A Survey of Mediterranean Shoreline Change Data Infrastructure, Availability and Nature

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This paper summaries finding from a survey of Mediterranean Shoreline Change Data Infrastructure (study sites, time extents, projects, programs, data assembly points, etc.) conducted in the framework of the Medsea_Checkpoint project on behalf of EMODnet and the European Union Directorate General for Maritime Affairs and Fisheries. The main goal of the project was to identify available data on sediment mass balance at the coast at regional scale. An intensive focused research was undertaken to identify possible data sources. This research developed a dual approach: Firstly, an extensive European and research projects spatial database survey and, secondly, a scientific literature survey from scientific databases. The results from both approaches were integrated in a GIS environment and the assessment concludes: (a) contrarily to sea level o sea surface oceanography variable, there is a lack of valid data on sediment mass-balance or shoreline change (erosion-accretion) along the Mediterranean at basin level. (b) Despite there are different datasets originated from national agencies, observation systems or research projects there is a lack of comparable methods, uniform time-extent and proper spatial coverage along all the Mediterranean shores. Therefore, against Global Change Issues, and Spatial Marine Planning or Integrated Coastal Management issues, there is a need to evaluate the existing best practices related to shoreline change, in order to develop homogenous and reliable datasets that would have to use comparable and spatial temporal scales, as it is accounting for other oceanographic thematic issues such as sea level, sea temperature or fisheries among others.
Keywords: *shoreline change, sediment budget, spatial data infrastructure, Mediterranean basin*.

ANÀLISI DE LA INFRAESTRUCTURA DE DADES DE LA VARIABILITAT DE LA LÍNIA DE COSTA DE LA MEDITERRÀNIA, DISPONIBILITAT I NATURALESA. El present treball resumeix els resultats de l'avaluació de la infraestructura de dades a propòsit de la variabilitat de la línia de costa a la conca Mediterrània (localitats d'estudi, abast temporal, projectes, programes, centres de compilació de dades, etc.) desenvolupada en el mar del projecte MEdsea_Checkpoint d'EMODnet i de la Direcció General d'Afers Marins i Pesqueries de la Unió Europea. L'objectiu del projecte fou el d'identificar les dades disponibles de balanços sedimentaris de la costa a escala regional pel que es procedí primer a explorar les fonts a l'ús de dades espacials de la Unió Europea, els productes d'alguns projectes de recerca europeus, així com un intens buidatge bibliogràfic. La informació resultant fou integrada a un Sistema d'Informació Geogràfica i de la seva anàlisi es desprèn: (a) a diferència d'altres variables d'interès oceanogràfic i costaner hi ha un buit important d'informació relativa al balanç sedimentari de les costes i la seva tendència (erosió-acreció) a nivell de conca Mediterrània; (b) tot i l'existència de diferents bases de dades o d'informació disponible existeixen diferències notables

en quant als mètodes, la continuïtat de les sèries temporals, l'abast temporal o els controls de qualitats de les dades. Així doncs, davant dels reptes del Canvi Global o les noves estratègies de Planificació Marina Espacial o de Gestió Integrada Costanera, els resultats del present treball posen de manifest la necessitat d'avaluar i millora les pràctiques i protocols d'obtenció i gestió de dades d'evolució de la línia de costa, tot seguint l'exemple d'altres iniciatives de la comunitat oceanogràfica com les que aborden el nivell marí, la temperatura del mar o les pesqueries, entre d'altres.
Paraules claus: *evolució de la línia de costa, balanç sedimentari, infrastructura de dades espacials, conca Mediterrània.*

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Introduction

Humans have occupied coastal areas since immemorial times. Nowadays the 70% of the Earth's population live in these settings (Brown *et al.*, 2002) and, at least, two-third of the biggest cities are placed on the coast (Crooks and Turner, 1999). In the Mediterranean region, coastal zones concentrate one of the highest population densities. Vallega (1990) calculated that the total Mediterranean coastal population in 2000 reached 123.7 millions of inhabitants and estimated that in 2015 the Mediterranean population pressure, including residents and tourists, would reach between 11,000 to 12,000 thousands inhabitants per km of coastline. Additionally, these zones also support an unparalleled concentration of infrastructures, productivity and tourism uses, as well as, they are a vital link between terrestrial and aquatic ecosystems (Agnew *et al*., 2013; UNEP, 2001).

Among these coastal zones low-coast sandy and other accumulation coasts (i.e. boulder beaches, barrier islands, marshes, etc.) provide a natural coastal defence, as well as other coastal services, by dissipating high-energy storms waves or attenuating the effect of surges (Hanley *et al*., 2013; Jiménez *et al*., 2011; Liquete *et al.*, 2013). Therefore, previously from approaches such as the Integrated Coastal Zone Management (ICZM) and recently from the Marine Spatial Planning (MSP), it is not unusual that shoreline dynamics –such as erosion accretion– jointly with climate change effects, naturals hazards have been identified as significant pressures on coastal development and growth, as well as on marine ecosystems, leading to deterioration of environmental status, loss of biodiversity and degradation of marine series (Sánchez-Arcilla *et al.*, 2011). According to that, UE (2014) stated that due regard should be had to these low-coast sandy environments in the form of on integrated planning and decisions, because healthy coastal and marine ecosystems and their multiples services can deliver substantial benefits in terms of food production, recreation and tourism, climate change mitigation and adaptation, shoreline dynamics control and disaster prevention.

Against this background and having in mind the contribution to an effective coastal marine planning and integrated management, many authors have claimed the need of

collecting and mapping detailed shoreline change patterns, mainly shoreline erosion, across large scales (i.e. van Koningsveld *et al*., 2005; Roca *et al*., 2008; Ciavola *et al*., 2011; Pranzini and Williams, 2013 or Yates and Le Cozannet, 2012, among others). This claim is also extensive to biodiversity and data requirements (Levin *et al*., 2014), sea-level infrastructure (Woodworth *et al*., 2009), sea-chlorophyll (Colella *et al*., 2016) or other oceanographic datasets (UNESCO, 2017).

Along with the developments and results from different research projects there is a progress in techniques and methods for obtaining data on shoreline change or coastal sediment mass budget (i.e., Sutherland, 2010; Psuty and Silveira, 2011b; Turner et al., 2016) and also in the number od data collections that enable the utilisation of the data by a wide number of new users engaged with coastal management or environmental policy. In 2013, an European Commission Directorate General for Maritime Affairs and Fisheries, Maritime Policy Atlantic, Outermost Regions and Artic project *called "Growth and innovation in ocean economy – gaps and priorities in sea basin observation and data: Medsea Check Point"* was started to address the stages of work required for desk-based assessments intended to calculate variables such as annual sea level rise, annual change in temperature or annual sediment mass balances at the coast, among others, over the Mediterranean. The opportunity was taken to undertake a survey of existing Mediterranean coastal sediment mass budget data infrastructure and availability.

The current article presents the results of this survey, evaluating the different data sources, methods, spatial coverage and resolution, and from an end-users point of view, the potential use by stakeholders and academic researchers. The first part of the paper presents what we understand as sediment mass balance at the coast, as well as, the preliminary literature review on desk-based existing available data. The second part of the paper relates to the scientific literature survey. Finally, we map and assess the main attributes of available shoreline change data and the applicability for different end-users. Lessons learned from this approach are summarized and presented as the arguments of a debate in order to standardize and sharing data among the coastal research and coastal management communities.

Materials and methods

Variables of interest

Sediment mass balance at the coast may be defined as the trend or sign of a sedimentary budget. In coastal morphodynamics it is a tool used to analyse and describe the magnitude and sign of the different sediment inputs (sources) and outputs (sinks) in the nearshore. The sediment budget can also be defined as the volume of sediment in, and moving through, a beach system (Short, 1999). According to this balance, the sedimentary budget results in morphological changes of sediments in any particular coastline over time. It also reflects the amount of erosion or accretion affecting the morphology of the coast. In order to maintain a beach, the sediment budget must either be balanced or positive, a negative budget will result in partial or complete beach erosion. One of the proxy indices on sediment mass balance is shoreline change (Psuty and Silveira, 2011a). It is known that at medium or large time scale, a positive sediment mass balance will result in the subaerial or

upper beach advance and a negative balance in a dry beach retreat. Therefore in this paper sediment mass balance has been interpreted as the shoreline advance and/or retreat, the shoreline change.

It is important to focus the approach on the variable of interest: "Sediment mass balance at the coastline". This can be interpreted as the annual shoreline retreat, in m/year, but also as the difference of sediment volumes in m^3/year (instead of mass, this is more commonly used in coastal engineering) between two dates. Notice that the former (shoreline retreat) is generally measured from coastline positions with a high spatial resolution (typical alongshore resolution of some meters) and requires less effort than the measurement of sediment mass volume that requires bathymetric data over the entire beach (multiple cross-shore beach profiles). The balance of sediment mass volume is generally given with lower horizontal resolution (order of km) because the values are generally given for the entire beach or for an overall coastal unit. An alternative to the two previous definitions that is sometimes used is the sediment mass balance given in m^2/year, defined as the difference of dry beach area between two dates. This can be obtained from the integration of the shoreline retreat over the entire beach (or over the entire coastal unit), or from restricting the analysis of sediment volume to the dry beach. Thus, the horizontal resolution of sediment mass balance in m^2/year is comparable to the resolution of the sediment mass balance in m^3/year.

Although the survey has been focused on localizing sediment mass balance data (essentially in m/year), other variables of interest have been identified. These are variables from which shoreline retreat/advance can be computed at regional scale –NUTS3 for European countries an equivalent regions for the non-European countries–. As previously suggested, sediment mass balance given in m^2/year and m^3/year will be identified as "other variables". We will refer as other variables the following variables:

a) Sediment mass balance in m^2/year
b) Sediment mass balance in m^3/year
c) Sediment mass balance in other units (e.g. in m, or in non-specified units)
d) GIS coastline series (at least 2 coastlines are needed to evaluate sediment mass balance)
e) Bathymetry or topography series
f) Orthophoto series

Data availability and survey rationale

For the purposes of this paper and according to the EC requests, availability is defined such as the degree to which datasets are ready four use and obtainable. According to Manzella *et* al. (2017) the availability can be measured in terms of visibility, accessibility and performance. Visibility is the ability to identify and quickly access the appropriate site delivering the desired data sets. It is the ability for all users, including non-experts, to perform data sourcing trough a EU Inspire catalogue. The accessibility is the ability for all the users to understand the retrieval model status and its appropriateness (i.e. data policy visibility, data policy statements, data delivery mechanisms, formats of uses, etc.). Finally, performance refers to the ability of a system to keep operating over time to meet real time operational conditions (timeliness or ability to process a request).

The main objective of the survey is therefore to localize available sediment mass balance data in the Mediterranean Sea, with main focus on (1) data of shoreline retreat/advance (i.e. given in m/year) and (2) data that cover entire Mediterranean NUTS3 regions in order to generate regional statistics. For these data, we will evaluate the possibility of producing annual time series. Sediment mass balance data given in other units (m^2/year, m^3/year) will be considered as secondary but will also be localized in NUTS3 where data in m/year are missing.

To this end we developed a dual approach after a general overview and exploration of the existing resources at main coastal and oceanographic assembly data portals: (a) Firstly, an extensive survey of EU data assembly portals and spatial data infrastructures or European Research Projects web pages. (b) Second, a thorough scientific literature review, using the most complete and well-recognized databases by the academic community was undertaken, exploiting information on erosion rates, monitoring techniques, data store and management.

Scientific literature survey

The main goal of this survey is to identify the existence of data on sediment mass balance published in scientific papers or scientific books. The search was made through standardized citation databases. To this end, sediment mass balance has been translated to the shoreline advance or retreat. The methodology of the survey is presented in the flow work chart (Fig. 1). The survey has been developed using the most widespread scientific databases, Scopus and Web of Science:

a) Scopus is a bibliographic database containing abstracts and citations for academic journal articles. It covers nearly 22,000 titles from over 5,000 publishers, of which 20,000 are peer-reviewed journals in the scientific, technical, medical, and social sciences (including arts and humanities) going back to 1966 and that belongs to Elsevier.

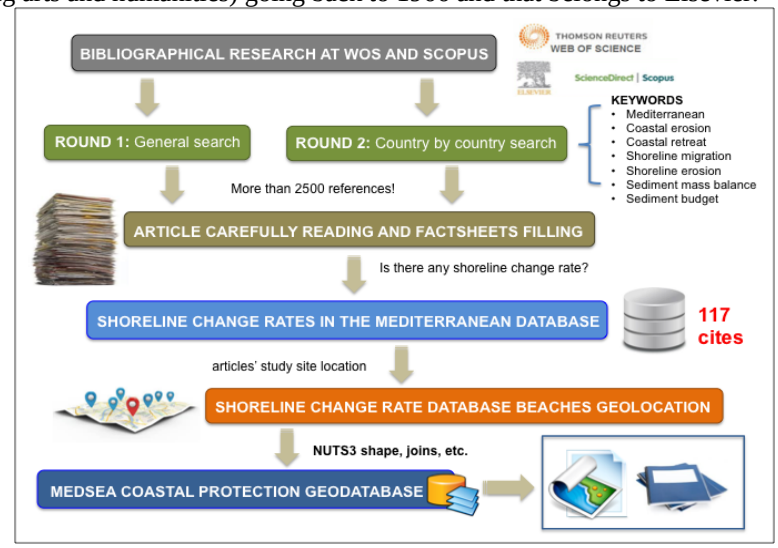

Fig. 1. Scientific literature survey methodology approach.
Fig. 1. *Aproximació metodològica a l'exploració de la bibliografia científica.*

b) Web of Science, WOS –previously known as (ISI) Web of Knowledge–, is an online subscription-based scientific citation indexing service maintained by Thomson Reuters. It gives access to multiple databases that reference cross-disciplinary research. It covers editorials, chronologies, abstracts, journals, books and technical papers from 1900 to the present.

The survey has been performed during two rounds in both databases:

Round 1. Round 1 focused on a general search using the combination of the fixed keywords "Mediterranean" with successive ones, such as "coastal erosion", "coastal retreat", "shoreline migration", "shoreline erosion" and "coastal erosion".

Round 2. Round 2 focused on a country-by-country search using the combination of the keywords "the name of the country" plus the following keywords: "coastal erosion", "coastal retreat", "shoreline migration", and "shoreline erosion".

This resulted in a list of references that have been reviewed to discriminate if they provide shoreline change rates. If it was the case, then the reference was indexed and a complementary file that included different fields:

- **Location:** This attribute refers to the geographical location (the central point) of the beach or the coast sector under study. There is the possibility that one reference describes different study sites or beach locations. In that case the same reference has been replicated as many as times as beach locations are addressed in the reference.
- **DOI:** This information, when it is available, refers to the digital object identifier (DOI) that is a unique alphanumeric string assigned by a registration agency (the International DOI Foundation) to identify content and provide a persistent link to its location on the Internet. Each publisher assigns a DOI when the article is published and made available electronically.
- **Title:** The full title of the article is registered in this field.
- **Authors:** Authors of the article
- **Year:** This attribute registers the year of publication of the article.
- **Type of publication:** Indicates the type of publication and separates between scientific journal, book chapter or proceedings.
- **Journal or book name:** the attribute lists the full name of the journal or the title of the book in case of book chapters.
- **NUTS3:** each study site referred in the article has been related to a specific or equivalent NUTS3 region. Nomenclature following the study domain presented at Section 2.
- **Survey beginning:** Date of survey initiation.
- **Survey end:** Date of survey end.
- **Minimum erosion rate:** minimum shoreline change rate value described in the article.
- **Maximum erosion rate:** maximum shoreline change rate value described in the article.
- **Methods:** This attribute summarize, if they are available in the original paper, the different methods used for calculating the shoreline change rates (i.e. survey, maps, orthophoto, aerial photography, satellite, etc.)

Results

An intensive and focused bibliographic research was undertaken to identify possible data sources of sediment mass balance for Mediterranean. Some sources like EMODnet geology data portal (www.emodnet-geology.eu), OneGeology (www.onegeology.org), or the European Atlas of the Seas (www.ec.europa.eu/maritimeaffairs/atlas/maritime atlas), despite accomplish the availability requirements described before, provide from a thematic point of view, only a rough identification of sediments near the coast, which is not enough to make any reasonable estimation. The project that most closely made an assessment of sediment status at a large scale was the EUROSION project in 2004 (www.eurosion.org). But the resulting database only includes qualitative information on shoreline erosion based on expert judgement.

International Projects and initiatives

More than 20 international projects have been identified (international projects refer to projects that includes at least two countries of the Mediterranean Sea). The list of these projects with their corresponding web page is displayed in Table 1. The coordinator or a key partner of each project has been contacted, furthermore, all the partners of the EUROSION project, all the participants of the AZAHAR programme and all the focal points of the PAP-RAC programme have been contacted individually. For non-European countries most of the coastal authorities have been contacted in the context of the AZAHAR and PAP/RAC programmes. These projects are described below.

Project acronym	**Project web page**
ADRIPLAN	http://adriplan.eu/
AZAHAR	http://ec.europa.eu/ourcoast/index.cfm?menuID=7&articleID=218
BEACHMED	http://www.beachmed.eu/
COASTANCE	http://www.coastance.eu/
COASTGAP	http://coastgap.facecoast.eu/
COASTVIEW	http://141.163.79.209/cd/index.html
EUROSION	http://www.eurosion.org/
FACECOAST	http://www.facecoast.eu/
MARE NOSTRUM	http://marenostrumproject.eu/
MAREMED	http://www.maremed.eu/
MEDCOAST	https://www.medcoast.net/
MEDLAB	http://www.medlivinglab.eu/
MEDSANDCOAST	http://medsandcoast.facecoast.eu/
MICORE	https://www.micore.eu/
OURCOAST	http://ec.europa.eu/ourcoast/index.cfm?menuID=3
PAP/RAC	http://www.pap-thecoastcentre.org/
PLANCOAST	http://www.plancoast.eu/
PEGASO	http://www.pegasoproject.eu/
RESMAR	http://www.res-mar.eu/fr/
RESPONSE	http://www.responsesproject.eu/
SHAPE	http://www.shape-ipaproject.eu/

Table 1. List of International projects and programmes contacted.
Taula 1*. Projectes i programes internacionals entrevistats.*

EUROSION Project is the reference project providing data of coastal erosion with a spatial extent approaching the scale of the present project is the EUROSION project (01/2002-05/2004), which has been commissioned by the EU Commission's Environment Directorate-General (DG) of the European Environment Agency (EEA). EUROSION ended in 2004 and has provided different datasets related with coastal erosion and coastal protection for the whole coastline of the European Union with a spatial horizontal resolution of 200 m available as GIS data layers (http://www.eea.europa.eu). The data available from the EUROSION datasets have the following limitations with respect to the initial objectives of the present project:

a) The data of sediment mass balance at the coast concerning the Mediterranean Sea are qualitative only. The data produced give information on the evolutionary trends of the coastline, by indicating if the coastline is stable, in erosion and in accretion, for each of the segment analysed (length of 200 m).

b) The EUROSION database covers the countries of the European Union (members in 2004). The spatial coverage is therefore smaller than the one expected that should cover the whole Mediterranean Sea. The countries from the African continent, from the Asian continent as well as countries from the European continent that were not EU member have to be included here. Precisely, the EUROSION database covers 36,000 km of the Mediterranean coastline while the coastline length of the whole Mediterranean Sea is 46,000 km.

Although the data provided by EUROSION are qualitative only, they could have been generated from quantitative data of sediment mass balance. For this reason, all the data providers of the Coastal Erosion Layer (EUROSION) for the Mediterranean coast were contacted.

The **AZAHAR Programme** is a response to the special awareness of Spanish society towards the needs of its neighbours in the Mediterranean basin, a region to which it is closely tied by both vocation and centuries of shared history. Within this framework, the Spanish Agency for International Cooperation of the Ministry of Foreign Affairs and Cooperation and the Directorate General of the Coast of the Ministry of Environment, in collaboration with the University of Cantabria, have organized different seminars on Integrated Coastal Zone Management aimed at representatives from Albania, Algeria, Bosnia-Herzegovina, Egypt, Lebanon, Morocco, Mauritania, Serbia, Montenegro, Syria, Palestinian Territories and Tunisia. Participants have been technical experts and managers of the coastal from the different administrations responsible of coastal works (Ministry of Public Infrastructures, etc.), or in charge of the protection of coastal environment (Ministry of Environment, etc.). All of them were contacted.

Priority Actions Programme/Regional Activity Centre (PAP/RAC), established in 1977, is a key component of the Mediterranean Action Plan (MAP), itself part of the United Nations Environment Programme (UNEP). The core of PAP/RAC is based in The Coastal Management Center (Split, Croatia) with the support of the Government of Croatia, however, PAP/RAC involves a large network of Mediterranean experts and institutions.

Both international initiatives and people contacted points up that there are not a complete and coherent dataset on sediment mass balance and shoreline change dataset at regional scale.

Scientific Literature Survey

The scientific literature survey identified, from published, indexed, available and summarized scientific papers cited in WOS and SCOPUS databases. More than 2500 references were analysed, from which only 117 provide shoreline change rates referred to 106 locations along the Mediterranean basin. Most of the countries have at least one reference with shoreline change rates, but sites like Libya, Lebanon, Cyprus, Montenegro, Bosnia-Herzegovina lack of any kind of published study. Focusing on NUTS3 regions, most countries do not have studies in all the NUTS3, and only some small countries –with few NUTS3- and Egypt –for Nile related studies- have at least one reference on shoreline change rates for each one of the NUTS3 regions.

Shoreline change rate: spatial extent and coverage

We have compiled 117 citations that showed data at 106 locations (Fig. 2). According to the source, 83.8% of the results related to shoreline change rates are published in scientific journal papers, while 12.8% are in the form of scientific proceedings and the remaining 3.4% in scientific books. All of them are cited at SCOPUS and/or WOS. The spatial distribution of those reveals significant differences among the basin and among states. Some areas of the Southern coast of the Mediterranean lacks of published and acces-

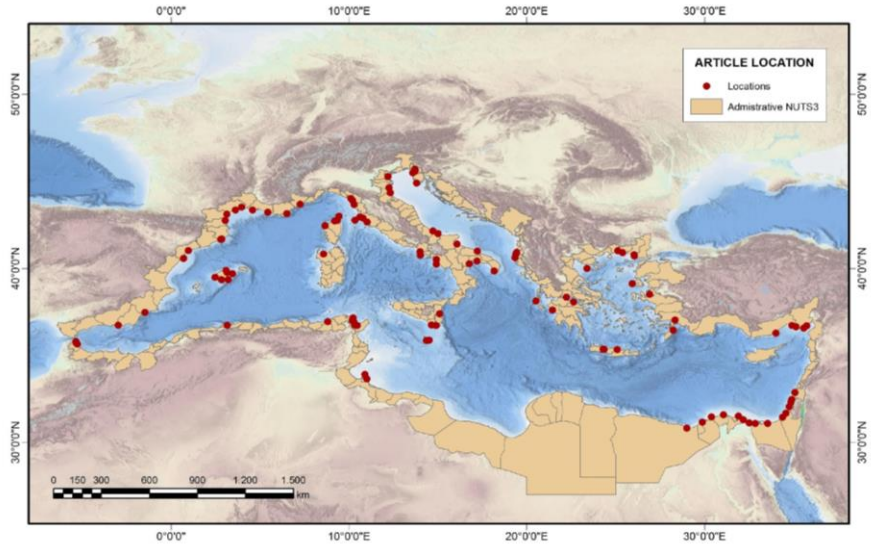

Fig. 2. Study sites described in the selected references. Red points refer to locations where shoreline change rates and additional information (i.e. survey time period, methods, etc.) are given.

Fig. 2. *Localitats d'estudi de les cites bibliogràfiques analitzades. Els punts vermell indiquen la localització de les zones caracteritzades als treballs que proveeixen d'informació sobre l'evolució de la línia de costa, així con d'altres paràmetres (p.e. període d'estudi, mètodes, etc.).*

sible shoreline change rates, whereas the Northern and Eastern coasts exhibit a larger number of beaches with some sort of quantification on sediment mass balance. There is a marked lack of data in the Mediterranean Morocco coast, the Libyan coast, the eastern coast of the Adriatic or the southern coast of Turkey or Syria.

The results of the bibliographical survey have been assigned to NUTS3 regions (Fig. 3) using spatial joins. This shows that only 35.7% (79 of 221) of the NUTS3 regions have been analysed in articles regarding shoreline rates changes. The remaining 64.3% (142 of 221) of the regions have not been mentioned in any scientific paper where shoreline changes were studied. By analysing the spatial distribution of the citations at regional level (Fig. 2), it can be clearly seen that there is a heterogeneous distribution. The big picture shows how the northern side of the basin, where EU countries are located, have been more intensively cited than the ones in the south. Paradoxically, the most studied country is Egypt (southern side), where all regions have been cited, especially those in the Nile river delta, a highly dynamic coastal area. The Israeli coast has been regularly studied due to coastal management and energy industry issues. All EU countries have citations in some regions. Small countries like Malta or Slovenia have all regions cited, and France has most of the regions, while the rest of the countries have an irregular distribution of citations. For example, Italy, Spain and Greece, with the longest coasts, have regions with many citations, while others are not cited. Nevertheless, it is important to remind that these maps just collect the number or articles or references in each NUTS3 region. There is not any assessment, in terms of regional characterizations, about if the studied beaches are representative, or not, of the region, and, in relation to this point, if the shoreline change rate can be assumed with confidence as an environmental descriptive indicator for the NUTS3 region.

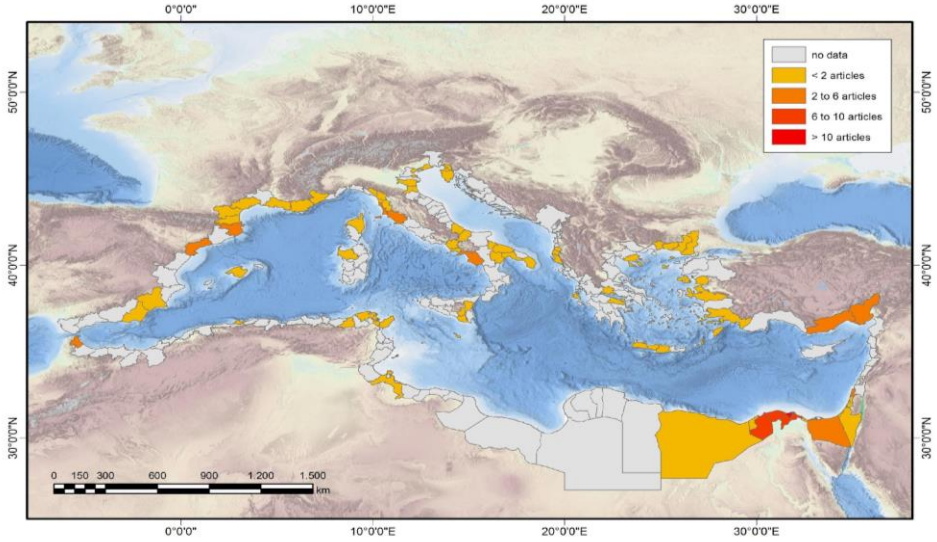

Fig. 3. Maps of NUTS3 describing the number of references with shoreline change rates.
Fig. 3. *Cartografia de les NUTS3 i el nombre de treballs amb taxes d'evolució de la línia de costa per a cada una de les unitats d'anàlisi espacial.*

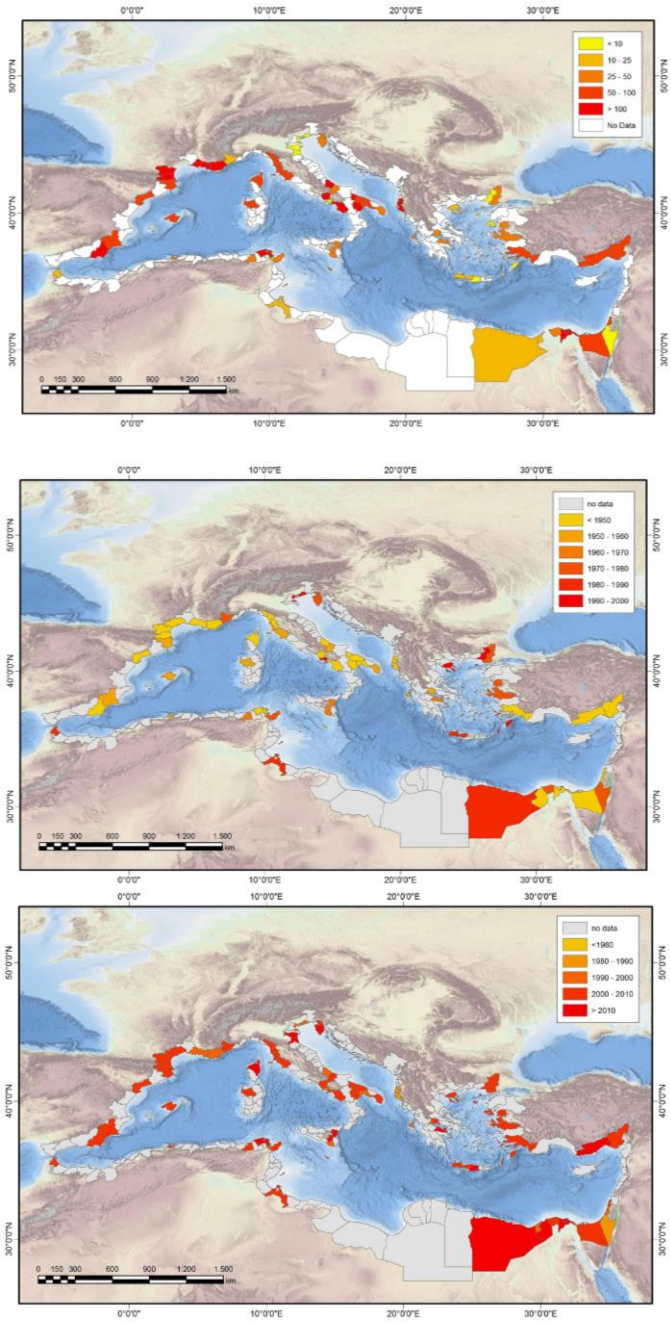

Fig 4. (A, upper) Maps describing the maximum temporal extent collected in each NUTS3 (in years). (B, middle) First shoreline citation date at NUTS3 scale. (C, lower) Last shoreline citation date at NUTS3 scale.

Fig. 4. *(A, superior) Cartografia de l'abast temporal màxim (anys) de l'evolució de la línia de costa per a cada NUTS3. (B, meitat) Any d'inici del seguiment de l'evolució de la línia de costa per a cada NUTS3. (C, inferior) Any final de seguiment de l'evolució de la línia de costa per a cada NUTS3.*

Shoreline change rate: temporal extent and coverage

The oldest coastline data goes back to 1799 and the most recent to 2013. From the NUTS3 regions with shoreline change data, the largest period of analysis covers 212 years while the shortest is only 2 years. Fig. 4A shows the maximum temporal extent. There are 28.6% of the NUTS3 with shoreline datasets covering a period of at least 100 years; 27.3% with temporal extension between 50 and 100 years; 24.6% between 50 and 25 years and 19.4% of NUTS3 cover less than 25 years. Among the last ones, the larger proportion accounts for studies covering less than 10 years between the oldest and the more recent shoreline analysis. It has to be noted that temporal extent does not imply regular analysis over the timeline. It may happen that a large extent is due to irregular analysis along the years (i.e. a study in the sixties and another one in 2010 for the same region). The results of the bibliographical survey also highlight differences in the dates of available shoreline. Oldest shorelines (Fig. 4B) are well represented in western and north-central basin. In these areas the oldest shoreline are previous to 1960, whereas in the eastern and southern shores they are post 1960. The shorelines most recently cited (Fig. 4C) show a homogenous scenario, with almost all NUTS3 regions having shoreline studies corresponding to the year 2000 or more recent.

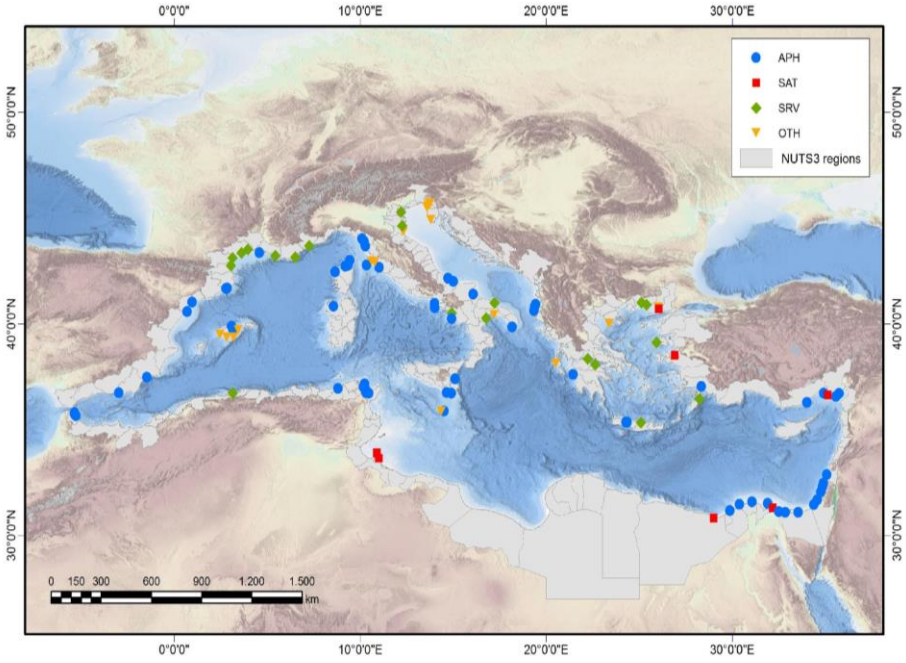

Fig. 5. Methods approach at the different study sites. APH: approaches mainly based on aerial photography analyses; SAT: approaches mainly based on satellite image processing; SRV: approaches dealing with topographical and bathymetric studies; OTH: other approaches.

Fig. 5. *Diferents mètodes de caracterització de l'evolució de la costa a les zones d'estudi. APH: aproximacions basades en fotografia aèria; SAT: aproximacions basades en imatge de satèl·lit; SRV: aproximacions a partir d'estudis topo-batimètrics; OTH: altres aproximacions.*

Shoreline change rate: methodological approach

Although the study is focused on locating sediment mass balance data, other variables of interest have been identified and incorporated into the bibliographical survey dataset, such as the methods and technologies used for computing the shoreline change rate. There is a wide range of methods and techniques to obtain the shoreline variations. For example, some papers present very imprecise sources, such as historical maps, to compare displacements at times when no instruments where available. More recent articles use obviously more precise instruments like DGPS-RTK and echo sounding surveys. Some other studies use satellite images and orthophotos large extensions have to be covered. There are many articles that combine different approaches. In order to have a synthetic overview, we have grouped the different methods in four categories (Fig. 5): Approaches mainly based in aerial photography shoreline capture techniques (APH), approaches based on satellite image processing (SAT), approaches based on field surveys (SRV) – topographic surveys, DGPS RTK, echo sounding, etc.-) and another group of cases (OTH) that (a) does not incorporate information on methods; or (b) they are related to rocky coasts erosion monitoring techniques. Fig. 5 shows the different methods used along the basin. 59.4% of the studies are based on aerial photography approaches, 18.9% of the studies refer to shoreline change rates computed comparing different topographic maps and surveys and 6.6% of the references deal with satellite images processing. 15.1% of the references are based on different approaches including panthometers or techniques related with rocky coasts either with studies that does not provide any explanation about the technique used for shoreline change determination.

Shoreline change rate: erosion and accretion rates

Extreme shoreline rates were collected as a reference to establish a picture of the most severe changes recorded. Fig. 6 shows the maximum positive and negative shoreline change rate values given for a specific location. Discarding erosion rated lower than 1 m/year, at basin level the minimum erosion rates are about 1.5 to 1.6 m/year and correspond to Marina de Cope (Spain) or Platamona (Italy); whereas the largest are registered at Foum El Oued (Tunisia) and the Nile Delta (Rosetta, Egypt) with 60.5 and 211 m/year respectively. Additionally the minimum accumulation rate corresponds to Xylokastro (Greece) with 1.3 m/year and the maximum to Alexandria (Egypt) where studies reported advances of 107 m/year. Nevertheless this information and this map should be used with caution because the database does not compile the averaged shoreline advance or retreat for a specific location, but the maximum or the minimum rate for a study site. This means that these values could correspond to a specific profile, and according to the characteristics and dynamics of each site, it could be representative or not of the whole beach. Notice that the descriptive articles we have addressed do not strive to determine erosion rates as a regional o location descriptive index. The aim of all these papers is generally to unravel the shoreline dynamics. According to that, the most dynamic location in terms of both erosion and accretion seems related to deltas, as it is the case for the Nile Delta, the Ebro Delta or the Rhone Delta, among others.

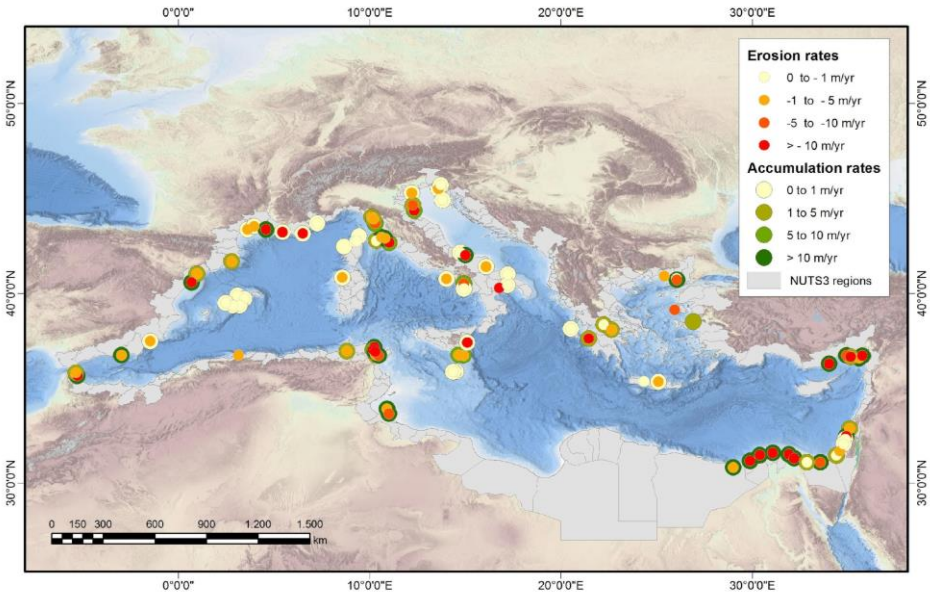

Fig. 6. Maximum positive (accretion) and negative (erosion) shoreline change rates (in m/year) for each literature reference study site.
Fig. 6. *Taxes màximes positives (acreció) i negatives (erosió) de canvis de la línia de costa (m/any) per a cada una de les localitats d'estudi de les referències bibliogràfiques.*

Survey results exploitation at Mediterranean scale: potential and troubles

Information about sediment mass balance has been collected from different published sources, and the main information in the form of shoreline change rates, has been given for a selected beach or for the entire NUTS3. Although the survey is focused on localizing sediment mass balance, other variables of interest have been identified to use the resulting dataset (i.e. methods used, maximum erosion and accumulation rates, etc.). Accordingly, a first warning should be made since our approach relates to available data and this means that the shoreline change rates provided are not necessarily representative of a NUTS3 region or a country. For instance there are some concerns about how representative is each beach in its regional context. Most of the studies summarized or included in the dataset refer to beaches with a scientific interest or deal with some sort of coastal management issue or conflict. So there is no assessment about the representability of any particular beach or about the coastal trends of the surrounding region. Moreover, the methods used can be quite different, from historical maps to bathymetry survey. Similarly, the uncertainties related to each method can be quite different and can obscure a metadata analysis based on this dataset. Nevertheless, results indicate that:

- The most common method for evaluating shoreline change rate is historical analysis based on aerial photography, orthophotos, etc.
- There is a spatial bias on available data along the basin, especially marked in the Mediterranean southern side. This spatial bias is accentuated when considering time

series extent: northern locations have larger datasets than southern or eastern ones, except for the case of the Nile delta. Nevertheless going deeper in temporal extent, it is impossible to produce maps useful for regional and UE stakeholders and coastal managers because of the heterogeneity of the time-intervals addressed in each paper.

- The quantitative shoreline change rate (accretion or erosion) obtained for some locations in the Mediterranean is a significant step forward from previous qualitative studies. However, a trend cannot be given due to the irregular extension of the available time series and the lack of spatial and temporal representability, different methodological approaches, etc. In other words, careful use of this dataset and of the above-mentioned limitations is highly recommended especially for critical analysis or meta-analysis studies.

Concluding remarks

This paper has summarized the main findings of a recent survey of the Mediterranean shoreline change and/or coastal sediment mass budget data infrastructure, availability and nature. The survey has shown that data assets vary considerable from country to country, even between provinces or regions in the same country. In particular the unique desk-based available and properly documented dataset at the Mediterranean level is the EUROSION dataset. Nevertheless this dataset just provides a qualitative estimation of sediment mass balance coded as stable, eroded, or accreted, without being specific on time extent, methods and approaches used. Other available data from EMODnet Portal, OneGeology Portal or from the European Atlas of the Seas provide data (i.e. sediment type, deep-sea water bathymetries) that do not fulfil the minimum requirements for a sediment mass balance assessment.

In spite of this gaps the specific surveys (i.e. surveys originated from national agencies or scientific literature) allowed us to identify a plethora of data sources that would be appropriate for the purposes of this paper. However, in most cases this data is not visible, neither easily available. Additional analyses and supplementary effort would be needed to locate and access them, and determine their usefulness and value to address the purposes or the potential use for non-expert users according to Manzella *et al*. (2017).

Additionally the scientific literature survey carried out shows that despite the existence of numerous studies in the Mediterranean, they are usually local and with an incoherent frequency. In addition, very different methods are used and as a consequence, it is very difficult to use and compare the resulting data. Additionally there is some concern on the representativeness of the locations surveyed for being used as NUTS3 regional indicators. Both the scientific literature survey and the specific surveys showed a persistent difference about the amount of data and the quality between countries and between the northern and southern coasts of the Mediterranean.

This report provides an overview of the sediment mass budget activities in the Mediterranean basin at the present time. The work carried out is also a starting point for more extensive and systematic surveys in the future, surveys that could be used for meta-analysis and comparisons with other regional datasets (i.e. sea level trend). These future projects should consider the importance of considering the need for comparable methods,

uniform time extents and proper spatial coverage along all the Mediterranean shores. Procedures that are widely acknowledge in the oceanographic community (i.e. Woodworth *et al*., 2009).

Contrarily to sea-level or sea surface temperature datasets, there is a lack of valid data on sediment mass-balance or coastal erosion-accretion at a basin level. This type of data is a key issue for coastal managers, stakeholders and public administration. Thus, the revision or new development of datasets such as EUROSION is highly advisable in order to provide homogeneous and reliable datasets that would have to use comparable spatial and temporal scales.

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