CO-EVOLVE

Promoting the co-evolution of human activities and natural systems for the development of sustainable coastal and maritime tourism

Deliverable 3.2.2

Mapping of coastal morphodynamics descriptors in Mediterranean touristic areas

Activity 3.2

Threats to co-evolution - Mediterranean scale: Climate changes and morphological stability

WP3

CNR - ISMAR

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1. Introduction

This report represents "*Deliverable 3.2.2 - Mapping of coastal morphodynamics descriptors in Mediterranean touristic areas*", which is the final output expected from the "*Activity 3.2 - Threats to co-evolution - Mediterranean scale: Climate changes and morphological stability*".
It provides a critical analysis of coastal morphodynamics in Mediterranean touristic areas, which has been achieved using data and information derived from previous studies on coastal morphology and driving anthropogenic and natural processes.
Past and present impacts induced on the littorals have been identified and analysed also taking into account relationships with littoralization, urbanization, and types of coastal tourism activities. Projections of future coastal evolution have been carried out in the light of climate change conditions.
Analysis of processes and threats has been carried out from Mediterranean to NUTS III scale (where possible), locally focusing on less extended coastal areas considered as noteworthy case studies for their morphodynamic behaviour and vulnerability.
Thematic maps at macro- and meso-scale have been realized for a clear visualisation and a rapid comprehension of the main coastal morphological features, recent evolution and threats (see annexes).

2. Material and methods

The first part of the activity was based on the collection of available studies on coastal morphology and driving physical processes in the Mediterranean touristic littorals. The collected material was organized into a Geographic Information System (GIS) database to make easier data management, analysis, and interpretation and to allow the realization of thematic maps summarizing the results obtained from this study.

2.1 The GIS database

The GIS database represents a data repository (from Mediterranean to NUTS III scale) containing information about coastal morphodynamics and oceanographic and climate conditions, necessary to analyse and identify threats to the coasts and related touristic activities. It has been created using the software "ArcGIS 10.2.2," which has given the possibility to store, georeference and compare data, analyse spatial information and create maps (Fig. 1). Spatial and alphanumeric information has been arranged in order to represent the main following variables for coastal setting and processes. Data are organized into tables, so that they can be readily retrieved, managed, and edited.

Stored data are:

- beach characteristics (geomorphology, lithology, sedimentology),
- coastal evolutionary trends,
- subsidence/uplift,
- coastal defence measures,
- hydrodynamic conditions,
- climate conditions,
- other driving physical natural processes and human activities/interventions that affect the littorals,
- land-use,
- tourism,
- coastal hazards.

Thus, the GIS database has provided an important framework for integrating existing multidisciplinary data produced at local, regional, national, and MED scales, allowing a rapid visualization of the status and recent evolution of the Mediterranean coasts. It represents an important tool for the immediate interpretation of the beach system dynamics and for coastal planning in view of future climate changes and sea-level rise.

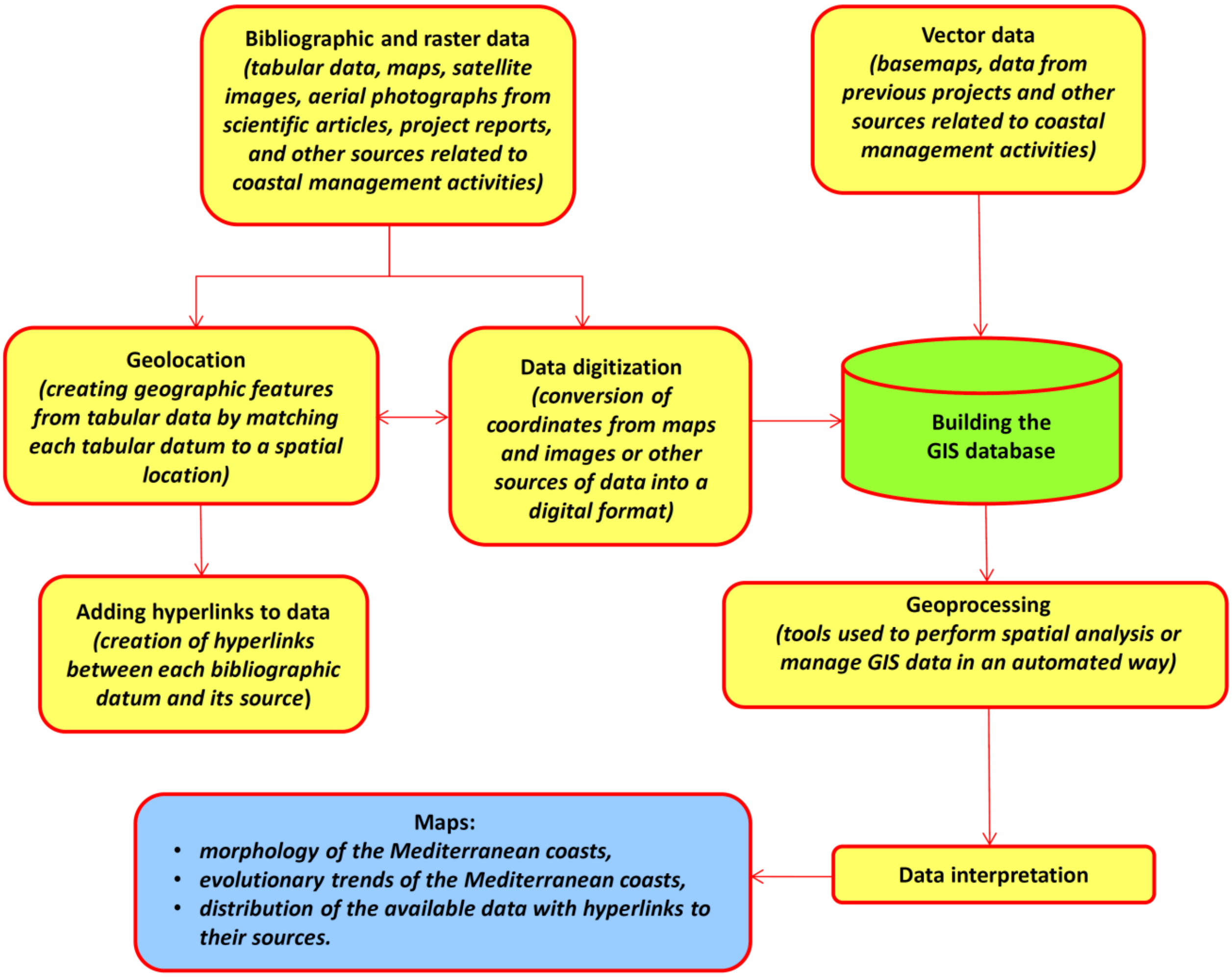


Figure 1: Block diagram of the GIS database.

Results coming from the integrated data analysis have allowed realizing maps that show the morphological and sedimentological characteristics of the Mediterranean littorals, as well as their evolutionary trends (i.e. erosion, stability, and accretion).

2.2 The morphological map of the Mediterranean coast

The morphological map of the Mediterranean coast shows the geomorphological and sedimentological characteristics of the littorals (Annex 1). In the European countries, it has been realized using the information available from the EUROSION (2002-2004) and SHAPE (2011-2014) projects. In the coastal stretches not covered by these studies, the characteristics of the littorals have been derived from satellite observations, scientific articles, and reports at different scales.

Ten categories have been defined to identify the coastal features starting from a reclassification of the categories proposed in the framework of the above-mentioned projects (Tab. 1).

Table 2 provides a detailed description of the classification criteria used within the EUROSION Project. It is useful to better understand the correspondence among the CO-EVOLVE and the EUROSION morphological coastal types.

The morphological maps of the Mediterranean coasts, produced at both Mediterranean and NUTSIII scales, are particularly useful for the rapid identification of the littorals that could be more exposed to erosion (e.g. sandy beaches) and flooding (e.g. deltas and estuaries, and tidal flats) under future climate change conditions and sea-level rise.

2.3 Map of the coastal evolutionary trends

The map of the evolutionary trends shows the coastal stretches that undergo erosion, progradation or stability (Annex 2).

In the countries belonging to the European Union (i.e. Spain, France, Italy, Slovenia, Greece, Cyprus, and Malta), information derived from the EUROSION Project has been considered as the starting point for the present analysis; their shoreline represents 63% of the entire Mediterranean coast. Data from more recent studies have allowed updating the previous results along 11% of the littorals analysed within the EUROSION Project. Moreover, available information collected within the CO-EVOLVE Project has given the possibility of defining the evolutionary trends of 22% of the non-European Mediterranean coasts.

Overall, erosion appears as a common process that affects not only sandy beaches and low-lying territories, but also cliffs.

Ten categories used to define coastal conditions within the EUROSION Project (Tab. 3) have been merged in five categories for a simpler graphic visualization of the evolutionary trends (Tab. 4).

In each map, black line segments indicate the updated evolutionary trends of the littorals, whereas the codes identify the related data source (Tab. 5).

Table 1: Categories used to classify the Mediterranean coast based on its geomorphological and lithological characteristics, according to the SHAPE Project (first column) and the EUROSION Project (second column). The third column shows the new classification proposed within the CO-EVOLVE project.

SHAPE Project	EUROSION Project	CO-EVOLVE Project
Sandy beach	E - developed beaches F - soft non cohesive sediments	Sandy beach
Gravel beach	D - developed beaches	Gravel beach
Mixed sand and gravel beach	X - Soft strands (heterogeneous category grain size)	Mixed sand and gravel beach
Artificial coastline	J - Harbour areas K - Artificial beaches L - Embankments Y - Artificial protections (dykes)	Artificial coastline
Cliff Rias Rocky coast	A - Rocks/hard cliffs (few erosion)	Cliff/rocky shore
Cliff with sandy beach Cliff with shingle beach Rocky shore with gravel beach Rocky shore with sandy beach	AC - Mainly rocky (< 200 m long) B - Cliffs subject to erosion C - Small beaches	Cliff/rocky shore with beach
Sheltered tidal flats/marsh	G - muddy sediments (waddens) N - Vegetative strands (pond or lake type)	Tidal flat/marsh
Estuary/river mouth	H - Estuary	River mouth (delta/estuary)
Wave-cut platform	P - Soft strands and rocky (platforms) R - Soft strands (beach rocks) S - Soft strands (mine-waste) sediments Z - Soft strands (uncertain category grain size)	Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)
Coasts built by organisms		Coasts built by organisms

Table 2: Criteria proposed within the EUROSION project for a morphological and lithological classification of the European coasts (Lenôtre et al., 2004).

Description: The morpho-sedimentology coding system, originally adopted for the CCEr database, allows characterising the principal morphological and sedimentological elements of intertidal strands from generally accessible data and information (photographs, maps, reports, etc.). Each coastal segment is characterised by a single morpho-sedimentology code chosen from the proposed nomenclature. Explanations are given, when needed, in order to limit the range of personal interpretations and to provide a homogeneous method for describing the European coastline. Moreover, unless the coast is delimited by rocky structures or artificial structures directly subjected to the action of the sea, the proposed classification emphasises the nature of the constitutive materials of the intertidal strand, this being the zone that exhibits the most visible signs of erosion or sedimentation processes and where the majority of coastal defence works are carried out.
A - Rocks and/or cliffs made of hard rocks (low level of erosion), sometimes with a rock platform.
B - Conglomerates and/or soft-rock cliffs (e.g. chalk), which are subject to erosion: presence of rock waste and sediments (sand or pebbles) on the strand.
AC - Mainly rocky, low level of erosion, with pocket beaches (<200 m long), not localised on the segment.
C - Small beaches (200 to 1000 m long) separated by rocky capes (<200m long).
D - Extensive beaches (>1 km long) with strands of coarse sediment (gravel or pebbles).
E - Extensive beaches (>1 km long) with strands of fine to coarse sand.
F - Coastlines of soft non-cohesive sediments (barriers, spits, tombolos).
P - Soft strands with rocky "platforms" (rocky flats) on intertidal strands. The rock platform was present before the soft strand was deposited. The strand is commonly a thin layer.
R - Soft strands with "beach rock" on intertidal strands. The beach rock (cemented sand) has developed within the beach strand. Such cases are usually found in Mediterranean countries.
N - Very narrow and vegetated strands (pond or lakeshore type). No sandy or muddy beach at high tide. Vegetation almost reaches the sea.
S - Soft strands made of mine-waste sediments. This kind of sediment does not have a greater physical impact than other sediments in terms of erosion but can have a strong impact in terms of environmental pollution. Such deposits can also be transported by coastal drift and deposited on other beaches.
K - Artificial beaches. This code concerns: - entirely man-made beaches such as those found in the Canary Islands. - beaches where the granulometric nature of the sediments changes after coastal defences. have been installed, e.g.: formation of a sand beach in front of a gravel beach after completion of coastal defence work. - nourished beaches.
X - Soft strands of mixed grain-size categories.
Z - Soft strands of unknown grain-size category.
G - Strands of muddy sediments: "wadden" and intertidal marshes with "slikkes and shorres".
Y - Artificial shoreline or shoreline with longitudinal protection works (walls, dikes, quays, rocky strands), without sandy strands.
L - Coastal embankments for construction purposes (e.g. earthworks).
J - Harbour areas.
H - Estuary (virtual line). Internal coasts of estuaries, rias, fjords, bays and coastal lagoons are excluded from the inventory when the mouth is less than an arbitrary width of 1 km. In these cases and in order to have a continuous coastline, the two sides of the estuary, ria, bay or coastal lagoon are joined by a virtual line.

Table 3: Criteria proposed within the EUROSION project to indicate the evolutionary trends of the Mediterranean coast (Lenôtre et al., 2004).

Evolutionary trends (EUROSION Project)
Each coastal segment is characterized by a code representing that segment's evolutionary trend. The ten code items are divided into four main classes: - not in nomenclature or absence of information - stability - erosion - aggradation (sedimentation, accretion) Owing to major disparities in the available data, it is not possible to have quantitative information on evolutionary trends at European scale. Moreover, the rate of erosion is far from constant in terms of time, and inversions can occur in the trend. It is therefore important to know the time-frame in which the data on erosion was collected, as well as the meteorological conditions that prevailed during that time: - measurements made during a storm will show severe erosion - measurements made after a storm may show aggradation - measurements made before and after the installation of a coastal defense system will produce a different range of values All these reasons explain why evolutionary trends are always qualitative.
No information
Not in nomenclature. e.g.: H (virtual line for mouth) and J for harbour areas.
No information on evolution. The evolutionary trend of a coastline is usually known for a localised area but not for the whole of a region or country. For the other areas, there is either no knowledge (no data available) or the knowledge is at a very local level (inhabitants).
Stability
Stable: evolution almost imperceptible at human scale. This code should be used whenever it is impossible to formulate an objective judgement on the recent evolutionary tendency of a coastal segment.
Generally stable: small "isolated" variations around a stable position – the evolutionary trend is uncertain. Seasonal fluctuations in the coastline may occur with variations in the rate of natural sediment deposition The time-scale of coastal monitoring is too short to show evolutionary trends with any certainty in this case.
Erosion
Erosion probable, but not documented. Coding based on questionnaires and assessments by experts of probable but undocumented tendencies.
Erosion confirmed (available data) along parts of the segment. Different cases can occur: - for morpho-sedimentological code "AC - mainly rocky with pocket beaches", the pocket beaches are not localized on the segment but they may be affected by from erosion, - erosion is very localised (measured on a part of the segment), - measurements only exist for part of the segment and there is no knowledge for the rest of the segment.
Erosion confirmed (available data) along almost the whole length of the segment.
Aggradation
Aggradation probable, but not documented. Coding based on questionnaires and assessments by experts of probable but undocumented tendencies.
Aggradation confirmed (available data) along parts of the segment. Different cases can occur: - for morpho-sedimentological code "AC - mainly rocky with pocket beaches", aggradation may be occurring on the pocket beaches (made of sand or mud) but they are not localised on the segment, - aggradation is very localised and measured on a part of the segment, - measurements only exist for part of the segment and there is no knowledge for the rest of the segment.
Aggradation confirmed (available data) along almost the whole length of the segment.

Table 4: Categories used to classify the evolutionary trends of the Mediterranean coast, according to the EUROSION Project (first column) and the CO-EVOLVE Project (second column).

<table>
<tr><th>EUROSION Project</th><th>CO-EVOLVE Project</th></tr>
<tr><td>Stable: evolution almost imperceptible at human scale</td><td rowspan="2">Stable</td></tr>
<tr><td>Generally stable: small "isolated" variations around a stable position – the evolutionary trend is uncertain</td></tr>
<tr><td>Erosion probable, but not documented</td><td rowspan="3">Erosion</td></tr>
<tr><td>Erosion confirmed (available data) along parts of the segment</td></tr>
<tr><td>Erosion confirmed (available data) along almost the whole length of the segment</td></tr>
<tr><td>Aggradation probable, but not documented</td><td rowspan="3">Progradation</td></tr>
<tr><td>Aggradation confirmed (available data) along parts of the segment</td></tr>
<tr><td>Aggradation confirmed (available data) along almost the whole length of the segment</td></tr>
<tr><td>Not in nomenclature</td><td>Artificial coastline</td></tr>
<tr><td>No information on evolution</td><td>No information on evolution</td></tr>
</table>

Table 5: Country codes.

Country code	Country
SPA	Spain
FRA	France
ITA	Italy
SLO	Slovenia
CRO	Croatia
ALB	Albania
GRE	Greece
TUR	Turkey
LEB	Lebanon
ISR	Israel
EGY	Egypt
TUN	Tunisia
ALG	Algeria
MOR	Morocco
CYP	Cyprus

3. Morphodynamics and vulnerability in touristic European coasts

3.1 Spain

Spain is located in southwestern Europe on the Iberian peninsula. Its territory also includes the Balearic, the Canary Islands, and two autonomous cities, namely Ceuta and Melilla, located in North Africa. Beaches and low-lying areas are common in the Mediterranean regions, associated to the presence of coastal plains with deltas.

Over the past fifty years, the Spanish coasts have undergone intense development, mainly due to tourism activities (75% of tourists visiting Spain head for coastal areas), the growing role of maritime trade and the energy industry and offshore oil deposits (Alterman et al., 2013; García-Ayllón, 2016). On the other hand, traditional primary activities, such as fishing and agriculture, have been neglected. These developments have produced a rapid urbanization that has been also responsible for remarkable morphological modifications of the littorals (García-Ayllón, 2015).

A significant part of this great transformation took place during the 1970s and 1980s. It was responsible for various threats to the conservation of the coast, including an accelerated process of land use, the gradual privatization of coastal areas, and the destruction of natural environments (Alterman et al., 2013). After becoming member of the EU in 1986, new environmental regulations have entered into force in Spain and in 1988 a new coastal law was adopted, which marked a tipping point in coastal policies and interventions.

Although additional environmental regulations have been instituted over time, some of the effects of the above mentioned problems remain, such as the presence of ineffective coastal defences (which have not solved erosion problems, but have displaced them to other zones along the coast), the environmental degradation of ecosystems and habitats, and risks of environmental hazards linked to erosion due to past coastal developments.

Moreover, in coastal inlands the land use transformation has continued over the following decades, sometimes based on past urban development decisions, sometimes on new ones, thus significantly increasing the share of “artificial land” in coastal areas. Some of the effects of this process, which could be pointed, include, for example, the loss of coastal natural landscapes and higher risks due to environmental pressures and, in some cases, hazards (e.g. floods).

Erosion due to wave energy threatens the human infrastructures located in the backshore and reduces the available surface of beaches for tourism (Mulder et al., 2010). When these infrastructures are basic for social and economic activities carried out on coastal areas, special measures to diminish erosion are usually taken. In the last decades, in Spain many engineering works have already been developed in response to erosion problems. In the mid-1970s, the study "Plan Indicativo de Usos del Dominio Público Litoral" allowed identifying coastal areas subjected to erosion, which gave the possibility to develop specific corrective actions, where necessary (Mulder et al., 2010). Since the beginning of the 1990s, this problem has been managed according to the rules established by the 1988 Shores Act (Ley de Costas). More recently, the Spanish Administration is adopting "coastal protection strategies" for certain coastal stretches where erosion problems are more serious and a global and renewed approach (in terms of territorial and time frame extents, and coastal engineering techniques), according to some ICZM principles, is needed.

Along the Andalusian Mediterranean coast, erosion is due to both natural and anthropogenic processes. The littorals are exposed to a microtidal (0 to 1.5 m) regime in a wave-dominated environment, generally subjected to low energy levels and high frequency waves (Regione Emilia-Romagna - Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010). Waves mainly approach from easterly directions, generating a prevailing westward littoral drift, and show a seasonal behaviour with storm conditions being recorded during November-March (Pita Lopez, 2003; Guisado et al., 2013). Winds from western directions, with associated sea waves and swell waves, give rise to an opposing drift (Guisado et al., 2013; Manno et al., 2016). Locally, this bidirectional behaviour can prevent sediment transport. In the last decades, fluvial sands and gravels, representing important sediment supplies to the beach system, have been reduced by the construction of dams and reservoirs (Guisado & Màlvarez, 2009). The interruption of natural beach-dune sedimentary interchange due to the emplacement of promenades in backshore and dune ridges has worsened this condition. As a result, coastal retreat processes have been enhanced. Groins and breakwaters have provided human settlements with permanent beaches, by means of *tombolo* formation and/or the creation of a series of swash-aligned shoreline cells, such as at Marbella, Benalmadena, Malaga. On the other hand, even if these accumulations close to ports and/or at protection structures have given rise to wide beaches, their sediments have been lost to the sediment budget because they are not removed by littoral transport (Manno et al., 2016).

On the Mediterranean coast of Andalusia, very narrow coastal plains originated in front of the slopes of the Betic Mountains. Here, urban development has progressively extended from the plains onto the adjacent areas, having steep slopes and high elevations. These zones are at risk because they are characterized by pre-existing and dormant landslides (Mateos et al., 2017). Nevertheless, they are highly urbanized because their elevations offer excellent sea views and a gentler slope than the adjacent, stable areas. An essential role for the landslide reactivation is played not only by intense precipitations and/or high values of rainfall accumulation, but also by the concentration of load due to urbanization on the upper parts of the landslides, with consequent damages to the buildings and other anthropogenic structures (Notti et al., 2015; Mateos et al., 2017).

In the Coastal Vulnerability Assessment, carried out by the Regional Ministry of Environment of Andalusia in the framework of a project started in 2007, the coast has been classified taking into account the Coastal Vulnerability Index (CVI) (Tab. 6), which was calculated using the following six variables: coastal geomorphology, erosion rate, coastal slope, average significant wave height, sea-level change rate, and average tidal range (Ojeda-Zújar et al., 2009). For the Andalusian coast, CVI value ranges from 2.23 and 35.35 (see also Fig. 2 and Fig. 3).

Table 6: Classification based on the Coastal Vulnerability Index (modified after Ojeda-Zújar et al., 2009).

CVI value	Classified CVI value	Level
(2.23 – 6.32)	1	Low
(6.32 – 10.00)	2	Moderate
(10.00 – 14.14)	3	High
(14.14 – 35.35)	4	Very high

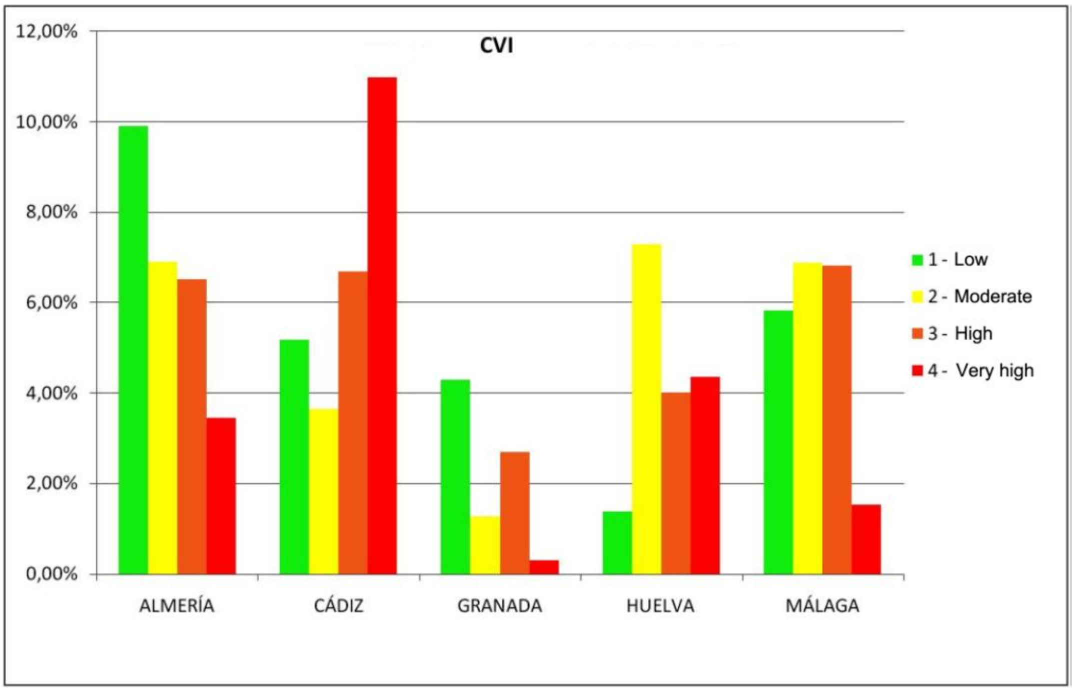


Figure 2: Results from CVI analysis at NUTS III scale (modified after Ojeda-Zújar et al., 2009).

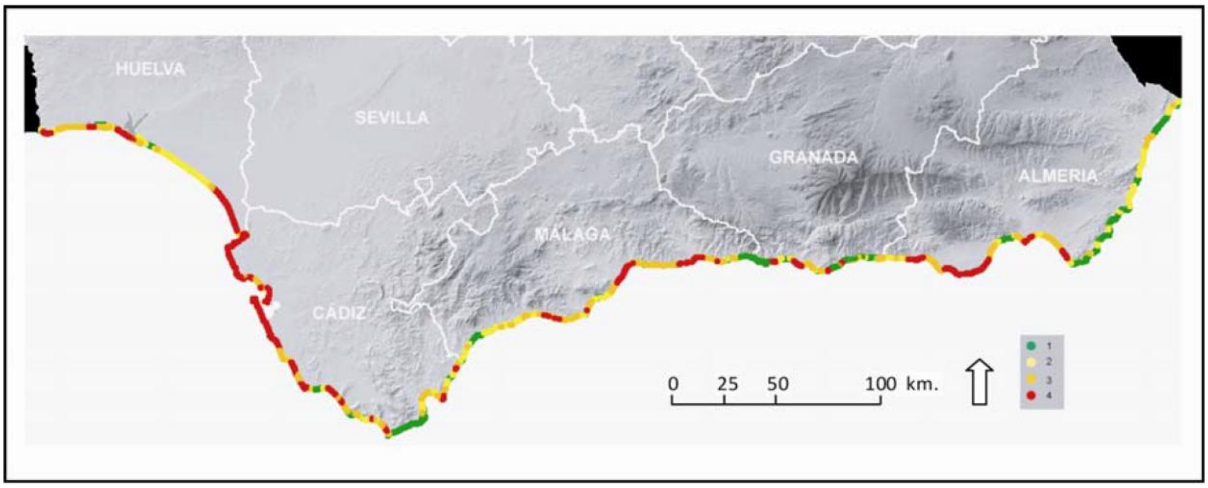


Figure 3: Coastal Vulnerability Index in Andalusia at NUTS III scale. 1: low; 2: moderate; 3: high; 4: very high (from Ojeda-Zújar et al., 2009).

At present, the Andalusian coast is one of the most protected. In the mid-1950s, the Mediterranean littoral stretches were characterized by a very low level of armouring and the most important settlements were coastal towns and associated fishing communities (Manno et al., 2016). In the following decades, the length of armoured coastline increased from 42.1 (1956) to 182.3 km (in 2001), representing about 33% of the total length of the Andalusian littoral. Several ports were enlarged and new marinas were built especially along the Costa del Sol without any appropriate and broad management plan. The induced coastal retreat was counteracted by progressive groin emplacement to enlarge tourist dry beach width, increasing its carrying capacity, and to make the littorals more attractive, often under the pressure from owners of newly constructed expensive properties (Guisado et al., 2013; Manno et al., 2016).

Over the last decades, the Costa del Sol has undergone one of the fastest rates of urban development. Nowadays, it also receives about 10,000,000 visitors per annum, making it one of the most important tourist destinations in Spain.

A stretch of the Andalusian coast characterized by a good preservation and poor urbanization is the littoral of Levante de Almeria because tourism has developed relatively late due to lack of common infrastructures (Tedesco, 2015). At present, tourism is becoming one of the main local socio-economic features and demand of houses by European residents is growing. These conditions are triggering a strong expansion of the housing activity and increasing of the value of the territory.

Erosion also occurs along the Valencia littorals, mainly characterized by beaches. The coasts of this region are characterized by a very small (less than 20 cm) tidal range and low energy waves; major waves develop during storms generated by the passage of low-pressure systems from the west (Sanjaume & Pardo-Pascual, 2005), which produces strong winds from NE and ENE (Pardo-Pascual, 1991). Storms may come through the entire year; however, the most severe events occur in November and December, when 6 m high waves with periods of 8-10 seconds have been recorded in deep water (Sanjaume & Pardo-Pascual, 2005).

Over the last century, human actions have strongly influenced the equilibrium of the Valencia coast. In particular, the extraction of sand and gravel from rivers and beaches and the building of dams have reduced sediment inputs to the littorals, whereas jetties and breakwaters, harbours and recreational activities have interfered with the alongshore sediment transport, which has been strongly modified or completely stopped. Reduced sediment availability and coastal response capacity against erosion has been also caused by the destruction of littoral dunes and confinement of other sedimentary deposits due to 60's and 70's coastal developments. Moreover, at a local scale, some engineering structures may have increased the nearshore slope, also favouring an increase of the wave energy on the littorals and in turn favouring the propagation of erosion waves along the coast.

In the Valencia region, nearly 70% of the population lives in coastal municipalities and population density in the coastal zone is about four times the average further inland (782 inhabitants per square km, versus 207) (Alterman et al., 2013). The seasonal influx of tourists multiplies these values by three, so pressures on natural and urban systems are very high.

High anthropogenic impact has also affected the Catalan coast, on which tourism and other human activities have led to a high degree of artificialization (Cadiou et al., 2015). In addition to the major harbours (Barcelona and Tarragona), 45 small and medium fishing harbours/marinas are scattered along the littorals (1 every 15 km) and 22 sites of artificial reefs have been created. During the second half of the 20th century, the Catalan coast has experienced a huge development due to the tourism boom and the concentration of population in coastal areas (Jiménez et al., 2012).

An important impact on port activity is also due to the meteorological tide as it may exceed 1.0 m in the Mediterranean regions, which are often prone to resonance events. This is the dominant water level factor for these Spanish microtidal environments, in which tidal range goes from 0.80 m at Malaga to about 0.20 m in the Catalan coast (Gracia et al., 2013).

On these intensively developed coastal stretches, the greatest damages are due to storm events and erosion. At present, about the 70% of the beaches of Catalonia are retreating at an average rate of 2 m/yr (CIIRC, 2010). The vulnerability to coastal flooding depends on the width, morphology, and spatial variability of the beach (including the presence of dune systems) in relation to the intensity of the ocean's forcing (Wright & Short, 1984; Sallenger, 2000; Sallenger et al., 2003; Duran et al., 2016). Consequently, during extreme events the joint action of erosion and storms will increase coastal risk because the beaches that are progressively narrowing will become more exposed to storm-induced hazards (Jiménez et al., 2012). At present, along the Catalan coast the most damaged areas correspond to shorelines presenting the largest erosion rates.

Along the Catalan coast, one of the most threatened social-ecological Spanish systems is represented by the Ebro river delta (Fatoric & Chelleri, 2012). Formerly susceptible to climate change owing to its topographic characteristics, over the last decades it has become more vulnerable because urbanization and economy have strongly modified its structure and functioning. Deficit of sediment supply, sea-level rise, also favoured by subsidence (both natural and human-induced), wave action, and storms are the main responsible for its erosion and produce a high exposition of its lower zones to flooding and shoreline retreat.

Shoreline retreat also occurs in the Llobregat river delta where erosion is the result of combined anthropogenic and natural factors. In particular, the expansion of the Barcelona harbour with the construction of a long jetty in the river has shortened the supply of sediment from the North, whereas a small craft harbour closes the cell at the South (Sánchez-Arcilla et al., 2016). The sequence of southern and northern storm waves is no longer able to produce alongshore sediment fluxes in the two shore parallel directions. The barrier effect enhances cross-shore transport (losses) and prevents river discharges necessary to supply sediment to the active coastal profile.

Studies based on storm data collected between 1958 and 2008 along the Catalan coast have shown that storm-induced damage has increased at a rate of about 40% per decade (Jiménez et al., 2012). However, they showed that the South and North areas (Ebro and Todera river deltas, respectively) appeared as the sites with the larger storminess values (in terms of wave length and storm duration), whereas the central coast (Llobregat river delta) as the mildest energetic zone (Jiménez & Bosom, 2009). Analysis of morphodynamics on periods of decades allowed observing that along the Catalan coast the higher hazard in terms of beach erosion and sediment transport occurred in the period 1999-2008, when also the greater damages were reported due to the impacts of storms, and was larger at the North and South ends. Nevertheless, the storm-induced coastal hazards cannot be considered more important in the North and South stretches and lower in the central zone because coastal geomorphology, which control the magnitude of the response to the storm forcing, was not taken into account during the study.

Storms could also be produced by tsunami events, as proved by the presence of large boulders in the Mallorca Island (Scheffers & Kelletat, 2005).

3.1.1 Future trends

Rising sea levels and storms represent serious threats for low-lying zones and urban areas developed along the coast. In fact, they increase the risk of flooding and intensify erosive processes. Consequently, they can cause the complete disappearance of the beaches, deltas, and marshlands.

Since the mid-1940s, along the Spanish coasts sea-level rise rates have varied from 0.9 (Gibraltar Strait) to mm/yr to 2.4 mm/yr (Northern Spain) (Gobierno de España - Ministerio de Agricultura, Alimentación y Medio Ambiente, 2014). Projections for 2100 show sea-level rise values between 0.5 and 1 m that will be responsible for severe impacts on beaches, deltas and other low-lying coastal areas owing to the risk of flooding. Sea-level rise and increased water withdrawals in response to future higher demand could also worsen salt-water intrusion into the aquifers. The process could be exacerbated by the possibly reduction in river runoff due to climate change. This problem would represent another threat to tourism owing to the reduced availability of drinking water.

Compared to other countries located further north, the protected Mediterranean coasts of Spain are less affected by winter storms from the Atlantic. However, owing to climate change conditions, higher storm activity over the adjacent Atlantic could lead to an increase in the intensity of winds by the end of the century and to the formation of hurricanes from the Atlantic Ocean (WWF, 2006) (see, for example, two events occurred in 2005, named hurricane Vince and tropical storm Delta).

On 24 July 2017, the Spanish Administration, following the provisions of the 2013 amendment of the Coastal Law, adopted the “Climate change adaptation strategy for the Spanish Coast”, which is aimed at increasing the Spanish coast resilience to climate change (and climate variability) and at integrating adaptation in coastal planning and management. It sets out a diagnosis as well as specific objectives, guidelines, and measures.

3.2 France

In France, eleven coastal regions face the Mediterranean Sea in the southeast and the Atlantic Ocean in the west. In addition, France has four overseas regions, namely Guadeloupe, Martinique, French Guiana and the Reunion Island.

Along the Mediterranean coast, the dominant coastal type is represented by sandy littorals. Wetlands, lagoons, and estuaries are also present. At the western and eastern extremities (Pyrenees and Alps, respectively), embayed and pocket beaches can be observed (Anthony & Sabatier, 2013).

Vulnerability to erosion is extremely variable owing to the different characteristics of the littorals; anyway, sandy beaches are the most exposed. Along the French Mediterranean coast, one of the main factors responsible for shoreline retreat is the general decrease of river sediment supply mostly caused by anthropogenic interventions carried out in their entire drainage basins since the mid-1950s. Locally, the process has been also worsened by the construction of coastal defence structures, which can impede the longshore transport of sediments. As a result, downdrift zones cannot be nourished (Anthony & Sabatier, 2013).

Examples of beach erosion induced by human actions are common along the coasts of the Gulf of Lion. These littorals mainly developed between the 1950s and 1980s, when river sediment supply were still considerable and the natural character of the shoreline favoured a good sedimentological functioning of the system. Studies carried out within the framework of the Coastance Project and focused on the littorals of the Department of Hérault have shown that since the 1990s the anthropization and urbanization of the coast have upset this fragile balance (Fig. 4) (Regione Emilia-Romagna - Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010). The reduced sand availability from dunes and the decrease of the sedimentary contribution from rivers (mainly due to canalizations, dams and extractions of sediments) have deprived the system of a considerable volume of sand.

Until the 1990s, the response to erosion was local. A few defence plans have been developed, but they have been only partially applied, as they have been often badly coordinated and under-financed. For several decades, the implementation of protection measures has locally slowed down or stopped erosion of some coastal stretches, but on the mid-term time scale, they have been responsible for negative impacts on the littorals (e.g. displacement of erosion to other sectors) and related structures.

At present, narrow flat beaches characterize the eastern and central stretches of the Hérault coastal zone where urbanization have locally reached the beach. The artificialization of the littorals is generally very widespread in the west sector and more limited elsewhere. Dunes are lacking or scarce; sometimes they are artificial (Regione Emilia-Romagna - Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010).

High shoreline retreats can be also measured along the Languedoc-Roussillon coastal stretch (western Gulf of Lions), which can be considered one of the most vulnerable to erosion. The main factors proposed to explain the decrease of shoreface sediment budget include i) the weak redistribution of sandy inputs from rivers toward the beaches, ii) the gradient of longshore transport, iii) considerable losses towards the offshore zone, and iv) sand dredging practices (Brunel et al., 2014). Owing to the high summer flux of people, this process, which has largely affected the beaches over the last decades (Durand, 1999), represents a serious threat to tourism. However, the presence of more than 250 works has not definitively resolved the problems and the growing need for maintenance and restoration has required additional costs (Regione Emilia-Romagna - Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010).

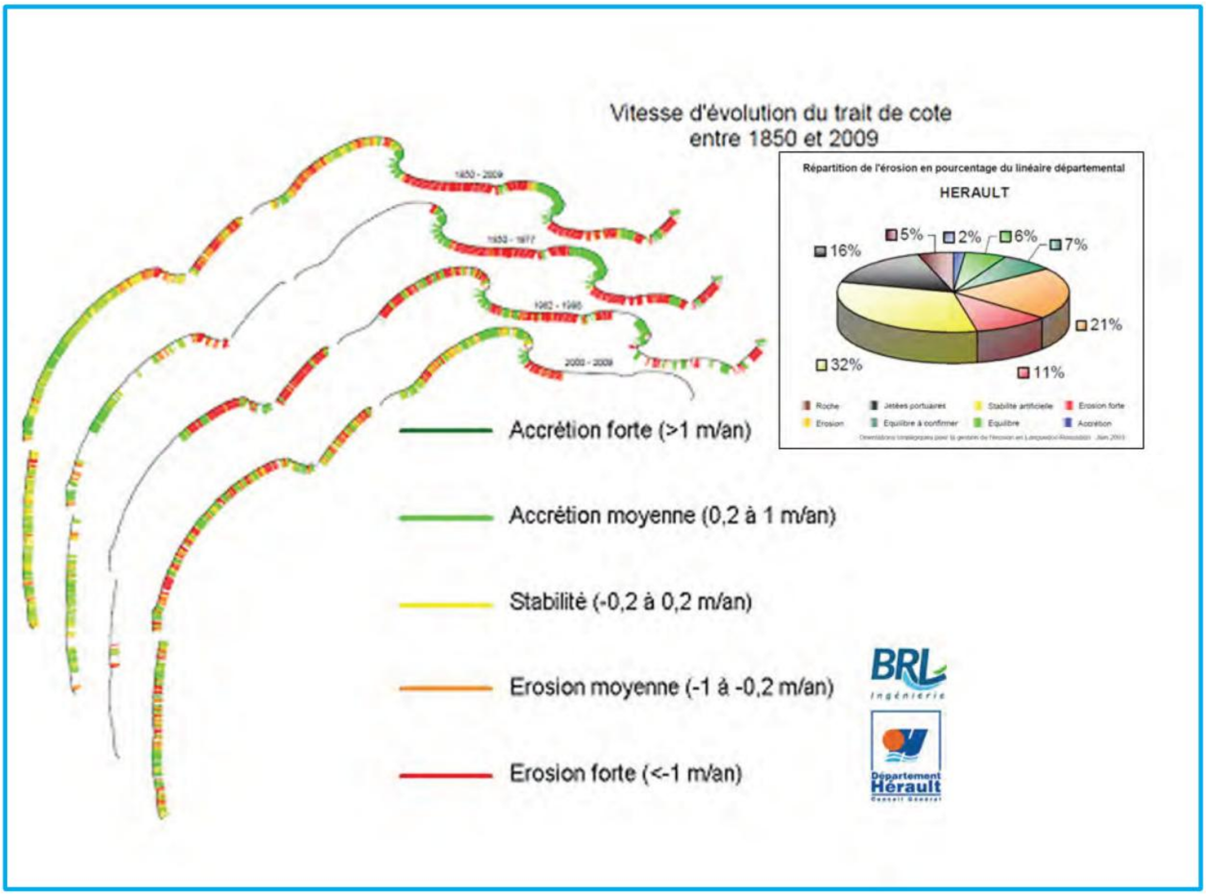


Figure 4: Evolution of the Département de l'Hérault coastal zone since 1850 (from (Regione Emilia-Romagna - Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010).

Flat and sandy coastal stretches that are experiencing strong erosion are also located in Camargue near the Rhône river mouth.

Another threat to coastal environments is represented by storm surges, which enhance erosion and increase flood-risk. Frequency, wave energy, and wave height of storm in the Gulf of Lions have been subject of many studies.

The Gulf of Lions is a microtidal, wave-dominated environment. Even if the tidal range is very low (<0.30 m at mean spring tides), large variations in water level can occur in response to wind forcing and atmospheric pressure fluctuations (Aleman et al., 2015). Set-up can attain 1 m near the shore (Certain, 2002) under the combined action of storm surges and waves. However, this coastal stretch could undergo very strong extreme events, as proved by the accumulation of boulders recently discovered along the rocky coast of the Gulf of Fos (located in the eastern part of the Gulf of Lion, between Marseille and the Rhône Delta)

(Vella et al., 2011). They are scattered to a distance of about 30 m from the coastline; in particular, the largest block weighs 33.5 tons and has been transported about 39 m inland, up to about 2 m a.s.l. On the Mediterranean coast, their origin is often attributed to tsunami-generated waves, but in this case, the origin is unclear; however, as their surface characteristics are different, they could be accumulated by several events generated by southwesterly storms.

Analysis of wave measurements collected in the period 1989-2009 in front of Sète in the Department of Hérault has shown that the mean annual duration of storm events was quite stable, whereas their frequency slightly increased, particularly from 1998 to 2004, when the number of events doubled (Balouin et al., 2009). However, no tendency in storm intensity (in term of wave heights and storm surge level) was detected and variations could have been probably due to climate variability rather than climate change. Balouin et al. (2009) also observed that in the Gulf of Lion the surge level (i.e. the water level measurements minus the astronomical tide) slightly increased between 1896 and 1999; the increase was about 2.9 mm/yr, which is more or less equivalent to the sea-level rise observed by satellites in this area (Cazenave et al., 2002). The maximum wave heights recorded at Sète are 5, 7.8, and 9 m for return periods of 1, 10, and 100 years, respectively (LCHF, 1984).

On the long time scale, in the northern part of the West Mediterranean, the temporal analysis of storm surges reveals only very weak increasing trends, in particular in the height of the annual maximum surge (+3.0 mm/yr ±0.6 mm) and in the annual frequency of the number of surges (+0.07 day/yr ±0.02 day/yr) (Sabatier et al., 2009). Waves from E to S, generated by onshore winds, are the most energetic. Wave energy also displays spatial variability, especially during storm events. On the other hand, the southern part of the Gulf of Lions is protected from S–SE storms by the rocky Pyrenees coast (Aleman et al., 2015).

Understanding the different morphological responses of the coast to storm events is crucial for managers to evaluate coastal risks and to develop the best measures to mitigate their effects (Gervais et al., 2012). Therefore, these authors have proposed a morphological thresholds scale for the northern part of the Gulf of Lions where storms can induce damage to infrastructure, coastal facilities, and sea defences (Tab. 7).

This approach gives regional coastal managers an estimation of the degree of the expected impacts on the littorals and should be used in coastal risk management plans.

Locally, erosion and flooding can be favoured by subsidence, which is frequently experienced by deltaic areas. One of these is the reclaimed land of the Var delta, on which the Nice Côte d'Azur international airport (southeast of France) has been built. Most of the airport's offshore extension was constructed in the late seventies (Cavalié et al., 2015). The large harbour seawall disappeared in a major submarine landslide in October 1979 generating a 2–3 m high local tsunami that killed nine people, mostly on the construction site

(Assier-Rzadkieaicz et al., 2000; Sahal & Lemahieu, 2011; Ioualalen et al., 2010). In this site, even if the main subsidence mechanism is the compaction of the thick Holocene sediment layer, a detectable influence on the lowering of the delta is due to land reclamation and to the overload caused by the presence of the airport (Cavalié et al., 2015).

Table 7: Morphological thresholds in the northern part of the Gulf of Lions (Gervais et al., 2012).

Hs threshold	Morphological response
<2.7 m	No major evolution
2.7 m	Change in the behaviour of coastal morphologies (offshore bar migration, backshore sand deposition)
4 m	Impact on the dune toe, on the flank of infrastructures, overtopping of the low natural areas
5 m	Overwash and breaching on natural lido, overtopping and destruction of infrastructures

As the southern French coast is highly anthropized and characterized by intensive tourism, all these hazards represent serious threats to population, urban environment, tourism and other economic activities. Locally, owing to this intense anthropization, the width of the flat sandy beaches has been also reduced by the expansion of the urban fronts (Anthony & Sabatier, 2013).

3.2.1 Future trends

Owing to beach morphology, the expected sea-level rise will affect the coasts for sure and will significantly increase erosion especially in sandy littorals and soft rock cliffs. Temporary flooding caused by storm waves and permanent inundation due to sea-level rise over long time scales will affect coastal areas (Le Cozannet et al., 2011). However, authors that have tried to estimate the effects on the littorals considering different scenarios have obtained different results. Outcomes from these researches, summarized by the UK Met Office (2011), indicate that by the 2080s, under a high sea-level rise scenario and without adaptation, the average annual number of people flooded in French coastal areas could be around 463,000, but this value could be greatly reduced with adaptation to around 2,500. Under a low sea-level rise scenario, 1,800 and 3,000 people could be flooded annually with and without adaptation, respectively. Moreover, if along the sandy littorals the problem of erosion is not counteracted sufficiently waves would get closer to the beach owing to rising sea level. This might increase coastal flood-risk, especially during storm surges (European Commission, 2009b). On the long time scale, in the northern part of the West Mediterranean the temporal analysis of storm surges (between 1905 and 2003) has revealed only very weak increasing trends, in particular in the height of the annual maximum surge (+3.0 mm/yr ±0.6 mm) and in the annual frequency of the number of surges (+0.07 day/yr ±0.02 day/yr) (Sabatier et al., 2009). However, up to 2050, a large part of the uncertainties in defining the future marine flooding occurrence originates from the wave set-up (the rise of sea-level due to wave breaking) whose contribution to high-water level can vary drastically in neighbouring locations, depending on the local beach slopes (Le Cozannet et al., 2015).

3.3 Italy

Italy consists of the Italian peninsula and the two largest islands in the Mediterranean, Sicily and Sardinia; 15 of its 21 regions are coastal regions. Owing to the physical setting of Italy, the coasts display various morphological and lithological types, from rocky littorals and cliffs to low sandy beaches. As they are characterized by diverse orientations, they are exposed to different hydrodynamic processes and weather conditions.

The coastline has a length of approximately 7500 km; about 3950 km (53%) are represented by low beaches or delta littorals and around 1600 km (42%) of these are already under erosion (Tab. 8) (Aucelli et al., 2006). Pocket beaches are eroding too; they are also frequent in small islands that benefits from tourism. Thus, their narrowing or disappearance causes serious impacts on local economy. In 2015, the Ministry of Environment and Territory and Sea established the “National Table on Coastal Erosion” (TNEC) with the involvement of all coastal Regions, aimed at identifying common methods for a correct and sustainable management of the coast, mostly in view of the expected future climate change. As a result, in 2017 the "National Guidelines for the coast protection: coastal dynamics management" has been produced (MATTM-Regioni, 2017).

Results coming from a number of studies on coastal evolutionary trends and vulnerability, carried out both at a regional and at a local scale along the Italian littorals, have shown that coastal erosion represents one of the major threats, largely enhanced by anthropogenic processes and worsened by the ongoing effects of climate change. Most of the Italian littorals are experiencing high human pressures, mainly due to urbanization, tourism, and industry. Consequently, the natural dynamics of the coastal zones has been seriously modified by the increasing development of urban settlements, infrastructures, and economic activities. This phenomenon has considerably transformed the natural features of the coastal fringe reducing its resilience: dunes have been largely fragmented and frequently destroyed and the width of most sandy beaches is now reduced to a few tens of meters, sometimes a few feet (Ministry for the Environment, Land and Sea, 2009).

The Adriatic coasts are mainly characterized by low sandy beaches commonly affected by significant erosion processes (Simeoni & Bondesan, 1997). Human activities have been largely responsible for these phenomena owing to an improper land use and misguided and incorrect coastal management and planning. Urbanization, construction of roads and railways, building of extensive defence structures, extraction of sediments from the riverbeds are just some of the most important causes that have produced drastic modifications on the littorals, either irreversible or rather difficult to correct.

Table 8: Coastal stretches subjected to erosion (modified from Aucelli et al., 2006).

Region	Coastline length (km)	Low coasts (km)	Coastal stretches subjected to erosion (km; %)
Liguria	466	94	31 (33)
Tuscany	442	199	77 (39)
Lazio	290	216	117 (54)
Campania	480	224	95 (42)
Calabria	736	692	300 (43)
Sicily	1623	1117	438 (39)
Sardinia	1897	459	195 (42)
Basilicata	56	38	28 (74)
Apulia	865	302	195 (65)
Molise	36	22	20 (91)
Abruzzo	125	99	50 (50)
Emilia Romagna	130	130	32 (25)
Marche	172	144	78 (54)
Veneto	140	140	25 (18)
Friuli-Venezia	111	76	10 (13)
Total	7569	3952	1681 (42)

The low-lying coast of the Northern Adriatic Sea is also very sensitive to land- and sea-elevation changes (Carbognin et al., 2009; Bitelli et al., 2010) (Fig. 5). Subsidence is due to both natural and anthropogenic processes: the former include sediment compaction and deformation of substratum, whereas anthropogenic subsidence is mainly due to ground fluid removal. In the north Adriatic coast, the combined effects of the lowering of the land-surface elevation and sea-level rise have threatened the industrial areas, the urban zones, and the surrounding vast reclaimed marshland, which have become more prone to being submerged.

This has resulted in a more serious risk of flooding and inundation, particularly in view of the ongoing climate change.

In the second half of the 20th century, anthropogenic subsidence also represented a serious problem for the Venice Lagoon preservation. Starting in the 1970s, it was strongly reduced or stopped after the halt of groundwater withdrawals (Carbognin et al., 2009). In this area, because of its high vulnerability exposure, the process has been, and is still, largely studied (e.g., Strozzi et al., 2009; 2010; Tosi et al., 2009; 2010; 2012, 2014; 2016; Kourkouli et al., 2014; Teatini et al., 2012; 2014).

At present, Venice remains one of the most vulnerable cities of the country with regard to flooding and extreme weather events.

Similar conditions of land subsidence have been detected in the Po river delta (e.g., Simeoni & Corbau, 2009; Fabris et al., 2014), in the Ravenna area (Teatini et al., 2005) and close to the Bevano river mouth (Taramelli et al., 2015).

As regards the Emilia-Romagna region, sandy beaches, having an average width of 70 m and generally protected by offshore breakwaters, represent the dominant coastal landscape (Armaroli et al., 2012). The littorals are currently experiencing a deficit in their sediment budget owing to a decrease in human-induced fluvial sediment transport from the 1970s onwards. The rapid coastal development occurred in the last 50 years has exacerbated this problem, also increasing the risk of sea ingression. In the last 30 years, the Emilia-Romagna coastline has been in a “frozen state,” except for the zones near Comacchio, owing to human interventions (coastal defences and widespread beach replenishments). Moreover, significant effects on the morphological modifications and damages along the Emilia-Romagna coastline have been produced by storms and flooding (Armaroli et al., 2012; Pescaroli & Magni, 2015; Sekovski et al., 2015).

Different types of littorals, from cliffs to low sandy beaches, characterize the Ionian and Tyrrhenian coasts. Consequently, erosion affects not only well-developed sandy littorals and pocket beaches, but also rocky shores. Cliffs are frequently prone to landslides both due to wave erosion and other weathering processes, but can be also enhanced by anthropogenic activities. Coastal stretches subjected to this types of processes are common in many Italian coastal regions, such as Liguria (e.g., Brandolini et al., 2006; 2009; 2013), Tuscany (e.g., Marchetti et al., 2008; Bini et al., 2013; Sciarra et al., 2014), Campania (e.g., Budetta et al., 2008; De Pippo et al., 2007; 2008; Pennetta & Lo Russo, 2011; Violante, 2013), Calabria (e.g. Blois, 2008), Apulia (e.g. Andriani & Walsh, 2007), Marche (e.g. Aringoli et al., 2011), Abruzzo (e.g. Aringoli et al., 2011) and Sardinia (e.g. Ginesu et al., 2014). Landslides, which can be also triggered by running waters and wave motion, represent a geomorphological risk for the road and railway networks, the stability of buildings and the safety of people, including swimmers and those in boats in the seaward sector.

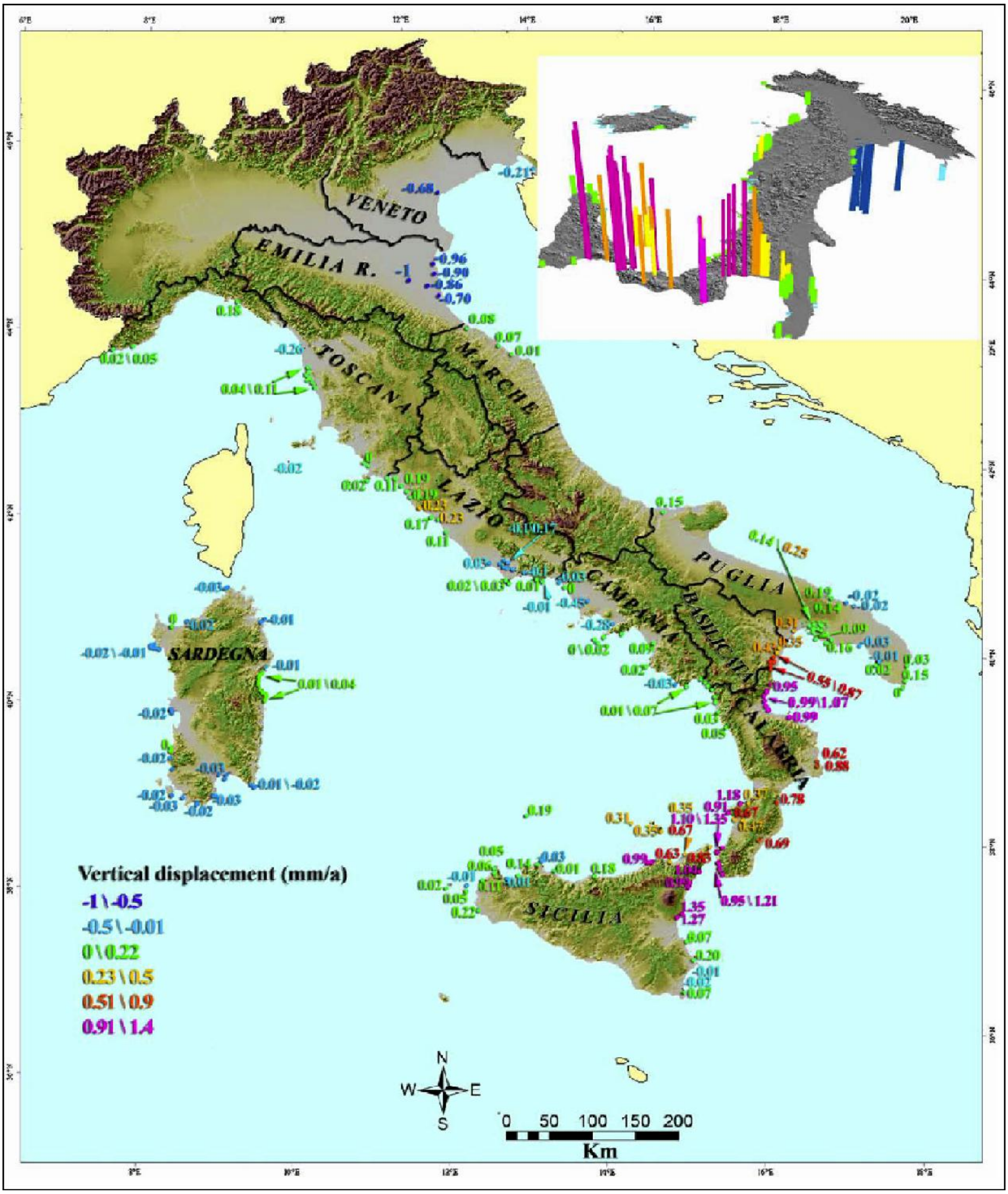


Figure 5: Vertical land displacements (mm/yr) along the Italian coasts (from Ferranti et al., 2005). Coastal stretches of Tuscany, Sardinia, southern Lazio, and western Sicily can be considered steady, whereas subsidence occurs along the Friuli, Veneto, and Emilia-Romagna littorals. On the contrary, the coast of Calabria and eastern Sicily are undergoing tectonic uplift.

3.3.1 Future trends

Over the next decades, climate change (in particular, relative sea-level rise and increased occurrence of extreme weather events, such as storms), together with the effect of anthropogenic pressures on natural resources, will produce negative impacts on the Italian coastal areas, which can be identified as follows (Ministry for the Environment, Land and Sea, 2009; 2013):

- coastal erosion and instability, with risk of coastline regression;
- flooding;
- loss of coastal land and of related economic activities, infrastructures, urban settlements, recreational areas and natural heritage sites, mainly where climate change combines with natural and/or anthropogenic subsidence;
- reduction or loss of biodiversity and ecosystems (especially wetlands), and decrease of marine life caused by the combined effect of climate change and anthropogenic stress;
- damages to coastal rural economy, due to salt water intrusion into coastal fresh-water beds;
- negative impacts on tourism and possible displacement of tourism flows from the coasts in summer, due to extremely hot temperatures and increased frequency of heat waves, also exacerbated by increasing shortage of water resources;
- possible threat to human health posed by flood events.

Sea-level rise will have serious implications for the Italian coastal zone. Table 9 shows sea-level rise scenarios in low coastal areas susceptible to marine flooding (Lambeck et al., 2011).

Under the same scenarios, the impacts will be different in relation to the morphological and lithological characteristics of the littorals and the processes occurring along the various coastal stretches (e.g. local hydrodynamics and vertical land movements). Besides these factors, socio-economic characteristics also make the coastal zones of Italy quite vulnerable as they host many residential as well as industrial sites (European Commission, 2009c). Anyway, the greatest risk of flooding and erosion is expected on the low-lying coastal areas and on low sandy beaches (Fig. 6). Specifically, about 4500 km^2 of Italian coasts are at risk of sea flooding from sea-level rise by the next 100 years; most of them are located in the North Adriatic Sea, but some Tyrrhenian and Ionian coasts may be at risk too. Considering only the evolutionary trend of Italian littorals and the current presence of activities and urban settlements located within 500 m from the coastline, the area subject to flood risk in coastal areas covers approximately 1000 ha (3% of the country) involving about 9% of the whole population (Ministry for the Environment, Land and Sea, 2009).

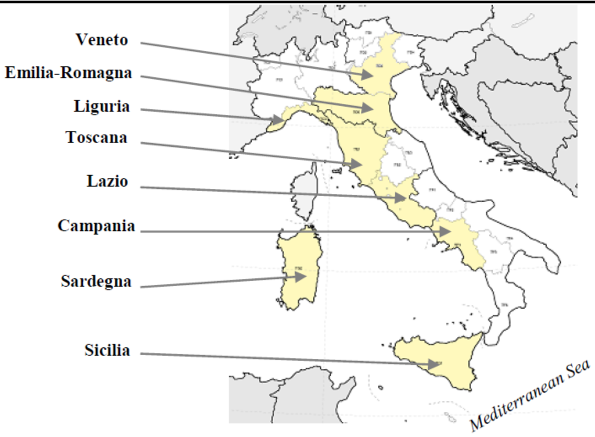
Table 9: Sea-level rise (cm) scenario for the year 2100 AD in coastal zones that are susceptible to marine inundation (from Lambeck et al., 2011).

Coastal plain	Vertical displacement rate	Vertical displacement for 2100 (isostasy + tectonics mm)	Relative sea level rise for the year 2100 calculated on 2010	
	(isostasy + tectonics mm/yr)		Lower impact scenario IPCC 2007 B1 (+180 mm)	Higher impact scenario Rahmstorf 2007 (+1400 mm)
Albinia	−0.33	-29.7	210	1430
Alento	−0.5	-45	225	1445
Cagliari	−0.6	−54	234	1454
Catania	0	0	180	1400
Cecina	−0.3	−27	207	1427
Coglians	−0.63	−56.7	237	1457
Colostrai-Flumendosa-Murtas	−0.63	−56.7	237	1457
Crati	0.2	18	162	1382
Fondi	−0.4	−36	216	1436
Garigliano	−0.4	−36	216	1436
Gioia Tauro	0	0	180	1400
Grosseto	−0.33	−29.7	210	1430
Burano Lagoon	−0.37	−33.3	213	1433
Lesina	−0.42	−37.8	218	1438
Manfredonia	−0.44	−39.6	220	1440
Metaponto	0.2	18	162	1382
Noto	−0.58	−52.2	232	1452
Oristano	−0.62	−55.8	236	1456
Orosei	−0.63	−56.7	237	1457
Pantani Cuba and Longarini	−0.58	−52.2	232	1452
Pilo	−0.63	−56.7	237	1457
Piombino e Follonica	−0.32	−28.8	209	1429
Po and Veneto-Friuli	−1.5	−135	315	1535
Pontina	−0.44	−39.6	220	1440
Pontina coastal lakes	−0.44	−39.6	220	1440
Porto Pino-Palmas	−0.6	−54	234	1454
Tiber (Rome Plain)	−0.39	−35.1	215	1435
S. Eufemia	0	0	180	1400
Trapani Saltponds	−0.57	−51.3	231	1451
Sele	−0.44	−39.6	220	1440
Tortolì	−0.63	−56.7	237	1457
Versilia	−0.3	−27	207	1427
Volturno	−0.44	−39.6	220	1440

The most vulnerable areas in the Northern Adriatic basin are the Venice Lagoon with its surroundings (Veneto) and the Po delta (Emilia-Romagna), the coasts of Toscana, the Tevere river mouth (Lazio), the southern part of Lazio, the Volturno river estuary and the coast south of Salerno (particularly in Cilento) in Campania and Sicily (Fig. 7) (European Commission, 2009c).

Unlike other Italian coastal stretches, the littorals of the southern Adriatic, Ionian, and southern Tyrrhenian seas could also be exposed to strong waves produced by tsunamis (Furlani et al., 2014).

Figure 6: Italian coastal areas that could be flooded by sea-level rise in 2100 (Antonioli, 2016). Scenarios are based on the last IPCC report (Church et al., 2013) and Rahmstorf (2007) projections, high-resolution DTMs and rates of vertical land movements, including the glacio-hydro-isostatic model of Lambeck et al. (2011). For the Po Delta and Venice Plain, mean values are reported. Data do not include the contribution of local compaction and fluid (gas and water) extraction.



Physical and socio-economic indicators	*Mediterranean Sea*
Sea Level Rise	Medium
Coastline length	7 468 km
10 km coastal zone below 5 metres elevation	< 5%
Coastline subject to erosion	1 704 km (22.8%)
GDP in 50 km zone (€ million)	558 306 (42%)
Population in 50 km zone	34 154 065 (59%)

Figure 7: Most vulnerable coastal regions of Italy in terms of flooding and an overview of the main physical and socio-economic indicators of the Italian coastal zones (from European Commission, 2009c). Source: Policy Research based on EEA (2006), The changing faces of Europe's coastal areas (for Sea-Level Rise and 10 km coastal zone below 5 m elevation); European Commission (EUROSION study) (2004), Living with coastal erosion in Europe: Sediment and space for sustainability (for coastline length and coastline subject to erosion); Eurostat (2004) (for GDP and population in 50 km zone).

Finally, the gradual worsening of desertification trends, already observed in the whole country, could be accelerated from climate change by increasing the actions of erosion, salinization of aquifers, loss of organic matter and drying up of soil (Ministry for the Environment, Land and Sea, 2013).

3.4 Slovenia

The entire Slovenian coast is about 46.6 km long and is characterized by three main coastal towns (i.e. Koper, Izola and Piran), ports, dense maritime traffic, attractive and developed touristic areas, marine and coastal protected zones and fishery activities.

The major pressures on the coastal zone are (RRC Koper, 2012):

- littoralization of the coastal strip and insufficiently sustainable pattern of urban development;
- growth in passenger transport, based on the use of personal vehicles;
- development of the commercial port, growing maritime transport and the related environmental pressures;
- tourism and recreational activities;
- urban waste water and municipal waste in conjunction with urban development and tourism;
- increasing risk of natural disasters arising from the climate change.

The coast has undergone a widespread urbanisation: more than 80% of the Slovenian coastline is urbanised and mostly within 1.5 km from the sea front. Therefore, only 8 km (18%) of coast preserve their natural conditions (Regione del Veneto, 2013). Urbanization does not only refer to the increase of population living in coastal areas but also to a significant expansion of activities, such as tourism and coastal artificialization. As Slovenia has a short coastline, this phenomenon appears particularly pronounced (UNEP-MAP-Blue Plan, 2005).

The Slovenian coast is characterized by cliffs up to 80 m high, composed of flysch alternating with marls, siltstones and sandstones; they are affected by wave erosion and subaerial weathering, which originate gravel/pebble beaches (Pikeli et al., 2013). Cliff erosion rate is 1-2 cm/year; the process is more intensive in uninhabited areas and natural reserves (Pikeli et al., 2013). Coastal slumps and rockfalls may represent a danger to both local population and tourists (e.g., beach tourism including swimmers).

Inhabited cliff zones subjected to erosion are protected (Pikeli et al., 2013). Defences built along the Slovenian coast successfully prevent and reduce the negative impacts of coastal erosion (RRC Koper, 2012). On the other hand, prevention measures need to be enhanced in relation to the increased frequency and intensity of high tides due to climate change, which are responsible for floods and, consequently, erosion of the littorals. In particular, it is necessary to reinforce the implementation of the spatial planning regulations and to limit the expansion of building in areas at risk (RRC Koper, 2012).

Sea floods are common and occur every year (Fig. 8); in particular, they are more frequent in autumn and winter and rather rare in spring. They are caused by high tides, strong southeast winds (which produce high waves) and drops in air pressure (Kolega, 2006). The waves can give the flood a destructive force because they can reach few meters in height; thus, these storm events often destroy or damage the structures along the coast and are responsible for the major changes in the cliff faces owing to a complex interaction between marine and non-marine factors (Kolega, 2006; Furlani et al., 2011).

In Slovenia, the highest level reached by the sea has between 1963 and 2003 has been 394 cm (Kolega, 2006). As shown in Table 10, the widest flood area is located in the municipality of Piran (mainly because of the presence of the salt-pans of Sečovlje, which increase the flood surface), whereas the smallest is in the municipality of Izola.

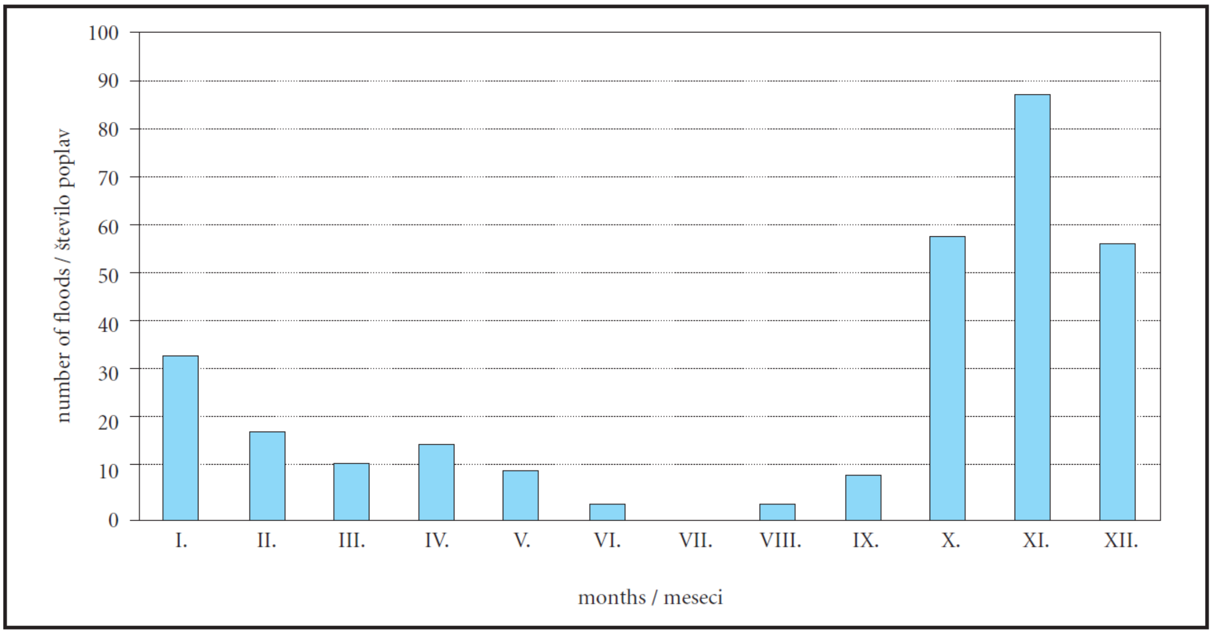


Figure 8: Floods per month between 1963 and 2003 (from Kolega, 2006).

Table 10: Surface of flood areas during extreme and yearly sea floods (from Kolega, 2006).

Area	Surface in km^2
Flood area during extreme floods	
Municipality of Koper	6.12
Municipality of Izola	0.20
Municipality of Piran	7.71
All three municipalities together	14.04
Flood area during yearly floods	
Municipality of Koper	0.25
Municipality of Izola	0.03
Municipality of Piran	3.48
All three municipalities together	3.77

3.4.1 Future trends

Kolega (2006) analyzed flooding risk assuming that medium sea level will be 0.5 m higher than the present value by the end of the 21th century, according to the estimates provided by Plut (1998) (Fig. 9). They concluded that, under this scenario, floods would occur very frequently, appearing even several times a month and submerging the lowest parts of the coast. Moreover, average flood height would be rather high, reaching the level of today's extreme floods (i.e. 359 cm). In the case of 50 cm sea-level rise, the territory inundated by yearly floods would be comparable to the territory flooded today by extreme floods. The largest flooded areas would be in the region of Koper's and Ankaran's Bonifika. Other wide inundated areas would be also in Izola, Strunjan, Piran, Lucija and Sečovlje territories; these extreme events could cause serious difficulties to both the Port of Koper and the Airport of Portorož. Owing to the quite high density of buildings and population living on coastal areas and the development of tourism and other economic activities, flooding will surely represent a serious threat and a number of inhabitants will be in danger.

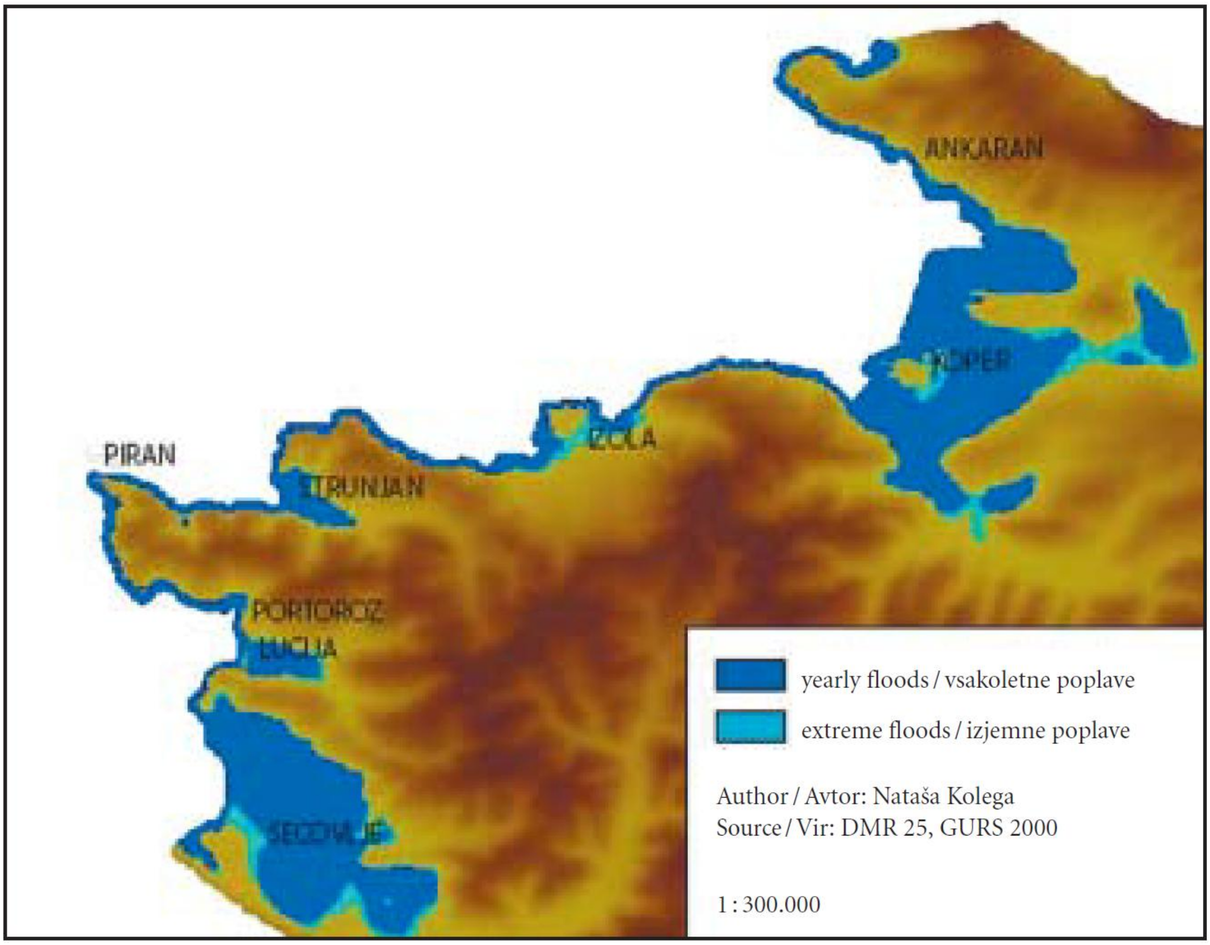


Figure 9: Map of flooding area due to a 50 cm rise of sea level because of global warming (from Kolega, 2006).

3.5 Croatia

The length of the Croatian coast is 6,278 km (about 70% belonging to its islands). Croatia has 1246 islands (79 islands, 525 islets, 642 rocks and reefs); they include almost all those located on the east and central coast of the Adriatic Sea, making them the second largest archipelago in the Mediterranean (Zavod za prostorno uređenje istarske županije, 2013). Most of the islands are uninhabited. Generally, the coastal strip is very narrow (few km wide) and is separated from the hinterland by chains of mountains, the slopes of which often correspond to the shoreline. Only two large coastal plains, the western part of the Istrian coast and the northern Dalmatia coast, lie between the towns of Zadar and Sibenik.

The coast is steep and indented and mainly composed of carbonate rocks (Duplančić Leder et al., 2000). Flysch occurs as a coastal bedrock only on the Rab Island, in the Split-Ploče zone and, locally, in other small coastal areas (Pikelj et al., 2013). Owing to its lithological characteristics, flysch is generally subjected to erosion, also favoured by marine abrasion and anthropogenic impacts. In particular, road construction and the rapid development of littoral urbanization and tourism in narrow coastal zones characterized by flyschioid formations have led to increasingly frequency of rockfalls that have endangered roads and beaches (Pikelj et al., 2013).

Gravel pocket beaches are also present and often serve as ports and recreational centres (Pikelj et al., 2013); they are threatened not only by sea-level rise and by increased storminess, but also by the unplanned anthropogenic structures, which have changed beach sediment equilibrium.

Croatia has seven coastal counties inhabited by 33% of total state population, with a population density of 57 inhabitant/km^2. They are characterized by urban settlements, industries, tourism structures, big harbours, and marinas. According to data collected since 2000, cities and other urbanised areas occupy about 850 km, corresponding to 15% of the total coastline (Zavod za prostorno uređenje istarske županije, 2013). The coastal stretch of the Istria Region is more densely populated (116 inhabitants/km^2). It can be subdivided in two main portions: the western and southern parts characterised by a dense urbanisation and the eastern sector in which urban settlements alternates with extended natural or semi-natural areas. Erosion is not a specific threat for Istria County because most of its eastern and western coasts are rocky (limestone); however, these areas could be highly vulnerable to erosion and natural hazards, as cliffs could be undergone detachments and mudslides (Zavod za prostorno uređenje istarske županije, 2013).

In Croatia, tourism has a long tradition and is mainly focused on the coast. It has been changed especially in the last 15-20 years, producing an increase of the related activities (traffic, urbanization, agriculture and commerce) (Pikelj et al., 2013). The consequent human impacts, in addition to hydrotechnical interventions along the rivers, coastal defences and harbours, have led to a modification of sediment supply and its distribution along the littorals, preventing the natural beach nourishment and favouring erosion (Pikelj et al., 2013 and references therein).

On the other hand, climate change may threaten tourism as it can induce environmental modifications exerting influence on the choice of tourist destinations and limit recreation opportunities (e.g., beaches can be eroded, cultural sites and natural protected areas can be submerged or damaged, urban settlements can undergo inundation) (Landau et al., 2009).

Croatian coast may also be vulnerable to increasing frequency and/or intensity of extreme events, such as storms, possibly responsible for a growing risk of flooding, in particular coastal flash floods. Sea-level rise could seriously affect low-lying coastal stretches, which are relatively scarce and mainly located in the country's northern regions (Republic of Croatia, Ministry of Environmental Protection, Physical Planning and Construction, 2006).

Until now, along the Croatian littorals different trends in sea-level rise have been observed; they are probably the result of differential local uplift and subsidence of the coast. Analysis of data collected between 1956 and 1991 from tide gauge stations has provided the following results (Barić et al., 2008): at Rovinj, sea level is falling with respect to the land at a rate of -0.50 mm/y; at Bakar, a relative rise is occurring (+0.53 mm/y); at Split, relative sea level is dropping at -0.82 mm/y and in the Dubrovnik area, relative sea level is rising by about +0.96 mm/y. Short term sea-level fluctuations can be related to climate variability over Europe, whereas longer term changes can be related to differential local tectonic movement.

3.5.1 Future trends

The impacts produced by different values of sea-level rise on Croatian coastal territories that could be inundated by sea water or could be at risk of flooding was analysed by various authors (Baric et al., 2008; Zavod za prostorno uređenje istarske županije, 2013).

Baric et al. (2008) identified the following Croatian coastal zones as possibly vulnerable to a sea-level increase:

- cities: Nin, Zadar, area of Šibenik, Split, Stari Grad on the island of Hvar, Dubrovnik;
- rivers: Raša, Cetina, Krka, Zrmanja, Neretva;
- lakes: Vransko jezero on the island of Cres, Vransko jezero near Biograd;
- western Istria coast;
- the island of Krapanj.

The joint analysis of data from Baric et al. (2008) and Landau et al. (2009) allowed obtaining the results shown in Table 11.

A sea-level rise of 20 cm would not have significant consequences on the coastal zone in terms of inundation and surge flooding (Barić et al., 2008); however, individual areas, such as the towns of Rovinj, Pula, and Split that currently suffer from surge flooding, would continue to be at risk. The effects on coastal erosion and existing pocket beaches is expected to be negligible because the majority of the pocket beaches are composed of relatively steep sand and gravel deposits and therefore are resistant to erosion along with most of coastline. At present, only two sites on the Croatian coast have noticeable coastal erosion problems that could be exacerbated by a sea-level increase of 20 cm: the island of Susak and an area of Nin town.

Table 11: Areas likely vulnerable to sea-level rise on the Croatian coast (from Landau et al., 2009).

West Istrian coast	Raša River
Vrana Lake on the Island of Cres (the freshwater reservoir)	Zrmanja River
Town of Nin	City of Zadar
Vrana Lake Nature Park near Biograd	The small but densely inhabited island of Krapanj
City of Split	Cetina River
Neretva River	City of Dubrovnik
City of Stari Grad on Hvar	River Krka
Areas around Šibenik	

A sea-level rise of 86 cm would have much more pronounced effects on the above mentioned areas, primarily because of the increasing risk of inundation and surge flooding (Baric et al., 2008). On the other hand, inhabited low-lying zones (in particular, the entire Istrian West Coast and the territories of the towns of Zadar, Omis, and Dubrovnik) could experience moderate effects in terms of inundation and surge flooding. For example, the detailed study for the islands of Cres/Losinj showed that a sea-level rise of 1 m would inundate or endanger approximately 13% of the current island population of 11,796 persons (Randic et al., 1996).

An 86-cm sea-level rise scenario would also have serious effects on marinas, shelters for small boats, harbours, beaches, and infrastructure in low-lying area. For example, the small-inhabited island of Krapanj would be almost totally inundated because its altitude is approximately 1 m above sea level (Baric et al., 2008). Historical town centres, such as Split, Pula, Rovinj, and Trogir, would also be at risk from inundation and surge floods. Moreover, sea-level rise would cause inundation of low-lying coastal agricultural areas, such those located in the Neretva River Delta, where significant production losses could occur because of flooding and the salinization of the remaining land (Fig. 10) (Landau et al., 2009).

According to other studies, a sea-level rise of 50 cm could be responsible for the flooding of more than 100 km^2 of the mainland, whereas in the case of 88 cm sea level rise additional 12.4 km^2 would be submerged (Fig 11) (Landau et al., 2009; Zavod za prostorno uređenje istarske županije, 2013). However, the methodology used to obtain these estimates has several limitations, especially the used elevation model that has a horizontal resolution of 25 m (Landau et al., 2009). Nevertheless, these studies are still helpful for identifying the potential threatened coastal areas and related economic damage.

Figure 10: Flood-affected area of the Neretva River Delta resulting from a 0.50 m (light grey) and 0.88 m (dark grey) sea-level rise (source: OIKON d.o.o. in Landau et al., 2009).

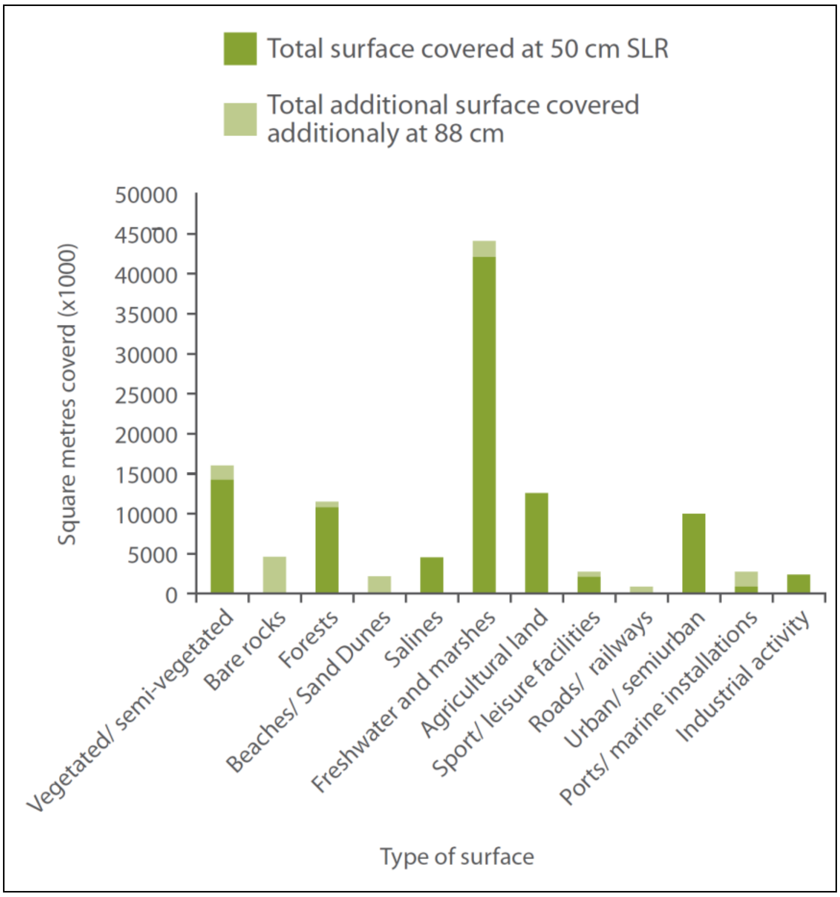


Figure 11: Types of land which would be covered by 50 cm of sea-level rise and the additional amount covered by 88 cm (from Landau et al., 2009).

In general, significant increase of sea-level rise rates and intensity/frequency of storm surges could endanger commercial and fishing ports (despite the presence of sea-walls, the ports could still be affected during storms by high waves generated by “jugo” winds and extreme sea-water levels, making them vulnerable to flooding), contaminate coastal freshwater sources (salt-water intrusion) in karstic zone, interfere with touristic and recreational activities and damage wetlands and swamps (such as the recently proclaimed Croatian Nature Park ‘Vrana Lake’, which could be threatened and potentially destroyed with a sea-level rise of 0.5 m) (Landau et al., 2009; Zavod za prostorno uređenje istarske županije, 2013).

3.6 Montenegro

In terms of coastal landforms, Montenegro shows a great variability, ranging from sandy littorals to rocky coasts, mainly characterized by steep limestone mountains rising from the sea level to an elevation of ca. 800 m above sea level and corresponding to a ria coast (Frankl et al., 2016). Among the cliffs along the coastline, there are pocket beaches made of sand to pebble sediments; twenty of them have been declared protected areas (RAC/SPA, IUCN-Med, 2014). In addition, rocky shores have been adapted as well as artificially beaches have been created; they are built of concrete or are artificially nourished with pebbles.

The coastal region is the most developed and most inhabited part of Montenegro and is recognized by its natural attractions and cultural heritages (Javno Preduzeće za upravljanje Morskim Dobrom, 2013). As such, it is of special importance for the development of tourism and considered attractive for living; for this reason, a continuous migrations from the country toward the coast is occurring. Montenegro is particularly exposed to pressures of littoralization, as it is a country with a short coastline length (UNEP/MAP/ Blue Plan, 2005). Consequently, the numerous settlements are built almost continuously along the bay coastline in addition to different artificial capes, docks and man-made concrete bathing areas (Javno Preduzeće za upravljanje Morskim Dobrom, 2013).

Recently, erosion has been noticed on several beaches, such as Mogren, Petrovac, and Przno in Budva, Sutomore in Bar municipality and Ada Bojana beach in Ulcinj, where erosion is caused by uneven and uncontrolled discharge of the Bojana river (Javno Preduzeće za upravljanje Morskim Dobrom, 2013). These changes started with the rapid littoralization of the coast, which caused the reduction of the beach width and, consequently, of the area for wave energy dissipation. On the landward side, urbanization cut off the flow of the streams that brought sediments to the beaches. Apart from the beaches, the rest of the coast is made of the stabile rocky cliffs that are not prone to erosion (Javno Preduzeće za upravljanje Morskim Dobrom, 2013).

In the rocky coastal areas of Montenegro, abundant rainfall can cause large flash floods, which may favour the abundant production of sediments that "feed" the beaches. Flash flood can also put property and lives in serious danger.

The coastal area of Montenegro is in the zone of strong northeastern wind (bora) that can reach the speed of a gale or even hurricane (Javno Preduzeće za upravljanje Morskim Dobrom, 2013).

Due to land characteristics (karst area), notwithstanding the fact that this area has the European maximum rainfall, floods are not a frequent phenomenon in the coastal zones.

3.6.1 Future trends

The coastal area of Montenegro, as it is a part of Eastern Adriatic, is exposed to risks deriving from natural disasters, such as earthquakes and floods, which could be exacerbated by climate change.

According to the National Strategy for Emergency situation, in Montenegro climate will be responsible for heavy rains that may result in floods, winter storms, extreme cold and heat, drought, dense fog and phenomena related to storm clouds (Javno Preduzeće za upravljanje Morskim Dobrom, 2013). A projected sea-level rise of about 35 cm by 2100 (scenario A2) would provoke serious impacts and would significantly increase coastal flood probability as well as the expansion of the inundation zones, with the consequent reduction of the beach area (and even disappearance of some beaches) and problems in the functioning of coastal infrastructure, such as ports and marinas (Ministry for Spatial Planning and Environment, Montenegro, 2010; Javno Preduzeće za upravljanje Morskim Dobrom, 2013). Damage would initially occur in the lower parts of the sandy beaches, lagoons and coastal terrain, such as in Tivat Salina, in the wetland area of the Bay of Buljarica, and in the area Velika Plaža-Knete-Ada Bojana (Ministry for Spatial Planning and Environment, Montenegro, 2010).

The timing and extent of sea-level rise will also have potentially important impacts on tourism opportunities along the coast. They includes not only effects on beach recreation activities and coastal fishing, but also on activities related to non-consumptive tourist use of the environment through costal bird watching and hiking (Callaway et al., 2010).

3.7 Albania

According to the 1995 Albania Coastal Zone Management Plan, the Albanian coastline can be divided approximately into three zones (Environmental Center for Administration &

Technology - ECAT – Tirana, 2012). The northern stretch, 54 km long, is characterized by the presence of four river mouths, deltas, and coastal wetlands; these low-lying coastal landscapes are strongly related to the large sediment load presently discharged by the rivers into the sea (Simeoni et al., 1997; Brew, 2003). This stretch has a potential mostly for ecotourism rather than mass tourism and for improved fisheries resource management. The central belt, 207 km long, displays many sandy beaches; thus, it has a greater potential for large-scale tourism and recreation. The southern stretch, with a coastline of 168 km, is characterized by steep wetlands hugging the shore(except for Butrint in the south), spectacular cliffs and grottos and potential for “high-end” tourism combined with the protection of the unique scenery and cultural heritage of the area; there is also the possibility for the development of marine tourism. Industrialized areas are also present.

The economic importance of the coast is growing, leading to an increase of urbanization and tourism. This development is producing anthropogenic, often irreversible, modifications. In particular, after 1990 the tourism infrastructures have developed very fast (especially on the littorals of Velipoja and Shëngjin, which represent the two main centres of beach tourism in the region), without considering the impact of climatic changes (e.g., floods, storms, coastal erosion, persistent dryness) (Islami et al., 2009). Consequently, the road infrastructure, water and electric energy supply and canalizations have been frequently damaged, especially due to marine floods produced by intense storms and tides).

According to Frasheri et al. (2011), the northern and central coastal stretches of Albania are characterized by accumulative and erosive segments (the formers prevailing over the latters), whereas the southern shoreline by erosion, contrary to what occurred until the 1990s (Simeoni et al., 1997). Hills close to the coast may be affected by landslides, both due to natural and anthropogenic processes (Hoxha et al., 2014).

At present, significant impacts on the coasts are due to waves up to 175 cm high, produced by strong winds (especially the southern winds, which have high speed and long duration) blowing from sea to land (Islami et al., 2002).

3.7.1 Future trends

At present, the ongoing climate change is making its adverse impact on erosion and hydrodynamic processes (Frasheri et al., 2011).

Sea-level rise will cause several direct impacts, including inundation and displacement of wetlands and lowlands, loss of currently emerged zones, enlargement of the lagoons, coastal erosion, increased salinity in estuaries and coastal aquifers, and rising coastal water tables

(Islami et al., 2009; Kurt & Dinçer, 2012). For example, in the coming 50–100 years, seriously threatened coastal zones could be the National parks of Kune-Vain (Lezha District) and Velipoja (Shkodra District), located along the Drin and Buna river deltas, between 0.8 to 2 m and 0–1.2 m above sea level, respectively (Islami et al., 2009). The beaches located in areas affected by land subsidence (e.g., Shëngjin, Kune-Vain, Tale, Patok, Ishëm) and many fields drained in the late 1950's and early 1960's will be swept over by floods. Likewise, these floods will find their way into important segments of the local and national roads (including a part of the new road Fushë Krujë-Lezhë running through the former Lac swamp land), will increase aquifer salinization and damage many lodging and tourism structures that have been, and continue to be built, along these beaches (Islami et al., 2002). As a result, this process could adversely affect social and economic life without a correct and proper land-use planning.

As regards salinization, the predicted sea-level rise of 20-24 cm by 2050 is not expected to have significant impact on ground water, whereas the sea-level rise of 48-61 cm expected by 2100 could cause the increase in the salinity of aquifers (Islami et al., 2002).

Other effects of climate change will be the increased frequency of extreme events (heavy rains, strong winds, droughts, flooding), which will cause adverse impacts on settlements and tourism.

3.8 Greece

The Greek coast has a total length of about 16,500 km, being one of the longest in the European countries. The half of it belongs to the 3,000 islands (or 9,800 if islets are included) (Kontogianni et al., 2012). Greece is frequently affected by coastal floods events (Fig. 12; Fig. 13) (Papathoma & Dominey-Howes, 2003; Papathoma et al., 2003) and is highly vulnerable to erosion, in particular the stretches characterized by the presence of beaches and low-lying coastal (including deltaic) plains owing to their morphological features (Alexandrakis et al., 2010). Results from the EUROSION Project (2002-2004) showed that more than fifteen years ago 28% of the Greek coastal area was under retreat and, more specifically, 6.1% in Thrace and East Macedonia, 10.3% in Central Macedonia, 2.3% in Thessaly, 14.7% in the North Aegean Islands, 10.8% in Attica, 25.9% in the Cyclades and the Dodecanese islands, 3.8% in Peloponnesus and 6.1% in the northern littorals of Crete (Alexandrakis et al., 2010).

In Greece, the major responsible for increasing erosion are the anthropogenic interventions, the strong winds and the storm surges in the Aegean Sea as well as the geomorphological and sedimentological characteristics of the coast (Papanikolaou et al., 2010). Thus, erosion can range from very high (several mm/year) in the case of low-lying land to low (approximately mm/year) in the case of hard coastal limestone formations (e.g. cliffs) (Kontogianni et al., 2012).

In general, the pressures that modify the natural sediment balance and erosion trends along the entire Greek coast mainly derive from the increasing of urbanization (the largest urban centres are located in the coastal zones) and tourism, the development of activities related to agriculture, aquaculture, fisheries and sea transportation (with construction of harbours and marines), the building of coastal defence structures and the damming of rivers (Fig. 14) (Kontogianni et al., 2012; Alterman et al., 2013).

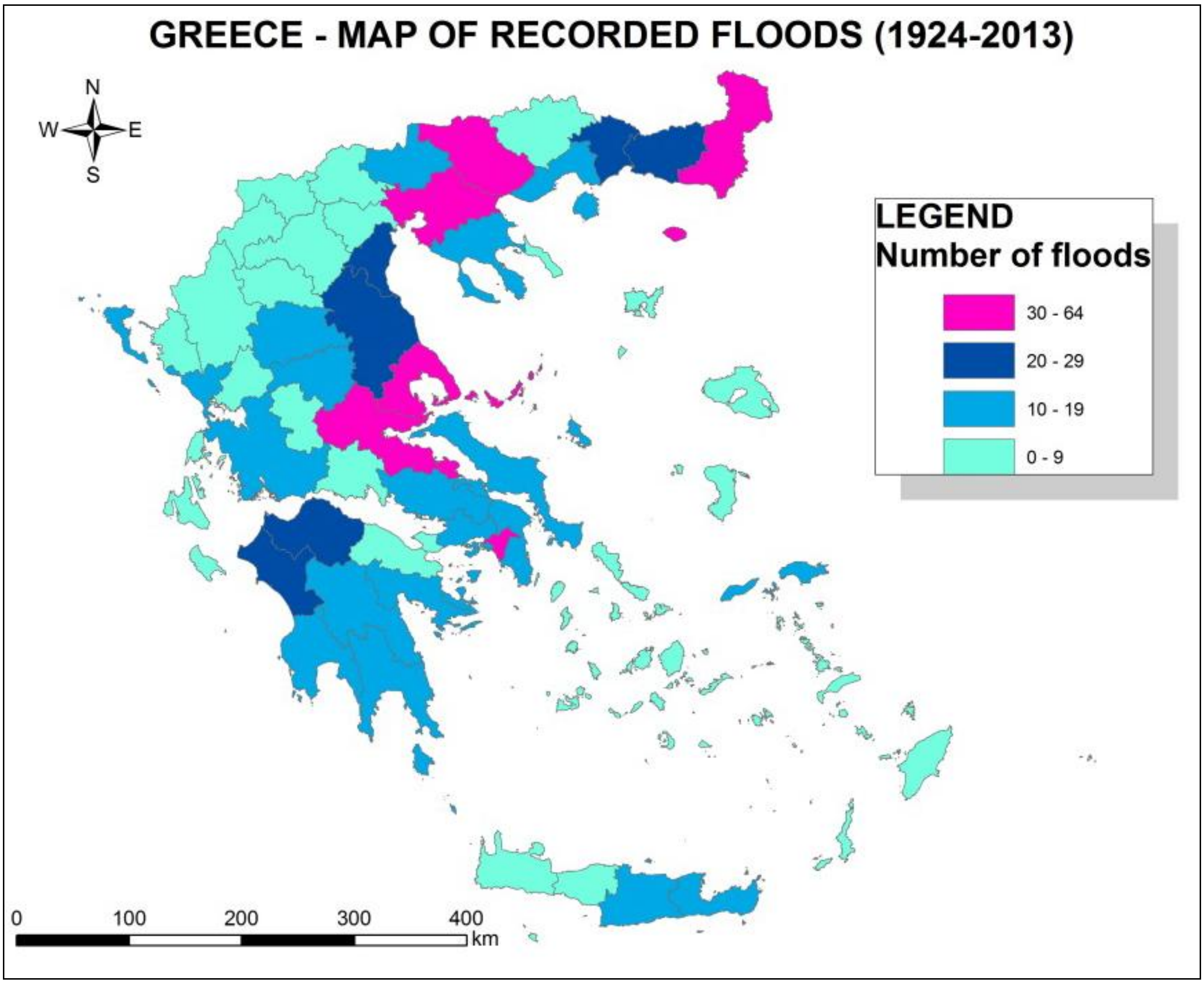


Figure 12: Flood map of Greece (from Nikolaidou et al., 2014).

On the Greek coast, the population density is more than double than the national average. In particular, about 33% of the Greek population inhabits coastal areas located at 1-2 km distance from the littoral and 85% of the total lives within 50 km from the shore (Kontogianni et al., 2012). Moreover, there is a constant increase in tourism, accommodated in construction that tends to be uncontrolled (Lalenis, 2014). Therefore, the knowledge of coast evolutionary trends and the realization of integrated coastal zone management schemes, incorporating the potential impact of a future and accelerating sea-level rise, are of great importance for Greece (Alexandrakis et al., 2010).

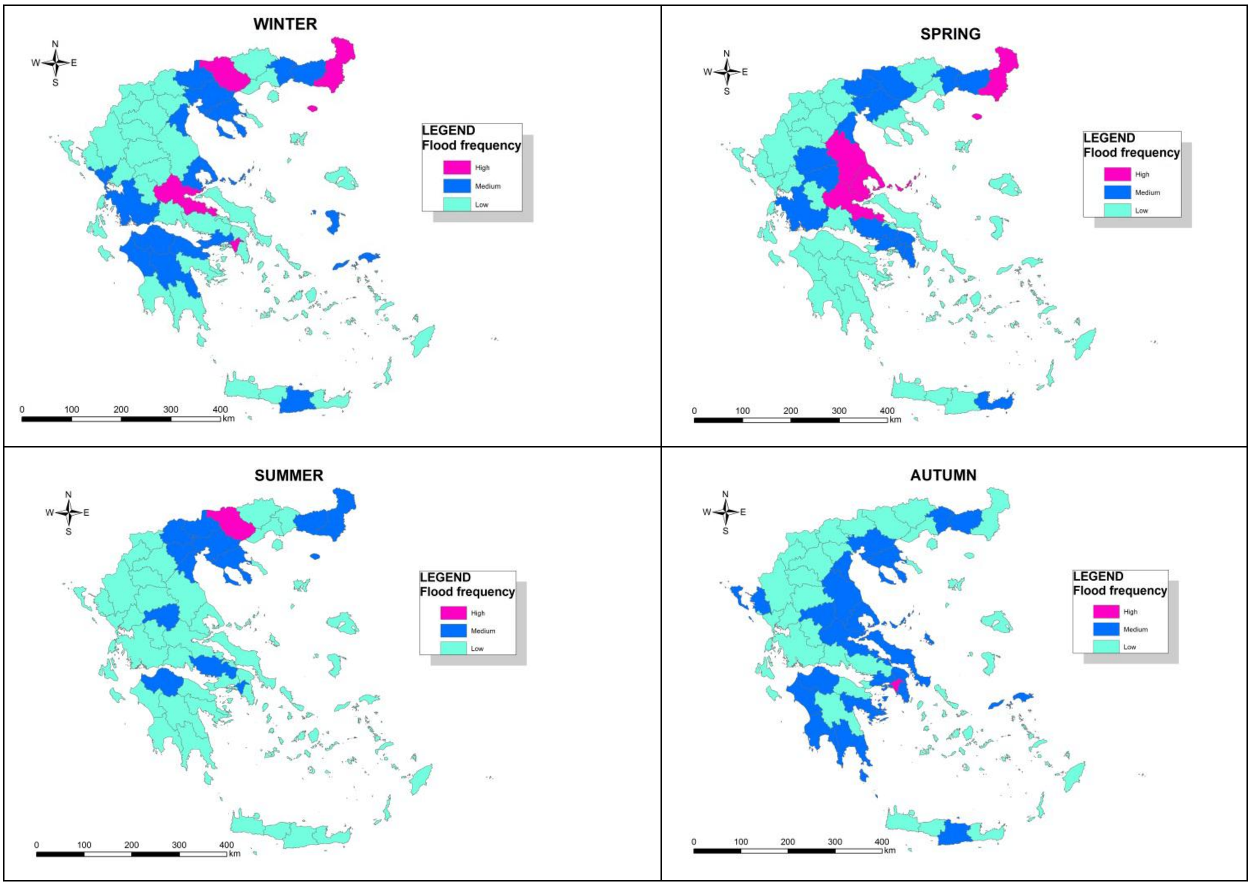


Figure 13: Seasonal flood frequency map of Greece (1924-2013) (from Nikolaidou et al., 2014).

The coast of the Region of Eastern Macedonia and Thrace (REMTH) can be considered as an example of urbanized littoral subjected to erosion. It is mainly low and flat (around 85%) with sandy beaches, but there are also low rocky shores and cliffs (around the cape Maronia) with accumulations of gravel and pebbles (Regione Emilia-Romagna - Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010). The shoreline is affected by a general retreat, whereas accretion is restricted to local areas. Erosion is mostly the consequence of a significant reduction (about 74%) of sediment supply due to anthropogenic interventions (e.g., the building of dams in rivers and the construction of ports, which intercept the sediment transport along the shore, such as in the Alexandroupolis zone and the Kariani beach, two sites that undergo intense coastal erosion due to the presence of harbours that impede longshore sediment transport). However, along some stretches, erosion is only due to natural processes, for example close to the cape of Nea Makri, where erosion (independent from anthropogenic or climatic interferences) occurs owing to the high wave energy potential and is responsible for the retreat of the 2-20 m high coastal cliffs (0.5 m/year) (Regione Emilia-Romagna - Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010).

In REMTH, touristic and recreational activities, promoted within a regional plan aimed at tourism development, are increasing and consequently the socio-economic pressure for coastal protection from erosion is gradually rising (Regione Emilia-Romagna - Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010).

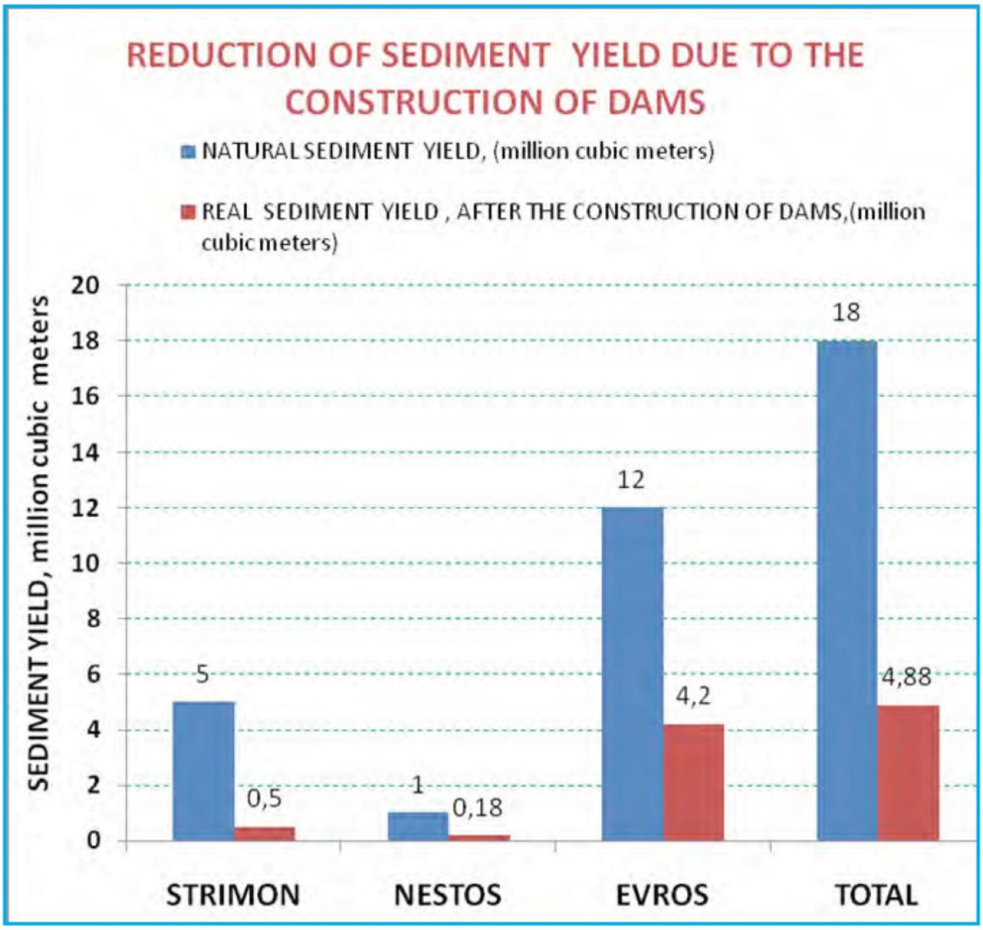


Figure 14: Reduction of sediment yield due to the construction of dams (Regione Emilia-Romagna - Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010).

Erosion can also increase due to storm waves. Wave data collected southwest of the Athos peninsula in the period 2000-2006 and from a station located in the area of Nestos river delta (North Aegean) between 1995 and 2004 allowed detecting frequency and intensity of storms in this region (Fig. 15; Fig. 16) (Regione Emilia-Romagna - Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010). Data were classified according to Mendoza and

Jimenez (2006); thus, five categories representing storms (defined as events exceeding a minimum significant wave height of 2.0 m and a minimum duration of 6 hours) characterized by increasing intensity, wave height and energy content were identified. In particular, storms belonging to the category "I" appear to be the most frequent in both areas (53.9% and 60%, respectively).

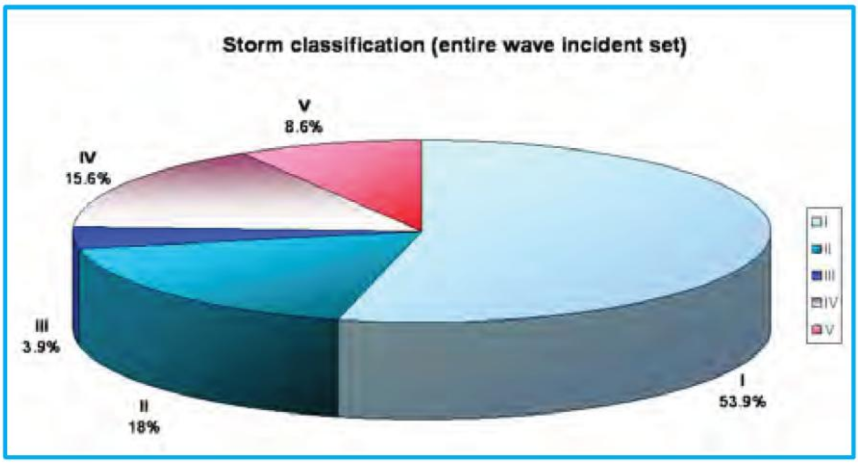


Figure 15: Storm classification for the entire wave incident set southwest of the Athos peninsula (Regione Emilia-Romagna - Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010).

As Greece is a tectonically active country, storms may be also caused by tsunamis. So, tsunami risk is high and the related consequences may be particularly severe because of the short distances between the tsunamigenic sources and the nearest exposed coasts (Anzidei et al., 2014).

In Greece, tectonics plays an important role also because a rise in sea level can be offset or amplified by uplift or subsidence, respectively (Hellenic Republic - Ministry of Environment, Energy and Climate Change, 2014). In particular, sea-level rise is counteracted in areas characterized by uplift, such as the coastal zones of the northern Peloponnese (uplift rate: 0.3-1.5 mm/year), Crete (uplift rate: 0.7-4 mm/year) and Rhodes (uplift rate: 1.2-1.9 mm/year) (Kontogianni et al., 2012).

On "Development Strategy Guidelines on Areas of Political Responsibility of Ministry of Environment, Energy and Climate Change," it is noted that Greece's 16.500 km of coastline subside up to 28.6% (Alterman et al., 2013). However, over the last decades, several regions in Greece have experienced land subsidence mainly due to aquifers overexploitation (Raspini et al., 2016, and references therein). One of the main subsiding zones is the Thessaloniki plain. The process is mainly due to ground water extraction for both urban and industrial purposes, started about sixty years ago. The greatest subsidence occurred in the southeastern zone of Kalohori, where a subsidence speed of 2.8 - 5 cm/year was detected (Doukas et al., 2004; Psimoulis et al., 2007). As some southern parts of this area lying below the mean sea level were frequently subjected to flooding, an embankment was built in 1968 and then improved until 2000 (Doukas et al., 2004). In the coastal zones where subsidence increased the nearshore water depths, an intensification of wave activity occurred; high-energy waves destroyed the defence barriers that protected the delta and catastrophic floods have taken place several times (Raucoules et al., 2008).

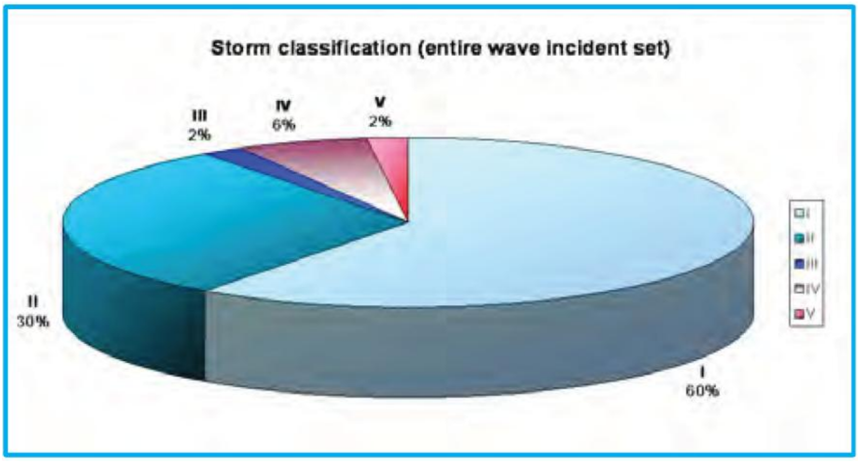


Figure 16: Storm classification for the entire wave incident set in the area of river Nestos (Regione Emilia-Romagna - Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010).

Another process that affects Greek coastal areas is salt-water intrusion. It has been estimated that the total surface area of aquifers impacted by seawater intrusion is about 1,500 km^2 (Daskalaki & Voudouris, 2008).

3.8.1 Future trends

Erosion is expected to increase in the future due to sea-level rise, the intensification of extreme wave phenomena and the further reduction of the river sediment supply due to changes in rainfall and construction of river management works (Velegrakis, 2010 in Kontogianni et al., 2012).

A reliable assessment of the potential risk associated with increasing sea level should take into account not only the trends and rates of the eustatic component, but also local factors such as tectonic vertical movements (which can locally counteract, increase or decrease the rates of sea-level rise), sediment supply and compaction, and storm surges (Poulos & Collins, 2002; Vött, 2007; Kontogianni et al., 2012).

Examples of areas characterized by high vulnerability to sea-level rise are Evinos in Messolonghi, Kalama in Igoumenitsa, Acheloos, Mornos at the Corinthian Gulf, Pineios, Alfeios, Aliakmonas and Axios at the Thermaic Gulf, the area of North Aegean near

Platamona, Amphipolis, Strymon, Nestos (to Abdyra), the Ebros, and the deltaic areas in Malliakos, Amvrakikos, Messiniakos and Argolikos Gulfs; on the other hand, vulnerability of rocky and high altitude coastal regions is low (Fig. 17) (Kontogianni et al., 2012).

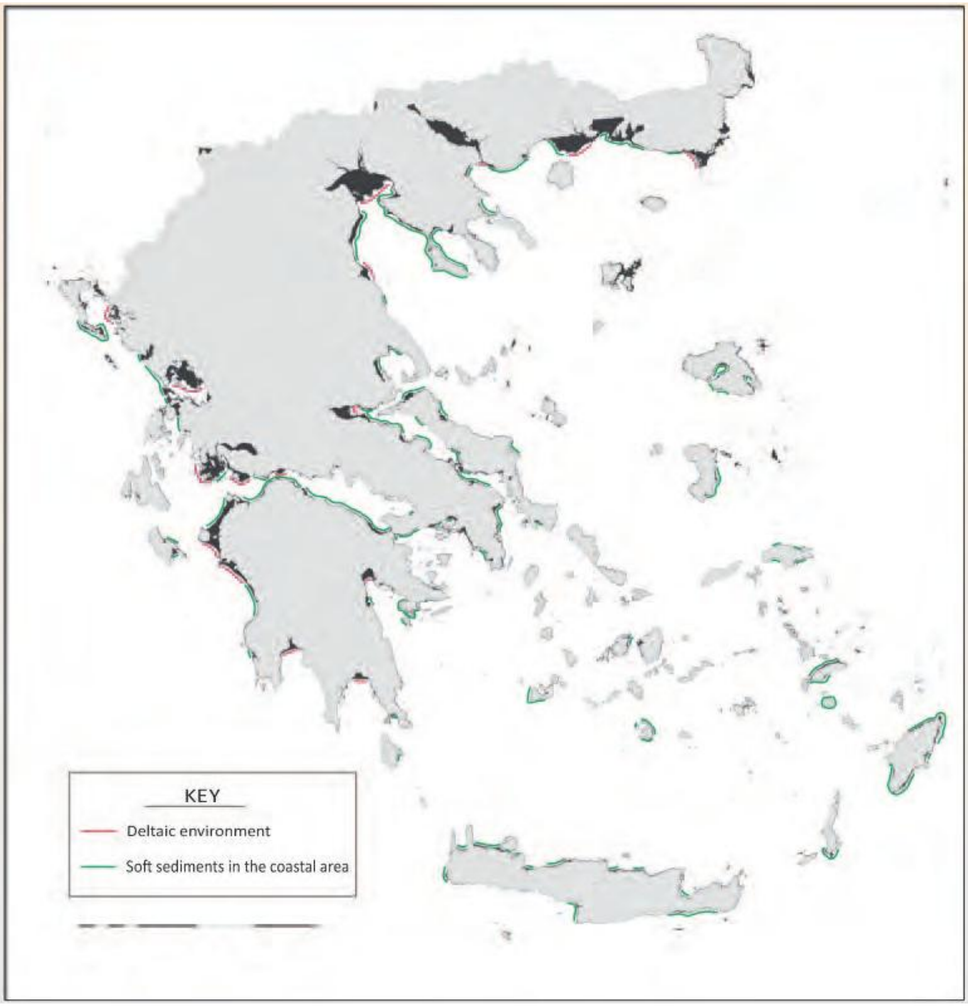


Figure 17: Greek coastal areas characterized by medium (green colour) and high (red colour) vulnerability to sea-level rise. Black colour indicates areas with altitudes below 20 m, usually of loose sedimentary deposits (Climate Change Impacts Study Committee, 2011).

Table 12 shows approximate values of flooded coastal areas and shoreline retreat (excluding the tectonics and geodynamics corrections) triggered by a possible SLR equal to 0.5 m and 1 m in high risk areas; they were calculated on the basis of studies reviewed until September 2010 (Kontogianni et al., 2012). A hypothetical increase of SLR equal to 0.5 m could be responsible for a coastal land retreat ranging from 15 m to 2,750 m, whereas an increase equal to 1 m could produce retreats from 400 m to 6,500 m. According to a projection based on 0.5 m sea-level rise by 2100, 15% of the total coastal wetlands in Greece could be submerged by flooding (Climate Change Impacts Study Committee, 2011).

In addition, the foreseen increase of frequency and energy of storms could be responsible for higher erosion rates and more extended flooding.

Table 12: Shoreline retreat and inundated area for potential sea-level rise of 0.5 m and 1 m (Kontogianni et al., 2012).

Coastal area	SLR (m)	Inundated area (10^3 m²)	Length/Area of shoreline	Source
Skala Eressos Mytilene	0.3	28	2.5 km	Doukakis, 2008
Gulf of Nafplio	0.5	4,200	25 km	Doukakis, 2005a
	1	8,700		
Lagoon Kotichiou	0.5	720	27.6 km	Doukakis, 2003
	1	1,760		
Hersonissos Crete	0.5	4,700	20 km	Doukakis, 2004
	1	5,200		
Aigio Achaias	0.5	1,070	6.8 km	Doukakis, 2005b
	1	1,800		
Lambi Kos	0.5	35	0.25 km	Papadopoulou & Doukakis, 2003
	1	52		
Kardamaina Kos	0.5	19	0.615 km	
	1	33		
Tigaki Kos	0.5	161	2.7 km	
	1	322		
Afantou Rhodes	0.5	375	3 km	
	1	439		
Vartholomio Ileias	0.5	190	2.65 km	
	1	300		
Acheloos River Delta	1	72	5.8 km	Doukakis, 2007
Plain of Thessaloniki	1	37,100	41.2 km	Kanelakis & Doukakis, 2004; Doukakis, 2007
Abdyra Macedonia	1	716	7 km	Doukakis, 2007
Lake Alyki Limnos	1	2,041	4.3 km	Pliakos & Doukakis, 2004; Doukakis, 2007
Saltmarsh Kitrous Pierias	0.5	9,450	-	Stergiou & Doukakis, 2003
	1	11,800		
Porto Heli	0.5	36	38.93 km	Seni & Karibalis, 2007
	1	161		
Ermioni	0.5	19	19.903 km	
	1	278		
Evinos River Delta	0.5	12,500	92 km2	Karibalis & Gaki-Papanastasiou, 2008
	1	21,300		
Mornos River Delta	0.5	2,580	28 km2	
	1	3,710		
Kalama River Delta	0.5	7,020	78 km2	
	1	10,060		
Penaeus River Delta	0.5	6,530	69 km2	
	1	14,780		
Alfeios River Delta (northern part)	0.5	224	110 km2	Poulos et al., 2009
	1	683		
Alfeios River Delta (southern part)	0.5	35		
	1	344		
Axios River Delta	0.5	10,825	390 km2	
	1	28,482		
Aliakmonas River Delta	0.5	4,875	120 km2	
	1	8,950		
Loudias-Aliakmonas Deltaic plain	0.5	8,900		
	1	25,575		
South Euboean Gulf	0.5	7,890	18.5 km	Roussos & Karibalis, 2009
	1	12,620		

3.9 Cyprus

Cyprus is an island country, the third largest island in the Mediterranean Sea, after Sicily and Sardinia, both in terms of area and population (Department of Environment Ministry of Agriculture, Natural Resources and Environment, 2013).

The Troodos Mountains cover most of the southern and western portions of the island, whereas the Kyrenia Mountains extend along the northern coastline; the Kyrenia range has lower elevation and occupies a more restricted area.

The coastal zone, defined as 2 km inland from the coastline, represents 23% of the country's total area (Zachariadis, 2016). It is characterized by rich wildlife and marine and shore areas of high ecological and scientific value (Department of Environment, Ministry of Agriculture, Natural Resources and Environment, 2010). 10 km coastal zone below 5 m elevation is less than 5% of the Cyprus shore.

The coastline displays a great variety of morphological features, from steep inaccessible cliffs and ragged rocky shorelines with sea caves to gentle sloping sandy beaches fringed with sand dunes (Demetropoulos, 2002; CYPADAPT, 2013). Beach materials vary from loose sand and gravel to cemented sandstone and rock formations; the former type of littoral, composed of "soft" materials, is usually narrow and erodible (Loizidou, 2000). According to its substrate, the shoreline is rocky, mainly with pebble and gravels beaches (54%) originated either from nearby rocks or from the inland bedrock. Sandy beaches and many small coves are also present (46%). Sandy beaches are predominant in the large bays of Cyprus, Famagusta, Larnaca, Limassol, Polis Chrysochou and Morphou (CYPADAPT, 2013). Sand dunes, salt flats, salt lakes, salt marshes, as well as freshwater marshes, occur in the Cyprus coastal belt although they are limited to few areas (Department of Environment, Ministry of Agriculture, Natural Resources and Environment, 2010).

In particular, about 30% of the Cyprus coastline is currently subjected to increasing erosion (Triton Consultants (Cyprus) Ltd, 2002), enhanced both by urbanization and pressure of tourism, which is the major economic activity (90% of the tourist industry is concentrated in coastal areas). In Cyprus, sand and gravel mining was permitted in coastal areas and riverbeds until the early 1970's, when it was prohibited by the law (Regione Emilia-Romagna, Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010). Estimations based on the data from the Mines Service of Cyprus allow assessing at 300,000 m^3 the sediment taken within the period from 1955-1970. Mining, cutting off the sediment transport by damming the rivers, decreasing the sediment transport efficiency by lowering water discharges due to decreased water availability, alteration of the usual pattern of coastal currents and the associated sediment transport due to man-made coastal structures, urban development too close to the shoreline, and land subsidence are the most important responsible for beach erosion (Özhan, 2002).

In the low-lying region of Larnaca, located in the south coast of the island, erosion (mostly due to human activities) constitutes a greater threat than flooding (Department of Environment Ministry of Agriculture, Natural Resources and Environment, 2013). This area represents the most vulnerable territory of Cyprus. Moreover, erosion also occurs along the coastal stretch that extends west of Larnaca (Regione Emilia-Romagna, Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2011). Thus, owing to the increasing development of tourism, littorals need annual nourishment to be preserved. In addition, many stretches of the southern coastline are exposed to more severe wave conditions (Regione Emilia-Romagna, Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010).

At present, the majority of coastal aquifers suffer of salt-water intrusion due to over-pumping. Cyprus is severely over-stressing groundwater resources since it is exploiting groundwater beyond what has been set as the ecological limit (Shoukri & Zachariadis, 2012).

3.9.1 Future trends

Even if in the coming years the coastal zone of Cyprus is not expected to become very vulnerable to sea flooding, in view of the foreseen climate change low-lying areas could become significantly prone to sea-level rise impacts (Fig. 18) and could be threatened by inundation risk and greater exposure to storms (Tab. 13) (Department of Environment Ministry of Agriculture, Natural Resources and Environment, 2013). On the contrary, on the basis of other studies, it is expected that the future exposure of touristic coastal zones to storm surges is limited (CYPADAPT, 2013). In any case, the coasts mostly exposed to large waves are those located on the western part of the island (Demetropoulos, 2002).

In certain areas, ground level is closed to the mean sea level and a future sea-level rise could cause submersion (Regione Emilia-Romagna, Direzione Generale Ambiente e Difesa del Suolo e della Costa, 2010). The most vulnerable zones are the low-lying area of Larnaca and the adjacent salt lake, the Akrotiri peninsula wetland, the Akamas Coastal/Marine protected area and especially the Lara/Toxeftra Turtle Reserve, Cape Greko marine caves, and Poli Chrysochous coastline (Republic of Cyprus 2006; Parari, 2009). Moreover, some of the most important infrastructures of Cyprus are located in low lying coastal areas like the Larnaca airport, the desalination plant as well as the major power generating stations.

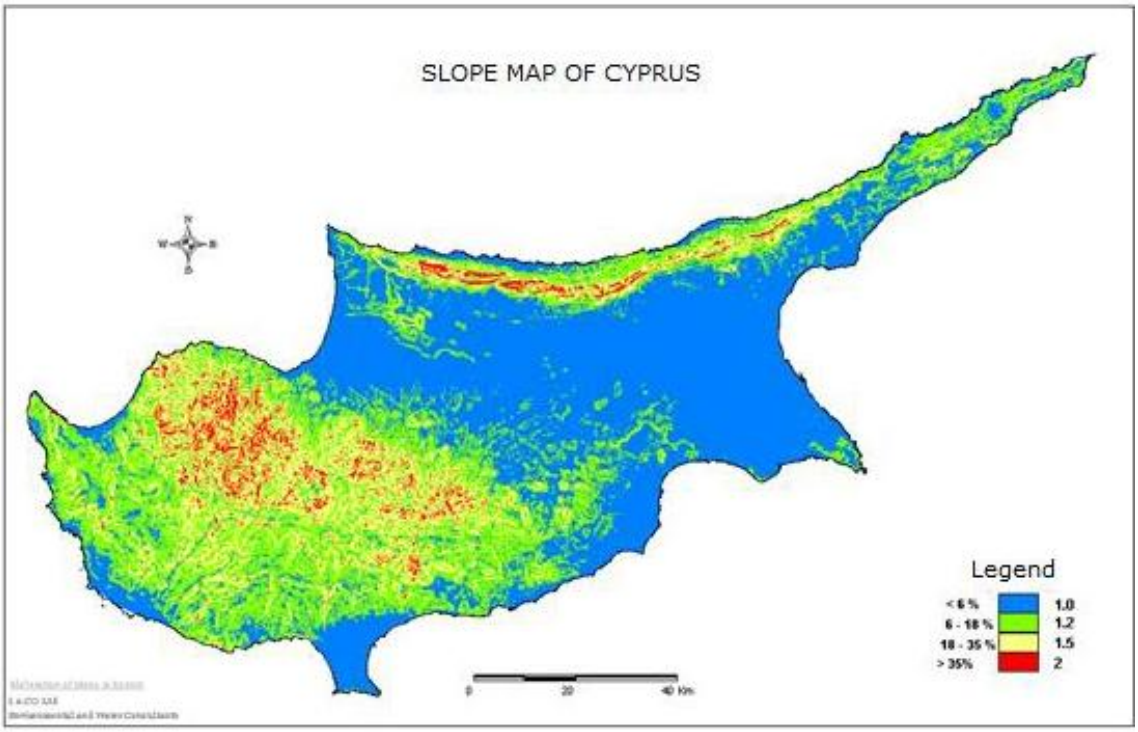


Figure 18: Slope map of Cyprus (from I.A.C.O. Ltd, 2008).

Table 13: Relationship between climate changes and impacts on the coastal zones of Cyprus (from CYPADAPT, 2013).

Potential climate changes	Impacts
Sea level rise	– Coastal Erosion, loss of beach area, increase of inundation canals – Decrease of the total coastline length – Inundation, flood and storm damage – Seawater Intrusion, altered water quality/salinity, soil Salinity, losses and/or changes of coastal ecosystems
Increase in the frequency and intensity of extreme weather events	– Damages on the coastal human environment, increased water levels and wave heights, risk of flooding, inundation, increase or decrease storm surge occurrence – Increased cross-shore erosion, removal of sediment supply, degradation of coastal ecosystems – Re-orientation of beach plan form, increase or decrease longshore transport
Sea surface temperature rise	– Increased stratification, algal blooms, degradation of coastal ecosystems, loss of natural attractions and species

No consistent data series are available for sea-level rise at the coasts of Cyprus; however, it is expected to be moderate (European Commission, 2009a). Furthermore, on the basis of archaeological data, Cyprus appears to be experiencing long-term uplift, ranging between 0 and 1 mm per year. Vertical land movement/tectonics must be taken into consideration, amongst other parameters, for the estimation of sea-level rise for the Cyprus seas, since reports argue that these parameters are counteracting this potential effect (Zachariadis, 2016).

Climate change impacts could exacerbate coastal erosion but there are no sufficient reported studies to clarify this occurrence (Shoukri & Zachariadis, 2012). Anyway, sea-level rise could also worsen seawater intrusion into coastal aquifers and their consequent salinization.

3.10 Malta

Malta is a small island state in the middle of the Mediterranean Sea, comprising three inhabited islands (i.e. Malta, Gozo and Comino) (Tab. 14) and smaller uninhabited islands, such as Cominotto and Filfla. The coast is mainly characterized by vertical cliffs, indented bays, clay slopes, boulder rocks and pocket beaches (Briguglio, 2000; Biolchi et al., 2016a). The Maltese Islands have an undulating tilt towards the northeast, thus producing two types of coastline: a gently sloping rocky coast on the northeastern side (marked by low hills, with plains towards the southern parts) and a steep cliff-dominated coastline on the southwest (with the land sloping down to a low-lying shoreline on the northern stretch) and west sides of the Islands (Borg, 2004; Vassallo, 2014). The structural setting of the northwestern coast, characterised by the superimposition of deeply jointed limestones on clayey materials, is responsible for local instability that causes a wide variety of landslides of different type, size, state, and rate of activity (Devoto, 2013; Mantovani et al., 2013). Actually, this stretch is one of the most aesthetically pleasant areas in the island and therefore it attracts tourists and locals in all seasons (Devoto, 2013); as landslides represent a threat to visitors, hazard and risk must be assessed to provide safe conditions and to preserve the natural environmental conditions at the same time.

The coastal zone presents a significant cultural and natural heritage, such as old fortifications, watch towers, spectacular cliffs and protected Posidonia oceanica meadows (Alterman et al., 2013).

In general, erosion is mainly visible where human intervention occurred in the form of development or incompatible actions (Borg, 2004); so, human intervention is considered the main factor that accelerates erosion. Furthermore, even activities that take place in the interior of the islands can affect the littorals, such as run-off from agriculture land to the sea and the rapid development in valleys, which at times create flooding in low-lying coastal zones (Alterman et al., 2013).

Table 14: Geographical data for the Maltese Islands (from NSO StatDB. StatDB. National Statistics Office, 2013 in Vassallo, 2014).

	Malta	Gozo	Comino	Total
Area	247 km²	66 km²	3 km²	316 km²
Shoreline	200 km	71 km (combined)		271 km
Maximum length	27.4 km	14.5 km	-	-
Maximum width	14.5 km	7.2 km	-	-

Modifications of the coast have been mostly produced by infrastructure development and urbanisation, which have led to loss of specific habitats, such as sand dunes and saline marshlands. In limestone coastal cliffs, the rate of erosion may accelerate owing to both destabilisation caused by engineering works and increased load over the underlying rock.

Sandy beaches in the Maltese Islands are very limited, constituting around 2.5% of its coastline (Borg, 2004). Some of them are important for their heritage value as they have archaeological and historical remains. As sandy beaches give an economic benefit to the tourism and recreation industry, erosion represents a threat to the development of these activities.

Storm waves already play a crucial role in assessing the present coastal vulnerability and risk of the island. In fact, the Maltese coasts are seasonally affected by extreme storm waves generated by NE and NW winds. In the past, similar effects could have been also produced by tsunami events (Tinti et al., 2004; Galea, 2007; Bertolaso et al., 2008; Pino et al., 2008; Mottershead et al., 2015; Biolchi et al., 2016b).

Seawater flooding is rather uncommon in Malta Island, but it can sometimes occur when there is a combination of high tide and heavy rainfall or because of atmospheric gravity waves (Malta Resources Authority, 2013). Shallow puddles of seawater occur in Sliema, along a small stretch of Triq ix-Xatt, in Msida, at Triq il-Marina and Triq ix-Xatt at Marsaskala and in the area of St George's Bay in Birzebbugia. In all cases, they form along the road that is adjacent to the water's edge and last a couple of hours, sometimes causing some inconvenience to traffic. These phenomena usually occur once or twice a year. The other parts of the coast of the Maltese islands do not experience such affects from seawater since a large proportion of the coast of the Maltese islands is made up of coastal cliffs (Malta Resources Authority, 2013).

3.10.1 Future trends

As a small-island, Malta is considered as being prone to increased vulnerability to the impacts of climate change, compared to other countries (Vassallo, 2014). The most important impacts include the deterioration of potable water supplies and quality, more frequent extreme weather events, soil degradation, erosion and intensified desertification process, threats to public health, changes in sea water mass characteristics, coastal erosion and inundation and biodiversity reduction (Tab. 15) (Republic of Malta, Ministry for Rural Affairs and the Environment and the University of Malta, 2004).

Table 15: Summary of land use vulnerability from climate change (adapted from MRA, 2010 in Vassallo, 2014).

Land use vulnerability
Low lying transport infrastructure in the North of Malta.
Any land reclamation projects near the coast which the Government is currently considering.
Low lying coastal areas that have been modified over the years through development on the coast, and which will be prone mostly to storm surges.
A total land area of 1.11 Km^2 or 0.36% of the land area will be affected by sea level rise.
Beaches will be particularly affected as they might be obliterated, reduced in size or, in the case of new beaches, replenishment will be very costly.
Increased rain intensity leading to more flooding in some urban areas, with some needing to eventually relocate to alleviate the problem.
Loss of soil and nutrients for agriculture from intense rain events.
Longer drought periods can lead to desertification, in particular the areas under dryland production.
Increase in wind gusting intensity will also affect the increasingly tall buildings which are being constructed mostly near the coast.
Extreme weather events, including the incidences of heavy hailstorms and thunderstorms will affect road surfaces, rubble walls (for the retention of soil in fields), retaining walls and power lines.
These impacts on agriculture, buildings and infrastructure will have a secondary impact on property values and insurance.

The predicted sea-level rise and increase in extreme weather events pose a serious threat to coastal population (Vassallo, 2014) and human activities, which are particularly concentrated along the littorals. In fact, Malta's coastal area plays a very important role in the social and economic development of the islands, and is probably the country's most important natural resource (Cassar, 2003). The impacts range from inundation, coastal erosion (including loss or movement of beaches), and damage cause by storm surges, waves and high winds;

extreme weather events could also affect part of Malta's coast made up of fragile Blue Clay (a easily erodible sedimentary rock) at sea level. Consequently, tourism too could be negatively impacted if the beaches become inundated and increasingly subjected to tidal activity; the risk of flooding could be also exacerbated by the increase of storm activity. This would lead to relatively large economic losses, since tourism is a major source of income in Malta (Briguglio, 2000).

Table 16 presents the overview of the main findings of modelling of climate change impacts presented in the Second National Communication of Malta (Vassallo, 2014).

Table 16: Main model results generated using MAGICC/SCENGEN version 5.3 applicable to the region of the Maltese Islands for the years 2025, 2050, 2075 and 2100 (from Vassallo, 2014).

	2025	2050	2075	2100	Comments
Increase in Temperature (°C)	1.1	2.0	2.6	2.8	Regional Mean
Change in Precipitation (%)	−2.4	−4.4	−3.7	−1.8	Regional Mean
Sea Level Rise (cm)	7	14	23	30	Global-mean

Current trends indicate that local sea-level rise is 1 cm/yr. Thus, a sea-level rise of 50 cm by 2050 and 100 cm by 2100 may be assumed for the assessments and adaptation measures in the Maltese islands (Republic of Malta, Ministry for Rural Affairs and the Environment and the University of Malta, 2004).

4. Morphodynamics and vulnerability in touristic Asian coasts

4.1 Syria

The Syrian coast (even if it is short) is characterized by an array of geomorphological features: sandy beaches, cliffs and rocky shores, hilly and flat coastal plains, narrow and wide coastal shelves, and wide variety of wetlands rocky headlands (Sanlaville et al., 1997; Saleh & Allaert, 2014).

This country has one of the lowest ratios of coast to land area and coast to population of any Mediterranean state (UNEP, 2009). The coastal region, consisting of the two coastal governorates Lattakia and Tartous, represents less than 2.5% of state area, but is home to 11% of the Syrians. the population density (which is the highest among all governorates except of Damascus), combined with its great strategic importance in terms of economy, recreation and tourism, creates disproportionate pressures on the narrow coastal zone, which often damage the environment and the local scenery. The high concentration of economic activities in the coastal strip is a consequence of the physical characteristics of the country, whose eastern hinterland is mountainous and mostly rocky, unsuitable for intense human settlement and utilization. Thus, its residents and accompanying activities have tended to move westwards to the coastal plain (UNEP, 2009). At present, the coastal zone is facing serious problems because of crowded uses and conflicting usage claims, such as the physical alteration, coastal erosion, declining of physical space, habitat destruction, degradation of natural and cultural heritage, pollution and saltwater intrusion due to overexploitation of fresh water.

Some Syrian coastal stretches are threatened by erosion, in particular the flat and low-lying coastal plains, deltas and estuaries and sandy shores. Frequently, erosion results from development projects and engineering works that have been carried out without adequately taking into account coastal dynamics and processes (UNEP, 2009; Saleh and Allaert, 2014). In addition, the littorals undergo physical alteration due to the increasing development of littoralization and tourism, levelling, dredging, dumping of soil and rock and illegal mining of sand and sandstone.

Littorals also suffer from flash flooding, storms, tsunamis, and earthquakes (Tab. 17). Syria is exposed to flash flood caused by very heavy rains exceeding sometimes 50 mm/hour and responsible for inundations with severe damage to humans, livestock, agriculture, and resulting in soil degradation (Meslmani, 2010; Saleh & Allaert, 2014).

Table 17: The profile risk in Syria in the last ten years (Source of Data: 2009 Global Assessment Report, OFDA/CRED International Disaster Database, in Saleh and Allaert, 2014).

Risk profile		National statistics		
Human exposure		Top 5 national disaster reported		
Hazard type	Population exposed	Disaster	Date	Affected people
Drought	2,027,540	Drought	2008	1,300,000
Flood	25,572	Drought	1999	329,000
Landslide	456	Storm	2004	180
Earthquake	5,370	Storm	2001	172
Tsunami	3,759	Mass mov. wet	2002	23

4.1.1 Future trends

Global warming and climate change impacts on Syrian coastal zones will vary because of local and regional differences in both the physical forcing functions (e.g., waves, winds, currents, sea level, etc.) and coastal types (Saleh & Allaert, 2014).

Sea-level rise represents one of the main threats to the coastal environment (Saleh and Allaert, 2014), which might adversely affect a number of the coastal zone's physical, ecological, biological and socio-economic characteristics, already under stress (Meslmani, 2010). In order to assess the possible impact of sea-level rise on coastal areas, six scenarios, ranging from very low to extreme risk, were developed (Tab. 18). The results indicate that different stretches would be vulnerable to a rise in sea level (Meslmani, 2010), but not at the same level in all regions (Faour et al., 2013); this process would have an impact on beaches, urban settings, and agricultural zones, producing: (1) inundation and displacement of lowlands and wetlands, (2) increased salinity of coastal aquifers, (3) increased coastal erosion, and (4) increased coastal flooding and damage (Meslmani, 2010). The most vulnerable coastal areas are flat and low-lying coastal plains (sandy and rocky areas within an elevation of 0–1 m above sea level), deltas and estuaries and sandy shores characterized by a gentle sloping beach face. Consequently, urban centres, ports, and holiday resort clusters around the low-lying portions of the coast would be highly threatened. Erosion of cliff coasts could worsen with increased storminess and sea-level rise as well (Saleh & Allaert, 2014).

A rising sea level would also cause more frequent coastal flooding of peripheral areas of coastal margins by extreme tides and storm surges (Saleh & Allaert, 2014). Inundation would facilitate erosion (Leatherman, 2001).

Over a short time frame, tectonic deformation could have a much larger local impact on relative sea-level rise than the gradual rates expected from global warming. In fact, Syria has a long history of seismic activity and over 2000 years of recorded events reveal more than two dozen magnitude 7 earthquakes near these Eastern Mediterranean countries (Ambraseys & Barazangi 1989; Saleh & Allaert, 2014).

Owing to the high seismicity of the eastern Mediterranean, tsunami risk along the Syrian coast is also high.

Table 18: Inundated Areas in 2100 according to various scenarios of a rise in sea Level (Meslmani, 2010)

Scenario	Trend (cm/yr)	Variation 2000-2100 (cm)	Inundated area (km^2)
Very low	0.6	60	17.56
Low risk	0.9	90	20.27
Moderate risk	1.3	130	23.89
Intermediate risk	1.9	1.9	27.57
High risk	2.5	250	30.35
Extreme risk	>5	500 up to 750	118.90

4.2 Lebanon

The coastline of Lebanon is characterized by a series of promontories, sandy beaches, cliffs, rocky capes and bays. The coastal zone is currently the most populated area of the Lebanese territory (Abou-Dagher et al., 2012). In fact, even if it represents only 8 % of the total area of the country, it encompasses 33 % of its total built-up area (Dar Al-Handasa & IAURIF, 2004). It is sensitive to erosion due to natural factors such as strong storms, and different local, anthropogenic factors, which act as pressures on coastal ecosystems (Ministry of Environment/UNDP, 2011).

Beach erosion due to sand and gravel extraction from the coastal areas and riverbeds has been extensive through the years of war. Currently, such activities are utterly prohibited by law (Decree 15649 - 1970), however they are still being practiced at a much lower rate due to the absence of strategies to find alternative sources of basic building material (see the following Report from the Pegaso project:

http://www.vliz.be/projects/pegaso/images/stories/WP5/D5.1%20CASEs%20reporting%20and%20evaluation%20report_UNIVE_compressed_3_a.pdf).

In particular, the analysis of the evolutionary trend of the northern littorals has demonstrated that the majority of erosion occurred between 1962 and 1994 and was followed by stabilization (Abou-Dagher et al., 2012). Extensive sea-filling activities, started in 1970 and continued until 2007, caused the destruction of intertidal and littoral habitats and led to modifications of coastal morphology and dynamics. In addition, off the coast of Lebanon and too close to the shore, dredging for construction material has caused severe beach territory loss (Roger & De Meyer, 1998).

Previous researches carried out within the context of the project "Integrated Management of East Mediterranean Coastlines (IMAC), funded by the European Commission (MED/2005/110 659) (IMAC project; home.balamand.edu.lb/IMAC), has revealed that beaches are highly eroded, increasing risk of storm surges and coastal flooding.

4.2.1 Future trends

Studies using altimetry data of the Topex/Poseidon satellite available since early 1993 show a continuous sea-level rise in the order of 5-10 mm/yr along the Lebanese coast. This observed sea-level rise is well correlated with sea surface warming in the period between 1993 and 1999 (Cazenave et al., 2001). If this condition continues in the future, the sea level along Lebanon's coast will be 12-25 cm by 2030 and 22-45 cm by 2050 (Ministry of Environment/UNDP, 2011). A rise in sea surface temperatures, which is expected in the Mediterranean due to climate change, will induce a likely increase in the frequency and intensity of storms and hurricanes (Jäger & Kok, 2009).

The vulnerability of the coastal zone to the effects of climate change (i.e. sea-level rise, storm surges, coastal inundation and flooding, and increased rainfall intensity) is higher in low-lying coastal areas as they are more exposed to tides and have lower natural defence structures (Tab. 19).

4.3 Israel

The Israeli Mediterranean coast extends about 188 km from north to south; 50 km are used for national infrastructures and defence uses and are closed to the public, whereas the remaining coastline has been designated as follows: 59 km as municipal shores (adjacent to urban settlements), 43 km as nature reserves and national parks, and 36 for open space (free of all infrastructures and facilities) (Gabbay & Brachya, 1999). Alongside its natural and environmental resources, Israel's coastal plain includes a rich cultural heritage because it has been characterized by human activities for thousands of years, leaving numerous archaeological remains along the shoreline and shallow water. In recent years, river mouths have also acquired great importance due to their ecological, physical, landscape, and human use aspects. They have undergone physical changes within short-time frames, as a result of floods, flows, storms, runoff and tides (Gabbay & Brachya, 1999).

Table 19: Vulnerability of coastal units (from Ministry of Environment/UNDP, 2011).

	SYSTEM	SENSITIVITY TO CLIMATE CHANGE	ADAPTIVE CAPACITY		VULNERABILITY
LOW LYING AREAS	Marginalized urban settlements	High due to the proximity of developments to the shoreline, high population density and to the existing state of seawater intrusion into coastal aquifers	Scenario A	Moderate	High
			Scenario B	Low	Very high
	Small and medium coastal enterprises	High due to the proximity of installations to the shore	Scenario A	Low	Very high
			Scenario B	High	Moderate
	Natural areas: Sandy beaches, gravel beaches and coastal habitats	Moderate due to the fragmentation of and pressure on natural areas by manmade structures and low altitude. The pressures may be counteracted by resilience and natural adaptation	Scenario A	Moderate	Moderate
			Scenario B	Low	High
	Coastal agricultural plains	High due to expected increase in sea surface temperature and a likely accompanying increase in storms and coastal inundation	Scenario A	Moderate	High
			Scenario B	High	Moderate

The coast is mainly characterized by flat sandy beaches, locally having backshore cliffs (e.g. Rosh Hanikra to Acre and the Sharon coast) or dunes (e.g.. Haifa Bay and the southern coast between Tel Aviv and the Gaza strip) (Gabbay & Brachya, 1999). The backshore ridges are unabraded along the northern coast and abraded in the central sector. In particular, around 45 km of Israel's coastline consist of unstable coastal cliffs, rising 10 meters or more above sea level. In recent decades, they have retreated east at a rate of about 15 cm to several dozen centimetres per year (Gabbay & Brachya, 1999; Alterman et al., 2013). The main driving force behind cliff retreat is wave-shore interaction; however, human interference (e.g., interventions on drainage, road-building, quarrying of sand, calcarenite and hamra in back-cliff areas, removal of sediments along the beaches, construction of offshore structures) has also have an impact on cliff destruction.

In the last decades, a significant number of tourism coastal areas have been affected by severe coastal erosion, which has caused damages to archaeological sites (e.g. Ashkelon Park) and popular beaches (e.g. North to Hertzliya Marina), endangering housing and hotels located on eroding coastal cliffs (Ashkelon, Netanya, Bet-Yanai and Herzliya) or denuding the Zamir beach at Haifa (Rosen, 2009; Alterman et al., 2013).

Along the Israeli sandy beaches, erosion has been accelerated by human activities, such as the construction of marinas and other offshore structures, which have obstructed the natural flow of sand along the coast and intercepted the longshore transport, favouring sediment accumulation on their upstream side and beach erosion downstream (Rosen, 2009; Alterman et al., 2013). The negative effects of these structures have been identified and quantitatively evaluated at several coastal localities including the Ashkelon-Eilat Pipeline Company, Ashkelon marina, Ashdod Port, Herzliya marina and Netanya (Gabbay & Brachya, 1999).

Until the mid-1960s, the most sediment supply to the Israeli beaches was provided by the Nile River, but then it stopped owing to the completion of the high Aswan dam in 1965 (Rosen, 2009). Moreover, a significant reduction of sediment supply to the Israeli littorals has been due to the use of beach sand for construction purposes, occurred from the beginning of the 20th century until 1964, when sand mining was outlawed and defence structures were built. This uncontrolled activity caused narrowing of the beaches and seasonal sand stripping (Gabbay & Brachya, 1999; Rosen, 2009). At present, a source of sediments for the natural nourishment of the Israeli littorals is represented by the Sinai sandy coast. Many experts agree that any disturbance, such as sand dredging, in depths down to 30 m should be avoided because sediment removal may divert an equal volume of sand from the shoreline, thus enhancing shore erosion (Gabbay & Brachya, 1999). Underwater sand depletion, as well as coastal erosion, has also led to the exposure of archaeological remains (Gabbay & Brachya, 1999; Rosen, 2009) that were previously buried causing additional serious damages to the archaeological sites.

The coastal plain has great economic significance because it hosts over half of Israel's population and major urban centres, deep-water harbours, most of the country's industry and a large part of its agriculture and tourist facilities (Gabbay & Brachya, 1999). However, due to the joint action of all these factors the coast appears to be severely affected by environmental pollution, extensive housing and industrial development, coastal and offshore structures and erosion, which threaten its recreational and ecological functions (Gabbay & Brachya, 1999; Society for the Protection of Nature in Israel, 2006). To tackle these threats, Israel has developed a widely diverse toolbox for protecting its coasts, comprised of plans, strategies, policies, government decisions and binding laws and regulations (Alterman et al., 2013).

4.3.1 Future trends

Near the Israeli coast, sea level is expected to rise 0.5 m by 2050 and approximately 1 m by 2100 (Rosen, 2011; Zachariadis, 2016).

Sea-level rise, the increased frequency of extreme storms, and the confirmed serious tsunami hazard in the Mediterranean could have serious impacts on the future development of the Israeli coast. The main risks include loss of the width of the beaches characterized by relatively gentle slopes, intrusion of seawater into the coastal aquifer and worsening of the salinization problem (Gabbay & Brachya, 1999).

5. Morphodynamics and vulnerability in touristic African coasts

5.1 Libya

The Libyan coast is about 1900 km long and mostly sandy, especially in its central part, in which the Sahara Desert faces the Mediterranean Basin; a remarkable exception is represented by the eastern region of Cyrenaica, occupied in its northern part by a 880 m-high limestone plateau (Gebel el-Akhdar or Green Mountain) extensively affected by both surface karst features and caves (Furlani et al., 2014). This flat-topped relief degrades towards the sea by means of a number of steps. The beaches are composed partly of terrigenous sand eroded from the cliffs and partly of calcareous sediments coming from sea floor organisms and the Pleistocene aeolianites, which fringe parts of the coast and extend beneath the sea (Schwartz, 2010).

The wave environment along the Libyan coast is that of a protected sea, with less than a 10% frequency of waves of 1.6 m height or more during at least two quarters of the year (Orme, 2005).

The coastal zone is currently the most populated area of Libya: 90% of the people live in less than 10% of the area, primarily along the coast (El Raey, 2010). About 88% of the population is urban, mostly concentrated in the two largest cities, Tripoli and Benghazi. Moreover, Libyan mostly virgin beaches are important social gathering places.

At present, coastal erosion due to storm surges occurs (e.g. Bennett et al., 2004).

5.1.1 Future trends

With a large and growing population in the coastal zone and a low ability to adapt because of low national wealth and adaptive capacity, most coastal countries of Africa appear to be highly vulnerable to sea-level rise (Brown et al., 2011).

Based on the findings of the Intergovernmental Panel on Climate Change (IPCC) and the Arab Forum for Environment and Development (AFED), the Libyan coast can be considered one of the most vulnerable of the Arab region to rising sea-level (Fig. 19) (Tolba & Saab, 2009; El Raey, 2010). In particular, owing to their morphological characteristics, the beaches of Libya could suffer direct inundation (as shown in Figure 20 by comparing the present condition with the simulation of sea-level rise of 1 m), which could have serious implications on the coastal shape, resources and tourism (El Raey, 2010).

Extreme events, such as storm surges, are also expected to be intensified by climate changes in both severity and frequency (El Raey, 2010). Their potential impacts on littorals and coastal cities would increase the vulnerability to flooding (Dasgupta et al., 2009b). Figure 21 indicates that Egypt, Algeria and Libya could be the most negatively impacted by increasing surges.

Increase of salt-water intrusion due to rising sea level on already scarce groundwater resources would also damage important water resources.

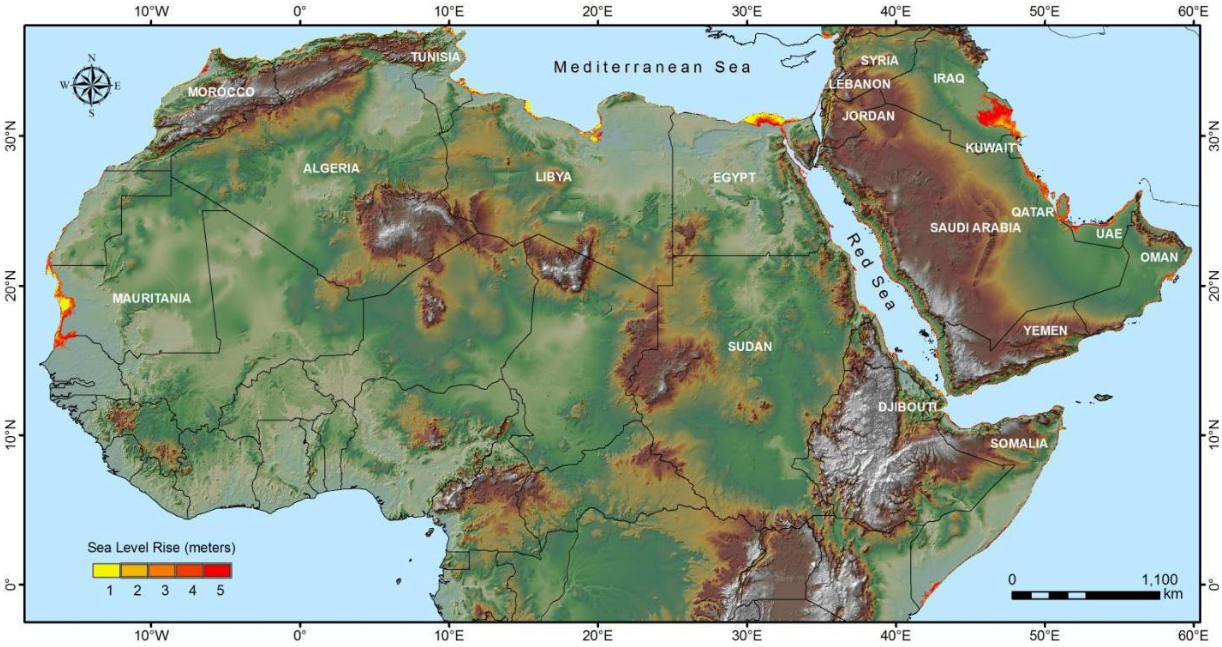


Figure 19: An overview of the most vulnerable coastal areas of the Arab Region due to sea- level rise (Tolba & Saab, 2009).

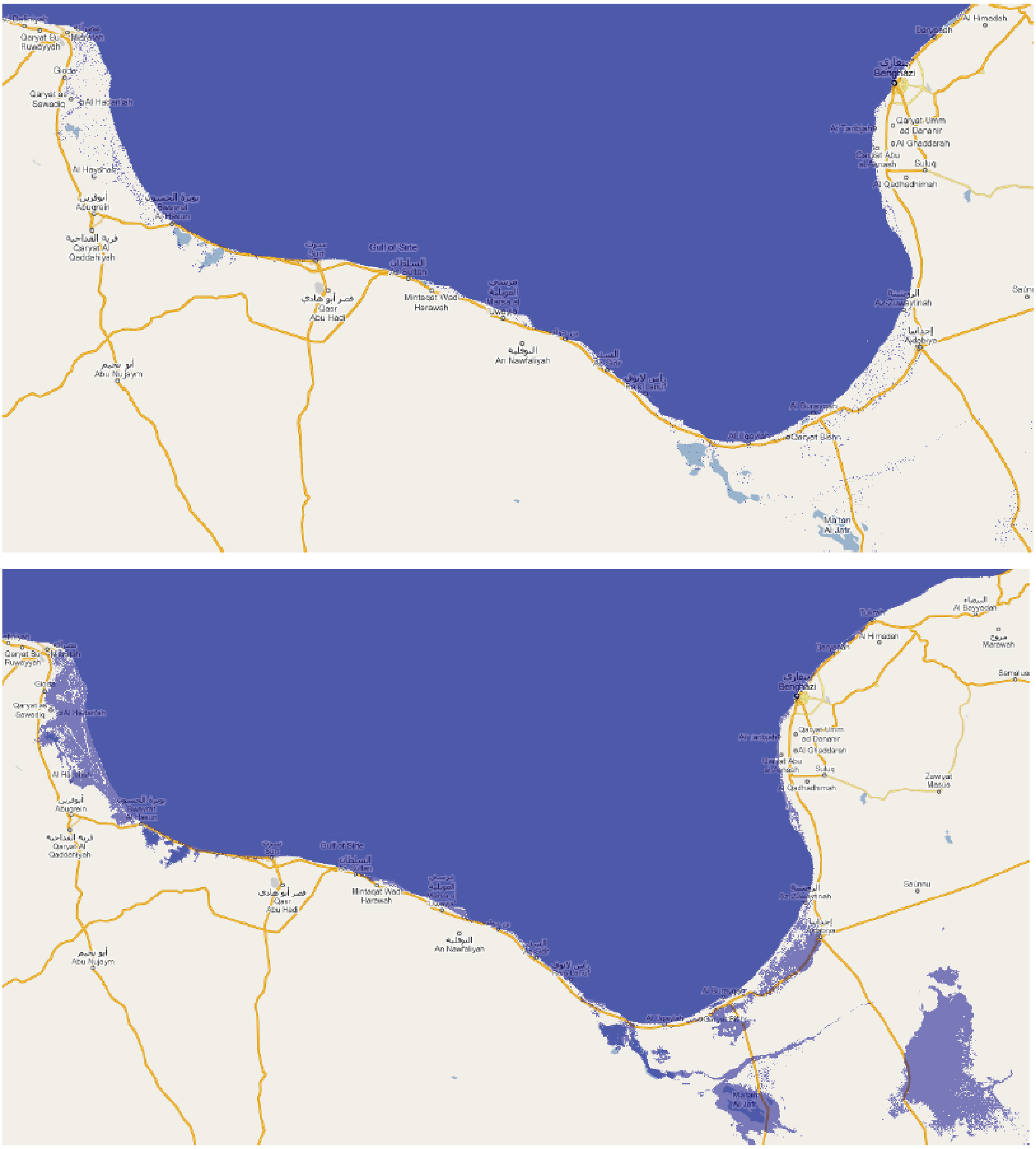


Figure 20: The Mediterranean coast of Libya indicating areas vulnerable to sea-level rise (upper: today; lower: simulating 1 m SLR) (El Raey, 2010; based on analysis by River Surveyor: http://flood.firetree.net).

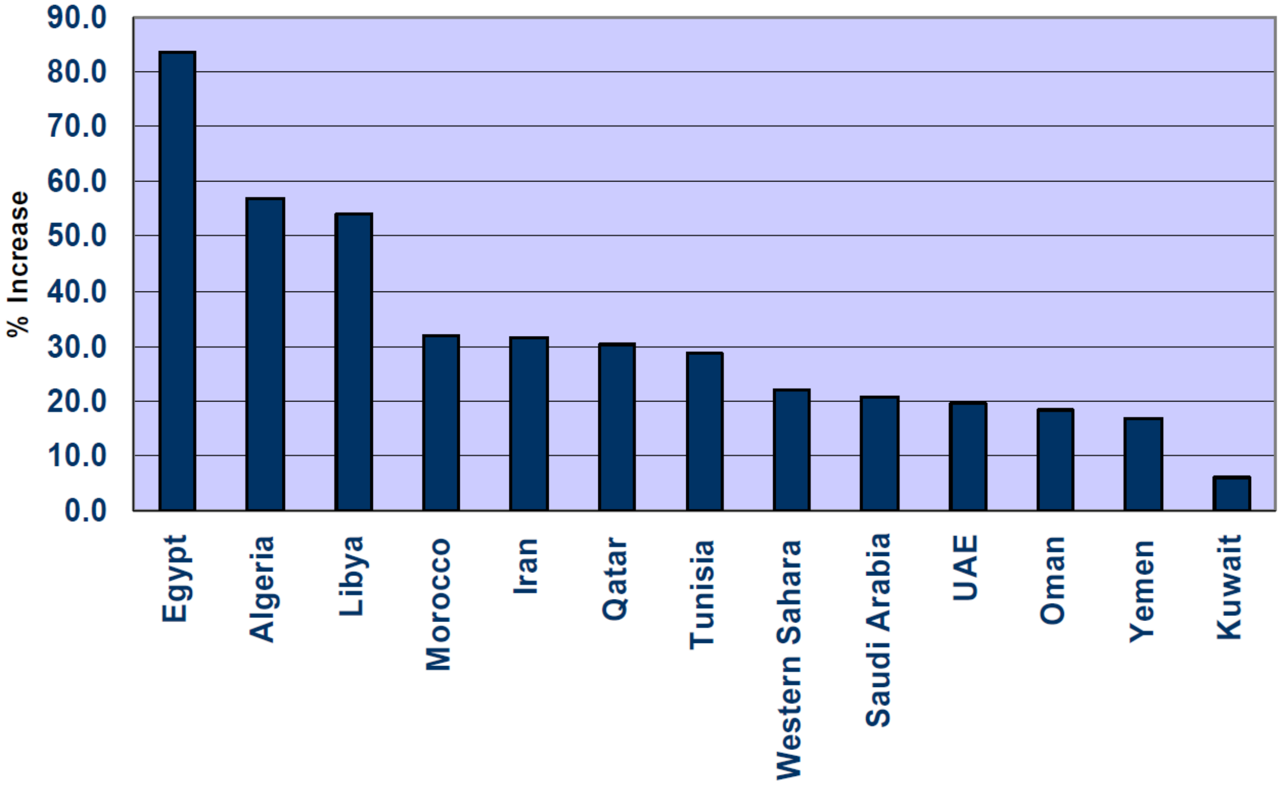


Figure 21: Percentage increase of storm surge impact on the coastal zone of the Arab countries (Dasgupta et al., 2009b).

5.2 Tunisia

The Tunisia northern coast mostly displays low-lying rocky shores, especially from the border with Algeria up to Cap Blanc (Furlani et al., 2014). In the eastern coast, sandy beaches predominate, particularly around the Gulf of Hammamet, in the vicinity of Mahdia and Gabes, in eastern Jerba and near Zarzis (Paskoff, 1985), whereas cliffs are small and infrequent.

Beach erosion and coastal flooding due to current climate variability are serious issues for Tunisia (Hinkel et al., 2015; Louati et al., 2015). Examples of coastal stretches affected by erosion are the coast of the Gulf of Tunis, where breakwater and coastal defence structures have been built in several parts of the bay (Cadiou et al., 2015), and the Jerba Island, where erosion has been caused by human interventions related to tourism (Paskoff, 1985). In particular, the morphological changes of Djerba Island have been also subject matter of more recent studies (e.g. Bouchahma & Wanglin, 2012). They have shown that accretion is generally more significant in the most part of the study sites; however, erosion, mainly produced by sand mining on the beach for building purposes, destruction of foredunes to build hotels close to the beach, and construction of dams, has been remarkable around the zone of Aghir and also in the north part of Rass Ermall territory (Paskoff, 1985; Bouchahma & Wanglin, 2012).

Coastal areas are fundamental for Tunisia's economy and tourism development. They represent an important resource for environmental, social, cultural and recreational activities. In Tunisia, tourism essentially revolves around its image as a beach and seaside resort; thus, it is particularly sensitive to the summer climate, rising sea levels and coastal erosion (Republic of Tunisia - Ministry of Environment and Sustainable Development, 2015). Concerning coastal erosion, the annual losses for the tourism sector resulting from the retreat of the beaches due to the rising sea level are estimated at around 5% of the sector's added value. Moreover, the coastal zone of Tunisia is home of two-thirds of the total population (http://adaptation-undp.org/projects/sccf-tunisia). Owing to all these reasons, it is considered one of the countries most exposed to climate change in the Mediterranean (Republic of Tunisia - Ministry of Environment and Sustainable Development, 2015).

Finally, the coast may be also affected by tsunamis, as demonstrated by the presence of large boulders accumulated in the NE stretches, which could have been transported by tsunami-induced waves rather than storm waves (May et al., 2010).

5.2.1 Future trends

The impacts of sea-level rise will be substantial in the 21st century for Tunisia (Hinkel et al., 2015). Dasgupta et al. (2009a) ranked it in the top ten most impacted developing countries (out of 84 developing coastal countries considered world-wide) in terms of population and land under a 1 m sea-level rise (considering the existing condition at the time of the study and assuming no defences). In fact, an increasing of storm surges and an accelerated rise of sea level of 1 m will affect 32% of the coastal area, 32% of the population and 52% of the wetlands (Dasgupta et al., 2011).

An analysis of the effects of sea-level rise on Tunisian coast was carried out by Hinkel et al. (2015) under three sea-level rise scenarios, i.e. 0.30 m, 0.51 m and 1.11 m. The expected relative sea-level rise in 2050 and 2100 are shown in Table 20 and Figure 22.

If no adaptation measures are taken, sea-level rise and socio-economic development would enhance flood risks substantially during the 21st century. The expected number of people flooded annually would increase from 140,000 in 2010 to 436,000 in 2100. Médenine is the municipality with the biggest potentially flooded area (Hinkel et al., 2015). Other municipalities exposed to large flooding potential are Bizerte and Sfax. In terms of cities, the widest potential flooding area is in Tunis. Other coastal plains at risk are located in Sfax and Monastir, while in Sousse and Bizerte only a small territory could be affected in 2100. Furthermore, rising sea level would be also responsible for an increase of salinization of coastal aquifers.

Table 20: Sea-level rise in Tunisia in 2050 and 2100 under the three sea-level rise scenarios (Hinkel et al., 2015).

Scenario	Sea-level rise Tunisia, 2050	Sea-level rise Tunisia, 2100
Low SLR	0.16 m	0.30 m
Medium SLR	0.20 m	0.51 m
High SLR	0.32 m	1.11 m

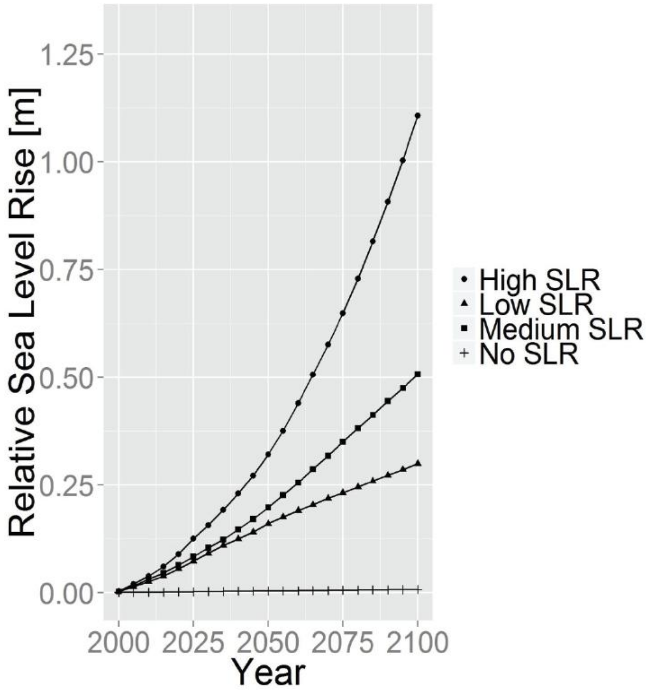


Figure 22: The average relative sea-level rise in Tunisia for three scenarios (Hinkel et al., 2015).

Coastal erosion is expected to be a further issue for Tunisia. Under the high sea-level rise scenario and without adaptation, sea-level rise could lead to the erosion of up to 520,000 m² of land annually in 2100, as erodible beaches constitute approximately 1/3 of the Tunisian coastline (equal to 734.2 km) (Fig. 23). Nabeul, Soussè, Médenine and Bizerte have been identified as the municipalities most affected by coastal erosion (Hinkel et al., 2015).

An analysis of the vulnerability of the Gulf of Gabes coasts was carried out by Rizzi et. (2016). Results showed that the areas at greatest risk of inundation due to 14 cm sea-level rise are located along the southern Tunisian coastline (i.e., the Governorate of Medenine) including most of the Kerkenna island, in front of Sfax. Although the total exposed area is relatively small, it contains some of the most densely populated stretches along the Tunisian coast. The same research also allowed identifying the exposure to storm surge impact of the littorals, assuming a storm surge of 187 cm (i.e., 173 cm of storm surge height plus the estimated sea-level rise value of 14 cm). The results demonstrated that most of the study area is classified as having ‘‘very high’’ exposure to storm surge flooding (in particular, Medenine and Sfax, followed by Gabes).

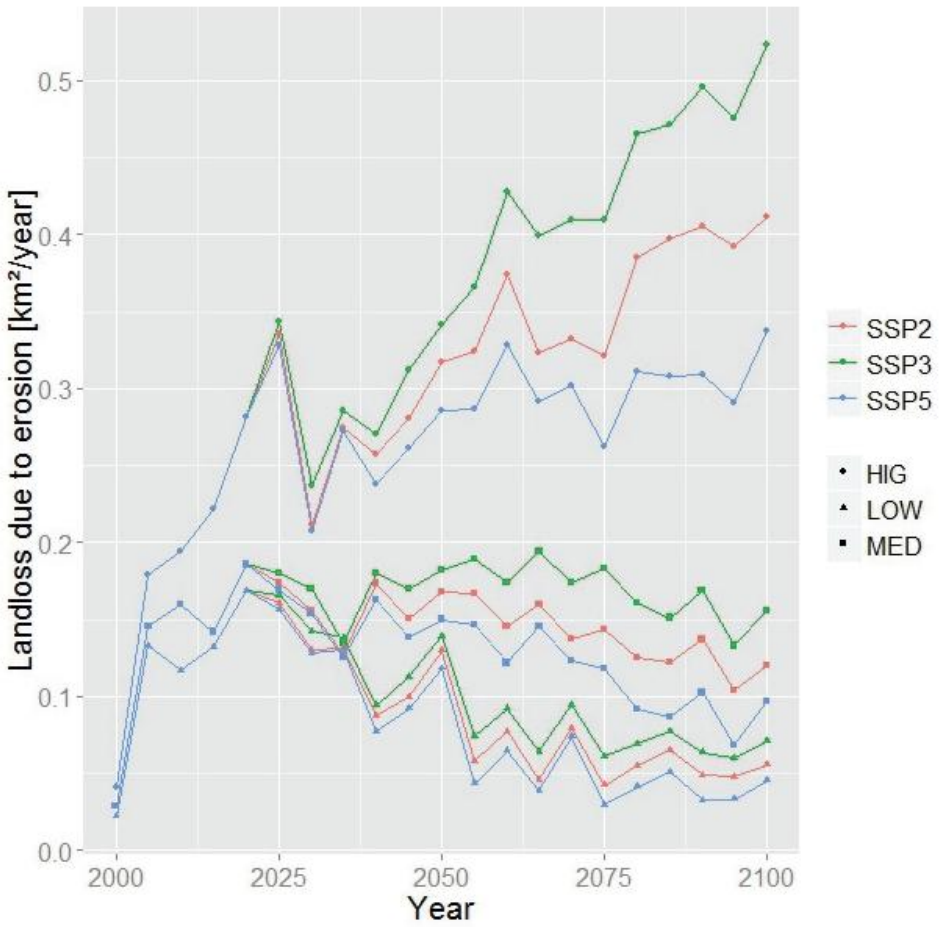


Figure 23: Annual land loss due to erosion until 2100 in Tunisia. Under the high sea-level rise scenario and without adaptation, sea-level rise is projected to erode 522,755 m² of land in 2100. In 2100, 155,606 m² and 70,814 m² could be lost under the medium sea-level rise and the low sea-level rise scenarios, respectively (Hinkel et al., 2015).

The effects of rising sea level on the coast have been described by Republic of Tunisia - Republic of Tunisia - Ministry of Environment and Sustainable Development (2015) as follows:

- loss by submersion of approximately 16,000 hectares of agricultural land in low-lying coastal areas,
- loss by submersion of approximately 700,000 hectares of built-up areas,
- loss by salinization of approximately 50% of the resources currently available in coastal aquifers,
- indirect loss of the potential for approximately 38,000 ha of irrigable land by 2050, i.e. 10 per cent of currently irrigated land,
- decline in the activities of seafront hotels, which have a total capacity of approximately 30,000 beds, owing to retreating beaches,
- decline in port and shore infrastructure.

5.3 Algeria

The Algerian coastline is the second longest in Southern Mediterranean (after Libya). It is backed by chains of mountains with slopes plunging abruptly into deep water and intervening sandy low coasts, which represent about 20% of the coastline (Larid, 2001).

At present, the littorals are exposed to several natural hazards, such as erosion, sudden changes in sea level induced by atmospheric disturbances and tsunami waves (Bouhmadouche & Hemdane, 2016, and references therein).

About 70-85% of the beaches has been retreated in recent decades, partly owing to stormier conditions in coastal waters, partly due to the quarrying of sand beach for building and road-making, and partly because sediment supply from rivers has been reduced by drier conditions and barrage construction (Larid, 2010). Many beaches are also eroded by winter storms; so, during summer, they are restored through the deposition of large quantities of fine sands. Onshore winds generally come from the northwest and then round to the northeast and produce waves averaging 2–3 m in height and reaching 5–6 m during storms (Larid, 2010).

Over the last decades the Algerian coast has witnessed a rapid growth of population and a great development of industrial activities. According to Gabbianelli et al. (2007), at least 66% of country's total population lives in the coastal zone and 52% of industries is located within 50 km from the shoreline. These phenomena, together with the lack of a rational planning of land use, resulted in severe degradation of Algerian coastal ecosystems, especially in the most developed regions such as the Wilaya d'Alger and the littorals of the Bejaja Bay. Illegal sand mining from wadis beds, old and actual dunes and beaches (Boutiba, 2006) have significantly contributed to coastal erosion, thus threatening the ecosystem equilibrium and the tourism potential (Kermani et al., 2016).

A coastal stretch characterized by strong economic activities (e.g. tourism and fisheries) is the littoral of the Bejaia-Jijel Bay, one of the most beautiful and attractive in Algeria (El Islam et al., 2017). In recent decades, the Jijelian sandy coast, which was left in its natural state until early 1980, has been subjected to a major regional development program that has contributed to the economic development of this territory and led to the construction of many infrastructures (e.g., a port, a railway, a highway, a power plant) (Kermani et al., 2016). However, this program has destabilized the natural balance of the coastal area, already largely affected by severe erosion, high hydrodynamic conditions and significant silting of ports (El Islam et al., 2017). Erosion, due to the impact of storm swell on the beach, has caused damages to the local natural patrimony, also affecting the various infrastructures built along the coast (Ayadi et al., 2016). In particular, the littoral is exposed to dominant waves coming from the East and West sectors with respective frequencies of 31% and 17%; from October to March the wave heights vary between 2.75 and 3.75 m (for 15-30% of the entire period), but waves up to 6 m high have been also recorded.

In the past, numerous destructive earthquakes and tsunamis have also affected the Algerian coast. In particular, tsunami hazard is related to earthquakes with epicentres located offshore the western Mediterranean margin or to slides due to the numerous submarine canyons (Yelles-Chaouche, 1991; Domzig et al., 2006). Coastal and offshore earthquakes have destroyed several coastal cities, whereas minor to moderate tsunamis were only responsible for coastal inundation induced or triggered by the consequent sea-waves (Amir et al., 2015). Evidences of catastrophic tsunami events are represented by the mega-block placed on the coast from Tipaza to Dellys, which could be deposited by tsunamigenic events having their sources off SE Spain and the Balearic islands (Maouche et al., 2009).

5.3.1 Future trends

With respect to the economic impact produced by climate change, Algeria can be considered one of the most vulnerable African countries under the A1B mid-range scenario in 2100 (Brown et al., 2011). By 2100, in Algeria the sea-level rise only due to climate change could produce the greatest residual damage cost of any African country (Tab. 21 to 26) (Brown et al., 2011). This condition could also worsen owing to the high negative potential impacts produced by storm surges, which are expected to increase in the future (Fig. 21) (Dasgupta et al., 2009b).

Table 21: Results for the Rahmstorf SLR and A1B socio-economic scenario for 2000, without adaptation (modified from Brown et al., 2011).

Locations	Total costs of adaptation (millions US$/yr)	Total costs of residual damage (millions US$/yr)	Land loss (submergence) (km^2/yr)	Net land loss (erosion) (km^2/yr)	People actually flooded (thousands/yr)	Protection level (* - averaged over coastal length) (year)	Relative sea-level change (since 1995) (** - average) (m)
Algeria	0	3.2	0	0.00	1.7	93	0.017

Table 22: Results for the Rahmstorf SLR and A1B socio-economic scenario for 2025, without adaptation (modified from Brown et al., 2011).

Locations	Total costs of adaptation (millions US$/yr)	Total costs of residual damage (millions US$/yr)	Land loss (submergence) (km^2/yr)	Net land loss (erosion) (km^2/yr)	People actually flooded (thousands/yr)	Protection level (* - averaged over coastal length) (year)	Relative sea-level change (since 1995) (** - average) (m)
Algeria	0	22.9	0.0	0.0	13.7	13	0.13

Table 23: Results for the Rahmstorf SLR and A1B socio-economic scenario for 2030, without adaptation (modified from Brown et al., 2011).

Locations	Total costs of adaptation (millions US$/yr)	Total costs of residual damage (millions US$/yr)	Land loss (submergence) (km^2/yr)	Net land loss (erosion) (km^2/yr)	People actually flooded (thousands/yr)	Protection level (* - averaged over coastal length) (year)	Relative sea-level change (since 1995) (** - average) (m)
Algeria	0	35.9	0.0	0.0	30.0	8	0.17

Table 24: Results for the Rahmstorf SLR and A1B socio-economic scenario for 2050, without adaptation (modified from Brown et al., 2011).

Locations	Total costs of adaptation (millions US$/yr)	Total costs of residual damage (millions US$/yr)	Land loss (submergence) (km^2/yr)	Net land loss (erosion) (km^2/yr)	People actually flooded (thousands/yr)	Protection level (* - averaged over coastal length) (year)	Relative sea-level change (since 1995) (** - average) (m)
Algeria	0	866.2	1259.2	0.0	316.8	0	0.35

Table 25: Results for the Rahmstorf SLR and A1B socio-economic scenario for 2075, without adaptation (modified from Brown et al., 2011).

Locations	Total costs of adaptation (millions US$/yr)	Total costs of residual damage (millions US$/yr)	Land loss (submergence) (km^2/yr)	Net land loss (erosion) (km^2/yr)	People actually flooded (thousands/yr)	Protection level (* - averaged over coastal length) (year)	Relative sea-level change (since 1995) (** - average) (m)
Algeria	0	1775.0	1775.0	0.0	612.4	0	0.73

Table 26: Results for the Rahmstorf SLR and A1B socio-economic scenario for 2100, without adaptation (modified from Brown et al., 2011).

Locations	Total costs of adaptation (millions US$/yr)	Total costs of residual damage (millions US$/yr)	Land loss (submergence) (km^2/yr)	Net land loss (erosion) (km^2/yr)	People actually flooded (thousands/yr)	Protection level (* - averaged over coastal length) (year)	Relative sea-level change (since 1995) (** - average) (m)
Algeria	0	3259.8	5.2	0.0	761.6	0	1.24

5.4 Morocco

In Morocco, the coastal zone, which extends for nearly 3,500 km along the Mediterranean Sea and the Atlantic Ocean, represents one of the main socioeconomic areas of the country with more than 60% of the population inhabiting the coastal cities, as well as incorporating 90% of the industry (Snoussi et al., 2008). However, due to diverse human pressures, many coastal zones are already experiencing acute environmental problems, such as erosion, pollution, degradation of dunes, and saline intrusion of coastal aquifers and rivers.

The Mediterranean Moroccan stretch extends from the Gibraltar Strait eastwards.

In the western sector, the Tetouan coast is one of the coastal territories that have been most rapidly and densely urbanized (Satta et al., 2016). It is characterized by beaches having variable width, locally interrupted by rocky headlands and anthropogenic structures (El Mrini et al., 2012b). It has a important economic role in the country thanks to industry, tourism and its geographical proximity to Europe (Cadiou et al., 2015). In this area, occupancy and use have significantly increased, in particular under the great development of tourism occurred in the last years. The construction of leisure ports (M'diq, Smir Marina and Kabila), residential centres, hotels and a motorway running along the coast (Gómez Bello et al., 2006), together with other coastal human activities, has affected the morphodynamic behaviour of the beaches and favoured the reduction in sediment inputs. Consequently, over the last 45 years, coastal erosion has strongly narrowed the beaches, thus increasing their vulnerability to sea-level rise (Snoussi et al., 2010). This condition has been worsened by dune destruction and by the construction of buildings on dune ridges, which has blocked the natural beach-dune interchange of sediments (El Mrini et al., 2012b). All these factors, in addition to damming of rivers (especially after 1991, when a dam was built on Wadi Smir), have altered sediment supply and affect coastal stability. Human influence has also had negative repercussions on two lagoons of great ecological interest (Castro et al., 2006; Nachite et al., 2004). Furthermore, the increase of the intensity and frequency of storm-surges, likely related to global warming, could explain the higher rates of erosion occurred in the last years (Snoussi et al., 2010). Anyway, the Alboran Sea (i.e. the westernmost portion of the Mediterranean Sea) is commonly an area of strong currents and turbulence resulting from the water exchanges between the Mediterranean Sea and the Atlantic Ocean (Cadiou et al., 2015). Wave data covering the period 2005-2008 have highlighted a moderate wave energy regime; heights exceeding 3 m have represented only 5% of the total spectrum (El Mrini et al., 2012b). The highest wave heights have been observed in December and January and generally have exceeded 4 m (El Mrini, 2011).

High anthropogenic impacts on littoral evolution have been also observed in the Saïdia coastal plain (Mediterranean Coast of northeastern Morocco) (Mouzouri & Irzi, 2011). In particular, the two dams built on the Moulouya River have caused a significant decrease in the sediment load transported between 1963 and 1988 and the marina has hampered the eastward dominant sedimentary transit, resulting in a 1 m/year retreat of the eastern shoreline between 1988 and 2006 and its shift to the west. Additionally, the recent coastal development projects, which have took place in the Saïdia and have increased coastal anthropization, have disrupted the natural evolution of coastal ecosystems and the related sedimentary bodies (Salmon et al., 2010; Mouzouri & Irzi, 2011). Consequently, the eastern part of the Mediterranean coast of Morocco can be considered another coastal zone physically and socio-economically vulnerable to accelerated sea-level rise, due to its low topography and its high ecological and touristic value (Snoussi et al., 2008).

5.4.1 Future trends

One of the main impacts of climate change on Moroccan coast will be produced by sea-level rise. Accelerated increase of sea level will intensify the stress on littorals, causing flooding of coastal lowlands, erosion of sandy beaches, destruction of wetlands and major salt-water intrusion. As the climate of Morocco is semi-arid, aquifer salinization could worsen during droughts because of rising temperatures (Snoussi, 2000) or after significant overexploitation.

Low-lying land, where further flooding due to sea-level rise could potentially occur, are the Nador lagoon, the river Moulouya and its delta (e.g. Ericson et al., 2006), and the coastal plains of Oued Nekkor and Oued Laou (Brown et al., 2011). Flooding could also affect many coastal buildings and industries located behind dune ridges and will threaten cultural sites (e.g. the historic city of Essaouria).

Snoussi et al. (2008) have performed an assessment of the potential future land loss due to flooding. They have considered a minimum inundation level of 2 m and a maximum value of 7 m, under scenarios of future sea-level rise ranging from 200 to 860 mm, with a 'best estimate' of 490 mm. Results have indicated that 24% and 59% of the area will be lost by flooding at the minimum and maximum inundation level, respectively. The most severely impacted sectors are expected to be the residential and recreational areas, agricultural land, and the natural ecosystem. Shoreline erosion will affect 50% and 70% of the total area in 2050 and 2100, respectively.

6. Morphodynamics and vulnerability in touristic transcontinental coasts

6.1 Turkey

Turkey has the third longest Mediterranean coastline (including islands). The western Mediterranean coast is characterized by high mountains running close to the shoreline. The width of the coastal area is very narrow (in the order of a few hundred meters); so, it is unsuitable for many coastal uses, including urbanization (PAP/RAC, 2005).

Along the Aegean coast, the mountains run perpendicular to the littorals; this setting allows the rivers like Buyuk Menderes to develop fertile alluvial plains and productive deltas (PAP/RAC, 2005). Coastal dunes, mainly located on the deltas of the Aegean and Mediterranean seas, represent natural barriers to storms and could be defence measures against the consequences of the future accelerated sea-level rise, at least in the short term (Karaca & Nicholls, 2008). However, recently they have been significantly damaged by road construction, plantations, sand extraction, secondary houses and tourism activities (State Planning Organization, 2001; Kuleli, 2010a). Since the mid-1950s the Seyhan, Ceyhan and Goksu deltas in the northeastern Mediterranean have been characterized by significant shoreline changes (Cetin et al., 1999). In particular, after the construction of dams, sediment flux to the coast has greatly decreased, preventing progradation and/or triggering erosion. This reduction in sediment supply is expected to have adverse long-term effects, which will exacerbate the effects of sea-level rise (erosion) (Güven, 2007). At present, coastal erosion is significantly affecting human activities; in fact, although coastal cities cover less than 5% of the total surface area of Turkey, they comprise 51% of the population, 80% of industry and 90% of tourism income (Albayrakoğlu, 2011).

Owing to the mountain orientation perpendicular to the shoreline, the Turkish Aegean shoreline is highly indented, housing numerous bays and coves that have been inhabited by humans since historic times (PAP/RAC, 2005). This makes the Aegean coast extremely important with respect to the presence of invaluable cultural sites and resources and thus a prime area for tourism and recreation, and other coastal uses that are also supported by numerous coastal features and natural attractions. Although some of the Turkish sandy coasts are national parks, one-third of them are degrading by rapid tourism development; in particular, tourist accommodations have been extensively constructed often close to the current shoreline (Karaca & Nicholls, 2008).

The Aegean coast is the richest in terms of the number of lagoons (40%) (Emiroglu et al., 2001). In the Mediterranean stretch, they represent 24% of the total and are mainly located in the deltaic systems. Lagoons of the Goksu, Seyhan and Ceyhan Deltas in the eastern Mediterranean are among the most important pristine nature preservation areas (Deniz, 2002). Moreover, there are also thirteen specially protected areas SPAs, nine of which are coastal SPAs, which cover sizable stretches of the coastline along the southern Aegean and the western Mediterranean.

Human activities in the coastal regions facing the Aegean and Mediterranean seas intensified in the second half of the 20th century, especially after the 1970s. There was a steady migration of population from eastern and southeastern Turkey towards coastal large cities and more socio-economically developed parts of the country (PAP/RAC, 2005; Karaca & Nicholls, 2008). The rapid growth of Turkish tourism and related facilities (e.g., hotels, holiday villages, marinas, restaurants) occurred at the same time of the very rapid urbanization of the coast and the construction of resorts, such as in Antalya and its environs, in the Mediterranean, and in Kusadasi, Marmaris, Fethiye and Bodrum, in the Aegean. As the increase of people living in coastal areas is expected to continue, the population exposed to sea-level rise is increasing too (Karaca & Nicholls, 2008). At present, sea-level rise rates along many stretches of the Turkish coast are within the generally accepted range (1-2 mm/yr). Rates substantially greater than the global value occur in several larger river deltas; this condition could be explained assuming that they are undergoing subsidence. The areas in which the rate of the sea-level rise has been less than 1-2 mm/yr (e.g. Antalya) are likely experiencing tectonic uplift (Güven, 2007).

Another threat to coastal areas is represented by storm surges. Periodically, they have been destructive on many sites of the Turkish coast, especially at Izmir Bay in the Aegean Sea, Fethiye and Antalya Gulfs and Mersin and Iskenderun harbours in the Mediterranean Sea (Karaca & Nicholls, 2008). Surges could be also produced by tsunamis, as proved by the occurrence of onshore boulders at 2.6 m a.s.l. in the Silifke district (southern Anatolia) along the coast of the central-southern Turkey, which could have been transported by tsunami waves with a minimum run-up of 3.0 m (Öğretmen et al., 2015).

Erosion also affects cliffs producing sliding and rockfall problems; so, owing to their potential geological hazards, high and steep rocky coastal areas need to be investigated to ensure the safety of tourists (e.g. Kaya & Topal, 2015).

6.1.1 Future trends

Turkey’s First National Communication on Climate Change prepared in 2007 indicates that the impacts of climate change in this country will be the increasing of summer temperatures, decreasing of winter precipitation in western provinces, loss of surface water, increased frequency of droughts, land degradation, coastal erosion, and flooding (T.R. Ministry of

Environment and Urbanization, 2012) as well as a worsening of saltwater intrusion into aquifers, also favoured by overexploitation in response to higher demand.

A number of national scale studies suggest that Turkey could experience appreciable coastal impacts from sea-level rise areas, particularly the low-lying deltaic plains (e.g., Demirkesen et al., 2008; Karaca & Nicholls, 2008; Alpar, 2009; Kuleli et al., 2009; Kuleli, 2010b; MET Office, 2011; Simav et al., 2013). The Black sea coast could be the most affected; however, rising sea levels and increases in storm surges could also have an effect along the Aegean and Mediterranean littorals (Karaca & Nicholls, 2008). Cities, population, tourism infrastructures, industrial centres and agriculture activities developed in low-lying coastal areas would be threatened by flooding and coastal erosion. Such zones would be also more prone to face extreme precipitation phenomena (T.R. Ministry of Environment and Urbanization, 2012).

On high rocky cliff coasts, sea-level rise could accelerate the rate of cliff recession, thus increasing the frequency and extent of landslides; this would be potentially damaging to coastal roads and communications (Karaca & Nicholls, 2008). Along low eroding soil cliffs, more intense wave erosion would gradually increase the rate of inland cliff migration; because these areas are often already densely populated, serious damage or destruction of coastal establishments would result (Karaca & Nicholls, 2008). However, protecting these areas from waves and inundation could often cause erosion elsewhere.

Considering the proximity of earthquake tsunamigenic zones (e.g., Hellenic and Cyprean arc subduction zones), the potential for local landslide-generated tsunamis and the evidence for past tsunamis that affected the Mediterranean coast of southern Turkey, this type of events has to be taken into account for tsunami risk assessment, particularly in areas where strategic infrastructure has been planned (Öğretmen et al., 2015).

6.2 Egypt

The Egyptian coast is characterized by different morphological settings: in the western stretch, a wide limestone bulge dominates; in the central part promontories are mainly present, whereas in the eastern sector there are coastal plains and the Nile Delta (Furlani et al., 2014). The western and the central stretches are modified by the interaction of marine and continental processes responsible for the formation of various geomorphological features, such as sea cliffs, drowned wadis and shore platforms (Embabi, 2004).

The Mediterranean coast of Egypt, with its six cities of El-Arish, Port Said, Damietta, Rosetta, Alexandria and Mersa Matrouh, hosts a large number of economic and industrial centres as well as important beaches and tourist resorts (Egyptian Environmental Affairs Agency, 2010).

It suffers from a number of serious problems including unplanned development, land subsidence, excessive erosion rates, water logging, salt water intrusion, soil salinization and ecosystem degradation. Erosion and sea-level rise also represent serious threats to the survival of the coastal lagoons, which are among the most productive natural systems in Egypt and internationally renowned for their abundant bird life (Egyptian Environmental Affairs Agency, 2010).

In general, the Mediterranean Egyptian coast is highly vulnerable to sea-level rise mainly due to its relative low elevation compared to the land around it (Egyptian Environmental Affairs Agency, 2010). The Nile Delta, consisting of flat, low-lying areas, is one of the most threatened zones (Fig. 24), in which the impacts of climate change will affect water resources, agricultural activities, tourism and human settlements (Egyptian Environmental Affairs Agency, 1999). The Nile Delta is also the most populated Egyptian coastal region as several main towns and cities, such as Alexandria, Port Said, Damietta, and Rosetta, are located on its north coast; they host several millions of population and large investments in industrial, touristic and agricultural activities, as well as the related infrastructure. In addition, the delta undergoes land subsidence that increases from west to east and enhances vulnerability to sea-level rise (Egyptian Environmental Affairs Agency, 2010). However, some areas are protected from inundation by natural systems, such as sand dunes or man-made structures (e.g. the banks of El-Salam Canal and the International Roadway).

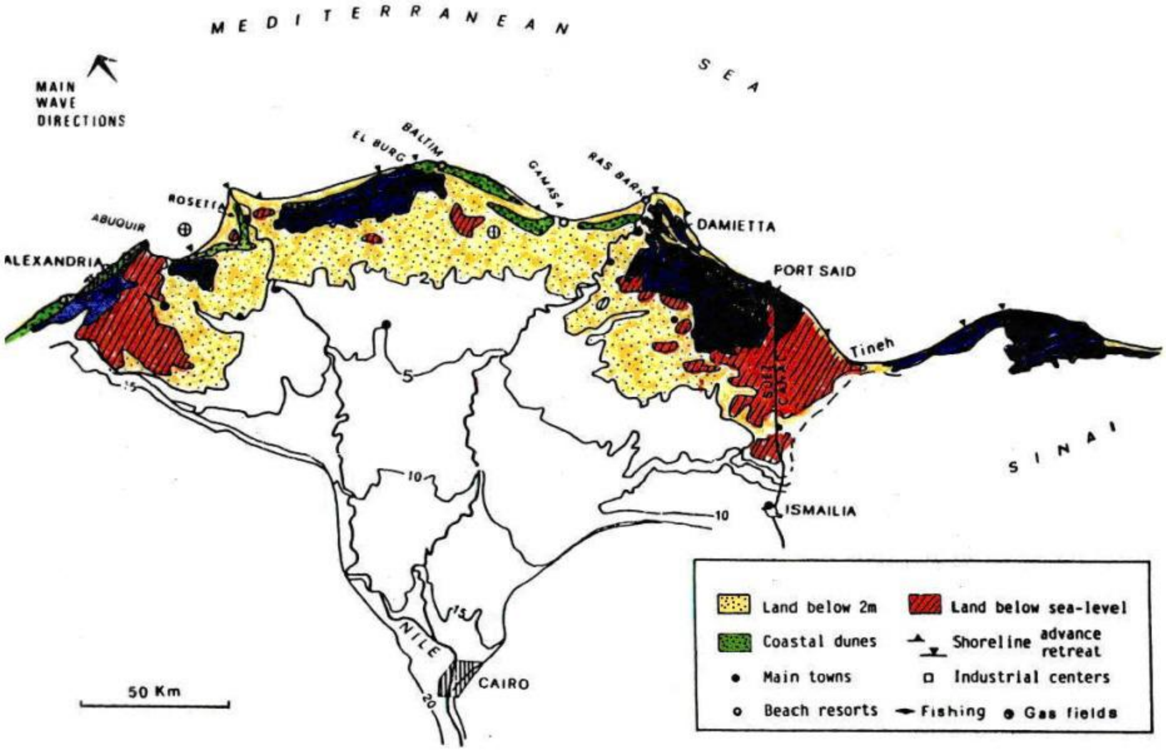


Figure 24: General topography of the Nile Delta indicating areas below mean sea level (El Raey, 2009).

Tide gauges data collected since the first half of the 20th century have revealed an increase of the relative sea level of about 1.6 mm/year at Alexandria, 1.0 mm/year at Al-Burullus and 2.3 mm/year at Port Said (Frihy, 2003) due to both land subsidence and sea-level rise (Fig. 25).

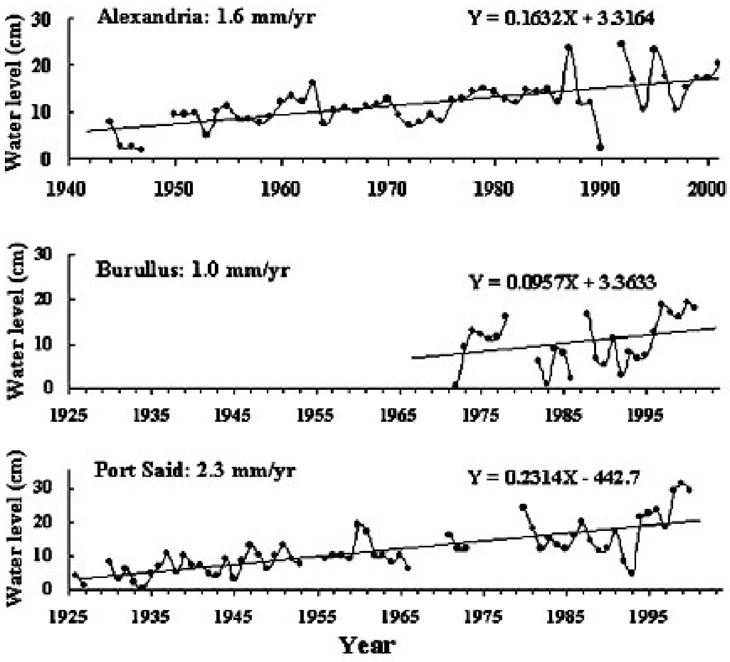


Figure 25: Long term sea-level rise based on mean annual sea levels measured by tide gauges located at Alexandria, Burullus and Port Said (Frihy, 2003).

The present coastal retreat of the delta is worsened by human interventions such as reduced sediment input, groundwater extraction and hard engineering work built along the coastal strip (World Bank, 2005). In particular, the Nile delta coast has experienced severe accelerated erosion since the construction of the Aswan High Dam occurred in 1964 and completed in 1971, mainly due to the entrapment of a large amount of river sediments behind it (Ghoneim et al., 2015). As a consequence, some stretches of the delta coast have been protected by hard structures as well as artificial nourishment that have been carried out along some littorals (Ministry of Water Resources and Irrigation, Coastal Research Institute, the Egyptian Shore Protection Authority, 2009). An example is represented by the Damietta promontory, a fragile costal area subjected to severe erosion, which needs monitoring due to its economic and touristic value; in fact, it includes the elite, historical and favourable resort beach of Ras El-Bar, which has also become a new permanent community for about a quarter of million persons (El-Asmar et al., 2016). Along the Ras El-Bar coast, several defence measures were implemented including two jetties lining the Damietta branch of the Nile River, seawalls, revetments, jetties and detached breakers parallel to shoreline, which

have led to a new pattern of wave reflection (also favoured by Damietta harbour constructions) with consequent erosion and accretion along the coast.
Another possible threat to the Nile delta coast could be represented by earthquake and tsunami events. Highly destructive tsunamis were recorded at a number of locations in the Mediterranean and a few of them are known to have affected Alexandria on the north coast of Egypt (Eckert et al., 2012). Various earthquakes have been also documented for the Egyptian coast, making Alexandria a hazardous place as two fault lines, the Suez-Cairo-Alexandria Line and the Qattara-Eratosthenes Line, converge in the area (Frihy, 2003; Eckert et al., 2012, Pagnoni et al., 2015)

6.2.1 Future trends

Dasgupta et al. (2009a) ranked Egypt in the top ten most impacted countries (out of 84 developing coastal countries considered world-wide) for population potentially displaced under a 1m sea-level rise scenario (considering the existing condition at the time of the study and assuming that there are not defences).
With reference to the Nile Delta, the expected local subsidence will produce a higher increase of relative sea-level rise than that expected by the end of the next century (Egyptian Environmental Affairs Agency, 1999; 2010) (Fig. 26). Analysis of the effects of sea-level rise on some important sites located on the delta coast has shown that, over the next century, an area of about 30% of Alexandria would be lost due to the inundation caused by a sea-level rise of 0.5-1.0 m, if no action is taken (Egyptian Environmental Affairs Agency, 1999; 2010). As regards Port-Said, several studies have pointed out the high vulnerability of the city to sea-level rise; the most affected sectors are expected to be the industrial, transportation and urban sectors. In addition, the increase in frequency and severity of storm surges would definitely wreck all coastal structures. It is noteworthy that in North Africa, Egypt is considered the country that will be most negatively impacted by increasing surges (Fig. 21).

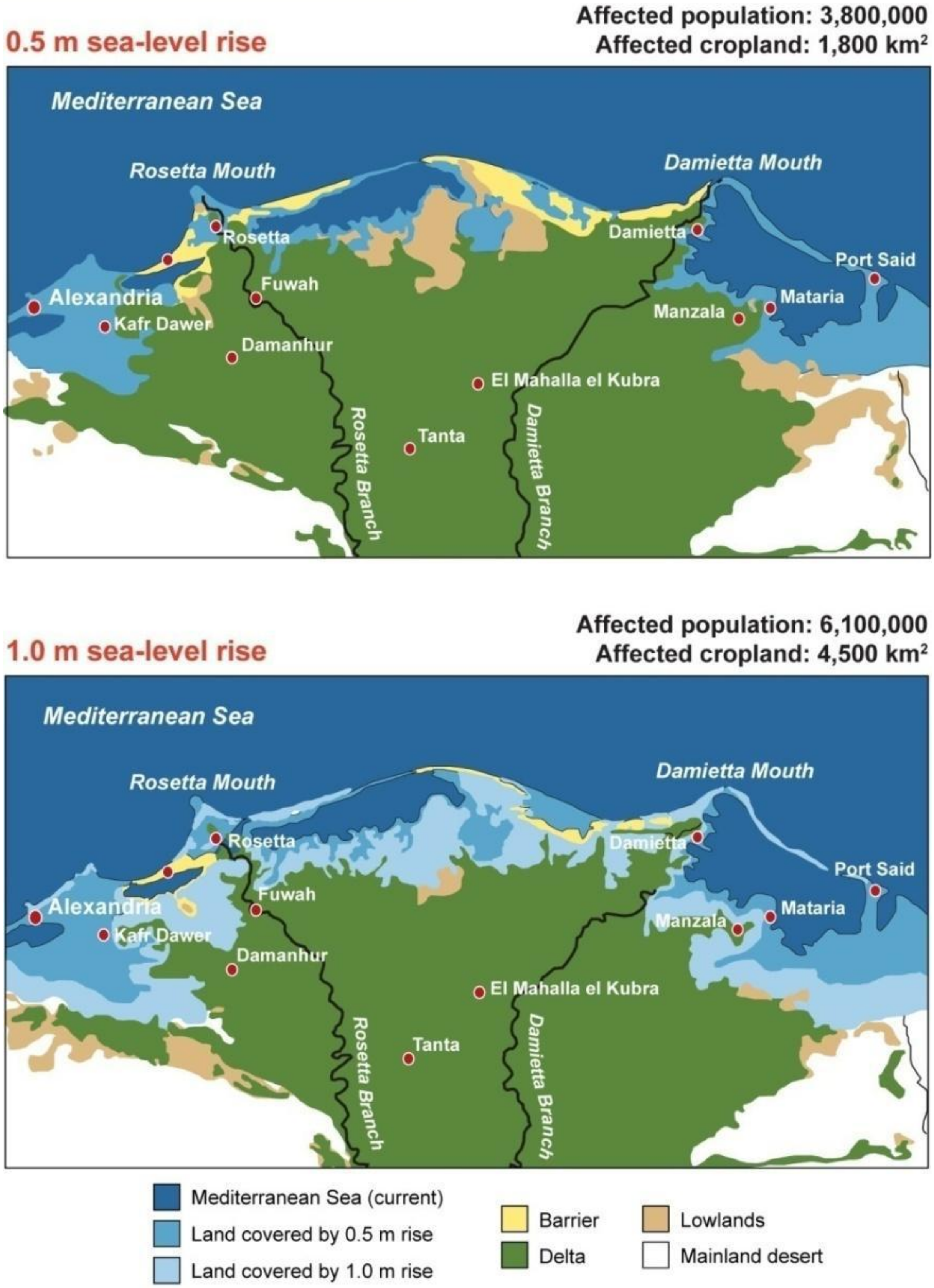


Figure 26: Potential direct inundation of the Nile delta region with two scenarios of sea-level rise indicating vulnerable cities of the delta (Fitzgerald et al., 2008).

Moreover, owing to sea-level rise, saline sea water will penetrate far into the northern delta and weed swamps will disappear (Egyptian Environmental Affairs Agency, 1999; 2010; Ministry of Water Resources and Irrigation, Coastal Research Institute, the Egyptian Shore Protection Authority, 2009). A migration of 6 to 7 million people from the delta coastal areas due to the inundation and loss of fertile lands could occur as a consequence of the impact of the rising sea level on human habitat and settlements (Egyptian Environmental Affairs Agency, 2010).

As regards tourism, sea-level rise on the low elevation Mediterranean coast of Egypt will definitely lead to losses of beaches and increasing water salinization, which will in turn lead to growing health problems and negative impact on tourism. In addition the effects of increasing temperatures and frequencies and severity of extreme events are expected to negatively impact also the archaeological Egyptian heritage and the coast might lose attractiveness (Egyptian Environmental Affairs Agency, 2010).

7. Gaps

In general, the problems occurred during the present analysis have been the scarcity of studies in non-EU countries, irregular and patchy distribution of available information at regional and local scale, and different reference periods for collecting data, which results in a non-homogeneous update of the present conditions of the Mediterranean coasts and their evolutionary trends.

Risk assessment in view of the expected climate change requires continuous monitoring actions along the entire coast at a local level because the impacts vary in relation to the different morphological and lithological characteristics of the littorals, shoreline orientation, and the processes occurring along the coast. This is fundamental to identify how the coast responds to natural processes and anthropogenic pressures and if it is able to counteract and survive the effects of climate change under the same forcing. Unfortunately, this information is not always available and possible scenarios are produced at a too small scale, inadequate to predict possible future coastal trends. So, major gaps persist in the identification of the behaviour of the different coastal stretches and their vulnerability. As a consequence, further studies are necessary to provide the missing information necessary for the correct planning and management of the littorals.

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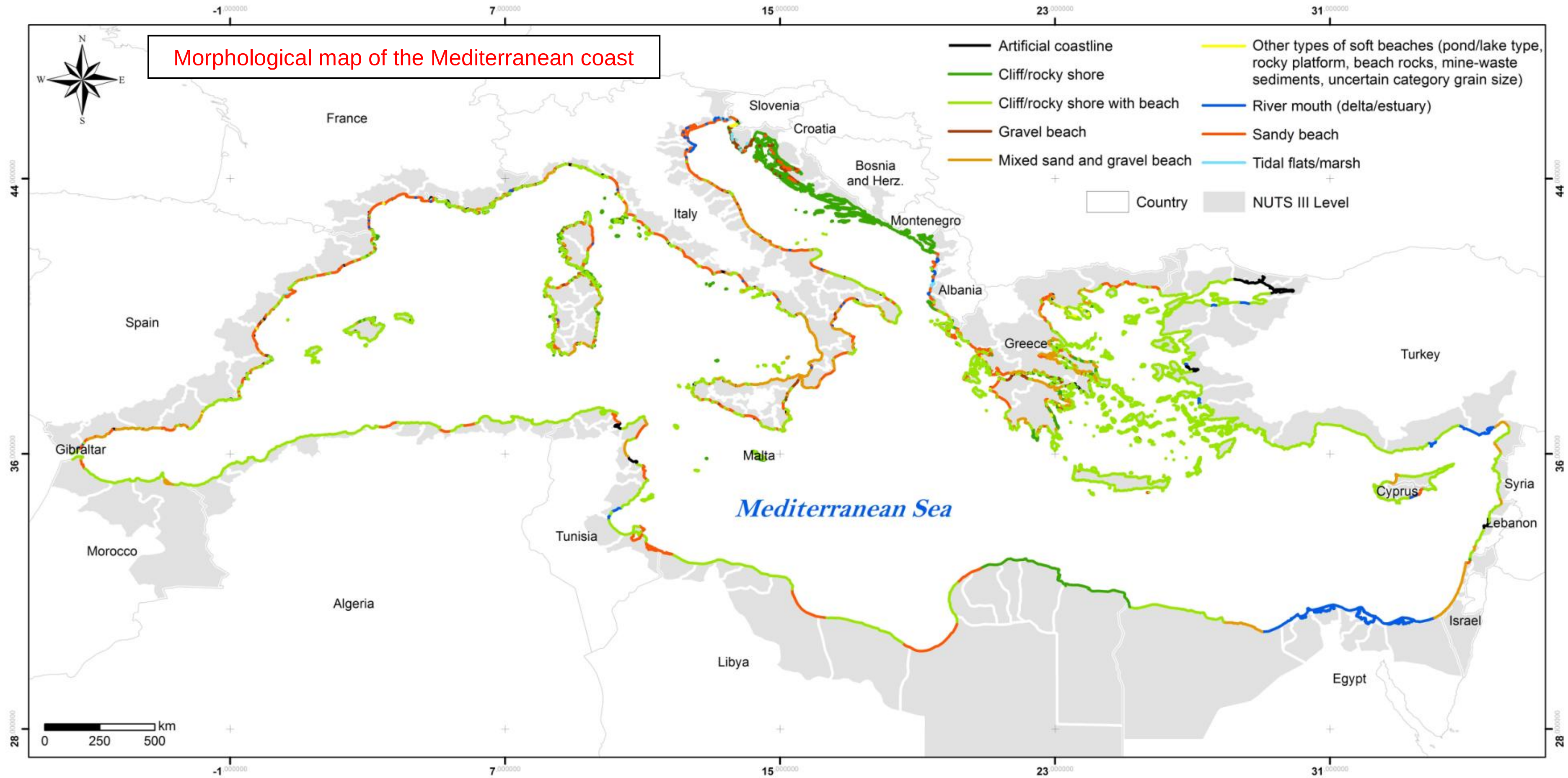
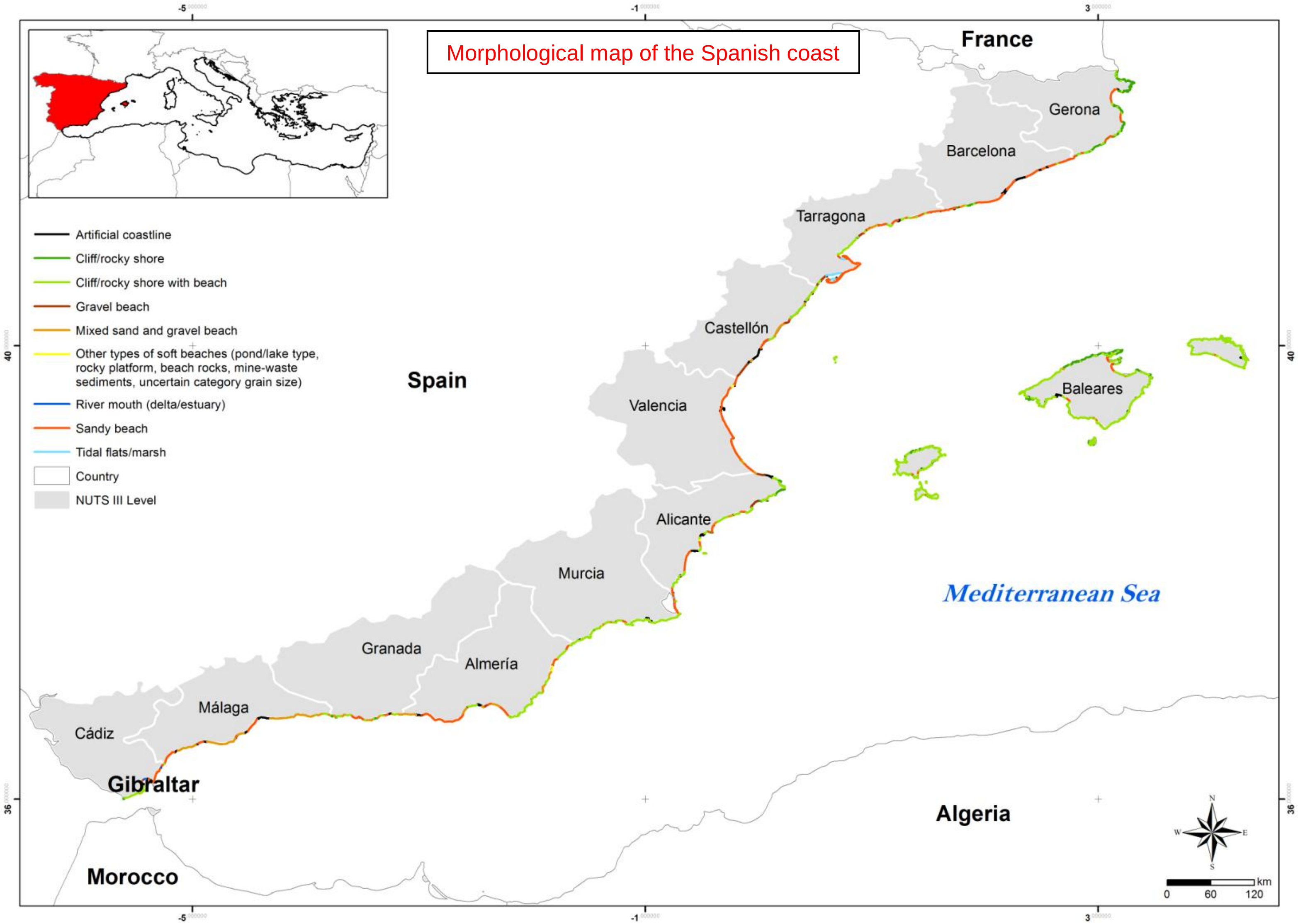
Annex 1 - The morphological maps of the Mediterranean coasts

Mediterranean coast



Spain


Morphological map of the Spanish coast
France
Gerona
Barcelona
Tarragona
Castellón
Valencia
Spain
Alicante
Murcia
Granada
Almería
Málaga
Cádiz
Gibraltar
Morocco
Algeria
Baleares
Mediterranean Sea
Artificial coastline
Cliff/rocky shore
Cliff/rocky shore with beach
Gravel beach
Mixed sand and gravel beach
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)
River mouth (delta/estuary)
Sandy beach
Tidal flats/marsh
Country
NUTS III Level
km
0
60
120

Cadiz

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	21,70	33
Sandy beach	27,36	41
River mouth (delta/estuary)	2,02	3
Cliff/rocky shore with beach	15,31	23

Malaga

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	36,09	20
Cliff/rocky shore	1,23	1
Sandy beach	38,94	22
Cliff/rocky shore with beach	14,80	8
Mixed sand and gravel beach	89,72	50

Granada

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	9,51	12
Cliff/rocky shore	11,74	15
Sandy beach	16,76	21
Cliff/rocky shore with beach	21,97	28
Mixed sand and gravel beach	18,14	23

Almeria

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	24,35	10
Gravel beach	9,76	4
Sandy beach	73,77	31
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	6,04	3
Cliff/rocky shore with beach	85,99	37
Mixed sand and gravel beach	35,43	15

Murcia

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	21,36	12
Cliff/rocky shore	4,43	2
Tidal flats/marsh	6,54	4
Sandy beach	35,71	20
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	0,90	0
Cliff/rocky shore with beach	114,12	62

Alicante

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	52,92	21
Cliff/rocky shore	30,26	12
Gravel beach	18,82	7
Sandy beach	48,45	19
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	1,75	1
Cliff/rocky shore with beach	94,88	37
Mixed sand and gravel beach	6,36	3

Valencia

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	29,55	22
Cliff/rocky shore	1,46	1
Gravel beach	1,66	1
Sandy beach	95,26	72
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	1,78	1
Mixed sand and gravel beach	3,43	3

Castellon

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	35,69	25
Cliff/rocky shore	2,34	2
Gravel beach	23,41	16
Sandy beach	19,08	13
Cliff/rocky shore with beach	47,32	33
Mixed sand and gravel beach	16,43	11

Tarragona

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	29,14	12
Cliff/rocky shore	1,02	0
Gravel beach	15,96	6
Tidal flats/marsh	29,99	12
Sandy beach	116,42	47
Cliff/rocky shore with beach	46,02	19
Mixed sand and gravel beach	8,51	3

Barcelona

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	51,84	35
Cliff/rocky shore	11,23	7
Gravel beach	2,19	1
Sandy beach	78,11	52
Cliff/rocky shore with beach	3,14	2
Mixed sand and gravel beach	3,43	2

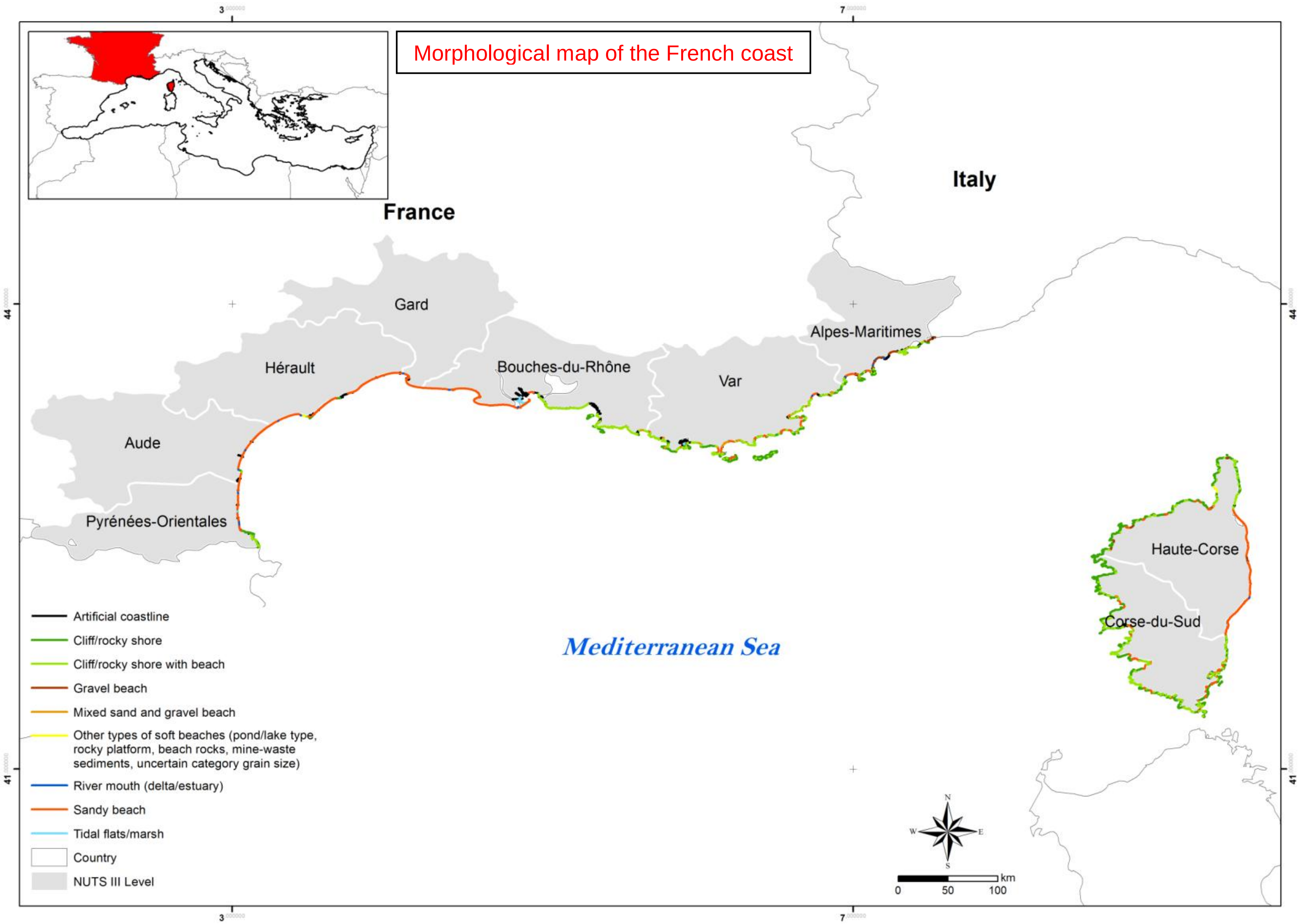
Gerona

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	3,94	2
Cliff/rocky shore	135,90	72
Sandy beach	37,11	20
Cliff/rocky shore with beach	11,61	6

Baleares

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	54,40	5
Cliff/rocky shore	151,42	14
Gravel beach	2,13	0
Sandy beach	42,59	4
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	10,84	1
Cliff/rocky shore with beach	801,35	75
Mixed sand and gravel beach	1,19	0

France


Morphological map of the French coast
France
Italy
Gard
Hérault
Aude
Pyrénées-Orientales
Bouches-du-Rhône
Var
Alpes-Maritimes
Haute-Corse
Corse-du-Sud
Mediterranean Sea
Artificial coastline
Cliff/rocky shore
Cliff/rocky shore with beach
Gravel beach
Mixed sand and gravel beach
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)
River mouth (delta/estuary)
Sandy beach
Tidal flats/marsh
Country
NUTS III Level
km
0
50
100

Pyrènées-Orientales

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	17,10	20
Cliff/rocky shore	26,65	31
Tidal flats/marsh	3,41	4
Sandy beach	29,42	34
River mouth (delta/estuary)	1,19	1
Cliff/rocky shore with beach	8,65	10

Aude

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	25,11	34
Cliff/rocky shore	3,41	5
Sandy beach	44,72	61
River mouth (delta/estuary)	0,34	0
Cliff/rocky shore with beach	0,21	0

Hérault

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	35,25	29
Cliff/rocky shore	4,95	4
Sandy beach	77,09	64
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	2,42	2
River mouth (delta/estuary)	0,49	0
Cliff/rocky shore with beach	0,33	0

Gard

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	9,43	33
Sandy beach	18,77	67

Bouches-du-Rhone

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	136,71	35
Cliff/rocky shore	44,68	11
Gravel beach	0,47	0
Tidal flats/marsh	20,03	5
Sandy beach	80,87	21
River mouth (delta/estuary)	1,11	0
Cliff/rocky shore with beach	106,29	27
Mixed sand and gravel beach	1,00	0

Var

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	120,25	25
Cliff/rocky shore	202,07	42
Gravel beach	0,97	0
Tidal flats/marsh	1,05	0
Sandy beach	45,43	9
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	1,73	0
River mouth (delta/estuary)	0,38	0
Cliff/rocky shore with beach	100,39	21
Mixed sand and gravel beach	10,95	2

Alpes-Maritimes

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	86,43	46
Cliff/rocky shore	43,90	23
Gravel beach	22,04	12
Sandy beach	9,79	5
River mouth (delta/estuary)	0,77	0
Cliff/rocky shore with beach	24,93	13
Mixed sand and gravel beach	1,07	1

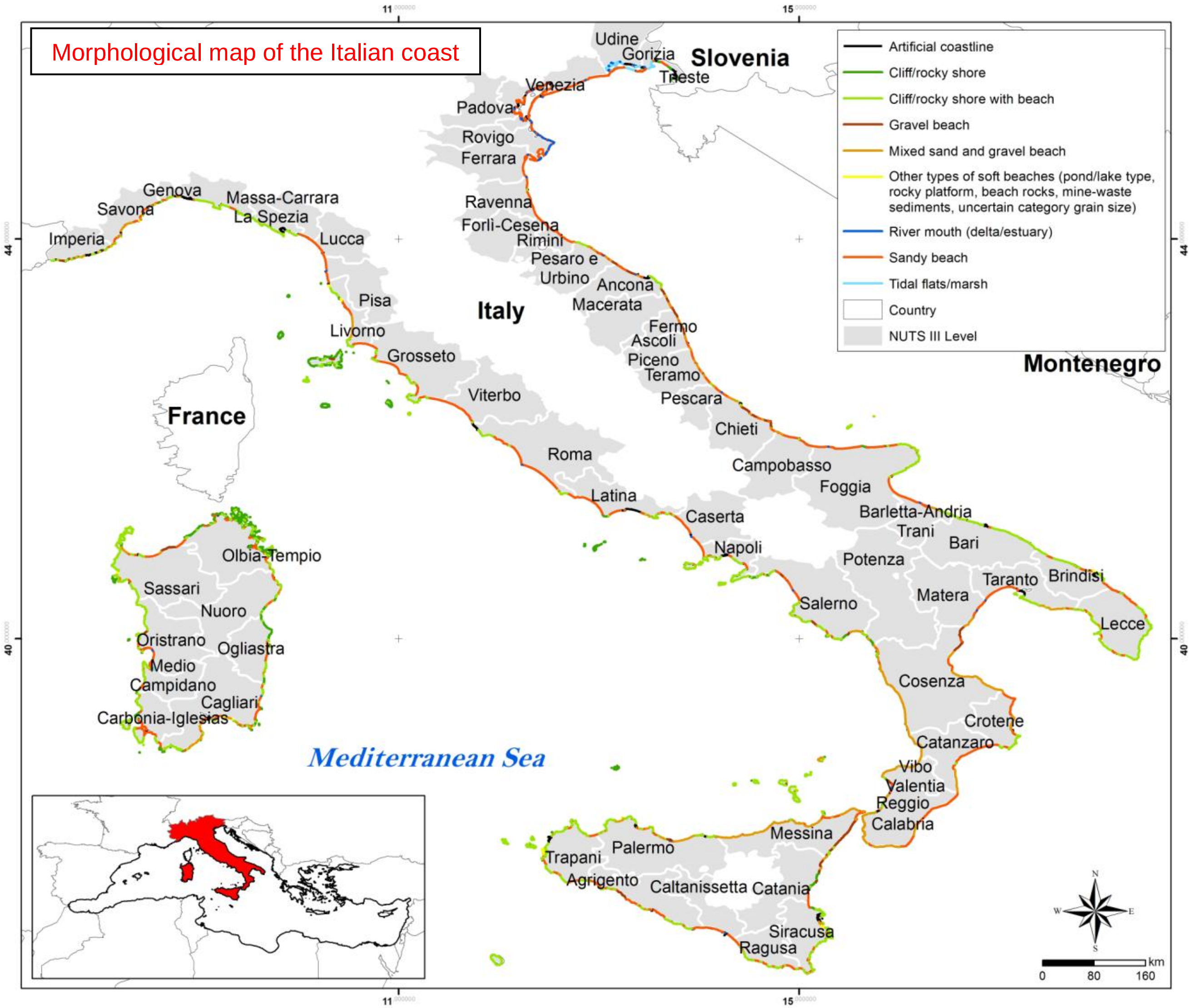
Haute-Corse

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	16,81	4
Cliff/rocky shore	226,98	57
Gravel beach	12,46	3
Sandy beach	103,71	26
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	3,99	1
River mouth (delta/estuary)	0,28	0
Cliff/rocky shore with beach	34,55	9
Mixed sand and gravel beach	0,85	0

Corse-du-Sud

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	16,34	3
Cliff/rocky shore	442,33	69
Tidal flats/marsh	1,19	0
Sandy beach	48,74	8
River mouth (delta/estuary)	0,50	0
Cliff/rocky shore with beach	134,37	21
Mixed sand and gravel beach	2,24	0

Italy


Morphological map of the Italian coast
Artificial coastline
Cliff/rocky shore
Cliff/rocky shore with beach
Gravel beach
Mixed sand and gravel beach
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)
River mouth (delta/estuary)
Sandy beach
Tidal flats/marsh
Country
NUTS III Level
Slovenia
Montenegro
France
Italy
Mediterranean Sea
Udine
Gorizia
Trieste
Venezia
Padova
Rovigo
Ferrara
Ravenna
Forlì-Cesena
Rimini
Pesaro e Urbino
Ancona
Macerata
Fermo
Ascoli Piceno
Teramo
Pescara
Chieti
Campobasso
Foggia
Barletta-Andria Trani
Bari
Brindisi
Taranto
Lecce
Matera
Potenza
Salerno
Napoli
Caserta
Latina
Roma
Viterbo
Grosseto
Livorno
Pisa
Lucca
Massa-Carrara
La Spezia
Genova
Savona
Imperia
Olbia-Tempio
Sassari
Nuoro
Oristrano
Ogliastra
Medio Campidano
Cagliari
Carbonia-Iglesias
Cosenza
Crotone
Catanzaro
Vibo Valentia
Reggio Calabria
Messina
Palermo
Trapani
Agrigento
Caltanissetta
Catania
Siracusa
Ragusa
N
S
E
W
0
80
160
km
11
15
44
40

Imperia

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	29,69	41
Gravel beach	14,94	21
Sandy beach	5,53	8
Cliff/rocky shore with beach	19,29	27
Mixed sand and gravel beach	2,12	3

Savona

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	21,83	26
Cliff/rocky shore	5,84	7
Gravel beach	5,07	6
Sandy beach	26,36	32
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	0,48	1
River mouth (delta/estuary)	0,42	1
Cliff/rocky shore with beach	8,47	10
Mixed sand and gravel beach	14,96	18

Genova

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	37,14	32
Gravel beach	2,41	2
Sandy beach	15,12	13
Cliff/rocky shore with beach	61,06	53

La Spezia

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	26,49	29
Gravel beach	3,39	4
Sandy beach	5,61	6
River mouth (delta/estuary)	0,77	1
Cliff/rocky shore with beach	54,49	60

Massa Carrara

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	2,14	16
Sandy beach	11,18	84

Lucca

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	4,64	19
Sandy beach	19,95	81

Pisa

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	1,30	4
Cliff/rocky shore	2,28	8
Sandy beach	25,99	86
River mouth (delta/estuary)	0,61	2

Livorno

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	16,97	5
Cliff/rocky shore	182,16	54
Gravel beach	2,74	1
Sandy beach	37,91	11
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	6,75	2
Cliff/rocky shore with beach	65,78	20
Mixed sand and gravel beach	22,08	7

Grosseto

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	5,95	3
Cliff/rocky shore	27,48	15
Sandy beach	85,59	45
Cliff/rocky shore with beach	69,64	37

Viterbo

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	0,38	1
Sandy beach	34,65	96
Cliff/rocky shore with beach	1,23	3

Roma

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	14,01	10
Gravel beach	2,61	2
Sandy beach	97,41	70
River mouth (delta/estuary)	0,25	0
Cliff/rocky shore with beach	23,97	17

Latina

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	27,18	16
Cliff/rocky shore	59,68	36
Gravel beach	1,24	1
Sandy beach	60,29	36
Cliff/rocky shore with beach	16,13	10
Mixed sand and gravel beach	2,34	1

Caserta

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	3,94	9
Sandy beach	36,37	88
River mouth (delta/estuary)	0,48	1
Cliff/rocky shore with beach	0,73	2

Napoli

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	40,66	18
Cliff/rocky shore	0,62	0
Sandy beach	42,96	19
Cliff/rocky shore with beach	140,72	62
Mixed sand and gravel beach	0,55	0

Salerno

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	2,85	1
Cliff/rocky shore	40,15	20
Gravel beach	26,61	13
Sandy beach	49,13	25
River mouth (delta/estuary)	0,17	0
Cliff/rocky shore with beach	69,06	35
Mixed sand and gravel beach	9,66	5

Potenza

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	0,68	3
Cliff/rocky shore	13,55	65
Gravel beach	0,62	3
Cliff/rocky shore with beach	3,67	18
Mixed sand and gravel beach	2,28	11

Cosenza

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	1,64	1
Cliff/rocky shore	9,08	4
Gravel beach	32,22	14
Sandy beach	28,96	13
River mouth (delta/estuary)	0,68	0
Cliff/rocky shore with beach	4,98	2
Mixed sand and gravel beach	149,91	66

Catanzaro

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	3,79	4
Sandy beach	45,96	43
River mouth (delta/estuary)	0,27	0
Cliff/rocky shore with beach	1,15	1
Mixed sand and gravel beach	55,43	52

Vibo Valentia

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	3,99	6
Cliff/rocky shore	6,11	9
Gravel beach	6,77	10
Sandy beach	10,29	15
River mouth (delta/estuary)	0,70	1
Cliff/rocky shore with beach	7,01	10
Mixed sand and gravel beach	34,37	50

Reggio Calabria

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	12,02	6
Cliff/rocky shore	10,83	5
Gravel beach	0,38	0
Sandy beach	84,10	42
River mouth (delta/estuary)	0,34	0
Cliff/rocky shore with beach	6,96	3
Mixed sand and gravel beach	86,76	43

Crotone

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	4,67	4
Sandy beach	60,48	53
River mouth (delta/estuary)	0,21	0
Cliff/rocky shore with beach	32,09	28
Mixed sand and gravel beach	15,99	14

Matera

Coastal morphology	Length (km)	Coast type (%)
Gravel beach	1,16	3
Sandy beach	22,61	61
River mouth (delta/estuary)	0,99	3
Mixed sand and gravel beach	12,32	33

Taranto

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	15,46	13
Cliff/rocky shore	0,89	1
Sandy beach	40,35	33
Cliff/rocky shore with beach	50,99	41
Mixed sand and gravel beach	15,22	12

Lecce

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	1,97	1
Cliff/rocky shore	1,49	1
Sandy beach	63,65	28
Cliff/rocky shore with beach	157,52	69
Mixed sand and gravel beach	4,68	2

Brindisi

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	14,24	14
Sandy beach	34,36	33
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	3,99	4
Cliff/rocky shore with beach	51,93	50

Bari

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	24,98	23
Sandy beach	3,61	3
Cliff/rocky shore with beach	77,98	73

Barletta

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	10,39	16
Sandy beach	32,34	49
River mouth (delta/estuary)	0,21	0
Cliff/rocky shore with beach	14,07	22
Mixed sand and gravel beach	8,39	13

Foggia

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	6,98	4
Cliff/rocky shore	5,71	3
Gravel beach	7,63	4
Sandy beach	93,77	48
River mouth (delta/estuary)	0,40	0
Cliff/rocky shore with beach	80,72	41

Campobasso

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	1,14	3
Gravel beach	2,85	7
Sandy beach	29,81	76
Cliff/rocky shore with beach	0,73	2
Mixed sand and gravel beach	4,85	12

Chieti

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	10,90	14
Cliff/rocky shore	3,78	5
Gravel beach	32,52	43
Sandy beach	15,76	21
Cliff/rocky shore with beach	2,12	3
Mixed sand and gravel beach	11,35	15

Pescara

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	0,41	3
Sandy beach	11,91	85
River mouth (delta/estuary)	0,26	2
Mixed sand and gravel beach	1,51	11

Teramo

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	3,35	7
Gravel beach	1,48	3
Sandy beach	29,43	60
Cliff/rocky shore with beach	3,36	7
Mixed sand and gravel beach	11,33	23

Ascoli Piceno

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	3,95	18
Gravel beach	6,66	30
Sandy beach	7,70	35
Mixed sand and gravel beach	3,53	16

Fermo

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	1,73	6
Gravel beach	17,66	65
Sandy beach	6,61	24
Mixed sand and gravel beach	1,33	5

Macerata

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	1,08	5
Gravel beach	13,48	60
Sandy beach	2,29	10
Mixed sand and gravel beach	5,57	25

Ancona

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	17,43	26
Gravel beach	15,84	24
Sandy beach	11,60	17
River mouth (delta/estuary)	0,36	1
Cliff/rocky shore with beach	20,27	30
Mixed sand and gravel beach	1,33	2

Pesaro - Urbino

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	4,13	9
Gravel beach	11,00	24
Sandy beach	11,10	24
River mouth (delta/estuary)	0,52	1
Cliff/rocky shore with beach	12,86	28
Mixed sand and gravel beach	6,83	15

Rimini

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	2,61	7
Sandy beach	33,63	93

Forlì - Cesena

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	0,37	4
Sandy beach	8,53	94
River mouth (delta/estuary)	0,13	1

Ravenna

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	1,54	3
Sandy beach	45,70	93
River mouth (delta/estuary)	0,49	1
Cliff/rocky shore with beach	1,19	2

Ferrara

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	0,60	1
Sandy beach	70,15	98
River mouth (delta/estuary)	1,01	1

Rovigo

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	69,73	87
River mouth (delta/estuary)	10,67	13

Venezia

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	98,11	31
Sandy beach	206,10	66
River mouth (delta/estuary)	9,63	3

Padova

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	0,88	6
Sandy beach	13,47	94

Udine

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	25,43	14
Tidal flats/marsh	135,61	72
Sandy beach	16,38	9
River mouth (delta/estuary)	10,94	6

Gorizia

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	15,27	29
Tidal flats/marsh	25,05	47
Sandy beach	10,85	21
River mouth (delta/estuary)	1,68	3

Trieste

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	32,65	67
Cliff/rocky shore	10,75	22
Tidal flats/marsh	0,21	0
Sandy beach	4,06	8
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	0,96	2

Messina

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	11,32	3
Cliff/rocky shore	15,20	4
Gravel beach	62,11	16
Tidal flats/marsh	0,36	0
Sandy beach	45,91	12
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	3,00	1
Cliff/rocky shore with beach	123,53	32
Mixed sand and gravel beach	125,49	32

Catania

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	8,01	12
Cliff/rocky shore	24,35	36
Gravel beach	16,67	25
Sandy beach	14,15	21
River mouth (delta/estuary)	0,22	0
Cliff/rocky shore with beach	0,76	1
Mixed sand and gravel beach	3,38	5

Siracusa

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	44,23	20
Cliff/rocky shore	7,83	4
Gravel beach	2,19	1
Sandy beach	60,62	28
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	5,40	2
Cliff/rocky shore with beach	94,48	43
Mixed sand and gravel beach	4,81	2

Ragusa

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	2,31	3
Sandy beach	60,19	66
Cliff/rocky shore with beach	28,50	31

Caltanissetta

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	13,47	34
Sandy beach	25,98	66
River mouth (delta/estuary)	0,18	0

Agrigento

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	19,90	10
Cliff/rocky shore	10,50	5
Gravel beach	15,79	8
Sandy beach	70,26	35
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	6,82	3
Cliff/rocky shore with beach	73,31	37
Mixed sand and gravel beach	2,42	1

Trapani

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	36,23	11
Cliff/rocky shore	5,31	2
Gravel beach	0,65	0
Sandy beach	54,46	17
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	20,77	6
Cliff/rocky shore with beach	204,12	63
Mixed sand and gravel beach	2,39	1

Palermo

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	24,91	12
Cliff/rocky shore	20,12	10
Gravel beach	9,14	5
Tidal flats/marsh	0,94	0
Sandy beach	26,44	13
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	1,68	1
Cliff/rocky shore with beach	85,37	42
Mixed sand and gravel beach	33,11	16

Olbia

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	18,72	3
Cliff/rocky shore	434,59	76
Gravel beach	2,25	0
Sandy beach	57,01	10
Cliff/rocky shore with beach	59,96	10
Mixed sand and gravel beach	1,37	0

Nuoro

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	2,27	3
Cliff/rocky shore	20,98	32
Sandy beach	19,60	30
Cliff/rocky shore with beach	16,23	25
Mixed sand and gravel beach	5,80	9

Ogliastra

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	2,57	3
Cliff/rocky shore	50,68	52
Gravel beach	1,81	2
Sandy beach	20,28	21
Cliff/rocky shore with beach	20,97	21
Mixed sand and gravel beach	1,88	2

Cagliari

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	23,63	9
Cliff/rocky shore	80,51	30
Gravel beach	1,78	1
Sandy beach	71,06	26
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	14,56	5
River mouth (delta/estuary)	0,38	0
Cliff/rocky shore with beach	54,92	20
Mixed sand and gravel beach	25,78	9

Carbonia-Iglesias

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	11,59	6
Cliff/rocky shore	12,90	6
Sandy beach	70,78	36
Cliff/rocky shore with beach	103,53	52

Medio Campidano

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	5,85	8
Tidal flats/marsh	7,00	10
Sandy beach	17,50	25
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	2,66	4
Cliff/rocky shore with beach	38,30	54

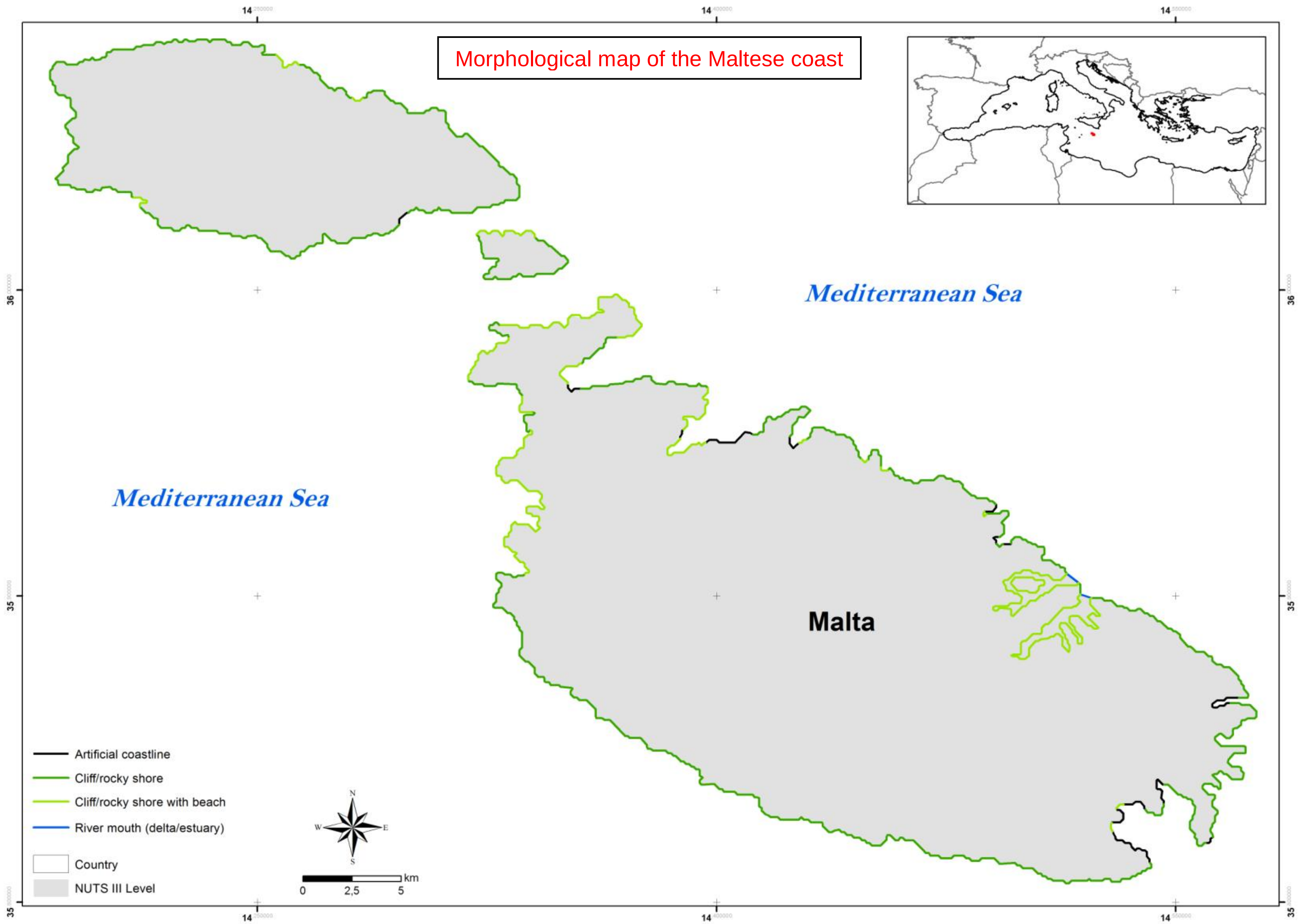
Oristano

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	1,35	1
Cliff/rocky shore	8,79	5
Gravel beach	6,05	4
Tidal flats/marsh	8,86	6
Sandy beach	59,72	37
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	1,54	1
River mouth (delta/estuary)	0,73	0
Cliff/rocky shore with beach	73,55	46

Sassari

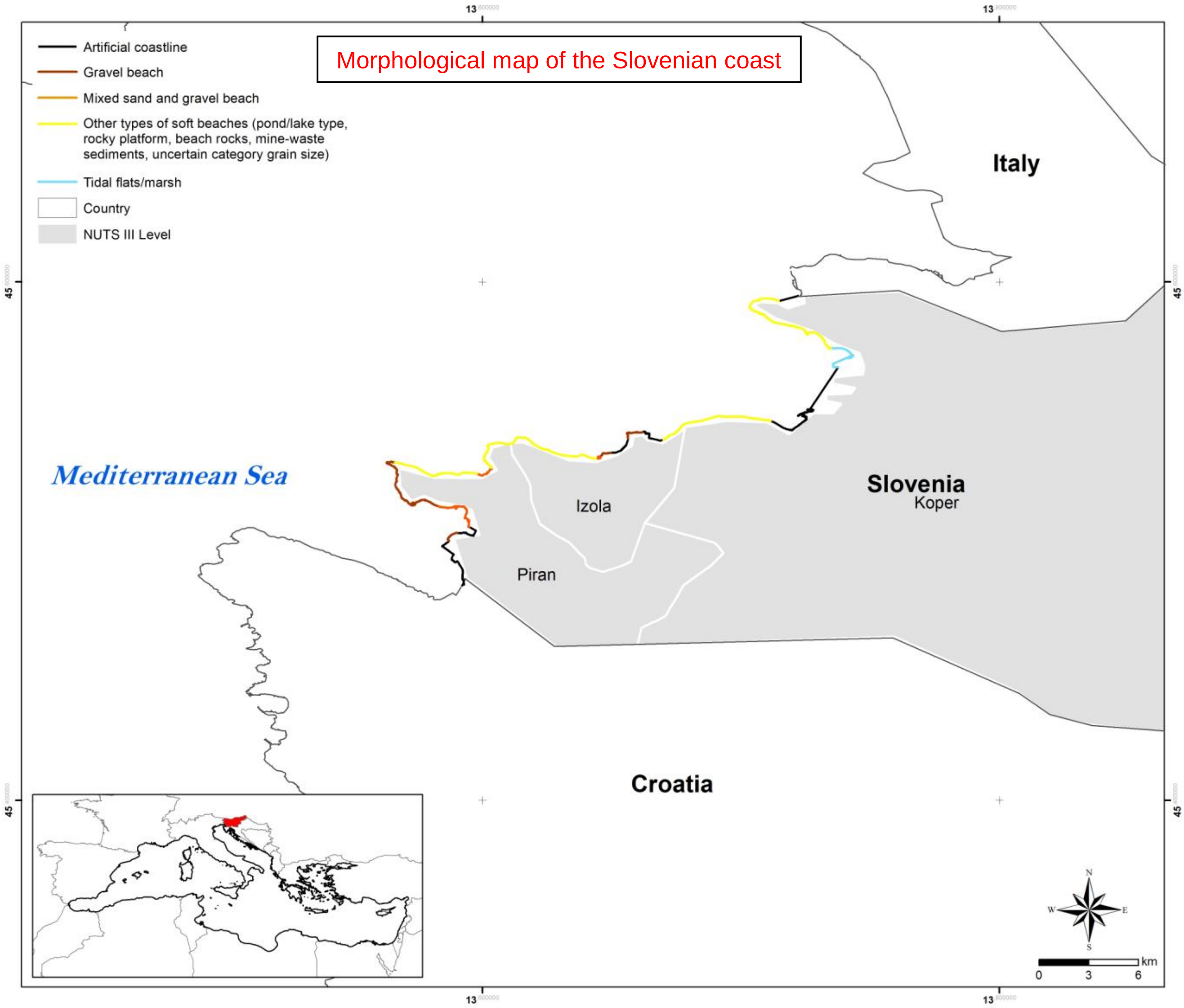
Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	11,56	4
Cliff/rocky shore	30,61	10
Gravel beach	17,45	6
Sandy beach	31,67	11
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	6,77	2
Cliff/rocky shore with beach	183,69	62
Mixed sand and gravel beach	12,94	4

Malta


Morphological map of the Maltese coast
Mediterranean Sea
Mediterranean Sea
Malta
Artificial coastline
Cliff/rocky shore
Cliff/rocky shore with beach
River mouth (delta/estuary)
Country
NUTS III Level
N
S
W
E
0
2,5
5
km

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	12,16	6
Cliff/rocky shore	126,64	65
River mouth (delta/estuary)	0,83	0
Cliff/rocky shore with beach	56,21	29

Slovenia


Morphological map of the Slovenian coast
Artificial coastline
Gravel beach
Mixed sand and gravel beach
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)
Tidal flats/marsh
Country
NUTS III Level
Italy
Mediterranean Sea
Slovenia
Koper
Izola
Piran
Croatia
N
W
E
S
0
3
6
km

Koper

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	5,45	6
Tidal flats/marsh	2,11	2
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	7,05	7
Cliff/rocky shore	81,74	85

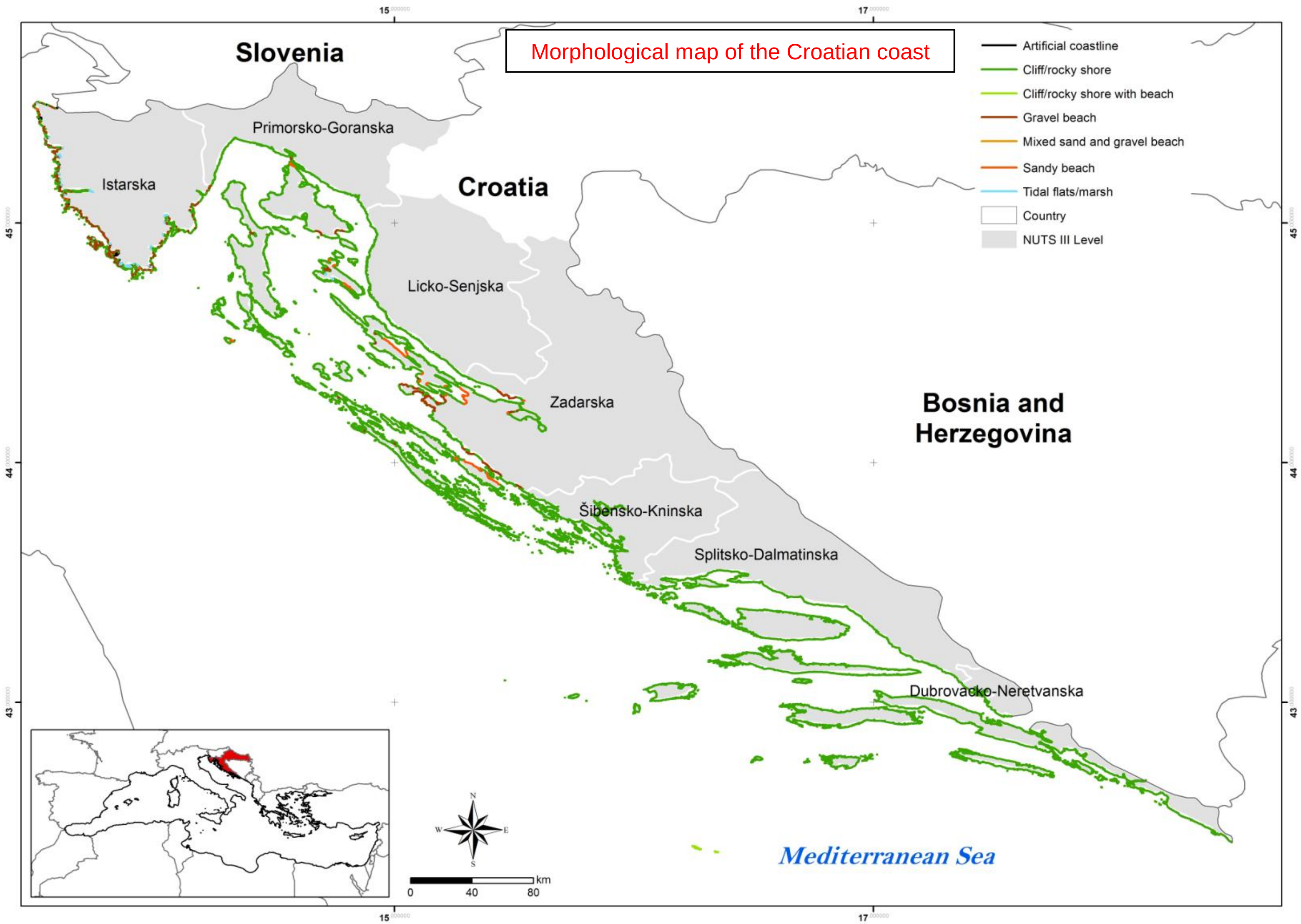
Izola

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	1,83	25
Gravel beach	1,36	19
Sandy beach	0,31	4
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	3,71	51

Piran

Coastal morphology	Length (km)	Coast type (%)
Gravel beach	4,47	36
Sandy beach	2,97	24
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	4,81	39

Croatia


Morphological map of the Croatian coast
Slovenia
Croatia
Bosnia and Herzegovina
Primorsko-Goranska
Istarska
Licko-Senjska
Zadarska
Šibensko-Kninska
Splitsko-Dalmatinska
Dubrovacko-Neretvanska
Mediterranean Sea
Artificial coastline
Cliff/rocky shore
Cliff/rocky shore with beach
Gravel beach
Mixed sand and gravel beach
Sandy beach
Tidal flats/marsh
Country
NUTS III Level
km
0
40
80
15
17
45
44
43

Istarska

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	77,61	15
Cliff/rocky shore	389,78	74
Gravel beach	43,06	8
Tidal flats/marsh	17,54	3
Sandy beach	1,20	0

Primorsko-Goranska

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	1084,32	97
Gravel beach	13,53	1
Tidal flats/marsh	2,42	0
Sandy beach	12,98	1

Licko-Senjska

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	467,61	94
Gravel beach	13,65	3
Sandy beach	18,83	4

Zadarska

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	983,91	91
Gravel beach	58,30	5
Sandy beach	35,97	3

Sibensko-Kninska

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	809,64	100

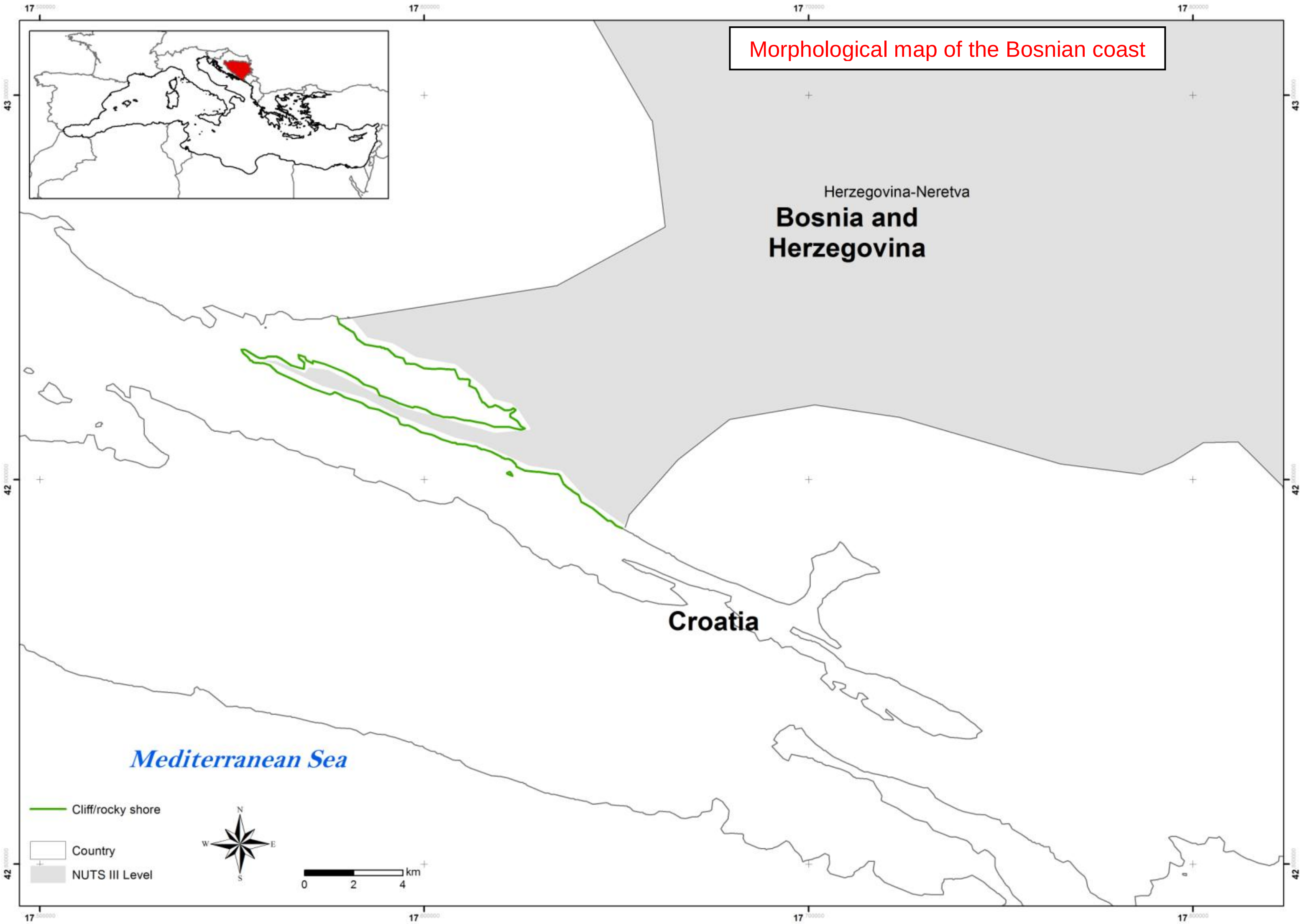
Splitsko-Dalmatinska

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	989,81	100

Dubrovacko-Neretvanska

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	1022,27	99
Cliff/rocky shore with beach	13,54	1

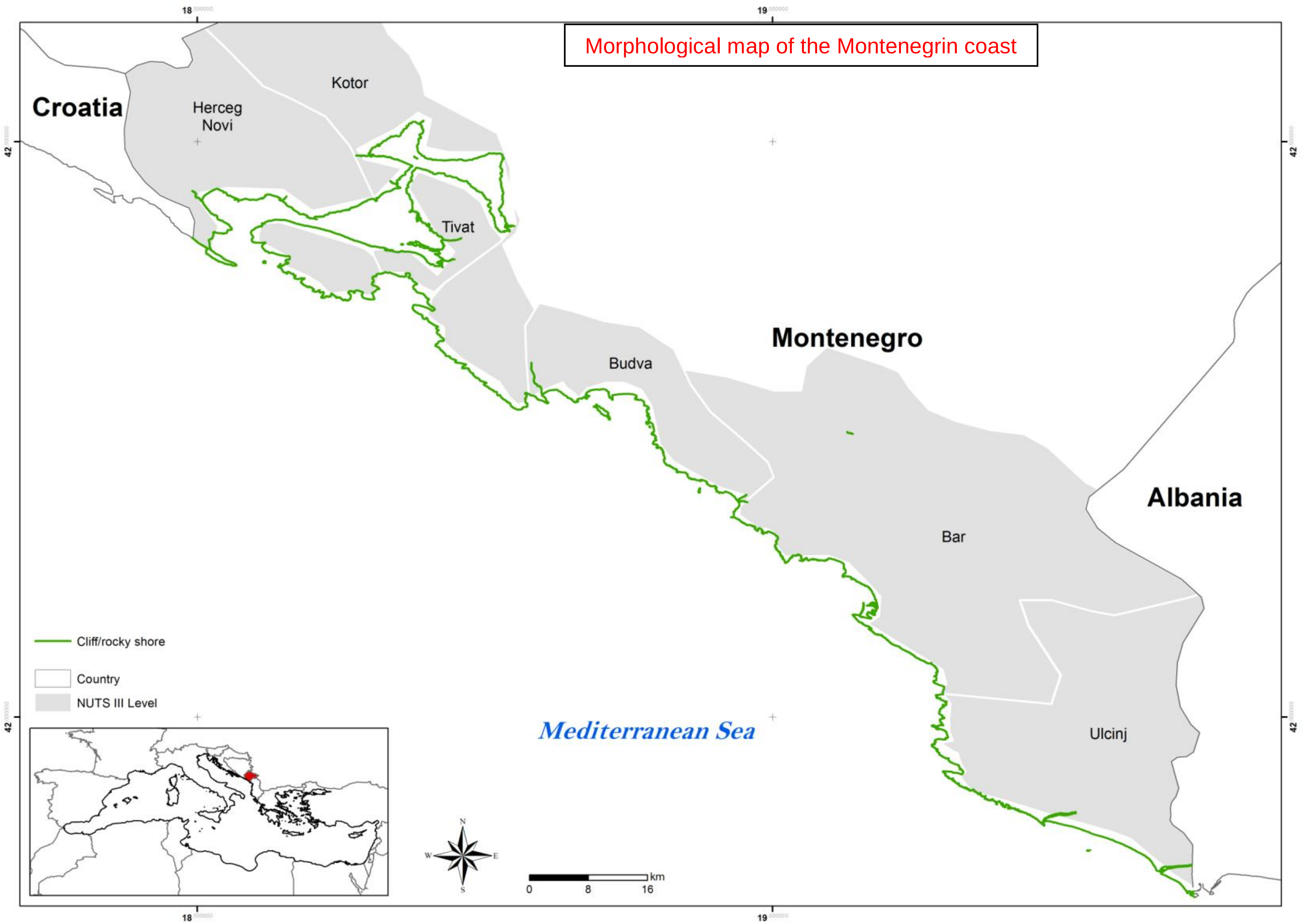
Bosnia and Herzegovina



Herzegovina-Neretva

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	24,12	100

Montenegro


Morphological map of the Montenegrin coast
Croatia
Herceg
Novi
Kotor
Tivat
Budva
Montenegro
Bar
Albania
Ulcinj
Mediterranean Sea
Cliff/rocky shore
Country
NUTS III Level
km
0
8
16
18
19
42

Herceg Novi

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	77,22	100

Tivat

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	48,72	100

Kotor

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	81,74	100

Budva

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	50,91	100

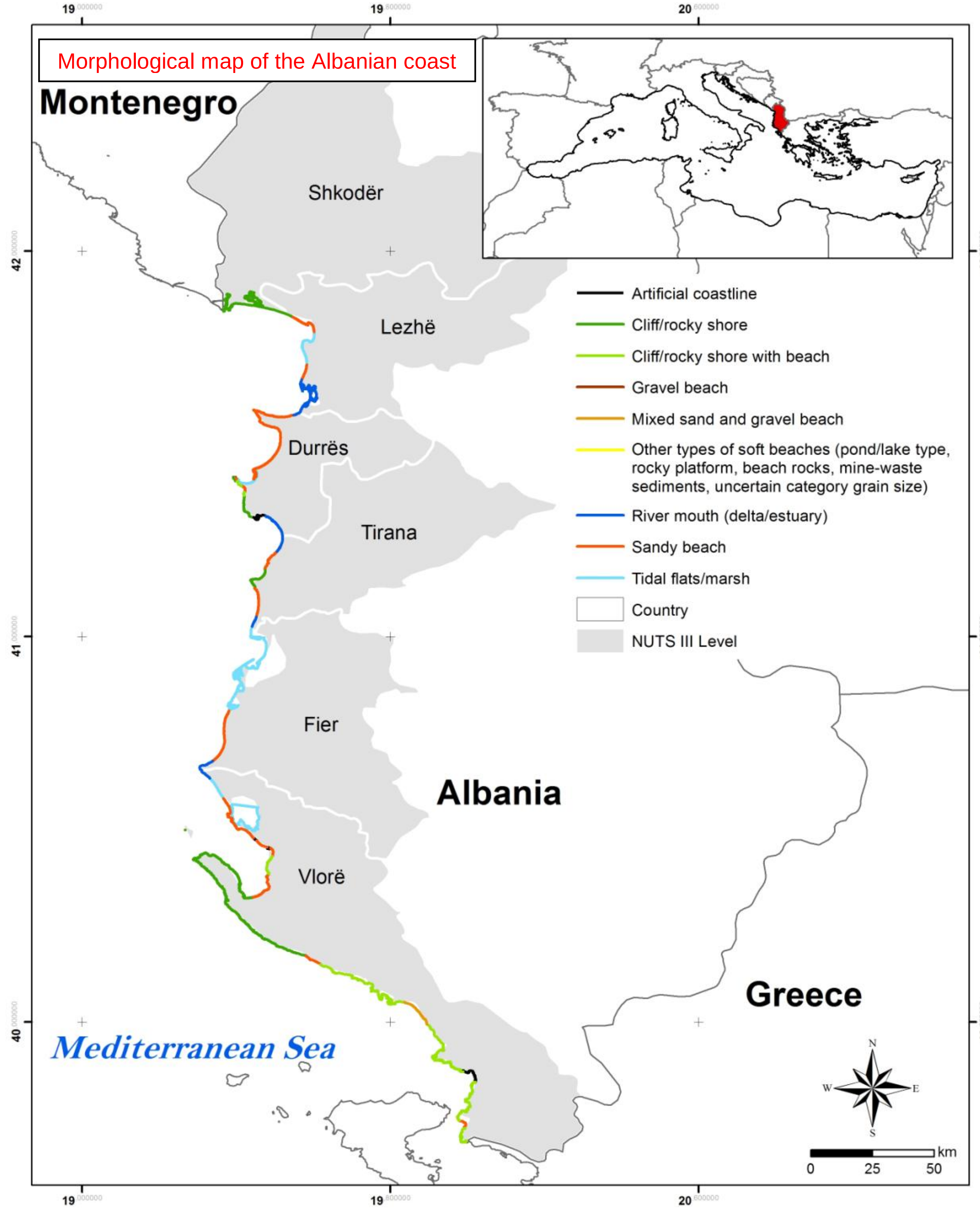
Bar

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	53,34	100

Ulcinj

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	59,95	100

Albania


Morphological map of the Albanian coast
Montenegro
Shkodër
Lezhë
Durrës
Tirana
Fier
Vlorë
Albania
Greece
Mediterranean Sea
Artificial coastline
Cliff/rocky shore
Cliff/rocky shore with beach
Gravel beach
Mixed sand and gravel beach
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)
River mouth (delta/estuary)
Sandy beach
Tidal flats/marsh
Country
NUTS III Level
N
W
E
S
0
25
50
km

Shkoder

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	69,35	100

Lezhe

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	1,55	2
Tidal flats/marsh	12,66	15
Sandy beach	13,82	17
River mouth (delta/estuary)	54,45	66

Durres

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	8,85	10
Cliff/rocky shore	9,41	11
Tidal flats/marsh	9,27	11
Sandy beach	46,19	53
River mouth (delta/estuary)	9,62	11
Cliff/rocky shore with beach	3,07	4

Tirana

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	8,76	25
Tidal flats/marsh	3,07	9
Sandy beach	15,41	43
River mouth (delta/estuary)	8,34	23

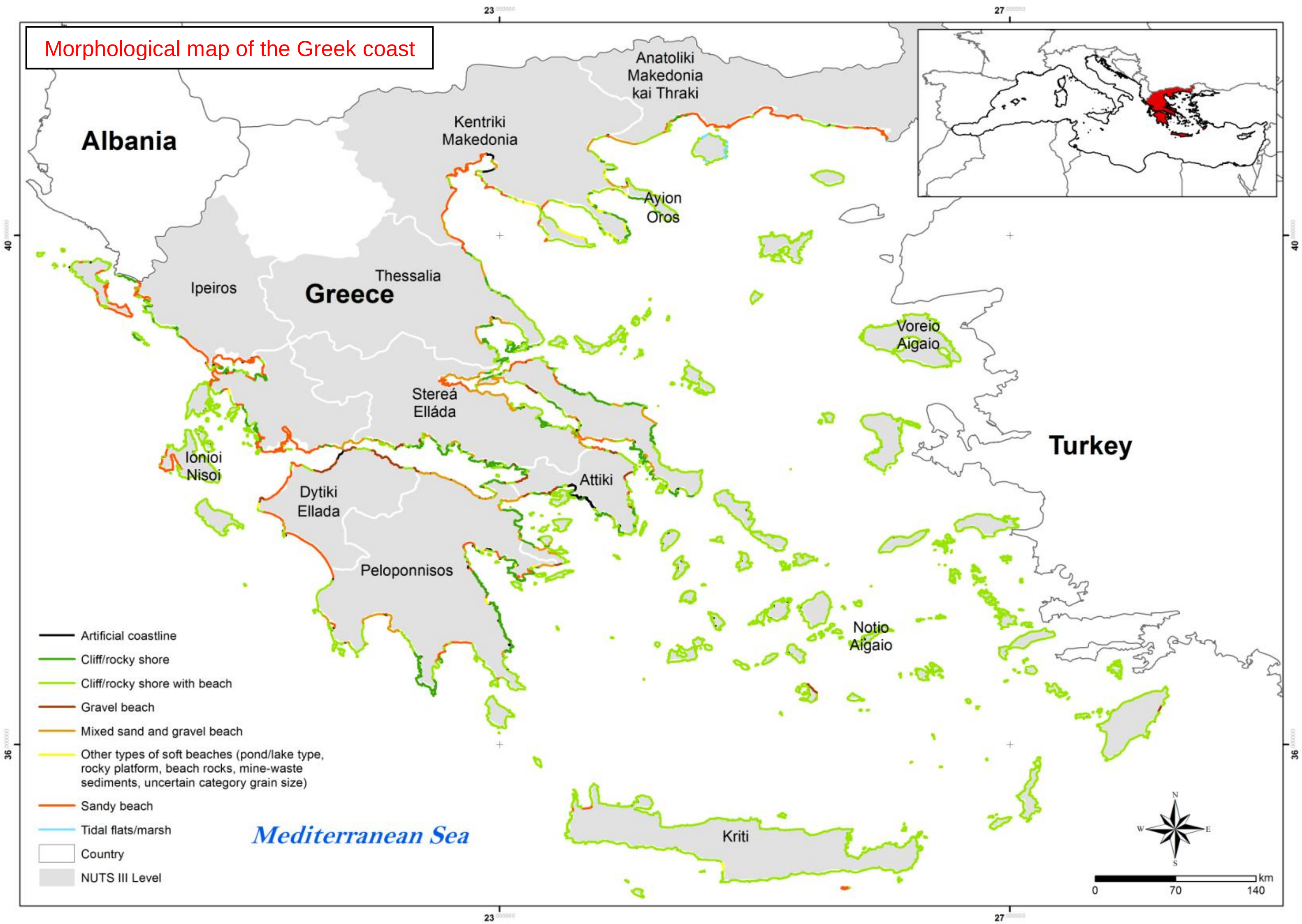
Fier

Coastal morphology	Length (km)	Coast type (%)
Tidal flats/marsh	85,48	81
Sandy beach	15,52	15
River mouth (delta/estuary)	4,33	4

Vlore

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	10,58	4
Cliff/rocky shore	75,39	28
Tidal flats/marsh	37,44	14
Sandy beach	39,26	15
River mouth (delta/estuary)	3,28	1
Cliff/rocky shore with beach	94,77	35
Mixed sand and gravel beach	8,49	3

Greece


Morphological map of the Greek coast
Albania
Greece
Turkey
Anatoliki Makedonia kai Thraki
Kentriki Makedonia
Ayion Oros
Ipeiros
Thessalia
Voreio Aigaio
Stereá Elláda
Ionioi Nisoi
Attiki
Dytiki Ellada
Peloponnisos
Notio Aigaio
Kriti
Mediterranean Sea
Artificial coastline
Cliff/rocky shore
Cliff/rocky shore with beach
Gravel beach
Mixed sand and gravel beach
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)
Sandy beach
Tidal flats/marsh
Country
NUTS III Level
0
70
140
km

Ipeiros

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	22,85	7
Cliff/rocky shore	75,57	24
Sandy beach	126,23	41
Cliff/rocky shore with beach	71,94	23
Mixed sand and gravel beach	13,33	4

Ionioi Nisoi

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	40,82	4
Cliff/rocky shore	12,56	1
Sandy beach	171,30	15
Cliff/rocky shore with beach	914,15	80

Dytiki Ellada

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	34,43	4
Cliff/rocky shore	141,94	17
Gravel beach	77,72	9
Sandy beach	344,44	41
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	11,69	1
Cliff/rocky shore with beach	196,72	24
Mixed sand and gravel beach	24,88	3

Peloponnisos

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	90,12	7
Cliff/rocky shore	426,41	34
Gravel beach	12,20	1
Sandy beach	84,38	7
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	14,30	1
Cliff/rocky shore with beach	480,34	38
Mixed sand and gravel beach	151,04	12

Kriti

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	31,17	3
Sandy beach	28,58	2
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	9,31	1
Cliff/rocky shore with beach	1122,85	94

Notio Aigaio

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	89,71	2
Gravel beach	20,01	1
Cliff/rocky shore with beach	3689,56	97

Attiki

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	98,21	9
Cliff/rocky shore	134,55	12
Gravel beach	57,41	5
Sandy beach	17,24	2
Cliff/rocky shore with beach	815,06	72
Mixed sand and gravel beach	17,33	2
Cliff/rocky shore with beach	0,02	0

Stereà Ellàda

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	58,13	4
Cliff/rocky shore	498,96	31
Gravel beach	35,92	2
Sandy beach	112,41	7
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	2,03	0
Cliff/rocky shore with beach	642,16	40
Mixed sand and gravel beach	239,08	15
Cliff/rocky shore with beach	0,02	0

Voreio Aigaio

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	37,60	3
Cliff/rocky shore with beach	1278,20	97

Thessalia

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	22,50	3
Cliff/rocky shore	149,56	20
Sandy beach	7,05	1
Cliff/rocky shore with beach	527,51	70
Mixed sand and gravel beach	45,74	6

Kentriki Makedonia

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	55,79	8
Cliff/rocky shore	75,08	11
Sandy beach	161,14	23
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	96,94	14
Cliff/rocky shore with beach	251,16	37
Mixed sand and gravel beach	47,55	7

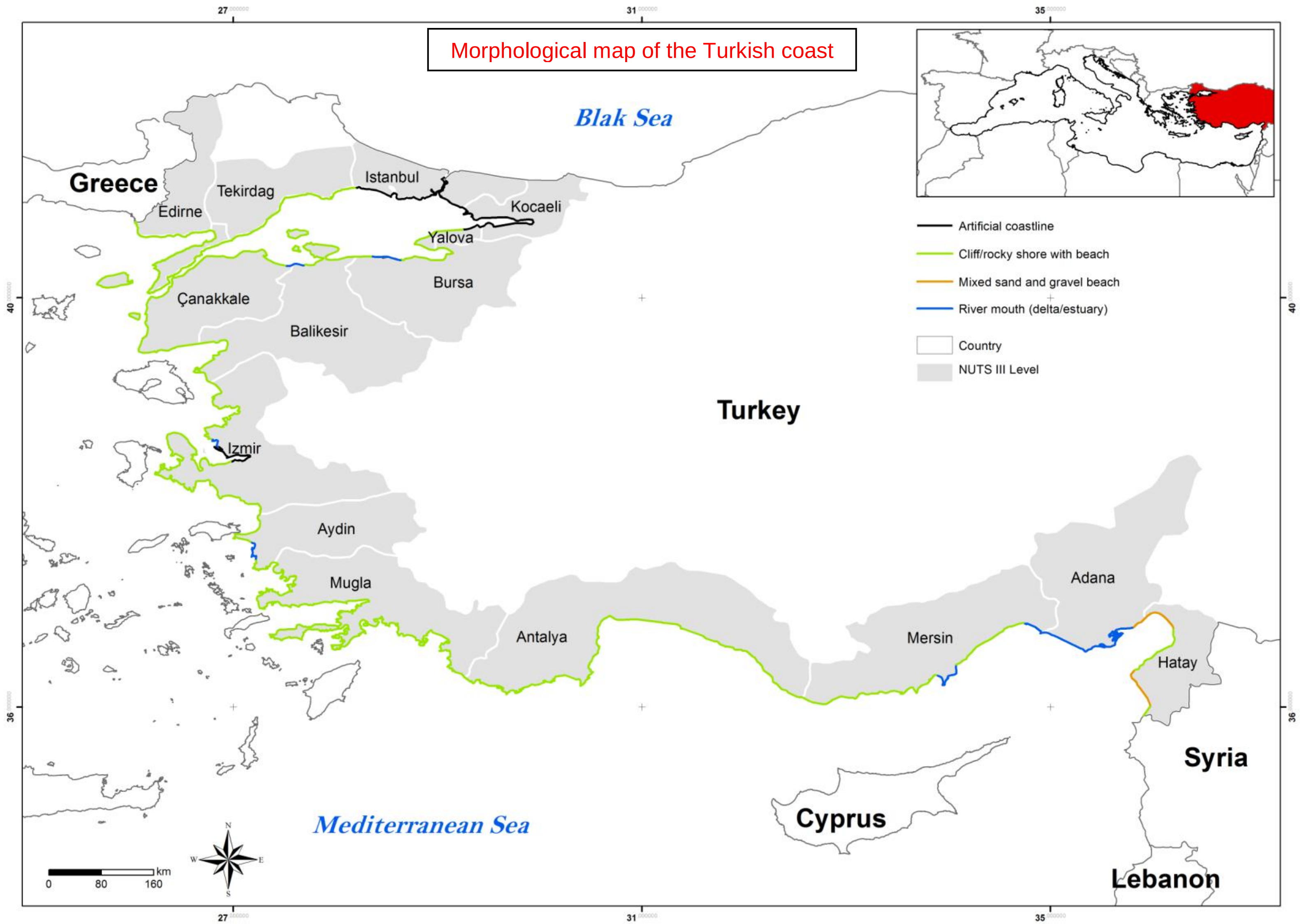
Ayion Oros

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	1,02	1
Cliff/rocky shore	20,86	17
Gravel beach	4,35	4
Other types of soft beaches (pond/lake type, rocky platform, beach rocks, mine-waste sediments, uncertain category grain size)	0,72	1
Cliff/rocky shore with beach	96,26	78
Mixed sand and gravel beach	0,98	1

Anatoliki Makedonia kai Thraki

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	19,45	4
Cliff/rocky shore	15,74	3
Tidal flats/marsh	47,63	10
Sandy beach	171,84	36
Cliff/rocky shore with beach	204,02	43
Mixed sand and gravel beach	20,03	4

Turkey


Morphological map of the Turkish coast
Blak Sea
Greece
Edirne
Tekirdag
Istanbul
Kocaeli
Yalova
Bursa
Çanakkale
Balikesir
Izmir
Aydin
Mugla
Antalya
Mersin
Adana
Hatay
Turkey
Syria
Cyprus
Lebanon
Mediterranean Sea
Artificial coastline
Cliff/rocky shore with beach
Mixed sand and gravel beach
River mouth (delta/estuary)
Country
NUTS III Level
km
0
80
160
27
31
35
40
36

Edirne

Coastal morphology	Length (km)	Coast type (%)
Tidal flats/marsh	0,41	0
Cliff/rocky shore with beach	90,46	100

Canakkale

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	626,83	99
River mouth (delta/estuary)	6,00	1

Tekirdag

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	153,77	100

Istanbul

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	2,06	1
Artificial coastline	166,98	99

Kocaeli

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	131,75	100

Yalova

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	18,18	22
Cliff/rocky shore with beach	65,85	78

Bursa

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	81,13	76
River mouth (delta/estuary)	25,69	24

Balikesir

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	249,28	96
River mouth (delta/estuary)	10,65	4

Izmir

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	524,71	85
River mouth (delta/estuary)	14,96	2
Artificial coastline	74,28	12

Aydin

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	102,56	77
River mouth (delta/estuary)	30,83	23

Mugla

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	948,87	100

Antalya

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	485,02	100

Mersin

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	236,29	77
River mouth (delta/estuary)	71,55	23

Adana

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	177,13	92
Mixed sand and gravel beach	15,31	8

Hatay

Coastal morphology	Length (km)	Coast type (%)
Mixed sand and gravel beach	85,43	53
Cliff/rocky shore with beach	76,73	47

References used to realize the map of the Turkish coastal morphology

Anzidei, M., F. Antonioli, A. Benini, K. Lambeck, D. Sivan, E. Serpelloni, P. Stocchi 2011a. Sea level change and vertical land movements since the last two millennia along the coasts of southwestern Turkey and Israel. Quatern. Int. 232(1-2): 13–20.

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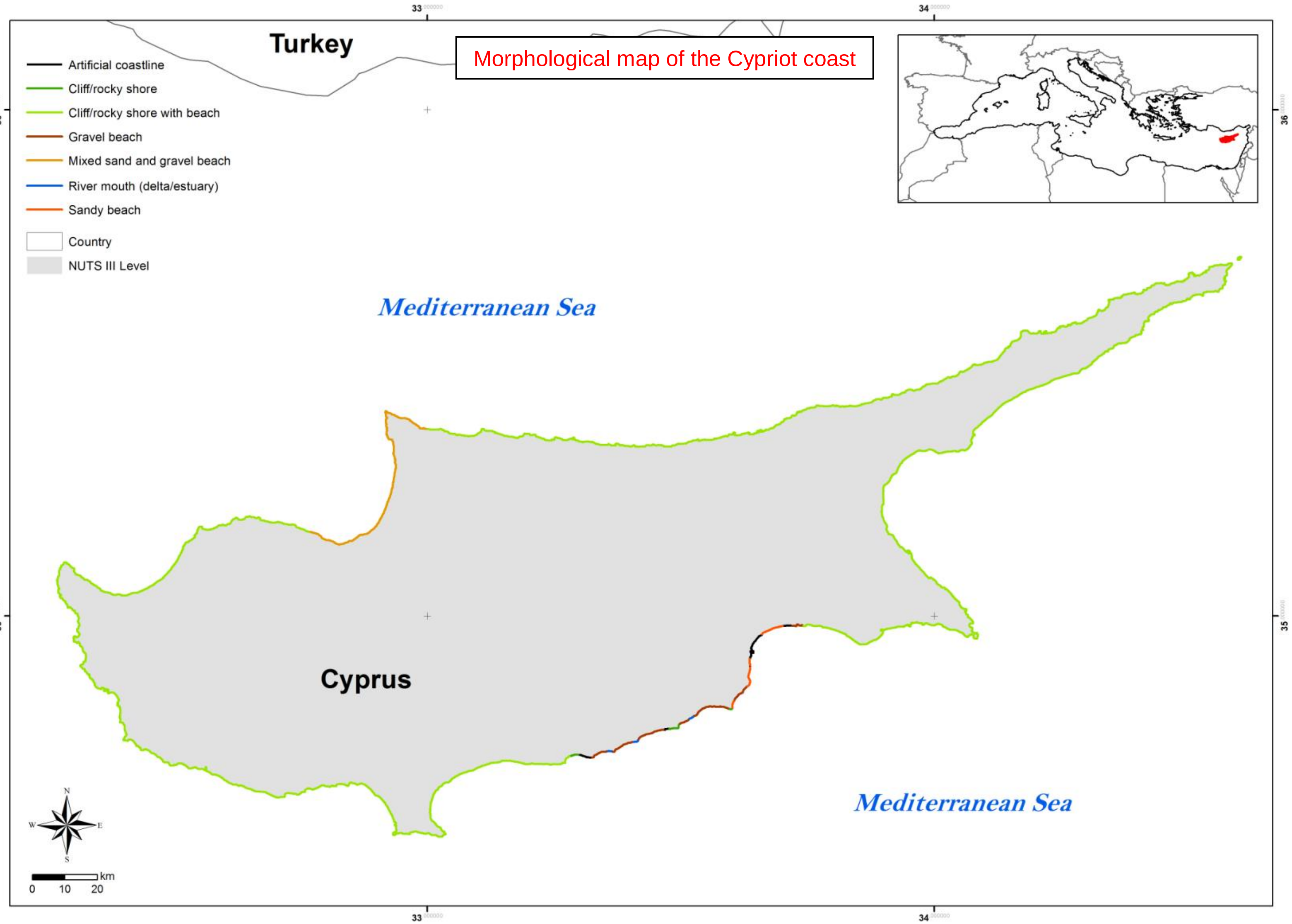
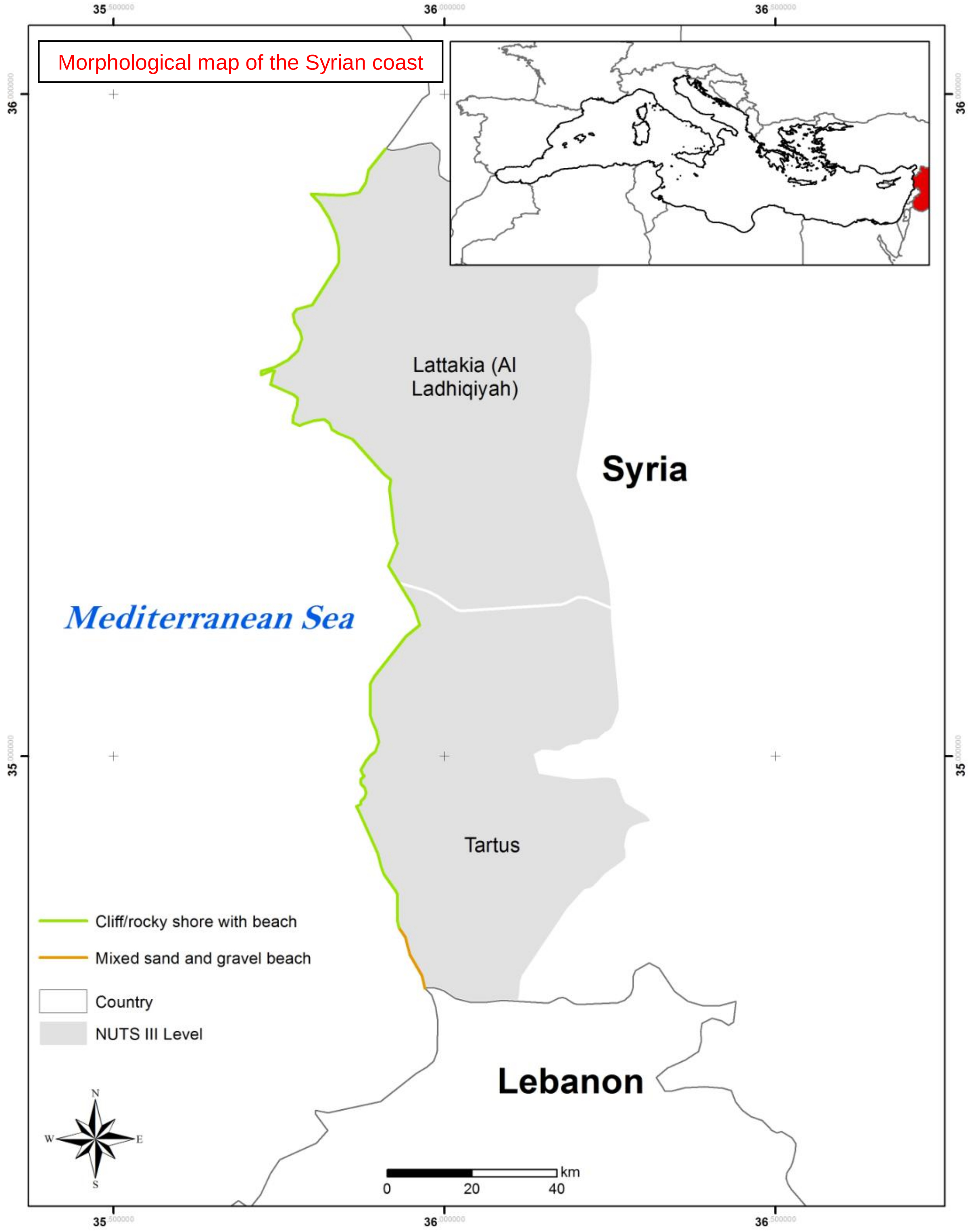
Cyprus


Turkey
Morphological map of the Cypriot coast
Artificial coastline
Cliff/rocky shore
Cliff/rocky shore with beach
Gravel beach
Mixed sand and gravel beach
River mouth (delta/estuary)
Sandy beach
Country
NUTS III Level
Mediterranean Sea
Cyprus
Mediterranean Sea
km
0 10 20
33
34
35
36

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	14,47	2
Cliff/rocky shore	5,99	1
Gravel beach	33,18	4
Sandy beach	12,68	2
River mouth (delta/estuary)	2,67	0
Cliff/rocky shore with beach	649,26	84
Mixed sand and gravel beach	54,61	7

Syria


Morphological map of the Syrian coast
Lattakia (Al Ladhiqiyah)
Syria
Mediterranean Sea
Tartus
Lebanon
Cliff/rocky shore with beach
Mixed sand and gravel beach
Country
NUTS III Level
N
W
E
S
km
0
20
40
35
36
36
35
36
36
35
35
36
36

Lattakia

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	106,07	100

Tartus

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	66,25	85
Mixed sand and gravel beach	11,71	15

References used to realize the map of the Syrian coastal morphology

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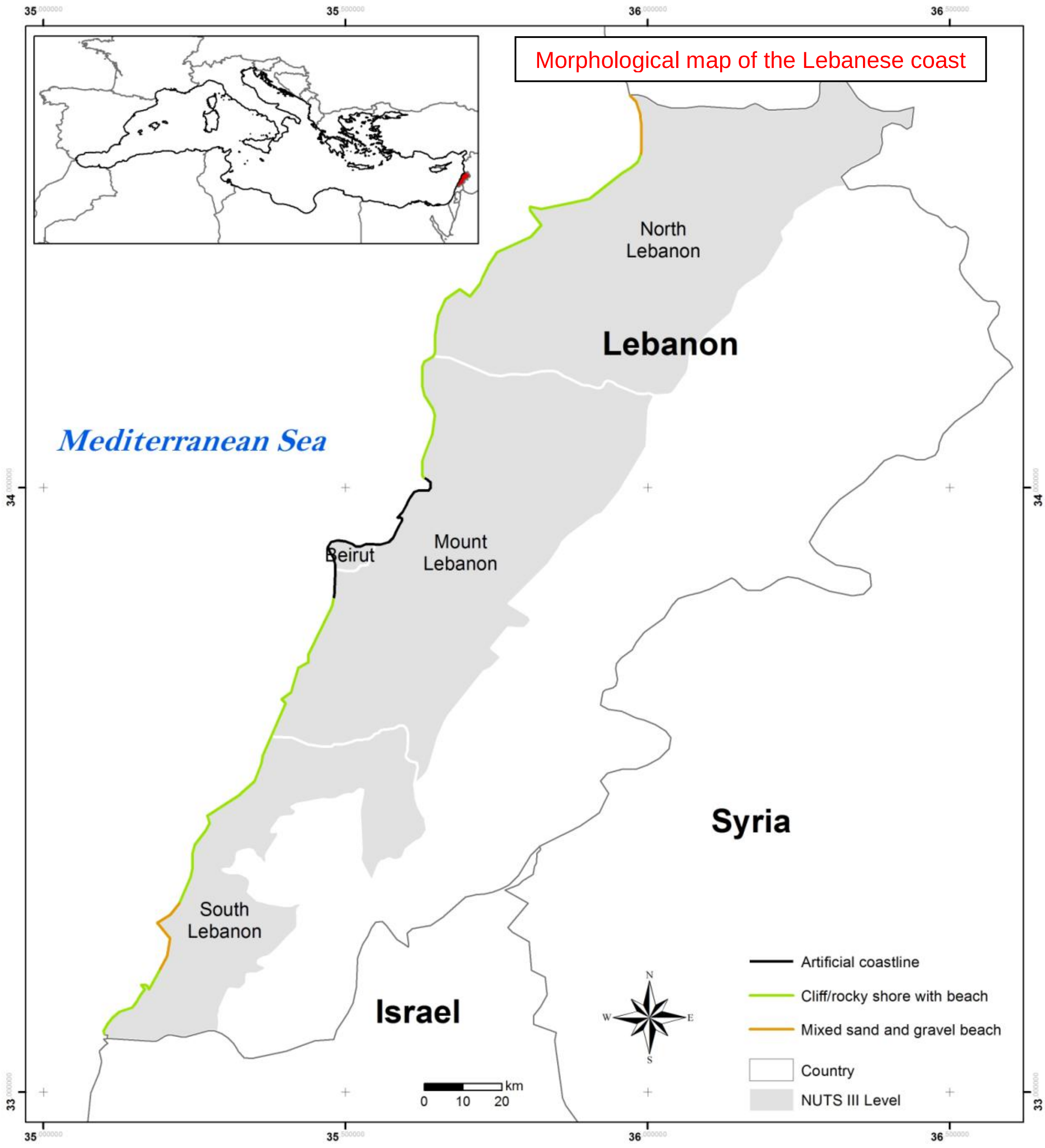
Lebanon


Morphological map of the Lebanese coast
Mediterranean Sea
North Lebanon
Lebanon
Mount Lebanon
Beirut
South Lebanon
Syria
Israel
Artificial coastline
Cliff/rocky shore with beach
Mixed sand and gravel beach
Country
NUTS III Level
km
0 10 20

North Lebanon

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	60,69	84
Mixed sand and gravel beach	11,33	16

Mount Lebanon

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	54,48	69
Artificial coastline	24,26	31

Beirut

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	13,64	100

South Lebanon

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	57,10	79
Mixed sand and gravel beach	14,94	21

References used to realize the map of the Lebanese coastal morphology

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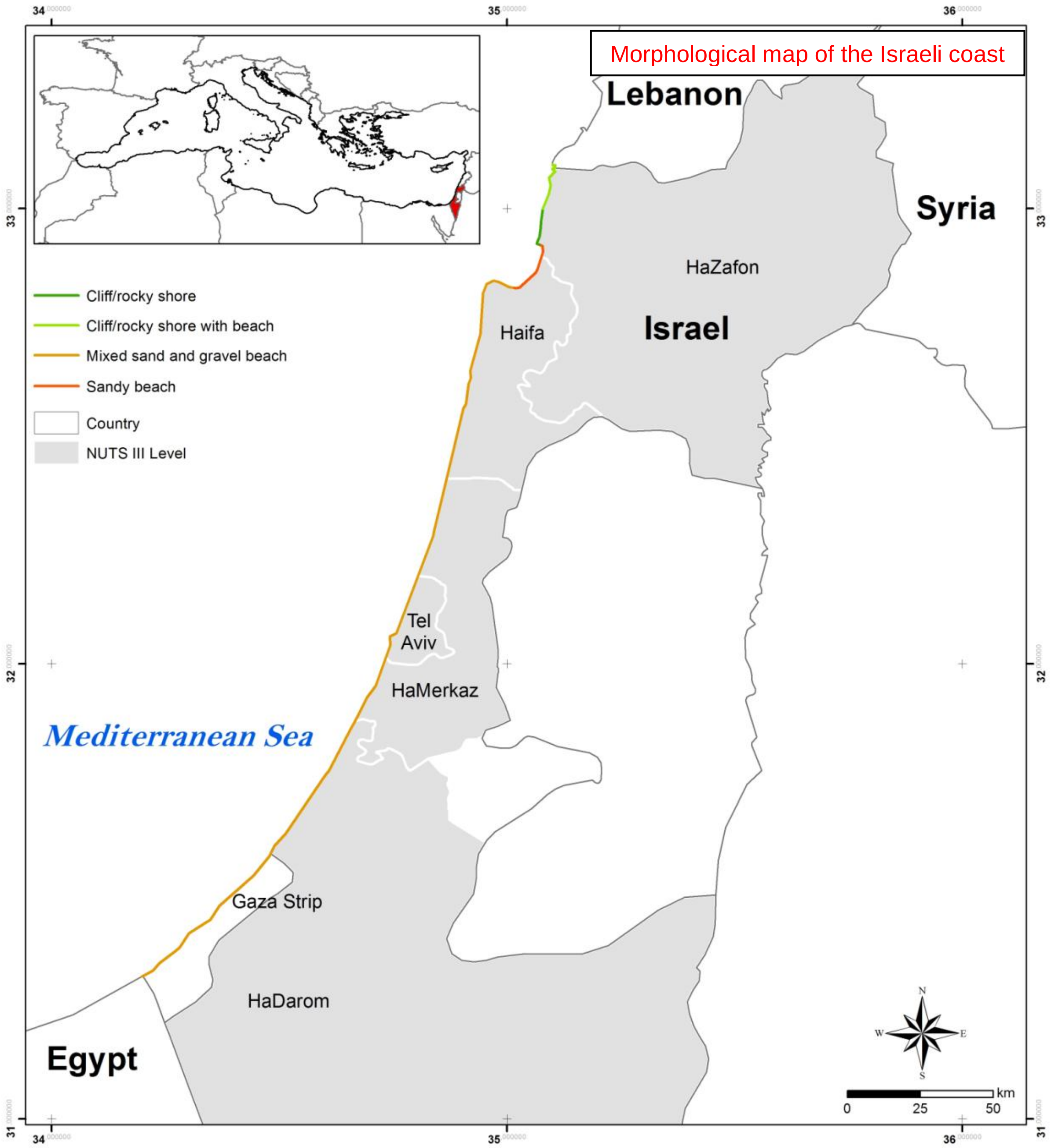
Israel


Morphological map of the Israeli coast
Lebanon
Syria
HaZafon
Israel
Haifa
Tel Aviv
HaMerkaz
Mediterranean Sea
Gaza Strip
HaDarom
Egypt
Cliff/rocky shore
Cliff/rocky shore with beach
Mixed sand and gravel beach
Sandy beach
Country
NUTS III Level
N
S
E
W
km
0
25
50
34
35
36
33
32
31

HaZafon

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	3,73	15
Cliff/rocky shore	9,57	38
Cliff/rocky shore with beach	11,58	47

Haifa

Coastal morphology	Length (km)	Coast type (%)
Mixed sand and gravel beach	57,24	85
Sandy beach	10,29	15

HaMerkaz

Coastal morphology	Length (km)	Coast type (%)
Mixed sand and gravel beach	43,11	100

Tel Aviv

Coastal morphology	Length (km)	Coast type (%)
Mixed sand and gravel beach	22,38	100

HaDarom

Coastal morphology	Length (km)	Coast type (%)
Mixed sand and gravel beach	38,40	100

References used to realize the map of the Israeli coastal morphology

Lichter, M., D. Zviely, M. Klein 2009. Morphological changes in the last 200 years in the mouth of the Na'aman River, northern coastal plain, Israel. Isr. J. Earth Sci. 58: 63–80.

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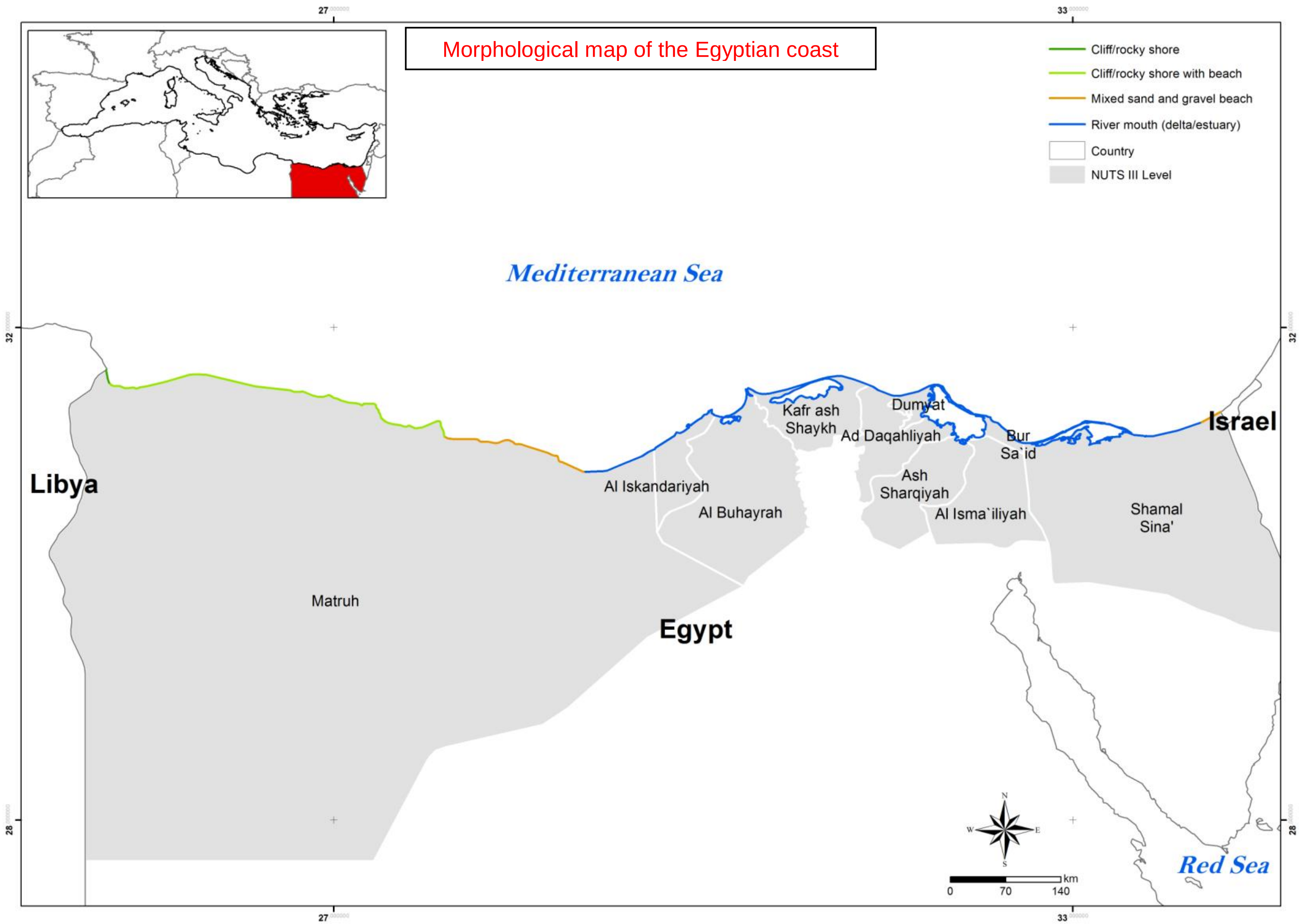
Egypt


Morphological map of the Egyptian coast
Cliff/rocky shore
Cliff/rocky shore with beach
Mixed sand and gravel beach
River mouth (delta/estuary)
Country
NUTS III Level
Mediterranean Sea
Libya
Israel
Egypt
Matruh
Al Iskandariyah
Al Buhayrah
Kafr ash Shaykh
Ad Daqahliyah
Dumyat
Bur Sa`id
Ash Sharqiyah
Al Isma`iliyah
Shamal Sina'
Red Sea
km
0
70
140

Shamal Sina

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	438,14	96
Mixed sand and gravel beach	18,18	4

Bur Sa`id

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	60,64	100

Al Isma`iliyah

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	2,77	100

Ash Sharqiyah

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	59,86	100

Dumyat

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	176,34	100

Ad Daqahliyah

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	138,73	100

Kafr ash Shaykh

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	261,90	100

Al Buhayrah

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	102,67	100

Al Iskandariyah

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	75,64	100

Matruh

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	60,76	12
Mixed sand and gravel beach	121,43	25
Cliff/rocky shore with beach	297,38	60
Cliff/rocky shore	12,81	3

References used to realize the map of the Egyptian coastal morphology

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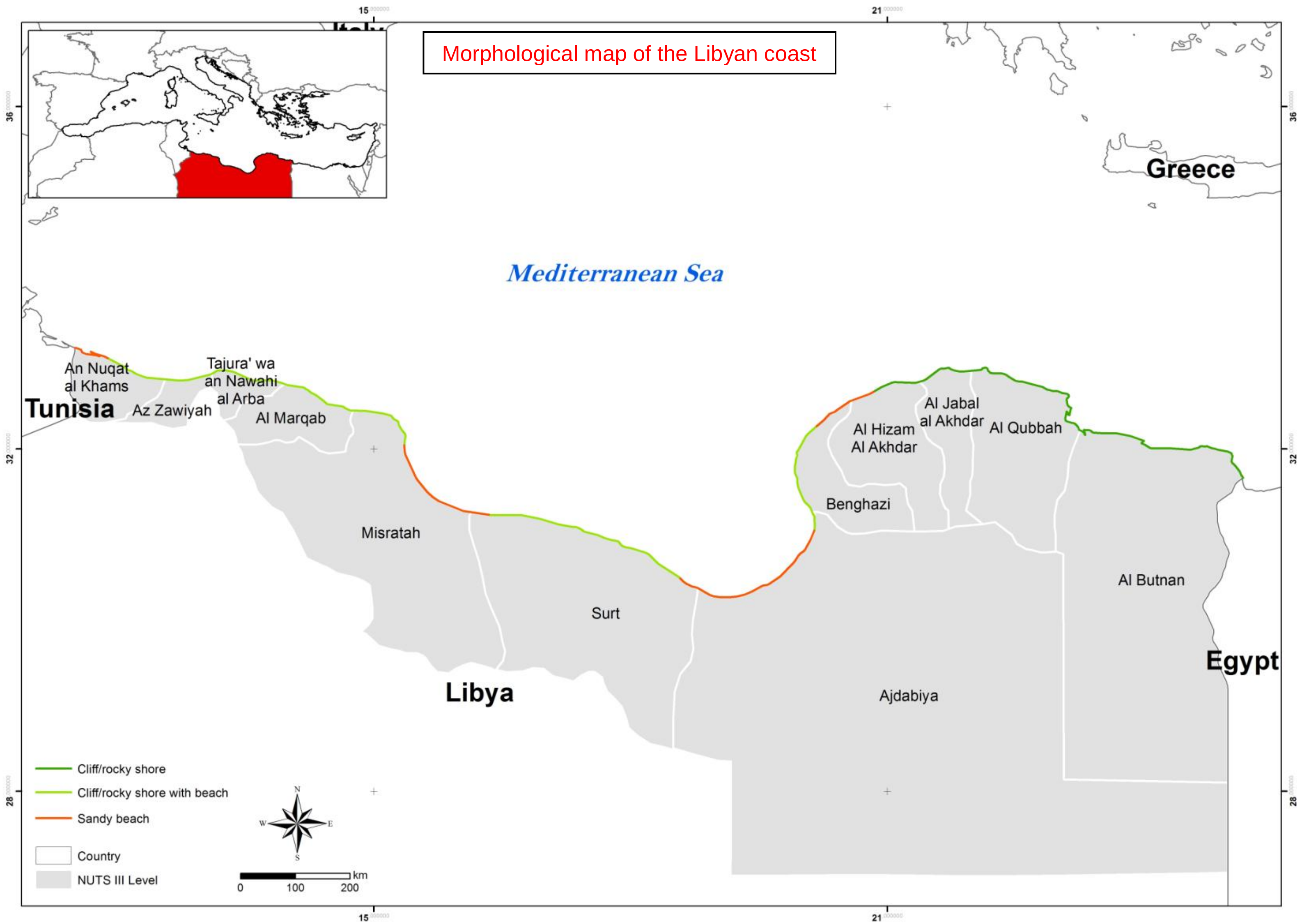
Libya


Morphological map of the Libyan coast
Mediterranean Sea
Greece
Tunisia
An Nuqat al Khams
Az Zawiyah
Tajura' wa an Nawahi al Arba
Al Marqab
Misratah
Surt
Libya
Benghazi
Al Hizam Al Akhdar
Al Jabal al Akhdar
Al Qubbah
Al Butnan
Ajdabiya
Egypt
Cliff/rocky shore
Cliff/rocky shore with beach
Sandy beach
Country
NUTS III Level
km
0
100
200

Al Butnan

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	230,99	100

Al Qubbah

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	187,31	100

Al Jabal al Akhdar

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	66,66	100

Al Hizam Al Akhdar

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore	52,10	65
Sandy beach	27,87	35

Benghazi

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	52,68	29
Cliff/rocky shore with beach	126,15	71

Ajdabiya

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	19,46	10
Sandy beach	173,69	90

Surt

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	48,12	17
Cliff/rocky shore with beach	233,47	83

Misratah

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	125,59	60
Cliff/rocky shore with beach	84,05	40

Al Marqab

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	83,02	100

Tajura' wa an Nawahi al Arba

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	85,07	100

Az Zawiyah

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	52,02	100

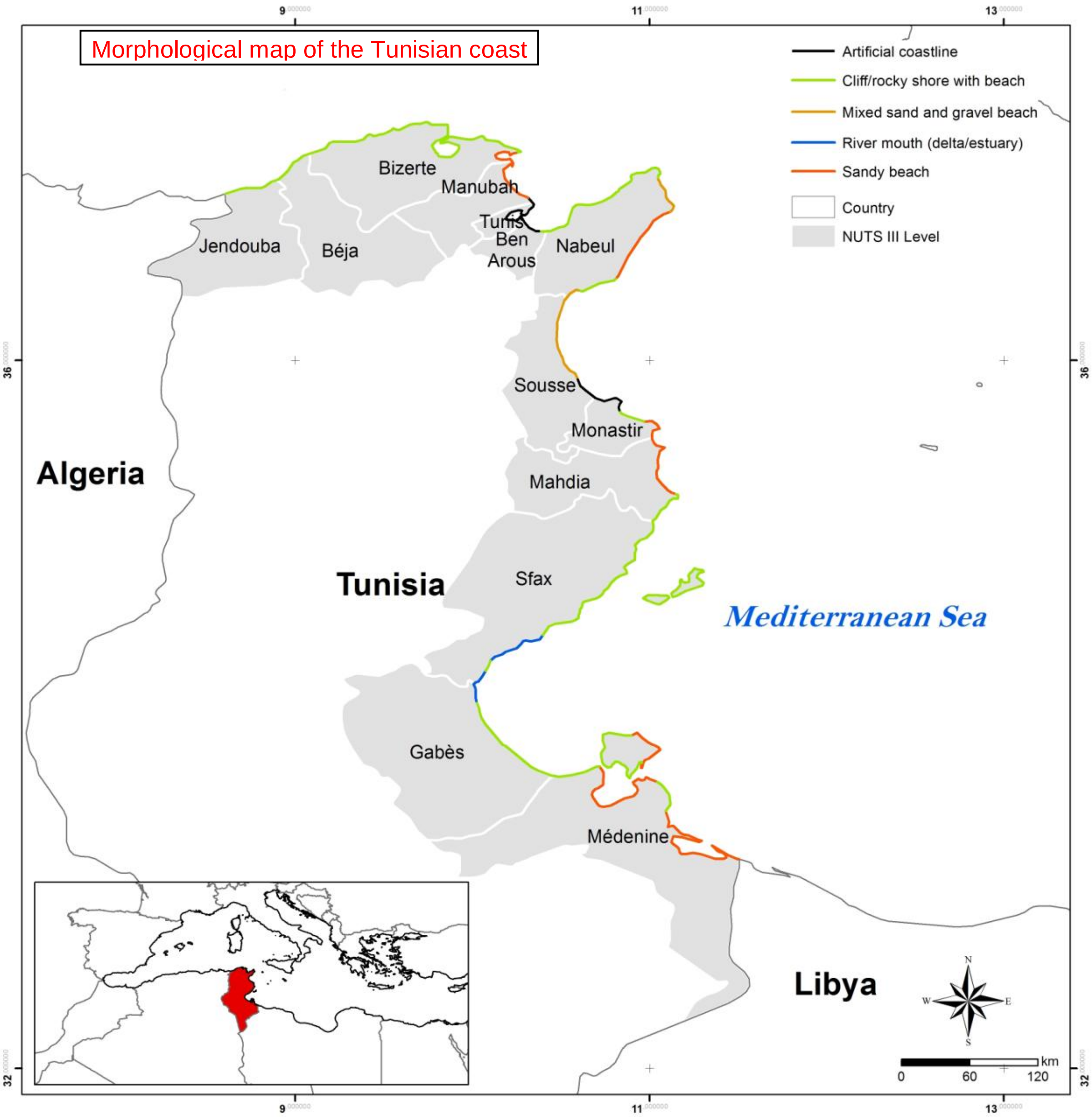
An Nuqat al Khams

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	64,71	49
Cliff/rocky shore with beach	68,49	51

Reference used to realize the map of the Libyan coastal morphology

Schwartz, M. 2010. Libya. In: Bird E. C. F. (ed.), Encyclopedia of the World's Coastal Landforms. Springer Science + Business Media, Dordrecht. 1: 897-898.

Tunisia


Morphological map of the Tunisian coast
Artificial coastline
Cliff/rocky shore with beach
Mixed sand and gravel beach
River mouth (delta/estuary)
Sandy beach
Country
NUTS III Level
Bizerte
Manubah
Tunis
Ben Arous
Nabeul
Jendouba
Béja
Sousse
Monastir
Mahdia
Sfax
Gabès
Médenine
Algeria
Tunisia
Libya
Mediterranean Sea
km
0
60
120

Medenine

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	228,35	66
Cliff/rocky shore with beach	118,19	34

Gabes

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	12,23	16
Cliff/rocky shore with beach	63,68	84

Sfax

Coastal morphology	Length (km)	Coast type (%)
River mouth (delta/estuary)	43,26	17
Cliff/rocky shore with beach	204,80	83

Mahdia

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	45,14	66
Cliff/rocky shore with beach	23,71	34

Monastir

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	18,14	33
Cliff/rocky shore with beach	14,36	26
Artificial coastline	22,01	40

Sousse

Coastal morphology	Length (km)	Coast type (%)
Mixed sand and gravel beach	53,96	78
Artificial coastline	14,93	22

Nabeul

Coastal morphology	Length (km)	Coast type (%)
Mixed sand and gravel beach	33,68	18
Cliff/rocky shore with beach	104,63	55
Sandy beach	50,31	27

Ben Arous (Tunis Sud)

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	3,08	15
Artificial coastline	18,00	85

Tunis

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	31,61	100

Manubah

Coastal morphology	Length (km)	Coast type (%)
Artificial coastline	3,51	9
Sandy beach	33,93	91

Bizerte

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	23,99	12
Cliff/rocky shore with beach	173,84	88

Beja

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	23,75	100

Jendouba

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	28,66	100

References used to realize the map of the Tunisian coastal morphology

Anzidei, M., F. Antonioli, K. Lambeck, A. Benini, M. Soussi 2011b. New insights on the relative sea level change during Holocene along the coasts of Tunisia and western Libya from archaeological and geomorphological markers. Quatern. Int. 232: 5-12.

Hinkel, J., A. T. Vafeidis, D. Lincke, C. Wolff 2015. Assessment of Costs of Sea-Level Rise in the Republic of Tunisia Including Costs and Benefits of Adaptation. Technical report, PAP/RAC, APAL. Pp. 62.

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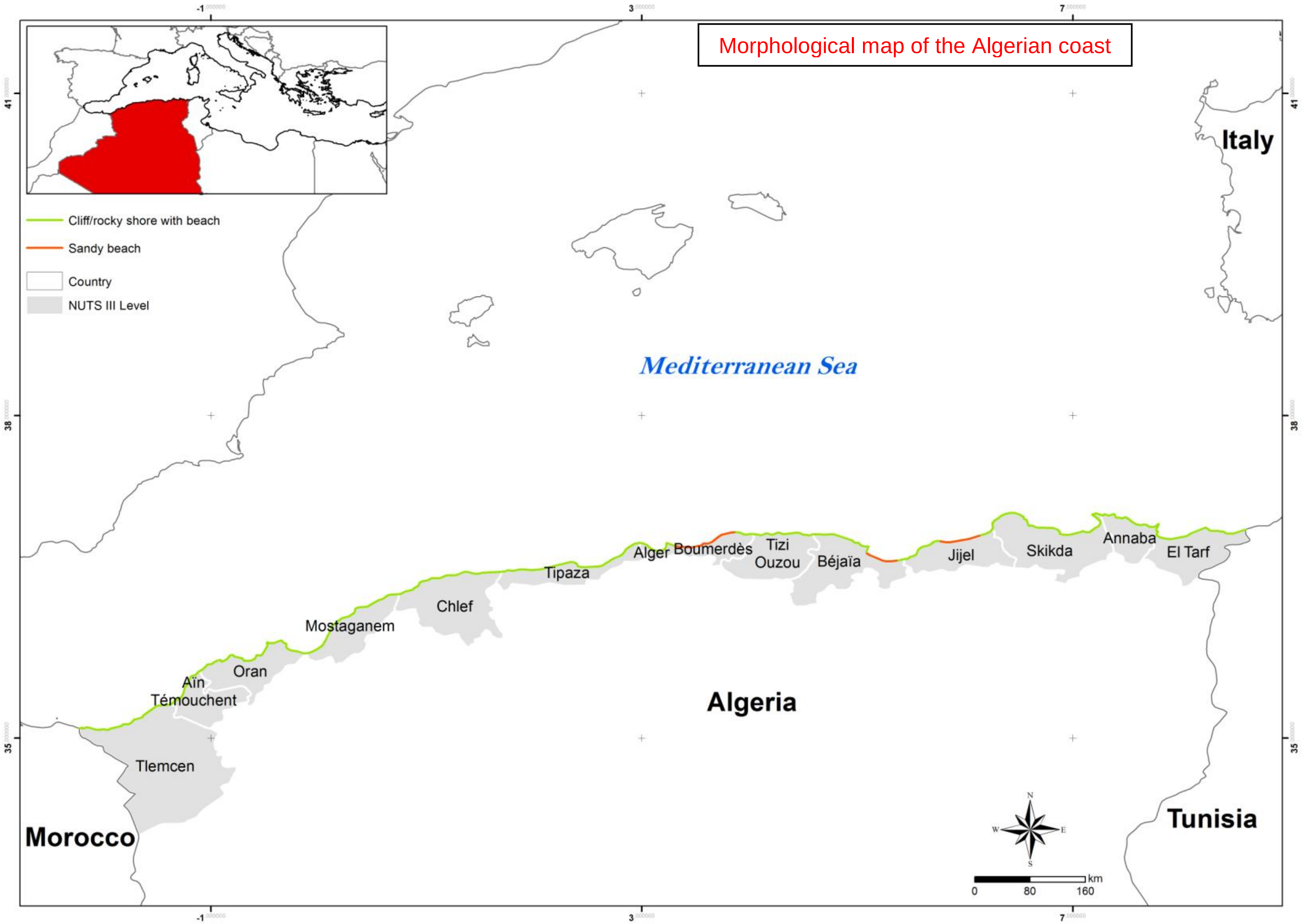
Algeria


Morphological map of the Algerian coast
Cliff/rocky shore with beach
Sandy beach
Country
NUTS III Level
Mediterranean Sea
Italy
Algeria
Morocco
Tunisia
Tlemcen
Aïn Témouchent
Oran
Mostaganem
Chlef
Tipaza
Alger
Boumerdès
Tizi Ouzou
Béjaïa
Jijel
Skikda
Annaba
El Tarf
km
0
80
160

El Tarf

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	81,06	100

Annaba

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	70,15	100

Skikda

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	138,09	100

Jijel

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	36,12	43
Cliff/rocky shore with beach	48,60	57

Bejaia

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	61,69	68
Sandy beach	28,79	32

Tizi Ouzou

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	52,63	100

Boumerdes

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	56,58	63
Cliff/rocky shore with beach	33,35	37

Alger

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	19,92	100

Tipaza

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	130,10	100

Chlef

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	95,94	100

Mostaganem

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	108,22	100

Oran

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	123,50	100

Ain Temouchent

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	44,58	100

Tlemcen

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	91,69	100

References used to realize the map of the Algerian coastal morphology

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Kermani, S., M. Boutiba, M. Guendouz, M. S. Guettouche, D. Khelfani 2016. Detection and analysis of shoreline changes using geospatial tools and automatic computation: Case of jijelian sandy coast (East Algeria). Ocean Coast. Manag. 132: 46-58.

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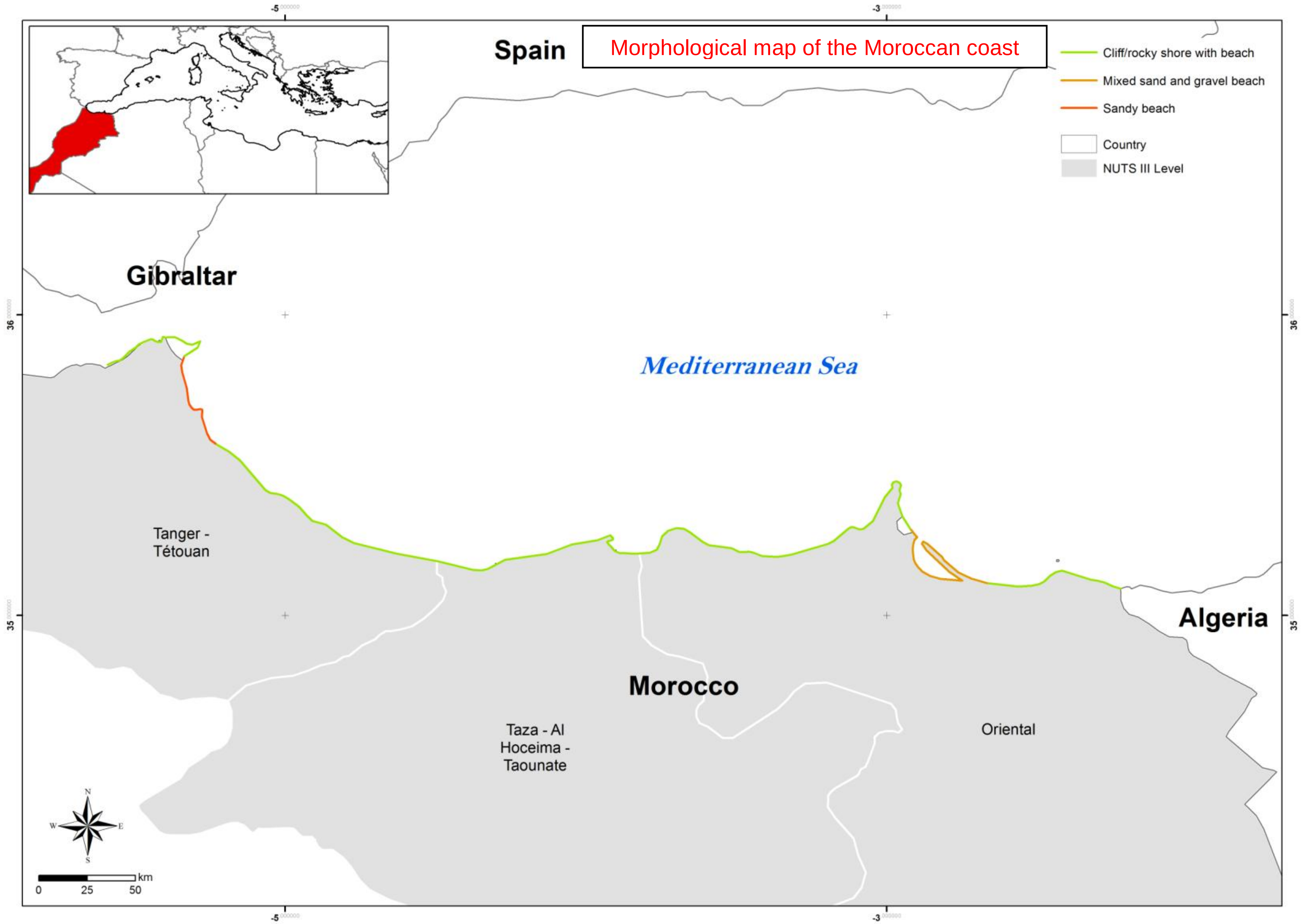
Morocco


Spain
Morphological map of the Moroccan coast
Cliff/rocky shore with beach
Mixed sand and gravel beach
Sandy beach
Country
NUTS III Level
Gibraltar
Mediterranean Sea
Tanger - Tétouan
Morocco
Taza - Al Hoceima - Taounate
Oriental
Algeria
km
0
25
50

Oriental

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	163,23	68
Mixed sand and gravel beach	75,66	32

Taza - Al Hoceima - Taounate

Coastal morphology	Length (km)	Coast type (%)
Cliff/rocky shore with beach	73,78	100

Tanger - Tetouan

Coastal morphology	Length (km)	Coast type (%)
Sandy beach	36,71	23
Cliff/rocky shore with beach	126,03	77

References used to realize the map of the Moroccan coastal morphology

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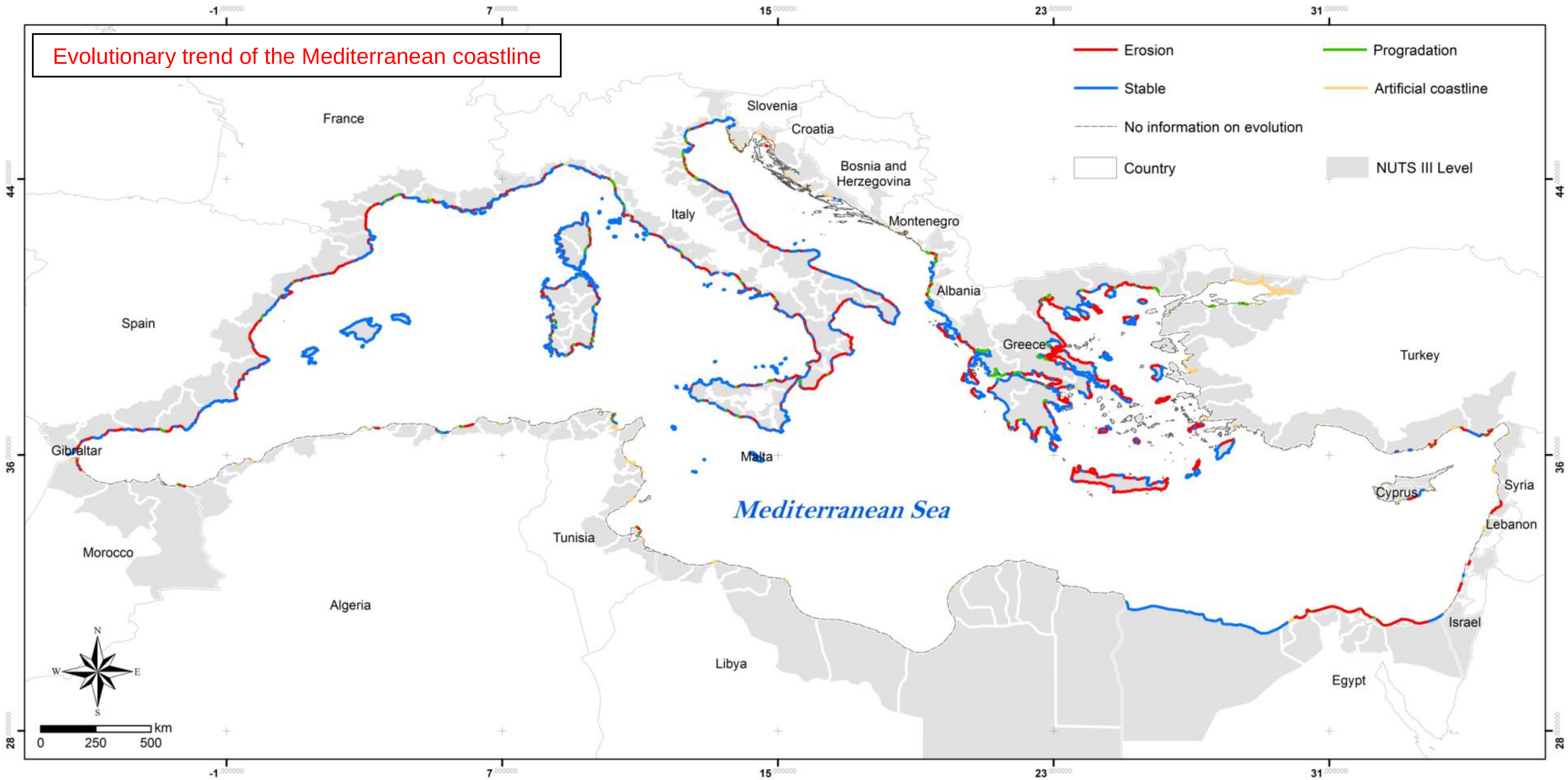
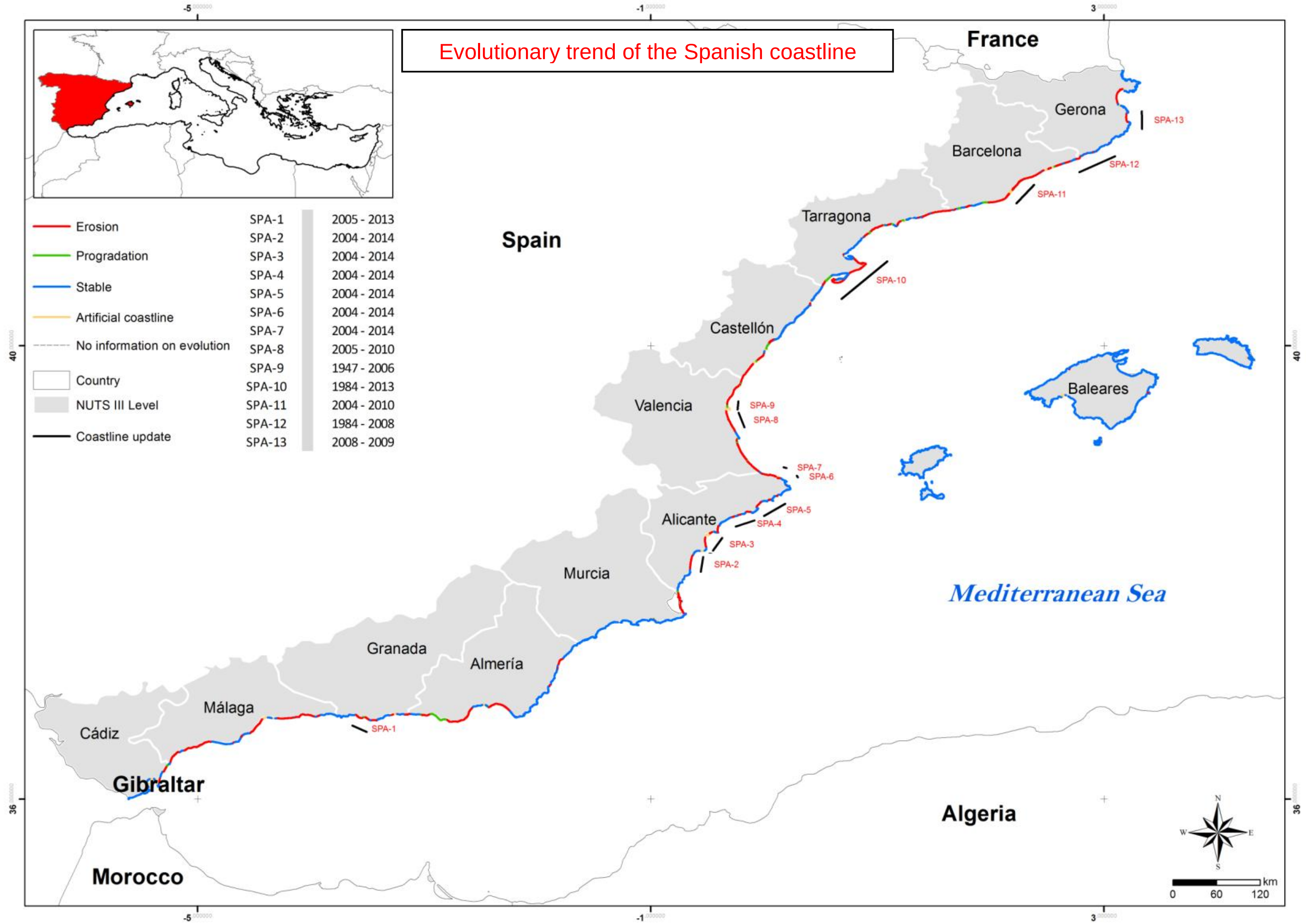
Annex 2 - The maps of the evolutionary trends

Mediterranean coast



**xxx-1: acronym representing updates.*

Spain



Evolutionary trend of the Spanish coastline
France
Spain
Gerona
Barcelona
Tarragona
Castellón
Valencia
Alicante
Murcia
Granada
Almería
Málaga
Cádiz
Gibraltar
Baleares
Mediterranean Sea
Algeria
Morocco
Erosion
Progradation
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
SPA-1 2005 - 2013
SPA-2 2004 - 2014
SPA-3 2004 - 2014
SPA-4 2004 - 2014
SPA-5 2004 - 2014
SPA-6 2004 - 2014
SPA-7 2004 - 2014
SPA-8 2005 - 2010
SPA-9 1947 - 2006
SPA-10 1984 - 2013
SPA-11 2004 - 2010
SPA-12 1984 - 2008
SPA-13 2008 - 2009
km
0 60 120

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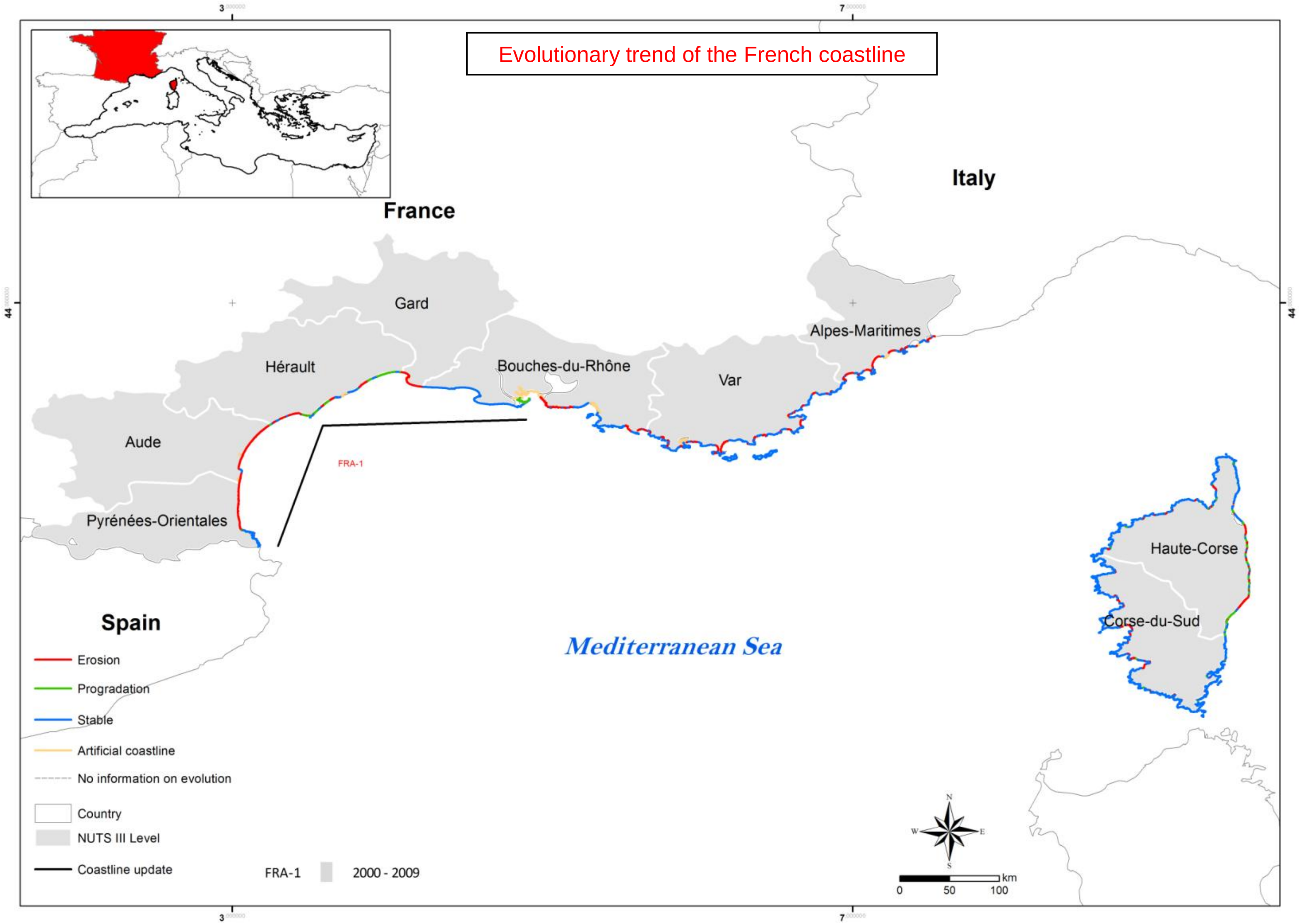
France


Evolutionary trend of the French coastline
France
Italy
Spain
Gard
Hérault
Aude
Pyrénées-Orientales
Bouches-du-Rhône
Var
Alpes-Maritimes
Haute-Corse
Corse-du-Sud
FRA-1
Mediterranean Sea
Erosion
Progradation
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
FRA-1
2000 - 2009
N
S
W
E
km
0
50
100
3
7
44

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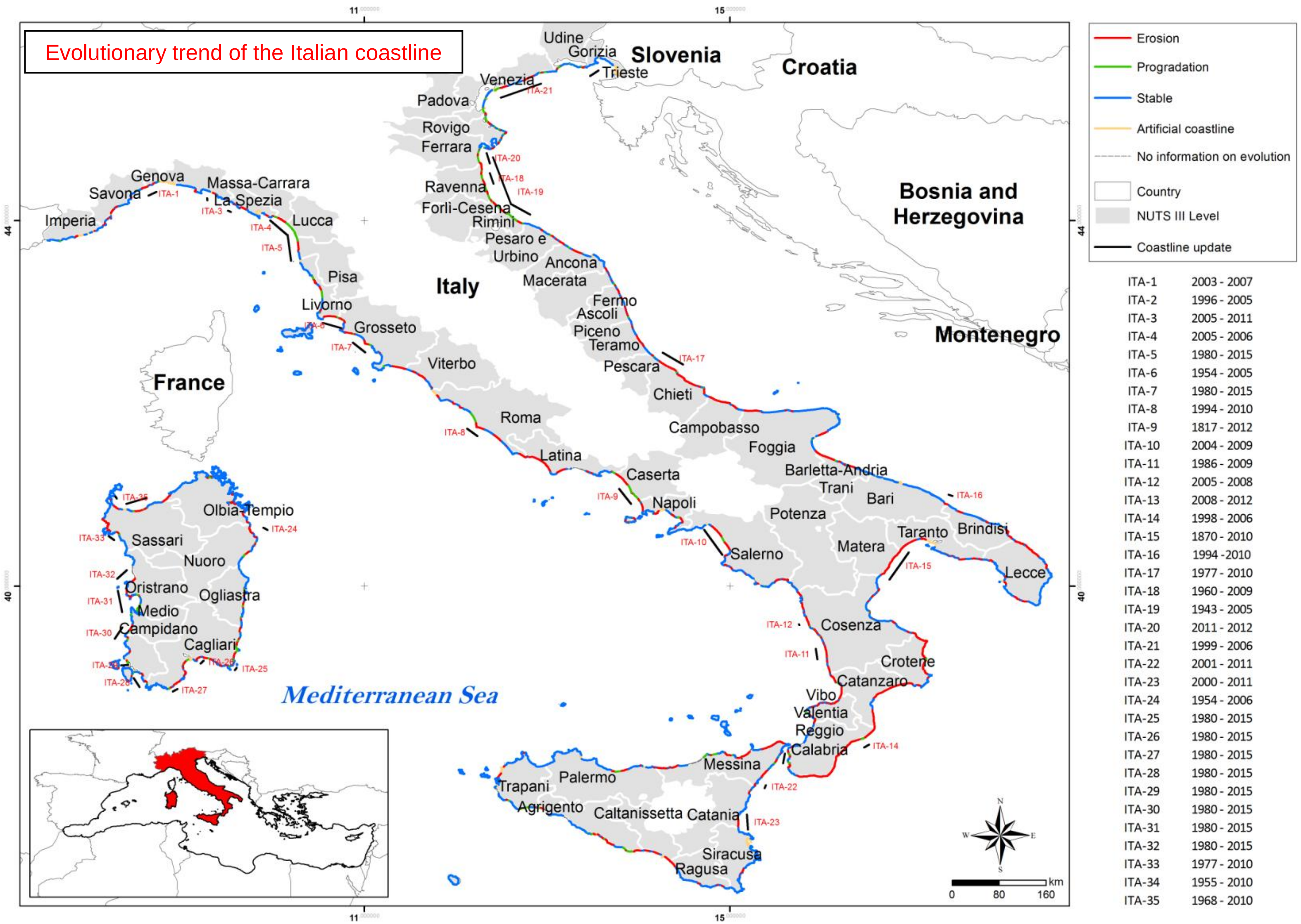
Shapefile data provided by French partners. (**FRA-1**)

Italy



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ITA-2	1996 - 2005
ITA-3	2005 - 2011
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ITA-6	1954 - 2005
ITA-7	1980 - 2015
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ITA-9	1817 - 2012
ITA-10	2004 - 2009
ITA-11	1986 - 2009
ITA-12	2005 - 2008
ITA-13	2008 - 2012
ITA-14	1998 - 2006
ITA-15	1870 - 2010
ITA-16	1994 -2010
ITA-17	1977 - 2010
ITA-18	1960 - 2009
ITA-19	1943 - 2005
ITA-20	2011 - 2012
ITA-21	1999 - 2006
ITA-22	2001 - 2011
ITA-23	2000 - 2011
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ITA-25	1980 - 2015
ITA-26	1980 - 2015
ITA-27	1980 - 2015
ITA-28	1980 - 2015
ITA-29	1980 - 2015
ITA-30	1980 - 2015
ITA-31	1980 - 2015
ITA-32	1980 - 2015
ITA-33	1977 - 2010
ITA-34	1955 - 2010
ITA-35	1968 - 2010

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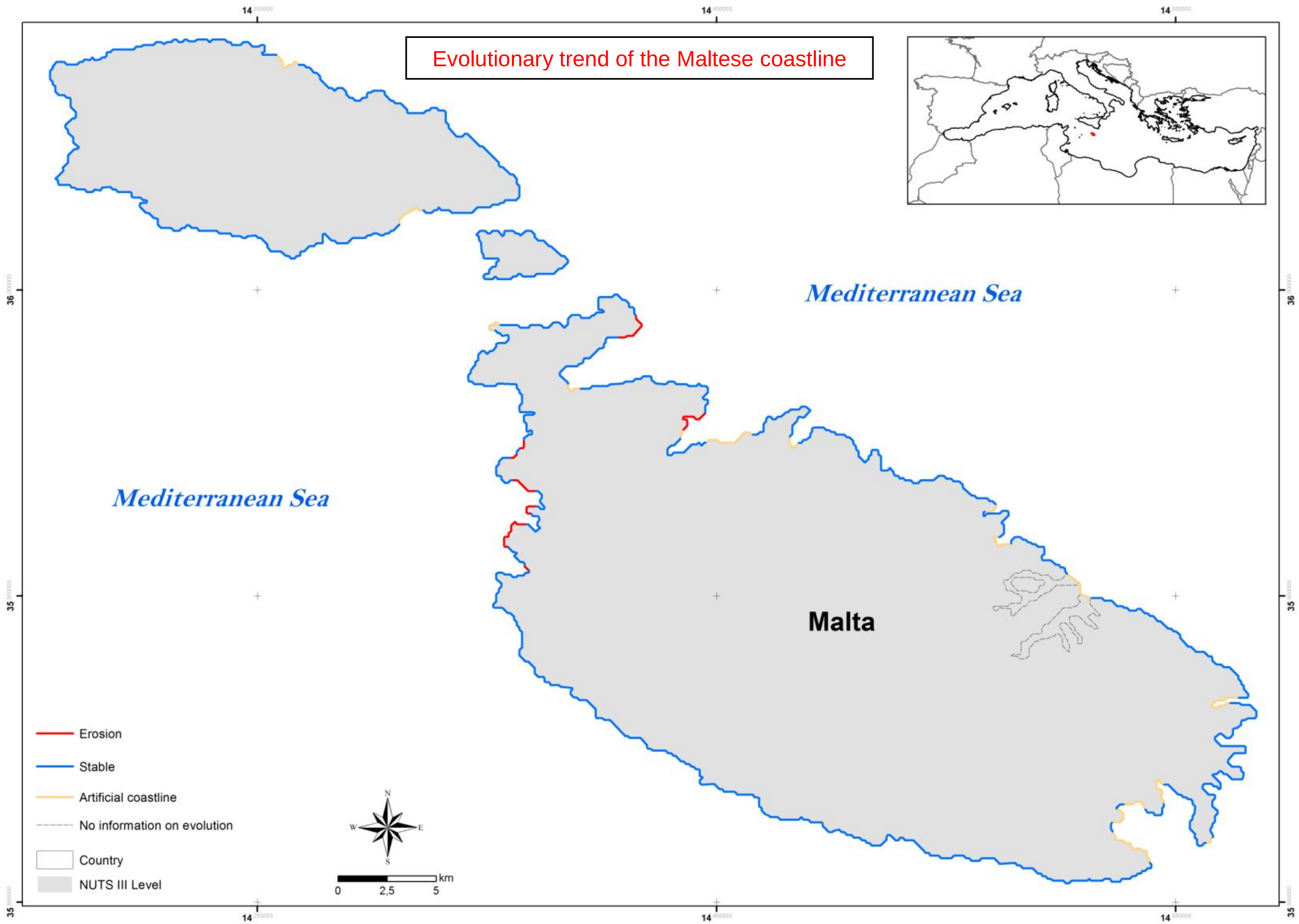
Malta


Evolutionary trend of the Maltese coastline
Mediterranean Sea
Mediterranean Sea
Malta
Erosion
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
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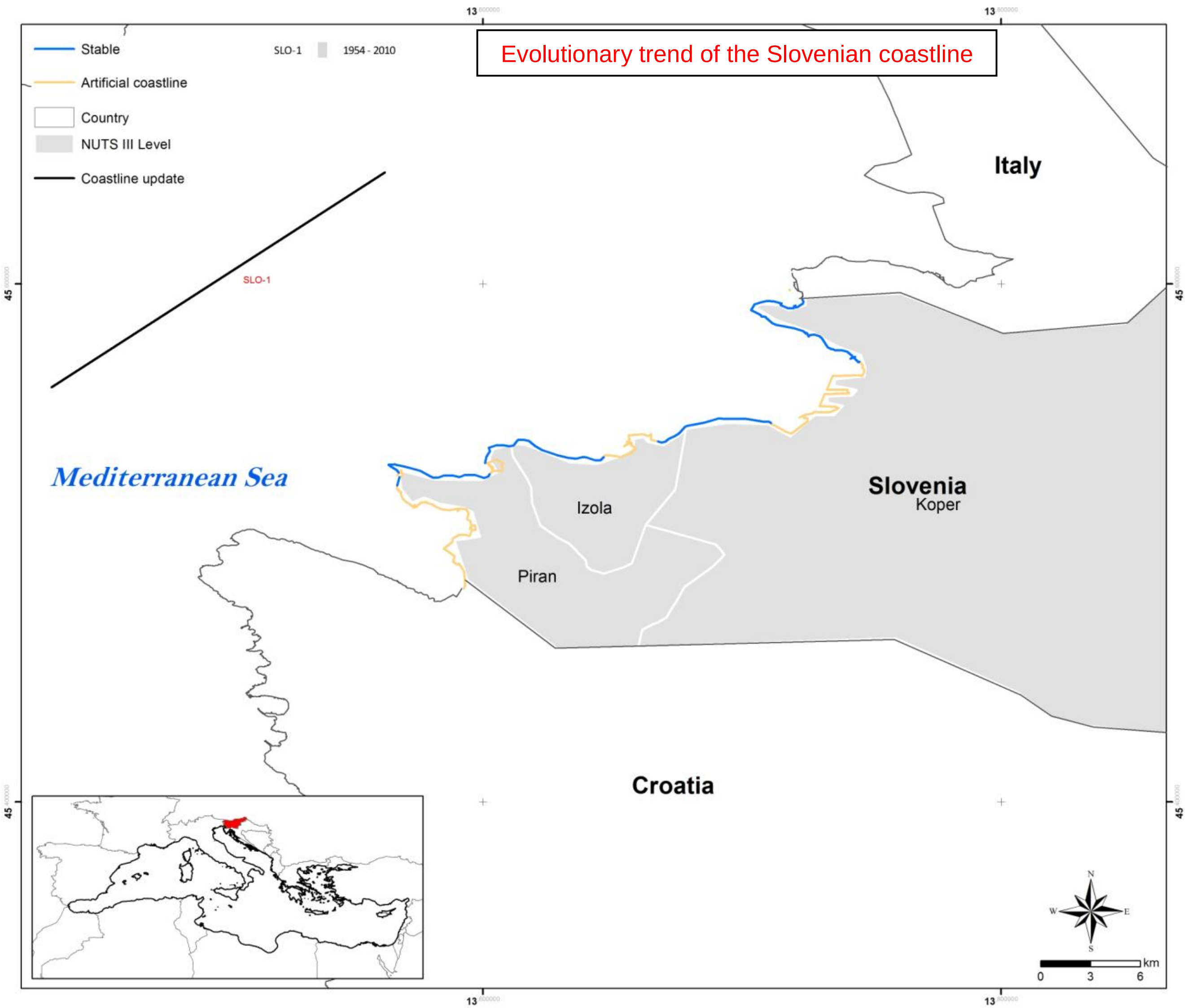
5

Slovenia


Evolutionary trend of the Slovenian coastline
Stable
Artificial coastline
Country
NUTS III Level
Coastline update
SLO-1
1954 - 2010
Italy
Mediterranean Sea
Slovenia
Koper
Izola
Piran
Croatia
km
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3
6

References used to realize the map of the evolutionary trend of the Slovenian coastline (*)

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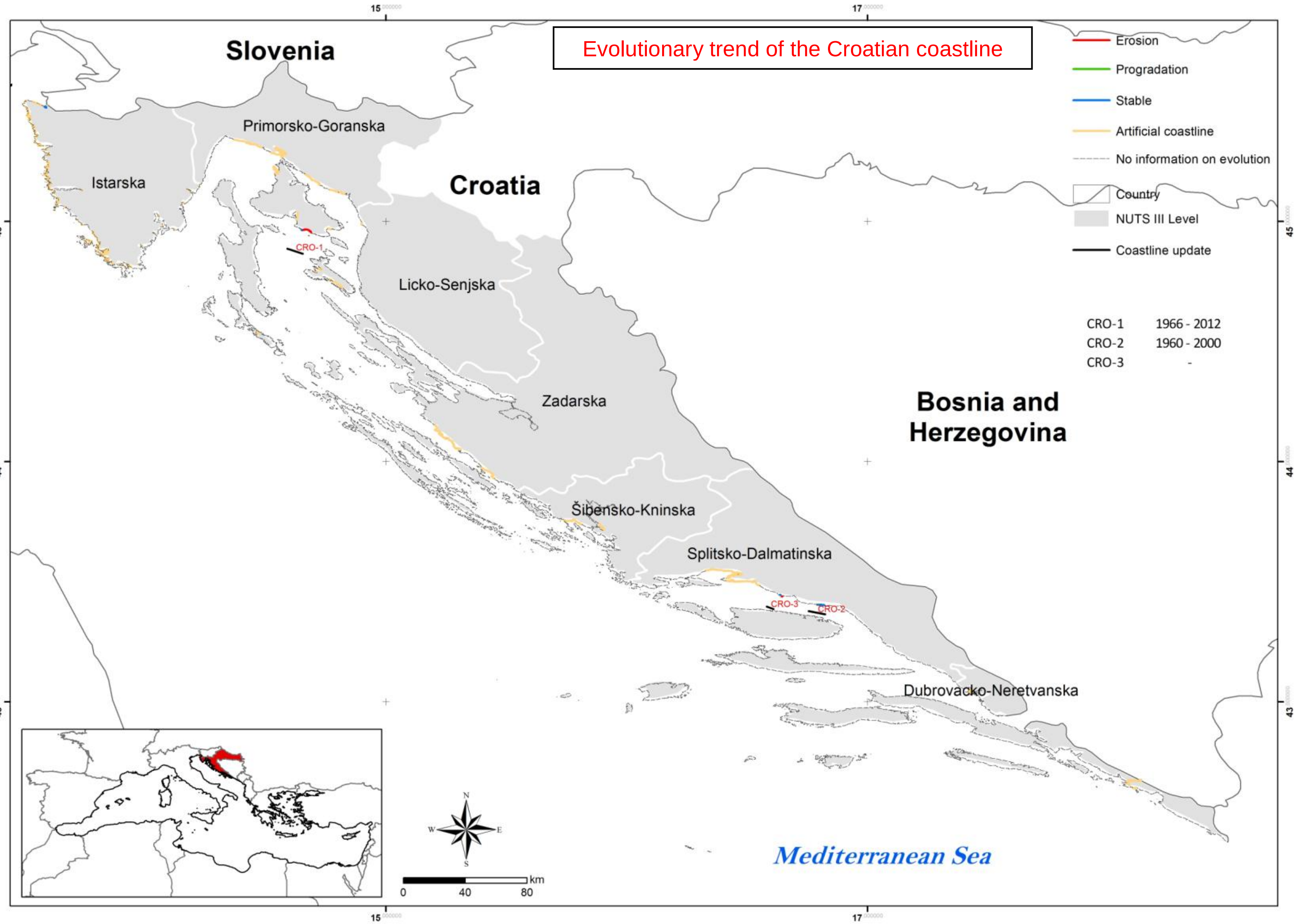
Croatia


Evolutionary trend of the Croatian coastline
Slovenia
Croatia
Bosnia and Herzegovina
Istarska
Primorsko-Goranska
Licko-Senjska
Zadarska
Šibensko-Kninska
Splitsko-Dalmatinska
Dubrovacko-Neretvanska
Mediterranean Sea
CRO-1
CRO-2
CRO-3
Erosion
Progradation
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
CRO-1 1966 - 2012
CRO-2 1960 - 2000
CRO-3 -
km
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References used to realize the map of the evolutionary trend of the Croatian coastline (*)

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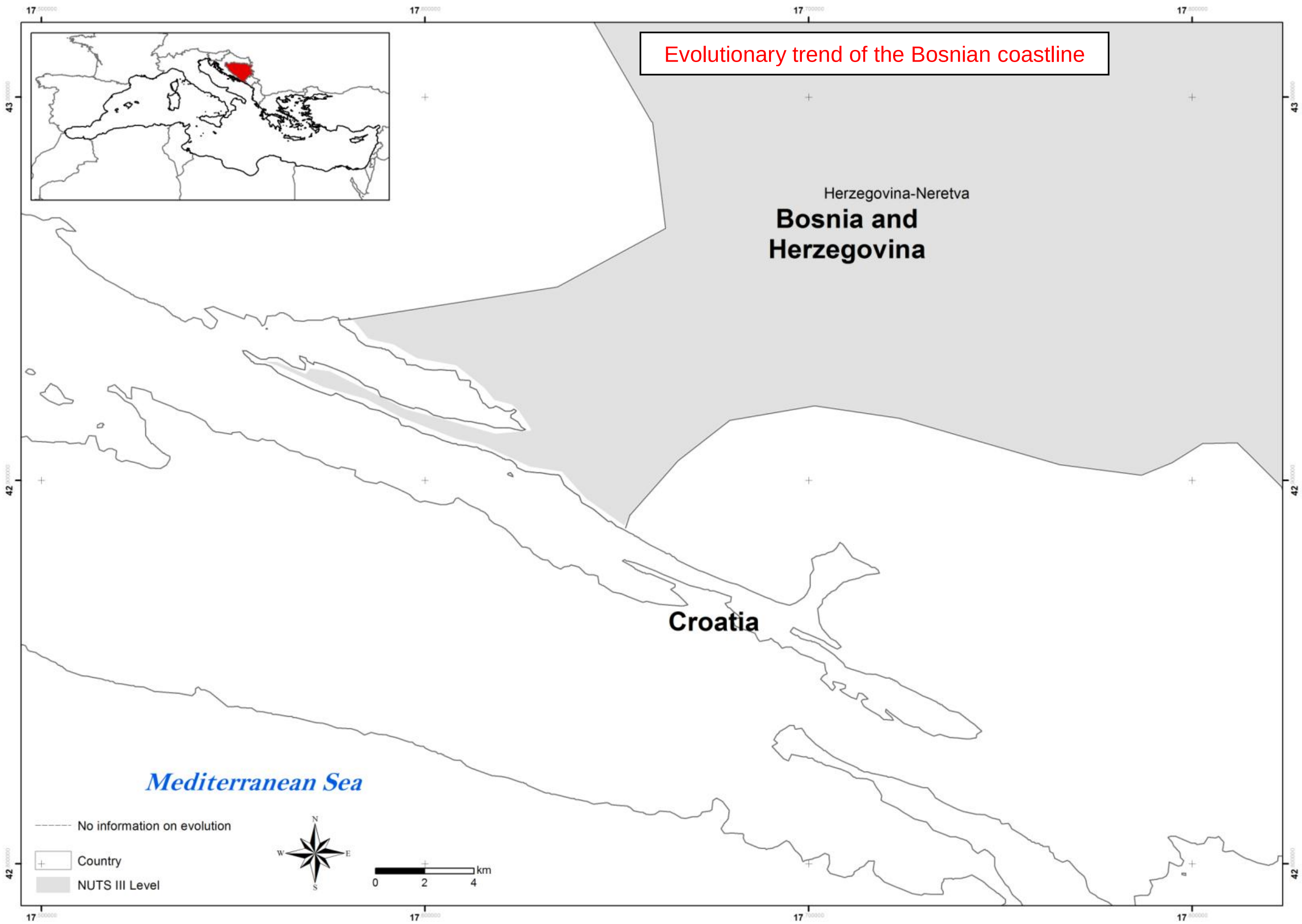
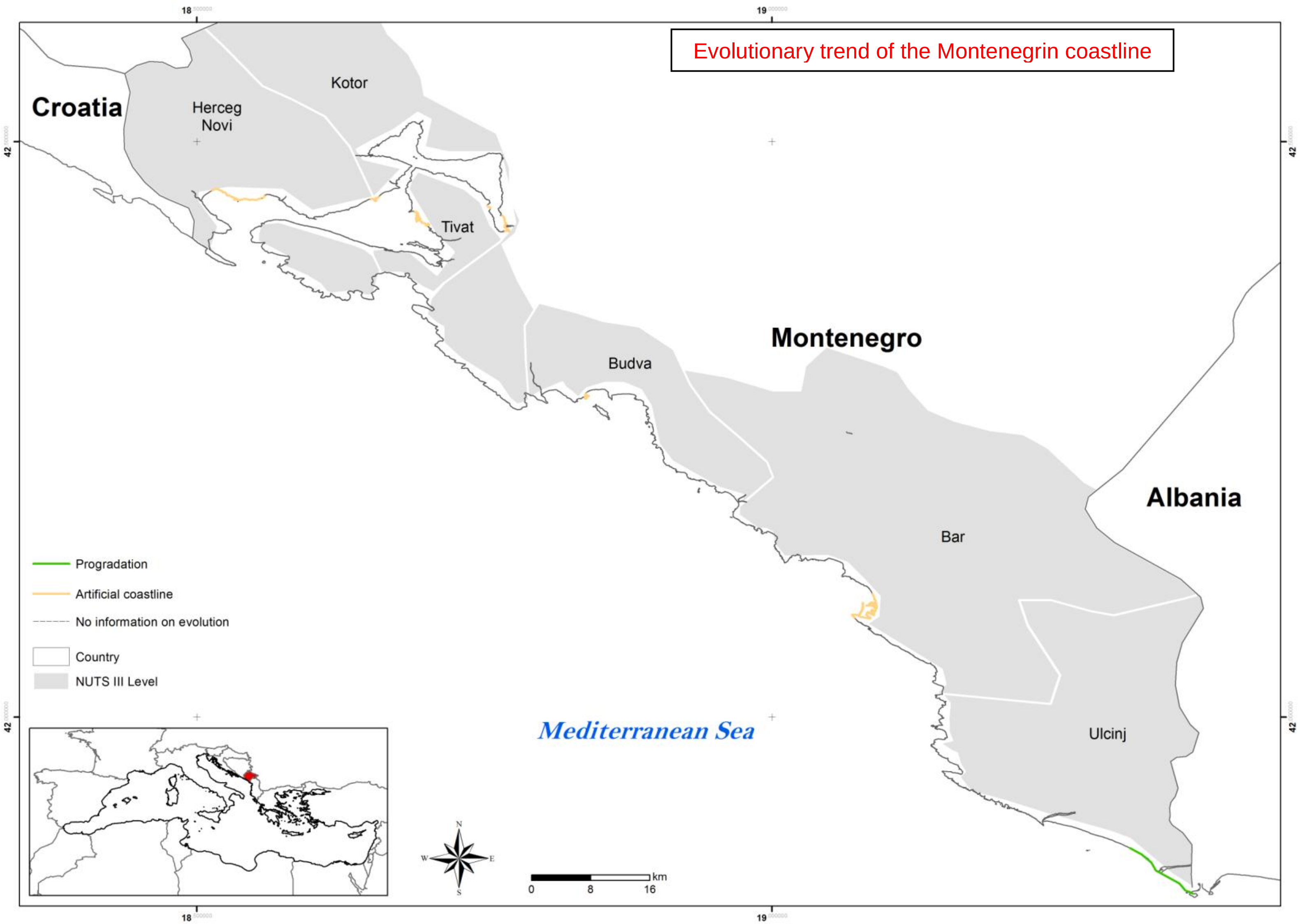
Bosnia and Herzegovina



Montenegro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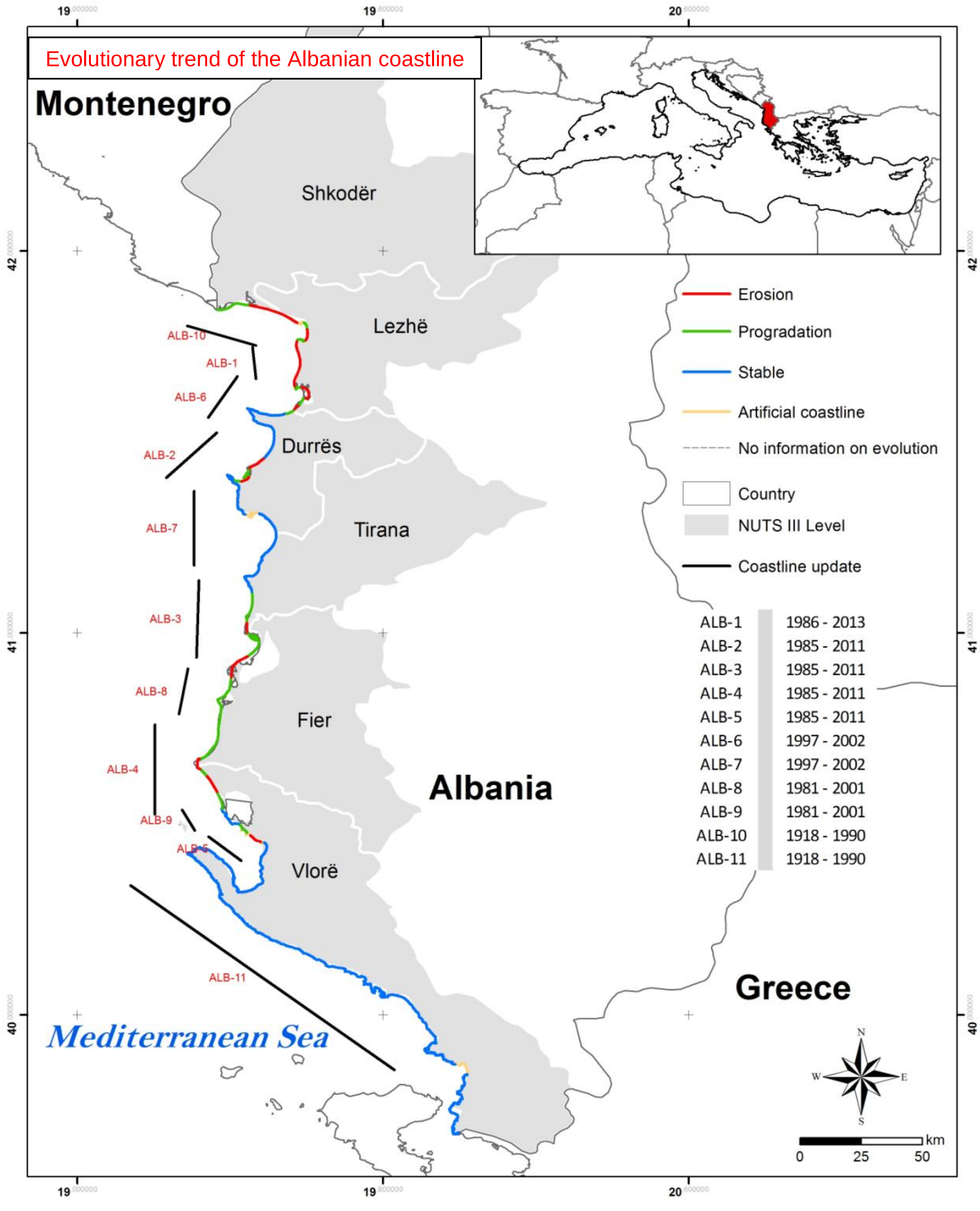
Croatia
Herceg Novi
Kotor
Tivat
Budva
Montenegro
Bar
Ulcinj
Albania
Mediterranean Sea
Progradation
Artificial coastline
No information on evolution
Country
NUTS III Level
km
0
8
16
18
19
42

Albania


Evolutionary trend of the Albanian coastline
Montenegro
Shkodër
Lezhë
Durrës
Tirana
Fier
Vlorë
Albania
Greece
Mediterranean Sea
ALB-10
ALB-1
ALB-6
ALB-2
ALB-7
ALB-3
ALB-8
ALB-4
ALB-9
ALB-5
ALB-11
Erosion
Progradation
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
ALB-1 1986 - 2013
ALB-2 1985 - 2011
ALB-3 1985 - 2011
ALB-4 1985 - 2011
ALB-5 1985 - 2011
ALB-6 1997 - 2002
ALB-7 1997 - 2002
ALB-8 1981 - 2001
ALB-9 1981 - 2001
ALB-10 1918 - 1990
ALB-11 1918 - 1990
N
S
E
W
km
0
25
50

References used to realize the map of the evolutionary trend of the Albanian coastline (*)

Frasheri, N., N. Pano, A. Frasher, S. Bushati 2011. Outlook on seawaters dynamics an geological setting factors for the Albanian Adriatic Coastline Developments. In: Proceeding of the European geosciences union, general assembly, Vienna, Austria. Pp. 37. (**ALB-6-7-8-9**)

Hoxha, E., S. Lipo, M. Dollma 2014. GIS Technology on Natural Disasters Management in Albania. IJSR. 3: 1759-1764. (**ALB-1**)

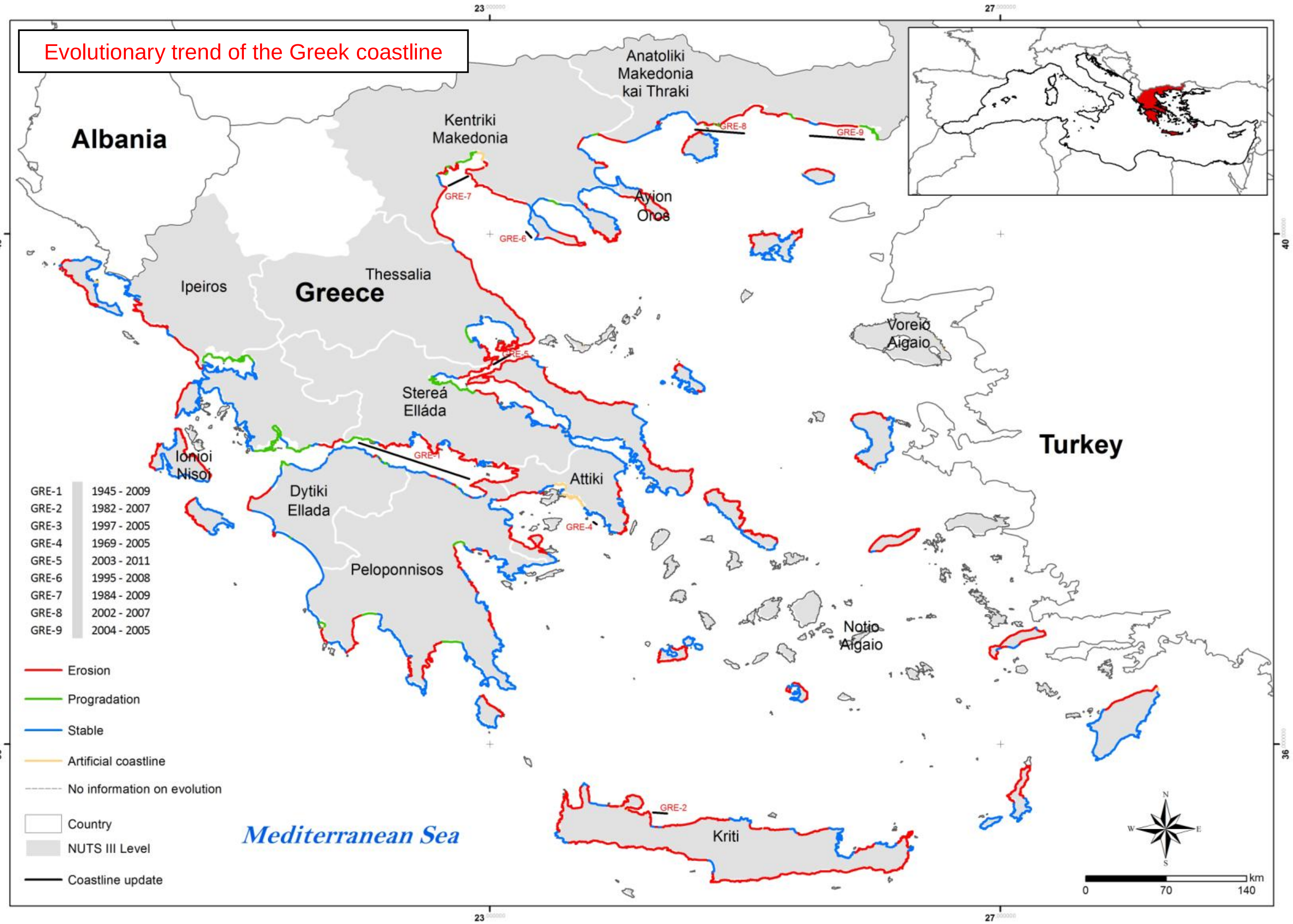
Pano, N., A. Frasheri, B. Avdyli, K. Gjoka, S. Bozdo 2007. Hydrology Days Hydro Geomorphological Classification of the Albanian Coastline in the Mediterranean Sea. Hydrology Days. 209-217.

Kanjir, U., N. Gregoric Bon 2016. Coastal changes and movements in the wider Vlora (Albania) area. GEOBIA 2016: Solutions and Synergies, 14-16 September 2016, University of Twente Faculty of Geo-Information and Earth Observation (ITC). Pp. 6.

Kurt, S., H. Dinçer 2012. Effects of global sea rise on the Adriatic coasts of Albania. 2nd International Balkan Annual Conference. IBAC. 2: 123-136. (**ALB-2-3-4-5**)

Simeoni, U., N. Pano, P. Ciavola 1997. The coastline of Albania: morphology, evolution and coastal management issues. Bull. Inst. océanogr. Monaco. 18: 151-168. (**ALB-10-11**)

Greece


Evolutionary trend of the Greek coastline
Albania
Greece
Turkey
Anatoliki Makedonia kai Thraki
Kentriki Makedonia
Ayion Oros
Ipeiros
Thessalia
Voreio Aigaio
Stereá Elláda
Ionioi Nisoi
Dytiki Ellada
Attiki
Peloponnisos
Notio Aigaio
Kriti
Mediterranean Sea
GRE-1 1945 - 2009
GRE-2 1982 - 2007
GRE-3 1997 - 2005
GRE-4 1969 - 2005
GRE-5 2003 - 2011
GRE-6 1995 - 2008
GRE-7 1984 - 2009
GRE-8 2002 - 2007
GRE-9 2004 - 2005
Erosion
Progradation
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
0 70 140 km

References used to realize the map of the evolutionary trend of the Greek coastline (*)

Anagnostou, C., P. Antoniou, G. Hatiris 2011. Erosion of a depositional coast in NE Rhodos island (SE Greece) and assessment of the best available measures for coast protection. J. Coast. Res. (SI64): 1316-1319. (**GRE-3**)

Andredaki M., A. Georgoulas, V. Hrissanthou, N. Kotsovinos 2014. Assessment of reservoir sedimentation effect on coastal erosion in the case of Nestos River, Greece. Int. J. Sediment Res. 29(1): 34-48. (**GRE-8**)

Chalkias, G., E. Grigoropoulou, G. Manthos, E. Karymbalis, M. Ferentinou, C. Chalkias 2011. Coastal vulnerability index along the southern coast of the gulf of Corinth (Greece). Proceedings of the 10th International Conference on the Mediterranean Coastal Environment, MEDCOAST 2011. 2: 615-626. (**GRE-1**)

Karymbalis, E., C. Chalkias, G. Chalkias, E. Grigoropoulou, G. Manthos, M. Ferentinou 2012. Assessment of the sensitivity of the southern coast of the Gulf of Corinth (Peloponnese, Greece) to sea-level rise. Open Geosci. 4(4): 561-577. (**GRE-1**)

Koutsomichou, I., S. E. Poulos, N. Evelpidou, C. Anagnostou, G. Ghionis, A. Vassilopoulos 2009. The role of beach rock formations in the evolution of embayed coastal zones of Attica (Greece) in relation to sea level rise. The case of Kalyvia beach zone. Geogr. Fis. Din. Quat. 32: 49–56. (**GRE-4**)

Petrakis, S., G. Alexandrakis, S. Poulos 2014. Recent and future trends of beach zone evolution in relation to its physical characteristics: the case of the Almiros bay (island of Crete, South Aegean Sea). Global Nest. J. 16: 104–113. (**GRE-2**)

Petropoulos, G. P., D. P. Kalivas, H. M. Griffiths, P. P. Dimou 2015. Remote sensing and GIS analysis for mapping spatio-temporal changes of erosion and deposition of two Mediterranean river deltas: The case of the Axios and Aliakmonas rivers, Greece. Inter. J. Appl. Earth Obs. Geoinf. 35: 217–228. (**GRE-7**)

Samaras, A. G., C. G. Koutitas 2014a. The impact of watershed management on coastal morphology: a case study using an integrated approach and numerical modeling. Geomorphology. 211: 52–63. (**GRE-6**)

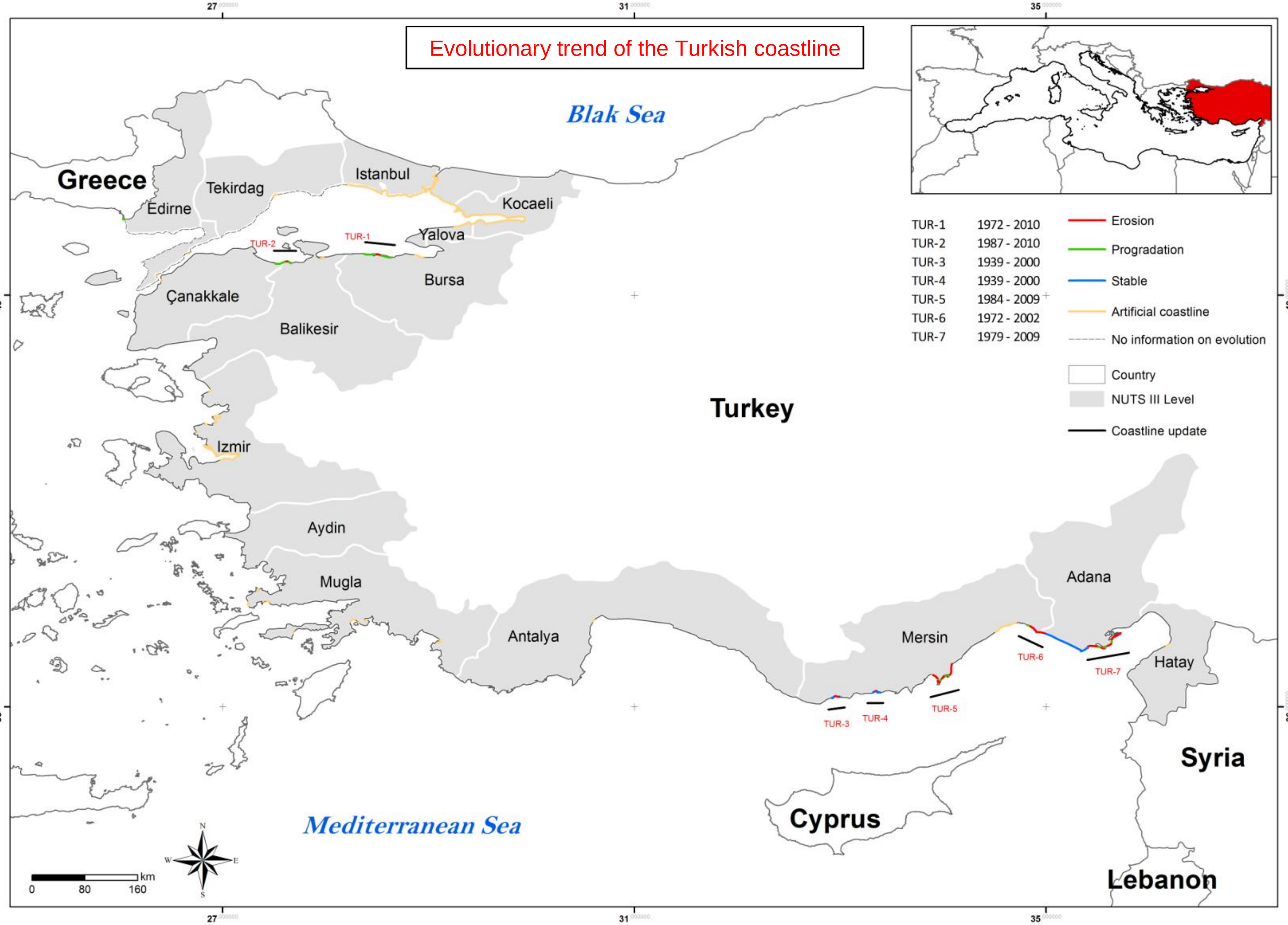
Samaras, A. G., C. G. Koutitas 2014b. Modeling the impact of climate change on sediment transport and morphology in coupled watershed-coast systems: a case study using an integrated approach. Int. J. Sediment Res. 29(3): 304–315. (**GRE-6**)

Vassilakis, E., K. Papadopoulou-Vrynioti 2014. Quantification of Deltaic Coastal Zone Change Based on Multi-Temporal High Resolution Earth Observation Techniques. ISPRS Int. J. Geo-Inf. 3: 18-28. (**GRE-5**)

Xeidakis, G. S., P. K. Delimani, S. G. Skias 2006. Sea Cliff Erosion in the Eastern Part of the North Aegean Coastline, Northern Greece. Journal of Environmental Science and Health Part A, 41, 1989–2011. (**GRE-9**)

Xeidakis, G. S., P. K. Delimani, S. G. Skias 2007. Erosion problems in Alexandroupolis coastline, North-Eastern Greece. Environ. Geol. 53: 835–848. (**GRE-9**)

Turkey


Evolutionary trend of the Turkish coastline
Blak Sea
Mediterranean Sea
Greece
Turkey
Syria
Cyprus
Lebanon
Edirne
Tekirdag
Istanbul
Kocaeli
Yalova
Bursa
Çanakkale
Balikesir
Izmir
Aydin
Mugla
Antalya
Mersin
Adana
Hatay
TUR-1
TUR-2
TUR-3
TUR-4
TUR-5
TUR-6
TUR-7
TUR-1 1972 - 2010
TUR-2 1987 - 2010
TUR-3 1939 - 2000
TUR-4 1939 - 2000
TUR-5 1984 - 2009
TUR-6 1972 - 2002
TUR-7 1979 - 2009
Erosion
Progradation
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
km
0
80
160
27
31
35
40
36

References used to realize the map of the evolutionary trend of the Turkish coastline (*)

Bal, Y., G. Kelling, S. Kapur, E. Akça, H. Çetin, O. Erol 2003. An improved method for determination of Holocene coastline changes around two ancient settlements in southern Anatolia: a geoarchaeological approach to historical land degradation studies. Land Degrad. Dev. 14(4): 363–376. (**TUR-3-4**)

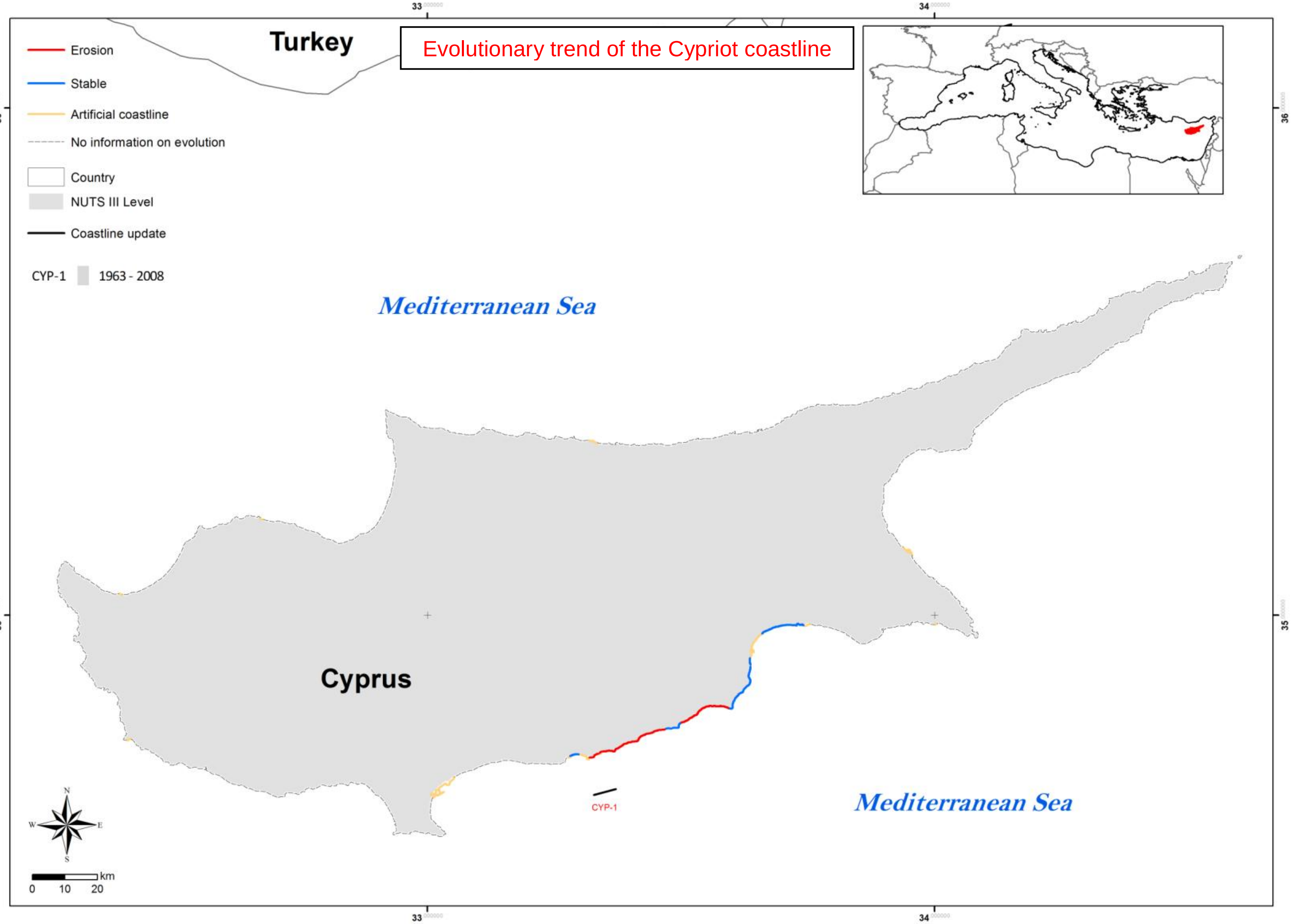
Emre Ö. 2015. Examination of Gönen and Kocasu River Deltas In Terms of Land Use and Changes In Shoreline (NW Turkey). Int. J. Innovative Environ. Studies Res. 3(1): 1-13. (**TUR-1-2**)

Kuleli, T. 2010a. Quantitative analysis of shoreline changes at the Mediterranean Coast in Turkey. Environ. Monit. Assess. 167: 387-397. (**TUR-6**)

Kuleli, T., A. Guneroglu, F. Karsli, M. Dihkan 2011. Automatic detection of shoreline change on coastal Ramsar wetlands of Turkey. Ocean Eng. 38: 1141–1149. (**TUR-5-7**)

Yılmaz, N., L. Balas, A. İnan 2015. Coastal Erosion Problem, Modelling and Protection, Ocean Sci. J. 50(3): 589-601.

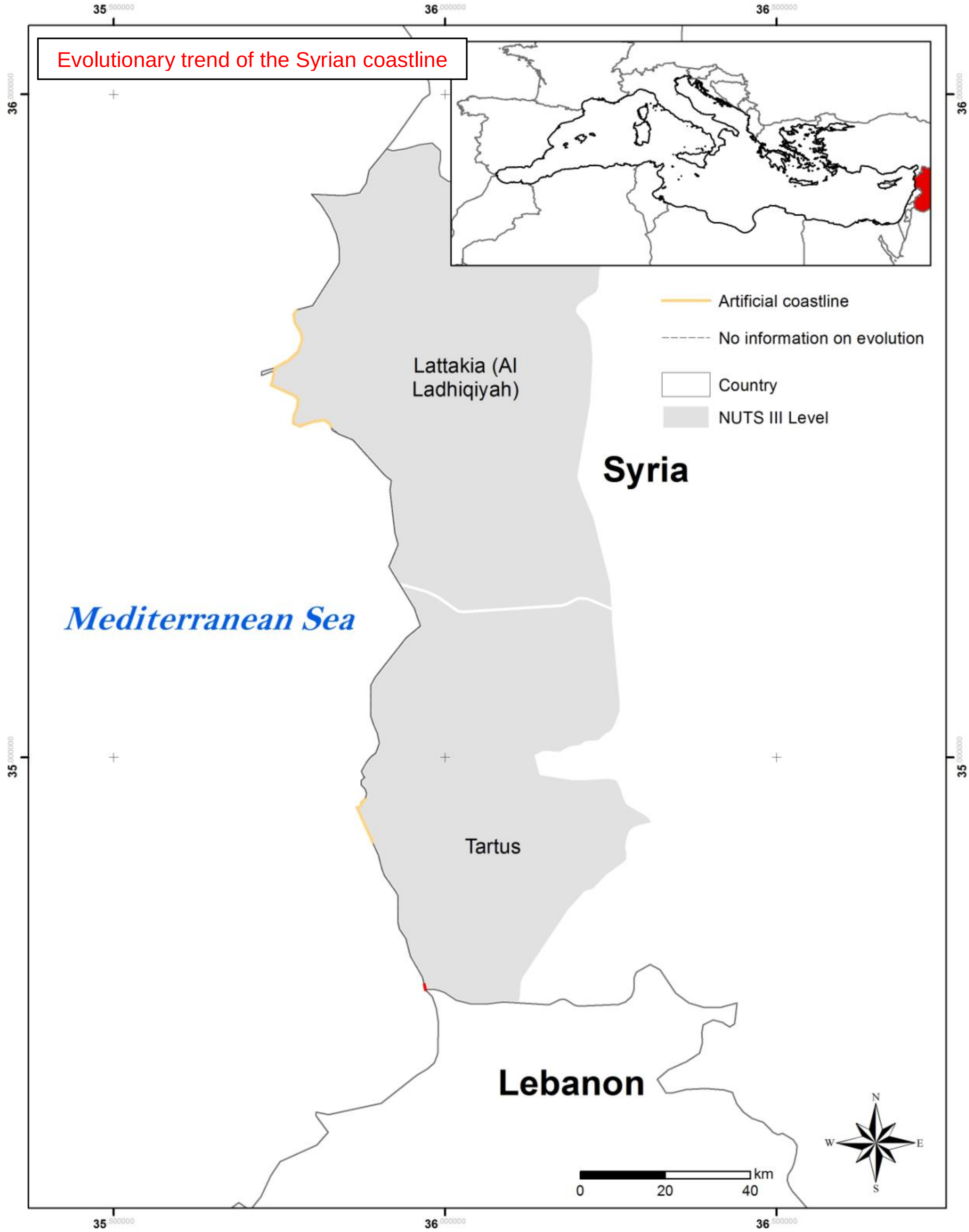
Cyprus


Evolutionary trend of the Cypriot coastline
Turkey
Erosion
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
CYP-1
1963 - 2008
Mediterranean Sea
Cyprus
CYP-1
Mediterranean Sea
N
S
W
E
km
0
10
20
33
34
35
36

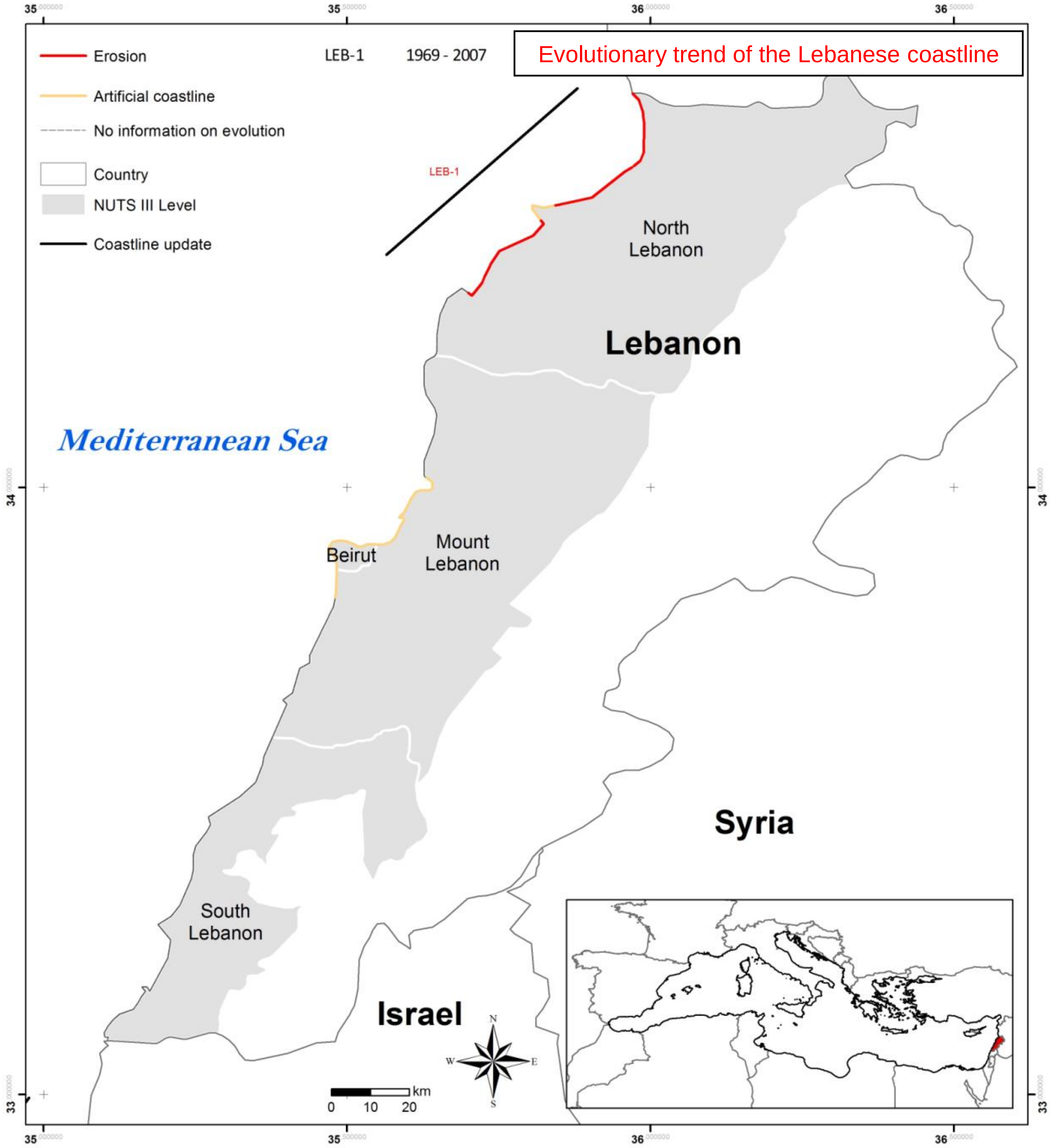
References used to realize the map of the evolutionary trend of the Cypriot coastline (*)

Andreou, G. M., R. Opitz, S. W. Manning, K. D. Fisher, D. A. Sewell, A. Georgiou, T. Urban 2017. Integrated methods for understanding and monitoring the loss of coastal archaeological sites: The case of Tochni-Lakkia, south-central Cyprus. J. Archaeol. Sci. 12: 197-208. (**CYP-1**)

Syria


Evolutionary trend of the Syrian coastline
Artificial coastline
No information on evolution
Country
NUTS III Level
Lattakia (Al Ladhiqiyah)
Tartus
Syria
Lebanon
Mediterranean Sea
km
0
20
40
N
E
S
W

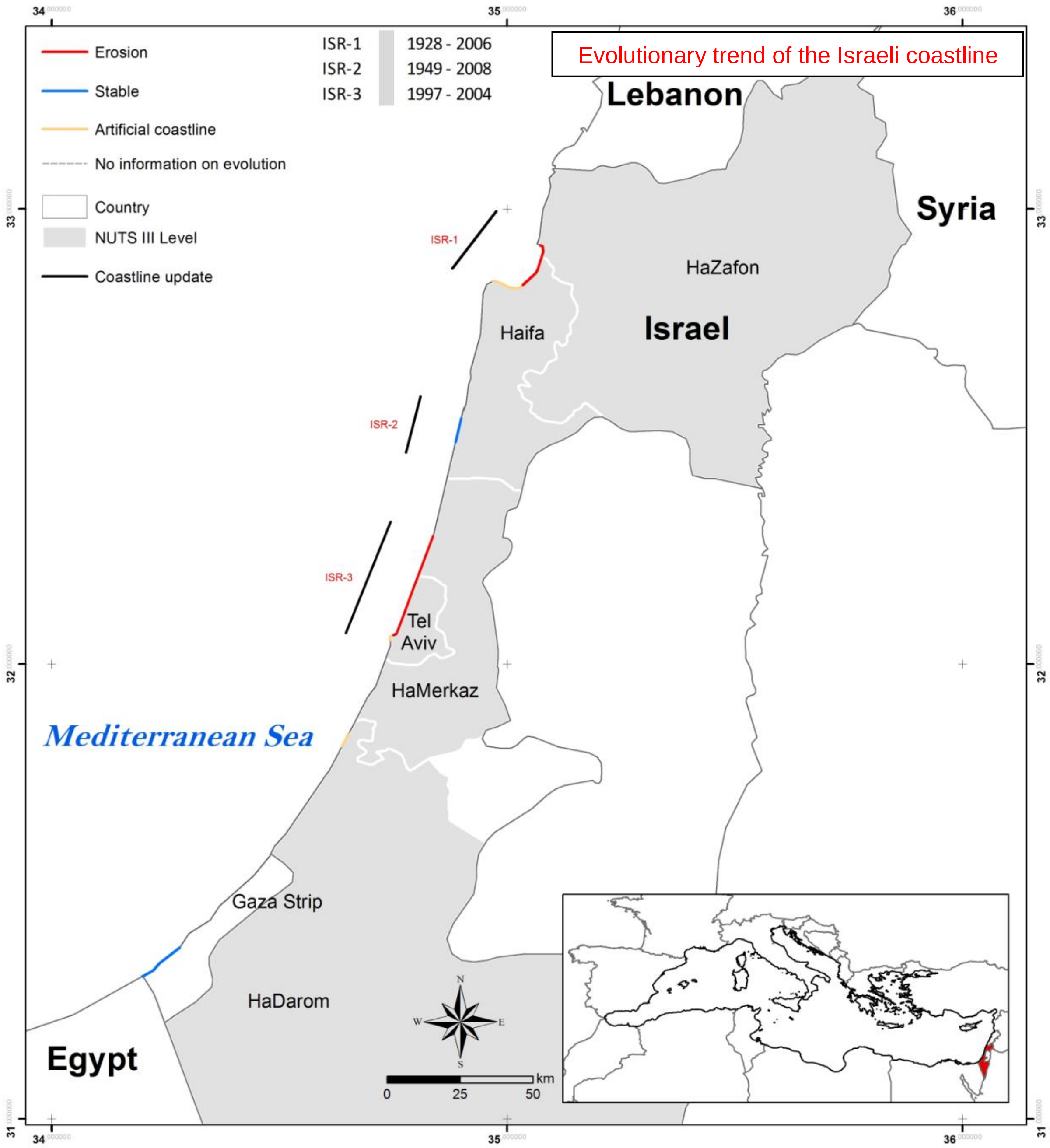
Lebanon


Evolutionary trend of the Lebanese coastline
Erosion
LEB-1
1969 - 2007
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
LEB-1
North
Lebanon
Lebanon
Mediterranean Sea
Beirut
Mount
Lebanon
Syria
South
Lebanon
Israel
km
0
10
20
N
S
W
E

References used to realize the map of the evolutionary trend of the Lebanese coastline (*)

Abou-Dagher, M., M. Nader, S. El Indary 2012. Evolution of the coast of North Lebanon from 1962-2007: mapping changes for the identification of hotspots and for future management interventions. Fourth International Symposium, Monitoring of Mediterranean Coastal Areas: Problems and Measurements Techniques, Livorno – Italy. 171-180. (**LEB-1**)

Israel


Evolutionary trend of the Israeli coastline
Erosion
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
ISR-1 1928 - 2006
ISR-2 1949 - 2008
ISR-3 1997 - 2004
Lebanon
Syria
HaZafon
Israel
Haifa
ISR-1
ISR-2
ISR-3
Tel Aviv
HaMerkaz
Mediterranean Sea
Gaza Strip
HaDarom
Egypt
0 25 50 km
34
35
36
33
32
31

References used to realize the map of the evolutionary trend of the Israeli coastline (*)

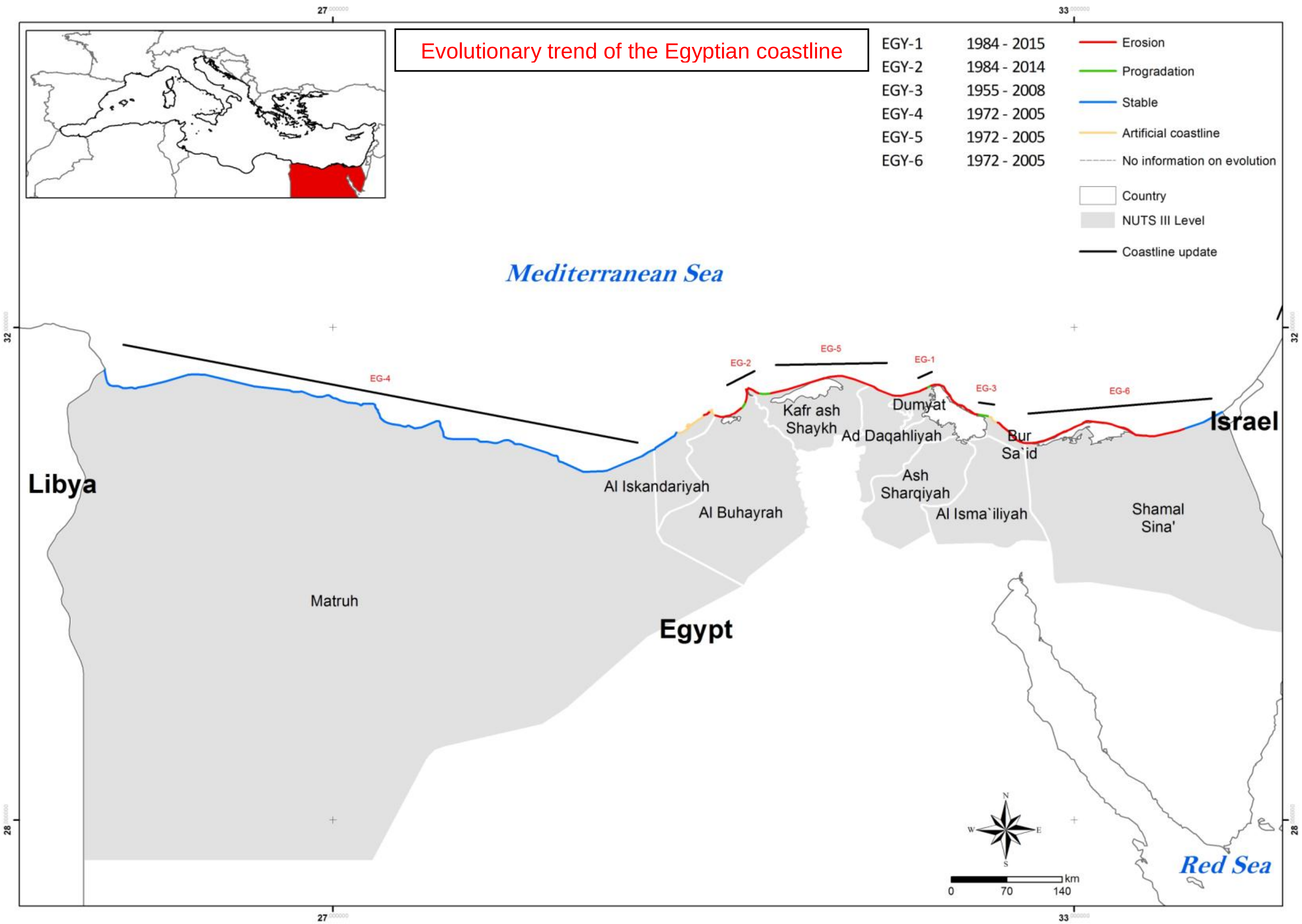
Rosen, S. D. 2009. Research on coastal cliffs and beach erosion in Israel. IOLR report H56/2009. Pp. 35. (**ISR-3**)

Rosen, S.D. 2011. Assessing present and future Mediterranean sea level rise impact on Israel's coast and mitigation ways against beach and cliff erosion. Proc. ICCE, Shanghai, China. Pp. 12. (**ISR-3**)

Shtienberg, G., D. Zviely, D. Sivan, M. Lazar 2014. Two centuries of coastal change at Caesarea, Israel: natural processes vs. human intervention. Geo-Mar. Lett. 34: 365–379. (**ISR-2**)

Zviely, D., E. Kit, B. Rosen, E. Galili, M. Klein 2009. Shoreline migration and beach-nearshore sand balance over the last 200 years in Haifa Bay (SE Mediterranean). Geo-Mar. Lett. 29: 93–110. (**ISR-1**)

Egypt


Evolutionary trend of the Egyptian coastline
EGY-1 1984 - 2015
EGY-2 1984 - 2014
EGY-3 1955 - 2008
EGY-4 1972 - 2005
EGY-5 1972 - 2005
EGY-6 1972 - 2005
Erosion
Progradation
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
Mediterranean Sea
Red Sea
Libya
Israel
Egypt
Matruh
Al Iskandariyah
Al Buhayrah
Kafr ash Shaykh
Ad Daqahliyah
Dumyat
Bur Sa`id
Ash Sharqiyah
Al Isma`iliyah
Shamal Sina'
EG-1
EG-2
EG-3
EG-4
EG-5
EG-6
0
70
140
km

References used to realize the map of the evolutionary trend of the Egyptian coastline (*)

El-Asmar, H. M., M. M. N. Taha, A. S. El-Sorogy 2016. Morphodynamic changes as an impact of human intervention at the Ras El-Bar-Damietta harbor coast, NW Damietta promontory, Nile Delta, Egypt. J. Afr. Earth Sci. 124: 323–339. (**EGY-1**)

Frihy, O. 2003, The Nile Delta-Alexandria Coast: Vulnerability To Sea-Level Rise, Consequences and Adaptation. Mitig adapt strategies glob. chang. 8: 115–138.

Frihy, O. E. S., E. A. Deabes, S. M. Shereet, F. A. Abdalla 2010. Alexandria-Nile delta coast, Egypt: update and future projection of relative sea-level rise. Environ. Earth Sci. 61: 253-273.

Frihy, O. E. S. M. K. El-Sayed 2013. Vulnerability risk assessment and adaptation to climate change induced sea level rise along the Mediterranean coast of Egypt. Mitig. adapt. strategies glob. chang. 18: 1215–1237. (**EGY-3**)

Ghoneim, E., J. Mashaly, D. Gamble, J. Halls, M. AbuBakr 2015. Nile delta exhibited a spatial reversal in the rates of shoreline retreat on the Rosetta promontory comparing pre- and post-beach protection. Geomorphology. 228: 1–14.

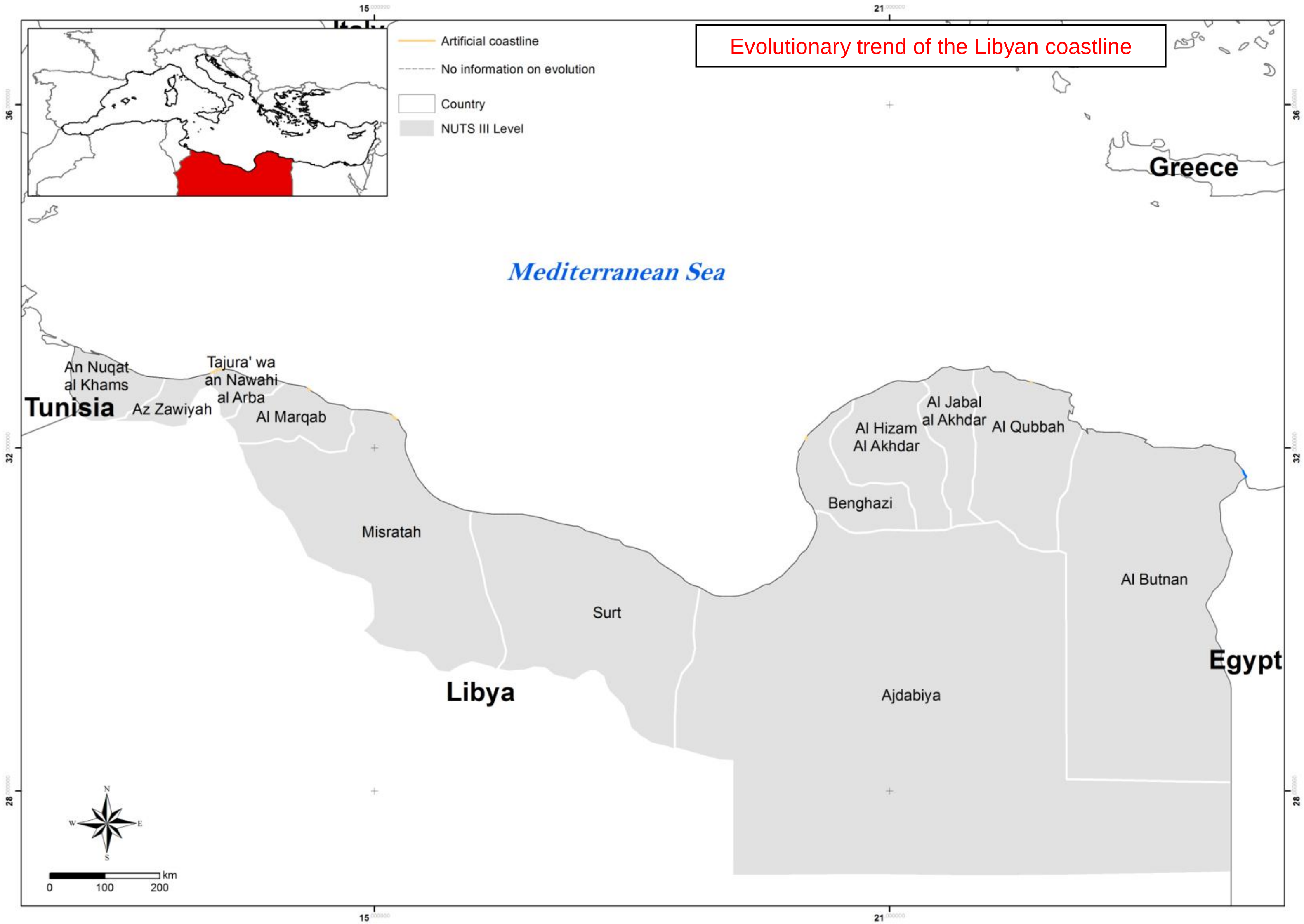
Hereher, M. 2015. Coastal vulnerability assessment for Egypt's Mediterranean coast. Geomat. Nat. Hazards Risk. 6(4): 342–355. (**EGY-4-5-6**)

Masria, A., K. Nadaoka, A. Negm, M. Iskander 2015. Detection of Shoreline and Land Cover Changes around Rosetta Promontory, Egypt, Based on Remote Sensing Analysis. Land. 4: 216–230. (**EGY-2**)

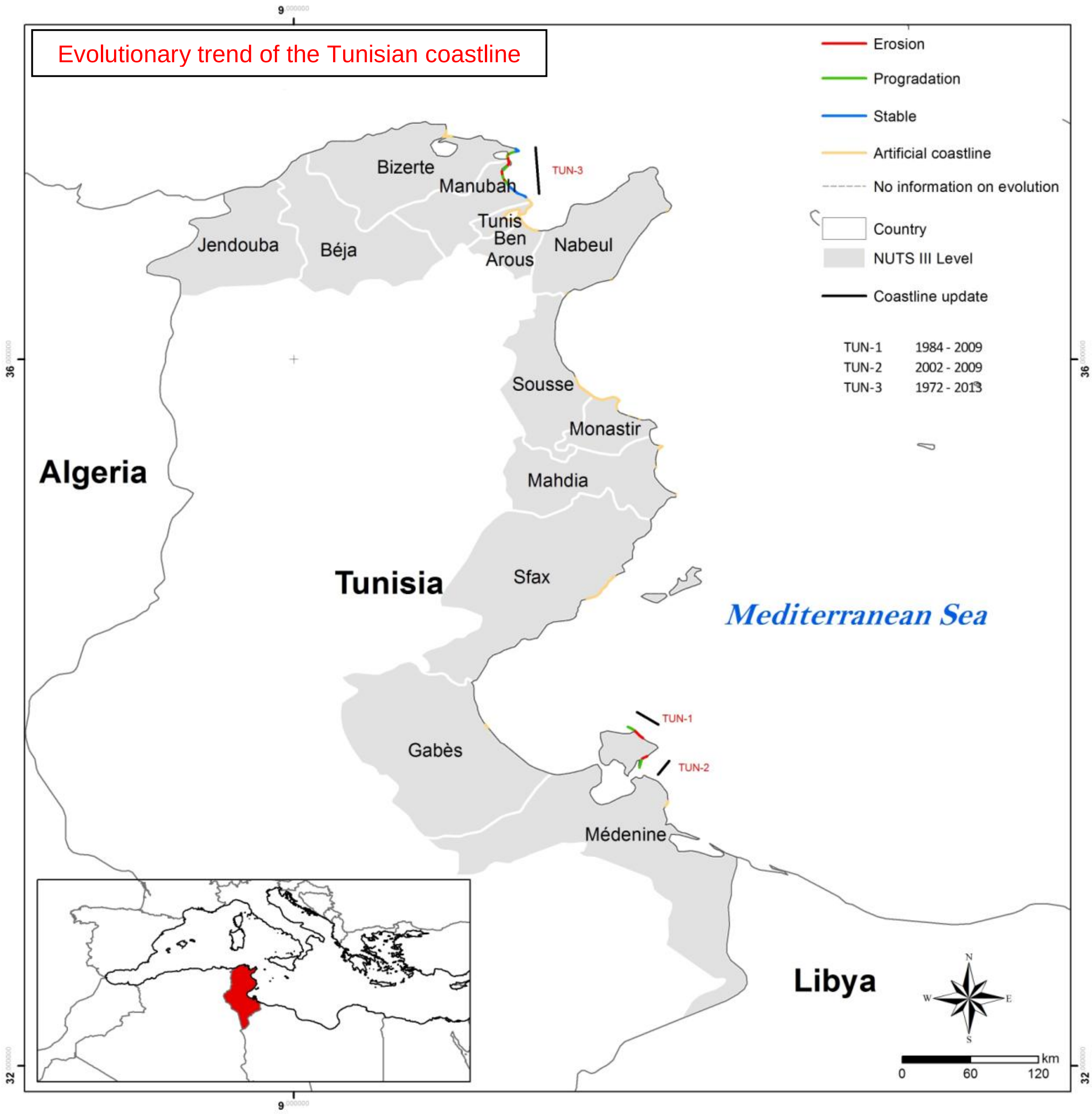
Masria, A., A. Negm, M. Iskander, O. Saavedra 2014. Coastal zone issues: a case study (Egypt). Procedia Engineer. 70: 1102–1111.

White, K., H. M. El Asmar 1999. Monitoring changing position of coastlines using Thematic Mapper imagery. Geomorphology. 29: 93–105.

Libya


Evolutionary trend of the Libyan coastline
Artificial coastline
No information on evolution
Country
NUTS III Level
Mediterranean Sea
Greece
Tunisia
Egypt
Libya
An Nuqat al Khams
Az Zawiyah
Tajura' wa an Nawahi al Arba
Al Marqab
Misratah
Surt
Ajdabiya
Benghazi
Al Hizam Al Akhdar
Al Jabal al Akhdar
Al Qubbah
Al Butnan
N
S
E
W
0
100
200
km
15
21
36
32
28

Tunisia

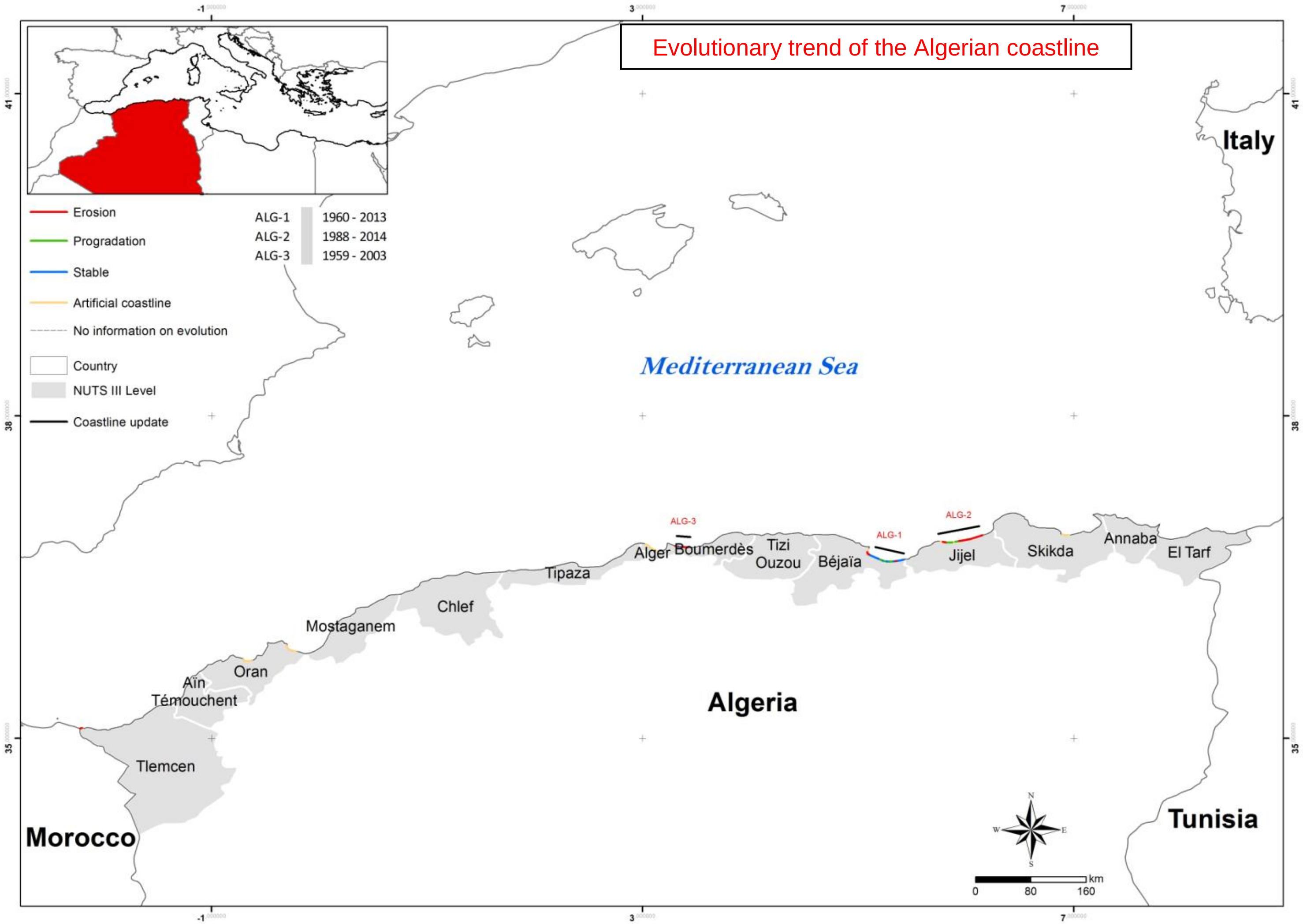

Evolutionary trend of the Tunisian coastline
Erosion
Progradation
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
TUN-1 1984 - 2009
TUN-2 2002 - 2009
TUN-3 1972 - 2013
Bizerte
Manubah
TUN-3
Jendouba
Béja
Tunis
Ben Arous
Nabeul
Sousse
Monastir
Mahdia
Algeria
Tunisia
Sfax
Mediterranean Sea
TUN-1
TUN-2
Gabès
Médenine
Libya
km
0
60
120

References used to realize the map of the evolutionary trend of the Tunisian coastline (*)

Bouchahma, M., Y. Wanglin 2012. Automatic Measurement of Shoreline Change on Djerba Island of Tunisia. Comp. Inf. Sci. 5(5): 17-24. (**TUN-1-2**)

Louati, M., H. Saïdi, F. Zargouni 2015. Shoreline change assessment using remote sensing and GIS techniques: A case study of the Medjerda delta coast, Tunisia. Arab. J. Geosci. 8: 4239–4255. (**TUN-3**)

Algeria


Evolutionary trend of the Algerian coastline
Erosion
Progradation
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
ALG-1 1960 - 2013
ALG-2 1988 - 2014
ALG-3 1959 - 2003
Italy
Mediterranean Sea
ALG-3
ALG-1
ALG-2
Alger
Boumerdès
Tizi Ouzou
Béjaïa
Jijel
Skikda
Annaba
El Tarf
Tipaza
Chlef
Mostaganem
Oran
Aïn Témouchent
Tlemcen
Algeria
Morocco
Tunisia
km
0
80
160

References used to realize the map of the evolutionary trend of the Algerian coastline (*)

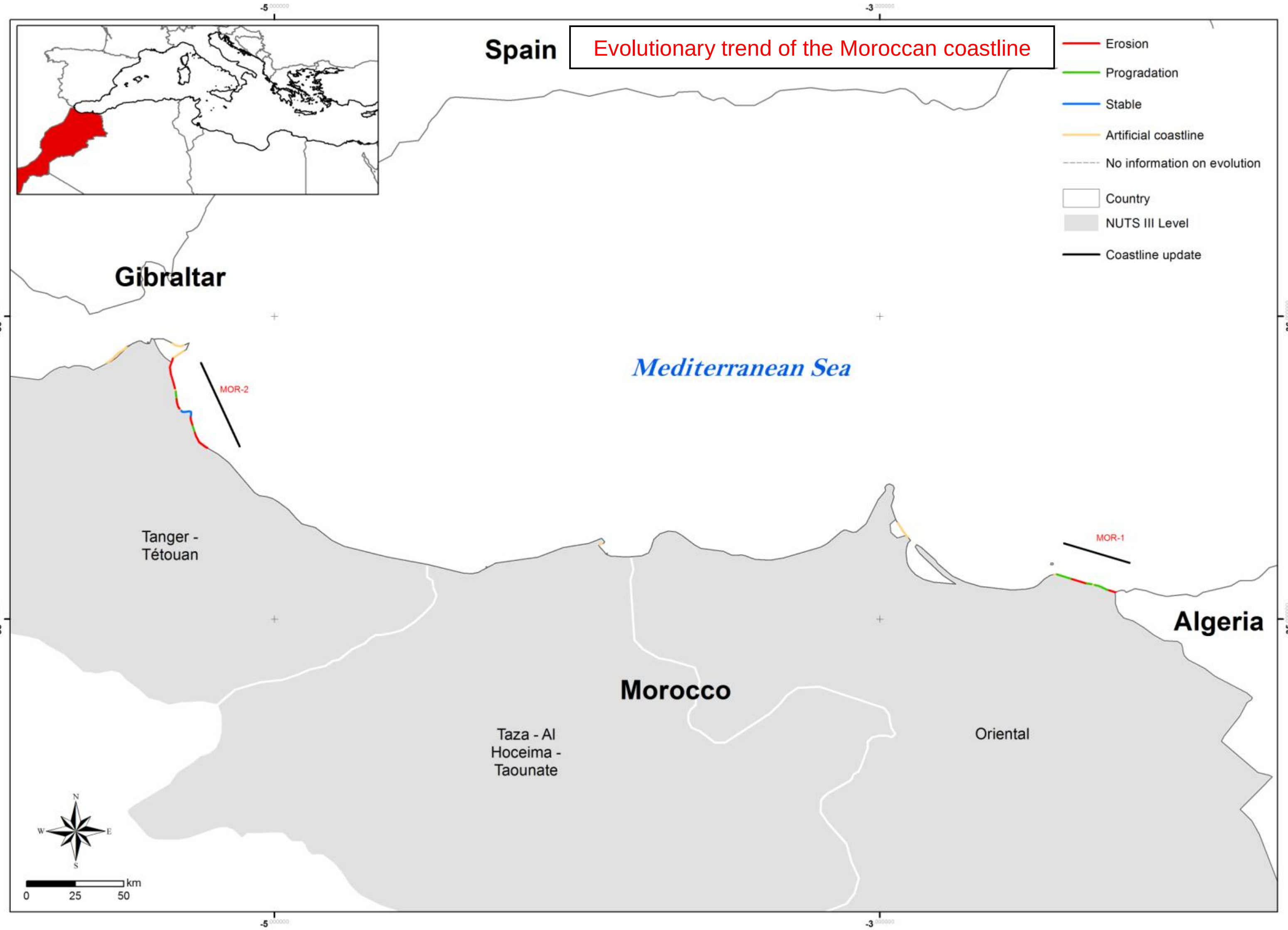
Ayadi, K., M. Boutiba, F. Sabatier, M.S. Guettouche 2016. Detection and analysis of historical variations in the shoreline, using digital aerial photos, satellite images, and topographic surveys DGPS: case of the Bejaia bay (East Algeria). Arab. J. Geosci. 9: 1-18. (**ALG-1**)

El Islam, B. N., F. Houma, K. Amarouche 2017. Combination of Satellite Images and Numerical Model for the State Followed the Coast of the Bay of Bejaia-Jijel. IJEGEO. 4(1): 1-7.

Gabbianelli, G., E. Fabbri, E. Ulazzi, M. Soldati, M. Gonella, S. Kocheida et al. 2007. Integrated Coastal Management: the AMIS project, Algeria. Integrated Coastal Management. 13-24. (**ALG-3**)

Kermani, S., M. Boutiba, M. Guendouz, M. S. Guettouche, D. Khelfani 2016. Detection and analysis of shoreline changes using geospatial tools and automatic computation: Case of jijelian sandy coast (East Algeria). Ocean Coast. Manag. 132: 46-58. (**ALG-2**)

Morocco


Evolutionary trend of the Moroccan coastline
Spain
Gibraltar
Mediterranean Sea
Morocco
Algeria
Tanger - Tétouan
Taza - Al Hoceima - Taounate
Oriental
MOR-2
MOR-1
Erosion
Progradation
Stable
Artificial coastline
No information on evolution
Country
NUTS III Level
Coastline update
km
0
25
50
N
S
E
W

References used to realize the map of the evolutionary trend of the Moroccan coastline (*)

Anfuso, G., A. Martinez del Pozo, D. Nachite, J. Benavente, A. Macias 2007. Morphological characteristics and medium-term evolution of the beaches between Ceuta and Cabo Negro (Morocco). Environ. Geol. 52: 933-946.

El Mrini, A., E. Anthony, M. Maanan, M. Taaouati, D. Nachite 2012a. Beach-dune degradation in a Mediterranean context of strong development pressures, and the missing integrated management perspective. Ocean Coast. Manag. 69: 299–306. (**MOR-2**)

El Mrini, A., E. Anthony, M. Taaouati, D. Nachite, M. Maanan 2013. A note on contrasting beach-dune morphodynamics, Tetouan coast, northwest Morocco: the role of grain size and human-altered dune morphology. J. Coast. Res. (SI65): 1-6.

El Mrini, A., M. Maanan, E. J. Anthony, M. Taaouti 2012b. An integrated approach to characterize the interaction between coastal morphodynamics, geomorphological setting and human interventions on the Mediterranean beaches of northwestern Morrocco. Appl. Geogr. 35: 334-344. (**MOR-2**)

Mouzouri, M., Z. Irzi 2011. Évolution et morpho-dynamique de la plaine côtière de Saïdia (littoral méditerranéen du Nord-Est du Maroc) durant la période 1958-2006. Bulletin de l'Institut Scientifique, Rabat, section Sciences de la Terre. 33: 65-76. (**MOR-1**)

Salmon, M., Sbaï, A., Boumeaza, T., Benata, M., Ozer, A. (2010). L'érosion des côtes meubles de l'extrême nord-est du Maroc. Revue BSGLg, Liège, 54, 97-106.

Snoussi, M., S. Niazi, A. Khouakhi, O. Raji 2010. Climate change and sea-level rise: a GIS-based vulnerability and impact assessment, the case of the Moroccan coast. In: Maanan, M., M. Robin, (Eds.), Geomatic Solutions for Coastal Environments. Pp. 36.