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D1.1-Literature Review Report

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V1.0	Salem Gharbia	22/12/2021	Final version

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Meaning / Full text
AI	Artificial Intelligence
AIS	Antarctic Ice Sheet
CCAP	Climate Change Adaptation Plan
CCLL	Coastal City Living Lab
CSI	Coastal Sensitivity Index
CVI	Coastal Vulnerability Index
EAD	Expected Annual Damages
EBA	Ecosystem-Based Approach
ESL	Extreme Sea Level
ETWL	Extreme Total Water Level
GHG	Greenhouse Gas
GIS	Greenland Ice Sheet / Geographic Information System
GMSL	Global Mean Sea Level
IPCC	Intergovernmental Panel for Climate Change
IIASA	International Institute for Applied Systems Analysis
LECZ	Low Elevation Coastal Zone. Coastal areas below 10m of elevation.
NOAA	National Oceanic and Atmospheric Administration
RCP	Representative Concentration Pathway
RFLI	Request For Local Information
SCORE	Smart Control of the Climate Resilience in European Coastal Cities
SIDS	Small Island Developing States
SLR	Sea Level Rise
SSP	Shared Socioeconomic Pathway
USD	United States Dollar
WP	Work Package

BACKGROUND: ABOUT THE SCORE PROJECT

SCORE is a four-year EU-funded project aiming to increase climate resilience in European coastal cities.

The intensification of extreme weather events, coastal erosion and sea-level rise are major challenges to be urgently addressed by European coastal cities. The science behind these disruptive phenomena is complex, and advancing climate resilience requires progress in data acquisition, forecasting, and understanding of the potential risks and impacts for real-scenario interventions. The Ecosystem-Based Approach (EBA) supported by smart technologies has potential to increase climate resilience of European coastal cities; however, it is not yet adequately understood and coordinated at European level.

SCORE outlines a co-creation strategy, developed via a network of 10 coastal city 'living labs' (CCLLs), to rapidly, equitably and sustainably enhance coastal city climate resilience through EBAs and sophisticated digital technologies.

The 10 coastal city living labs involved in the project are: Sligo and Dublin, Ireland; Barcelona/Vilanova i la Geltrú, Benidorm and Basque Country, Spain; Oeiras, Portugal; Massa, Italy; Koper, Slovenia; Gdańsk, Poland; Samsun, Turkey.

SCORE will establish an integrated coastal zone management framework for strengthening EBA and smart coastal city policies, creating European leadership in coastal city climate change adaptation in line with The Paris Agreement. It will provide innovative platforms to empower stakeholders' deployment of EBAs to increase climate resilience, business opportunities and financial sustainability of coastal cities.

The SCORE interdisciplinary team consists of 28 world-leading organisations from academia, local authorities, RPOs, and SMEs encompassing a wide range of skills including environmental science and policy, climate modelling, citizen and social science, data management, coastal management and engineering, security and technological aspects of smart sensing research.

EXECUTIVE SUMMARY

This document is a deliverable of the SCORE project, funded under the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003534.

The aim of this document is to summarise the results of a literature review process on the effects of past extreme climate events and sea level rise for coastal cities. The literature review includes relevant scientific and technical journals; relevant data from international, European, national and local government agencies; non-technical media sources (newspapers, news portals, etc.); and other relevant sources of information.

The review encompasses extreme climate impacts, sea level rise, coastal flooding and erosion at European and Global scale to develop a comprehensive understanding of key risks, focusing on nominated European coastal cities with CCLLs.

LINKS WITH OTHER PROJECT ACTIVITIES

A number of work packages are being prepared under the umbrella project « Smart Control of the Climate Resilience in European Coastal Cities » (acronym: SCORE) between 2021 and 2025:

- Work Package 1 – Mapping the baseline exposure and risk of extreme climate impacts on coastal cities
- Work Package 2 – Coastal City Living Labs Design, Implementation, and Evaluation
- Work Package 3 – Regional and Local Projections, Analyses, Modelling and Uncertainties
- Work Package 4 – CCLL co-warning and comonitoring
- Work Package 5 – Pre/post-EBA Interventions Evidence Collection and Knowledge Marketplace
- Work Package 6 – Strategies to increase the financial resilience of coastal cities
- Work Package 7 – Socio-economic assessment of adaptation strategies and policy recommendations
- Work Package 8 – Development of integrated early warning support and spatial digital twin solution prototypes
- Work Package 9 – Dissemination, communication, exploitation
- Work Package 10 – Coordination and management

This report has been prepared as the first of four deliverables of Work Package 1 – Mapping the baseline exposure and risk of extreme climate impacts on coastal cities:

- **Deliverable 1.1** – Literature review report
- **Deliverable 1.2** – Map and report of key climate-change hazards
- **Deliverable 1.3** – Map and report of baseline exposure and vulnerability
- **Deliverable 1.4** – Report of baseline risk analysis

This report summarises the literature review process results and conclusions. The literature review is complemented by data collected from the CCLLs in WP2, and with information on relevant past and ongoing EU funded and other related projects in WP9.

The report outcomes will directly feed next WP1 tasks and will contribute to the development of WP3, WP5, WP6, WP7 and WP8 particular tasks.

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1. INTRODUCTION

1.1. Project Context

Climate change can affect coastal areas in a variety of ways. According to the EPA, coasts are sensitive to the increse in atmospheric temperatures, sea level rise, changes in the frequency and intensity of storms, increases in precipitation, sea warming and ocean acidification. At the same time, these hazards can trigger additional challenges or worsen problems that coastal areas already face (e.g., shoreline erosion, coastal flooding, droughts, landslides, water pollution, etc.).

However, this report focus on the climate change extreme impacts on coastal cities. For this reason, not all the impacts mentioned above will be addressed, as not all of them can be classified as extreme, as it will be discussed in the following points.

1.1.1. Climate Change Extreme Events

In the literature, an event is generally considered extreme if the value of a variable exceeds (or lies below) a threshold (Seneviratne et al., 2021). The thresholds are defined in various ways, leading to different interpretations about what a extreme event might be. Due to the nature of this report, two definitions of extreme events are considered.

First, extreme values can be defined as the values above a relative threshold, usually a high percentile (90th or higher) from a time series. For instance, given the annual maximum daily value time series (e.g. annual maximum daily rainfall, annual maximum daily temperature), all the values above the relative threshold would be considered as extreme.

Second, extreme values can be alternatively defined as those values exceeding an absolute threshold. Following the previous example, for a given magnitude, extreme events would be associated to those annual maximum daily values exceeding a threshold value, regardless the time series. The boundary between non-extreme and extreme events is usually defined based in the consequences that these extreme values may trigger (e.g. health impacts, irreversible damage to goods, biodiversity loss).

Lastly, the frequency and intensity of climate change extreme events are increasing. In this sense, changes in extremes can refer to changes in the frequency for a given magnitude, or changes in the magnitude for a particular return period. In fact, changes in climate change extreme events, often have greater impacts on ecosystems (Ummenhofer & Meehl, 2017), infrastructure (Pregnolato et al., 2016) and humans (Curtis et al., 2017) than changes in climate change average events.

1.1.2. Sea Level Rise as a Key Driver

Assessments of coastal impacts need to consider relative sea level rise (RSLR), which includes climate-induced global mean sea level (GMSL) rise and regional variations, as well as local non-climate-related sea level changes, and extreme sea levels (ESL).

The major factors that contribute to GMSL rise are the oceans thermal expansion due to the higher temperature; meltwater from glaciers, icecaps, and ice sheets of Greenland and Antarctica; and changes in land-water storage, through groundwater depletion and water impoundment (Fox-Kemper et al., 2021).

In this context, the IPPC AR6 Chapter 9 (Fox-Kemper et al., 2021) provides updated GMSL rise projections under 5 scenarios of projected socioeconomic global changes up to 2100 – Shared Socioeconomic Pathways (SSPs).

Table 1 – Updated global mean sea-level projections for 5 SSP scenarios, relative to a baseline of 1995-2014, in meters. Median values for likely ranges (in brackets) are shown. From: Fox-Kemper et al. (2021).

Year	SSP1-1.9	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2030	0.09 (0.08-0.12)	0.09 (0.08-0.12)	0.09 (0.08-0.12)	0.09 (0.08-0.12)	0.10 (0.09-0.12)
2050	0.18 (0.15-0.23)	0.19 (0.16-0.25)	0.20 (0.17-0.26)	0.22 (0.18-0.27)	0.23 (0.20-0.29)
2090	0.35 (0.26-0.49)	0.39 (0.30-0.54)	0.48 (0.38-0.65)	0.56 (0.46-0.74)	0.63 (0.52-0.83)
2100	0.38 (0.28-0.55)	0.44 (0.32-0.62)	0.56 (0.44-0.76)	0.68 (0.55-0.90)	0.77 (0.63-1.01)

Moreover, ocean and meterological dynamics; glacial isostatic adjustment; changes in Earth Gravity, Earth Rotation and viscoelastic solid Earth Deformation (GRD); and vertical land motion (VLM) as a consequence of plate tectonics, soil consolidation processes, changes in sediment delivery to the coast, or extraction of subsurface resources (gas, oil, groundwater), among others; lead to variations in RSLR from regional to local scales (Fox-Kemper et al., 2021). In this report, regional sea level refers to spatial scales of around 100 km, while local sea level refers to spatial scales smaller than 10 km.

The changes in sea level described above correspond to gradual long-term trends, usually reflected in annual variations of milimeters or few centimeters per year. Processes including high tides, storm surge and wave setup lead to short duration events where sea level reaches exceptional high values, namely extreme sea levels (ESL).

The occurrence of ESL can impact coastal cities in a variety of ways. According to Oppenheimer et al. (2019), there are five main concerns for low-lying coasts due to local extreme sea levels: more frequent and intense coastal flooding; enhanced coastal erosion; loss of and change in coastal ecosystems; salinisation of soils, ground and surface water; and impeded drainage. On the coastlines of developed countries, changes in weather and climate extremes and sea level rise may impact the demand for housing; recreational facilities; the capacity of the urban drainage systems in absorbing storm water; the construction of renewable energy infrastructure; and critical infrastructures such as transportation, ports, and naval bases (Hadley, 2009; Zellou & Rahali, 2019). In the case of the nominated coastal cities, the main concerns identified in the RFLI responses regarding SLR are coastal flooding, storm surge and coastal erosion. As storm surge is part of the definition of ESL, coastal flooding and coastal erosion will be the only climate change extreme impacts on coastal areas considered in this report. Storm surge will be considered as a driver of these impacts.

1.1.3. Coastal Flooding

Coastal flooding is defined as a temporary inundation of a terrestrial area that is not normally submerged (Pollard et al., 2019). According to Ranasinghe et al. (2021), episodic coastal flooding is caused by Extreme Total Water Levels (ETWL), which is the combination of RSLR, tides, storm surge and wave setup at the shoreline (Kirezci et al., 2020; Koks et al., 2019; Melet et al., 2018; Vitousek et al., 2017; Vousdoukas et al., 2018, 2020).

From the most common coastal flooding metrics described in Ranasinghe et al. (2021), ETWL frequency distribution and 100-year average return interval storm tide (storm surge + high tide) level are considered the most relevant coastal flooding metrics for this report (McInnes et al., 2016; Mills et al., 2016; K. Walsh et al., 2016; Zheng et al., 2015).

1.1.4. Coastal Erosion

Coastal erosion can be defined as the net removal of material from one coastal location to another. It is driven by many natural factors including storm surge, changes in wave energy, sediment supply and sea level rise (Dawson et al., 2009; Hinkel et al., 2013; Mentaschi et al., 2017; Penland et al., 2005; Wong et al., 2014). Coastal erosion is generally accompanied by shoreline retreat, which can occur as a gradual process (e.g., due to sea level rise) or as an episodic event due to storm surge and/or extreme waves, especially when combined with high tide (Ranasinghe, 2016; Ranasinghe et al., 2021).

The most commonly used shoreline retreat index is the magnitude of shoreline retreat by a pre-determined planning horizon such as 50 or 100 years into the future. Commonly used metrics for episodic coastal erosion include the beach erosion volume due to the 100-year recurrence storm wave height, the full exceedance probability distribution of coastal erosion volume (Li et al., 2014; Pender et al., 2015; Ranasinghe & Callaghan, 2017) and the cumulative storm energy and storm power index (Godoi et al., 2018).

1.1.5. Other Extreme Events Considered

In general, the extreme events enhanced by climate change include heatwaves, cold spells, heavy precipitation and pluvial floods, river floods, droughts and storms (including tropical cyclones) (Seneviratne et al., 2021). Moreover, more than one of the extreme events above (including coastal flooding and coastal erosion) may occur simultaneously, leading to compound events (multivariate and concurrent extremes). While coastal flooding and coastal erosion specifically concern to coastal cities and will be therefore reviewed in more detail, the literature review will include all extreme events mentioned in this section.

1.2. Purpose of the Report

The aim of this report is to provide a thorough understanding of the effects of past extreme climate events and sea level rise for coastal cities and to identify key risks. The scope of the study includes establishing the definition of climate change extreme event and climate change extreme impact considered here; describing the information about the reviewed sources and data collection; and the results of the literature review at global, European and nominated coastal cities scales.

2. METHODOLOGY

2.1. Overview

The sources consulted to produce the report are listed and described in this section. It is also presented how the information has been extracted and analysed.

The information sources have been categorised in four main groups:

I. Climate change agencies

II. CCLLs – Request for Local Information (RFLI)

III. Scientific-technical sources

IV. Non-technical media

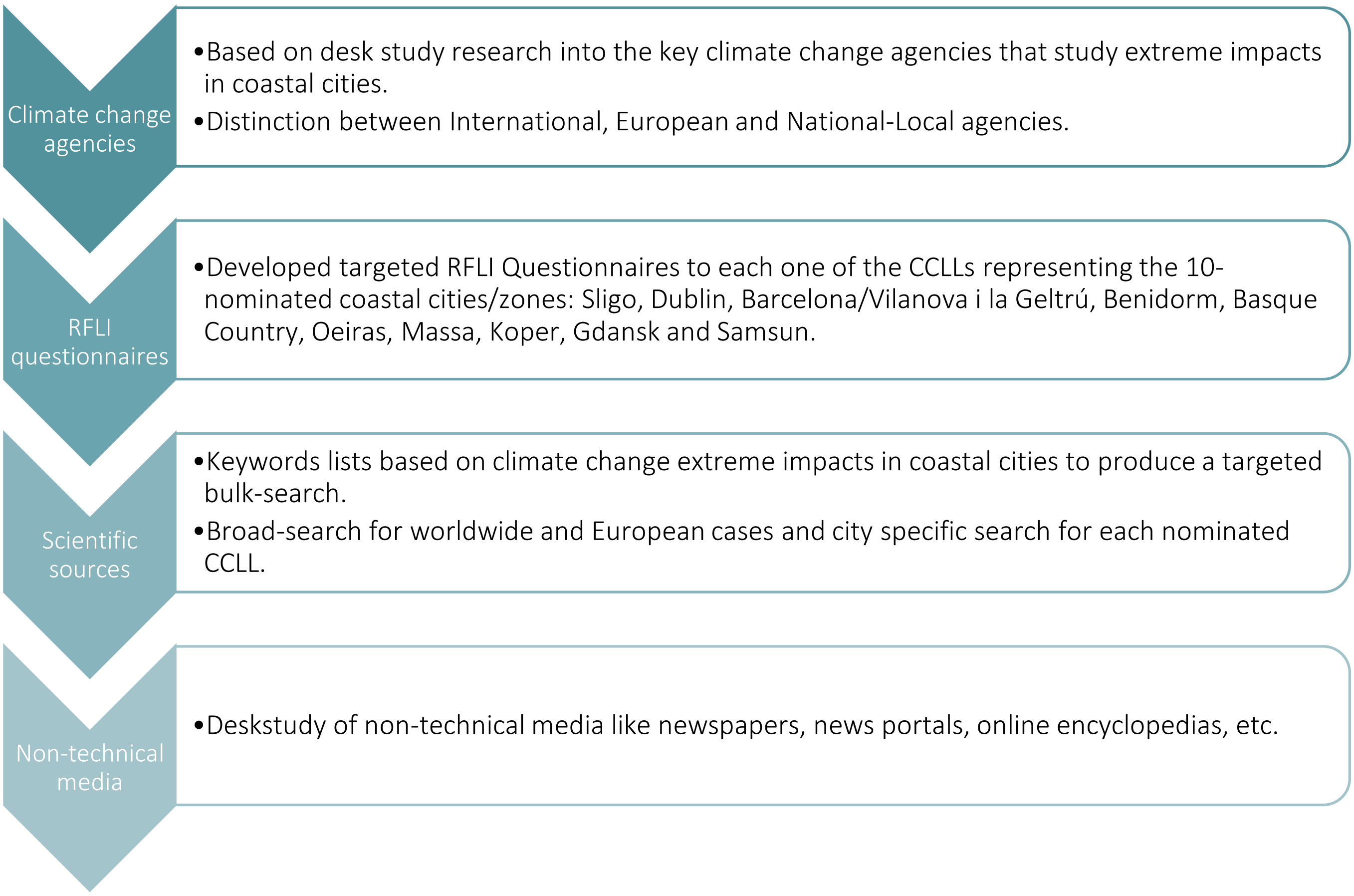

Figure 1 – Scheme of the main sources of information reviewed.

Climate change agencies provide a baseline of the state-of-the-art of the discussion topic. The starting point is complemented with local knowledge on each of the 10-nominated coastal cities after consulting the CCLLs through two Request for Local Information (RFLI) questionnaires. Based on both previous sources, sets of related keywords were used in a targeted bulk-search in the main scientific browsers. Finally, non-technical media like newspapers, news portals, online encyclopedias, etc., were used to cover detected gaps.

Aditionally, some sub-categories under the previous four groups have been established and are also described throughout the following sections.

2.2. Information Sources

2.2.1. Climate Change Agencies

Climate change agencies and similar bodies (herein called climate change agencies for ease of reading) provide information on climate change for policymakers and the general public, gathering data and producing assessments on a wide range of topics related to climate change (e.g., GHG emissions reduction, impacts on the environment and human-systems, climate change adaptation and mitigation, sustainable development).

In this report, climate change agencies focusing on international to European and national-local scales were consulted through desktop study, with the purpose of collecting the available information regarding climate change extreme impacts on coastal cities. Jointly, climate change agencies data have been used to build an overall picture of the state-of-the-art on the discussion topic and will be frequently cited throughout the document.

The climate change agencies consulted in this report are presented in the following points.

2.2.2. International agencies

The international climate change agencies presented in Table 2 are a reliable source for climate change general information. Moreover, they usually provide specific studies concerning climate change impact on coastal cities, due to their economic relevance for policymakers. The non-EU national climate changes agencies

Table 2 – International climate change agencies utilised as sources of information.

Agencie name	Short description
Intergovernmental Panel of Climate Change (IPCC)	IPCC provides comprehensive assessments of the state of scientific, technical and socio-economic knowledge on climate change, including, *inter alia*, its causes, potential impacts and response strategies.
United Nations Framework Convention on Climate Change (UNFCCC)	UNFCCC is a Rio Convention, one of two opened for signature at the Rio Earth Summit in 1992. The Convention acknowledges the vulnerability of all countries to the effects of climate change and calls for special efforts to ease the consequences.
United Nations Environment Programme (UNEP)	The UNEP is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system, and serves as an authoritative advocate for the global environment.
World Meteorological Organization (WMO)	WMO is the UN system's authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the land and oceans, the weather and climate,and the resulting distribution of water resources.
Center for Climate and Energy Solutions (C2ES)	The C2ES is an independent, nonpartisan, nonprofit organization working on practical solutions to climate change. C2ES is the successor to the Pew Center on Global Climate Change.

2.2.3. European agencies

The consulted European institutions, bodies, agencies, organisations or programmes on the topic of climate change are shown in Table 3.

Table 3 – European climate change agencies utilised as information sources.

Agencie name	Short description
European Environment Agency (EEA)	EEA provides sound, independent information on the environment for those involved in developing, adopting, implementing and evaluating environmental policy, and also for the general public.
European Environmental Bureau (EEB)	EEB is Europe’s largest network of environmental citizens' organisations.
EU Climate Action	The Directorate-General for Climate Action (DG CLIMA) leads the European Commission's efforts to fight climate change at EU and international level.
Climate Action Network Europe (CAN Europe)	CAN Europe is Europe’s leading NGO coalition fighting climate change.

Climate Change Committee (CCC)	CCC is an UK independent, statutory body established under the Climate Change Act 2008.
Copernicus	Copernicus is the European Union's Earth observation programme coordinated and managed by the European Commission in partnership with the European Space Agency (ESA), the EU Member States and EU agencies.
European Centre for Medium-Range Weather Forecasts (ECMWF)	ECMWF is an independent intergovernmental organisation supported by most of the European nations. It operates one of the largest supercomputer complexes in Europe and the world's largest archive of numerical weather prediction data.

2.2.4. National and local agencies

Most of the national and local climate change agencies compiled here have been extracted from the RFLI responses explained below and will be detailed in Section 3.4.

2.2.5. CCLLs – Request for Local Information

Communication with CCLL has been crucial to understand how climate change is affecting each particular nominated coastal area and what are the most relevant impacts related to extreme events. CCLLs were requested to provide information through the response of two questionnaires – herein called Request for Local Information (RFLI) questionnaires – sent by IHS and Naider in collaboration with WP leaders. The RFLI questions were divided in groups corresponding to the project Work Packages according to their content.

The first RFLI questionnaire was submitted in June 2020. Background information of the CCLLs extracted from its responses is summarised in Table 4.

Table 4 – CCLLs partners and associated coastal area.

CCLL	Country	Partner name(s)	Geographical coastal area
Samsun	Turkey	University of Samsun	Kızılırmak Delta
Koper	Slovenia	Science and Research Centre, Koper, Slovenia	Littoral Coast/Karst
Massa	Italy	Municipality of Massa	Marina di Massa
Lisbon	Lisbon	Câmara Municipal de Oeiras	Tagus River estuary
Sligo	Ireland	Institute of Technology Sligo	County Sligo coastal line
Gdańsk	Poland	The University of Gdańsk	Vistula Spit
Basque Country	Spain	Oarsoaldea and Naider	East coastline of Guipúzcoa province
Barcelona Province / Vilanova i la Geltrú	Spain	Vilanova i la Geltrú City Council (Ajuntament de Vilanova i la Geltrú), Barcelona Provincial Council	Coast of Vilanova i la Geltrú and

		(Diputació de Barcelona), and ENT Environment and Management	Province of Barcelona
Alicante	Spain	University of Alicante	Coast of Benidorm
Dublin	Ireland	University College Dublin, and Dún Laoghaire-Rathdown County Council	Coast of Great Dublin Area

The second RFLI questionnaire was sent in October 2021. The purpose of WP1 questions included in this questionnaire was to built on the acknowledgement of the specific concerns of each city and to gather all available information regarding the discussion topic. The responses to the WP1 questions (see Table 5) are discussed in section 3.4.

Table 5 – WP1 questions included in the second RFLI questionnaire.

1. What are the main sources (scientific-technical publications, local or national climate change / environment agencies/institutions, non-technical media or other) which provide information about climate change extreme impacts in your area?
2. What is the relationship between hazards and impacts? I.e.: how can flooding affect the tourism?
3. Which of the selected natural or climatic-related hazards do you consider is the most dangerous for your CCLL and why?
4. Which of the selected impacts do you consider is the most relevant for your CCLL and why?
5. Is there any related past or ongoing project(s) on the area of the CCLL? If yes, could you please provide references and a brief summary of each of them?

2.2.6. Scientific Sources

Scientific sources including conference proceedings, scientific-technical reports and peer-reviewed scientific journal articles, have been reviewed through the most relevant scientific databases. Scopus, Web of Science, Google Scholar, Academia and Research Gate were initially selected. However, Scopus and Web of Science were finally considered as the preferred databases, as they featured the most suitable exportation options for this work; while the other three databases were discarded.

The criteria to select the keywords introduced in the search tool were:

A. Coastal cities: study sites are cities located along a coastal zone.

B. Extreme: we are only considering extreme events or impacts.

C. Climate change: climate change must play a key role as the event or impact driver.

Moreover, the search followed other recommendations:

- The use of keywords that were able to capture several climate change hazards was preferred.
- It was avoided using too specific keywords. For example, we opt using 'Coastal Erosion' instead of 'Beach Erosion' or 'Cliff Erosion' as the first keyword may include the other two.
- The use of short and general keywords was preferred to obtain broader results, allowing to filter them afterwards if needed. For example, it has been considered better to use the word 'Storm' instead of the combination of 'Coastal Storm Surge'.

According to the criteria mentioned above and the RFLI responses, two sets of keywords were developed to perform the search. The keywords presented in Table 6 are oriented to the World and European case studies, while the keywords indicated in Table 7 target the nominated CCLLs. Both tables present the number of preliminary results exported from Scopus and Web of Science for each keywords series.

Table 6 – Keywords and results targeting at worldwide and European scales.

Keywords	Number of publications exported	
	Scopus	Web of Science
Climate Change Coastal Flooding	2,271	4,311
Climate Change Coastal Erosion	2,798	3,994
Climate Change Shoreline Retreat	283	394
Coastal Cities Sea Level Rise	859	910
Climate Change Coastal Cities Temperature Rise	77	99
Climate Change Coastal Cities Storm	320	376
Climate Change Extreme Impacts Coastal cities	160	224
Climate Change Coastal Cities Tourism	61	68
Climate Change Coastal Cities Drought	86	88
Climate Change Coastal Cities Rainfall	148	225
TOTAL	**7,063**	**10,689**

Note that in the case of the nominated coastal areas (Table 7), the search expression combined the keywords shown in the left column with the name of the CCLLs. In addition, in order to reduce the number of words that will be used in the desk study, some of the hazards identified in the first RFLI questionnair have been combined or covered by more general concepts. In particular, 'Flood (Coast)' and 'Flood (Land)' are included within 'Flooding'; 'Coastal Storm Surge' is included within 'Storm'; and 'Landslide' and 'Heatwave' are covered by 'Climate Change Extreme Impacts' (which include other potential impacts). Aditionally, 'Shoreline Retreat', 'Sea Level Rise', 'Temperature Rise' and 'Rainfall' have been included in the final list as they are relevant hazards, as well as broad enough to cover possible gaps.

Table 7 – Keywords and results targeting at the nominated coastal cities/areas.

Keywords	Source	CCLL									
		Sligo	Dublin	Vilanova i la Geltrú	Benidorm	Basque Country	Oeiras	Massa	Koper	Gdańsk	Samsun
Climate Change	Scopus	7	71	0	7	1	2	7	6	63	14
	WOS	10	81	1	7	0	3	4	5	86	23
Flooding	Scopus	2	18	0	0	0	0	4	4	29	6
	WOS	2	33	0	0	0	1	0	3	57	10
	Scopus	0	1	0	1	0	0	0	0	23	6

Coastal Erosion	WOS	0	0	0	0	0	0	0	0	20	0
Shoreline Retreat	Scopus	0	0	0	0	0	0	0	0	1	1
	WOS	0	0	0	0	0	0	0	0	1	0
Sea Level Rise	Scopus	0	7	0	0	4	0	0	2	22	2
	WOS	0	4	0	0	0	0	0	1	20	4
Temperature Rise	Scopus	1	4	0	0	0	0	1	1	13	3
	WOS	1	18	0	3	0	0	1	0	14	13
Storm	Scopus	0	35	0	12	1	1	4	2	58	1
	WOS	0	19	0	23	0	0	1	2	42	1
Climate Change Extreme Impacts	Scopus	0	2	0	1	0	0	0	0	3	0
	WOS	0	2	0	0	0	0	0	0	2	0
Climate Change Tourism	Scopus	0	0	0	1	0	0	0	0	4	0
	WOS	0	0	0	1	0	0	0	0	1	1
Drought	Scopus	0	8	0	3	0	1	0	0	5	12
	WOS	0	11	0	5	0	2	0	0	3	36
Rainfall	Scopus	3	30	0	3	1	0	8	1	16	13
	WOS	3	33	0	4	0	2	2	1	31	17
TOTAL		**29**	**377**	**1**	**71**	**7**	**12**	**32**	**28**	**514**	**163**

The number of results shown above correspond to all scientific sources containing – for each case – all the keywords within any of the following sections: title, abstract or related keywords; without date restrictions; only documents in English; and allowing all type of documents (proceedings, books and scientific articles, etc.).

Metadata of the preliminary selected documents – including scientific database, search keywords, document author(s), document title, year of publication, source title (e.g. journal title), volume, issue, number, page start, page end, cites, link, abstract, author keywords and index keywords were exported and saved within a dedicated database in Excel.

After the exportation, a detailed selection was carried out by reading the abstracts of the previously selected documents, allowing to choose only those related to the study scope.

Finally, the attained information is presented and discussed in Section 3.

2.2.7. Non-technical Media

In the cases where information obtained from the previous sources was scarce, non-technical media were reviewed in order to fill the gaps.

2.3. Limitations of the Literature Review

While this review addresses a broad variety of studies collected from the main scientific databases, constraints and limited access to information means that some relevant results may have not been included. Moreover, although the literature on this subject abounds, the amount of studies have also a high geographical dispersion, leading to regional gaps on the literature. Nevertheless, relevant examples for the three levels have been included, allowing to obtain a meaningful understanding of the state-of-the-art of the discussion topic.

3. RESULTS

3.1. Overview

Having defined the study subject in Section 1 and detailed the methodology followed in Section 2, the primary purpose of this section is to share the outcomes of the reviewed literature regarding climate change extreme impacts. The review has been undertaken for three levels: (i) worldwide; (ii) Europe; and (iii) the nominated coastal cities.

3.2. Worldwide

The development of coastal cities continues to grow around the world(Neumann et al., 2015), while the frequency and severity of extreme events are increasing as a result of climate change (Dale et al., 2001; Knutson et al., 2010). As the population exposed to mean and ESL events is expected to grow significantly throughout the 21st century(Oppenheimer et al., 2019), there is a continuous increase of studies focused on climatic changes and their consequences to coastal populations (Kulp & Strauss, 2019; Lima & Bonetti, 2020; Oppenheimer et al., 2019; Wong et al., 2014). In this context, the literature review shows that the most threaten areas are the estuaries of China, India, Bangladesh and Vietnam in Asia; the Nyle estuary, the Guinea Gulf and eastern countries in Africa; the northern coast of Europe; the North-Atlantic coast of America; and a variety of islands across the world including Indonesia and Australia.

The aim of the following sections is to highlight the variety of climate change extreme events and impacts ocurring around the world. It will be possible to draw an overall picture of their may trends, focusing on the most threatened regions, to understand the nominated coastal CCLLs regional context. For this reason, the case of Europe will be separately discussed in Section 3.3.

3.2.1. Global studies

Northwestern Europe and Asia were identified as the global hotspots likely to have a significant change in episodic flooding by the end of the century(Kirezci et al., 2020). Neumann et al. (2015) investigated how coastal populations will be affected by a range of coastal hazards including sea level rise and its related effects. This study also considered population and urbanisation growth at global and regional scales by the years 2030 and 2060 based on four different sea-level and socio-economic scenarios. Results are consistent with Merkens et al. (2016) and show that the number of people living in the Low Elevation Coastal Zone (LECZ), as well as the number of people exposed to flooding from 1-in-100 year storm surge events, is higher in China, India, Bangladesh, Indonesia and Vietnam; while Egypt and sub-Saharan countries in Western and Eastern Africa are expected to experience the higher rates of population growth and urbanisation in the coastal zone. Assessing 120 cities globally, Abadie (2017) found that in the year 2100, and for a mixed RCP scenario (25% RCP 2.6, 50% RCP 4.5 and 25% RCP 8.5), USA and China will need to make major adaptation investments, with Expected Annual Damage (EAD) of US$ 1,251,732 millions for

New Orleans (USA) and US$ 1,196,517 millions for Guangzhou (China). The largest increases in extreme wave heights will likely be experienced in general at higher latitudes in a global-scale by the end of the twenty-first century, and particularly in the waters of South Australia, the Arabian Sea and the Gulf of Guinea at regional scales (O'Grady et al., 2021).

Other significant studies have been identified. The review of extreme weather and climate events in northern high latitudes, including the Arctic, reveals changes in extremes in temperature, precipitation, snow, atmospheric blocking, cyclones, floods, drought, coastal erosion, terrestrial ecosystems impacts, and marine ecosystems impacts(J. E. Walsh et al., 2020). Qeshta et al. (2019) showed how past coastal flooding events and storms resulted in damage and collapse of many coastal bridges worldwide. Bell & Masys (2020) examine extreme climate related events and the health impacts that they have on regional and global health security with specific attention on climate related migration. Moreover, a review on the interactions between climate change and local human impacts on coastal zones highlights how these interactions can damage a variety of coastal ecosystems (e.g., salt marshes, mangrove forests, seagrass beds, kelp forests, coral reefs, soft sediments, and oyster reefs) (Q. He & Silliman, 2019). Becker et al. (2018) studied the impacts of storms in ports and provided a map showing that approximately 1,100 of a total of 3,700 ports were within a 50 km range to a tropical storm trayectory from 1960 to 2016. Climate change is likely to increase drought duration and intensity (Vicente-Serrano et al., 2020). In this context, the vulnerability of cities to droughts is increasing in many world regions (Elmqvist et al., 2019; Sudradjat et al., 2020; Wang et al., 2020). The drought events in Cape Town (South Africa), California (USA), Australia, and Europe between 2016 and 2019 (de Brito et al., 2020; García-Herrera et al., 2019; Simpson et al., 2019) highlighted the relevance of droughts across world regions (Cremades et al., 2021). In this sense, the Australian Bureau of Meteorology provides a record of historial droughts in Australia[1].

3.2.2. Africa

Examples of particularly vulnerable coastal lowland cities in Africa include Rabat and Salé (Morocco), Lagos and Port Harcourt (Nigeria), Banjul (Gambia) and Durban (South Africa) (Douglas et al., 2008; Loureiro et al., 2014; Zellou & Rahali, 2019). In the case of Morocco, a storm in February 2017 produced over 120 mm of rain in just a few hours, causing flooding in the coastal neighboring cities of Rabat and Salé. This was not a one-time event as these cities have been recently experiencing several flood events (Zellou & Rahali, 2019). For example, heavy rains caused by unusually high temperatures over the Indian Ocean killed more than 112 people and forced tens of thousands of people to leave their home in East Africa (Douglas et al., 2008). Furthermore, heavy rains and pluvial floods are worsening in the African coastal cities of Accra (Ghana), Lagos (Nigeria) and Maputo (Mozambique) (Douglas et al., 2008). Coastal areas of Egypt and various East African coastal settlements are also threatened by sea-level rise (Hendy et al., 2021). Moreover, ESL will occur with increasing frequency as a result of the RSLR in Alexandria (Egypt) (Hendy et al., 2021).

3.2.3. America

At the US Atlantic coast, extra-tropical cyclones (low pressure weather systems that occur in the middle latitudes of the Earth) are responsible for the largest ESL events, whereas at the Gulf Coast and Caribbean tropical cyclones dominate (Muis et al., 2019). However, the contribution of tides in ESL can be significant along the US Atlantic coast (Muis et al., 2019) – with contributions up to 55% in some locations –, whereas in the Mexican Southern Gulf coast this does not occur. In fact, the Gulf of Mexico coast is most vulnerable to storm surge and related ESL, while New Orleans (USA) is a striking hotspot where storm winds lead to high surge levels (Yin et al., 2020).

[1] http://www.bom.gov.au/climate/drought/knowledge-centre/previous-droughts.shtml.

Nevertheless, the literature review shows that extreme storms are the main concern regarding climate change in the Northwest Atlantic coast, with a large amount of publications addressingr the impact of cyclones in this region, and providing many past examples. A variety of publications examines the effects of Hurricane Katrina (2005), Hurricane Sandy (2012) and Harvey (2017) in the American Eastern coast (Bell & Masys, 2020; Crawford et al., 2022; Fritz, 2007; Muis et al., 2019; Stagg et al., 2021; Yin et al., 2020). Although they affected other countries as well, NOAA National Hurricane Center and the Central Pacific Hurricane Center provide a database of hurricanes ocurring in the USA between 1900 and 2008[2]. The assessment of past impacts and projections of extreme hurricanes (Ullman et al., 2019) predict that storm surge resulting from increasing extreme hurricanes may surpass current flood defences and lead to severe flooding in southern New England (USA), exceeding 7 m in height. Although a warming global climate tends to decrease the extreme snowfall events along the coast of the Northeast United States, the number of extreme rainfall events is expected to increase (Chen et al., 2019). However, extreme snowfall events remain a matter of concern. During 1980-2015, Boston had the most important winter extreme snowfall events, with a total of 69, followed by New York City (40), Philadelphia (36), and Washington D.C. (30) (Chen et al., 2019). Finally, floods occurring due to extreme precipitation events dramatically reduced the capacity of the Neuse River estuary (USA) to retain and process terrestrial flux of dissolved organic carbon (Hounshell et al., 2019).

Furthermore, the effects of interannual to multidecadal ESL variability on the amplification of flood frequencies and risks for 17 major U.S. coastal cities can lead to amplification factors of ESL up to 79 (Rashid et al., 2021). In other words, the 100 year return period event may become a 1.26 year event during certain time periods when ESL variability peaks high. Thus, the aggregated 100 year flood losses for those cities can increase around US$ 142 billion (or 28%) (Rashid et al., 2021). The magnitude and frequency of extreme precipitation events are projected to increase between 2016 and 2099. For instance, southeastern Virginia is expected to observe an increase in the magnitudes of extreme precipitation up to 300% and of flooding up to 50% (Sridhar et al., 2019).

The literature is less extensive for other regions of America, yet other extreme impacts can be outlined. Information on historical floods and their impact on two coastal cities of eastern Canada (Charlottetown and Fredericton[3]) is utilised to analise the homogeneity in patterns of coastal flooding between different cities (Abbas et al., 2020). Rivera Arriaga et al. (2020)provided a summary of historic floods in San Francisco de Campeche (Mexico) from 1807 to 2011 due to upwelling and extreme rains. Coastal flooding runoff after severe storms affected reef corals, sponges, and other benthic invertebrates (Shore et al., 2021). Extreme rain events in Puerto Rico coastal neighborhoods correlated with spikes in Gastro Intestinal illness (de Jesus Crespo et al., 2019).

3.2.4. Asia

Flooding and cyclone are the most common extreme weather events in the Mahanadi delta region (India) (Ghosh et al., 2019). From a total of 41 cyclones that occurred in Asia between 1970 and 2017, about 23 made landfall in India, where regions in Gujarat and northern Maharashtra were the most affected (Poulose et al., 2020). Episodes of heavy rainfall – as the ones that occurred in Chennai (Southeast India) during November and early December of 2015 – are expected to increase by the end of 21st century (Jyoteeshkumar et al., 2020). Finally, Poulose et al. (2020) have mapped cyclone-induced extreme water levels along Gujarat and Maharashtra coasts in the Arabian Sea, showing an ESL increase of up to 1.5 m under the worst climate change projections by the end of 21st century.

A review of storm surge disasters happening in China between 1949 and 2009 can be found in Fang et al. (2016). The impacts of typhoons in 1962, 1974 and 1981 are evaluated in Xian et al. (2018), and impacts of storm flooding caused by typhoons in Shangai for the years 1905, 1997 (Typhoom Winnie), 2005 (Typhoon Matsa), and 2013 are available

[2] https://www.nhc.noaa.gov/outreach/history/.
[3] https ://www.elgegl.gnb.ca/0001/en/Flood/Search.

in Shan et al. (2021). Typhoon Winnie was of special relevance as it is considered the worst tropical cyclone to impact some Chinese provinces in 200 years. Plus, it affected other regions such us the Northern Mariana Islands, Philippines, Taiwan, Japan, the Korean Peninsula and the Russian Far East, causing 372 fatalities and $3.2 billion (1997 USD) in damage. In addition, land use losses due to extreme storm and flood risks under RCP8.5 scenario in Shangai are expected to reach, in terms of EAD, 30.4 million USD in 2030, 65.6 million USD in 2050, and 119.0 million USD in 2100. These estimates are 1.7 to 3.0 times higher than the EAD associated with the RCP2.6 scenario (Shan & Yin, 2021). Furthermore, a characterization of the spatial and temporal variations of extreme sea level around the low-lying and densely populated margins of the South China Sea is developed in Pham et al. (2019), based in sea level data from 1960 to 2014. The Pearl River Estuary was severely affected by typhoon Hato in 2017 and Typhoon Mangkhut in 2018, leading to severe heavy rain and pluvial flooding, coastal flooding and coastal erosion (Bao et al., 2019). Same authors have also produced maps of precipitation associated with extreme rainfall events in Zhuhai city – one hour and daily period precipitation for various return-periods for the 1980–2019 time series.

More examples of significant past extreme impacts affecting other regions in Asia are the extreme saltwater intrusion in the Vietnamese Mekong Delta in 2016, where saltwater intruded further inland up to more than 90 km affecting 11 out of 13 provinces of the delta(Tran et al., 2021); or typhoon Maemi (Yum et al., 2021), which was the most powerful typhoon to strike South Korea since record-keeping began in the country in 1904. This event caused 120 fatalities and $4.8 billion (2003 USD) in damage across Japan, Taiwan, South Korea and North Korea.

3.2.5. Oceania

Similarly to what occured in the eastern coast of the USA, the northeastern coast of Europe and the south coast of China, extreme storms have had severe impacts on the cities along the coast of Australia and other islands of Oceania, including Small Island Developing States (SIDS), leading to frequent coastal flooding and coastal erosion events. However, other climate change-related impacts have been identified as well. Significant results encompass the review of Australian east coast low pressure systems (cyclones) and associated extremes and impacts (Dowdy et al., 2019) such as coastal flooding, heavy rainfall, pluvial floods, coastal erosion, etc. Regarding coastal erosion, a series of extratropical cyclones that ocurred between 24 May and 16 June of 1974 resulted in the most severe beach erosion that has been observed along the New South Wales coastline (Tamura et al., 2019). On the other hand, a review of extreme heatwaves and floods highlights the detrimental effects on key marine habitat-forming organisms (e.g., corals, kelps, seagrasses, and mangroves) along more than 45% of the continental coastline of Australia between 2011 and 2017 (Babcock et al., 2019).

3.3. Europe

Extreme events in Europe are expected to increase in frequency and intensity, notably those referring to heat waves, droughts, and heavy precipitation events (Kovats et al., 2014). Weather-related disasters could affect about two-thirds of the European population annually by the year 2100 (351 million people exposed per year on average) compared with 5% during the reference period (1981–2010; 25 million people exposed per year) (Forzieri et al., 2017).

Moreover, about 50 times the number of fatalities occurring annually during the reference period 1981–2010 (3,000 deaths on average) could occur by the year 2100 (152,000 deaths on average), mainly through a rise in the frequency of heatwaves, with the highest changes towards southern Europe (Forzieri et al., 2017). Europe had two severe heat waves in the Summers of 2013 and 2019 (Walsh, et al., 2020). The 2003 heat wave led to what was, at the time, the hottest summer on record in Europe since at least 1540 and caused more than 70,000 fatalities (Robine et al., 2008), while the 2019 event led to all-time high temperature records in Belgium, France, Germany, Luxembourg, the Netherlands, and the United Kingdom[4].

The increase in extreme precipitation events is a main concern in Northern Europe and Continental Europe (climate zones) (Kovats et al., 2014). Moreover, mapping of risk-prone areas of extreme rainfall in Central Europe and in the Mediterranean Basin shows that the coastal area of the Adriatic Sea, the Northern Italy, and the Alps are foreseen to experience the highest variations for the 30-year period of 2071-2100 under the high-emissions scenario RCP 8.5 (Sardella et al., 2020).

In the case of coastal cities, coastal storms remain as the main hazard. A climate risk assessment performed by L. M. Abadie et al. (2016) estimated annual average losses for main European coastal cities of €1.1 billion in 2030 up to 36.1 billion by the end of the century with Istanbul, Odessa, Izmir, Rotterdam and St. Peterburg ranking highest.

Moreover, the current 100-year ESL could become the 1-year ESL for five million Europeans by the end of this century under high-end warming, increasing the coastal flooding risk significantly (Vousdoukas et al., 2017).

3.3.1. Coastal flooding

Vousdoukas et al. (2017) is one of the most relevant studies addressing ESL along the European coast. The study shows that, by the end of this century, the 100-year ESL along Europe's coastlines is projected to increase on average by 57 cm and 81 cm according to scenarios RCP4.5 and RCP8.5, respectively[5]. These results are consistent with other regional coastal flooding assessments made for the German Bight (Lang & Mikolajewicz, 2019, 2020), UK (Howard et al., 2019), Portugal (Antunes et al., 2019), Adriatic Sea (Lionello et al., 2021), Baltic Sea (Wiśniewski et al., 2011) and Balearic Sea (Luque et al., 2021).

According to Vousdoukas et al. (2017), the North Sea region is projected to face the highest increase in ESLs, followed by the Baltic Sea and Atlantic coasts of the UK and Ireland, mainly due to changes in storm surges and waves.

The combination of ESL and heavy rains led by more frequent and intense storms are one of the main threats identified in Northwestern Europe, exacerbating both coastal and pluvial flooding events (Ganguli & Merz, 2019). Recently extreme events include, for instance, a series of large floods in the United Kingdom during the summer of 2007, affecting several coastal cities in England (Filey[6] and Scarborough[7]), Northern Ireland (Belfast, Portstewart[8] Ballygally[9], Portrush[10] and Bangor[11]), and Wales (Prestatyn[12], Newport[13] and Barry[14]). Three relevant storm episodes that occurred in the Northwestern Europe included storms Capella (January 1976), Xynthia (February–March 2010) and Xaver (December 2013). An investigation of the spatial pattern of compound flood severity for these three storms and its comparison with the associated coastal water levels anomalies during 1970–2014, led to the identification of compound flooding hotspots (Ganguli & Merz, 2019). The impacts of extreme storms are well described in Howard et al. (2019) for Storm Xaver in December 2013: storm surge affected sites all along the east

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4 https://www.insider.com/europe-heat-wave-record-temperatures-deaths-uk-2019-7.
5 http://data.jrc.ec.europa.eu/collection/LISCOAST.
6 http://news.bbc.co.uk/2/hi/uk_news/england/north_yorkshire/6905066.stm.
7https://web.archive.org/web/20090506080650/http://archive.thenorthernecho.co.uk/2007/6/16/235885.html.
8 http://news.bbc.co.uk/1/hi/northern_ireland/6260766.stm.
9 http://news.bbc.co.uk/2/hi/uk_news/northern_ireland/6901878.stm.
10 https://web.archive.org/web/20070820002347/http://www.belfasttelegraph.co.uk/news/local-national/article2776814.ece.
11 http://news.bbc.co.uk/2/hi/uk_news/northern_ireland/6753987.stm.
12 http://news.bbc.co.uk/1/hi/wales/north_east/6903051.stm.
13 http://news.bbc.co.uk/2/hi/uk_news/wales/south_east/6221060.stm.
14 http://news.bbc.co.uk/2/hi/uk_news/wales/south_east/6908215.stm.

coast of the UK and caused seawater inundation of more than two thousand homes and businesses and three thousand hectares of farmland. Over ten thousand people were evacuated, and flood defences were breached in around fifty locations. Hurricane Katia (August–September 2011) was a another intense hurricane that had substantial impact across Europe, causing 4 fatalities and $157 million (2011 USD) in damage. More recently, Hurricane Ophelia (October 2017) was regarded as the worst storm to affect Ireland in 50 years and caused 3 fatalities and over $87.7 million (2017 USD) in damage. The strongest winds from Storm Hector (June 2018) over the northern coast of Ireland were coincident with high spring tides, leading to coastal flooding and wave overtopping in many coastal areas of Donegal and Galway counties (Guisado-Pintado & Jackson, 2019).

A variety of studies of sea level rise in the Baltic Sea have been conducted within the last decades, with major increases expected in Gdańsk. Although the results of the Baltic coast review will be discussed in more detail in section 3.4.1.7, a general overview indicates that the increase in storminess, in addition with a shrinkage of sea ice due to the temperature rise of Baltic sea, will expose coastal areas to more storms, changing its geomorphology.

The magnitude of storm surge is not expected to increase along the Southwestern Europe coast significantly (Antunes et al., 2019; Lopez-Gutierrez et al., 2020). Indeed, reductions in surge and wave extremes offset RSLR projections by 20–30% along the Portuguese coast and the Gulf of Cadiz (Spain) (Vousdoukas et al., 2017).

A variety of historical reviews of how coastal flooding episodes impact on European cities can be found in the literature. For instance, information on past extreme weather events and flooding episodes in Copenhagen (Denmark) (Madsen et al., 2019); ESLs in Venice (Italy) (Lionello et al., 2021); or the analysis of historic storms in nine European coastal areas – Belgium, Bulgaria, France (Aquitane and Mediterranean), Italy (Northern Adriatic), Netherlands, Poland, Portugal (Western and Southern coast), Spain (Atlantic Andalusia and Catalonian coast) and United Kingdom – under the EU funded MICORE project[15] (Ciavola et al., 2011).

In the absence of further investments in coastal adaptation, the present EAD of €1.25 billion is projected to increase by two to three orders of magnitude by the end of the century, ranging between 93 and €961 billion (Vousdoukas et al., 2018). The current expected annual number of people exposed (EAPE) to coastal flooding of 102,000 is projected to reach 1.52–3.65 million by the end of the century. Coastal flood impacts at a broad scale include losses of coastward migration, urbanization and asset values.

3.3.2. Coastal erosion

The increases in storm severity mean also the enhancement of their potential to erode coasts. For this reason, the coastal-flooding-prone areas described above are additionally susceptible to coastal erosion, as it is also deducted from the number of publications regarding this topic in the Northernwest coast of Europe, the Mediterranean basin, the Baltic Sea, and the Black Sea.

The storm sequence of the 2013/14 winter left many beaches along the Atlantic coast in their most eroded state in decades (Dodet et al., 2018). The January-February 2009 and the December 2011–January 2012 storms caused significant coastal erosion in Arrifana´s beach (Portugal) and in Portstewart Strant (Ireland), respectively (Loureiro et al., 2014). Since 2006, coastline retreat has significantly accelerated along the Asturias coast (Spain) due to the increased frequency in powerful storms (Flor-Blanco et al., 2021). The severe erosion of sandy beaches and dunes observed in 2013/14 reached up to 40 m of coastline retreat, destroying numerous ports and seafront promenades.

In the Adriatic Sea, a review analysis of coastal erosion events in the coastline of Manfredonia Gulf is conducted in Pasquali et al. (2019), showing the exposure of the area to coastal erosion, coastal flooding and also flooding from

[15] http://www.micore.eu/.

the Ofanto river. In Porto Garibaldi (Italy), a drastic modification in dune system occurred in 2015 by the action of Saint Agatha storm (Fernández-Montblanc et al., 2020).

More than 50% shoreline retreat is expected on about 20%-60% of sandy beaches in the Balearic Islands (Spain) by 2100, as a result of sea-level rise (RCP4.5 and RCP8.5) and the continuous action of storm surges and waves. This may lead to a gross domestic product (GDP) loss up to 7.2% with respect to the 2019 GDP due to touristic recreational services losses (Luque et al., 2021).

The increase in wave heights during extreme storms combined with higher storm surges is expected to result in a lower resilience of the sea shore to erosion and flooding in the Baltic Sea (Cerkowniak et al., 2015). The intensification of coastal erosion and the washing away of storm retention tanks are considered a relevant threat, as they lead to the discharge of significant toxic sedimentary deposits into the sea basin (Bełdowska et al., 2016; Bełdowska & Kobos, 2016, 2018; Kwasigroch et al., 2018; Nawrot et al., 2018; Saniewska et al., 2014).

As regards the Black Sea, a variety of articles are reviewed with more detail in the case study of Samsun (Section 3.4.1.8), showing the high vulnerability of the Kızılırmak Delta to coastal erosion.

3.3.3. Relevant EU projects

EU projects funded in programme *Horizon 2020 Framework Programme* and related call *Building a low-carbon, climate resilient future: climate action in support of the Paris Agreement* (H2020-LC-CLA-2018-2019-2020) are also of special relevance. Briefs of the four projects under this call are summarised below.

CLINT (2021-2025) – CLImate INTelligence: Extreme events detection, attribution and adaptation design using machine learning

CLINT[16] will draw from data collected by the Copernicus Climate Change Service and from recent advances in artificial intelligence (AI). By applying an AI framework composed of machine learning techniques and algorithms, it will process big climate datasets for improving climate science in terms of detection, causation, and attribution of extreme events. CLINT will also cover extreme events' quantification impacts on various socio-economic sectors at the pan-European scale and at the local scale in different types of climate change hotspots.

CoCliCo (2021-2025) – Coastal Climate Core Services

CoCliCo[17] aims to deliver an open web-platform that will help inform decision-making on coastal risk and adaptation. The platform will look into the main risk drivers and adjust visualisation and analysis techniques to local decision contexts. It will further combine important and high-quality geospatial information layers. Users of the platform will be able to visualise, download and analyse multiple decision-oriented coastal risk scenarios.

PROVIDE (2021-2024) – Paris Agreement Overshooting – Reversibility, Climate Impacts and Adaptation Needs

PROVIDE[18] will study the impacts of overshooting the temperature threshold targets included in the Paris Agreement. The project aims to: (i) produce global multi-scenario, multi-sectoral climate information which integrates and quantifies impacts across scales by means of novel climate and impact emulators; (ii) assess climate system uncertainties and feedbacks, and the (ir)reversibility of climate impacts to provide comprehensive risk assessments of overshooting; (iii) co-develop a generalisable overshoot proofing methodology for adaptation strategies to enhance adaptation action in response to overshoot risks; (iv) identify and prioritise overshoot adaptation needs in four case study regions; and (v) integrate all project outcomes into a PROVIDE Climate Service Dashboard.

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[16] https://cordis.europa.eu/project/id/101003876
[17] https://cordis.europa.eu/project/id/101003598
[18] https://cordis.europa.eu/project/id/101003687

XAIDA (2021-2025) – Extreme Events: Artificial Intelligence For Detection And Attribution

XAIDA[19] will fill the gaps regarding extreme event detection, attribution and projections studies using new AI techniques, and a strong two-way interaction with key stakeholders. It will (i) characterise, detect and attribute extreme events using a novel data-driven, impact-based approach, (ii) assess their underlying causal pathways and physical drivers using causal networks methods, and (iii) simulate high-intensity events and unseen events that are physically plausible in present and future climates.

Moreover, WP9 includes a variety of other EU projects considered for synergies with SCORE in its Appendix I.

Finally, other past or ongoing EU funded projects addressing climate change extreme impacts at the nominated CCLLs level are reported in the next section.

3.4. Coastal cities

The 10 coastal city living labs (CCLLs) involved in the project are: Sligo and Dublin, Ireland; Barcelona/Vilanova i la Geltrú, Benidorm and Basque Country, Spain; Oeiras, Portugal; Massa, Italy; Koper, Slovenia; Gdańsk, Poland; Samsun, Turkey. The CCLLs responses to the provide an overview of the main hazards and impacts related to climate change extreme events (Table 8).

Table 8 – Natural or climate-change-related hazards and potential impacts identified in RFLI first questionnaire.

Natural or climate-change-related hazards	Possible impacts to the coastal area
Flood (coastal)	Tourism
Flood (land)	Energy networks
Landslide	Transport networks
Coastal erosion	Cultural heritage
Heatwave	Commercial buildings
Coastal storm surge	Residential buildings
Drought	Others: agricultural stress
Other: sea level rise	

According to RFLI first questionnaire responses, the main natural or climatic hazards that affect the CCLLs are coastal flooding, land flooding, landslides, heatwaves, droughts, storm surge, coastal erosion and sea level rise (see Table 9).

Table 9 – Natural or climate-change-related hazards concerning the nominated CCLLs.

Coastal area	Natural or climatic related hazards that affect the area							
	Coastal flooding	Land flooding	Landslide	Heatwave	Drought	Storm surge	Coastal erosion	Others
Samsun	X	X					X	
Koper	X			X	X	X		
Massa	X	X				X	X	

[19] https://cordis.europa.eu/project/id/101003469

Oeiras	X	X	X	X	X	X	X	
Sligo	X	X					X	
Gdańsk	X	X						
Basque Country	X	X	X			X	X	
Province of Barcelona/Vilanova i la Geltrú	X	X	X	X	X	X	X	
Alicante	X					X	X	
Dublin	X	X	X	X		X	X	Sea level rise

These hazards are considered to impact on tourism, cultural heritage, commercial buildings, residential buildings, energy networks, transport networks and agriculture (Table 10).

Table 10 – Climate change extreme impacts on the nominated CCLLs.

Coastal area	Impacts of these hazards to the area						
	Tourism	Cultural heritage	Commercial buildings	Residential buildings	Energy networks	Transport networks	Others
Samsun		X					Agricultural stress
Koper	X	X		X		X	
Massa	X	X	X	X			
Oeiras	X	X	X	X	X	X	
Sligo	X	X	X				
Gdańsk	X	X	X	X	X	X	
Basque Country	X	X	X	X	X	X	
Province of Barcelona/Vilanova i la Geltrú	X	X	X	X	X	X	
Alicante	X	X		X			
Dublin	X	X	X	X	X	X	

The literature review for each nominated city will be carried out in the next section.

3.4.1. Sligo

No relevant journal publications have been identified for Sligo concerning climate change extreme impacts. The information presented below corresponds to the Sligo CCLL responses to the RFLI questionnaires.

County Sligo has 190 km of coastal line, with many sand beaches such as Strandhill and Rosses Point, where the main natural or climatic-related hazards are storms, coastal and land flooding, and coastal erosion.

Increased frequency and intensity of winter storms are the main hazards identified as these had the most significant impact in recent years. Coastal flooding and erosion are highlighted as some of the most severe hazards in recent years, with a high potential of causing a more significant and irreparable damage. Particularly, the impact on municipal infrastructure and chronic, short term transport disruption are especially relevant.

Moreover, information regarding potential hazards and impacts is available in Sligo County Council's Climate Adaptation Strategy[20] (CAS). However, in relation to the SCORE project we will be mainly considering the impact of more frequent and intense weather events and the potential for flooding and coastal erosion, as well as their impact on the present and future lives of citizens, and how this can possibly be mitigated and/or adapted to.

Additionally, Sligo County Council's Climate Adaptation Strategy contains technical and local information as well as a list of actions that the Local Authority is committed to with regard to Climate Adaptation. IT Sligo is also working with the Atlantic Seaboard North – Climate Action Regional Office (ASBN CARO) and their website contains several information about climate, sustainability, energy, biodiversity, etc.[21]

Also, there is currently an OPW funded survey of coastal issues in the Sligo Bay area being carried out by consultants. This Coastal Erosion & Flood Risk Management (CEFRM) Study in Sligo Bay will focus on two areas of particular interest – Strandhill and Easkey. The study will involve issues such as:

- Review and assessment of existing information.
- Surveys including those of existing coastal protection structures.
- Preparation of detailed maps for current and future scenarios of coastal change.
- Detailed risk assessment.
- Options and feasibility assessment.
- Preparation of CEFRM plan.
- Economic assessment of benefits and costs.
- Reporting and recommendations.

The study will guide and inform Sligo County Council as to the optimum decisions to be made in addressing the issues of concern in these areas.

Finally, the ASBN CARO is also involved in a Sand Dune Protection and Restoration project[22], with potential sinergies identified.

3.4.2. Dublin

Coastal flooding will have dramatic impact on Dublin over the coming years as there are limited defences in place and no significant public support to make necessary improvements such as higher flood walls[23]. For instance, in February 2002 the City of Dublin experienced severe flooding as a result of what was believed to be a combination

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[20] https://www.sligococo.ie/Environment/ClimateAction/.
[21] https://www.caro.ie/the-caros/atlantic-seaboard-north.
[22] https://www.caro.ie/projects-research/campaigns/sand-dune.
[23] https://www.irishtimes.com/news/environment/no-sense-of-urgency-clontarf-flood-defences-delayed-until-at-least-2027-1.4696624.

of unusually high tides and meteorological surge (Cooke et al., 2005). Furthermore, historical analyses of exposure and vulnerability to flood hazards in Irish cities (Cork, Galway and Dublin) can be found in Jeffers (2014).

The increasing trend in extreme rainfall has been confirmed by al Saji et al. (2015). Among others, impacts on the municipal transport network are a critical issue. Moreover, coastal flooding impacts the DART (commuter rail system) as well as primary roadways and busy tourist areas in the city. Coastal flooding regularly disrupts the public and private transport in Dublin. There is also a challenge with the combined-drainage system which can be blocked during floods.

Similarly to what occurs in Sligo, coastal flooding and erosion caused some of the most severe impacts recorded in recent years. Another impact found in literature is on houserenting in Dublin – particularly, houses located within a floodplain have lower market values than equivalent houses located outside the floodplain.

Additionally, there is meaningful literature regarding droughts in Ireland. Wilby et al. (2016) analyse persistent meteorological drought in this country, including in the city of Dublin. For instance, the summer of 2018 brought a significant meteorological drought (Falzoi et al., 2019). Particular studies of maximum temperatures in County Dublin can be found as well in O'Sullivan et al. (2020), although heat-attributable deaths are very unusual in this area (Baccini et al., 2009).

The Office of Public Works[24] (OPW), which coordinates flood management in Ireland, is another important source of information. The OPW developed Flood Plans and provides information about flood risk in Ireland.

Finally, the implementation of the Climate Change Action Plan (CCAP) 2019-2024[25] is an ongoing shared vision of the four Dublin local authorities, who are working together to reduce GHG, increase energy efficiency, and enhance the climate resilience of Dublin as a city region. The efforts of the local authorities are supported by the Climate Action Regional Offices[26].

3.4.3. Barcelona/Vilanova I la Geltrú

Vilanova I la Geltrú is a municipality of the Barcelona Province. It is located at 22 metres above sea level, though the higher part of the city is at 300 m above sea level and placed in the north side (Serra del Bonaire I del Teixidor). The main part of the population lives in the city center, but there are also several residential areas spread in the city's territory. The Garraf massif – in the northern half of the municipality – and the Plana del Garraf – in the southern half – are the main units that make up the geology and geomorphology of Vilanova I la Geltrú.

Coastal flooding, coastal erosion, landslides, droughts and heatwaves have been identified as the main hazards affecting the area. According to RFLI responses, the combination of these hazards can trigger in:

- Risk to tourism and local economy– Vilanova I la Geltrú´s economy is based in the tourism and tertiary sectors.
- Loss of cultural heritage – there are some cultural heritage elements protected by heritage law throughout the area.
- Damage to commercial buildings – many economic activities lie in the coastal area (restaurants, bars, hotels, stores, etc.) as a Mediterranean city in the surroundings of Barcelona.

24 www.floodinfo.ie.
25 https://www.dlrcoco.ie/en/environment/climate-change-action-plan-2019-2024.
26 https://www.caro.ie/.

- Damage to residential buildings – Vilanova I la Geltrú is a compact city, having also some disseminated urbanization areas.
- Loss of wetlands – although they do not cover a large area, two important wetlands are featured within the municipality.
- Loss of animal habitat – vulnerable sandy and subaquatic habitats.
- Loss of biodiversity – species from the habitats mentioned in the previous point.
- Damage to civil infrastructure – important infrastructures are located along the coastal area (e.g. harbour, road infrastructure, etc.).
- Danger to the citizen – potential risk, especially if we do not have an effective early warning system of extreme (and atypical) weather episodes.

Moreover, a non-exhaustive list of examples of the potential relationships between the hazards and sectoral impacts considered in SCORE's grant agreement (Part B – page 10) is presented in Table 11.

Table 11 – Examples of the potential relationships between the hazards and sectoral impacts considered in SCORE's grant agreement (Vilanova I la Geltrú)

Hazard	Examples of sectoral impacts:
Coastal flooding	E.g., damage to residential and commercial buildings located near the coastline of Vilanova I la Geltrú; etc.
Land flooding	E.g., damage to residential and commercial buildings; damage to public spaces (including green areas); additional pressure on the sewage system, leading to discharges into the sea, with negative implication on water quality and marine life; etc.
Coastal erosion	E.g., loss of beach area, which supports several recreational and cultural activities developed in the municipality; etc.
Coastal storm surge	E.g., loss of beach area; damage to energy networks; negative implication on coastal and marine habitats and related species.

Furthermore, forest fires are also considered as an important impact because of the geographical location of Vilanova I la Geltrú (Mediterranean area, which is more prone to forest fires), and the important forest area in the municipality. The risk of forest fire has also increased due to a population pressure, especially in the Summer, where the region receives more tourists (e.g., overuse of vulnerable spaces such as forest trails, etc.).

As mentioned above, climate change can lead to coastal erosion and to more frequent coastal storms, which may generate damages on coastal infrastructure, physical harm on the population, and negative implications in the local economy. Some examples include the coastal storms occurred in August 2019[27], and in January 2020[28].

Lastly, the following table presents a vulnerability analysis (high, medium, low vulnerability) of different climate change risks and some related effects, adapted from the Sustainable Energy and Climate Action Plan of Vilanova I la Geltrú[29].

[27] https://www.ccma.cat/el-temps/la-violencia-de-lesclafit-de-vilanova-i-la-geltru/noticia/2941833.
[28] https://beteve.cat/medi-ambient/un-any-temporal-gloria-barcelona/.
[29] Climatic profile of Vilanova i la Geltrú: https://www.vilanova.cat/doc/doc_11816021.pdf.

Table 12 – Vulnerability analysis (red: high; orange: medium; yellow: low vulnerability) of different climate change risks and some related effects.

Risks	Vulnerability
Heat waves / temperature increase	Red
Energy demand increase	Orange
Impact of heat on infrastructure	Orange
Impact on the more vulnerable people (increased mortality)	Orange
Worsening of climate comfort (accentuation of the heat island effect)	Red
Crop changes	Orange
Drought and water availability	Orange
Supply problems	Red
Problems in agriculture and livestock production	Orange
Problems in green urban areas	Orange
Aquifer availability	Orange
Effects on forests	Orange
Forest fires	Red
Forest pests	Orange
Drought, less water availability	Orange
Landscape values and biodiversity	Orange
Erosion	Orange
Loss of tourist interest associated with natural landscape (non-coastal)	Yellow
Biodiversity loss	Red
Storms and torrential rains	Red
Floods	Red
Sea level rise	Orange
Loss of beaches and dunes	Orange
Loss of coastal tourist interest	Red

Floods are considered one of the most important hazards by the Climate Change Adaptation Plan (CCAP) as they can cause human and material losses.

According to the CCAP:

- In 1964, the stream *Torrent de la Pastera* overflowed on two occasions causing damage to beaches, housing, and industries.

- In 1972, there was a severe episode of flooding caused by a coastal storm. The water level had an increase of 3 meters.
- In 2000, the stream *Torrent de la Pastera* overflowed again, as well as the streams of *Sant Joan* and *Presa*, affecting several zones of the municipality.

The main agencies/institutions at the municipality level of Vilanova I la Geltrú are the three following:

- Environment Local Service and Local Energy Agency (both from the town hall).
- Bioacoustic Applications Laboratory (Polytechnic University of Catalonia – UPC).
- Neapolis (Technological centre depending on the town hall).

Other sources associated with the local, regional, and national levels include:

- Sustainable Energy and Climate Action Plan of Vilanova I la Geltrú[30] – in Catalan, Pla d'Acció per l'Energia Sostenible I el Clima (PAESC).
- Local (county level) adaptation plans to climate change[31]. For instance, Maresme county adaptation plan to climate change. Also, adaptation plans of Garraf (where Vilanova I la Geltrú is located) and Baix Llobregat counties are currently under development.
- Catalan Strategy for Adapting to Climate Change 2013-2020[32].
- The Spanish National Climate Change Adaptation Plan 2021-2030[33].
- Adaptation Plan to Climate Change of Barcelona Metropolitan Area 2018-2030[34].
- Local Adaptation Plans to Climate Change of some municipalities of Barcelona Metropolitan Area[35] (Gavà, el Prat de Llobregat, Sant Adrià de Besòs, Viladecans).

Finally, the following projects and actions refer to the municipality of Vilanova I la Geltrú.

- Climate Change Adaptation Plan, drafted in November 2018, which analyses and proposes different actions to reduce the effect of climate change.
- Study of the peri-urban developments of the county (comarca) of Garraf, vulnerability of the population and of infrastructures.
- Improvement of the *Sant Joan* stream mouth.
- Implementation of the Prevention Plans in Urbanizations (PPU).
- Study and assessment of executive actions in the streams of *La Pastera* and *Santa Magdalena*.
- Improvement of *Santa Maria* stream in its final section.

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30 https://www.vilanova.cat/ciutat_verda/paesc#.
31 https://www.diba.cat/mediambient/adaptacio-canvi-climatic.
32 https://canviclimatic.gencat.cat/en/ambits/adaptacio/escacc/index.html.
33 https://www.miteco.gob.es/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/pnacc-2021-2030-en_tcm30-530300.pdf.
34 https://docs.amb.cat/alfresco/api/-default-/public/alfresco/versions/1/nodes/f5d049e4-216e-4528-a683-afaf580cdaaa/content/Pla_%20Adaptacio_Canvi_Clima_2030.pdf?attachment=false&mimeType=application/pdf&sizeInBytes=4855707.
35 https://www.amb.cat/s/web/ecologia/sostenibilitat/canvi-climatic/adaptacio.html.

- Recovery and conservation of the natural area of the beach *Platja Llarga*.

3.4.4. Benidorm

According to Benidorm CCLL, the main source of information is *Puertos del Estado*[36] (Spain State Ports), while the main negative consequences of climate change in this area are:

- Decrease in beach witdth and consequently its recreational space.
- Impact on the infrastructures attached to the beach (promenades, businesses, etc.).
- Floods in exposed (low) areas.
- Possible increase in the frequency and intensity of storms.
- Risk to tourism.

Coastal erosion is a critical issue in this CCLL. A review of daily soil erosion in Western Mediterranean areas between 1983 and 2004 can be found in Gonzalez-Hidalgo et al. (2007). The main conclusions reached are that, although soil erosion varies from site to site, and from year to year, annual amount of soil eroded depends on a few daily extreme coastal erosion events, mainly due to heavy rainfall. In fact, each year (statistically), the three highest daily erosive events represent more than 50% of annual soil eroded. Furthermore, the Benidorm Surface soil has the highest erodibility in Alicante province (Imeson et al., 1998).

An increase in the frequency and intensity of droughts in the Mediterranean basin has been observed since 1950, posing additional challenges to existing environmental problems (Cramer et al., 2018). Particularly in Alicante, a steady rise in minimum temperatures has been detected, while most of the precipitation is produced by just a few rainfall events with high variability in the interannual and interdecadal trends across the last decades (Fernández Montes & Sánchez Rodrigo, 2014). Moreover, insights of Benidorm´s urban development under drought-prone conditions can be found at Cremades et al. (2021).

In this sense, Olcina et al. (2016) reviewed and analysed the adaptation measures to drought risk in the hotel sector of Benidorm. The study shows that drought risk has been drastically reduced with the creation of the supra-municipal water agency and the implementation of systems that use non-conventional water resources (treated wastewater and desalination). This was also confirmed by Martínez-Ibarra (2015). Broadly, adaptation strategies of the hydrosocial cycles in the Mediterranean region are also reviewed and analysed in Arahuetes Hidalgo et al. (2018).

3.4.5. Basque Country

Accorging to RFLI responses, the main sources which provide information concerning climate change extreme impacts in Basque Country area are summarised in Table 13.

Table 13 – Main sources regarding climate change extreme impacts in Basque Country according to RFLI responses

Source	Short description
Naturklima	Gipuzkoa Provincial Council's Climate Change Foundation, attached to the Council's Department of the Environment.
Ihobe	Ihobe is a publicly-owned company of the Basque Government. Its mission is to support the Basque Government's Ministry for the Economic Development, Sustainability and

[36] https://www.puertos.es/es-es/oceanografia/Paginas/portus.aspx.

	Environment in implementing environmental policy and in spreading the green sustainability culture within the Basque Autonomous Community.
Klimatek Project	Through the Ministry for the Economic Development, Sustainability and Environment, the Basque Government has performed several studies regarding impact of climate change under the *Klimatek Project*. E.g. *Evaluation of climate drivers impact on sea level rise along the Basque coast* (*Evaluación del impacto de los factores climáticos en el ascenso del nivel del mar sobre el litoral vasco*) and *High resolution climate change scenarios for the Basque Country* (*Elaboración de escenarios regionales de cambio climático de alta resolución sobre el País Vasco*)
Azti-Tecnalia	AZTI is a scientific and technological centre that develops high-impact transformation projects with organisations aligned with the United Nations 2030 SDGs. Among other issues, AZTI specializes in climate change impact assessment on coastal hazards.
Mater	Mater is a floating ecomuseum and environmental education center which develop environmental education projects in which climate change impacts are included.

On the other hand, the main climate change-related hazards and extreme impacts identified in the RFLI responses are flooding, coastal erosion, landslides and storm surge; and tourism, cultural heritage, commercial and residential buildings and energy and transport networks; respectively. According to Basque Country CCLL, the natural phenomena that affect tourism are the changes in the climate that make the tourists' interes change towards other destinations, and the loss of beaches and tourist areas due to rising sea levels that produce material damage and economic losses. Businesses, jobs, and residential areas are detrimentally affected.

It has been also found that human impacts (e.g., artificialization and soil denudation, construction of channels for estuarine riverbeds and sediment accretion in river mouths due to the construction of coastal defence structures) overwhelm the effects of sea-level rise on Guipuzcoa coastal habitats (e.g., saltmarshes, vegetated dunes, shingle beaches, estuarine zones and piers), at least between 1954 and 2004 (Chust et al., 2009). Deba area (Guipuzcoa) is intensely affected by frequent shallow landslides triggered by rainfall (Rivas et al., 2020) – with 1,180 landslides inventoried in a 60-years span. Above all, flooding of residential and tourist areas near the sea is specially relevant, as many Guipúzcoa municipalities are settled in old marshes.

3.4.6. Oeiras

The Environment Portuguese Agency[37] (APA) is responsible for the public database that has most of the records related to hydrological variables (with emphasis on rainfall and river discharges). The meteorological institute – Portuguese Institute for Sea and Atmosphere, I. P.[38] (IPMA, IP) – also provides information related to most of the atmospherics variables.

Hazards associated to floods affect, *inter alia*, tourism and the daily lives of citizens. Such hazards can directly affect several assets (e.g., public facilities infrastructures), as well have societal impacts on health and public services. Although droughts take longer to develop and be noticeable in comparison with floods, they affect the whole society, for example, by introducing constraints in terms of water security. Both of these phenomena are expected to become more frequent and intense by climate-related changes in the years to come, each time with lower uncertainty.

[37] https://apambiente.pt/.
[38] https://www.ipma.pt/en/oipma/.

Although Oeiras Municipality is connected to many climatic-related hazards, flooding is seen as the most relevant one due to the historical occurrences and to the expertise that the Association of *Instituto Superior Técnico* for Research and Development (Portuguese accronym IST-ID) is able to address. In other words, as the IST-ID works on extreme hydrological events, they are only able to provide contributions regarding droughts, floods, extreme rainfalls and heat waves. However, other natural hazards, such as earthquakes or wildfires, are also acknowledged but not considered for the time being.

Climate-induced changes of the rainfall pattern in Oeiras Municipality will have an impact on several economic sectors and ecosystem services. Especial attention is iven to the impacts on the Portuguese wine industry around Oeiras, since grapes are one of the most sensitive crops to climate change. These predicted impacts, among others, will mainly come from alterations of the water availability throughout the hydrological year and sudden occurrences of extreme rainfall. The former can be translated into rainfall decrease, rainfall deficit, water scarcity, and drought; and the latter into flood and flash floods. Additionally, as climate change models predict a drier climate in Portugal with longer summers and shorter rainy seasons accompanied by a significant increase in extreme rainfalls, droughts, and in particular floods, will become more frequent than in the last century.

3.4.7. Massa

The alert system operated by the CFR (Regional Functional Center) of the Tuscany region is the main source of information about extreme impacts of climate change in this area.

The CFR provides constant hydrological and hydraulic weather monitoring throughout the territory of Tuscany. Together with the LAMMA (Environmental Monitoring and Modelling Laboratory for sustainable development), which periodically publishes studies on this topic (e.g., *Il Clima che cambia, uno sguardo sulla Toscana* – Climate Change, a look at Tuscany (Magno et al., 2012)), it contributes to the study of local climate change.

There are also a series of studies carried out by the Tuscany Region to analyse the impact of climate change. One example is the study promoted by the agency Irpet in 2009, *Tuscany CO2*[39]. More recent data can be found in a series of workshops published online promoted in 2020 and 2021 by the Tuscany Region.

In Tuscany, as in other Italian regions, there is a trending increase of particularly intense precipitation episodes. These have led to significant negative impacts on this CCLL in recent decades. For example, in November 2010 a landslide in the hilly area caused by the intense precipitation caused three deaths in the neighbourhood of Mirteto[40].

From the point of view of the safety of people, and given the risk of producing lethal consequences, the most dangerous hazard is represented by the floods in lowland areas and landslides in the hilly area (D'Amato Avanzi et al., 2013). Extreme rainfall events have intensified in the last years in the Magra River basin, causing severe floods in December 2009, December 2010 and October 2011 (Sacchi, 2012). This last flash flood was particularly extreme, which caused important landslides, has been analysed in Amponsah et al. (2016) and Nardi & Rinaldi (2015). In November 2012, a flood devastated the neighbourhood of Ricortola causing serious damages to assets, but fortunately without victims[41]. Additionally, most hotels and second homes are located in flood-prone areas, meaning that if no solutions are put in place, these disasters can also have serious repercussions on tourism.

From the point of view of economic consequences, the most dangerous hazard is represented by coastal erosion. For instance, in the last decade there has been an intensification of the phenomenon of tidal waves on the coast of

[39] http://www.irpet.it/?lang=en
[40] https://www.upi.com/Top_News/World-News/2010/11/02/Storms-in-Italy-cause-deaths-evacuations/46781288711648/.
[41] https://www.reuters.com/article/italy-floods-venice-tourists-idINDEE8AB07520121112.

the hamlets of Ronchi and Poveromo with serious consequences of beach erosion. The reduction of the beach area by the erosion is one of the main economic problems arised due to the impact on the tourist offer.

Over the years, the Region of Tuscany has financed a series of projects to secure the areas at greatest risk from flooding and landslides, some of which have been completed and others are still ongoing.

As regard coastal erosion, the Tuscany Region and the Municipality of Massa are carrying out several actions: development of plans of beach replenishment with reuse of the sands obtained by dredging port areas; construction of coast protection works; accommodation of waterways with remodelling and widening of the riverbeds; and maintenance of water courses and periodic cutting of vegetation in the riverbed.

3.4.8. Koper

The main sources which provide information about climate change extreme impacts in this area are summarised in Table 14.

Table 14 – Main sources regarding climate change extreme impacts in Piran according to RFLI responses

Source	Short description
Scientific journals	
Geodetski Vestnik[42]	*Geodetski vestnik* is the publication of the Association of Surveyors of Slovenia (*Zveza geodetov Slovenije*) and it is an open access journal, issued quarterly in print and online versions. The journal is designed to serve as a reference source and an archive of advancements in the disciplines that make use of the geodetic, geospatial and spatial planning fields.
Slovenian Journal of Social Science (*DružBoslovne Razprave*)[43]	*Družboslovne razprave* publishes double-blind peer reviewed articles in Slovenian and English languages in the fields of sociology, media studies, political science, cultural studies and other studies which are close to these fields is published by the Slovenian Sociological Association and the Faculty of Social Sciences, University of Ljubljana.
Organisations/Agencies/Institutes:	
National Institute of Biology – Marine Biology Station Piran (NIB MBP)	National Institute of Biology (NIB) is the largest independent Public Research Institution for Life Sciences in Slovenia. As a part of the NIB, the Marine Biology Station Piran is the only institution for marine research and monitoring of sea – water quality in Slovenia. Research groups of the MBS pursue research in the fields of physical, chemical and biological oceanography.
Environmental office of Municipality of Piran[44]	-

42 http://www.geodetski-vestnik.com/en/home.
43 https://www.druzboslovne-razprave.org/en/.
44 https://okoljepiran.si/podjetje/telefonski-imenik/.

Slovenian Environment Agency (*Agencija Republike Slovenija za Okolje*) (ARSO)[45]	The Environment Agency is a body of the Slovenian Ministry of the Environment and Spatial Planning. Its mission is to monitor, analyse and forecast natural phenomena and processes in the environment, and to reduce natural threats to people and property.
Institute for Water of the Republic of Slovenia (*Inštitut za vode Republike Slovenija*) (IzVRS)[46]	The Institute for Water of the Republic of Slovenia is a leading applied research and advisory institution in the area of integrated water management and the common European water policy in the Republic of Slovenia.
Geodetic Institute of Slovenia (Geodetski inštitut Slovenije) (GIS)[47]	Geodetic Institute of Slovenia is a leading Slovenian public institution for geodetic, cartographic, geo-informatic, and hydrographic research and development.
Morigenos – Slovenian Marine Mammal Society (*Slovensko društvo za morske sesalse*)[48]	*Morigenos* – Slovenian Marine Mammals Society is an independent and non-profit professional non-governmental organization that combines scientific research, monitoring, education, public awareness, staff development and management of natural resources for the effective protection of the marine environment and biodiversity.

As mentioned in 3.3.1, the northern area of the Adriatic Sea is prone to storms (Lionello, et al., 2016). For example, a review of coastal flooding events along the Slovenian coast with emphasis on their formation, extent and impacts can be found in Kovačič et al. (2016).

Estimates of the number of buildings affected and the number of inhabitants at risk due to flooding as a result of 1 m of sea level rise in Koper are analysed in Kovačič et al. (2016). Aditionally, authors deal with discharge characteristics of rivers in Slovene Istria.

A similar study is carried out in Grubar et al. (2019), where land exposure to flooding (in hectares) is determined for sea level rises of 50 and 100 cm along the Slovenian coast. For the worst scenario, great urban areas would be submerged, including the old city centre of Piran.

Thus, the main concern for this CCLL is coastal flooding, which threatens buildings and heritage sites. For instance, coastal flooding affected the Tartini Square (Piran) in November 2019. It also damaged infrastructure, leading to road cut-offs, isolating the people. Moreover, coastal flooding produces damage to life and property and water infrastructure, access to fresh water, and adverse effects on aquacultures receiveing the storm runoff.

Finally, briefs of the related past and ongoing projects on the area of Koper are provided in the following lines.

The **I-STORMS**[49] project takes into account coastal areas in the Adriatic including Slovenia, Italy and Croatia. The I-STORMS Guidelines are organised in accordance with the phases of the Floods Directive 2007/60/EC:

- "Prevention of risk due to sea storms concerns non-structural actions, that correspond to regulatory and administrative measures envisaged for the reduction of coastal risk and which may regulate land use, but

45 https://www.arso.gov.si.

46 http://www.izvrs.si.

47 https://gis.si/en/.

48 https://www.morigenos.org/kontakt/.

49 https://istorms.adrioninterreg.eu.

they do not involve the construction or maintenance of works or the modification of the state of these work places".

- "Protection from sea storms refers to structural actions representing interventions that involve the construction or maintenance of works or the modification of the land cover morphology".
- "Preparation for risk due to sea storms refers to the early warning systems (including forecasting systems and communication procedures) and the emergency management procedures (also exercises and information to the population) and represents the most significant part of the Guidelines".
- "Post-evaluation event and reconstruction concerns procedures and tools available to estimate the impacts from sea storms events and measures adopted for restoration after a sea storm event that has caused damage".

ADRIADAPT[50] – A Resilience Information Platform for Adriatic Cities and Towns (Interreg V A Italy Croatia Cross-border Cooperation Programme 2014-2020 No. 10045081) – is a project aimed at supporting the building of local and regional resilience by developing the knowledge base required to identify and plan appropriate climate change adaptation options. In order to achieve this goal, from the beginning of 2019 to June 2021, a set of activities was carried out. High-resolution climate projections with detailed information on climate parameters for the Adriatic regions have been produced, and this information is available on the platform. This knowledge platform for the Adriatic region contains an overview of different adaptation options, case studies, guidance documents, legal frameworks and other useful material on climate change adaptation. The knowledge platform was tested during the implementation of Adriadapt pilot projects.

The projecte SECAP[51] – Supporting Energy and Climate Adaptation Policies (Interreg V A Italija Slovenija Cross-border Cooperation Programme 2014-2020) – had the main goal of fostering the sustainable development of the cross-border territory by promoting low-carbon strategies for different zones, particularly urban areas,and creating relevant adaptation and mitigation measures. The project led to the cross-border sharing of tools, methodologies and databases, generating positive effects on local planning in the whole programme area. The sustainable development models of the Covenant of Mayors will therefore be promoted by improving the quality of life and resilience to climate change.

To sum up, we include here two conclusions reached by the Koper CCLL.

Coastal risk, and in particular sea storms risk, has not been officially defined within national specific Directives in the same way as the hydrogeological-hydraulic risk has been. Nevertheless, forecasts and response to coastal events are of a more concerning than continental storms and flood events, meaning that specialised and specific action plans are needed for coastal areas.

The risk management strategies and plans to reduce damage due to sea storms are issues that must be managed and coordinated at a national level, even if they have local peculiarities that must be studied in depth and addressed depending on the specific situation.

3.4.9. Gdańsk

According to RFLI responses, the main non-technical information sources for the discussion topic are indicated as follows. Most of them are only accessible in Polish:

- Non technical media

[50] https://adriadapt.eu/.
[51] https://www.ita-slo.eu/en/secap.

    - https://gospodarka.morska.pl
    - https://gospodarkawodna.net
- Internet portals
    - https://wp.pl
    - https://onet.pl
    - https://trojmiasto.pl
    - https://interia.pl
    - https://dziennikbaltycki.pl
    - https://wyborcza.pl

The scientific literature concerning climate change in Gdańsk is the most extensive of the nominated cities and the main results are summarised in the following lines.

The local warming tendency in the Gulf of Gdańsk is confirmed by Swiatek (2019) and Grelowska & Kozaczka (2020).. How eventual extreme changes in temperature – both heatwaves and colds – affect human mortality in Gdańsk – among many Polish cities – is analysed in Kuchcik (2021).

Moreover, a variety of studies addressing sea level rise in the Baltic Sea have been conducted within the last decades, with a major increase expected in Gdańsk. One of the last contributions is given by Wiśniewski et al. (2011). The strongest impacts are expected on the service sector, mainly tourism, since all beach areas will be affected, as well as the water supply sector (Staudt et al., 2006). Moreover, 40 cm sea-level rise would considerably increase the frequency of flooding in the Polish Baltic Coast (Urbański & Ślimak, 2008). Differences between the maximum and minimum ESL have increased during the last decades, with the highest peaks occuring in the autumn and winter months (Wiśniewski et al., 2009).

Updated estimates of exposure of land, population and assets for storm surge and sea level rise scenarios are provided in Paprotny & Terefenko (2017). This study uses up-to-date and detailed cartographic materials, including the majority of flood defences in the area. Results show that flood hazard concentrates in the Vistula and Odra estuaries (Gdańsk).

Threshold values of extreme sea and weather events on the Polish Baltic coast are determined in Tylkowski & Hojan (2018), and probabilities of extreme rainfall events are analysed in Szpakowski & Szydłowski (2018), showing that since 2000, at least 4 rainfall events should be classified as a 100-year rain event. Badur & Cieślikiewicz (2018) assseses the spatial variability of long-term trends in significant wave height in the Gulf of Gdańsk. Main results indicate that storminess is expected to increase in the open, eastern part of the gulf, and to decrease in the sheltered, western part.

Coastal erosion events and the washing away of retention tanks due to heavy rain lead to the introduction of large amounts of sedimentary deposits into the marine environment. These were found to concentrate heavy metals such as mercury (Hg) (Bełdowska et al., 2016; Bełdowska & Kobos, 2016, 2018; Kwasigroch et al., 2018; Saniewska et al., 2014), copper (Cp), cadmium (Cd), zinc (Zn) and plumb (Pb) (Nawrot et al., 2018; Suligowski & Nawrot, 2018)

Furthermore, it is predicted a significant increase in wave heights during extreme storms combined with anticipated higher storm surges, leading to a lower resilience of the sea shore to erosion and flooding (Cerkowniak et al., 2015).

In recent years, two severe flash floods occurred in Gdańsk (Suligowski & Nawrot, 2018). The first flash flood hit the city in July 2001, producing important economic and social losses (Majewski, 2016; Woloszyn, 2003). Secondly, the extreme precipitation events that occurred in July 2016 in the watershed of Strzyza Creek (Gdańsk) caused two fatalities and the highest daily rain sum registered in the city in the history of meteorological measurements (Szpakowski & Szydłowski, 2017). A complete review of historical floods can be found in Marosz (2007).

The following points summarise the main negative consequences from climate change in Gdańsk, according to Staudt & Kordalski (2005) and the Polish SEAREG project[52]:

- All beach areas will be strongly affected, having a negative impact on tourism in the region.
- Industrial areas located near the coastline or the city canals may be affected.
- Groundwater areas drawing their supplies from the shallow quaternary aquifers along the shoreline can be affected by a rising water table due to brackishwater intrusion with the sea level rise.
- Areas where embakment walls are smaller than 1 m may be seriously affected during river floods and storm events.
- Low-lying areas in the hinterland (Vistula Delta Plain) are especially vulnerable to river floods.

Finally, an impact matrix predicting how sea level rise will impact on several human systems in terms of permanent land loss due to submergence or eventual flooding is also provided by Staudt & Kordalski (2005) for Gdańsk (Table 15).

Table 15 – Sea level rise impact matrix for Gdańsk. Values: "no impact", "low", "medium", and "strong", weighted values from six local planning and environment experts. From: Staudt & Kordalski (2005).

Sea level rise effects	Sector agriculture fishery forestry	Sector industry its waste	Sector services	Infrastructure	Housing	Open urban areas	Groundwater watersupply	Green areas
Inundation (permanent land loss)	Low	Medium	Medium	Medium-strong	Low-medium	Low	Medium	Low-medium
Flooding (flood prone areas)	Low	Medium	Medium	Medium-strong	Medium	Low-medium	Medium-strong	Low-medium

3.4.10. Samsun

Samsun CCLL responded to the RFLI with an extensive summary of significant scientific and technical publications, which have been complemented with other meaningful publications identified in the literature review.

Firstly, summaries of the most significant scientific-technical publications are provided hereunder.

Kökpinar et al. (2007) studied the coastal erosion in the Bafra Plain nearby the Kızılırmak River mouth by applying physical and mathematical models. Based on the results of the physical model, a shore protection structure system was developed and implemented at the site. In addition, a one-line model was applied for this part of the shoreline to study the problem mathematically. Results show that, similar trends were obtained in the physical and numerical models, meaning that that the behavior of protection structures was successfully represented by a mathematical

[52] https://keep.eu/projects/742/Sea-Level-Change-Effecting-th-EN/.

model. The study also indicates that the erosion was completely controlled after one year from the completion of the protection.

Faik & Sesli (2010) produced maps monitoring changes observed in 1935, 1972 and 2006 along the Sumsun shoreline and coastal area throug the use of aerial data images and digital photogrammetry.

Simav (2012)[53] studied the sensitivity of the Kızılırmak delta, which is the most productive coastal region of Turkey, to sea-level rise. In this study, coastal vulnerability was investigated by applying a CVI analysis at the national scale. Furthermore, the study assessed the vulnerability of Kızılırmak Delta to hazards such as sea level rise within a period of 100 years by using satellite altimeter observations and GIS tools. The main results of the CVI analysis applied in the coastal areas of the Kızılırmak Delta are: (i) the identification of the area of permanent and temporary inundation resulting from sea level rise and extreme sea conditions; (ii) the identification of potential socio-economic impacts of permanent and temporary flooding; and (iii) the evaluation of sea level rise in terms of shoreline change and coastal erosion. It is revealed that 15% of agricultural areas, 74% of wetlands, 13% of bare areas including settlements and beaches, 2% of forest areas, and 6% of transportation infrastructure will be affected in a 7.5 meter flood that may occur in the Kızılırmak Delta. It is predicted that this situation may affect 12,000 people and cause at least US$ 20,000,000 in damage losses.

Cüneyt et al. (2014) attempted, for the first time, to investigate the coastal erosion problem at the Kızılırmak River mouth, notably in the Bafra alluvial plain.. The study developed a 2DH numerical beach evolution model to study both medium- (weeks to months) and long-term (years to decades) beach evolution problems. The model was successfully applied to several data sets of laboratory experiments of Wang et al. (2002) and Gravens & Wang (2007). Following these validation studies, the beach evolution model is applied to the shoreline change problem at the Kızılırmak Rivermouth. Within the boundaries of the study area and considering the level of detail of the available field data, the numerical model results are in agreement with the measurements. The overall performance of the numerical model is promising in that it may be used in investigating similar problems (e.g., ongoing erosion problems at the adjacent shores of the river mouth).

Allenbach et al. (2015) presented the first comprehensive digital record of all Black Sea beaches and provided a rapid assessment of their erosion risk under different scenarios of sea level rise. Through the digitisation of freely available remote-sensed images on the web, they provided broad information on the spatial characteristics and other attributes of all Black Sea beaches. Following more than 17,000 experiments using different combinations of wave conditions, beach sediment textures and slopes according to 11 scenarios of sea level rise (up to 2 m), the means (best fits) of the lowest and highest projections by the model ensemble were estimated. These were then compared to the maximum widths of the Black Sea beaches. The analysis showed that sea level rise will have highly significant impacts on the Black Sea beaches: For a 0.5 m of sea level rise, 56% of all beaches are projected to retreat by 50% of their maximum width; With a 0.82 m of sea level rise, about 41% are projected to retreat by their entire maximum width; whereas for a 1 m of sea level rise, about 51% of all Black Sea beaches are projected to retreat by their entire maximum width. Results confirm the risk of beach erosion as a major environmental problem along the Black Sea coast.

Ozturk & Sesli (2015) investigated the shoreline changes of the Lagoon Series located in the Kızılırmak Delta which is one of the most important wetlands protected by the Ramsar Convention in Turkey. The study determined the shoreline changes in the delta between 1962 and 2013 and discussed the relationship between the shoreline changes in the Kizilirmak Delta and lagoons. Landsat-MSS/TM/OLI satellite images and 1/100,000 topographic maps were used to measure the shorelines. The Net Shoreline Movement, End Point Rate and Shoreline Change Envelope

53 https://polen.itu.edu.tr/bitstream/11527/1679/1/13062.pdf

methods were used to determine the changes in the delta shoreline. As a result of the study it is determined that the lagoons tended to shrink between 1962 and 1987, the period when the Kızılırmak River carried abundant sediments before the construction of the Altinkaya and Derbent Dams. After the construction of the dams, the delta development stopped due to the disruption of the sediment flow to the delta between 1987-2013. As a result, the increase in wind and wave erosion caused a coastal erosion, narrowing the barrier spit in front of the lagoons along the eastern coasts of the delta.

Ozturk et al. (2015) determined the temporal changes of the Kizilirmak Delta. Landsat-5 thematic mapper (TM) satellite images from 1987, 1998, 2002, 2007, and 2011 were used to determine temporal changes. The shoreline change envelope (SCE), end point rate (EPR), and linear regression rate (LRR) methods were used to determine shoreline changes. Results of the study show that the maximum amount of erosion occurred near the river mouth. Moreover, it is indicated that the dams built on the Kizilirmak River and close to the delta significantly increased erosion. The spurs, which were built to prevent coastal erosion and provide partial protection, where found as unable to fully prevent erosion.

Demir & Kisi (2016) produced flood hazard maps of the Mert River Basin (Samsun district) using GIS and HEC-RAS for floods of different return periods (10, 25, 50, 100, and 1,000 years). In Samsun, the main reason of devastating flood is the influence of the Mert River and seasonal rainfall, which eventually make the district vulnerable to flooding. Authors also state that the human-based constructions and the collapse of water retaining structures are among the main causes of flooding.

Tătui et al. (2019) have computed a Coastal Sensitivity Index (CSI) at 1-km spatial scale for more than 4,000 geographical sectors around the Black Sea, taking into consideration geological–geomorphological and physical characteristics of each sector through the following parameters: type of coast (coastal geomorphology and lithology); coastal slope (from shoreline to 20m depth); shoreline changes in the last 33 years; wave incidence (the angle between the shoreline and the dominant storm waves); significant wave height during storm conditions; and relative sea level rise. The results for each parameter presented and aggregated into CSI. The most sensitive sectors to erosion are superposed on the areas with relatively high storm waves and incidence angles, namely: the deltaic coastlines of the main deltas (Danube, Kizilirmak, Yesilirmak, Sakarya, Rioni, Enguri, Kodori, Chorokhi) of the Black Sea; and the the low-lying areas along the lagoons, limans, coastal barriers and spits from Kalamitsky, Odessa and Karkinitsky Bays, Chornomorske – Yevpatoriya area (in Crimea), Taman – Anapa (in Russia) and Karasu – Karaburun (in Turkey) and the rocky areas Gelendzhik – Tuapse (in Russia), Sevastopol – Cape Meganom (in Crimea) and Inebolu – Eregli (in Turkey). These highly sensitive sectors cover extensive areas along the coastlines of Russia (57%), Georgia (46%), Turkey (44%), Romania (43%) and Ukraine (35%).

Beden & Ulke (2020) analyses how flooding would affect the Mert Basin (Samsun). For this purpose, 1D/2D coupled flood models of the Mert River were developed. The study considered the return periods of 100, 500 and 1000 years and estimated the potential flooded area in hectares – 184 ha, 262 ha and 304 ha, respectively, of the 1,200 ha study area. Main results show that the study area is particularly flood prone.

Görmüş et al. (2021) carried out a basin-scale and long-term shoreline change analysis for the Black Sea coastline. The study involves 28 geographical sections, split in a total 78,943 subsections along the coastline. A total of 96 Landsat satellite images were used between 1972 and 2018 for the analysis. Average conditions are characterized by erosion in the Black Sea with an average coastline change value of - 0.17 m/year, while 23% of the coastline has been eroded by more than 1 m/year in the last 40+ years. The results show that different mechanisms and processes driven by river sediment loads (e.g. Danube and Kızılırmak Deltas), anthropogenic effects (e.g. Turkey's Southeast Black Sea coast) and coastal sediment retention are active along the coastline and long-term coastline dynamics. On a perennial scale, it has been shown that erosional hotspots are generally located in the low sandy coastal areas of the Yeşilırmak, Danube and Kızılırmak Deltas, along barriers and spits from the northwestern Crimea and southwestern Black Sea coast. Therefore, 21% of the widest beaches of the Black Sea have been eroded by more than 1 m per year in the last 40+ years. The total length of the Black Sea coastline is estimated at 4,987 km according to the analysis of the latest satellite images.

Secondly, Table 16 presents the main local or national climate change, environment agencies and institutions.

Table 16 – Samsun local and national climate change non-scientific sources. References to documents in English. From: Samsun CCLL responses to RFLI questionnaires.

Republic of Turkey Ministry of Environment and Urbanisation

• Republic of Turkey Climate Change Action Plan 2011-2023[54]
• Republic of Turkey Climate Change Adaptation Strategy and Action Plan 2011-2023[55]
• Support Project for the Preparation of the 7th National Communication and the 3rd Biennial Report[56]
• National Biodiversity Strategy and Action Plan[57]
• Climate Change Risk Management In Turkey[58]
• Enhancing Required Joint Efforts on Climate Action Project
  ○ Water management modelling of Kızılırmak Delta Project within the scope of Samsun's Adaptation Process to Climate Change[59]
  ○ Samsun Kızılırmak Delta Natural Site, Wetland and Bird Sanctuary 2019-2023 Management Plan[60]

Republic of Turkey Ministry of Agriculture And Forestry
• Climate Change and Agriculture
Republic of Turkey Ministry of Culture and Tourism
• Samsun Cultural Heritage Preservation Regional Board Directorate
Presidency of The Republic of Turkey Presidency of Strategy And Budget
• Eleventh Development Plan 2019-2023[61]
Turkish Republic Samsun Governorship
Samsun Metropolitan Municipality

[54] https://webdosya.csb.gov.tr/db/iklim/editordosya/file/eylem%20planlari/iklim_degisikligi_eylem_plani_EN_2014.pdf.
[55] https://webdosya.csb.gov.tr/db/iklim/editordosya/file/eylem%20planlari/uyum_stratejisi_eylem_plani_EN_Final.pdf.
[56] https://webdosya.csb.gov.tr/db/cygm/icerikler/yed-nc--ulusal-b-ld-r-m-20190909092640.pdf.
[57] http://www.surdurulebilirkalkinma.gov.tr/wp-content/uploads/2016/06/ULUSAL_B%C4%B0YOLOJ%C4%B0K_%C3%87E%C5%9E%C4%B0TL%C4%B0L%C4%B0K_STRATEJISI_VE_EYLEM_PLANI.pdf.
[58] https://www.undp.org/content/dam/turkey/docs/projectdocuments/EnvSust/UNDP-TR-Iklim_Degisikligi_Risk_Yonetimi.pdf.
[59] https://www.iklimin.org/en/hibe%20projeleri/samsunda-iklim-degisikligine-uyum-sureci-kapsaminda-kizilirmak-delta-projesinin-su-yonetimi-modellemesi-projesi/.
[60] https://webdosya.csb.gov.tr/db/tabiat/icerikler/k-z-l-rmak_yp_tr-20180921095516.pdf.
[61] https://www.sbb.gov.tr/wp-content/uploads/2020/06/Eleventh_Development_Plan-2019-2023.pdf.

• Kizilirmak Delta Water Footprint Determination Report, 2018, Samsun Metropolitan Municipality
Samsun Kızılırmak Delta Conservation and Development Association (Acronym: SAMKUS)
Middle Black Sea Development Agency (Acronym: OKA)
• Samsun Provincial Forest and Water Works Action Plan
• Samsun Provincial Agriculture and Rural Development Works Action Plan
General Directorate of State Hydraulic Works (Acronym: DSI)
Turkish State Meteorological Service (Acronym: MGM)
Disaster and Emergency Management Authority (Acronym: AFAD)

Both scientific and non-scientific studies have revealed that coastal erosion/shoreline change is the most important problem of the Kızılırmak Delta, while coastal and land floods are other important disasters for the region.

Loss of cultural heritage and agricultural stress are the most relevant impacts for this CCLL. The most important feature of this area is that it is a Ramsar site that needs to be protected. On the other hand, the Kızılırmak delta, which was formed by the fertile alluviums brought by the Kızılırmak River, is a very important farming area, with a significant contribution to the regional and national economy. For this reason, agricultural stress, coastal erosion, and the destruction of fertile land are major threats to the region. Moreover, the expected sea level rise in the Black Sea will disrupt both the water quality and the ecosystem balance in the lagoons of Kızılırmak delta, which is a habitat and protected area for many rare species.

Finally, the plans and studies regarding climate change identified in the region are listed below.

- Environment and Urbanization Action Plan of Samsun Province (OKA, 2018-2023)
- Samsun Metropolitan Municipality 2015-2019 Strategic Plan; Strengthening Climate Adaptation Action Project in Turkey (2019-2023).
- Ministry of Environment and Urban Planning; "Water Management Modeling Project of Kızılırmak Delta Project within the Scope of Climate Change Adaptation Process (TR2013 / 0327.05.01-02 / 083)".
- Cross-Border Cooperation Program in the Black Sea Basin "Energy Efficiency Plan in Buildings in the Black Sea Basin (BSBEEP)".

4. CONCLUSIONS

The report has summarised the main results after the literature review process regarding climate change extreme impacts on coastal areas. The generalised sea level and temperature rise, in addition to the increasing frequency and intensity of storms and temperature extremes, strength a variety of hazards: coastal flooding and erosion events, heavy rains and pluvial/river floods, heat waves and cold spells, and landslides, among others. Moreover, the hazards can trigger a number of impacts: destruction of land as it is permanent submerged or eroded; economic and social losses due to the impacts on infrastructure, buildings, facilities, services, industry and agriculture; and loss of coastal ecosystems produced when the environmental conditions are altered.

There is a general lack of information on past extreme events and impacts in the scientific literature to support future data gathering and the development of hazard, exposure, vulnerability and risk maps. This contributes to an increasing interest of scientific community in studying future climate change-related trends, using computational models and only few past events to calibrate the models, instead of producing general reviews of past events. Apparently, there is also a high geographic heterogenity in the number of publications, which concentrates the results in some few regions, and therefore the availability of past examples for analysis.

In regard to the nominated coastal cities, there are few well-referenced cases – mainly Samsun and Gdańks –, while the scientific literature for other cities is scarce – Vilanova i la Geltrú, Sligo and Oeiras. In this aspect, the knowledge provided by the CCLLs has been of great help to complete the available information, although some gaps still remain. In this sense, future collaboration is crucial, and new RFLI questionnaires are in development. There is an an opportunity to maximise the knowledge on the nominated cities in the next tasks of WP1 and other WPs.

Altogether, the report developes a comprehensive understanding of the key climate change events and impacts concerning coastal cities and adjacent areas, thanks to the different study cases reviewed. Thus, the overall objective of the report is achieved.

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