coastal changes are available with both organisations, the LKN and LLUR. Both are represented as end user in Space for Shore.

Close interactions with universities and research centres are in place for investigating coastal erosion processes and provide data and information for monitoring purposes.

Table 20. Details about the end-user community in Germany

	End-user original name ***End-user translated name***	**Type**	**Short description of their mission**	**Acronym**
North Sea	Landesamt für Landwirtschaft, Umwelt und ländliche Räume (LLUR) *Regional Authority for Agriculture, Environment and Rural Areas Schleswig-Holstein*	Governmental agency	Surveying, compiling and assessing a wide range of area-related data in the different sectors of nature protection and landscape conservation, forestry, technical aspects of nature protection, agriculture and water management, geology, fisheries and rural development.	GE_ LLUR

	Landesbetrieb für Küstenschutz, Nationalpark und Meeresschutz Schleswig-Holsterin (LKN) *Schleswig-Holstein Agency for Coastal Defense, National Park and Marine Conservation*	State Office	State service provider for (among others!) coastal defence on the North Sea and the Baltic Sea and flood defence along the rivers, for nature conservation and sustainable development in the National Park Schleswig-Holstein and the Wadden Sea and Halligen Biosphere Reserve or for the storm surge and flood warning service.	GE_LKN
Baltic Sea	Landesamt für Landwirtschaft, Umwelt und ländliche Räume (LLUR) *Regional Authority for Agriculture, Environment and Rural Areas Schleswig-Holstein*	Governmental agency	See above	GE_ LLUR
	Landesbetrieb für Küstenschutz, Nationalpark und Meeresschutz Schleswig-Holsterin (LKN) *Schleswig-Holstein Agency for Coastal Defense, National Park and Marine Conservation*	State Office	See above	GE_LKN

4.2.3 Greece

In Greece, coastal management is a matter which concerns numerous actors, such as public and semi-public authorities and research organizations. While the actual management lies on the public and semi-public authorities, the research institutions provide their scientific insight but only through specific research projects that have no reflection on the management.

In Greece, no coordinated actions are undertaken in the field of coastal protection to date. Measures are decided upon in an ad-hoc way by different national authorities and implemented by local municipalities. The main actors involved at the national level are the Ministry of Environment, Physical Planning and Public Works, the Ministry of Mercantile Marine and the Ministry of Economy and Finance. Funding for coastal protection projects is mainly provided by European programs.

Currently, several national tenders for the development of Coastal Erosion Monitoring Centres with the support of EO data and services, are being procured by the local Regions. These tenders anticipate the provision of infrastructure (hardware and software) as well as services to complete the concept of an integrated Coastal Erosion Monitoring Centre. Still there is a lot of way ahead in order for this initiative to complete and cover all 13 Greek Regions.

In particular the following categories of actors in the coastal management can be recorded:

- Public authorities:
  - Public Authorities attached to the General Administration (i.e. ministries, agencies, directorates, etc.):
    - The Ministry of Environment, Energy and Climate Change has replaced the former Hellenic Ministry for the Environment, Physical Planning & Public Works, and is in charge of environmental policies and measures as well as spatial planning. The Ministry aims to achieve the protection of the natural environment and adjustment to the implications of climate change. In order to protect and promote biodiversity and the natural landscape, the Ministry of Environment, Energy and Climate Change has developed the NATURA 2000 Network.

- The Central Water Agency, set up in 2005 by the Ministry of Environment, Physical Planning and Public Works in light of the Water Framework Directive, is responsible for defining the national water policy and coordinating the activities of regional directorates.
- The Ministry of Mercantile Marine is responsible to protect marine and coastal areas from pollution.
- The Ministry of Economy and Finance is concerned with the planning and follow-up of coastal protection investments in Greece.

- Regional and local authorities (i.e. regions-prefectures, municipalities) and its respective directorates:
  - Regions/ Prefectures: By definition, regions are areas that are broadly divided by physical characteristics, human impact characteristics and the interaction of humanity and the environment. In Greece, there are thirteen (13) Regions and each one them has its Regional Authority. More specific, Regional Authorities are the developed regional governance bodies that aims to promote the coordination of public service provision, by gathering and processing data & information concerning general or specific issues about the mission and the work (actions) of the Regions. They are responsible for taking preventive measures against the climate change and its consequences always in cooperation with competent bodies of the government.
  - Civil Protection Directorate, within the Regions: Civil Protection Directorate, is government directorate under the provision of Regional Authorities that protects citizens from accidents, natural disasters and other incidents. Its main mission is to preserve lives, prevent and alleviate human suffering and safeguard the integrity and dignity of populations affected by natural disasters & man-made crises. It is responsible to coordinate and monitor civil protection tasks for the prevention, preparedness, and disaster recovery within the boundaries of its territory.
  - Directorate of Public Works within the Regions: Directorate of Public Works, handles a broad category of infrastructure projects, financed and constructed by the government for recreational, employment, health and safety uses in the greater community. The Directorate supervises Studies and Implementation of Public Works of different Regions. The Department of Environmental Structures is conducting studies, announcing tenders and supervising the execution of public works.
  - Municipalities: Municipalities are usually single administrative divisions having corporate status and powers of self-government or jurisdiction as granted by national and regional laws to which they are subordinate. Municipalities carry out coastal protection projects to the extent they receive sufficient financial means by the state or the EU.

- Semi-public authorities, Natura Management Bodies - Legal Entities of Private Law: Management Bodies consists of a group of people that has the authority to exercise governance over an organization or political entity. They work under the supervision of the Hellenic Ministry for the Environment, Physical Planning and Public Works and their role is to inform and raise awareness to the local people about the issues that relates to the conservation of natural resources and biodiversity.
- Research institutes:
  - Hellenic Centre for Marine Research (HCMR): The Hellenic Centre for Marine Research, is a governmental research organisation operating under the supervision of the General Secretariat for Research and Technology (GSRT) of the Ministry of Education, Research and Religious Affairs. The Institute's main objective is to conduct multidisciplinary applied and basic research in areas such as the structure and functioning of inland, coastal and marine ecosystems, including ecosystem modelling the effects of natural and human-induced pressures and hazards on the marine environment (e.g. oil spills, pollution, tsunamis, floods, aquatic invasions, HABs, slumps).
  - National Observatory of Athens (NOA): The National Observatory of Athens, is the first research Institution created in Greece. NOA's main areas of activity are Astronomy & Astrophysics, Ionospheric Physics, Remote Sensing, Space Physics, Telecommunications, Geophysics – Seismology and Environment & Climatology. The *Institute of Environmental Research and Sustainable Development (IERSD)*, studies the Environment following an integrated/multidisciplinary approach, performing leading edge research and providing high quality services. Due to the fact that the National Observatory of Athens is one of the oldest research Institutes in Greece with

more than 170 years in research and society, their contribution and expertise in issues related to the natural environment is undeniable.

Greek Legislation

Concerning the Greek legislation for coastal areas an early law (1837) dealing with the Greek public domain defined the "seashore" area as public property. Decades later, in 1940, the country's first Coastal Law tried to protect the public domain status of the coastal zone. This law added definitions for "old seashore" and "beach" as additional elements of the Greek coastal zone and applied a setback zone of 30 meters from the seashore in which construction was prohibited outside of existing older settlements. A main characteristic of this was that there is no reference to the protection of coastal areas from an environmental perspective. In 1998, that the Greek Council of State has supported arguments that the coast is a vulnerable ecosystem and should be protected from intensive forms of development. The 1999 assessment report of the European Environment Agency indicated a continuing degradation of conditions in the coastal zones of Europe as regards both the coasts themselves and the quality of coastal water.

In 2001, Greece's enacted a new Coastal Law which prioritized the protection of the coastal zone as a public good, an environmental asset and an economic good. This law defined the beach as a zone adjacent to the seashore, with a width of "up to 50metres". This zone is a buffer zone between land and sea and, like the seashore, is included within the Greek public domain. It is usually defined in spatial plans of coastal settlements and rural areas as "open space", but may be used for roads, pedestrian and bicycle routes.

This law restricts development on the coastal zone and beyond but it also provides many exceptions to these restrictions in order to encourage the tourism potential of the coast. The most recent law (4178/2013) nullifies any previous laws which allowed for legalization, though still provides exceptions for types of development which may be legalized.

Table 21. Details about the end-user community in Greece

	End-user original name ***End-user translated name***	**Type**	**Short description of their mission**	**Acronym**
Eastern Macedonia & Thrace	*Eastern Macedonia and Thrace Civil Protection Directorate*	Regional authority	Coordination and monitoring of civil protection tasks for the prevention, preparedness, response and disaster recovery, within the boundaries of its territory. Responsibility for the implementation of the annual national civil protection plan, that all programs, measures and actions concerned are implemented at regional level. Coordination of all regional services, both public and private, to ensure preparedness, disaster response and damage recovery.	GR_CPDEMT
	Management Body of Protected Areas of Evros Delta and Samothraki	Natural site manager	Legal Entity of Private Law, non-profit, under the supervision of the Hellenic Ministry for the Environment, Physical Planning and Public Works Promote the protection of nature in the Evros Delta, ecotourism and public awareness of the ecological values of Evros Delta. Other activities of the Visitor Centre include participation in the local events, organization of events, wardening, monitoring, maintenance and provision of equipment, plantations, operation of a library, communication with users of the wetland, etc.	GR_EDS
	Delta Nestos Lakes Vistonida-Ismarida Management Body	Natural site manager	Legal Entity of Private Law, non-profit, under the supervision of the Hellenic Ministry for the Environment, Physical Planning and Public Works Conservation of natural resources and biodiversity. Restoring and preserving ecological balance. Informing and raising awareness to the local people. Monitoring of development of human activities. Environmental education and the development of ecotourism.	GR_DNLVI
Peloponnese (GR	Directorate of public works, Region of Peloponnese	Regional authority	*Supervising Service for Studies and Implementation of Public Works of the Peloponnese Region* *Department of Environmental Structures* *The Department of Environmental Structures is conducting studies, supervising studies, announcing tenders and supervising the execution of public works*	GR_DPW

4.2.4 Portugal

In Portugal the Portuguese Agency of Environment (APA) and its mission and policy

In Portugal the APA aims propose and develop the integrated management of the policies related with the environment promoting a sustainable development of them, in articulated fashion with other sectoral policies and in collaboration with public and private entities working towards the same end, with a view to a high level of protection and of valuing the environment and providing high quality services to citizens.

Coastal erosion and the consequent retreat of the coastline have assumed in the last decades as a worrying reality in several coastal sectors of mainland Portugal, often requiring the implementation of diverse interventions, such as cases of construction, repair and maintenance of coastal defense works, artificial feeding of beaches, and the reconstruction and preservation of dune fields. More recently, in order to fulfill the commitments made to Portugal as a member of the European Union, a number of actions are underway, notably the Strategy for the Integrated Management of the National Coastal Zone (EGIZCN), the project "Information System to Support Legal Replenishment "and the Coastal Planning Plans. The EGIZCN bases claim, in a document by order of the Ministry of the Environment, Regional Planning and Regional Development (Order no. 212/2005), among other aspects, the creation of monitoring of the coastal zone. More recently, the approved Law entitled “National Strategy for Coastal Zone Management” (ENGIZC, Government Resolution 82, 8 Sept. 2009) highlight this topic. The change in the coastal protection policy towards the adoption of “soft” measures is reflected in the recommendations of the working group for the coastal zone (Grupo de Trabalho do Litoral - GTL) nominated by the Portuguese government nominated, in early 2014 (Despacho n.º 6574/2014, 20th May). The Aveiro lagoon littoral in the Portuguese west coast, which is exposed to the high energetic North Atlantic wave climate, is a high vulnerable littoral stretch where the GTL recommended the implementation of a sustainable policies to protect the littoral. In mainland Portugal the costs related with the damages induced by the 2014 winter storms at the coast exceed 20 M€.

Coastal cities and intermunicipal cooperations

Coastal cities are facing directly coastal hazards and their consequences, with regards to many aspects that affect them, e.g. coastal land planning (damage to first-line houses and buildings), human safety (risk to lost lives furing extreme storm or flooding events), coastal tourism (loss of beach width at high tide may lead to loss of attractivity). Mayors have the legal responsibility for land planning, including the coastal areas towards security of their citizens and goods. They are now due to consider in appropriate ways the coastal hazards their town is facing and to elaborate local shoreline management plans.

Table 22. Details about the end-user community in Portugal

	End-user original name ***End-user translated name***	**Type**	**Short description of their mission**	**Acronym**
Northwest coast	Agência Portuguesa do Ambiente *National agency for the environment*	National Agency	The national authority for coastal and risk management. Coastal Monitoring and Risk Unit, part of the Department of Littoral and Coastal Protection. The Unit undertakes regular monitoring and maintains a comprehensive database on qualitative and quantitative data that describe the state of the coastal environment, in order to respond to coastal risk management.	PT_APA
	Municipality of OVAR	Coastal Municipality	Coastline monitoring and risk management (Environment Division)	PT_OVAR

	Municipality of ALCOBAÇA	Coastal Municipality	Local Government Planning Unit, part of the Department of Planning and Urban Management	PT_ACOBAÇA

4.2.5 Romania

Erosion is one of the main environmental and administrative challenges along the Romanian coast. It represents an issue for many governmental agencies, public institutions, research centers (universities or public) and municipalities.

Basin Administration "Dobrogea Litoral" is a public institution of national interest under the coordination of central authority for water management, National Administration "Apele Romane" (Ministry of Water and Forests). The institution is responsible with beach protections and maintenance activity in the Romanian shore of the Black Sea. BADL elaborated the Master Plan for "Protection and rehabilitation of coastal area". It sets out the framework for coastal zone management and provides sustainable long-term approach to address coastal erosion and other related implications. Another main attribute is to implement the European Union directives and policies related to water domains.

The key responsibilities of the National Institute for Marine Research and Development comprise fundamental oceanographic research, coastal and marine engineering, ecology of the marine environment and management of living resources of the Black Sea. Department of coastal and marine engineering is responsible for activities related to coastal erosion problems, such as:

- Survey of coastal geomorphology and erosion/accretion processes and development of protection/rehabilitation measures;
- Studies regarding the state, evolution and efficiency of hydrotechnical protection works;
- Providing scientific substantiation for the implementation of national and international legislation in the field of integrated coastal zone management (ICZM).

NIMRD plays a key role in issuing recommendations for main administrative bodies in charge of littoral management. The institute is also the national scientific responsible for the implementation of national and international legislation in the field of integrated coastal zone management (ICZM).

University of Bucharest - Sfântu Gheorghe Marine and Fluvial Research Station (SCMF) is a research center of the University of Bucharest, located in Sfantu Gheorghe village, Danube Delta.

The SCMF members deal with a wide range of coastal topics: coastal landscape evolution (deltaic lobes, barrier spits and islands), coastal geomorphology (beach morphodynamics, foredune development, nearshore sandbars behaviour), coastal climate (storm evolution and impact, climate variability), nearshore hydrodynamics, river mouth behaviour.

The results of Space for Shore project are of high interest to the entire activity of the group, taking into consideration the research interests mentioned above. The group was involved in the past years in the development of a new masterplan for the reduction of coastal erosion on the Romanian Black Sea coast which was already partly implemented by the coastal managers.

Table 23. Details about the end-user community in Romania

	End-user original name *End-user translated name*	Type	Short description of their mission	Acronym
Romanian entire coast	*Cosmomar Competence Center*	Public research Center	Cosmomar is focused on marine EO application area, towards monitoring and rapid assessment of the marine and coastal environment state, development of environmental friendly bio-technologies and materials with applicability in spatial programs, as well for support of local and regional small, medium and big enterprises development in accessing opportunities of the EU spatial programs	RO_ CCC
	Directia Hidrografica Maritima*Maritime Hydrographic Directorate*	Governmental agency	The main activities Maritime Hydrographic Directorate is being involved are management of the national maritime hydrographic data system and developing and updating the information contained on cartography, marine geodesy and maritime navigation.	RO_MHD
	Administratia Bazinala Dobrogea Litoral Basin Administration "Dobrogea Litoral"	Public Institution	The institution is responsible with beaches protection and maintenance activities in the Romanian shore of Black Sea.	RO_BADL
	Stațiunii de Cercetări Marine și Fluviale Sfântu Gheorghe Sfântu Gheorghe Marine and Fluvial Research Station (SCMF)	University Research Station	The SCMF members deal with a wide range of coastal topics: coastal landscape evolution (deltaic lobes, barrier spits and islands), coastal geomorphology (beach morphodynamics, foredune development, nearshore sandbars behaviour), coastal climate (storm evolution and impact, climate variability), nearshore hydrodynamics, river mouth behaviour.	RO_SCMF

4.3 Space for Shore Products

The following subsections present the product and indicators expected by end-user per country (Table 24 to Table 28).

4.3.1 France

Table 24. Details of Space for Shore products requested in France

Product	Erosion indicator / proxy	Suggested POC site	End-user	Objectives	End-user priority 1=high 2=medium 3=low
Digital elevation model (DEM) of rocky cliff	Cliff DEM	Erretegia cliffs	FR_CAPB	Monitoring & prevention	1
			FR_OCA	Monitoring & prevention & research	2
		Corniche Basque	FR_CAPB	Monitoring & prevention	1
	Foot line	Erretegia cliffs	FR_CAPB	Monitoring & prevention	1
			FR_OCA	Monitoring & prevention	1
		Corniche Basque	FR_CAPB	Monitoring & prevention	1
			FR_OCA	Monitoring & prevention	1
		Calvados POC site	FR_UC	Monitoring & research	1
		Seine-Maritime POC site	FR_UC	Monitoring & research	1
	Apex line	Erretegia cliffs	FR_CAPB	Monitoring & prevention	1
			FR_OCA	Monitoring & prevention	3
		Corniche Basque	FR_ CAPB	Monitoring & prevention	1
			FR_OCA	Monitoring & prevention	3
		Calvados POC site	FR_UC	Monitoring & research	1
		Seine-Maritime POC site	FR_UC	Monitoring & research	1

	Intertidal offshore extension and bottom type	Erretegia cliffs	FR_OCA	Monitoring	1
		Corniche Basque	FR_OCA	Monitoring	1
	Cliff movement and typology	Erretegia cliffs	FR_OCA	Monitoring & prevention	1
		Corniche Basque	FR_OCA	Monitoring & prevention	1
	Cliff front characteristics (area, slope) and volume of landslide	Erretegia cliffs	FR_CAPB	Monitoring & prevention	1
		Corniche Basque	FR_CAPB	Monitoring & prevention	1
	Cliff scars	Erretegia cliffs	FR_ CAPB	Monitoring & prevention	1
		Corniche Basque	FR_CAPB	Monitoring & prevention	1
Digital elevation model (DEM) of beach	Beach DEM	Bidart central beach	FR_CAPB	Monitoring & beach reprofiling	3
		Anglet beach	FR_CAPB	Monitoring & beach reprofiling	3
	Sediment stock above rocky substratum	Bidart central beach	FR_CAPB	Monitoring & beach nourishment & beach reprofiling	1
	Intertidal beach topography	Biscarrosse beach	FR_CCGL	Monitoring & beach nourishment	1
Coastal defense monitoring	VHR coastal defense DEM to assess coastal defense state	All	FR_CAPB	Monitoring & rebuilding	3
	Seawall boulder displacement	Bidart central beach	FR_CAPB	Monitoring & rebuilding	2
	Inventory of existing coastal defenses	Camargue	FR_DDTM	Inventory & monitoring	3
		Camargue	FR_DREAL	Inventory & monitoring	3
Nearshore bathymetry	Nearshore bathymetry	Calvados POC site	FR_UC	Monitoring & research	1
		Seine-Maritime POC site	FR_UC	Monitoring & research	1
		5 PACA POC sites	4 PACA EUs	Monitoring & decision making & defense building	1
		Biscarrosse beach	FR_CCGL	Monitoring & beach nourishment	2
	Bar location	Erretegia cliffs	FR_CAPB	Monitoring & prevention	1
		Bidart central beach	FR_CAPB	Monitoring & beach nourishment & beach reprofiling	1

		Calvados POC site	FR_UC	Monitoring & research	1
		Seine-Maritime POC site	FR_UC	Monitoring & research	1
		Biscarrosse beach	FR_CCGL	Monitoring	2
	Sediment stocks above rocky substratum	Erretegia cliffs	FR_CAPB	Monitoring	1
			FR_OCA	Monitoring	1
		Bidart central beach	FR_CAPB	Monitoring & beach nourishment & beach reprofiling	1
			FR_OCA	Monitoring	1
		Calvados POC site	FR_UC	Monitoring & research	1
		Seine-Maritime POC site	FR_UC	Monitoring & research	1
	Displacement of sand deposit facing rocky cliffs	Erretegia cliffs	FR_CAPB	Monitoring	1
		Corniche Basque	FR_CAPB	Monitoring	1
Nearshore bottom type mapping	Boundary of alive Posidonia seagrass meadow	5 PACA POC sites	4 PACA EUs	Monitoring & decision making & defense building	2
	Discrimination of rocky seabed, alive Posidonia seagrass, dead sea grass	5 PACA POC sites	4 PACA EUs	Monitoring & decision making & defense building	2
	Discrimination of sandy bed and rocky bed	Bidart central beach	FR_CAPB	Monitoring & beach nourishment	2
		Bidart central beach	FR_OCA	Monitoring	2
Beach morphology	Beach width	Bidart central beach	FR_CAPB	Monitoring & beach nourishment & beach reprofiling	2
		Biscarrosse beach	FR_OCA	Monitoring	2
		Biscarrosse beach	FR_CCGL	Monitoring & beach nourishment	1
	Bar/rip location and orientation	Biscarrosse beach	FR_OCA	Monitoring & sand removal/nourishment strategy	1
		Biscarrosse beach	FR_CCGL	Monitoring & beach nourishment	1
	Dune foot location	Biscarrosse beach	FR_OCA	Monitoring & prevention	1
		Biscarrosse beach	FR_CCGL	Monitoring & beach nourishment	1

	Intertidal sandspit-shaped bar/rip systems	Arcachon Inlet (north coast)	FR_OCA	Monitoring & prevention & beach nourishment	1
Shoreline	Average and upper swash excursion during weak wave conditions	5 PACA POC sites	4 PACA EUs	Monitoring & decision making & defense building	1
	Maximal swash excursion during storm wave conditions	5 PACA POC sites	4 PACA EUs	Monitoring & decision making & defense building	1
	Upper limit of the active beach (defense structure foot / lower boundary of vegetation)	5 PACA POC sites	4 PACA EUs	Monitoring & decision making & defense building	1

4.3.2 Germany

Table 25. Details of Space for Shore products requested in Germany

Product	Erosion indicator / proxy	Suggested POC site	End-user	Objectives	End-user priority 1=high 2=medium 3=low
Cliff indicators	Cliff lines (foot, apex) and their change	Brothener Cliff	GR_LURR	Monitoring & prevention	1
		Schönhagener Cliff	GR_LURR	Monitoring & prevention	1
	Vegetation dynamic at cliff foot	Brothener Cliff	GR_LURR	Monitoring	1
		Schönhagener Cliff	GR_LURR	Monitoring	1
	Changes in cliff foot area	Brothener Cliff	GR_LURR	Monitoring	1
		Schönhagener Cliff	GR_LURR	Monitoring	1
Beach morphology	Water line identification	Sylt Odde	GR_LURR	Monitoring & beach nourishment & prevention	1

	Barrier beach change	Sylt Odde	GR_LURR	Monitoring & beach nourishment	1
	Wet-dry sand dynamics	Kiel/Probstei	GR_LURR	Monitoring & beach nourishment	1
	Underwater sand banks identification and their dynamic	Sylt Odde,	GR_LURR	Monitoring & beach nourishment	1
		Kiel/Probstei	GR_LLUR	Monitoring	1
Characterization of tidal creeks (channels)	Number and length	Blauortsand	GR_LURR	Monitoring	1
	Lateral changes in terms of distance and direction	Blauortsand	GR_LURR	Monitoring	1
	Form of tidal creek edges	Blauortsand	GR_LURR	Monitoring	1
	Form and number of tidal creek endings	Mememgrund	GR_LURR	Monitoring	1
	Habitat mapping (vegetation / sand)	Blauortsand	GR_LURR	Monitoring	1

4.3.3 Greece

Table 26. Details of Space for Shore products requested in Greece

Product	Erosion indicator / proxy	Suggested POC site	End-user	Objectives	End-user priority 1=high 2=medium 3=low
Digital elevation model (DEM) of rocky cliff	Foot line	Vistonis-Maroneia	GR_CPDEMT	Monitoring & prevention, sand removal/nourishment strategy	2
	Apex line	Vistonis-Maroneia	GR_CPDEMT	Monitoring & prevention, sand	2

				removal/nourishment strategy	
	Coastal Land motion/ DEM of the emerged coastal areas	Evros Delta	GR_EDS	Monitoring & prevention	3
		Vistonis-Maroneia	GR_CPDEMT	Monitoring & prevention	3
		-	GR_DPW		
Beach morphology	Waterline identification (waterline = wet-dry sand transition)	Evros Delta	GR_EDS	Monitoring & prevention	1
		Vistonis-Maroneia	GR_DNLVI	Monitoring & prevention	1
		Vistonis-Maroneia	GR_CPDEMT	Monitoring & prevention, sand removal/nourishment strategy	1
		-	GR_DPW		
	Barrier beach change	Vistonis-Maroneia	GR_DNLVI	Monitoring & prevention	2
	Sand bar location (crest) and dynamics	Vistonis-Maroneia	GR_CPDEMT	Monitoring & prevention, sand removal/nourishment strategy	3
	Dune foot location	Vistonis-Maroneia	GR_DNLVI	Monitoring & prevention	2
	Lower vegetation boundary	Vistonis-Maroneia	GR_DNLVI	Monitoring & prevention	3
Habitat indicator / land cover classification	Habitat mapping (vegetation/sand) Classification maps per species	Vistonis-Maroneia	GR_DNLVI	Monitoring & prevention	3
	Habitat mapping (vegetation/sand) Classification maps per species	Evros Delta	GR_EDS	Monitoring & prevention	2
Nearshore bathymetry	Bar location	Vistonis-Maroneia	GR_CPDEMT	Monitoring & prevention	2

4.3.4 Portugal

Table 27. Details of Space for Shore products requested in Portugal

Product	Erosion indicator / proxy	Suggested POC site	End-user	Objectives	End-user priority 1=high 2=medium 3=low
Nearshore bathymetry	Nearshore bathymetry	Aveiro coast	PT_APA		3
			PT_OVAR		3
Land use / Land cover classification	Identification of marine, dry beach, dune, vegetated and urbanized areas	Aveiro coast	PT_APA		2
	Classification of dry-beach area, dune area, vegetated area, urbanized area, etc		PT_OVAR		2
	Classification of beach area, dune area, forest area, agriculture area, water lines, urbanized areas, etc...	Alcobaça coast	PT_ALCOBAÇA		2
Shoreline	Dune/cliff/structure foot	Aveiro coast	PT_APA		1
			PT_OVAR		1
	Cliff lines (foot and apex)	Alcobaça coast	PT_ALCOBAÇA		1

4.3.5 Romania

Table 28. Details of Space for Shore products requested in Romania

Product	Erosion indicator / proxy	Suggested POC site	End-user	Objectives	End-user priority 1=high 2=medium 3=low

Water line position	Water line position (waterline = water/sand interface)	Sulina – Sfântu Gheorghe Sector	RO_MHD	Monitoring & Management activities	1
			RO_SCMF	Monitoring & Research activities	1
			RO_CCC	Monitoring & Research activities	1
		2 Mai – Vama Veche Sector	RO_BADL	Coastal management	1
			RO_MHD	Monitoring & Management activities	1
Vegetation	Vegetation density over the beach-dune system	Sulina – Sfântu Gheorghe Sector	RO_SCMF	Monitoring & Research activities	2
DEM for cliff areas	Sea cliff shore	2 Mai – Vama Veche Sector	RO_MHD	Monitoring & Management activities	3
Nearshore bathymetry & sandbar location and dynamics	Submerged sandbar location	Sulina – Sfântu Gheorghe Sector	RO_SCMF	Monitoring & Research activities	1
			RO_CCC	Monitoring & Research activities	1
	Nearshore bathymetry	Sulina – Sfântu Gheorghe Sector	RO_MHD	Monitoring & update navigation charts	2
		2 Mai – Vama Veche Sector	RO_MHD	Monitoring & update navigation charts	2
Beach morphology	Run-up limit	Sulina – Sfântu Gheorghe Sector	RO_SCMF	Monitoring & Research activities	1
			RO_CCC	Monitoring & Research activities	1

5 END-USER PRODUCT & SERVICE REQUIREMENTS

This section aims at grouping all identified indicators for coastal erosion (refer to section 4.3 for the full list of indicators) into family of products. The objective is to synthesize the needs in terms of accuracy, frequency of production and delivery time. Tables summarizing this information for each family of product are provided within the following subsections. Additionally, first critical analysis on the relevance of the production of these indicators by the Space for Shore consortium are presented. Products for which a high priority has been identified are highlighted in green within the product family tables.

5.1 Shoreline location and change

This first family of products (Table 29) encompasses all indicators being directly associated with the shoreline definition. These are primary indicators to be considered when addressing the topic of coastal erosion. Following the geomorphological and hydrodynamics patterns of coastal areas, specific indicators apply:

i) over microtidal areas (tidal range below 1 m), the relevant shoreline proxy to be monitored is the waterline, either on the field using a GPS and completed by other means (e.g. aerial orthophotos). In every case, the waterline, i.e. the boundary between sea and land, is preferably monitored or extracted during low wave agitation conditions, in order to be relevant from one date to another and not to depend on sea level fluctuations due to wind/storm events. There are 2 types of waterlines mentioned by end users: the first one is the instantaneous interface between the sea and the beach (as expressed in Romania and Greece), while the second one is the middle of the swash zone (asked by French and Romanian end users), i.e. an average position of the waterline as the swash is going up and down over the beach. In both cases, European end users are requiring a metric planimetric accuracy in the range of 1-5 m, and to get this information at least once or twice per year, and more frequently during wintertime (every month typically, plus a before/after diagnosis when major storms happen). Note that waterline proxies are cited 14 times in the collected requirement forms. Another waterline proxy that is also frequently mentioned (6 times in France and Romania) is the position of the maximum run-up excursion over the beach, as reached by water during storm events. The same range of planimetric accuracy is required and updating on a monthly basis (Romania) or during the few days consecutively to severe storm events.

ii) over macrotidal sandy coasts where a coastal dune system is present, end users require to monitor the dune foot as the main indicator of shoreline variations. The planimetric accuracy for dune foot position should be 1 m (as defined in France and Portugal) and updated several times a year on a seasonal basis. In general, it is asked to provide this indicator 2 times per year: 1) at the end of winter in order to get the cumulative effects of winter storms and 2) at the end of summer in order to evaluate the way that the beach is recovering. While dune foot is a major shoreline proxy, the number of citations is limited to 3, because dune foot can only be observed over natural coastal areas, where coastal dunes have been preserved (Aquitaine coast in France, Portugal). In many other places, shoreline artificialization makes it needless for large-scale monitoring (example over the French Mediterranean coast where very few natural coastal dunes are still present). Over both Aquitaine and Portugal coastal areas, a high-frequency (weekly) monitoring may be relevant occasionally in situations where coastal erosion is dramatic when a major storm is announced, and/or spring high tide levels, and/or when specific beach morphological patterns (e.g. a large ridge-runnel system) may affect shoreline change. The same applies after major storms as end users require a post-storm emergency mapping of the shoreline retreat.

Iii) over rocky coasts, end users are asking for the monitoring of the cliff foot and cliff apex (9 citations each). This kind of coastline is well represented over the demonstration areas of the project: 2 regions in France (Normandy and Aquitaine), in Germany over the Baltic Sea region, in Portugal and Greece as well. The required planimetric accuracy is 1-5 m in average, like for the dune foot, in order to be relevant enough to provide adequate quantification of cliff retreat (note that mean annual cliff erosion is very low, about 0.1 m/yr due to significant changes occurring during heavy rain falls and storm events). Many end users mentioned a yearly basis for cliff monitoring (once or twice a year in south French New Aquitaine region, Germany and Portugal) while for the French Normandy region, a coastal erosion expert required one survey every 5 years (as a consequence of low cliff retreat).

Table 29. Product family – Shoreline location and change

	Indicator	Country	Horizontal accuracy (m)	Vertical accuracy (m)	Temporal frequency	Citation number
Shoreline location and change	Cliff foot	FR GER GR PT	1 10 ng 1	-	AQ: 2/year; N: 1/5years 1/year 1/1-10years 2/year	9
	Cliff apex	FR GER GR PT	1 10 ng 1	-	AQ: 2/year; N: 1/5years 1/year 1/1-10years 2/year	9
	Dune foot	FR GR PT	1 ng 1	-	4/year; 1/week in emergency 1/1-10years 2/year; post-storms	3
	Waterline (sea/land interface)	GER GR RO	10 0.5-1 5	-	1/year 1-2/year 1/month	8
	Waterline (sea/land interface) spring water low tide	FR	< 10	-	2-4/year	5
	Wet/dry sand boundary dynamics	FR GER	5-10 10	-	2-4/year 1/year	2
	Middle of swash zone	FR RO	1-5 1-5	-	2-3/year; 2/month in winter; before/after storms 1/month	6
	Maximum swash (or run-up) excursion during major storms	FR RO	1-5 5	-	During/after storms 1/month	6
	Lower vegetation boundary	GER GR	10 maximal	-	1/year 1/1-10years	2
	Natural habitat vulnerability to coastal erosion	FR	ng	-	ng	2

5.2 Extraction and Change of Morphological patterns

This section encompasses a variety of geomorphological features and derived parameters (Table 30) that may be extracted from the EO data over all the relevant coastal compartments, i.e. over the nearshore area, the foreshore, beach system and tidal flats, the coastal dunes and cliffs. To ease the understanding of the table, they have been sorted accordingly:

In the nearshore coastal waters, a vast majority of European coastal managers are in need of understanding and getting knowledge on the bottom morphology and sandbar dynamics, since this underwater area is as crucial as the aerial beach, tidal flat system and the shoreline. The demand (requested by 8 end-users) is on a product showing and monitoring variations in sand bar location (cross-shore and longshore migrations over time) and morphology (shape, width) at a monthly to yearly frequency. Ground resolution required is of the order of Sentinel-1/-2 resolution (10 m) but may need in some circumstances to reach very high resolution (2-5m) when more details in morphological patterns are sought (see also the bathymetry product specifications). The influence of sand nourishment on these sand bar dynamics is of special interest for the German end users.

Along beaches and tidal flats many end users mentioned to be relevant to get information with regards to changes in beach width and geomorphological patterns (intertidal sandbars i.e. ridge-and-runnel systems, upper beach berm and tidal creeks in the Wadden Sea). Typically, there is a good chance that satellite capabilities match quite well end user

requirements; a planimetric accuracy of 1 m is required for beach width, which increases to 5-10 m for sandbar / tidal creek location. In average, an annual update of these parameters seems to be sufficient, and up to several times per year cited for coastal areas facing severe coastal erosion (e.g. New Aquitaine region, SW France). In regions characterized by relatively large morphological bodies or large date-to-date variations of their position (typically several tens or hundreds of meters), a 10-m planimetric accuracy in the positioning of these patterns is cited as enough. For the intertidal coastal compartment, the beach width product presents the highest number of citations (a total of 8), which were collected in the requirement forms from France and Portugal. Products related tidal creeks (shape and number, erosion dynamics) were citated only once by one-end-user from Germany (Wadden Sea), mainly because the coastal area concerned by this product is unique within the regions of interest included in the Space for Shore project. Despite, this apparent low representativeness within the Space for Shore end-user requests, these products keep a high-priority because it is the top-one product of the Wadden Sea end-user.

For coastal rocky cliffs, 2 end-users requested few other products to monitor their morphological change. One end-user from France (New Aquitaine region, SW France) requested products allowing to track the morphological change of the cliff front, including erosion scar development cliff front area and slope change, and material volume displaced by past landslides. These products should help better understanding the dynamics of eroding cliffs over which are built several high-valued and strategical infrastructures and supporting coastal erosion risk prevention on the long-term. Such products are expected to be produced and delivered 2 times per year (before and after the winter) with a 2-m planimetric accuracy. The end-user also requested the products ot be generated before and after every oceano-meteorological event (energetic aggressive waves, heavy rains), which may occur at least 6 times a year. A second end-user from Germany (Baltic Sea) was also interested in tracking the vegetation dynamics at the base of the cliff foot it is a proxy of vulnerability of cliff with respect to erosion processes. A 10-m planimetric accuracy and an update/delivery frequency of 1 time per year is required for this product.

For coastal dune systems, two typical proxies (blow-outs and dune crest erosion notches) allowing to study dune erosion processes were required by 1 end-user from France (New Aquitaine region, SW France). As the dynamics of these proxies occurs at meter-scale and evolve rapidly within a season a 1-m planimetric accuracy and an update/delivery frequency of at least 4 times per year are required. More related with the sand accumulation in supratidal areas than the coastal dune system itself, a product characterizing sandy barrier island width and its dynamics was requested by another end-user for German areas. The barrier islands delimit the Wadden Sea from North Sea and protect the shoreward intertidal areas and the coastline, making the monitoring of their state and dynamics of great interest to coastal managers. For this product, no particular requirements in terms of accuracy and temporal frequency were mentioned by the end-user.

Table 30. Product family – Extraction and change of morphological patterns

	Indicator	Country	Horizontal accuracy (m)	Vertical accuracy (m)	Temporal frequency	Citation number
Extraction and change of morphological patterns	NEARSHORE / SUBTIDAL					
	Sandbar location	FR GER PT GR RO	5-10 10 10 ng 10	-	3/year up to 1/month 1/year ng ng 1/month	8
	INTERTIDAL					
	Beach width	FR PT	1-5 1	-	2-4/year 1/year	8
	Lower beach width	FR	1	-		1
	upper beach width	FR PT	1-5 1	-	2-4/year 1/year	3

	Ridge and runnel location and orientation	FR	5-10	-	4/year		2
	Berm location	FR	5-10	-	4/year		1
	Shingle bar width	FR	0.5-1	-	1-2/year		1
	Tidal creeks: number, length, form of edges, form and number of tidal creek endings, and changes	GER	10	0.5	1/year		1
	Erosion edges of tidal creeks	GER	10	0.5	1/year		1
	ROCKY CLIFFS						
	Cliff scars	FR	2	-	2/year		1
	Cliff front surface	FR	2	-	2/year		1
	Cliff slope	FR	2	-	2/year		1
	Landslide volume	FR	ng	-	2/year		1
	Vegetation dynamics at cliff foot	GER	10	-	1/year		1
	COASTAL DUNES						
	Dune erosion notches	FR	1	-	4/year		1
	Blow-out	FR	1	-	ng		1
	Barrier beach change	GER	ng	-	ng		1

5.3 Seabed, foreshore and land cover mapping

Another product family (Table 31) emerging from end-users is related to the determination and dynamics of the seabed, foreshore and land cover type. The cover types to be tracked vary from one site to another, as a result of the wide range of environmental conditions encompassed by the project and the different challenges addressed by the end-users.

From the end-user interviews it came out that for underwater and foreshore coastal areas, the detection of (1) sand/shingle deposits covering rocky substratum, (2) alive vegetation covering sandy or rocky substratum, (3) dead vegetation naturally-deposited along the upper beach and (4) sand/shingle deposits and vegetation at cliff base are essential for coastal managers because these features offer natural barriers against the erosive impact of storm waves (due to wave energy dissipation). The characterization of sand deposits (position and dynamics) in underwater and foreshore areas along rocky-dominated coasts is also crucial to coastal managers, in order to optimize nourishment strategies at embayed and pocket beaches. At least 7 of our end-users (French, German, Portuguese) express the need of obtaining satellite-derived maps differentiating rocky, sandy, vegetated (dead or alive) areas within the underwater and foreshore areas. From the few end-users who managed to formalized technically their needs, it appears that such a product should be delivered from 1 to 2 times a year with a 10-m horizontal accuracy, which is likely reachable with Copernicus EO data (Sentinel-1 and Sentinel-2). Note that 1 end-user (Portuguese) wished to obtain a 1-m accuracy, which would require the use of VHR EO data. Concerning the detection of dead vegetation deposited on the upper beach, the updating frequency request by the end-user is higher with 2-4 products per month during spring and fall seasons, which seems challenging if the consortium only rely on Copernicus EO data. In addition, the 10-m accuracy/resolution required by other end-users may be not enough as from our knowledge these dead vegetation patches present a maximal cross-shore extent of some meters. While waiting for the end-user confirmation about required accuracy, it seems that this cover type can only be tracked using VHR EO data.

For supratidal coastal areas three type of products emerge. Firstly, 3 end-users from Portugal expressed the need to obtain satellite-derived maps differentiating general land cover types including dry-beach area, dune area, vegetated area, urbanized area and inland water body in order to assess the coastal land uses and changes and to establish relevant strategies for coastal area development. Here again, a 1-m horizontal accuracy is expected with a delivery frequency of updated product from 1 to 2 times a year. Due to the high expectation in terms of horizontal accuracy, the use of Copernicus EO data may not suit, though the update/delivery times could be satisfied. Another group of 3 end-users (French, Greek, Romanian) showed interest in obtaining maps of habitat indicators to identify the extent of high ecological/heritage value areas threatened by coastal erosion (this requires a superimposition with shoreline retreat

maps). Unfortunately, for this product not relevant details were provided by end-users till now in terms of product accuracy, updating and delivery times. The third product requested by a Romanian intermediate end-user, is related to the determination of vegetation density over coastal dunes; a proxy of the beach-dune system sedimentary dynamics which influence the response to storms events. The end user expects that: (1) the density is detected with 80% of thematic accuracy, (2) the density maps present a 5-m horizontal accuracy and (3) the update and delivery occur monthly. These requirements are somewhat challenging for HR- and VHR-EO-data-derived products because of the expected high accuracy and short update/delivery time, respectively.

Table 31. Product family – Seabed, foreshore and land cover mapping

	Indicator	Country	Horizontal accuracy (m)	Vertical accuracy (m)	Temporal frequency	Citation number
Seabed, foreshore and land cover mapping	Underwater seabed type (sandy/rocky/vegetated)	FR PT	5 1	-	ng 2/year	7
	Upper boundary of alive seagrass	FR	ng	-	ng	4
	Intertidal / foreshore type (sandy/rocky/shingle/…)	FR GER PT	ng 10 1	- - -	ng 1/year 2/year	5
	Presence/absence/envelope of dead seagrass on the beach	FR	ng	-	2-4/month during autumn and spring seasons	4
	Habitat mapping (several levels)	FR GR RO	ng ng ng	- - -	ng ng ng	3
	Vegetation density over coastal dunes	RO	5 m & 80% classification accuracy	-	1/month	1
	Coastal area Land Cover (vegetation/forest/urban)	PT	1	-	1-2/year	3

5.4 Coastal DEM

Many of the end-user expressed a strong interest for products related to the 3D coastal morphology (Table 32) and which apply to the below-cited coastal compartments. End-users usually order well-proven techniques to obtain the topography and bathymetry over coastal areas such as single/multi beam echo-sounding (for bathymetry – expensive and non-responsive), UAV photogrammetry (topography – cheap and responsive but spatially limited) and or airborne LIDAR (topography and bathymetry – covering large coastal areas but very expensive and non-responsive) which both offer centimetric-metric horizontal and vertical accuracies. However, topographic and bathymetric products derived from EO data would be complementary approaches even if less accurate, as EO data are acquired regularly over the full extent of end-user areas, offering in turns more reactivity and cheaper costs for coastal management activities.

Underwater areas: One of the most cited products is the nearshore bathymetry with 15 interested end-users, even though not often mentioned as a priority, from 4 countries covered by the Space for Shore consortium (France, Greece, Portugal and Romania). The knowledge of the nearshore bathymetry is essential to coastal managers to supports various activities such as dredging for navigation safety, updating navigation charts, sediment extraction for beach nourishment,

development of operational modelling systems for prevention of coastal erosion and flooding risks. For Greek, Portuguese and Romanian end-users the bathymetries must be delivered with a horizontal accuracy of 10 m, while for French end-users a higher accuracy is sometimes required (5-10 m). Expected vertical accuracy was only specified by French end-users with an accuracy of 0.2-1 m. According to the use of the bathymetry product the update/delivery frequencies vary strongly. It ranges from 1 product per month to 1 every 2 years, with a usual request of 2-3 per year. Space for Shore consortium targeted this product as a priority and may essentially rely on Copernicus HR EO data for product generation. However, to fulfil the need for French end-users in terms of accuracy, VHR EO data may also be involved. In addition to the bathymetry, some French end-users asked to derive a sub-product indicating sediment stocks over the rocky substratum, that is the thickness of the sandy layer. This will support the local sediment management strategy (beach nourishment and re-profiling). The expected accuracies and update/delivery frequencies are the same as for the bathymetry. To compute this product the end-users must provide the substratum elevation map that will be subtracted to the bathymetry. Although this product concerns only two end-users, this product will be investigated due to its simplicity of computation.

Intertidal areas: The intertidal and upper beach topography has sometimes been evoked by few end-users (French and Greek), but did not appears as a high-priority product. End-users order/conduct regular beach topography surveys to monitor the beach width and shape, which can be time-consuming, costly on the long-term and does not always cover the full alongshore extent of the beach. From the end-user requirements such a product should be computed with a horizontal and vertical accuracy of 1 m and 0.1-0.2 m respectively and should be generated and delivered up to 4 times per year. Generation of such product requires certainly the use of numerous VHR EO data, which could be costly as well and not advantageous for the end-users. All these elements indicate that this product may not be interesting regarding the objectives of the Space for Shore consortium.

Supratidal areas: In supratidal areas, three other topographic products were requested: topography of coastal cliffs, topography of coastal dunes and topography of coastal defence structures. The knowledge of cliff topography is useful to coastal managers (3 end-users, France and Romania) as it allows monitoring the cliff dynamics including the development of instability areas, cliff scars and cliff volume change, which are indicators of past or upcoming landslides and rockfalls threatening life safety and properties. Expected horizontal and vertical accuracies for French end-users are of 1 and 1-5 m, respectively, while for the Romanian end-user they are of 5 and 0.5 m, respectively. The update/delivery frequency should be about 2 per year. The knowledge of coastal dune topography is also of great interest for 1 French end-user along sandy coasts where the wave climate is energetic, as coastal dunes provides natural barriers against coastal flooding induced by extreme storm waves. Detection of coastal dunes changes, including volume decrease, blow-out developments and vertical erosion notches on dune top, help localizing erosion hotspots where sediment supply could be realized and where risk prevention must be done. Expected accuracies for all end-users are higher due to the usual lower-scale sizes of coastal dunes with respect to cliffs. The horizontal and vertical accuracies required by the end-user are of 1 m and 0.2-1 m, respectively, while expected update/delivery frequency was not provided. Computation of Digital Elevation Models (DEM) for cliff and coastal dunes with such accuracies should be achievable with VHR EO data. But due to the low number of interested end-user, these products should not represent a priority for the Space for Shore consortium. The topography of coastal defences (usually exposed to damaging factors) was also requested by only one French end-user, in order to support the meticulous monitoring of their structural conditions. The expected horizontal and vertical accuracies are centimetric, which makes the use of EO data inappropriate to compute such a product, at present date.

Table 32. Product family – Coastal DEM

	Indicator	Country	Horizontal accuracy (m)	Vertical accuracy (m)	Temporal frequency	Citation number
Coastal DEM	UNDERWATER					
	Bathymetry	FR GR PT	5-10 10 10	0.2-1 1 ng	2-3/year 1/5years 2/year	15

		RO	10	1	1/month to 1/2years	
	Sandy stocks over rocky substratum	FR	5-10	0.2-1	2-3/year	2
	INTERTIDAL					
	Beach topography	FR GR	ng 1	0.1-0.2 ng	up to 4/year	4
	SUPRATIDAL					
	Coastal cliff DEM	FR RO	1 5	1-5 0.5	2/year ng	3
	Coastal dune DEM	FR	1	0.2	ng	1
	Coastal defense topography	FR	0.01	0.01	ng	1

5.5 Vertical motion of coastal land

Two end-users manifested a potential interest in products indicating terrestrial vertical movements within low-lying sandy deltas to quantify the subsidence effect (French and Greek end-user) inherent to such areas or at cliff top to detect cliff instability development and to anticipate large landslides and rockfalls (French end-user) (Table 33). End-users did not provide relevant details on expected horizontal and vertical accuracies and update/delivery times, making difficult the critical analysis of their needs regarding existent EO data and methods and consortium production capacity. Therefore, the development of a product indicating the vertical movement of coastal land may not be conducted by the Space for Shore consortium.

Table 33. Product family – Vertical motion of coastal land

Vertical motion of coastal land	Indicator	Country	Horizontal accuracy (m)	Vertical accuracy (m)	Temporal frequency	Citation number
	Vertical movement of low-lying sandy deltas	GR FR	ng ng	ng ng	ng ng	2
	Vertical movement at Top-of-the-cliff vertical movement	FR	ng	ng	ng	1

5.6 Coastal defense monitoring

This last product family (Table 34) derive from two low-priority needs expressed by only few end-users from France.

The first product should allow assessing quantitatively the displacement of boulders (meter-scale) composing coastal defence structures such as seawalls, groynes and breakwaters (number of boulders, distance of displacement, and volume loss within the structure) in order to monitor efficiently their structural condition (e.g. after storm events) and to apply coordinated rebuilding strategies. This product, mentioned by 1 end-user from SW France, is definitely not compatible with the use of Copernicus HR EO data as the spatial resolution must be at least sub-metric for basic detection of displaced boulders and at least of tens of centimetres combined with stereoscopic acquisitions to assess changes in structure volume.

The second product consists of the detection of the existing defence structures and their change over the time, which will allow coastal managers to make an inventory of still exiting old-established defence structures (for which documentation may have been lost with administration changes) and recent ones. This product, requires less resolution/accuracy than the first product because (1) defence structures usually present pluri-decametric dimensions and (2) no quantitative information must be retrieved. Thus, the use of Copernicus HR EO data such as Sentinel-2 imagery for such product is totally relevant. Although this product was mentioned by only 2 end-users from the PACA French region (Mediterranean

area) where an impressive number of coastal defences are present, it is expected that such a product would interest many coastal managers within European countries. Accordingly, the development of this second product may be carefully investigated by the Space for Shore consortium. Few technical aspects should be kept in mind: (1) such a product is only relevant for shingle/sandy coasts to allow optical detection of defence structures; (2) the update/delivery times are of the order of some years as the coastal defences building and removal occurs on the medium term.

Table 34. Product family – Coastal defense monitoring

	Sub-products/ sub-indicators	Country	Horizontal accuracy (m)	Vertical accuracy (m)	Temporal frequency	Citation number
Coastal defense monitoring	Displacement of boulders of seawalls, groynes, breakwaters, …	FR	< 1	-	2/year	1
	Inventory and change detection of coastal defenses	FR	ng	-	1/1-3years	2

6 AVAILABILITY OF VALIDATION DATASETS

This section of the document aims at giving an overview of the availability of existing validation datasets over the different regions of interest for both large-scale demonstration and of course over POC areas. Favorite products the most frequently asked by end users are highlighted in green while the availability of validation data over each region is symbolized by '+' to '+++' (upon the volume of validation data available over the 10/25 last years). In regions where end users have shown interest in the product but not provided any relevant information about such existing datasets, a question mark '?' is indicated. Grey cells are for regions where end users have expressed no interest about the specific product.

By validation datasets, we mean all datasets available at end-user premises or other institutions / scientists that can be made available for the project and for the validation of satellite-derived products. This includes ground truth obtained on the field by GPS (monitoring of shoreline proxies, topo-bathymetric surveys, Terrestrial Laser Scanning, underwater habitats by diving mapping) or by means of aerial remote sensing (photogrammetry, lidar surveys, photo-interpreted shorelines from historical orthophotos…). Validation data are critical to assess the performance of satellite-derived products and evaluate how far end user requirements are met.

Indications of existing datasets were provided by the end users themselves; this data could be available either directly in their own premises when the end user is the owner, or indirectly through other people known from the end users. In this case, the end user has given information about contact points from which validation data can be found. At this stage of the project and given the information obtained from the end user interviews and summed up in their forms, we only have a preliminary definition of the extent of existing validation data to be used in the project. Typically, in France, this work of making the inventory of the existing is almost finished, it is known the dates (month/year) and exact location of field truth, and data ownership. There is not always field truth / validation data in front of each products cited by the end users, for several reasons:

- The interviewed end user may not be directly involved in beach / coastal survey and shoreline monitoring, thus not having a complete understanding of what has been done in the past or currently;
- The interviewed end user has given names of people responsible of coastal monitoring and field surveys in other organizations, and these people are on the way to be reached by the project team.
- The product is of interest, but it does not exist any field truth to the end user's knowledge.

The strategy we propose for the project is to work on the most frequently asked products and to prototype satellite products by working exclusively first on POC areas where validation data is sufficient at least over the 10 past years. We do not have the ambition to validate all prototyped products because it is clearly not feasible due to the lack of field data to do so, even more at the end user desired frequency. But nonetheless, we expect that all selected POC areas have at least some synchronous field truth/satellite pairs in order to perform validation analysis. **If there is no appropriate validation data found over certain POC areas, a specific strategy should be adapted for these ones with agreement of the potential end-users (either the site will be discarded or kept but with product provision at very local scale for instance).**

Followingly, we propose to analyze each set of required products under the consideration of both the concept of priority (how essential is the product for the end user and the associated regional coastal erosion community in each country) and the availability of validation data.

6.1 Shoreline products

There are 4 main sub-products to be prototyped,

- Cliff lines *i.e.* cliff foot and cliff apex along rocky coasts,

- Dune foot along sandy coasts,
- Waterline and/or middle of the swash zone along microtidal coastal areas (enclosed seas, Mediterranean Sea, Baltic Sea, Black Sea),
- The maximum swash (or run-up) excursion during major storm events, also in microtidal coastal areas mainly.

Relatively exhaustive validation datasets have been identified for use (Table 35), especially over POC sites in France, Portugal and Romania and Germany; in these countries, ground and aerial surveys will provide the necessary amount of expected data for the experimentation and validation of shoreline satellite-based products. In Greece, limited information is available. However, quantitative information exists, and additional data will be search for in order to provide full relevance to product validation in Greece also.

Table 35. Existing validation datasets in the regions to be used for shoreline indicators

		Regions of interest								
		FR AQ	FR NOR	FR PACA	GER WS	GER BS	PT NWC	GR EMT	GR PEL	RO
Shoreline	Cliff foot	++	+++			++	+++	+	+	
	Cliff apex	++	+++			++	+++	+	+	
	Dune foot	++					+++	+		
	Waterline (sea/land interface)					++		++		+++
	Wet/dry sand boundary dynamics					?				
	Middle of swash zone			++						+++
	Maximum swash (or run-up) excursion during major storms			?						+++
	Index of shoreline change (m/yr)		?						?	

Shoreline products being the most popular pointed out by the end users, our proposition is to select cliff foot, cliff apex, dune foot, Waterline, middle of swash zone and maximum swash (or run-up) excursion during major storms for POC activities. In addition, all POC areas should be considered to derive shoreline products.

6.2 Coastal morphological patterns

There is a range of products to be potentially produced (Table 36), but they are clearly secondary products very less popular than shoreline products, except for the German Wadden Sea where they are the main required by the end user. Note that these products have all been mentioned by expert end users having a very good background in coastal erosion processes:

- Nearshore sandbar location and dynamics,
- Beach width over sandy coasts,
- Tidal creeks (channels) morphology in low-lying macrotidal areas (e.g. the Wadden Sea),
- And other relevant indicators, like cliff scars and coastal erosion notches along coastal dunes (direct proxies of coastal erosion), but not representative of the European coastal erosion end user panel (only 1 end user over 20+ talked about it).

Even cited only a few times, these morphological patterns are certainly to be kept among the products to be prototyped because they bring expert useful information complementary to the main shoreline indicators, they can be derived easily from high-resolution satellite data reinforcing Sentinel-1/2 capabilities for addressing the coastal erosion issue, and also because the amount of validation data seems sufficient over the relevant POC areas (Table 36). **Thus, our proposition is to select the 4 main products for POC activities (sandbar location, beach width, tidal creek morphology and erosion at**

tidal creek edges) and also to investigate at the margins a few others with lower priority (cliff scars, coastal erosion notches, shingle bar width) and at the very local scale.

Table 36. Existing validation datasets in the regions to be used for morphological pattern indicators

		Regions of interest								
		FR AQ	FR NOR	FR PACA	GER WS	GER BS	PT NWC	GR EMT	GR PEL	RO
Coastal morphological patterns	NEARSHORE / SUBTIDAL									
	Sandbar location	+			?		?			?
	INTERTIDAL									
	Beach width	+++		?			?			
	Ridge-and-runnel location / orientation	+++								
	Berm location	+++				+				
	Shingle bar width		?			+				
	Tidal creeks: number, length, form, form and number of tidal creek endings				?					
	Erosion at tidal creek edges				?					
	ROCKY CLIFFS									
	Cliff scars	+								
	Cliff front surface and slope	+								
	Landslide volume	+								
	Vegetation at cliff foot					+				
	COASTAL DUNES									
	Dune erosion notches	++								
	Blow-out	?								

6.3 Seabed, foreshore and land cover mapping

Products allowing the characterization of coastal area cover type and their change were cited several times by end users, often with different requirements. Two main products to be prototyped emerged:

- Seabed and foreshore cover type determination (basic types: sand, shingle, rock, vegetation), targeting a 10-m planimetric accuracy with an update/delivery from 1 to 2 times per year,
- Land cover type determination with an emphasis in the differentiation of the different vegetation types/habitats, targeting a metrical accuracy with an update/delivery from 1 to 2 times per year.

Validation data are not abundant within the Space for Shore end-user community (Table 37). **For the two products it appears that only aerial imageries will be available to validate the accuracy of the cover type classification from EO data**. One Romanian end-user could provide ground observations of vegetation type and density at few observation points but the horizontal area covered by each observation point (1 m²) may be too small with respect to VHR and HR EO data resolution, making this dataset useless for future product validation.

Table 37. Existing validation datasets in the regions to be used for seabed, foreshore and land cover mapping

		Regions of interest								
		FR AQ	FR NOR	FR PACA	GER WS	GER BS	PT NWC	GR EMT	GR PEL	RO
Seabed, foreshore and land cover mapping	Underwater seabed type (sandy/rocky/vegetated)	?		+			?			
	Upper boundary of alive seagrass			?						
	Intertidal / foreshore type (sandy/rocky/shingle/…)	?			?	?	+			
	Presence/absence/envelope of dead seagrass on the beach			?						
	Coastal habitat and land cover mapping (several levels)		?				?	?		+
	Vegetation density over coastal dunes									+

6.4 Coastal DEM

These 3D products have been poorly cited by end users, except for the nearshore bathymetry (depth in the range of 0-10 m) for which the demand is high. The reason may be that end users are considering (quite rightly) that EO-data cannot match conveniently their requirements in terms of ground resolution (often < 1m) and accuracy (<< 1 m). Topographic surveys are abundant over POC areas, being acquired routinely on the field or by aerial surveys. Even if topographic DEMs are not really required, it is very likely that it will be necessary to produce them as an intermediate product to *in fine* extract some shoreline indicators, over rocky coastlines in particular (to get cliff lines).

The few available bathymetric data will be used for the validation of satellite-derived bathymetry to be produced over several POC areas (Table 38). Note that 7 of the 9 regions are asking for such a bathymetric product. At the moment, the exact amount of field bathymetric surveys available over POC areas is not well known and needs to be refined, in Greece in particular where the existence of such bathymetric data is not proven. In France, a few surveys exist, in particular some exhaustive bathymetric lidar surveys (only 1 recent date is available in many French regions). In Portugal and Romania, bathymetric surveys appear to be more common, maybe less exhaustive than those obtained by aerial lidar, but provide recurrence and thus, the possibility to perform several validation cases.

Table 38. Existing validation datasets in the regions to be used for coastal DEM

		Regions of interest								
		FR AQ	FR NOR	FR PACA	GER WS	GER BS	PT NWC	GR EMT	GR PEL	RO
Coastal DEM	Bathymetry	+	+	+			++	?	?	+++
	Beach topography	+++						?		
	Coastal cliff Topography	++								?
	Coastal dune Topography	++								
	Coastal defense topography	+								

6.5 Vertical motion of coastal land

Two products of vertical motion over coastal land were identified during user interviews (Table 39). Typical validation data for such products are centimetric-accuracy DGPS measurements, which appears available for only one of the targeted regions (high accuracy topography surveys are available over Basque country cliffs, Nouvelle Aquitaine region, SW France). However, the survey accuracy level has not been confronted to the order of magnitude for the vertical movement expected to be detected. In addition, these products were requested by only two end-users with a low-priority. These elements suggest that the Space for Shore consortium should not focus on the development of these products.

Table 39. Existing validation datasets in the regions to be used for vertical motion of coastal land

		Regions of interest								
		FR AQ	FR NOR	FR PACA	GER WS	GER BS	PT NWC	GR EMT	GR PEL	RO
Vertical motion of coastal land	Vertical movement of low-lying sandy deltas							?		
	Vertical movement at top-of-the-cliff	++								

6.6 Coastal defense monitoring

Two sub-products have been asked by the end users with low priority. In addition, there is no easy-access of relevant validation data (Table 40).

The first product considered is the displacement of boulders. In the literature, such application is found using very high-resolution airborne imagery. Result shows that centimetric to decametric resolution is required to identify the boulders. However, the boulders must be marked with specific shapes or color to allow their identification. Therefore, if adapted test areas exist, further evaluation may be now performed with the panchromatic channel of Pleiades satellite since available data are archived. But Sentinel resolution will not be adapted.

There might be charts or some GIS layers with the location of coastal defenses along the Camargue coasts that could be used. This product is not the priority as cited only few end-users. However, if the end-users become proactive in providing exploitable validation data, this product could be still considered.

Table 40. Existing validation datasets in the regions to be used for coastal defense monitoring

		Regions of interest								
		FR AQ	FR NOR	FR PACA	GER WS	GER BS	PT NWC	GR EMT	GR PEL	RO
Coastal defense monitoring	Displacement of boulders	?								
	Inventory and change of coastal defenses			+						

7 SYNTHESIS AND CONCLUSIONS

This first phase of user requirement collection carried out over a European panel of potential users of Space for Shore service has been quite successful with regards to the number of products requested and to the large panel of coast morphology represented.

The requirements have been collected, maturated and the forms fully completed have been reviewed and formally approved by the end users before being analyzed by the project team.

Overall, 22 end-users have been interviewed within the public sector including national governmental agencies, regional authorities, intermunicipal cooperation and municipalities, as well as natural site managers, research centers and coastal observatories. At this stage of the project no any private company was involved within the Space for Shore end-user community. The positive answers and implication of all these coastal managers and stakeholders in France, Germany, Greece, Portugal and Romania confirm that coastal erosion is a common issue shared all along European coastline and for all types of coast (rocky, sandy, low-lying shores made of sand and mud) and all hydrodynamical conditions (low- to high-energy wave conditions, micro- to macro-tidal).

From this panel of potential users of Space for Shore services, more than 40 products were requested to support current and future practices to manage issues related to coastal erosion. To help synthetize end-user requirements these products were grouped in 6 product families. This task enabled to fully characterize the end-user needs in terms of product accuracy as well as the update and delivery frequency. It also evidenced that some products were systematically requested by end-users of different region of interest, while others were mentioned only by one or two end-users.

As the production capacity of the Space for Shore consortium is not unlimited, effort production should focus on products that are the most attractive to the end-user point of view (highest priority and number of end-users) and that can be reasonably produced during phase 1 of the project regarding technical specifications of EO data currently available. In addition, the existence of ground-truth data provided by end-users is required to validate the products generated by the consortium at the different POC sites suggested by the end-users. Thus, availability of validation data influences the selection of products that will be prototyped during phase 1 and determine the POC sites suggested by end-users where the product will be developed and validated. High-priority products, together with preferred POC sites are summarized in Table 41.

In Table 41, “Beach width” stands for "Total beach width", "Lower beach width" and "Upper beach width". These various definitions have been cited by the end-users. All refer to a single product named “Beach width” hereafter. Also, “Habitat mapping (several levels)” has been grouped with “Coastal habitat and land cover mapping (several levels)” since the same approaches are used to map natural habitats (coastal or not), land cover or even land use.

Table 41. List of high-priority products identified for POC activities. Yellow cells: the most favorable POC sites according to existing validation data. Light brown cells: POC sites that will be further discussed with potential end-users.

Family name	Product name	Regions of interest								
		FR AQ	FR NOR	FR PACA	GER WS	GER BS	PT NWC	GR EMT	GR PEL	RO
Shoreline	Cliff foot									
	Cliff apex									
	Dune foot									
	Waterline (sea/land interface)									
	Middle of swash zone									

	Maximum swash (or run-up) excursion during major storms									
Coastal morphological patterns	Sandbar location									
	Beach width									
	Tidal creeks: number, length, form, form and number of tidal creek endings									
	Erosion at tidal creek edges									
Coastal DEM	Bathymetry									
Seabed, foreshore and land cover mapping	Underwater seabed type (sandy/rocky/vegetated)									
	Intertidal / foreshore type (sandy/rocky/shingle/…)									
	Coastal habitat and land cover mapping (several levels)									

Lower-priority products are listed in section 6; they will be assessed again with the end-users. Clarifications about existing field data, usefulness of the product at large scale and coherence with management use needs must be brought by the end-users. If this information is relevant, low priority products may be included in the Proof of Concept phase.

In addition, the door is wide-open to the production of lower priority indicators during Phase 2. They will be reviewed one by one at the end of phase 1. Depending on POC results, on the introduction of new end-users, on needs emerging during the Mid Term Review, they might be considered for production during Phase 2. Additional end-users already demonstrated their interest in the project, they could not participate in the requirement collect. However, they will be associated to the large-scale demonstration phase.

Finally, we need to underline that a careful review of the image archive needs to be done in order to finalize the selection of the POC sites. The final Data Procurement Plan will derive from this ultimate analysis.

– End –