ENI CBCMED
Cooperating across borders in the Mediterranean

Project funded by the EUROPEAN UNION

REGIONE AUTÒNOMA DE SARDIGNA
REGIONE AUTONOMA DELLA SARDEGNA

Union for the Mediterranean
Union pour la Méditerranée
الاتحاد من أجل المتوسط

Co-Evolve4BG

Climate Change and Morphological Stability

- Mediterranean Scale -

The present document has been produced with the financial assistance of the European Union under the ENI CBC Med Program. The contents of this document are the sole responsibility of *National Institute of Marine Sciences and Technologies* (Tunisia) and can under no circumstances be regarded as reflecting the position of the European Union of the program management structures.

OVERVIEW

The present document was produced in the framework of **Co-Evolve4BG** project "*Co-evolution of coastal human activities & Med natural systems for sustainable tourism & Blue Growth in the Mediterranean*" in relation to Threats and Enabling Factors for maritime and coastal tourism development at a national scale" Co-funded by ENI CBC Med Program (Grant Agreement A_B.4.4_0075).

This document constitutes the **Deliverable 3.1.1.1** (Climate Change and morphological stability – Med scale) of the **Activity 3.1.1** (Threats and Enabling Factors at Mediterranean scale: Med scale analysis) under the **Output 3.1** (Integrated analysis of Threats and Enabling Factors for sustainable tourism at Med scale) of the project.

REVIEW

Authors

Sadok BOUCHNAK, Master's degree

Faculty of Sciences of Tunis

Hanene SAIDI, PhD

Faculty of Sciences of Tunis

Reviewers

Martina BOCCI, PhD

t-ELIKA, Venice – Italy

Harry COCOSSIS, PhD

International consultant

Hatem KANFOUDI, PhD

National Engineering School of Tunis

Editor

Béchir BEJAOUI, PhD

National Institute of Marine Sciences and Technologies

http://www.instm.agrinet.tn/index.php/fr/

Arnaldo Marin ATUCHA, PhD Biology

University of Murcia

https://www.um.es/

Contributors to the report

Béchir Béjaoui, Khouloud Athimen, Mahmoud Moussa, Rafik Ben Charrada, Saber Amira, Raghda Mestiri, Giuliano Tallone, Erica Peroni, Lorenzo Barbieri, Serena Muccitelli, Stefano Magaudda, Paraskevi Chouridou, Maria Chamitidou, Savvas Chrysoulidis, Giorgos Gkiouzepas, Ioanna Papaioannou, Arnaldo Marin Atucha, Nuria Garcia-Bueno, Pedro Martinez-Banos, Nahed Msayleb, Sana Abi Dib, Talal Darwish, Amin Shaban, Malek Ghandour.

LAYOUT

Houaida BOUALI, Engineer

National Institute of Marine Sciences and Technologies

Mohamed Ali BRIKI, Engineer

Coastal Protection and Planning Agency, Tunisia

Laura PÉREZ, Graphic Designer

Fundación Valenciaport

Emma CASANOVA, Technician

Fundación Valenciaport

Carolina NAVARRO, Engineer

Fundación Valenciaport

Index

List of figures

Abstract

This summary report aims to identify various threats and challenges related to climate change and the morphological stability of the Mediterranean coast. It is developed by reviewing existing data at the national and regional levels. The document structure includes:

Section 1: provides an overview of the present trends of surface temperature, water temperature and evolution of sea level rise at the Mediterranean scale.

Section 2: highlights the analysis of coastal stability parameters.

Section 3: focuses on the effects of relative Sea Level Rise on coastal stability and tourism development.

I. Introduction

Climate change is considered as a phenomenon that will cause long-term changes in the global average physical weather patterns. Most of the scientific community recognizes climate change as one of the fundamental environmental problems facing all countries worldwide. Because estuaries and enclosed seas are usually shallow and have limited exchange with the open ocean, their water temperature is closely related to air temperature and therefore likely to be more sensitive to climate warming than the open ocean. For example, since 1985 the average sea temperature in the Baltic Sea has been augmented 0.03°C per year (MacKenzie, B. R., & Schiedek, D. 2007; IPCC, 2013). Tourism is likely to be strongly influenced by climate change. Many tourist activities depend on weather and natural resources so most tourists have great flexibility in adapting to their holiday destinations (Hein, L., Metzger, MJ & Moreno, 2009). Coastal areas are very important for tourism and the need to protect these resources is essential to the economy of nation (Phillips, M. R., & Jones, A. L. 2006). However, many regions face growing dilemmas. Beaches are synonymous with tourism, while the current climate change and rising sea level forecasts are already evident, threatening with major erosion beaches around the world. So, impacts on the world tourism industry are expected (Phillips, M. R., & Jones, A. L. 2006).

II.
Climatic parameters analysis

II. Climatic parameters analysis

II.1. Atmospheric temperature

The Mediterranean climate is a particularly worrying problem within the context of regional climate variability and change (Xoplaki, , et al, 2003). Pörtner et al., 2022 showed that higher temperatures and hotter days increase in frequency during the twenty first century. In this context, two maps have been drawn up which show the distribution of atmospheric temperature according to five countries and according to the regions of each country.

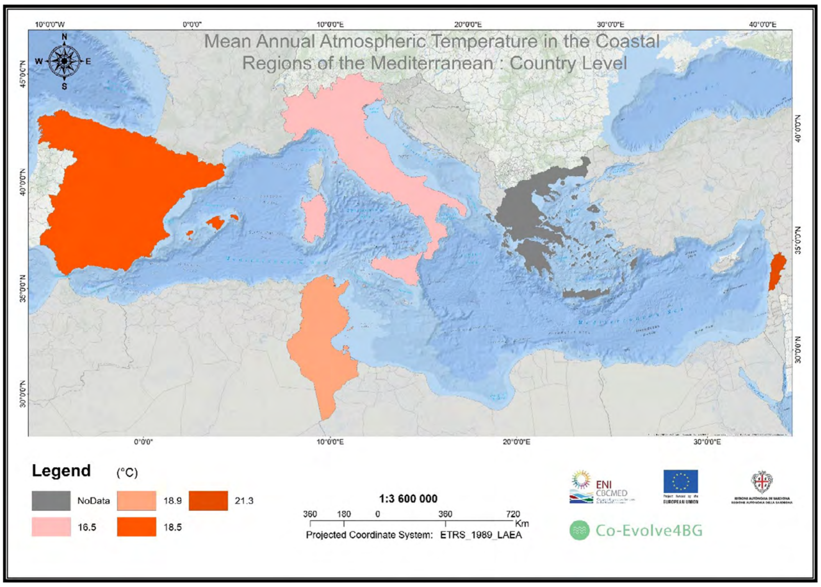

Figure 1.Mean annual atmospheric temperature in the coastal regions of the Mediterranean (country level).

In general, the distribution of annual mean atmospheric temperature in the coastal zones of five countries (Tunisia, Italy, Spain, Greece and Lebanon) does not show a large variability. However, we note that the lowest averages are on the coast of Italy (16.5C°) while on the contrary the highest are detected on the coasts of Lebanon in the order of (21.3C°).

In Lebanon scenarios of temperature and precipitations' projections for Lebanon were developed based on two of the Representative Concentration Pathways (RCPs) developed by the Intergovernmental Panel on Climate Change (IPCC), RCP4.5 (moderate case scenario) and RCP8.5 (worst-case scenario). These projections show that temperatures will increase on the coast by around 1°C by the year 2040, and will further increase by 3.5°C by 2090.

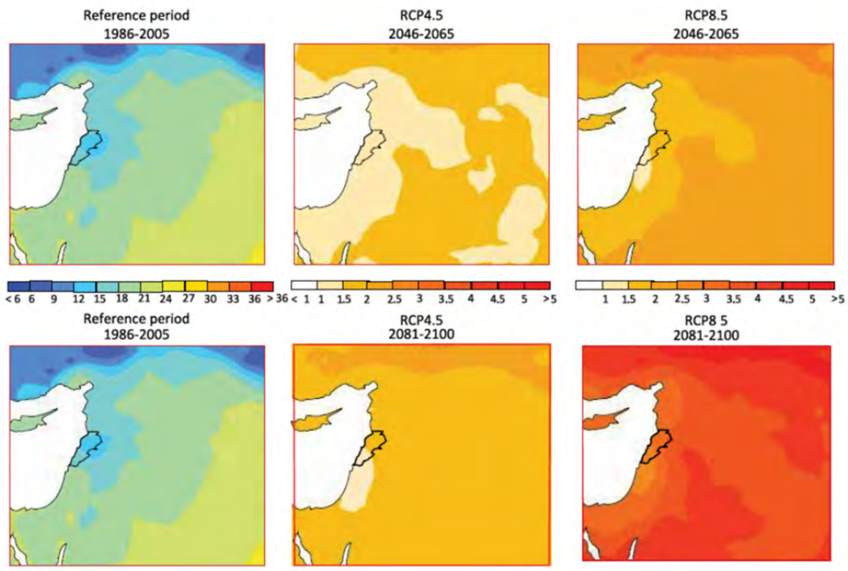

Figure 2. Projected Changes in Temperature in Lebanon (Moderate and Worst-case Projections). Source: Adapted from ESCWA, 2015.

Currently the evolution of the atmospheric temperature in the Mediterranean is positive. Considering the five countries of study (data available only for Tunisia, Spain and Lebanon), we note that Tunisia shows the fastest thermal evolution by an annual average with 0.050C°.

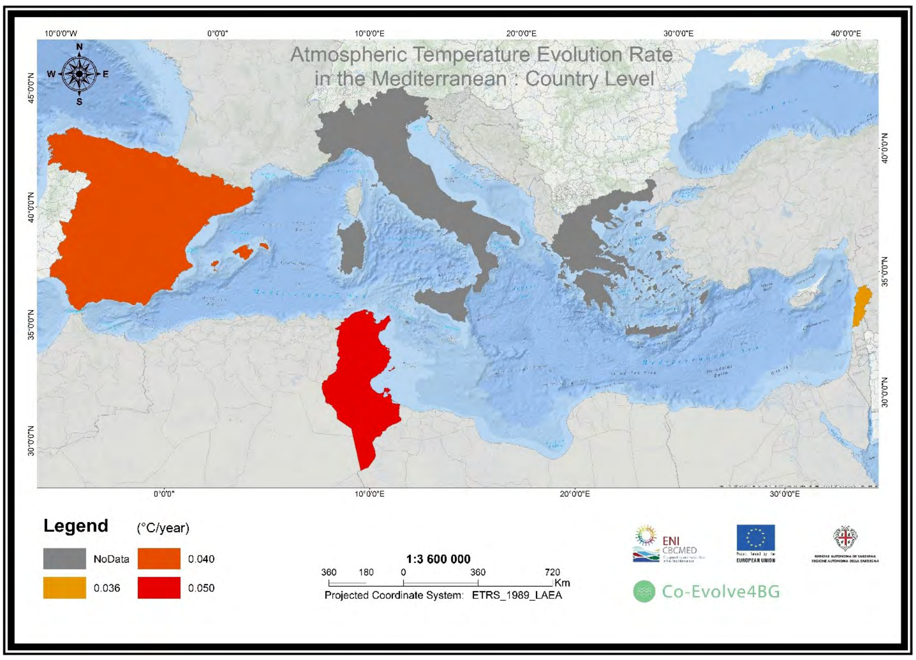

Figure 3. Atmospheric temperature evolution rate in the Mediterranean (country level).

II.2. Water temperature

In recent studies, sea surface temperature in the Mediterranean has been shown to play a relevant role in the genesis and/or intensification of torrential rains across the whole basin, especially in the Western Mediterranean basin. The last three decades the Mediterranean Sea has experienced an estimated increase in its global surface temperature of 0.6-1 ℃. Some predictions based on these data, and considering the trends of recent years, suggest that this increase could reach 5.8 ℃ by 2100 (Sakalli, 2017) (Figure 4).

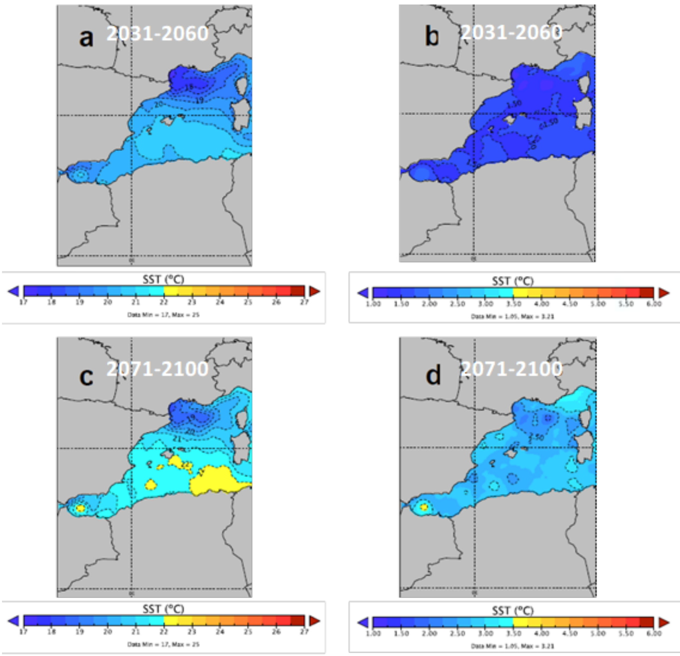

Figure 4. Distribution of the predicted 30-year, i.e. a) 2031-2060 and b) 2071-2100 average sea surface temperature in the Mediterranean Sea, and the relative differences (c and d) to the 30-year study period (1986-2015), respectively. Source: modified from Sakalli, 2017.

The predicted changes in sea water temperature show homogeneity along the entire Spanish coast (Figure 5), the estimated values are changes of 2.5-3 ºC per year, these changes can be considered moderate if we compared to the eastern Mediterranean (Sakalli, 2017).

If we want to better understand the current situation of the water temperature distribution in the Mediterranean, we need to analyze the evolution of this phenomenon in the five country sub-regions.

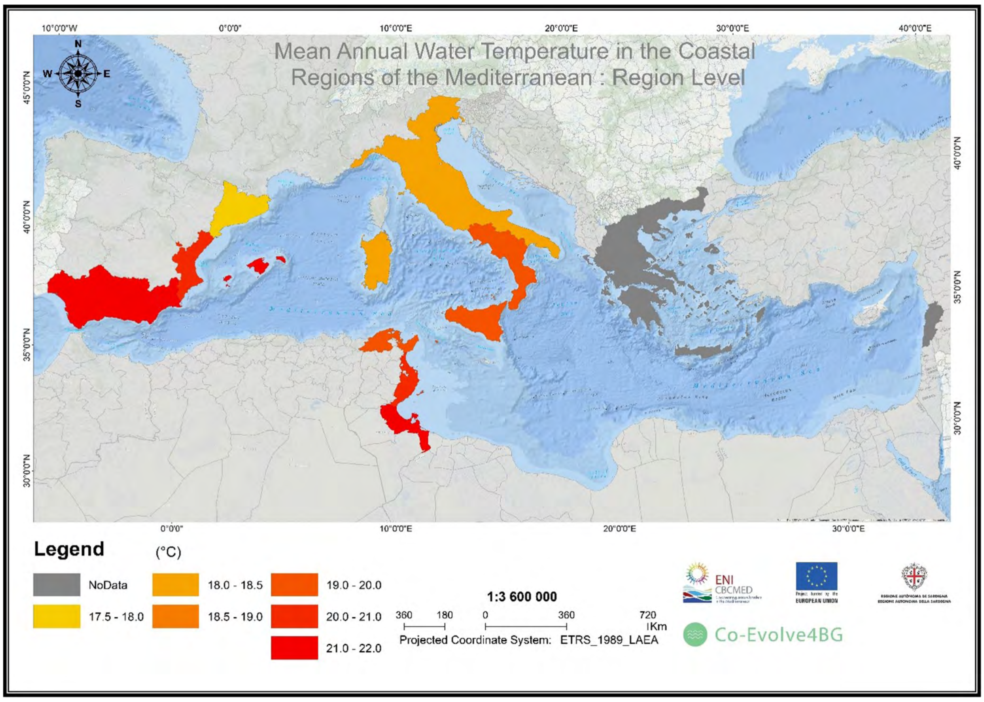

Figure 5. Mean annual water temperature in the coastal regions of the Mediterranean (region level)

The map shows a unidirectional evolution where the increase in water temperature is always towards the south. For example, in Italy, the water temperature goes from 18°C in the Adriatic and Northern regions to 20°C in the Ionian and Tyrrhenian regions. Towards the south (Tunisia), the water temperature continues to rise until it reaches 22°C in the southeast of Tunisia.

II.3. Sea Level rise evolution

Thermal expansion of sea water is a consequence of ocean heat uptake and one of the major contributors to global-mean sea level rise (Church et al., 2011). Sea level rise, as one of the most important Climate Change effects will have serious implications in terms of agriculture, natural resources, tourism, and industry in our case study. In the case of a widespread Sea Level Rise (SLR), the most vulnerable areas are the deltas and enclosed beaches. Research studies have indicated that without beach nourishments, a 0.5 m SLR, which is a reasonable scenario for Spain by 2100, could result in the disappearance high percentage of the beaches from the Mediterranean. Such rise in sea level would result in the disappearance of about 50% of the Ebro Delta in the region of Cataluña (Sánchez-Arcilla et al., 2008).

Regarding the maximum sea levels, we present in the following two figures a distribution of this level along the Mediterranean.

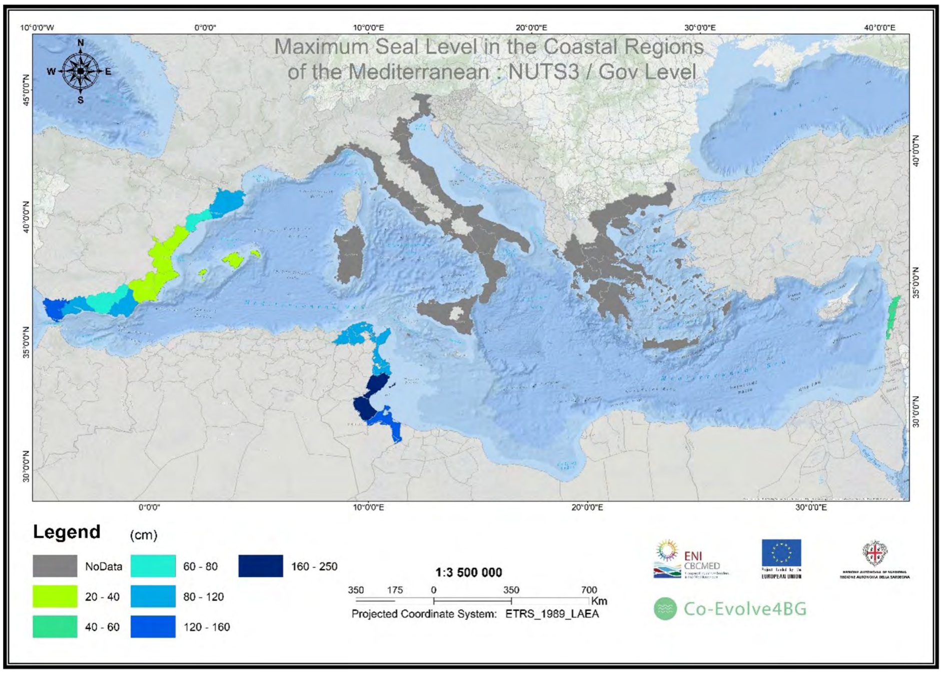

Figure 6. Maximum Sea level in the coastal regions of the Mediterranean: NUTS/ GOV Level.

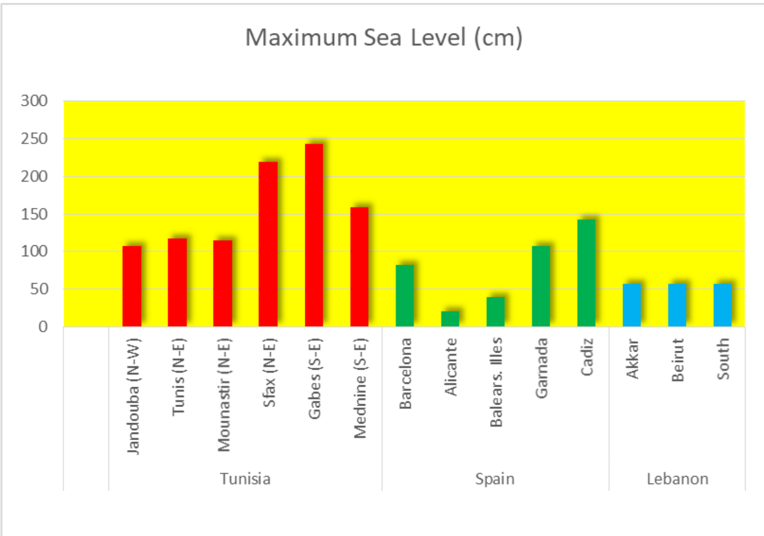

Figure 7. Histogram of the maximum sea level detected in the coastal regions of Tunisia, Spain & Lebanon.

For example, the maximum sea level detected in Spain was at Cadiz governorate between (120 and 160 centimeter (cm)). We can explain this by the position of this governorate in relation to the Atlantic Ocean, towards the north of Spain the maximum levels will have decreases then in Barcelona the maximum level almost meets the level of Cadiz between (80 and 120cm). Nevertheless, in the Mediterranean level the highest maximum level sea was detected in the south-east of Tunisia at Gabes governorate with (243cm). In the east of the Mediterranean basin the lowest maximum sea levels are detected at the littoral governorates of Lebanon (Beirut 57cm).

Regarding sea level rise, currently Lebanon coastal regions admit the strongest annual evolution of sea level rise in the Mediterranean (0.50 cm/year) and in the second order; we have Tunisia with (0.20 cm/year) (Figure 8).

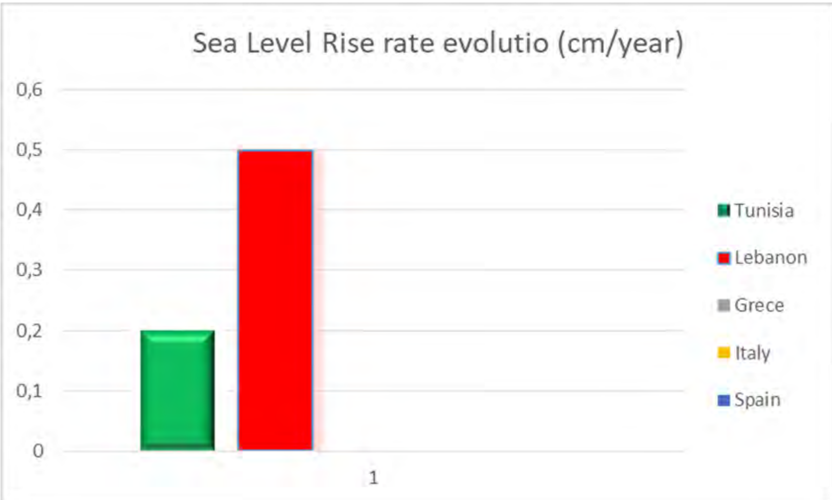

Figure 8. Histogram of Sea Level Rise (cm/year) in the study countries (only data from Tunisa and Lebanon are available).

In terms of sectorial impacts and vulnerability, the National Adaptation Plans (NAP) specifies that coastal areas are an important national asset. The known issues are in regard to the warming and acidification of water, sea level rise and coastal erosion. With respect to the latter, the document highlights how the change in environmental processes may have consequences in the production of ecosystem services, which are highly sensitive to climate change. The temperature increase could drastically change the water ecosystem, while the significant sea level rise expected in Italy could increase erosion and expose the Italian coast to surges and flooding. A level of acidification is also expected (0.1 less pH units in a year).

III. Comparative presentation of some coastal stability parameters at the Mediterranean scale

III. Comparative presentation of some coastal stability parameters at the Mediterranean scale

III.1. Distribution of coastline types at the Mediterranean scale:

Mediterranean coasts being relatively long and showing varied and sometimes very changeable morphologies over short distances, they are distinguished in five types whose existence, frequency and representativeness vary, obviously, from one sector to another. They are Rocky, Sandy, Cliff, Dune, Marshes.

The most varied and long coasts are in Italy where sandy beaches are the most developed with a length of 3500km, in second order Spain with a sum of 1000km sandy beaches, the third one is Tunisia with 400km of sandy beaches and the last one is Lebanon with 60km. It is widely recognized that tourism is one of the world's largest and fastest growing industries. Historically sandy beaches have played an important role as locations for recreation and as attractions upon which tourism development has been based. This use of beaches for recreation and tourism has had significant impacts environmentally, socially and economically. Consequently, it is now understood that significant part of the costs are often associated with tourism development. Irrespective of this, demand for high quality beach areas continues to grow while the corresponding availability of such areas is diminishing. Thus, significant conflicts are arising. Simplistic management approaches will not solve this dilemma, rather creative, dynamic and ongoing applications tailor-made to the needs of specific areas are needed to ensure the future of these most popular of tourism attractions. The use of sandy beaches for tourism will be one of the significant management challenges in the coastal zone in the 21st Century (Orams, MB, 2003).

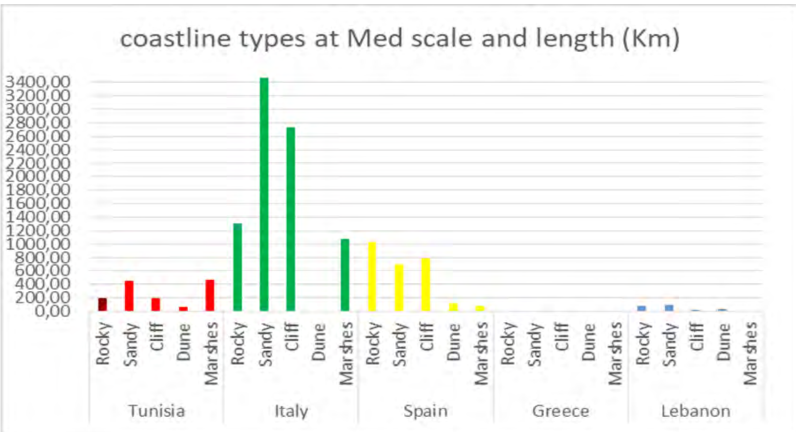

Figure 9. Coastline types and length (km) at Mediterranean scale

III.2. The evolution of coastal stability at Mediterranean scale

III.2.1. Eroded coasts and erosion rate

Beach erosion increases in coastal zones as a result of both natural and anthropogenic pressures in the context of global climate change (Hinkel et al. 2013; Logar and Bergh 2014; Semeoshenkova and Newton 2015). Beach erosion significantly threatens both environmental and economic values from tourism and biodiversity and increases the negative effects and risks of land loss, and destruction of natural defenses and coastal areas (Thinh, Nguyen An, and al 2019). In this context, we have produced two maps showing respectively the length of eroded coastal areas and the rate of erosion in the studies countries. The most eroded coasts are in Italy with 11.6 % and Spain with 12.8 % relative to percentage the national coastal length. Coastal erosion in Tunisia and Lebanon is less developed than Italy and Spain coasts. It does not exceed 22.3 % in Tunisian coasts and 58 % in Lebanon.

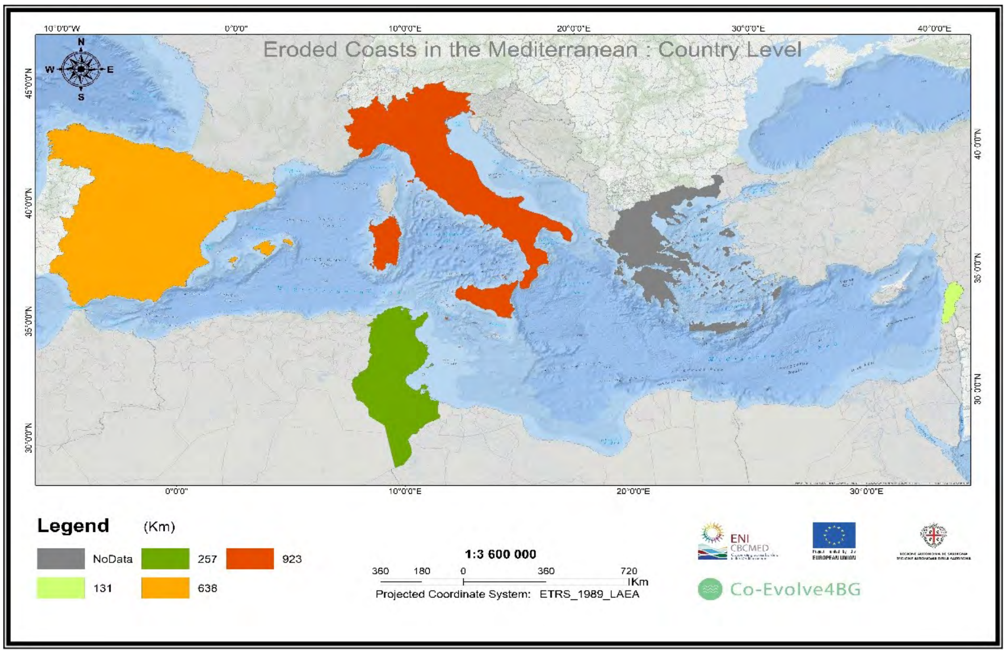

Figure 10. Length of the coast under erosion in the studies countries

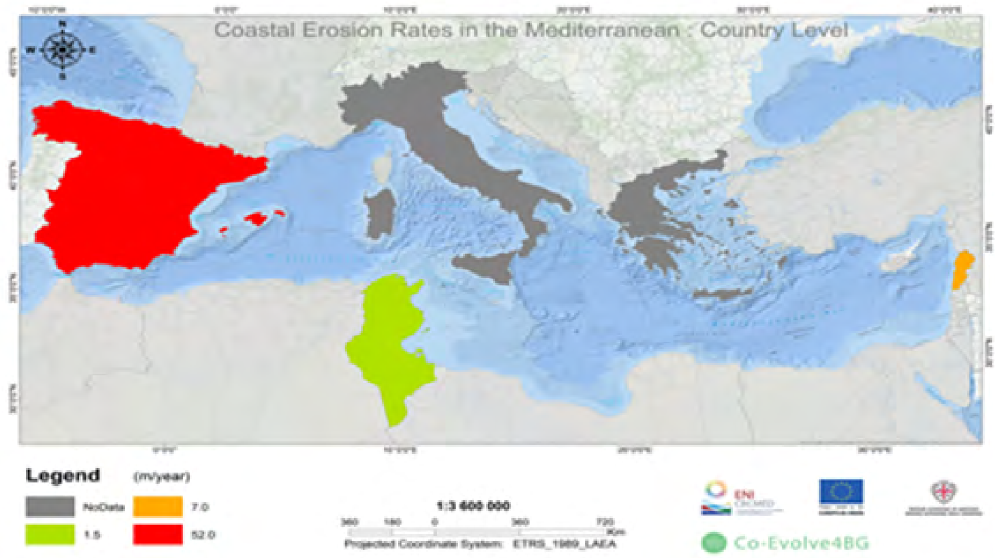

Figure 11. Coastal erosion rates in the Mediterranean (Country level).

In most cases, Bruun's formula (Bruun, 1962) is applied, which theoretically allows, in the case of a beach in equilibrium, to calculate the value of the shoreline retreat for each region of Tunisia

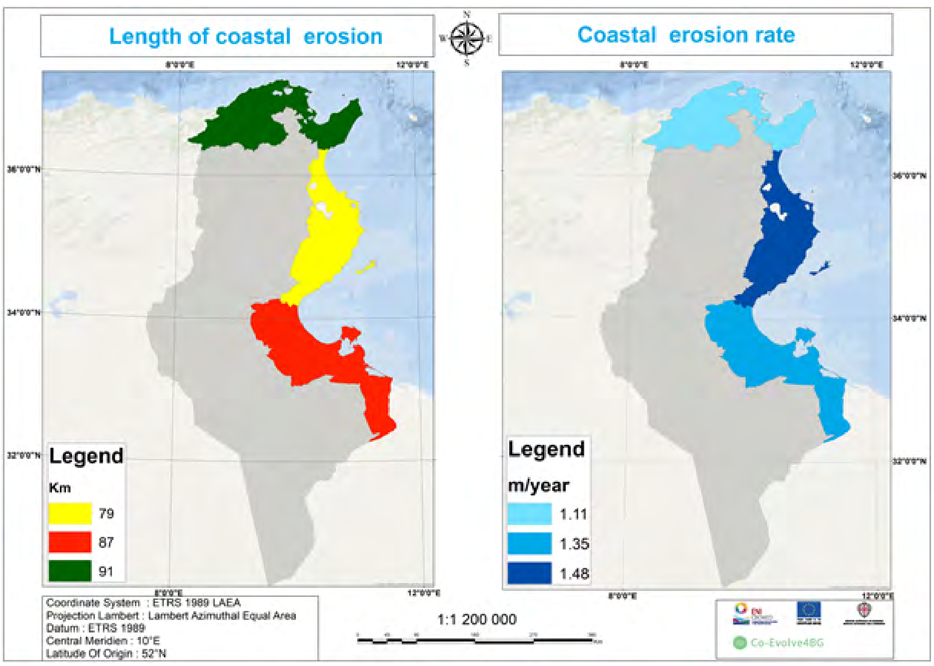

Figure 12. Estimated Lengths of coastal erosion and coastal erosion rates for North, East and South-East Tunisia

As a broad line, governments of Mediterranean countries should take measures to reduce beach erosion in a cost-benefit context. In the cost-benefit analysis of beach protection, it is important to realize that the investments are for the present generation, while the benefits will be in the future. Uncertainties about the options available include the timing of benefits and the nature and extent of those benefits. Beach protection and recovery measures can only be sustainable if coastal processes are fully considered and a detailed cost-benefit analysis is conducted (Thinh, Nguyen An, & al 2019). Additional policies should support the management plans for beach tourism (Alexandrakis & al. 2015).

III.2.2. Coast stability and aggregation rate

Considering coastal stability, Italy and Spain show the most stable data among the studies countries (see Figure 13).

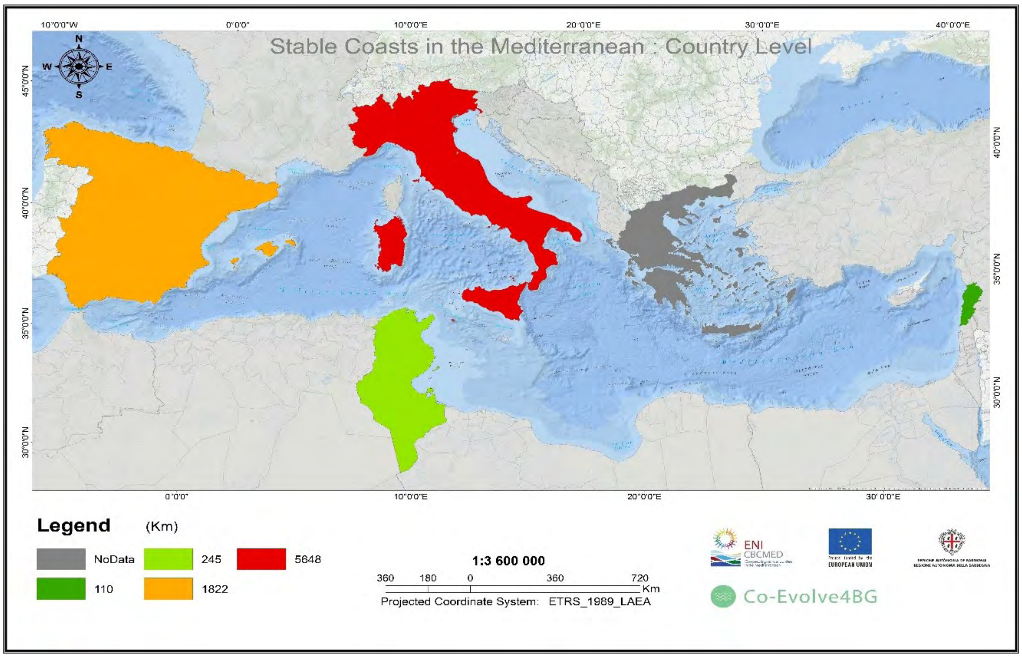

Figure 13. Stable Coasts in the Mediterranean (country level).

The analysis of the attenuation curve of the coastal stability parameters allows a better understanding of the variation in coastal stability.

However, in Spain for example, we noted the highest aggregation rate of the Mediterranean countries with 28.38 meters per year; we can explain this by the length of the Spanish coastline and the average coastal erosion. In general, we can conclude that the parameters of erosion and aggregation rate are linked in nature to make the preferred balance. (Figure 14).

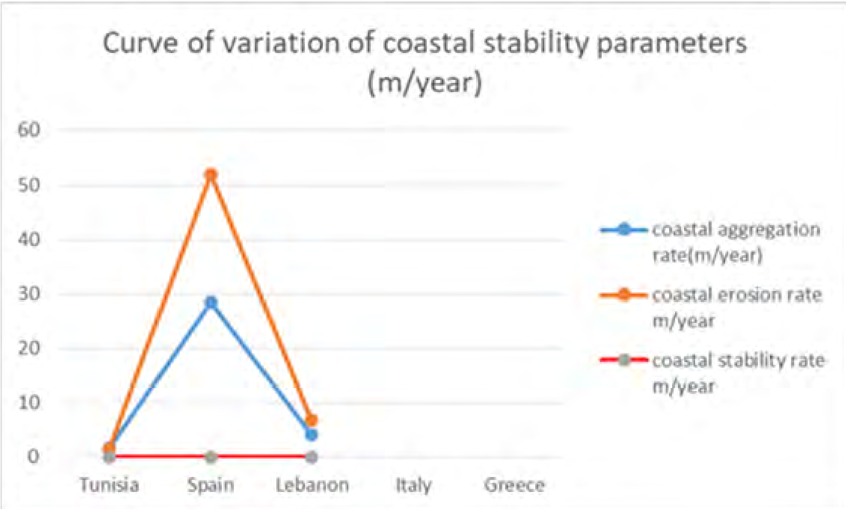

Figure 14. Dimming Curve of Coastal stability parameters (m/year).

IV.
The impacts of climate change on tourism development

IV. The impacts of climate change on tourism development

Tourism is a major global economic sector. That is undergoing tremendous growth in emerging economies, and is often touted as salient for development and poverty alleviation in developing countries. Tourism is recognized as a highly climate-sensitive sector, one that is also strongly influenced by environmental and socioeconomic change influenced by climate change, and is a growing contributor to anthropogenic climate change (Scott, D., Gössling, S. & Hall, CM. 2012).

In 2003, the UN coordinated the First International Conference on Climate Change and Tourism in Djerba, Tunisia. Which recognized the interrelationships between tourism and climate change, the need to better understand the implications of climate change for the sustainability of tourism, and highlighted the obligations of the sector to reduce its GHG emissions and accede to all relevant international agreements to mitigate climate change. The scientific assessment commissioned for the Second International Conference on Climate Change and Tourism (MacKenzie, B. R., & Schiedek, D. 2007) addressed some of the information priorities, identified regional tourism vulnerability 'hotspots', reviewed the state of adaptation within the sector, provided an estimate of the contribution of global tourism to climate change (roughly 5% of CO2 emissions in 2005; later refined to 5.2–12.5% of radiative forcing), and set out options for decoupling future growth in the tourism sector from

GHG emissions. The conference concluded that [climate change] must be considered the greatest challenge to the sustainability of tourism in the twenty-first century'.6 Prior to the COP-15 conference in Copenhagen, Denmark, the WTTC5 issued its first position paper on climate change, which included 'aspirational' carbon emissions reduction targets of 25% by 2020 and 50% by 2035 (both from 2005 levels) (Scott, D., Gössling, S. & Hall, CM. 2012).

Climatic Change and Altered Geographic and Seasonal Tourism Demand:

Climate has direct and salient effects on tourism operators, destinations, and tourists alike and understanding the implications of climatic change for destination competitiveness and tourist demand patterns have been identified as a research priority in this field (Scott, D., Gössling, S. & Hall, CM. 2012). Varied approaches used to examine the potential geographic and seasonal redistribution of climatic resources for tourism and how tourist demand might respond tend to support some common broad scale patterns of influence on international tourism, but the contrasts also reveal some important areas for future research. A number of studies have utilized a 'Tourism Climate Index', which integrates multiple climate variables relevant to tourism, to examine how the distribution of climate resources for tourism could be altered over the 21st century (Scott, D., Gössling, S. & Hall, CM. 2012).

Winter Sports Tourism: With its highly visible sensitivity to climate variability, the risks posed by climate change to the large international ski tourism industry have received considerable attention. The ski industry was the first and the most studied aspect of climate change impacts on tourism, with more than 30 known studies in 13 countries. Diverse methodologies have been used to examine both supply- and demand-side impacts of climate change as well as the adaptive capacity of the ski industry (Scott, D., Gössling, S. & Hall, CM. 2012).

Sea Level Rise and Coastal Tourism is one of the most prominent impacts of global climate change, a considerable literature has developed over the past 20 years examining the potential impacts of sea level rise (SLR) on ecosystems, economies, and society, and even the physical existence of some sovereign nations (Scott, D., Gössling, S. & Hall, CM. 2012). Although coastal tourism has been identified as the largest tourism activity segment globally and despite the massive ongoing investment in coastal tourism and vacation home properties, there has been remarkably little analysis of the implications for the tourism sector. The lack of readily available geospatial data sets of coastal tourism assets (resorts, beaches, transport infrastructure) at the regional or global scale may partially explain the absence of tourism in global-scale SLR impact assessments (Scott, D., Gössling, S. & Hall, CM. 2012)

V.
Conclusions

V. Conclusions

To conclude we can present this figure illustrating the multifaceted interface between climate change and the tourism system.

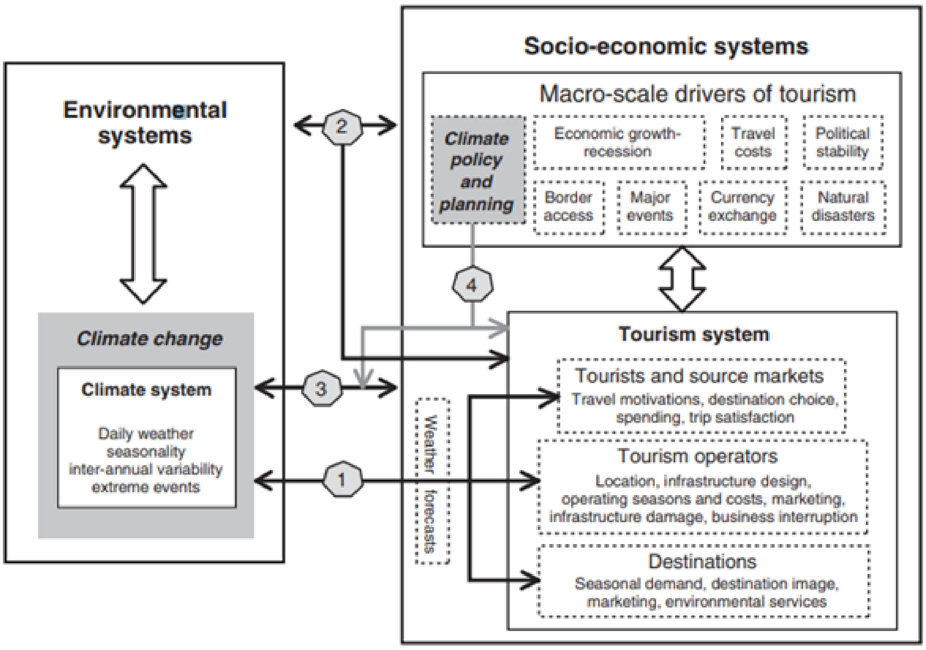

Figure 15. Climate change impact pathways on internaional Scott, D., Gössling, S. & Hall, CM. 2012

The notion of a tourism system is extremely important when considering the impacts of climate change. One of the limitations of the literature is that studies have tended to examine potential climate change impacts only in terms of one element of the tourism system, usually a destination or market segment, rather than considering the broader tourism system (Scott, D., Gössling, S. & Hall, CM. 2012).

References

Alexandrakis, G., Manasakis, C., & Kampanis, N. A. (2015). Valuating the effects of beach erosion to tourism revenue. A management perspective. Ocean & Coastal Management, 111, 1-11.

Bruun, P. (1962). Sea-level rise as a cause of shore erosion. Journal of the Waterways and Harbors division, 88(1), 117-130.

Church, J. A., White, N. J., Konikow, L. F., Domingues, C. M., Cogley, J. G., Rignot, E., ... & Velicogna, I. (2011). Revisiting the Earth's sea-level and energy budgets from 1961 to 2008. Geophysical Research Letters, 38(18).

ESCWA, U., ECA, U., ESCAP, U., & ECE, U. (2013). A regional perspective on the post-2015: United Nations development agenda.

Gössling, S., Peeters, P., Hall, C. M., Ceron, J. P., Dubois, G., & Scott, D. (2012). Tourism and water use: Supply, demand, and security. An international review. Tourism management, 33(1), 1-15.

Hein, L., Metzger, M. J., & Moreno, A. (2009). Potential impacts of climate change on tourism; a case study for Spain. Current Opinion in Environmental Sustainability, 1(2), 170-178.

Hinkel, R., Penzkofer, D., Zühlke, S., Fischer, A., Husada, W., Xu, Q. F., ... & Dimmeler, S. (2013). Inhibition of microRNA-92a protects against ischemia/reperfusion injury in a large-animal model. Circulation, 128(10), 1066-1075.

MacKenzie, B. R., & Schiedek, D. (2007). Daily ocean monitoring since the 1860s shows record warming of northern European seas. Global change biology, 13(7), 1335-1347.

IPCC, (2013). The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324.

Logar, I., & van den Bergh, J. C. (2014). Economic valuation of preventing beach erosion: comparing existing and non-existing beach markets with stated and revealed preferences. Journal of Environmental Economics and Policy, 3(1), 46-66.

Nguyen, T. A., Le, P. M. T., Pham, T. M., Hoang, H. T. T., Nguyen, M. Q., Ta, H. Q., ... & Hens, L. (2019). Toward a sustainable city of tomorrow: a hybrid Markov–Cellular Automata modeling for urban landscape evolution in the Hanoi city (Vietnam) during 1990–2030. Environment, development and sustainability, 21(1), 429-446.

Orams, M. B. (2003). Sandy beaches as a tourism attraction: a management challenge for the 21 st century. Journal of Coastal Research, 74-84.

Phillips, M. R., & Jones, A. L. (2006). Erosion and tourism infrastructure in the coastal zone: Problems, consequences and management. Tourism Management, 27(3), 517-524.

Pörtner, H.O., Roberts, D.C., Adams, H., Adler, C., Aldunce, P., Ali, E., Begum, R.A., Betts, R., Kerr, R.B., Biesbroek, R. and Birkmann, J., 2022. Climate change 2022: Impacts, adaptation and vulnerability. IPCC Sixth Assessment Report.

Sakalli, A. (2017). Sea surface temperature change in the Mediterranean Sea under climate change: a linear model for simulation of the sea surface temperature up to 2100.

Sánchez-Arcilla, A., González-Marco, D., & Bolaños, R. (2008). A review of wave climate and prediction along the Spanish Mediterranean coast. Natural hazards and earth system sciences, 8(6), 1217-1228.

Semeoshenkova, V., & Newton, A. (2015). Overview of erosion and beach quality issues in three Southern European countries: Portugal, Spain and Italy. Ocean & Coastal Management, 118, 12-21.

Scott, D., Gössling, S., & Hall, C. M. (2012). International tourism and climate change. Wiley Interdisciplinary Reviews: Climate Change, 3(3), 213-232.

Xoplaki, E., González-Rouco, J. F., Luterbacher, J., & Wanner, H. (2003). Mediterranean summer air temperature variability and its connection to the large-scale atmospheric circulation and SSTs. Climate dynamics, 20(7), 723-739.

Partners:

Associated partners