D1.4 - Report of baseline risk analysis

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V 0.2	Gregorio Iglesias (UCC), Emilio Laíño Rebollido (UCC)	07/06/2023	Updated draft internally reviewed
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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Meaning / Full text
AEMET	Spanish Meteorology Agency
CCLL	Coastal City Living Lab
CSI	Coastal Sensitivity Index
DART	Dublin Area Rapid Transit
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EBA	Ecosystem-Based Approach
GDP	Gross Domestic Product
GIS	Geographical Information System
HEC-RAS	Hydrologic Engineering Center River Analysis System
ICPSS	Irish Coastal Protection Strategy Study
LECZ	Low Elevation Coastal Zone
MERIT	Multi-Error-Removed Improved-Terrain
MSL	Mean Sea Level
MSLR	Mean Sea Level Rise
OPW	Office of Public Works
SAC	Special Area of Conservation
SCORE	Smart Control of the Climate Resilience in European Coastal Cities
SFRA	Strategic Flood Risk Assessment
SLR	Sea Level Rise
SPA	Special Protection Area
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), Vilanova i la Geltrú, Benidorm and Basque Country (Spain), Oeiras (Portugal), Massa (Italy), Piran (Slovenia), Gdańsk (Poland) and 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 organizations 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.

This document primarily describes the methodology and summarises the results and conclusions of Task 1.4 – Baseline risk analysis and mapping of extreme climate impacts and sea level rise. It is the last part of the work included in WP1, whose main objective is to produce a high-level baseline risk map of extreme climate impacts and sea-level rise based on a semi-quantitative assessment of exposure and vulnerability for the ten CCLLs

This report is based on the results of the literature review carried out in Task 1.1 – Impacts of extreme climate events and sea level rise on coastal cities: literature review ,Task 1.2 – Mapping of past extreme events and identification of key hazards in the coastal cities, Task 1.3 – Mapping of coastal cities exposure and vulnerability to climate effects and sea level rise and on a participatory process involving the CCLLs in conjunction with WP2.

This report, entitled *D1.4 - Report of baseline risk analysis*, combines the information on past climate events, sea-level rise, key climate-related hazards and indicators of vulnerability to produce a high-level assessment of risk in the CCLLs under current climatic conditions.

The analysis includes the risk of all the CCLLs (Sligo and Dublin in Ireland, Vilanova i la Geltru, Benidorm and Oarsoaldea in Spain, Oeiras in Portugal, Massa in Italy, Piran in Slovenia, Gdańsk in Poland and Samsun in Turkey) to the key climate-related hazards identified in Task 1.2. The analysis encompasses the risk of the population, the residential buildings, the industry, the commercial buildings, the agriculture, the critical infrastructure, the beach areas and the natural areas.

A global risk score is calculated for each CCLL based on the indicators of vulnerability produced in Task 1.3 and the risk between the CCLLs is compared. Then, the results are complemented and extended using existing information on the matter, i.e., previous assessments of risk and results from Task 1.1, and hot spots of risk are identified in each CCLL.

Finally, the results are summarised in the form of maps at the end of the document, depicting the scoring of risk and the hot spots of risk.

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

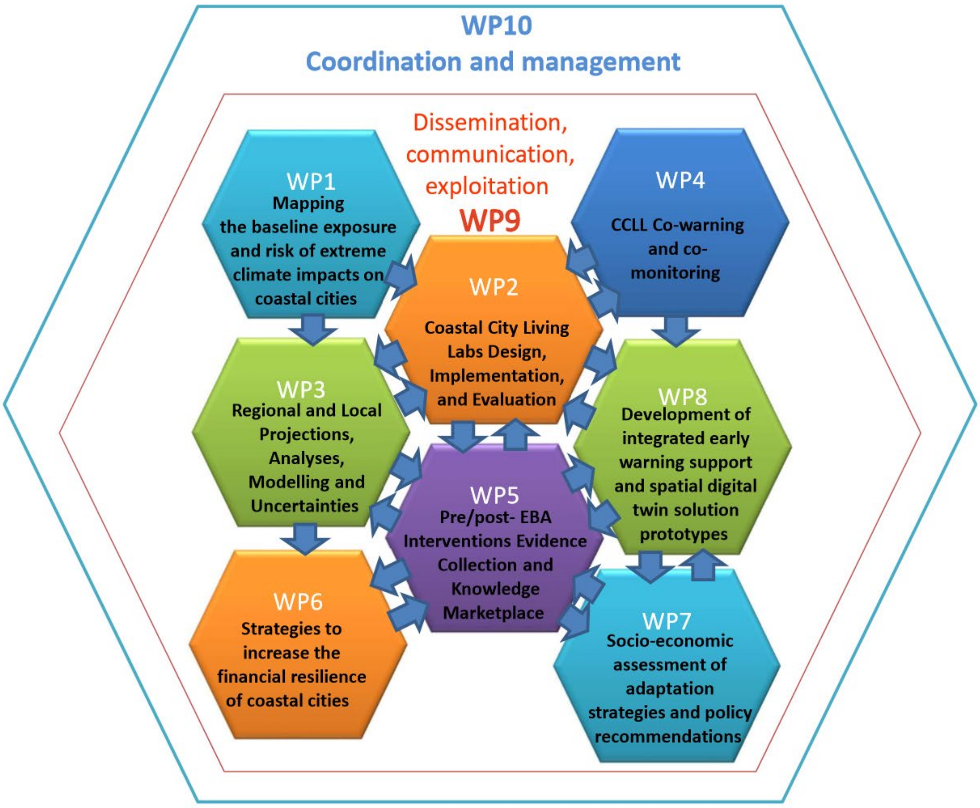

Figure 1: SCORE work packages structure.

In this vein, this report has been prepared as the last of a total 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

The documents *D1.1 - Literature review report*, *D1.2 - Map and report of key climate-change hazards* and *D1.3 - Map and report of baseline exposure and vulnerability* were completed in December 2021, June 2022 and April 2023, respectively. This document achieves the main goal of WP1: to produce a high-level baseline risk map of extreme climate impacts and sea-level rise based on a semi-quantitative assessment of exposure and vulnerability for the ten CCLLs. The main output of this task is a set of risk maps integrating the results from the previous reports of WP1, which together can provide stakeholders with an initial understanding of the baseline risk. This understanding form the foundation for the subsequent analysis of risk under climate change in WP6 and contribute to the development of certain tasks in WP3, WP5, WP7 and WP8. The documents produced in WP1 are complemented by the data collected from the CCLLs in WP2.

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1.INTRODUCTION

Risk describes the vulnerability of coastal systems to adverse effects when exposed to sea-level rise and climate-related hazards. The risks faced by the different elements of the coastal system may vary according to their characteristics, the distribution of hazards and different degrees of exposure and vulnerability.

As global temperatures increase, melting ice sheets and thermal expansion of seawater contribute to rising sea levels. This can lead to coastal erosion, increased flood risk, and saltwater intrusion into freshwater sources. Along with sea-level rise, the CCLLs may experience more frequent and intense flooding events due to changing precipitation patterns and more severe storms. This can result in damage to infrastructure, property, and disruption of daily life in the city. The storm surges leaded by extreme weather events can cause extensive damage to coastal areas, including coastal flooding, coastal erosion and destruction of infrastructure.

Climate change can also impact the ecological balance of coastal ecosystems. Rising temperatures, changes in precipitation patterns, and increased saltwater intrusion can negatively affect coastal habitats, such as salt marshes and dune systems, and disrupt the delicate balance of biodiversity in the region.

Furthermore, the risks associated with climate change can have significant impacts on the infrastructure and economy of the CCLLs. Flooding and storm damage can affect transportation systems, energy infrastructure, and property, resulting in costly repairs, interruptions in services, and economic losses. Other related climate-related hazards, such as landslides, strong winds, heat waves and forest fires, can pose additional risks to the CCLLs.

These risks are interconnected, and their severity can be influenced by factors such as the rate of climate change, local environmental conditions, and adaptation measures implemented by the city. The CCLLs are actively working on climate resilience strategies and initiatives to address these risks and protect its residents and infrastructure.

This Task integrates the hazard, vulnerability and exposure components developed in Tasks 1.2 and 1.3 in order to carry out a high-level baseline risk assessment for all the CCLLs (Figure 2). This baseline risk is defined as the integration of hazard, exposure and vulnerability under existing climatic conditions. GIS software has been used to geospatially represent the findings where appropriate.

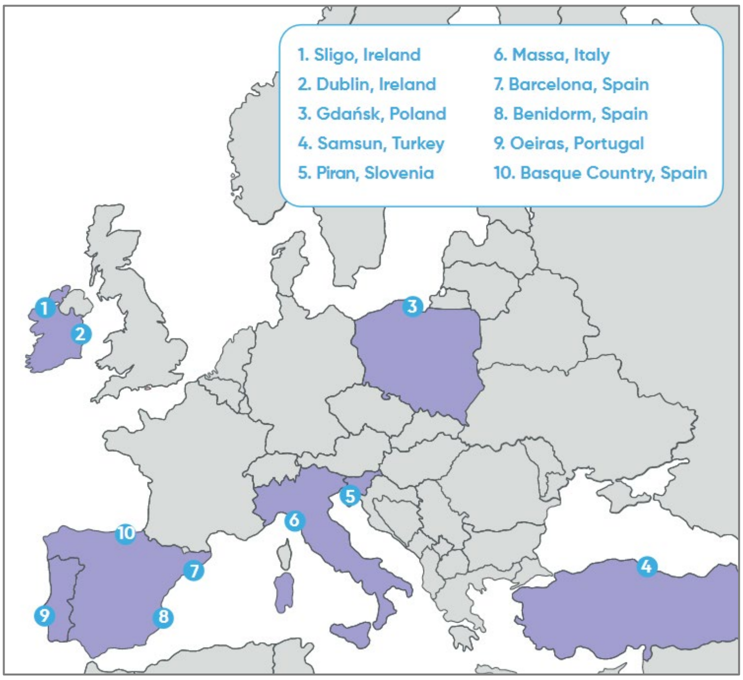

Figure 2: Location of the CCLLs.

The output of this task is a set of maps representing vulnerability, exposure and hazard, which together can provide stakeholders with an initial understanding of the baseline risk. This understanding forms the foundation for the subsequent analysis of risk under climate change in WP6. In particular, the maps will help identify risk hot spots across the various CCLLs, which will be further investigated using quantitative risk approaches in WP6. These areas of high risk can result in of high-priority action.

The characterisation of risk encompasses the analysis of the risk of the population, the residential areas, the industrial and commercial uses, the agriculture, the beach areas, the critical infrastructure and the natural areas. The next points overview the main risks posed by the different climate-related hazards assessed to the previous elements of risk in the CCLLs.

1.1. Coastal erosion, coastal flooding and land flooding

Although not the only, coastal erosion, coastal flooding and land flooding are the main hazards affecting the CCLLs leading to several risks. Firstly, they pose a direct threat to human lives, as people may be caught in rapidly rising waters or swept away by strong currents. Floods can result in injuries, loss of life, and displacement of individuals and communities. Disrupted access to basic services such as healthcare, food, and clean water can also lead to health issues and an increased risk of disease outbreaks. The psychological well-being of the affected population may also suffer due to the trauma and stress caused by the event.

Floodwaters can infiltrate homes, causing structural damage, destroying belongings, and rendering them uninhabitable. Waterlogged foundations can weaken the structural integrity of buildings, leading to collapse or long-term damage. In severe cases, entire neighbourhoods may be submerged, resulting in the complete loss of homes and the need for extensive rebuilding efforts.

Figure 3: Coastal flooding over Benidorm on 05/10/2014. From METEORED[1].

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[1] https://www.tiempo.com/

Manufacturing facilities, warehouses, and businesses located in flood-prone areas may experience significant damage to their infrastructure, equipment, and inventory. This can result in production disruptions, loss of business revenue, and even permanent closures. Additionally, flooded industrial areas can lead to the release of hazardous materials and pollutants, posing environmental risks and potentially contaminating water sources.

Farmlands can become waterlogged, leading to crop losses and reduced yields. Floodwaters may carry sediments, debris, and contaminants, damaging crops and making them unfit for consumption. Livestock can also be adversely affected, with a risk of drowning or being displaced. Flood-induced soil erosion can deplete nutrients, degrade soil quality, and hinder future agricultural productivity.

Beach areas are particularly susceptible to the impacts of floods, especially when there is a potential risk of compound coastal and land flooding. Erosion of beachfronts can occur due to the force of floodwaters, leading to the loss of sand and coastal habitats. Flooding can also result in the deposition of sediments and debris on beaches, making them less appealing for recreational purposes. The infrastructure and amenities associated with beach areas, such as boardwalks, facilities, and parking lots, may suffer damage or destruction.

Roads and bridges may become impassable due to high water levels, debris, or damage caused by the force of floodwaters. This can hinder emergency response efforts, evacuation procedures, and the movement of goods and services. Flooded airports and ports can result in the suspension or cancellation of flights and shipping activities, leading to economic losses and logistical challenges. The effects of floodings into the infrastructure associated to water and wastewater, energy, communication and coastal protection should also be considered.

Floods can have both positive and negative impacts on natural areas. In some cases, flooding can provide ecological benefits by replenishing water bodies, recharging groundwater reserves, and supporting the growth of wetland ecosystems. However, severe or prolonged floods can lead to the loss of habitats, displacement or drowning of wildlife, and alterations to the natural landscape. Flooding can disrupt the delicate balance of ecosystems, impacting biodiversity and potentially causing long-term ecological changes.

1.2. Landslides

Landslides present a severe risk to human life in areas prone to these hazards, as it will be discussed in the CCLLs of Oarsoaldea and Massa. They can result in tragic loss of life when people are caught in their path. Additionally, landslides can lead to the displacement of populations living in affected areas.

Landslides can cause extensive damage to houses, buildings and other structures, rendering them unsafe or uninhabitable. Buildings located on unstable slopes are particularly vulnerable and may collapse during landslides, putting residents' lives at risk. Moreover, landslides contribute to soil erosion, which can further destabilize the surrounding areas and increase the risk of future landslides.

Crop loss is a significant concern when landslides destroy agricultural fields and crops, leading to significant economic losses for farmers. The movement of soil during landslides can result in soil erosion, which reduces fertility and hampers future agricultural productivity. Furthermore, landslides can introduce debris, pollutants, or sediments into agricultural lands, potentially contaminating water sources and impacting crop quality.

Industrial facilities, including factories and warehouses, are susceptible to damage, leading to disruptions in production and economic losses. In some cases, landslides can release hazardous materials, leading to environmental contamination and requiring clean-up efforts. Furthermore, transportation routes serving industrial areas can be disrupted, affecting the movement of goods and impacting industries reliant on timely deliveries.

Roads, railways, bridges, and tunnels are all vulnerable to landslides. When landslides occur, they can block or damage these critical lifelines, resulting in road closures, detours, and traffic congestion. Transportation services, including railways, airports, and ports, can be interrupted, affecting regional connectivity. Steep slopes, geological conditions, and inadequate maintenance can further increase the vulnerability of transportation infrastructure to landslides.

Landslides can cause habitat destruction, altering or destroying natural habitats and negatively impacting local flora and fauna. Soil erosion and increased sedimentation in water bodies are common consequences of landslides, affecting aquatic ecosystems and water quality. The loss of biodiversity is also a concern as landslides displace or destroy plant and animal species, reducing overall biodiversity.

1.3. Forest fires

In Vilanova i la Geltrú, the risk of forest fire has increased due to its geographical location, the important forest area in the municipality and an increase in population pressure, especially in the summer, where the region receives more tourism.

Forest fires can lead to the displacement of residents, especially if the fires become too close to residential areas. People may be forced to evacuate their homes, which can result in temporary or permanent relocation. In severe cases, injuries or fatalities can occur, endangering the safety and well-being of the population. Additionally, the exposure to smoke and air pollution caused by forest fires can have detrimental effects on the respiratory health of individuals, particularly those with pre-existing conditions.

The flames can quickly spread and engulf houses, causing extensive damage or complete destruction. Even if the buildings themselves are not directly affected by the fire, they can still suffer damage from smoke, heat, and ash. This damage can render the structures uninhabitable and require extensive repairs or reconstruction, leading to financial and emotional burdens for homeowners.

The coastal areas often house factories, warehouses, and businesses, which can be vulnerable to fires due to the presence of flammable materials and equipment. Fires can disrupt operations, leading to production delays, financial losses, and potential job cuts. The destruction or damage of industrial facilities can also result in environmental pollution, as hazardous materials may be released into the surrounding areas, impacting both human health and the ecosystem.

Farms and plantations near or within forested areas can be engulfed by flames, leading to the loss of crops, livestock, and infrastructure. The destruction of agricultural land can have long-lasting effects on the local economy, as farmers may struggle to recover their livelihoods. The loss of agricultural resources can also lead to food shortages and increased prices for consumers, impacting both local and regional food supply chains.

Forest fires can indirectly impact beach areas, as the smoke and ash generated by the fires can drift towards the coast, reducing air quality and creating discomfort for beachgoers. Additionally, the destruction of vegetation in nearby forests can result in increased erosion and sediment runoff, which can negatively affect water quality and the overall health of coastal ecosystems. The loss of vegetation can also impact the aesthetic appeal of beach areas, affecting tourism and recreational activities.

Power lines, communication networks, and transportation systems can be at risk if the fires spread near or across these areas. Damage to critical infrastructure can result in disruptions to essential services, including electricity, water supply, and emergency response systems. The restoration of infrastructure can be time-consuming and costly, causing further inconvenience and potential safety concerns for the affected population.

The fires can destroy or degrade ecosystems, leading to the loss of biodiversity and disrupting ecological balance. The destruction of natural areas can also have long-term consequences for soil quality, water resources, and carbon sequestration, affecting the overall health and resilience of the environment. Efforts to restore these natural areas after a fire can be challenging and require extensive time and resources.

1.4. Strong winds

Strong winds may cause discomfort and inconvenience in the population, especially if they are persistent and intense. Strong winds can also pose safety risks, such as the potential for falling debris or trees, and can hinder outdoor activities. Additionally, strong winds can impact transportation systems, leading to delays or disruptions, which may affect the movement and daily routines of the population.

Depending on their intensity, they can damage roofs, windows, and other external structures, as it was seen in Terra Mitica theme park and Pere Maria Orts high school in Benidorm. In extreme cases, strong winds can even lead to structural failures or collapse of buildings.

Strong winds can disrupt operations, particularly for outdoor industries such as construction, logistics, and shipping. For example, strong winds may lead to the closure of ports or restrict the movement of large cargo ships. Additionally, high winds can damage infrastructure and equipment, resulting in downtime and financial losses for businesses.

Regarding agriculture, strong winds can damage crops, especially if they are in their vulnerable growth stages. High winds can uproot or break plants, reduce pollination, and cause soil erosion. In coastal areas, salt-laden winds can also have a detrimental effect on crops by increasing salinity in the soil, making it less suitable for cultivation.

In bathing areas, strong winds can create rough and dangerous sea conditions, making swimming or water sports hazardous. High winds can also lead to the formation of large waves, potentially causing beach erosion and loss of sand. Additionally, strong winds can affect the comfort and enjoyment of beachgoers by blowing sand and debris, making it unpleasant to spend time on the beach.

High winds can also cause power outages by damaging electrical infrastructure, disrupt communication networks, and impair transportation services through fallen trees or debris on roads and railways. In general, critical infrastructure needs to be designed and maintained to withstand strong winds to ensure the continuity of essential services.

Strong winds can have both positive and negative impacts on natural areas in the natural areas of the CCLLs. They play a crucial role in dispersing seeds, helping with pollination, and shaping the coastal ecosystem. However, excessive wind speeds can also cause damage to trees, coastal vegetation, and wildlife habitats. Coastal erosion can be accelerated by strong winds, leading to the loss of natural areas and altering the landscape.

1.5. Heat waves

Heat waves can lead to heat-related illnesses and fatalities, especially among vulnerable groups such as the elderly, children, and individuals with pre-existing health conditions. Heat waves can also cause discomfort, reduced productivity, and psychological stress among the general population.

High temperatures can lead to the overheating of buildings, especially those without proper insulation or cooling systems. This can result in discomfort for residents and increased energy consumption for cooling, leading to higher electricity bills. In extreme cases, prolonged heat waves can cause structural damage to buildings.

In a lower degree, heat waves can impact industrial and commercial areas in several ways. High temperatures can affect the efficiency and performance of machinery, leading to decreased productivity and potential equipment failures. Heat waves can also increase energy demands for cooling in commercial spaces, contributing to strain on the power grid. Additionally, extreme heat can disrupt supply chains, especially for industries reliant on temperature-sensitive materials.

High temperatures, combined with increased evaporation and decreased soil moisture, can lead to drought conditions and reduced crop yields. Heat stress can also negatively impact livestock, affecting their health and productivity. The agricultural sector may face economic losses and food security challenges as a result of heat waves.

Heat waves impact beach areas by attracting larger crowds seeking relief from the heat. This increased foot traffic can strain infrastructure and services in these areas, such as parking, waste management, and lifeguard resources. Moreover, prolonged heat waves can result in elevated water temperatures, leading to harmful algal blooms or other ecological imbalances, which can impact marine life and water quality.

Power grids may face increased demand for electricity due to heightened cooling needs, potentially leading to blackouts or system failures. Additionally, heat stress can affect the integrity of roads, bridges, and other infrastructure, increasing the likelihood of structural damage and disruptions to transportation networks.

High temperatures and drought conditions can increase the risk of wildfires, threatening delicate ecosystems, including mangroves, coral reefs, and wetlands, leading to ecological imbalances and loss of biodiversity.

2. METHODOLOGY

2.1. Risk as a function of hazard and vulnerability

The main objective of Deliverable D1.4 is the integration of the elements of hazard and vulnerability produced in the previous deliverables in order to estimate the baseline risk of the CCLLs to climate-related events.

In D1.2, past extreme climate events were collected and categorised and the key climate-related hazards were identified and mapped in a participatory process involving the CCLLs and WP2. This task was partially based in the results from the literature review carried out in Task 1.1. In particular, bespoke maps and lists of past extreme climate-related events were produced for each CCLL.

In D1.3, the vulnerability assessment involved the evaluation of three fundamental parameters of vulnerability: exposure, sensitivity and resilience. These parameters were identified and measured by means of indicators encompassing the key climate-related hazards, the physical system, the economic activity, the critical infrastructure, the population, the ecosystems and the adaptive capacity of the CCLLs. Almost forty indicators were produced, evaluated numerically and scored.

In Task 1.4, the results of the previous deliverables are combined according to the expression of risk as a function of hazard and vulnerability. When substituting vulnerability by its three components, a formula which relates risk to all the results produced in the previous tasks is obtained. Commonly, the relationship between the components of risk is a product. This relationship is suitable when the risk assessment involves only one hazard. In order to allow the assessment of multiple hazards, the typical equation of risk has been adjusted. Essentially, the risk for each CCLL to the key climate-related hazards identified in task 1.2 is evaluated according to the vulnerability indicators developed in task 1.3. Therefore, risk is calculated according to the next expression:

$$R \equiv R(Hazard, Vulnerability) = R(V^{H_1}, V^{H_2}, \dots, V^{H_m})$$

where:

$V^H \equiv Vulnerability\ for\ a\ given\ key\ hazard$

$R \equiv Baseline\ risk$

The CCLLs face different climate-related hazards and impacts between them. Also, the Frontrunner/Fellow status that the CCLLs hold within the SCORE project must be considered. And, furthermore, the availability of data is very heterogeneous between the cities. For these reasons, the methodology has been designed to adapt to the particularities of each city.

The total vulnerability is calculated as the sum of the values of the different elements of vulnerability. These elements of vulnerability are calculated from the indicators developed in Task 1.3.

$$V^H \equiv V^H(Exposure, Sensitivity, Resilience) = {V^H}_E + {V^H}_S + {V^H}_R$$

$$V^H \in [0, 1]$$

Where:

${V^H}_E \equiv Partial\ vulnerability\ corresponding\ to\ the\ exposure\ to\ a\ given\ hazard\ H$

${V^H}_S \equiv Partial\ vulnerability\ corresponding\ to\ the\ sensitivity\ to\ a\ given\ hazard\ H$

${V^H}_R \equiv Partial\ vulnerability\ corresponding\ to\ the\ resilience\ to\ a\ given\ hazard\ H$

The indicators used to evaluate vulnerability depend on the key climate-related hazard considered. These indicators are measured and scored according to the thresholds developed in D1.3. The thresholds are based in existing indicator-based methods from the literature and adjusted through the comparison of the results considering all the CCLLs. Moreover, weights are assigned to each indicator. These weights ponder the importance of the different indicators in the assignment of risk and constrain the risk into a value between 0 and 1 (where 0 means no risk and 1 represents the highest risk possible). The different elements of vulnerability are calculated as the sum of the scores of the indicators multiplied by their corresponding weights. Finally, a total score of risk can be obtained considering all the hazards in a CCLL.

$$V^H{}_E = \sum_{i=1}^{n_E} I_{E\,i} \cdot \omega_{E\,i} = \underbrace{I_{E\,1} \cdot \omega_{E\,1} + I_{E\,2} \cdot \omega_{E\,2} + \cdots + I_{n_E} \cdot \omega_{n_E}}_{n_E\ indicators\ of\ exposure\ to\ H}$$

$$V^H{}_S = \sum_{i=1}^{n_S} I_{S\,i} \cdot \omega_{S\,i} = \underbrace{I_{S\,1} \cdot \omega_{S\,1} + I_{S\,2} \cdot \omega_{S\,2} + \cdots + I_{n_S} \cdot \omega_{n_S}}_{n_S\ indicators\ of\ sensitivity\ to\ H}$$

$$V^H{}_R = \sum_{i=1}^{n_R} I_{R\,i} \cdot \omega_{R\,i} = \underbrace{I_{R\,1} \cdot \omega_{R\,1} + I_{R\,2} \cdot \omega_{R\,2} + \cdots + I_{n_R} \cdot \omega_{n_R}}_{n_R\ indicators\ of\ resilience\ to\ H}$$

$$\sum_{i=1}^{n_E} \omega_{E\,i} = 0.3; \sum_{i=1}^{n_S} \omega_{S\,i} = 0.5; \sum_{i=1}^{n_R} \omega_{R\,i} = 0.2;\ \omega_{E\,i} + \omega_{S\,i} + \omega_{R\,i} = 1$$

Where:

$I_{E\,i} \equiv Score\ of\ the\ indicator\ of\ exposure\ i$

$I_{S\,i} \equiv Score\ of\ the\ indicator\ of\ vulnerability\ i$

$I_{R\,i} \equiv Score\ of\ the\ indicator\ of\ resilience\ i$

$\omega_{E\,i} \equiv Weighting\ factor\ for\ the\ indicator\ of\ exposure\ i$

$\omega_{S\,i} \equiv Weighting\ factor\ for\ the\ indicator\ of\ sensitivity\ i$

$\omega_{R\,i} \equiv Weighting\ factor\ for\ the\ indicator\ of\ resilience\ i$

$n_E \equiv Number\ of\ indicators\ measuring\ the\ exposure\ to\ a\ given\ hazard\ H$

$n_S \equiv Number\ of\ indicators\ measuring\ the\ sensitivity\ to\ a\ given\ hazard\ H$

$n_R \equiv Number\ of\ indicators\ measuring\ the\ resilience\ to\ a\ given\ hazard\ H$

2.2. Indicators of vulnerability considered per key climate-related hazard

The next subsections justify the indicators used to calculate the risk from each key climate-related hazard. Also, summary tables presenting the indicators and their weighting are given.

2.2.1. Coastal erosion

The risk to coastal erosion has been analysed from the following indicators:

Relative sea-level changes (mm/year). There is a direct relationship between the rise of the sea level and the erosion of coastlines (Per, 1962).

Mean significant wave height (m). The mean significant wave height is one the main parameters that define the energy of waves. Increases in this parameter mean a greater capacity of waves to erode coastlines.

Tidal range (m). The tidal range determine the extent of foreshore exposed to wave action and currents. In addition, the compound effect of high astronomical tides and storm surge can lead to large episodes of coastal flooding and erosion.

Lithotype hardness. The resistance of the foreshore to coastal erosion largely depends on the hardness of the coastal lithotype (Stephenson, 2013).

Area of beaches, dunes, and sand plains within the LECZ (%). Sandy formations are especially vulnerable to coastal erosion due their dynamic morphology in short temporal scales and the interest that societies have on them. The reduction of the beach width can result in the loss of property, assets, ecosystems and landscape values along the coast and the loss of socioeconomic activities and tourism in the region.

Areas of high ecological value within the LECZ (%). The areas of high ecological value represent the green urban areas, natural vegetation zones, wetlands and water bodies. These areas are considered important due to their capacity to host ecosystems and leisure spaces.

Local coastal adaptation planning. The presence of coastal adaptation plans on the CCLLs can increase the resilience to the adverse effects of climate change and the detection of opportunities.

National sea level rise preparedness. The sea-level rise studies at national scale can affect the adaptive capacity of the CCLLs, especially in the absence of studies at lower scales.

MSL rise projections spatial scale. The spatial scale of the sea-level rise projections (e.g., national, regional or local scales) determine the uncertainty of the effects of sea-level rise in the CCLLs.

The weights assigned to the indicators of risk to coastal erosion are summarised in Table 1

Table 1: Indicators used in the assessment of risk to coastal erosion.

Indicator	Weight (%)
Relative sea-level changes (mm/year)	10.00
Mean significant wave height (m)	10.00
Tidal range (m)	10.00
Lithotype hardness	20.00
Area of beaches, dunes, and sand plains within the LECZ (%)	15.00
Areas of high ecological value within the LECZ (%)	15.00
Local coastal adaptation planning	10.00
National sea level rise preparedness	5.00
MSL rise projections spatial scale	5.00
Total	100.00

It's important to note that these indicators provide a general overview and that local variations within each area can exist. Factors such as local geomorphology, coastal engineering, and human interventions can also influence vulnerability and, therefore, risk to coastal erosion.

2.2.2. Coastal flooding

The exposure to coastal flooding is directly related to higher values of the indicators *Relative sea-level changes (mm/year)*, *Mean significant wave height (m)* and *Tidal range (m)* (Ranasinghe et al, 2021).

The extent of the CCLL potentially affected by coastal flooding has been estimated through the concept of low-elevation coastal zone (LECZ). Therefore, the indicators of *LECZ area (%)* and *LECZ area per coastline length (m^2/km)* measure are play an important role in the assessment of this hazard.

The percentage of the population living in the LECZ (*LECZ population (%)*), the youngest and eldest fraction of the population (*Most vulnerable population (age) (2020)*) and the indicator *Area of residential land use within the LECZ (%)* measure the vulnerability of the population to coastal flooding.

The sensibility of the main economic activities are measured through the indicators of *Area of industrial/ commercial land use within the LECZ (%)*, *Area of agriculture land use within the LECZ (%)* and *Area of beaches, dunes, and sand plains within the LECZ (%)*, in addition to the indicators related to critical infrastructure (*Area of critical infrastructure within the LECZ (%)*, *Presence of railway within the LECZ*, *Presence of port within the LECZ*, and *Presence of airport within the LECZ*).

The indicator *Areas of high ecological value within the LECZ (%)* measure all the areas susceptible to host ecosystems and leisure spaces that are contained within the LECZ and can be potentially affected by coastal flooding.

The resilience of the CCLLs to adapt to coastal flooding has been measured through the indicators of *Local coastal adaptation planning*, *National sea level rise preparedness* and *MSL rise projections spatial scale.*

Table 2 summarises the weights assigned to the previous indicators.

Table 2: Indicators used in the assessment of risk to coastal flooding.

Indicator	Weight (%)
Relative sea-level changes (mm/year)	5.0
Mean significant wave height (m)	5.0
Tidal range (m)	5.0
LECZ area (%)	10.0
LECZ area per coastline length (m2/km)	5.0
LECZ population (%)	5.0
Most vulnerable population (age) (2020)	2.5
Area of residential land use within the LECZ (%)	5.0
Area of industrial/ commercial land use within the LECZ (%)	5.0
Area of agriculture land use within the LECZ (%)	5.0
Area of beaches, dunes, and sand plains within the LECZ (%)	5.0
Area of critical infrastructure within the LECZ (%)	2.5

Indicator	Weight (%)
Presence of railway within the LECZ	2.5
Presence of port within the LECZ	2.5
Presence of airport within the LECZ	2.5
Areas of high ecological value within the LECZ (%)	12.5
Local coastal adaptation planning	15.0
National sea level rise preparedness	2.5
MSL rise projections spatial scale	2.5
Total	100.0

2.2.3. Land flooding

The exposure to land flooding is measured by the indicator *Extent of flood-prone area (%)*. As explained in the deliverable D1.3, this indicator measures the portion of the total area of the CCLL which is potentially reached by the flood event corresponding to the 100-year return period.

Analogously to the case of coastal flooding, the population living in the flood-prone areas have been estimated (*flood-prone areas population (%)*), as well as the residential land uses within these areas (*Area of residential land use within the flood-prone areas (%)*). Moreover, the indicator *Most vulnerable population (age) (2020)* is reused for this hazard.

The sensibility of the main economic activities in the flood-prone areas are measured through the indicators of *Area of industrial / commercial land use within the flood-prone areas (%)*, *Area of agriculture land use within the flood-prone areas (%)* and *Area of beaches, dunes, and sand plains within the flood-prone areas (%)*, in addition to the indicators related to critical infrastructure (*Area of critical infrastructure within the flood-prone areas (%)*, *Presence of railway within the flood-prone areas*, *Presence of port within the flood-prone areas*, and *Presence of airport within the flood-prone areas*).

The indicator *Areas of high ecological value within the flood-prone areas (%)* is equivalent to the indicator *Areas of high ecological value within the LECZ (%).*

Finally, the resilience to land flooding is measured by the indicators of *Local coastal adaptation planning*, *National sea level rise preparedness* and *MSL rise projections spatial scale*.

Table 3 summarises the weights assigned to the previous indicators.

Table 3: Indicators used in the assessment of risk to land flooding.

Indicator	Weight (%)
Extent of flood-prone areas (%)	30.0
Flood-prone areas population (%)	5.0
Most vulnerable population (age) (2020)	2.5
Area of residential land use within the flood-prone areas (%)	5.0
Area of industrial/ commercial land use within the flood-prone areas (%)	5.0

Indicator	Weight (%)
Area of agriculture land use within the flood-prone areas (%)	5.0
Area of beaches, dunes, and sand plains within the flood-prone areas (%)	5.0
Area of critical infrastructure within the flood-prone areas (%)	2.5
Presence of railway within the flood-prone areas	2.5
Presence of port within the flood-prone areas	2.5
Presence of airport within the flood-prone areas	2.5
Areas of high ecological value within the flood-prone areas (%)	12.5
Local coastal adaptation planning	10.0
National sea level rise preparedness	5.0
MSL rise projections spatial scale	5.0
Total	100.0

2.2.4. Landslides

The indicators used to assess the landslide, forest fires and strong winds hazards are analogous to the indicators used to assess the land flooding hazard, but considering the areas affected by these hazards instead of the flood-prone areas (for more details, see the document D1.3), and omitting the use of the indicators of *National sea level rise preparedness* and *MSL rise projections spatial scale*. Table 4 summarises the weights assigned to the previous indicators.

Table 4: Indicators used in the assessment of risk to landslides.

Indicator	Weight (%)
Extent of the landslide-prone areas (%)	30.0
Landslide-prone areas population (%)	5.0
Most vulnerable population (age) (2020)	2.5
Area of residential land use within the LECZ within the landslide-prone areas (%)	5.0
Area of industrial/ commercial land use within the landslide-prone areas (%)	5.0
Area of agriculture land use within the landslide-prone areas (%)	5.0
Area of beaches, dunes, and sand plains within the landslide-prone areas (%)	5.0
Area of critical infrastructure within the landslide-prone areas (%)	2.5
Presence of railway within the landslide-prone areas	2.5
Presence of port within the landslide-prone areas	2.5
Presence of airport within the landslide-prone areas	2.5

Indicator	Weight (%)
Areas of high ecological value within the landslide-prone areas (%)	12.5
Local coastal adaptation planning	20.0
Total	100.00

2.2.5. Forest fires

The forest fire hazard has been considered key only in the CCLL of Vilanova i la Geltrú, as explained in the document D1.2. The summary of the indicators and weighting factors is presented in Table 5.

Table 5: Indicators used in the assessment of risk to forest fires.

Indicator	Weight (%)
Extent of the forest-fire-prone areas (%)	30.0
Forest-fire-prone areas population (%)	5.0
Most vulnerable population (age) (2020)	2.5
Area of residential land use within the forest-fire-prone areas (%)	5.0
Area of industrial/ commercial land use within the forest-fire-prone areas (%)	5.0
Area of agriculture land use within the forest-fire-prone areas (%)	5.0
Area of beaches, dunes, and sand plains within the forest-fire-prone areas (%)	5.0
Area of critical infrastructure within the forest-fire-prone areas (%)	2.5
Presence of railway within the forest-fire-prone areas	2.5
Presence of port within the forest-fire-prone areas	2.5
Presence of airport within the forest-fire-prone areas	2.5
Areas of high ecological value within the forest-fire-prone areas (%)	12.5
Local coastal adaptation planning	20.0
Total	100.00

2.2.6. Strong winds

The hazard of strong winds has only been assessed in Vilanova i la Geltrú CCLL, as explained in the document D1.2. The summary of the indicators and weighting factors is presented in Table 6.

Table 6: Indicators used in the assessment of risk to strong winds.

Indicator	Weight (%)
Extent of the forest-fire-prone areas (%)	30.0
Forest-fire-prone areas population (%)	5.0

Indicator	Weight (%)
Most vulnerable population (age) (2020)	2.5
Area of residential land use within the forest-fire-prone areas (%)	5.0
Area of industrial/ commercial land use within the forest-fire-prone areas (%)	5.0
Area of agriculture land use within the forest-fire-prone areas (%)	5.0
Area of beaches, dunes, and sand plains within the forest-fire-prone areas (%)	5.0
Area of critical infrastructure within the forest-fire-prone areas (%)	2.5
Presence of railway within the forest-fire-prone areas	2.5
Presence of port within the forest-fire-prone areas	2.5
Presence of airport within the forest-fire-prone areas	2.5
Areas of high ecological value within the forest-fire-prone areas (%)	12.5
Local coastal adaptation planning	20.0
Total	100.00

2.2.7. Heat waves

The heat wave hazard has only been assessed in Vilanova i la Geltrú CCLL. In this case, due to the nature of the hazard (extreme values of the temperature field), the assessment has been adapted.

The number of heat waves and total days of heat wave were calculated in the deliverable D1.3, according to the methodology proposed by the Spanish Meteorology Agency (AEMET) and data from the weather station located in the airport of Barcelona. In total, 41 heat waves have occurred in Vilanova i la Geltrú since 1971, with a cumulative duration of 272 days. An upward tendency was observed for these parameters when the reference period (1971-2000) was compared to the following years (2001-2022). In addition, in the period 2017-2022 (11.76% of time between 1971-2022), 16 heat waves (39.02% of the events) occurred accumulating up to 90 days of heat wave (33.09% of total heat wave time). These results show that the exposure to heat waves has considerably increased in the last years in Vilanova i la Geltrú CCLL, thus the exposure to heat waves has been considered as high.

Although the indicator *Most vulnerable population (age) (2020)* can be used in this case, the sensibility to this hazard will be discussed in the results (Vilanova i la Geltrú). This assessment will be based in the results from the coastal adaptation plan of Vilanova i la Geltrú and will consider population, residential areas, economic activities, critical infrastructure and areas of high ecological value.

Finally, the resilience is scored by the indicator *Local coastal adaptation planning*, as in the previous cases.

The summary of the indicators and weights used for the evaluation of this hazard are presented in Table 7.

Table 7: Indicators used in the assessment of risk to heat waves.

Indicator	Weight (%)
Exposure to heat waves	30.0
Sensibility of population	7.5

Indicator	Weight (%)
Sensibility of residential land uses	5.0
Sensibility of economic activities	15.0
Sensibility of critical infrastructure	10.0
Sensibility of areas of high ecological value	12.5
Local coastal adaptation planning	20.0
Total	100.00

2.3. Synthesis of results

The results from the risk analysis are compared between the CCLLs in the next section. This approach allows to understand the differences between the CCLLs, information useful in the development of the SCORE project.

In addition, a detailed study is performed for each CCLL through the analysis of local information, with the identification of hot spots of risk. In this manner, the users can develop a comprehensive understanding of the particularities of each CCLL.

2.4. Information sources

This report builds on the findings from the documents *D1.1 – Literature Review Report*, *D1.2 – Map and report of key climate-change hazards* and *D1.3 - Map and report of baseline exposure and vulnerability*. In this sense, data for this task have been collected from the responses to WP2 questionnaires, the previous tasks and existing databases.

The information sources utilised for the derivation of the key climate-related hazard and the calculation of the different indicators used in this report can be consulted in the documents , *D1.2 – Map and report of key climate-change hazards and D1.3 - Map and report of baseline exposure and vulnerability, respectively*. However, a summary of the main sources used in the risk calculations can be found in Appendix I – Information sources.

2.5. Other considerations

The methodology developed herewith is based in a series of hypothesis which adapt to the particularities of the SCORE project. The strengths and limitations of these hypothesis are discussed in the next lines.

- The CCLLs are studied together within the same project (SCORE project). This hypothesis means that the methodology considers all the CCLLs at the same time. Conversely, the methodology is not developed to assess the CCLLs independently, rather to compare risk between them. This approach is therefore not intended for a detailed local study.
- The focus is on the CCLLs. Many indicator-based approaches are developed to assess extensive coastal regions, not coastal cities. The methodology described in this document is designed to assess the CCLLs. The methodology described in this document allows the consideration of particularities of the CCLLs that could be omitted otherwise (state of the art of related literature, participation of local expertise, identification of key climate-related hazards, consideration of local coastal adaptation planning, etc.).

- The methodology is suitable for the assessment of multiple climate-related hazards. This approach is convenient because the CCLLs cover different climatic regions and the climate-related hazards may vary between them.
- The methodology allows refinement. In this task, a series of indicators are used to evaluate the various CCLLs together. In future steps of the project, the weights of the indicators could be modified by each CCLLs according to its own criteria and even include new indicators. Also, the indicators can be measured using datasets with higher resolution if they become available. Therefore, the methodology can be continuously refined, and it is possible to decrease the level of detail.
- The level of the assessment is high. It's important to note that a detailed assessment of each CCLL would require a comprehensive study incorporating localized data, climate models, and local authorities' assessments. The information provided here serves as a general comparison and should be supplemented with more specific and up-to-date studies for accurate assessments.

3. RISK SCORING

The total score and the individual indicators provide an overview of the risk to coastal flooding for each coastal area. It is important to note that the interpretation of the results should consider the specific context, local conditions, and available data for each area. In this sense, the next section analyse the resuls having into account specific local studies for each CCLL.

3.1. Coastal erosion

The calculations summarised in Table 57 show that the risk to coastal erosion is highest in the CCLL of Sligo, with a punctuation of 72.50 over 100, followed by the CCLLs of Benidorm (66.25) and Samsun (66.25). Finally, Massa and Dublin CCLLs scored lowest with 58.75 and 48.75, respectively.

The exposure to a high-energy wave climate from the North Atlantic Ocean is key to understand the risk to coastal erosion in Sligo CCLL. Moreover, in Sligo, the mean sea level change rate and the tidal range are higher than the registered in the other CCLLs, especially those located in enclosed seas (Benidorm and Massa CCLLs in the Mediterranean Sea and Samsun CCLL in the Black Sea).

Conversely, the hardness of the coastline of Sligo is apparently harder than the rest of cases. For example, the lithotypes found in Samsun (softer sedimentary rocks and alluvial deposits) and Benidorm CCLLs (sandy beaches) are generally softer, although the East façade of Benidorm often consists of harder rocks, including limestone and sandstone. Notwithstanding, in most of the cities, the coastal landscape features diverse landforms including areas of low-lying terrain, estuaries, and sandy beaches, where the risk to coastal erosion is naturally higher.

In general, coastal erosion affects large areas of high-ecological value in most of the cases. The affection to beaches is relatively high in the case of Benidorm CCLL, medium in Sligo CCLL and low in the rest of cases.

The indicators of resilience result in low scores in Benidorm and medium or high values in the rest of CCLLs, especially in the CCLLs of Massa and Samsun.

3.2. Coastal flooding

The CCLLs of Sligo, Massa and Piran have the highest total scores of 71.88, 71.88 and 70.63, respectively, indicating the highest risk to coastal flooding among the CCLLs (Table 58 and Table 59). Dublin (48.75), Vilanova i la Geltrú (40.63), Benidorm (47.50), Oarsoaldea (62.50), Oeiras (58.13), Gdańsk (62.60) and Samsun (63.75) CCLLs have varying total scores, reflecting their relative risk to coastal flooding.

In terms of exposure, the CCLLs of Sligo, Oarsoaldea, Oeiras and Samsun have high relative sea-level changes and tidal ranges, indicating a greater variability in water levels and a higher flood risk. Sligo and Oeiras CCLLs also have a high mean significant wave height, indicating a higher wave energy and potential for coastal flooding. The areas exposed to coastal flooding, measured through the concept of LECZ in the form of the indicators *LECZ area (%)* and *LECZ area per coastline length (m^2/km)*, are high in both cases in Gdańsk CCLL. In the CCLLs of Massa, Piran and Samsun, the indicators range between medium and high, whereas they score low in the rest of the CCLLs.

The results for the indicators measuring sensitivity vary between the CCLLs. Oarsoaldea, Massa, Piran and Gdańsk have high LECZ populations, suggesting a large relative number of people at risk, while Dublin, Vilanova i la Geltrú, Benidorm and Oeiras have relatively lower LECZ populations. Moreover, the CCLLs of Benidorm, Oarsoaldea, Massa and Piran concentrate more vulnerable population in terms of age (2020 census). The sensitivity of the economic sectors greatly varies between the CCLLs. Oarsoaldea and Piran stand out for having low scores regarding these indicators. The areas associated to transport infrastructure are relatively high in the CCLLs of Vilanova I la Geltrú and Oarsoaldea, with the presence of railway and port in both cases. Although these areas are low in Sligo and Samsun CCLLs, both cities are present railway, port and airport areas within their LECZs. Lastly, the areas of high-ecological value are relatively large in the CCLLs of Sligo, Dublin, Benidorm, Oeiras, Massa, Piran and Samsun.

The results of the indicators measuring the resilience are the same as in the previous point, indicating high resilience in Benidorm CCLL and low values of resilience in the rest of CCLLs, especially in the CCLLs of Massa and Samsun.

3.3. Land flooding

Gdańsk CCLL ranks highest in risk to land flooding, with a score of 64.38, whereas the CCLLs of Sligo, Dublin, Vilanova i la Geltrú, Oarsoaldea and Samsun show reduced values in comparison (42.50, 37.50, 39.38, 44.38 and 45.63, respectively) (Table 60 and Table 61).

One of the main reasons justifying this result is that the extent of the flood-prone areas (for the 100-year return period) is much higher in Gdańsk CCLL than in the other CCLLs, and, therefore, its exposure.

Also, the sensitivity of the economic sectors is highest (especially industrial and commercial areas and agriculture) in Gdańsk CCLL, as well as the sensitivity of the transportation infrastructure (also including Dublin in this subject). On the other hand, the sensitivity to land flooding is high when the indicators related to population are considered in Oarsoaldea CCLL and those associated to the areas of high-ecological value in Samsun CCLL.

The resilience, considering the presence of local coastal adaptation planning, the national preparedness to sea-level rise and the spatial scale of the projections of MSL rise, is lowest in Samsun CCLL, but also considerably low in the CCLLs of Sligo and Oarsoaldea.

3.4. Landslides

The risk to landslides has been assessed in Oarsoaldea and Massa CCLLs, resulting in similar scores (51.25 and 49.38 relatively) for almost all the indicators considered, with the only exception of the presence of port areas in Oarsoaldea CCLL (Table 62). The areas affected by landslides do not affect areas concentrating economic activities and residential land uses. Instead, the transportation infrastructure and the areas of high-ecological value are the elements exposed to risk. Regarding the adaptive capacity, both cities lack of a coastal adaptation plan.

3.5. Forest fires

In Vilanova i la Geltrú CCLL, there is a substantial population living in the areas affected by forest fires in the past (medium score). This area also covers areas intended to agricultural uses and areas of high-ecological value (forest) in general. The risk to forest fires is considered in the coastal adaptation plan of Vilanova i la Geltrú, increasing the adaptive capacity to this hazard in the medium-long term. The total risk score assigned to this hazard is of 38.75 (Table 63).

3.6. Strong winds

Regarding the risk to strong winds in Vilanova i la Geltrú CCLL (46.25) (Table 64), the residential areas affected by past events are high, and the other indicators related to the sensitivity of population result in medium scores. Moreover, the strong winds affect medium values of land associated to agriculture and high-ecological values and railway and port areas.

3.7. Heat waves

Vilanova i la Geltrú CCLL demonstrates high exposure to heat waves. Moreover, the risk to heat waves is analysed in the coastal adaptation plan of Vilanova i la Geltrú. It shows that the sensibility of population and residential land uses can be also considered as high, whereas the sensibility to the economic activities and critical infrastructure is lower, and the sensibility of the areas associated to high-ecological values is of a medium value. The overall risk has been accordingly scored with a value of 60.00 (Table 65).

4. IDENTIFICATION OF HOT SPOTS OF RISK

The key climate-related hazards in the CCLLs were identified in the document D1.2 – Map and report of key climate-change hazards (Figure 4). Complementarily, a serious of technical documents have been complementarily used to analyse these hazards in more detail. The information on hazards is then combined with the results of the high-level assessment of vulnerability performed in the document D1.3 – Map and report of baseline exposure and vulnerability. Finally, risk maps showing the hotspots of risk for the aforementioned hazards are produced (Appendix III – Maps).

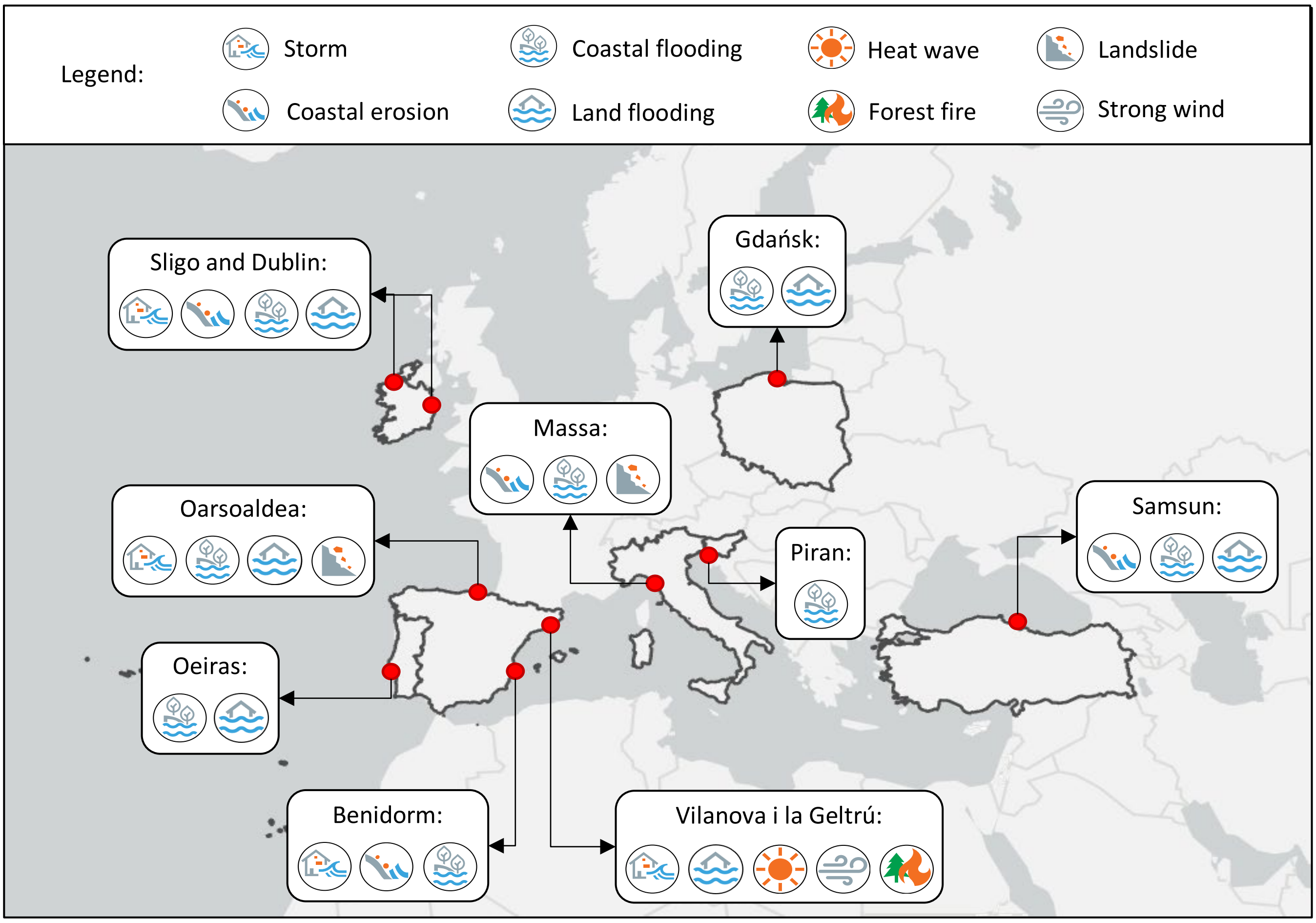

Figure 4: Schematic representation of the key climate-related hazards identified in the ten coastal cities studied.

4.1. Sensitivity of economic sectors

Complementarily, the shares of gross domestic product that the main economic sectors have on the CCLLs at regional level will be considered in the characterisation of risk. For example, it will be seen that coastal flooding affects a large extent of lands intended to agricultural use, but the contribution of this sector to the economy is very low in this CCLL (whereas the services sector is much more important), reducing the overall risk assigned to agriculture.

The weight of the main economic sectors in the Gross Domestic Product (GDP) at the lowest level of disaggregation available are summarised in Table 8. The values correspond to the prepandemic year 2019, with the exception of the Metropolitan Region of Lisbon, where no data were available before 2020.

Table 8: Shares of gross domestic product by economic sector and study region.

Region	Year	Agriculture, forestry and fishery (%)	Industry (%)	Services (%)	Source
North-West (Ireland)	2019	5.2	5.8	79.6	Central Statistics Office Ireland
Dublin (Ireland)	2019	0.5	14.7	83.1	Central Statistics Office Ireland
Barcelona (Spain)	2019	0.3	17.1	71.6	National Statistics Institute Spain
Alicante (Spain)	2019	3.5	14.8	68.0	National Statistics Institute Spain
Gipuzkoa (Spain)	2019	1.2	22.2	68.0	National Statistics Institute Spain
Metropolitan Region of Lisbon (Portugal)	2020	0.4	9.5	86.5	Statistics Portugal
Massa-Carrara (Italy)	2019	0.8	19.5	74.3	National Statistics Institute Italy
Slovenia	2019	2.0	28.9	56.4	World Bank
Pomorskie Voivodship (Poland)	2019	2.1	25.7	63.5	Statistical Office in Gdańsk
Turkey	2019	6.2	21.9	66.5	Turkish Statistical Institute

These results have been compared between the CCLLs and they have been assigned a sensitivity score according to Table 9.

Table 9: Thresholds for the indicators of sensitivity of the economic activities.

Agriculture, forestry and fishery (%)	Industry (%)	Services (%)	Scoring
<1	<10	<70	Low sensitivity
Between 1-5	Between 10-20	Between 70-80	Medium sensitivity
>5	>20	>80	High sensitivity

4.2. Sligo

4.2.1. Coastal and land flooding

Regarding land flooding risk, Figure 5 shows the flood-prone areas for the event associated to the 100-year return period in County Sligo, based in the results from Dottori et al. (2021). In general, the flood extents are limited. However, the locality of Ballysadare and adjacent railway areas can be considered at risk. As it be discussed hereinafter, more localities are at risk when low-level results are considered.

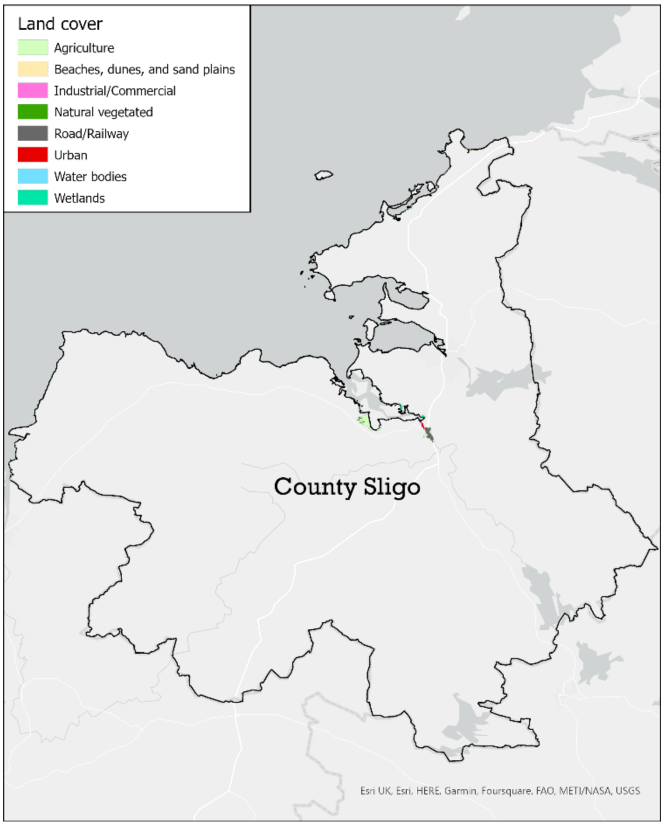

Figure 5: Land cover of flood-prone areas for the 100-year return period river flooding event in Sligo CCLL. Source: Dottori et al. (2021).

The document *Strategic Flood Risk Assessment (SFRA)*[2] analyses flood risk in County Sligo and identifies areas of high risk subjected to some limitations[3]. It is based in a number of sources, including the Preliminary Flood Risk Assessment Maps – which delineate flood-prone areas – CFRAM programme, Irish Coastal Protection Strategy Study (ICPSS) 2012, OPW National Flood Hazard Mapping (www.floodmaps.ie), Historical Flood Risk Indicator Mapping, OPW Benefitting Land Maps, Mineral Alluvial Soil Mapping/Wetland database, aerial photography, public consultation, working knowledge from Area Engineers and the flood event occurred in December 2015. In particular, the document identifies and discusses flood risk in the following 32 settlements: Aclare, Ballinacarrow, Ballinafad, Ballincar, Ballintogher, Ballygawley, Ballysadare, Banada, Bellaghy, Bunnanadden, Carney, Castlebaldwin, Cliffony, Cloonacool, Collooney, Coolaney, Culfadda, Curry, Dromore West, Drumcliff, Easky, Geevagh, Gorteen, Grange, Monasteraden, Mullaghmore, Ransboro, Rathcormack, Riverstown, Rosses Point, Tourlestrane and Strandhill. Thirteen (13) of these areas were selected for a further risk assessment due to potential flood risk issues. These localities are: Ballinacarrow, Ballysadare, Bellaghy, Bunnanadden, Carney, Collooney, Coolaney, Curry, Drumcliff, Gorteen, Grange, Rathcormack and Riverstown. The main results of these specific flood risk assessments are a series of maps defining flood hazard and vulnerability in three different levels. For flood hazard, the thresholds (namely, A, B and C) are based on the probability of flooding, with zone A representing a probability greater than 1% for river

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[2] https://www.sligococo.ie/cdp/DraftCDP2017-2023StrategicFloodRiskAssessmnt.pdf

[3] It is important to note that compliance with the requirements of the Guidelines on Flood Risk Management and of the Floods Directive 2007/60/EC is a work in progress and is currently based on emerging and incomplete data, as well as estimates of the locations and likelihood of flooding.
Accordingly, all information in relation to flood risk is provided for general guidance only. It may be substantially altered in light of future data and analysis. As a result, all landowners and developers are advised that Sligo County Council and its agents can accept no responsibility for losses or damages arising due to assessments of the vulnerability to flooding of lands, uses and developments. Owners, users and developers are advised to take all reasonable measures to assess the vulnerability to flooding of lands in which they have an interest prior to making planning or development decisions.

flooding or 0.5% for coastal flooding, zone B representing a probability of river flooding between 0.1% and 1% and between 0.1% and 0.5% for coastal flooding, and zone C representing a probability of either river flooding or coastal flooding lower than 0.1%. The vulnerability of different land uses is divided into “highly vulnerable”, “less vulnerable” and “water-compatible”. As example, a flood map from the specific flood hazard assessment of Strandhill is shown in Figure 6.

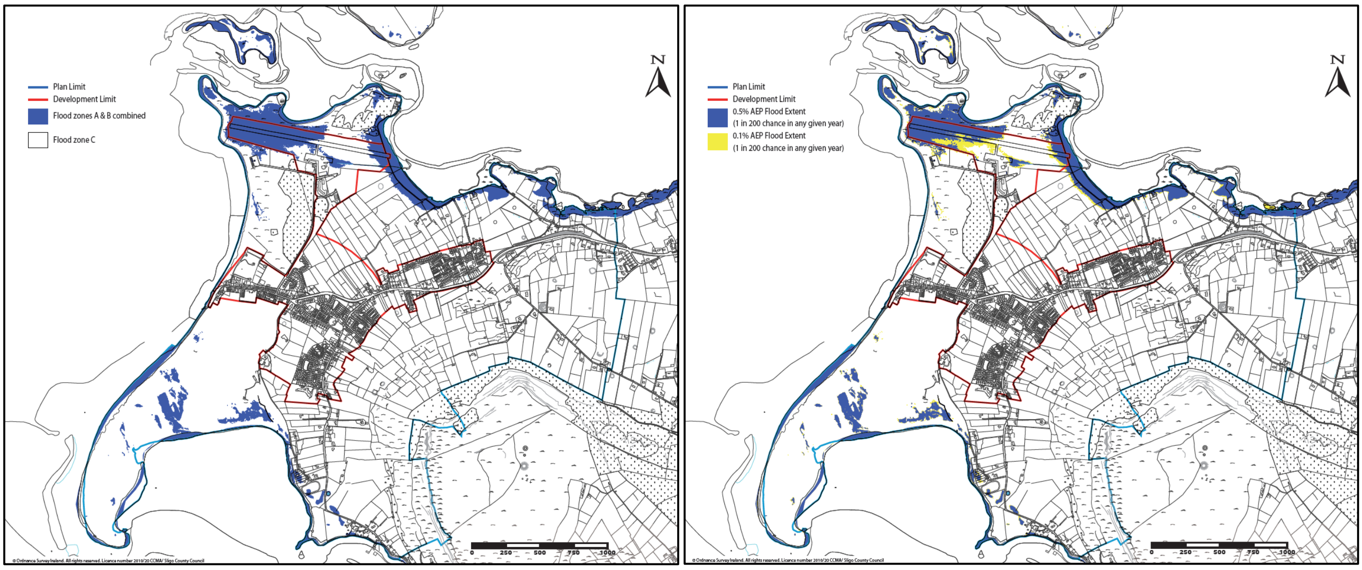

Figure 6: Flood hazard zoning (Flood Zones A, B and C) and associated probabilities according to the document “Strategic Flood Risk Assessment Report on Strandhill Mini-Plan – Variation No.1 of the Sligo County Development Plan 2011-2017”, based on the results from the work “Irish Coastal Protection Strategy Study – Phase V – North-West Coast Flood Extent Map” (May 2012) by Office of Public Works (OPW) Ireland.

The information provided by the previous documents and the results from Tasks 1.1 and 1.2 have been synthetised in the maps representing the localities concentrating coastal flooding and land flooding hazards in County Sligo shown in Figure 7 and Figure 8. The coastal areas of Ballysadare Bay, Cummeen Strand Bay and Drumcliff Bay and the coastal area from Streedagh Point to Cliffony are identified of areas of potentially significant coastal flooding hazard. In other words, the frequency, intensity and extent of coastal flooding episodes within these areas are significantly larger than those values in other coastal areas along the coastline of County Sligo.

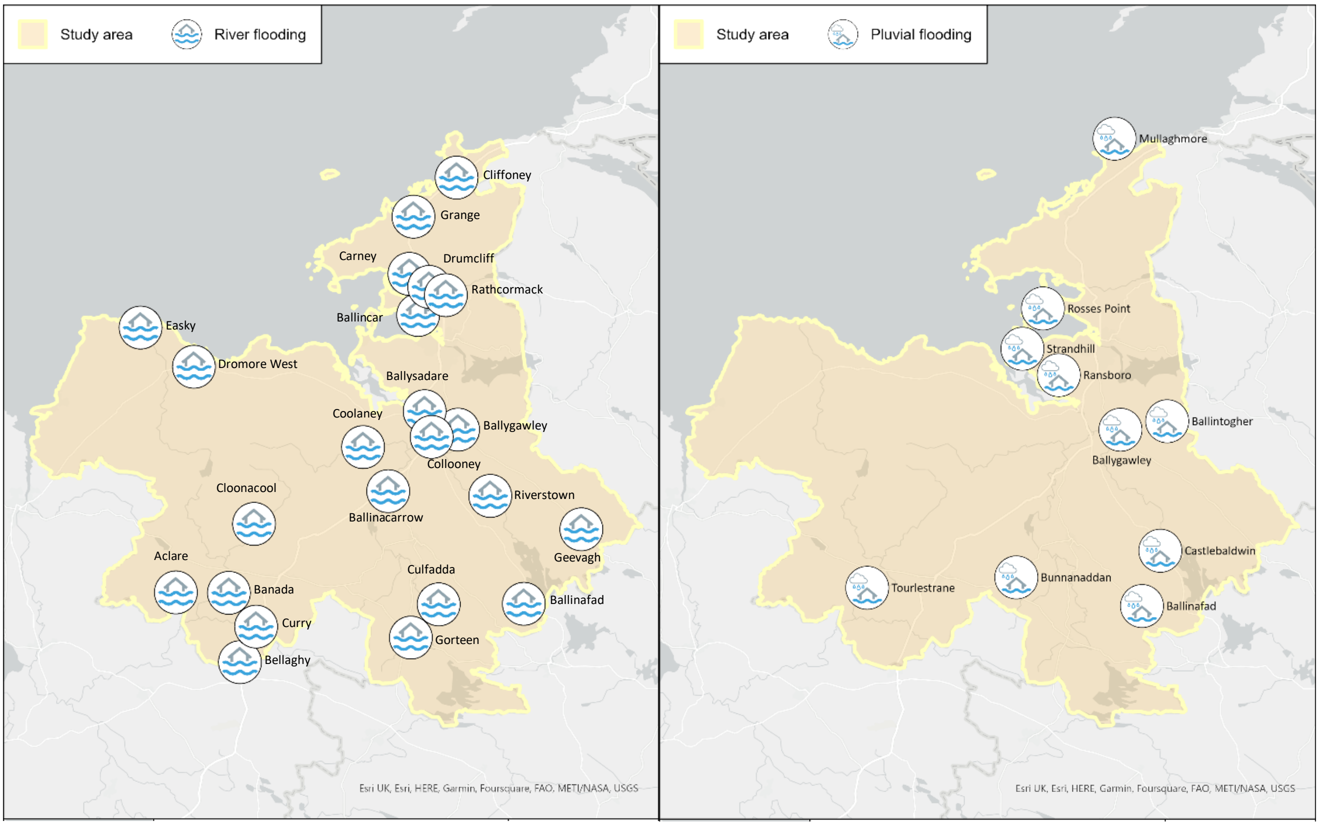

Figure 7: Localities with significant river flooding hazard (left) and pluvial flooding hazard (right) in Sligo CCLL. Source: "Strategic Flood Risk Assessment" by Office of Public Works (OPW) Ireland.

Figure 8: Localities with significant coastal flooding hazard. Source: "Strategic Flood Risk Assessment" by Office of Public Works (OPW) Ireland.

Although the results of the works described previously have some limitations, their accuracy has been considered to be appropriate for the high-level, baseline analysis of risk performed in this document. In consequence, the information on flood hazard provided by the SFRA is combined with the results from Tasks 1.2 and 1.3 to define flood risk in County Sligo. For this purpose, a summary of the results of *D1.3 – Map and report of baseline exposure and vulnerability* for Sligo CCLL is presented in Table 10 and Table 11.

Table 10: Summary of the indicators assessing coastal flooding risk in Sligo CCLL.

Indicator	Value	Threshold	Score
LECZ area (%)	4.6	(10; 25)	Low
LECZ / Coastline (ha/km)	39.9	(50; 150)	Low
LECZ population (%)	10.7	(10; 25)	Medium
Most vulnerable population (age) (2020) (%)	10.29	(9; 11)	Medium
Area of residential land use within the LECZ (%)	3.3	(10; 25)	Low
Area of industrial/ commercial land use within the LECZ (%)	1.3	(5; 10)	Low
Area of agriculture land use within the LECZ (%)	60.5	(20; 40)	High
Area of beaches, dunes, and sand plains within the LECZ (%)	6.5	(5; 10)	Medium
Area of critical infrastructure within the LECZ (%)	1.1	(5; 10)	Low
Presence of railway within the LECZ	Yes	(No; Yes)	High
Presence of port within the LECZ	Yes	(No; Yes)	High
Presence of airport within the LECZ	Yes	(No; Yes)	High
Areas of high ecological value within the LECZ (%)	33.6	(10; 25)	High
Local coastal adaptation planning	No	(No; Yes)	High
National sea level rise preparedness	Reasonably well	(Not well; Reasonably well; Well/very well)	Medium
MSL rise scenario scale	National	(Local; Regional; National)	High

Table 11: Summary of the indicators assessing land flooding risk in Sligo CCLL.

Indicator	Value	Threshold	Score
Flood-prone area (%)	0.16	(10; 25)	Low
Flood-prone areas population (%)	0.9	(10; 25)	Low
Most vulnerable population (age) (2020) (%)	10.29	(9; 11)	Medium

Indicator	Value	Threshold	Score
Area of residential land use within the flood-prone areas (%)	4.7	(10; 25)	Low
Area of industrial/ commercial land use within the flood-prone areas (%)	0.7	(5; 10)	Low
Area of agriculture land use within the flood-prone areas (%)	42.7	(20; 40)	High
Area of beaches, dunes, and sand plains within the flood-prone areas (%)	4.7	(5;10)	Low
Area of critical infrastructure within the flood-prone areas (%)	17.3	(5; 10)	High
Presence of railway within the flood-prone areas	Yes	(No; Yes)	High
Presence of port within the flood-prone areas	No	(No; Yes)	Low
Presence of airport within the flood-prone areas	No	(No; Yes)	Low
Areas of high ecological value within the flood-prone areas (%)	17.3	(10; 25)	Medium
Local coastal adaptation planning	No	(No; Yes)	High
National sea level rise preparedness	Reasonably well	(Not well; Reasonably well; Well/very well)	Medium
MSL rise scenario scale	National	(Local; Regional; National)	High

4.2.2. Coastal erosion

The indicators developed in D1.3 show the highest scores compared to other CCLLs (Table 12), with the exception of the lithotype hardness.

Table 12: Summary of the indicators assessing coastal erosion risk in Sligo CCLL.

Indicator	Value	Threshold	Score
Relative sea-level changes (mm/year)	1.5	(0.5; 1.0)	High
Mean significant wave height (m)	3.7	(1.5; 2.5)	High
Tidal range (m)	1.1	(0.5; 1.0)	High
Lithotype hardness	Hard	(Hard; medium; soft)	Low
Area of beaches, dunes, and sand plains within the LECZ (%)	6.5	(5; 10)	Medium
Areas of high ecological value within the LECZ (%)	33.6	(10; 25)	High
Local coastal adaptation planning	No	(No; Yes)	High
National sea level rise preparedness	Reasonably well	(Not well; Reasonably well; Well/very well)	Medium

Indicator	Value	Threshold	Score
MSL rise projections spatial scale	National	(Local; Regional; National)	High

Regarding the distribution of the risk, substantial information on coastal erosion for County Sligo (and flood hazard, as reported in the SFRA) can be found in the project *Irish Coastal Protection Strategy Study – Phase 5* by OPW[4,5,6]. In particular, two sets of erosion maps with the expected position of the coastline in 2030 and 2050 for existing climatic conditions were prepared for the purpose of assessing the degree of coastal erosion hazard and risk to assist in the identification and development of measures for coastal management. For full guidance (e.g., project information, derivation of maps, uncertainty) on the scope and limitations of the maps, please see the reference document. Based on the maps corresponding to 2030, three areas of potentially significant coastal erosion in County Sligo are identified: the coastal area from Marley's Point to Strandhill (Ballysadare Bay), the coastal area of Raghly and the coastal area from Streedagh Point to Cliffony (Figure 9).

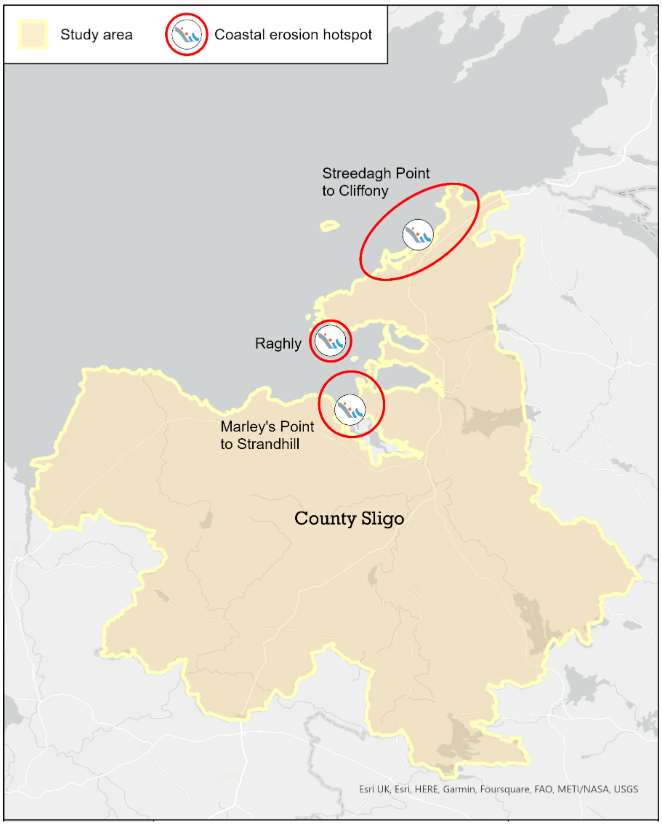

Figure 9: Areas of potentially significant coastal erosion in County Sligo, based on the results from the work "Irish Coastal Protection Strategy Study – Phase V" by Office of Public Works (OPW) Ireland.

Also, coastal erosion and flooding extents at Rosses Point as a result of a 1 in 200 -year return period storm under current climate conditions are calculated in the document *Coastal Flood and Erosion Risk Management Study - Rosses*

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[4] https://www.gov.ie/en/collection/d23916-irish-coastal-protection-strategy-study-phase-5-north-west-coast/#appendix-4-erosion-mapping

[5] https://www.gov.ie/en/collection/d52a5e-irish-coastal-protection-strategy-study-phase-3-north-east-coast/#appendix-8-erosion-mapping

[6] The ICPSS maps should not be used to assess the flood hazard and risk associated with individual properties or point locations or to replace detailed local flood risk assessment. Local factors such as flood defence schemes have not been accounted for.

Point/Drumcliff Bay (2016)[7], from RPS Group. The results show that a 1 in 200 return period storm does not produce coastal flooding over the dune system, even considering the cumulative effect of a 100-year period coastal erosion process.

4.2.3. Final considerations

There are seven SPA areas and four SAC areas along the coastline of County Sligo which have been considered as areas of high sensitivity due to their high-ecological value. All the natural protected areas are reported in Table 13 and the boundaries of SAC areas are represented in Figure 10.

Table 13: Special Protection Area (SPA) and Special Area of Conservation (SAC) along County Sligo coastline.

SPA	SAC
• Drumcliff Bay SPA (004013) • Cummeen Strand SPA (004035) • Inishmurray SPA (004068) • Ballysadare Bay SPA (004129) • Aughris Head SPA (004133) • Ardboline Island and Horse Island SPA (004135) • Ballintemple and Ballygilgan SPA (004234)	• Cummeen Strand/Drumcliff Bay (Sligo Bay) SAC (000627) • Streedagh Point Dunes SAC (001680) • Ballysadare Bay SAC (000622) • Bunduff Lough and Machair/Trawalua/Mullaghmore SAC (000625)

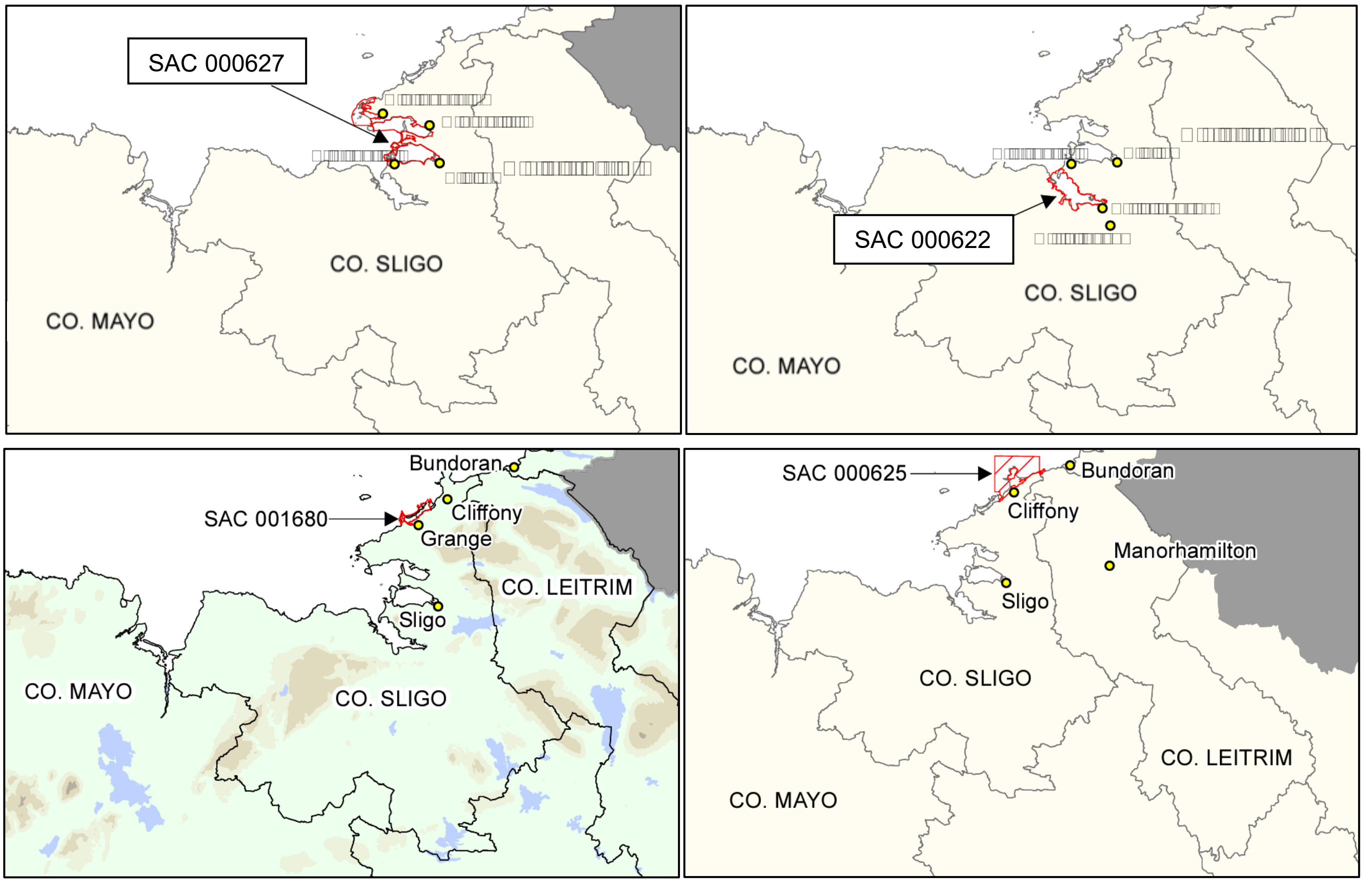

Figure 10: Boundaries of areas categorised as Special Area of Conservation along County Sligo coastline.

Based on the previous results, the area around Sligo Bay has been identified as a risk hotspot since there is a number of high-vulnerability elements lying within its LECZ and it also concentrates coastal flooding and coastal erosion

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[7] https://www.sligococo.ie/media/RPointCFERMFina161216.pdf

hazards. Additionally, the confluence of high river flows from the Garavogue River and storm surge during heavy rainfall can increase the flood risk in areas close to the river, such as Sligo town. Some of these vulnerable elements are:

- **Sligo Bay** contains three estuary bays, namely Cummeen Strand, Drumcliff Bay and Ballysadare Bay.
- **Strandhill** is a village 9 km west of Sligo town.
- **Sligo Airport** is located north of Strandhill, very close to the sea.
- **Killaspugbrone** is an early Christian church on the coast north of Strandhill and near of Sligo Airport, also containing a graveyard (**Killaspugbrone Graveyard**).
- **Strandhill's wastewater treatment plant** is also located very close to the sea in the coast west of Strandhill village.
- **Rosses Point peninsula** is located north of Sligo Bay and includes the localities of **Rosses Point**, **Bomore Point** and **Deadman's Point**.
- **Drumcliff Bay** is a small bay located north of Rosses Point peninsula and **Cummeen Strand** is a tidal flat within Sligo Bay, which are both declared as Special Protection Area (SPA) and Special Area of Conservation (SAC) (i.e., sites within the Natura 2000 network) and contain different types of dunes and ecosystems[8].
- **Coney Island** (Inishmulclohy in Irish) is an island between the Rosses Point and Coolera peninsulas.
- **Oyster Island** is a small island between Coney Island and Rosses Point.

Risks of the population, residential and commercial buildings, industrial uses, agriculture, beach areas, critical infrastructure and areas of high ecological value around Sligo Bay are accordingly assessed in Table 14 in a Low-Medium-High risk scale.

Table 14: Elements of risk around Sligo Bay.

Risk element	Risk
Population	Medium
Residential building	Medium
Commercial building	Medium
Industrial use	Low
Agriculture	Medium
Beach areas	High
Critical infrastructure	High
Areas of high ecological value	High

Finally, risk has been expressed for each locality analysed in a Low-Medium-High scale considering the different key climate-related hazards identified in Task 1.2 and developed in more detail in this section, and the vulnerability

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[8] https://www.npws.ie/protected-sites/sac/000627

indicators developed in Task 1.3. As result, these parameters and the final risk score are summarised in Table 15 and mapped in Figure 11.

Table 15: Results of the high-level risk characterisation in Sligo CCLL.

Locality	Climate-related hazards	Areas exposed	Risk
Aclare	River flooding	Marshy lands	Low
Ballinacarrow	River flooding	Marshy lands and mixed-use lands	Medium
Ballinafad	River flooding, pluvial flooding	Marshy lands	Low
Ballincar	River flooding and coastal flooding	Undeveloped land	Low
Ballintogher	Pluvial flooding	Wetlands and mixed-use backlands	Low
Ballygawley	River flooding and pluvial flooding	Marshy lands and green areas	Low
Ballysadare	River flooding and coastal flooding	Marshy lands, railway area, green area and mixed-use land	High
Banada	River flooding	Green areas	Low
Bellaghy	River flooding	Marshy lands, commercial use land and mixed-use land	Medium
Bunnanaddan	Pluvial flooding	Marshy lands and residential use lands	High
Carney	River flooding and coastal flooding	Green areas, commercial use land, residential use land and mixed-use land	High
Castlebaldwin	Pluvial flooding	Marshy lands	Low
Cliffoney	River flooding and coastal erosion	Beach area and natural vegetation area	Medium
Cloonacool	River flooding	Natural vegetation area and residential	Low
Collooney	River flooding	Marshy lands, residential use land and mixed-use land	High
Coolaney	River flooding	Wetlands, residential use land and mixed-use land	High
Culfadda	River flooding	Natural vegetation land	Low
Curry	River flooding	Green areas and residential use land	Medium
Dromore West	River flooding	Green areas	Low
Drumcliff	River flooding and coastal flooding	Green areas and mixed-use land	High
Easky	River flooding and coastal flooding	Natural vegetation area	Low
Geevagh	River flooding	Marshy lands	Low
Gorteen	River flooding	Residential use land and mixed-use land	High

Locality	Climate-related hazards	Areas exposed	Risk
Grange	River flooding and coastal erosion	Residential use land, beach areas and green areas	High
Mullaghmore	Pluvial flooding, coastal flooding and coastal erosion	Port area, beach areas and green areas	Medium
Raghly	Coastal erosion	Port area and beach areas	Medium
Ransboro	Pluvial flooding	Green areas	Low
Rathcormack	River flooding	Green areas and commercial use land	Medium
Riverstown	River flooding	Commercial use land and residential use land	High
Rosses Point	Pluvial flooding and coastal flooding	Green areas and residential use land	Medium
Strandhill	Pluvial flooding, coastal flooding and coastal erosion	Airport area, golf course, beach areas and residential use land	High
Tourlestrane	Pluvial flooding	Natural vegetation area	Low

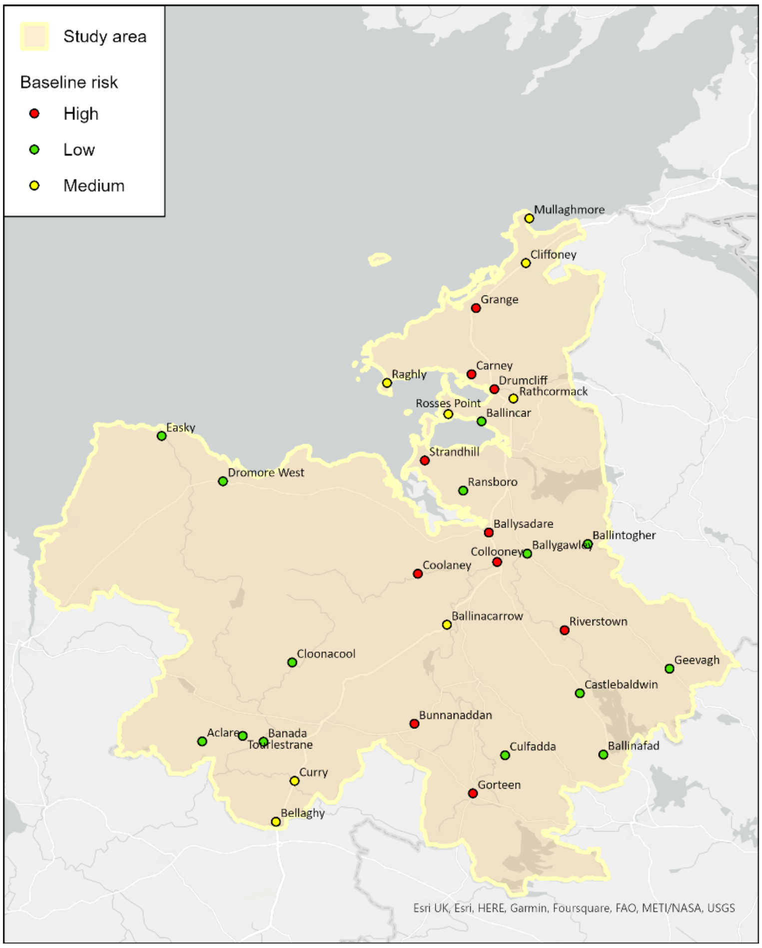

Figure 11: Baseline risk in Sligo CCLL.

Finally, risk related to the three key climate-related hazards in Sligo CCLL is assessed in Table 16. In Sligo CCLL, the LECZ area is small compared to other CCLLs (4.6% of total CCLL area). However, certain high-risk elements have been identified. The population density in Sligo CCLL is low, although a medium percentage of population live in the LECZ

(10.7%), especially around Sligo Bay. The proportion of vulnerable population also presents a medium value of 10.29 %. Regarding socioeconomic activity, LECZ mostly corresponds to agricultural land (60.5%). Residential, commercial and industrial land uses are scarce (less than 5% in total), but they concentrate around Sligo Bay. The area of critical infrastructure within the LECZ also presents a low value in comparison to other CCLLs (1.1%). Notwithstanding, the LECZ includes the presence of Sligo airport, port area and railway, which are also included within the coastal area of Sligo Bay. The areas of high-ecological value within the LECZ are high (33.6%). In particular, a number of natural protected areas lies along the coastline of Sligo CCLL, as reported in Table 13. These areas match the zones concentrating coastal flooding and coastal erosion.

Considering the maps from Dottori et al. (2021), the land-flooding-prone areas are small. However, after analysing the SFRA, it has been observed that land flooding affects various localities throughout the municipality. Land flooding mainly affects rural residential areas and agricultural areas, including risks to population and critical infrastructure.

Considering the lack of local coastal adaptation planning and sea-level rise projections, the adaptive capacity against the previous risks is low.

Table 16: High-level risk characterisation in Sligo CCLL.

Risk element	Coastal erosion	Coastal flooding	Land flooding
Population	Low	Medium	Medium
Residential building	Low	Medium	High
Commercial building	Low	Low	Low
Industrial use	Low	Low	Low
Agriculture	Low	High	High
Beach areas	Medium	Medium	Low
Critical infrastructure	Low	High	Medium
Areas of high ecological value	High	High	Medium

4.3. Dublin

4.3.1. Coastal erosion

According to Devoy (2009), coastal erosion rates on the sediment-dominated coast (soft coast) of Great Dublin reach average values of 0.2-0.5 m/year, commonly rising to 1-2 m/year. Moreover, the ICPSS produced coastal erosion maps for existing conditions, available online[9]. These maps were completed in 2013 and do not include for projected future changes in climate such as sea level rise, increased storm frequency or associated variations in erosion rates and the effect of coastal defences. More information on these maps is available in the ICPSS's website[10].

Similarly, the previous web-viewer includes coastal flooding hazard maps. For this task, the map representing the extents of the 200-year return period coastal flooding event under current climatic conditions has been analysed. The following figures (Figure 12, Figure 13, Figure 14 and Figure 15) show the expected shoreline in 2050 and the flood-prone areas for the aforementioned coastal flooding hazard event. The areas potentially affected by coastal

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[9] https://www.floodinfo.ie/

[10] https://www.gov.ie/en/publication/eed0fb-irish-coastal-protection-strategy-study-icpss/

flooding cover some areas in Bettystown and Laytown in County Meath, the coastal areas around Donabate and Baldoyle, North Bull Island and some areas of Dublin city centre in County Dublin, and the coastal area from Newcastle to Wicklow Town in County Wicklow.

Figure 12: Flood extent for the 200-year return period coastal flooding event (left) and expected shoreline in 2050 (right) in the coastal area of County Meath under current climatic conditions. Source: https://www.floodinfo.ie.

Figure 13: Flood extent for the 200-year return period coastal flooding event (left) and expected shoreline in 2050 (right) in the coastal area of Fingal under current climatic conditions. Source: https://www.floodinfo.ie.

Figure 14: Flood extent for the 200-year return period coastal flooding event (left) and expected shoreline in 2050 (right) in the coastal area of Dublin and Dún Laoghaire-Rathdown under current climatic conditions. Source: https://www.floodinfo.ie.

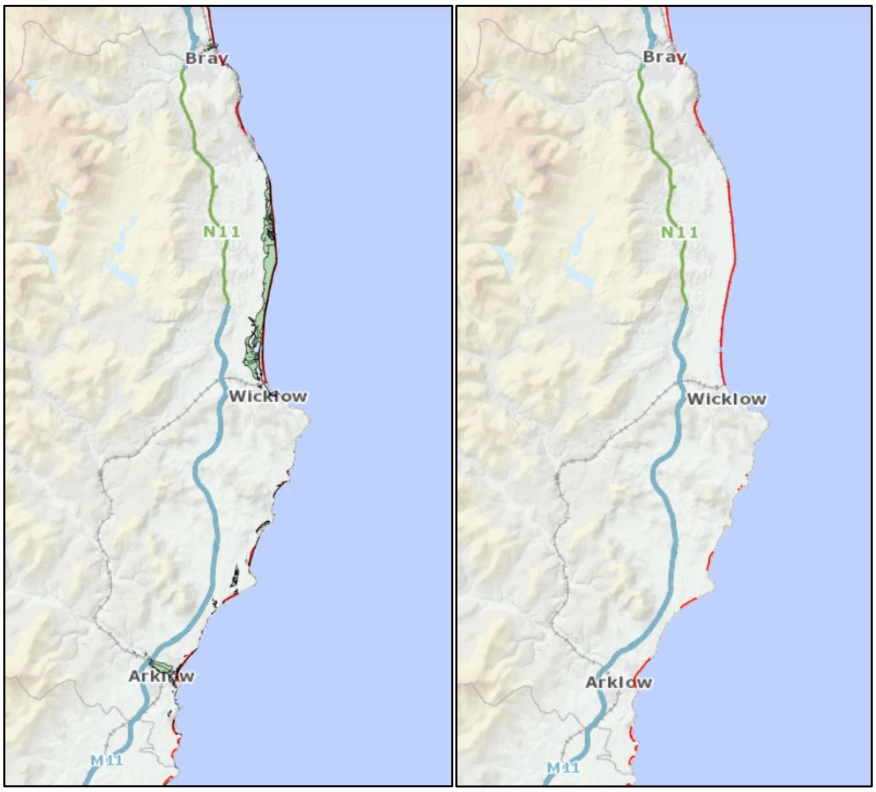

Figure 15: Flood extent for the 200-year return period coastal flooding event (left) and expected shoreline in 2050 (right) in the coastal area of County Wicklow under current climatic conditions. Source: https://www.floodinfo.ie.

The proportion of coastline potentially affected by coastal erosion in Ireland has been summarised by Climate Ireland[11]. The data for the coastal counties of Great Dublin are presented in Table 17. Practically the entire coastline of County Meath is at risk. The percentage of coastline potentially affected is approximately of 70.5% in County Wicklow and 12.6% in County Dublin.

Table 17: Coastline at risk of coastal erosion in Great Dublin. Source: Climate Ireland.

County	Coastline length (km)	Coastal length exposed by coastal erosion (km)	Coastal length exposed by coastal erosion (%)
Meath	21	21	100
Dublin	95	12	12.6
Wicklow	61	43	70.5

Finally, the indicators developed in D1.3 show low scores compared to other CCLLs (Table 18), with the exception of the areas of high-ecological value.

Table 18: Summary of the indicators assessing coastal erosion risk in Dublin CCLL.

Indicator	Value	Threshold	Score
Relative sea-level changes (mm/year)	0	(0.5; 1.0)	Low
Mean significant wave height (m)	1.4	(1.5; 2.5)	Low
Tidal range (m)	0.8	(0.5; 1.0)	Medium
Lithotype hardness	Medium	(Hard; medium; soft)	Medium
Area of beaches, dunes, and sand plains within the LECZ (%)	1.3	(5; 10)	Low
Areas of high ecological value within the LECZ (%)	26.4	(10; 25)	High
Local coastal adaptation planning	Yes	(No; Yes)	Low
National sea level rise preparedness	Reasonably well	(Not well; Reasonably well; Well/very well)	Medium
MSL rise projections spatial scale	National	(Local; Regional; National)	High

4.3.2. Coastal flooding

In the case of Dublin CCLL, the areas affected by coastal flooding are very similar to the LECZ calculated in Task 1.3 (Figure 16). The analysis performed in D1.3 – Map and report of baseline exposure and vulnerability for Dublin CCLL, where indicators of exposure within the LECZ were determined, can be used to assess coastal flooding risk instead.

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[11] https://www.climateireland.ie/#!/tools/hazardTool/hazardscopingCoastalErosion

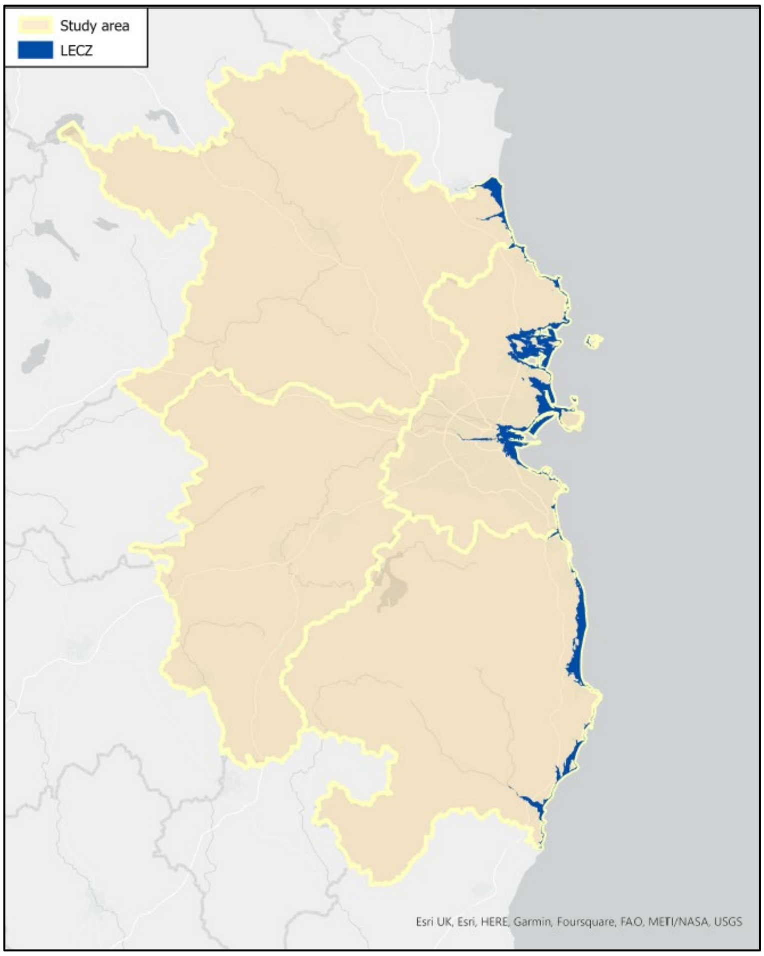

Figure 16: Low elevation coastal zone (LECZ) in Dublin CCLL.

A summary of the vulnerability and exposure indicators developed in Task 1.3 for Dublin CCLL is presented in Table 19. As previously explained, the elements of exposure within the LECZ are closely related to the elements affected by the 200-year return period coastal flooding event. Assuming this relationship precise enough, the vulnerability scores can be converted into coastal flooding risk scores in this particular case.

Table 19: Summary of the indicators assessing coastal flooding risk in Dublin CCLL.

Indicator	Value	Threshold	Score
LECZ area (%)	1.7	(10; 25)	Low
LECZ / Coastline (ha/km)	36.7	(50; 150)	Low
LECZ population (%)	8.4	(10; 25)	Medium
Most vulnerable population (age) (2020) (%)	9.79	(9; 11)	Medium
Area of residential land use within the LECZ (%)	15.6	(10; 25)	Medium
Area of industrial/ commercial land use within the LECZ (%)	6.1	(5; 10)	Medium
Area of agriculture land use within the LECZ (%)	43.6	(20; 40)	High
Area of beaches, dunes, and sand plains within the LECZ (%)	1.3	(5; 10)	Low

Indicator	Value	Threshold	Score
Area of critical infrastructure within the LECZ (%)	2.6	(5; 10)	Low
Presence of railway within the LECZ	Yes	(No; Yes)	High
Presence of port within the LECZ	Yes	(No; Yes)	High
Presence of airport within the LECZ	No	(No; Yes)	Low
Areas of high ecological value within the LECZ (%)	26.4	(10; 25)	High
Local coastal adaptation planning	Yes	(No; Yes)	Low
National sea level rise preparedness	Reasonably well	(Not well; Reasonably well; Well/very well)	Medium
MSL rise scenario scale	National	(Local; Regional; National)	High

In addition, the document *National Risk Assessment of Impacts of Climate Change: Bridging the Gap to Adaptation Action* assesses climate-change risk at national level[12]. In particular, results of the assessment for residential and commercial buildings under 6 SLR scenarios are summarised hereinafter.

Potentially vulnerable residential and commercial addresses were identified under 6 SLR scenarios based on the *An Post GeoDirectory* (collaborative geocoded directory of Irish property addresses between the Irish Post Office Service and Ordnance Survey Ireland). The areas of potential vulnerability to SLR were calculated from the Irish 20-m medium-scale resolution DTM produced by the Irish Environmental Protection Agency.

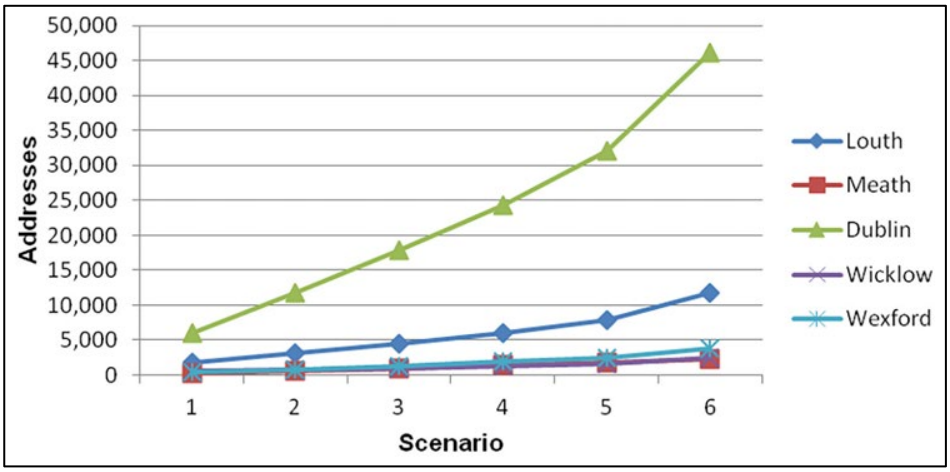

Figure 17: Total numbers of vulnerable addresses in the coastal counties of Leinster province under six SLR scenarios. Scenarios 1–6 represent SLR of 0.5 m, 1 m, 2 m, 3 m, 4 m and 6 m, respectively. Source: National Risk Assessment of Impacts of Climate Change: Bridging the Gap to Adaptation Action.

According to the data from Irish Insurance regarding the insurance costs of November 2009 and October 2011 flood events, Table 20 provides estimates of the potential insurance costs in each coastal county of Great Dublin. An average insurance claim per residential household of €16,500 and an average insurance claim per commercial property of €75,000 are considered.

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[12] https://www.epa.ie/publications/research/climate-change/research-346-national-risk-assessment-of-impacts-of-climate-change-bridging-the-gap-to-adaptation-action.php

Table 20: Potential insurance claims for Great Dublin under six SLR scenarios. Source: National Risk Assessment of Impacts of Climate Change: Bridging the Gap to Adaptation Action.

SLR scenario (m)	Potential insurance claims (€M)			
	Co. Meath	Co. Dublin	Co. Wicklow	Total (Great Dublin)
0.5	5	151	16	172
1.0	1	303	22	326
2.0	22	458	28	508
3.0	30	607	39	676
4.0	37	806	50	893
6.0	46	1,194	77	1,317

4.3.3. Land flooding

River floods have been a frequent hazard throughout the history of the Dublin, whereas coastal and pluvial flooding have also occurred periodically, although there is an increasing trend in extreme rainfall (Al Saji et al., 2015; Jeffers, 2014). For instance, in 2002 the city experienced severe coastal and river flooding in separate events occurring in February and November. The flood-prone areas for the 100-year return period river flooding event have been obtained from the Joint Research Centre Data Catalogue (Dottori et al., 2021). These areas are mapped in Figure 18, Figure 19 and Figure 20. The largest extensions are concentrated in the counties of Meath and Kildare and the highest values of depth are reached in the counties of Meath and Dublin, especially in the areas around the Boyne river from Navan to Slane in Co. Meath.

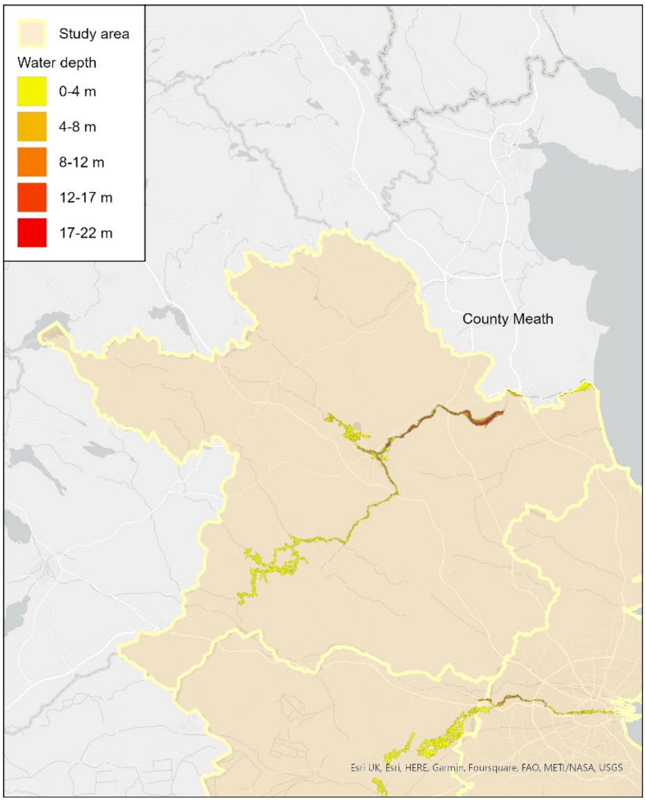

Figure 18: Flood-prone areas for the 100-year return period river flooding event in County Meath. Source: Dottori et al. (2021).

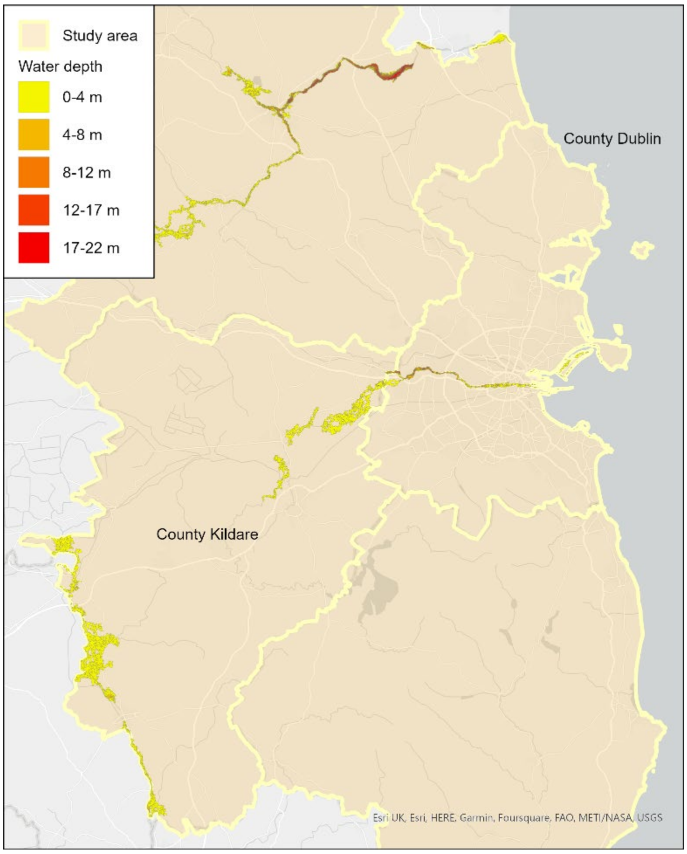

Figure 19: Flood-prone areas for the 100-year return period river flooding event in County Dublin and County Kildare. Source: Dottori et al. (2021).

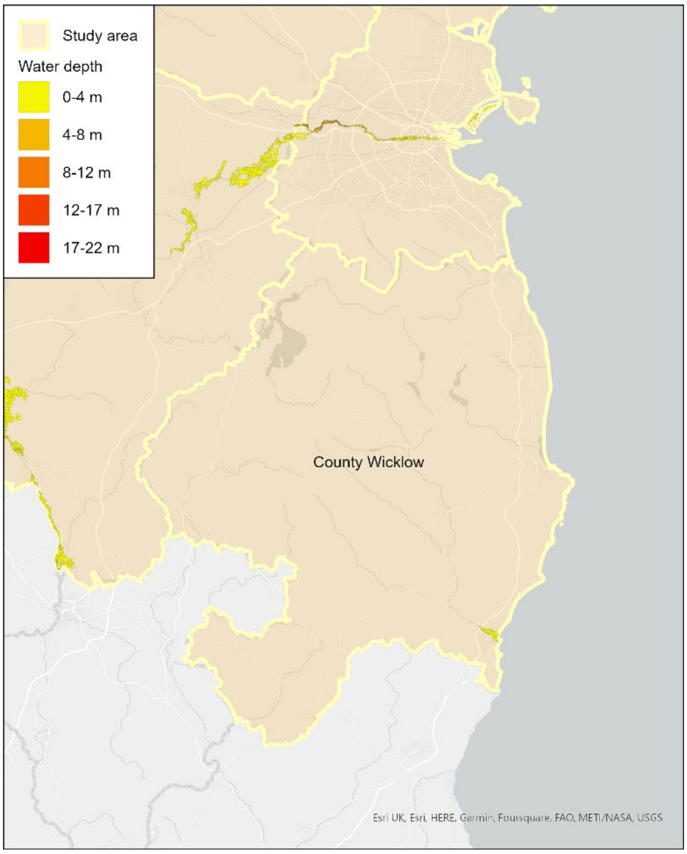

Figure 20: Flood-prone areas for the 100-year return period river flooding event in County Wicklow. Source: Dottori et al. (2021).

The exposure and vulnerability indicators developed in Task 1.3 have been calculated for the flood-prone areas in order to assess the river flooding hazard. The results of these calculations are summarised in Table 21. In general, land flooding has a reduced impact compared to coastal flooding. However, in this case, the airport of Dublin can be potentially affected, increasing the risk associated to critical infrastructure.

Table 21: Summary of the indicators assessing land flooding risk in Dublin CCLL.

Indicator	Value	Threshold	Score
Flood-prone area (%)	1.4	(10; 25)	Low
Flood-prone areas population (%)	2.7	(10; 25)	Low
Most vulnerable population (age) (2020) (%)	9.79	(9; 11)	Medium
Area of residential land use within the flood-prone areas (%)	5.6	(10; 25)	Low
Area of industrial/ commercial land use within the flood-prone areas (%)	2.9	(5; 10)	Low
Area of agriculture land use within the flood-prone areas (%)	69.3	(20; 40)	High
Area of beaches, dunes, and sand plains within the flood-prone areas (%)	0	(5;10)	Low
Area of critical infrastructure within the flood-prone areas (%)	2.5	(5; 10)	Low
Presence of railway within the flood-prone areas	Yes	(No; Yes)	High
Presence of port within the flood-prone areas	Yes	(No; Yes)	High
Presence of airport within the flood-prone areas	Yes	(No; Yes)	High
Areas of high ecological value within the flood-prone areas (%)	19.6	(10; 25)	Medium
Local coastal adaptation planning	Yes	(No; Yes)	Low
National sea level rise preparedness	Reasonably well	(Not well; Reasonably well; Well/very well)	Medium
MSL rise scenario scale	National	(Local; Regional; National)	High

4.3.4. Final considerations

In Dublin CCLL, the overall coastal erosion risk is the lowest between the ten CCLLs. Nevertheless, it may considerably affect areas of high-ecological value and have medium impacts in the railway system due to its proximity to the sea and in the beach areas due to the high importance of the services sector in the region of Dublin.

Regarding coastal flooding risk, the area of critical infrastructure within the LECZ presents a low value compared to other CCLLs (2.6%). However, coastal flooding can affect railway and port infrastructure of national significance, mainly the Irish rail track from Dublin to Arklow, the Dublin Area Rapid Transit (DART) and the ports of Howth, Dublin, Dún Laoghaire, Wicklow and Arklow. In general, the risk associated to coastal flooding can be considered as medium in most of the elements studied. Again, although the affection to beaches is scored as low, the risk associated to this element has been increased to medium, due to the high impact of the sector services to the economy. Similarly, the risk to agriculture has been reduced from high to medium, as this sector has a lower weight in the economy of Dublin.

Critical infrastructure is the main element of high risk when considering land flooding risk, as it affects areas of railway, ports and airport. The elements of commercial buildings, industry, agriculture and areas of high ecological value are at medium risk. Finally, population, residential buildings and beach areas are at low risk.

The risks associated to coastal erosion, coastal flooding and land flooding are summarised in Table 22. Finally, Table 23 synthetises the previous results at county level, showing a comparison between the counties in Dublin CCLL.

Table 22: High-level risk characterisation in Dublin CCLL.

Risk element	Coastal erosion	Coastal flooding	Land flooding
Population	Low	Medium	Low
Residential building	Low	Medium	Low
Commercial building	Low	Medium	Medium
Industrial use	Low	Medium	Medium
Agriculture	Low	Medium	Medium
Beach areas	Medium	Medium	Low
Critical infrastructure	Medium	Medium	High
Areas of high ecological value	High	High	Medium

Table 23: Comparative risk between the counties of Great Dublin.

Climate-related hazard	Co. Kildare	Co. Meath	Co. Dublin	Co. Wicklow
Coastal erosion	-	Medium	Low	High
Coastal flooding	-	Medium	High	Medium
Land flooding	Medium	High	Medium	Low

4.4. Vilanova i la Geltrú

Land flooding, coastal flooding, coastal erosion, strong winds and forest fires have been identified as the main hazards affecting the area, leading to impacts on tourism and local economy, damage to residential and commercial buildings and coastal infrastructure; loss of ecosystems and biodiversity (forest, wetlands, sandy and subaquatic habitats); and population safety.

4.4.1. Coastal flooding

Coastal flooding mostly affects urban land uses (Table 24), approximately a half of the total LECZ area. In this sense, Vilanova i la Geltrú has a diverse urban landscape, combining historic areas with modern residential neighbourhoods and commercial districts. The historic centre showcases architectural heritage, including buildings from different eras, whereas newer residential areas feature a mix of apartment complexes, houses, and urban developments.

The service sector plays a significant role, with businesses involved in healthcare, education, tourism, hospitality, retail, and administrative services. Coastal flooding affects the sandy beaches of Ribes Roges Beach and Adarró Beach, which are popular recreational spots and an important hot spot of tourism and services.

The transportation network affected (13.2% of LECZ area) includes roads and highways connecting the city to neighbouring areas, a railway station providing regional and commuter train services and the port area of Vilanova i la Geltrú, which facilitates commercial activities, nautical tourism and supporting to the local fishing industry and adds to the city's coastal charm.

At lower level, coastal flooding affects industrial/commercial and agricultural uses (5.5% and 31.3%, respectively). In general, the industrial presence encompasses manufacturing, automotive, logistics, and technology sectors. The agricultural activities focus on crops such as grapes, olives, cereals, and vegetables, which are more developed in the surrounding rural areas.

Table 24: Summary of the indicators assessing coastal flooding risk in Vilanova i la Geltrú CCLL.

Indicator	Value	Threshold	Score
LECZ area (%)	5.5	(10; 25)	Medium
LECZ / Coastline (ha/km)	12.1	(50; 150)	Low
LECZ population (%)	9.3	(10; 25)	Low
Most vulnerable population (age) (2020) (%)	10.77	(9; 11)	Medium
Area of residential land use within the LECZ (%)	47.5	(10; 25)	High
Area of industrial/ commercial land use within the LECZ (%)	5.5	(5; 10)	Medium
Area of agriculture land use within the LECZ (%)	31.3	(20; 40)	Medium
Area of beaches, dunes, and sand plains within the LECZ (%)	0	(5; 10)	Low
Area of critical infrastructure within the LECZ (%)	13.2	(5; 10)	High
Presence of railway within the LECZ	Yes	(No; Yes)	High
Presence of port within the LECZ	Yes	(No; Yes)	High
Presence of airport within the LECZ	No	(No; Yes)	Low
Areas of high ecological value within the LECZ (%)	2.4	(10; 25)	Low
Local coastal adaptation planning	Yes	(No; Yes)	Low
National sea level rise preparedness	Well/very well – Reasonably well	(Not well; Reasonably well; Well/very well)	Low
MSL rise scenario scale	National	(Local; Regional; National)	High

4.4.2. Land flooding

The river flood maps from the Joint Research Centre Data Catalogue do not display any information in Vilanova i la Geltrú. However, the partners from Vilanova i la Geltrú CCLL have mapped historical flood-prone areas in the municipality. These areas, represented in Figure 21, have been used to assess the land flooding risk. Table 25 summarises the results obtained.

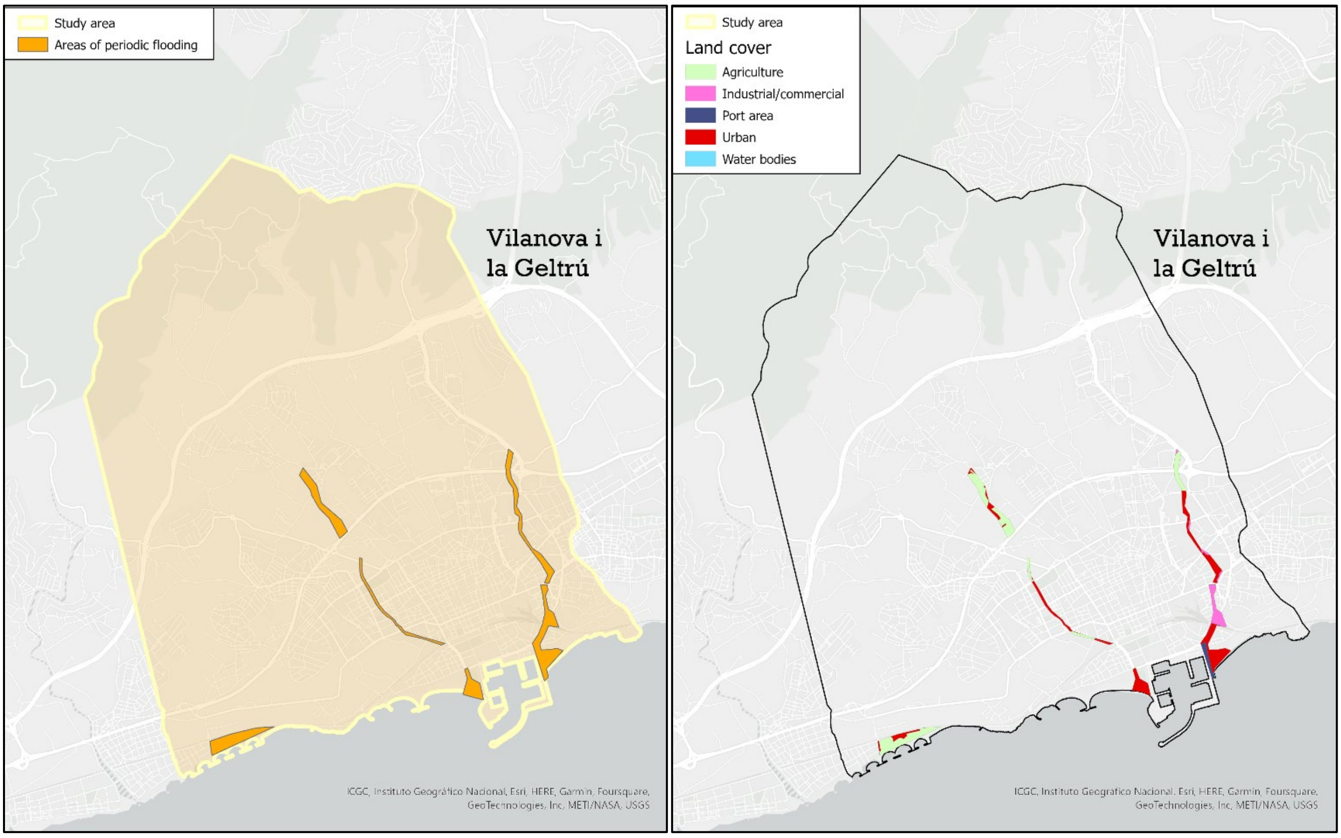

Figure 21: Areas of periodic flooding (left) and corresponding land uses (right) in Vilanova i la Geltrú CCLL.

The flood-prone areas involve 1.5% of the municipality area, where 45.8% and 10.7% of these areas correspond to residential and industrial/commercial uses (high score), respectively. A considerable portion of the affected territory is formed by agricultural land (39.4%). The characteristics of the previous areas are the same that those affected by coastal flooding. Again, the flooding extents include the railway extension and many roads.

Table 25: Summary of the indicators assessing land flooding risk in Vilanova i la Geltrú CCLL.

Indicator	Value	Threshold	Score
Flood-prone area (%)	1.5	(10; 25)	Low
Flood-prone area population (%)	3.4	(10; 25)	Low
Most vulnerable population (age) (2020) (%)	10.77	(9; 11)	Medium
Area of residential land use within the flood-prone area (%)	45.8	(10; 25)	High
Area of industrial/ commercial land use within the flood-prone area (%)	10.7	(5; 10)	High
Area of agriculture land use within the flood-prone area (%)	39.4	(20; 40)	Medium
Area of beaches, dunes, and sand plains within the flood-prone area (%)	0	(5; 10)	Low

Indicator	Value	Threshold	Score
Area of critical infrastructure within the flood-prone area (%)	4.1	(5; 10)	Low
Presence of railway within the flood-prone area	Yes	(No; Yes)	High
Presence of port within the flood-prone area	Yes	(No; Yes)	High
Presence of airport within the flood-prone area	No	(No; Yes)	Low
Areas of high ecological value within the flood-prone area (%)	0	(10; 25)	Low
Local coastal adaptation planning	Yes	(No; Yes)	Low

4.4.3. Forest fires

In relation to the risk of forest fire, the forest area is quite significant in the municipality (38% of land is forest with the presence of trees) and is mostly concentrated in the northern part of the municipality, separated from the residential areas. Although there are no private estates with forest management instruments in the municipality, most of the forest area is part of the natural area Parc del Garraf. In this sense, the forest management of this space is carried out in a coordinated way with Parc del Garraf. At supra-municipal level, most of the exposed forest areas are part of the natural protected area of Serres del Litoral central (SAC ES5110013) (Figure 22)[13].

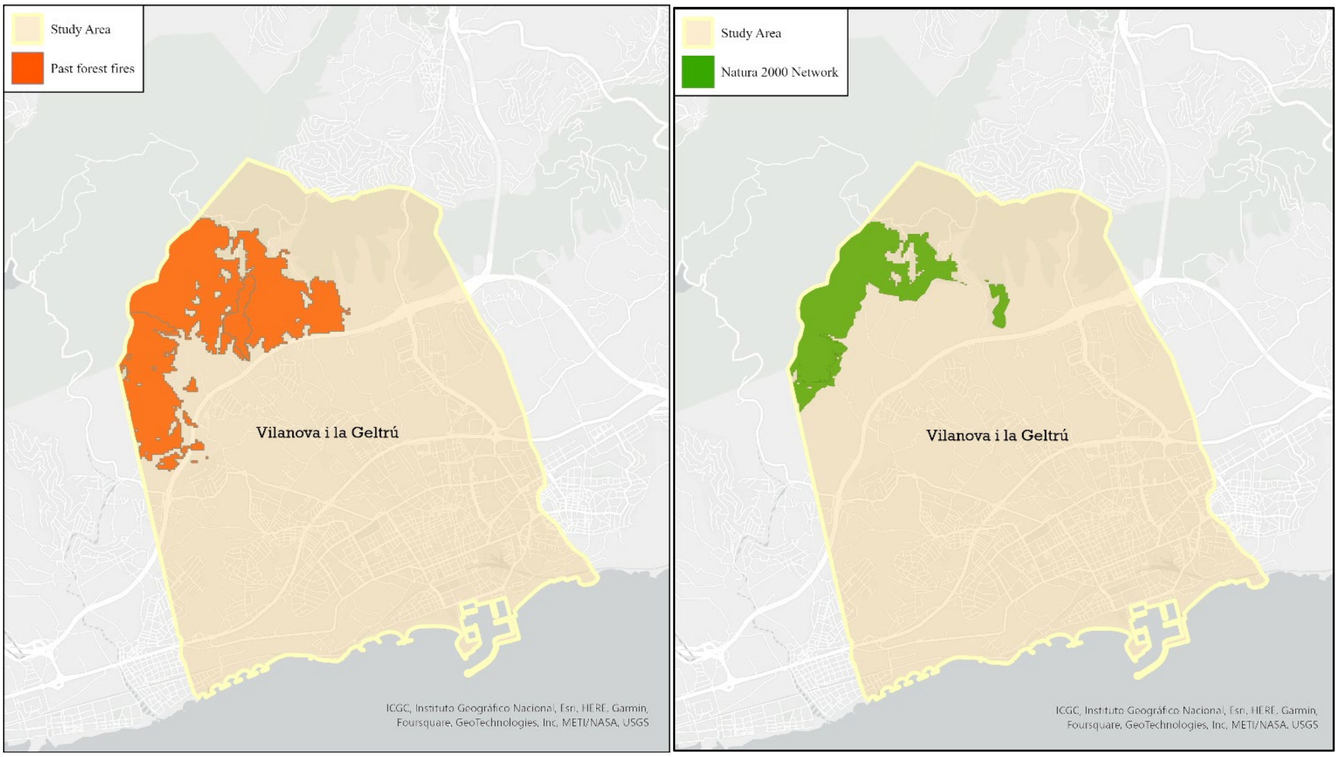

Figure 22: Areas historically affected by forest fires (left) and Natura 2000 sites (right) in Vilanova i la Geltrú CCLL.

The extent of the municipality identified to be potentially at risk of forest fire reaches the 14%, where most of the land is no vegetated (burnt areas). The sensible areas include land intended to agricultural uses and areas of high-ecological value, mainly forest, as reported in Table 26.

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[13] https://natura2000.eea.europa.eu/info/?i=1,10442

Table 26: Summary of the indicators assessing forest fires risk in Vilanova i la Geltrú CCLL.

Indicator	Value	Threshold	Score
Extent of the forest-fire-prone areas (%)	14.0	-	Medium
Forest-fire-prone areas population (%)	0.1	(10; 25)	Low
Most vulnerable population (age) (2020)	10.77	(9; 11)	Medium
Area of residential land use within the forest-fire-prone areas (%)	0.0	(10; 25)	Low
Area of industrial/ commercial land use within the forest-fire-prone areas (%)	0.0	(5; 10)	Low
Area of agriculture land use within the forest-fire-prone areas (%)	8.4	(20; 40)	Medium
Area of beaches, dunes, and sand plains within the forest-fire-prone areas (%)	0.0	(5; 10)	Low
Area of critical infrastructure within the forest-fire-prone areas (%)	0	(5; 10)	Low
Presence of railway within the forest-fire-prone areas	No	(No; Yes)	Low
Presence of port within the forest-fire-prone areas	No	(No; Yes)	Low
Presence of airport within the forest-fire-prone areas	No	(No; Yes)	Low
Areas of high ecological value within the forest-fire-prone areas (%)	11.0	(10; 25)	Medium
Local coastal adaptation planning	Yes	(No; Yes)	Low

The coastal adaptation plan indicates that the presence of a large number of housing estates in a legal situation, with infrastructural deficiencies and access difficulties greatly increases their vulnerability in the event of a fire. According to the regional forest fire planning in Catalonia (INFOCAT), the housing estates vulnerable to fire in Vilanova i la Geltrú include Torre del Veguer, Mas Tapet, Mas Ricard, Corral del Roc and Corral d'en Milà, all located in the northern half of Vilanova i la Geltrú.

Conversely, at least three figures of protection have been identified in Vilanova i la Geltrú with regard of forest fires: the *Municipal Action Plan*, the *Fire Protection Plan* and the *Forest Fire Information and Surveillance Plan*. Moreover, the capacity to respond is high, as there is a fire station in the municipality and the City Council is part of the Garraf Forest Defense Group (ADF).

Although there are mechanisms to protect Vilanova i la Geltrú CCLL from forest fires, the increase in heat waves episodes and the high vulnerability of the areas exposed to this hazard (vulnerable housing estates and natural protected areas) have led to the consideration of the northern part of the municipality as a hotspot of risk. In conclusion, forest fires in Vilanova i la Geltrú CCLL can potentially lead to:

- Loss of vegetation and productive soil, increase in erosion.
- Loss of biodiversity, forest masses with immature plant communities, increased vulnerability of forests to pests.
- Losses and damage to property, real estate and infrastructure.
- Human losses or serious accidents.

4.4.4. Strong winds

The risk related to strong winds has been assessed from the past extreme events database generated in Task 1.2 for Vilanova i la Geltrú CCLL, including the storm events, as they are usually accompanied by strong winds. A score between Low-Medium-High hazard was assigned to the areas elaborated by the CCLL partners according to their descriptions, as shown in Table 27. The areas associated to the events SW1, SW2 and ST2 were given a score of high, due to their high intensity and sea-proximity. The storm event ST1 was scored as of medium hazard because, although it is not recorded as a strong wind event, it has the longest duration of all the events and occurred along the coastal façade. Part of the original area of this event was overlapping the high-hazard areas, being consequently clipped and conservatively maintaining the high-hazard areas. Finally, the area associated to the event SW3 was characterised as a low-hazard area, due it is defined as a secondary area, less affected.

Table 27: Past extreme strong wind events and high-level hazard categorisation in Vilanova i la Geltrú CCLL.

Extreme event ID	Extreme event type	Short description	Date	Duration	Hazard scoring
ST1	Storm	Accumulated rainfall of up to 787.7 liters per square meter.	20/01/2020	3 days	Medium
SW1	Strong winds	Column of air in rapid descent that after impacting the surface extends in all directions.	12/08/2019	1 day	High
SW2	Strong winds	Column of air in rapid descent that after impacting the surface extends in all directions.	12/08/2019	1 day	High
SW3	Strong winds	Secondary area, less affected.	12/08/2019	1 day	Low
ST2	Storm	Tornado.	23/11/2021	2 days	High

After the hazard extent and grade were defined, the exposure and vulnerability of the elements contained within the affected areas were analysed. The areas of high hazard affect the port area, a large part of the city centre and part of the beaches of Playa del Faro de Sant Cristofol and Ribes Roges. The medium-hazard area occupies the areas between the beach of L'Aiguadolc and the beach of Prat de Vilanova and some urban areas backwards, including some campsites. The high and medium-hazard areas also include part of the railway track. Finally, some peripherical urban developments and open spaces are included within the low-hazard area.

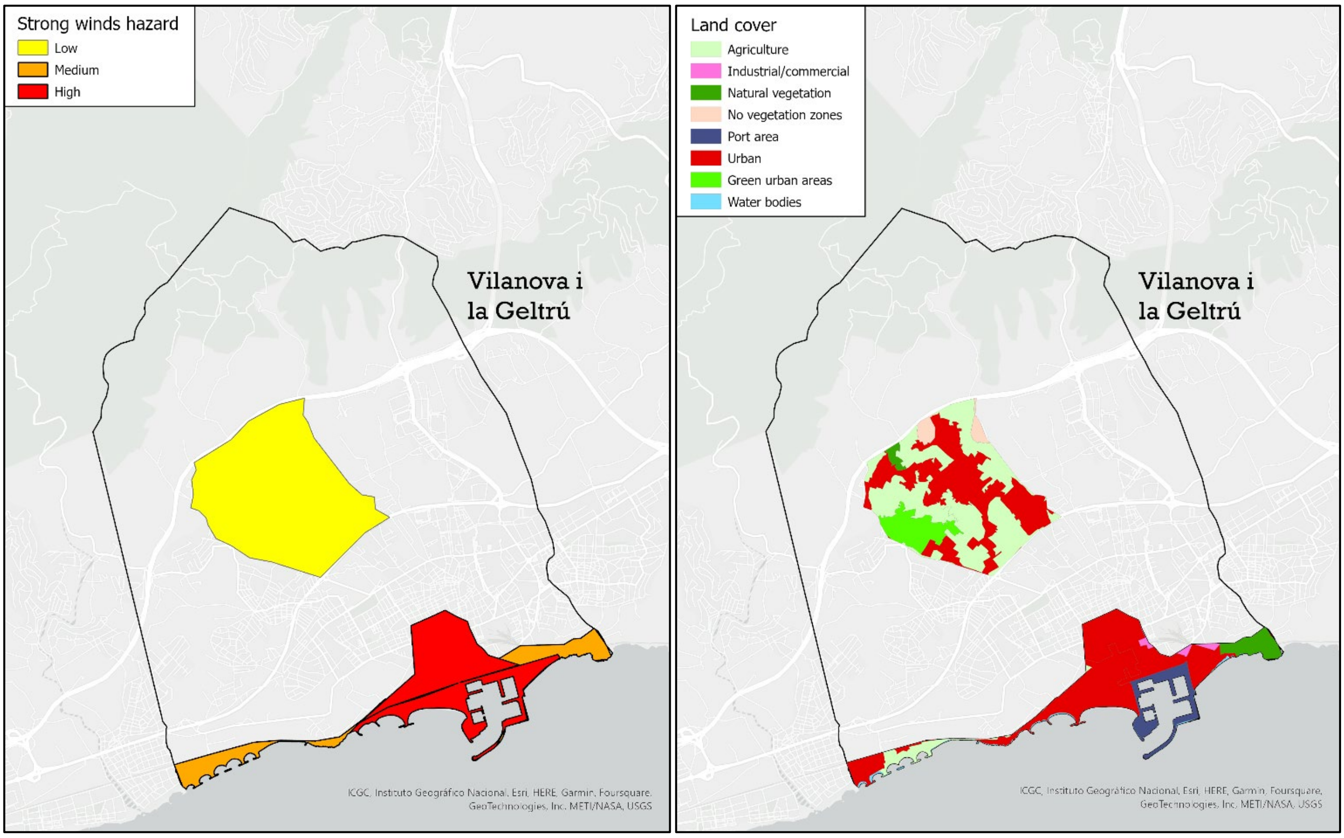

Figure 23: Scoring of areas affected by strong winds in Vilanova i la Geltrú CCLL (left) and land cover within these (right).

4.4.5. Heat waves

As shown in D1.3, the increase in temperatures, especially in summer, will lead to a worsening of the climatic comfort of the inhabitants of the municipality. In addition, it will contribute to increasing the heat island effect.

According to the coastal adaptation plan of Vilanova i la Geltrú in relation to the heat wave hazard, the dense urban core and the large amount of urbanized and paved surface contributes to increasing the air temperature (both at roof level and at ground level), which contributes to increasing the effect of the heat island.

The urban core, characterised by a dense urban fabric with narrow streets and little opportunity for large green spaces, concentrates most of the population. The centre of Vilanova i la Geltrú concentrates an important number of old houses with important needs in relation to energy rehabilitation and the characteristics of an important portion of the buildings in the unplanned peri-urban developments are of medium to low quality in terms of thermic isolation.

In relation to the population's vulnerability to heat, the population over 75 years of age (especially those who live alone and have dependency problems) represent one of the groups most affected by extreme heat and is close to 9% of the population of Vilanova i la Geltrú. Also, the relationship between population over 65 years old and population under 15 years old is of 118% and the proportion of population over 85 years old over the population over 65 years old is of 15 %, higher than the average values for the Catalonian region (102% and 13.5%, respectively).

Following on the discussed in Heat waves section, the heat wave hazard may impact on:

- The increase in energy consumption, especially in summer.
- The increase in the vulnerability of the population, especially dependent elderly people and those with low economic resources (increase in hospitalizations and mortality due to heat strokes or due to problems arising from the cold).

- The increase in the resources intended to implement heat wave and cold wave protocols.
- The occurrence of forest fires.

4.4.6. Final considerations

According to the analysis, the beach areas and some parts of the city centre are affected by coastal erosion, coastal and land flooding, strong winds and heat waves. Hence, these areas are identified as hotspots of multiple hazards, increasing the overall risk. Other critical elements at risk are the port area, the railway infrastructure and the northern natural area.

Table 28: High-level risk characterisation in Vilanova i la Geltrú CCLL.

Risk element	Coastal flooding	Land flooding	Heat waves	Forest fires	Strong winds
Population	Low	Low	High	Medium	Low
Residential building	Medium	High	Medium	High	Medium
Commercial building	Medium	High	Low	Low	Low
Industrial use	Medium	High	Low	Low	Low
Agriculture	Medium	Medium	Medium	Medium	Medium
Beach areas	High	Low	High	Low	High
Critical infrastructure	Medium	Medium	Low	Low	High
Areas of high ecological value	High	Low	High	High	Low

4.5. Benidorm

The key climate-related hazards identified in Benidorm CCLL are coastal flooding, coastal erosion and land flooding, as reported in D1.2.

4.5.1. Coastal erosion

In Benidorm, the amount of soil eroded depends on a few daily extreme coastal erosion events, mainly due to heavy rainfall (Fernández Montes & Sánchez Rodrigo, 2014; Gonzalez-Hidalgo et al., 2007). Moreover, according to the coastal adaptation plan of Benidorm municipality, the greater affectation and intensity of maritime storms, the sea-level rise and the lower contribution of sediments from natural channels –since most of them have been modified, sealing and channelling them, thus reducing the contribution of sediments that they deposited in their floods– can generate major problems and alterations in the coastal façade of Benidorm[14]. In particular, the erosive processes on cliffs can generate landslides during large storms along the coastal sector of the island of Benidorm and Serra Gelada, whereas in the sector from Levante beach to Cala Finestrat, coastal erosion can lead to regression on the beaches.

The indicators developed in Task 1.3 show that the sensitivity to coastal erosion is elevated (Table 29). Although the conditions of exposure from the sea are relatively low (e.g., relative sea-level changes of 1 mm/year, mean significant

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[14] https://benidorm.org/es/ayuntamiento/concejalias/obras/ingenieria/proyectos-ingenieria/plan-de-adaptacion-ante-el-cambio-climatico-de-benidorm

wave height of 0.7 m and tidal range of 0.2 m, approximately), the coastal area of Benidorm features relatively large extents of sandy beach areas and areas of high-ecological value.

Table 29: Summary of the indicators assessing coastal erosion risk in Benidorm CCLL.

Indicator	Value	Threshold	Score
Relative sea-level changes (mm/year)	1	(0.5; 1.0)	Medium
Mean significant wave height (m)	0.7	(1.5; 2.5)	Low
Tidal range (m)	0.2	(0.5; 1.0)	Low
Lithotype hardness	Soft	(Hard; medium; soft)	High
Area of beaches, dunes, and sand plains within the LECZ (%)	24.1	(5; 10)	High
Areas of high ecological value within the LECZ (%)	30.1	(10; 25)	High
Local coastal adaptation planning	Yes	(No; Yes)	Low
National sea level rise preparedness	Well/very well	(Not well; Reasonably well; Well/very well)	Low
MSL rise projections spatial scale	Regional	(Local; Regional; National)	Medium

The risk of these areas is increased due to the relevance of the services sector in the local economy and the presence of natural protected areas. It was shown in D1.3 that the seabed is mainly composed by unconsolidated very fine-grained sediments, which are mostly sand, and that the seabed is also a natural protected area (Figure 24).

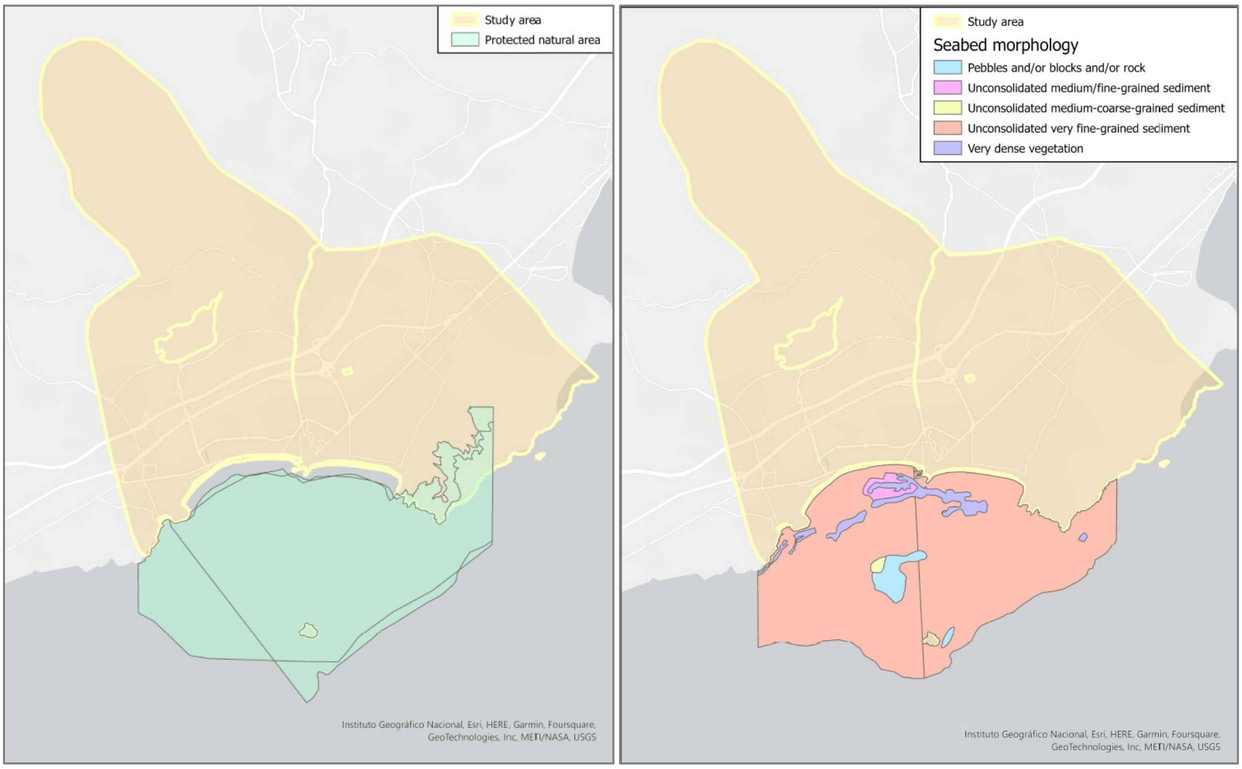

Figure 24: Benidorm CCLL – protected natural areas (left) and seabed morphology (right).

4.5.2. Coastal flooding

Similarly, coastal flooding affects large values of beach areas and ecological areas, but also the relative highest extent of residential land uses between the CCLLs (62.8%) (Table 30), although the extent of the LECZ is limited to a 4.1% of the total municipality area. The other elements of risk analysed show lower values of risk in general, with reduced industrial and agricultural uses in the LECZ. Moreover, the adaptive capacity of Benidorm CCLL has been scored as high, considering the existence of the local coastal adaptation plan and regional projections of sea-level rise.

Table 30: Summary of the indicators assessing coastal flooding risk in Benidorm CCLL.

Indicator	Value	Threshold	Score
Relative sea-level changes (mm/year)	1	(0.5; 1.0)	Medium
Mean significant wave height (m)	0.7	(1.5; 2.5)	Low
Tidal range (m)	0.2	(0.5; 1.0)	Low
LECZ area (%)	4.1	(10; 25)	Low
LECZ / Coastline (ha/km)	9.5	(50; 150)	Low
LECZ population (%)	5.5	(10; 25)	Low
Most vulnerable population (age) (2020) (%)	11.20	(9; 11)	High
Area of residential land use within the LECZ (%)	62.8	(10; 25)	High
Area of industrial/ commercial land use within the LECZ (%)	2.7	(5; 10)	Low
Area of agriculture land use within the LECZ (%)	0	(20; 40)	Low
Area of beaches, dunes, and sand plains within the LECZ (%)	24.1	(5; 10)	High
Area of critical infrastructure within the LECZ (%)	0.4	(5; 10)	Low
Presence of railway within the LECZ	No	(No; Yes)	Low
Presence of port within the LECZ	Yes	(No; Yes)	High
Presence of airport within the LECZ	No	(No; Yes)	Low
Areas of high ecological value within the LECZ (%)	30.1	(10; 25)	High
Local coastal adaptation planning	Yes	(No; Yes)	Low
National sea level rise preparedness	Well/very well – Reasonably well	(Not well; Reasonably well; Well/very well)	Low
MSL rise scenario scale	Regional	(Local; Regional; National)	Medium

4.5.3. Land flooding

In Benidorm, the water network is characterized by the absence of permanent flow channels (the river flood maps from the Joint Research Centre Data Catalogue do not display any information in this CCLL). However, there are several ravines with an intermittent water regime which only carry water during episodes of heavy rain. Among them, the Lliriet-Derramador Ravine stands out, the longest at 9.6 km in length, which rises at the foot of Puig Campana mountain, the Barranc d'Iborra, which flows downstream to the aforementioned Lliriet-Derramador Ravine, the Barranc de Barceló to the northwest of the Serra Gelada and the Barranc de la Tàpia that rises to the south of the Serra de la Cortina. According to the study on floods and adaptation to climate change of the coast of the province of Alicante by Sánchez-Almodóvar et al. (2023), the ravines with the highest flood and geomorphological risk (runoff water) associated are Barceló, Lliret–Derramador and Tapiada–Murtal, whereas flood risk is of a lower degree in the area around the ravine of Xixo. The ravine of Barceló is the most problematic as it generates floods in the final section of its channel where campsites are located.

Figure 25: Flood-prone ravines in the urban nucleus of Benidorm. Sources: Town Council of Benidorm and (Sánchez-Almodóvar et al., 2023).

The Climate Change Adaptation Plan of Benidorm analyses how flooding risk affect the hotels, campsites and traffic infrastructure in Benidorm according to the regional flooding hazard assessment PATRICOVA[15]. The risk is characterised according to three scenarios: the flood event for a 100-year return period and water depth of 0.8 m, the flood event for a 500-year return period and water depth of 0.8 m and the runoff areas. The results from this analysis are summarised hereinafter. As hotels, campsites and traffic infrastructure have been considered as critical elements for the city, risk have been directly assigned to the exposure of these elements to the flooding hazard scenarios in a high-medium-low scale, respectively.

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[15] https://politicaterritorial.gva.es/es/web/planificacion-territorial-e-infraestructura-verde/patricova-plan-de-accion-territorial-de-caracter-sectorial-sobre-prevencion-del-riesgo-de-inundacion-en-la-comunitat-valenciana

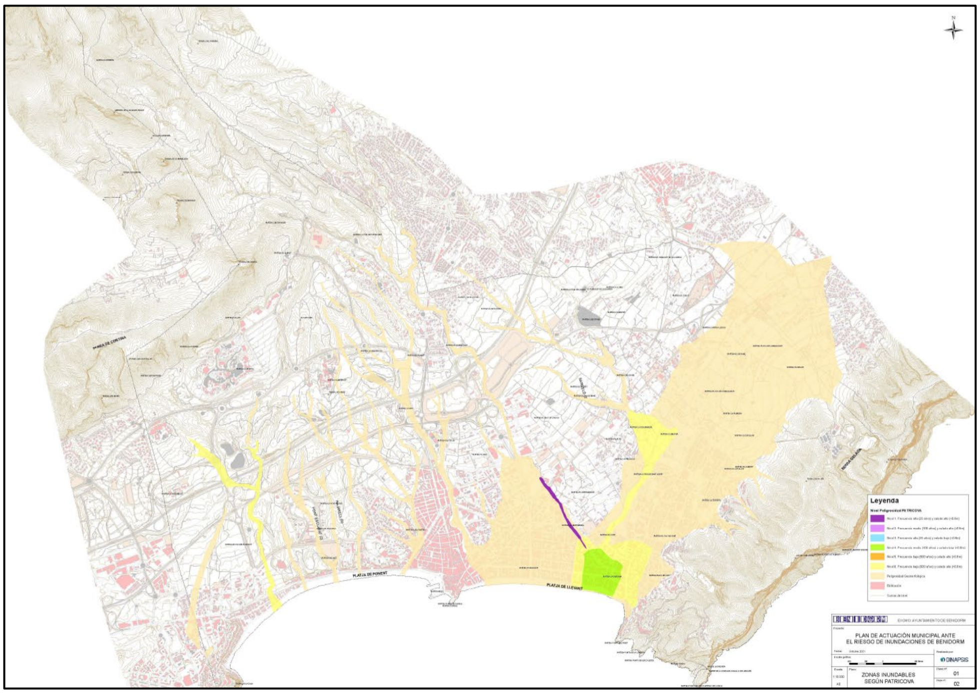
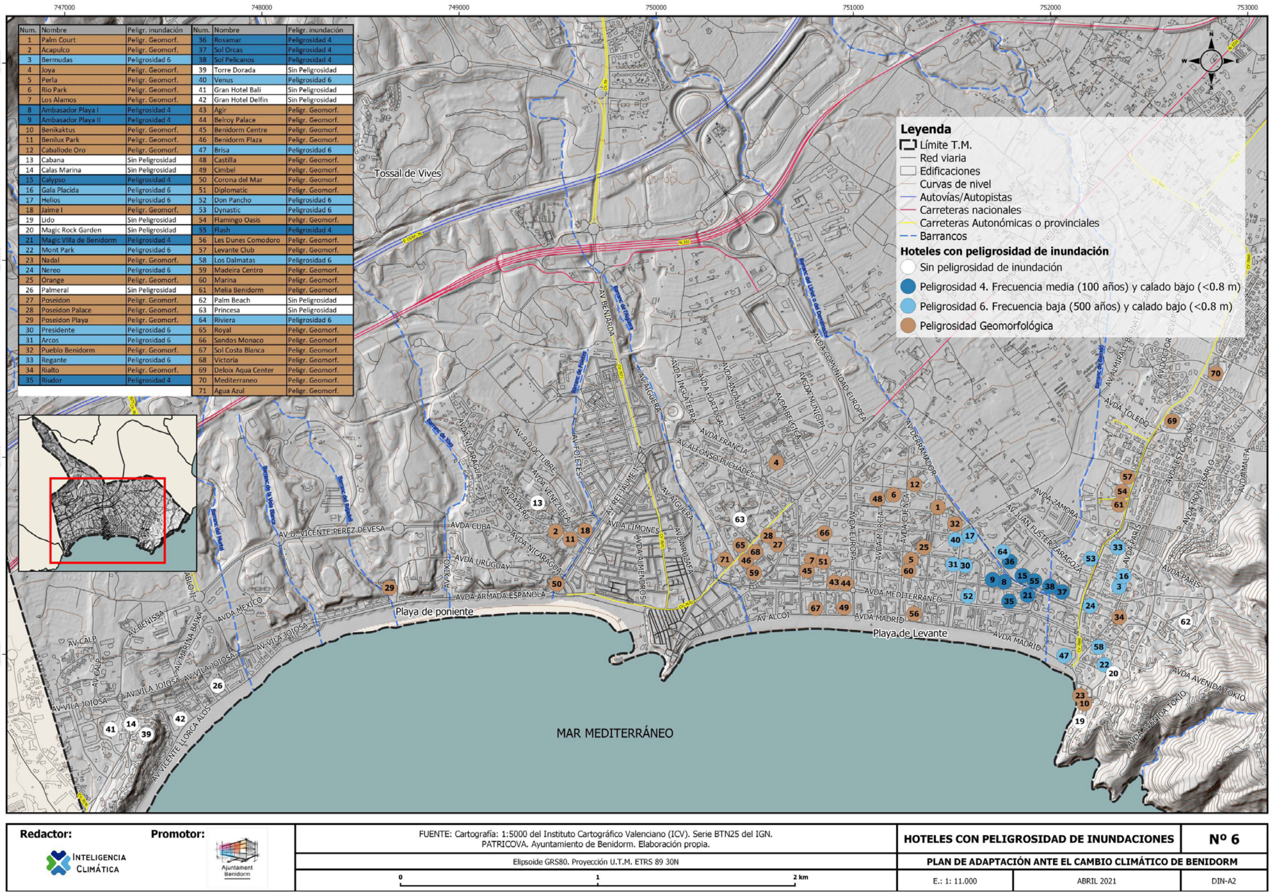


Figure 26: Flooding hazard map of Benidorm municipality. Source: PATRICOVA.

In regard of the hotels, the areas of La Martinenca, Rincón de Loix and Pla de Baió are the most affected by the flooding hazard. The runoff hazard affects a large number of hotels scattered around practically the entire urban core, due to the physical characteristics of the municipality with numerous ravines crossing the urban core (Figure 27).



Num.	Nombre	Peligr. inundación
1	Palm Court	Peligr. Geomorf.
2	Acapulco	Peligr. Geomorf.
3	Bermudas	Peligrosidad 6
4	Joya	Peligr. Geomorf.
5	Perla	Peligr. Geomorf.
6	Rio Park	Peligr. Geomorf.
7	Los Alamos	Peligr. Geomorf.
8	Ambasador Playa I	Peligrosidad 4
9	Ambasador Playa II	Peligrosidad 4
10	Benikaktus	Peligr. Geomorf.
11	Benilux Park	Peligr. Geomorf.
12	Caballode Oro	Peligr. Geomorf.
13	Cabana	Sin Peligrosidad
14	Calas Marina	Sin Peligrosidad
15	Calypso	Peligrosidad 4
16	Gala Placida	Peligrosidad 6
17	Helios	Peligrosidad 6
18	Jaime I	Peligr. Geomorf.
19	Lido	Sin Peligrosidad
20	Magic Rock Garden	Sin Peligrosidad
21	Magic VIlla de Benidorm	Peligrosidad 4
22	Mont Park	Peligrosidad 6
23	Nadal	Peligr. Geomorf.
24	Nereo	Peligrosidad 6
25	Orange	Peligr. Geomorf.
26	Palmeral	Sin Peligrosidad
27	Poseidon	Peligr. Geomorf.
28	Poseidon Palace	Peligr. Geomorf.
29	Poseidon Playa	Peligr. Geomorf.
30	Presidente	Peligrosidad 6
31	Arcos	Peligrosidad 6
32	Pueblo Benidorm	Peligr. Geomorf.
33	Regante	Peligrosidad 6
34	Rialto	Peligr. Geomorf.
35	Riudor	Peligrosidad 4
36	Rosamar	Peligrosidad 4
37	Sol Orcas	Peligrosidad 4
38	Sol Pelicanos	Peligrosidad 4
39	Torre Dorada	Sin Peligrosidad
40	Venus	Peligrosidad 6
41	Gran Hotel Bali	Sin Peligrosidad
42	Gran Hotel Delfin	Sin Peligrosidad
43	Agir	Peligr. Geomorf.
44	Belroy Palace	Peligr. Geomorf.
45	Benidorm Centre	Peligr. Geomorf.
46	Benidorm Plaza	Peligr. Geomorf.
47	Brisa	Peligrosidad 6
48	Castilla	Peligr. Geomorf.
49	Cimbel	Peligr. Geomorf.
50	Corona del Mar	Peligr. Geomorf.
51	Diplomatic	Peligr. Geomorf.
52	Don Pancho	Peligrosidad 6
53	Dynastic	Peligrosidad 6
54	Flamingo Oasis	Peligr. Geomorf.
55	Flash	Peligrosidad 4
56	Les Dunes Comodoro	Peligr. Geomorf.
57	Levante Club	Peligr. Geomorf.
58	Los Dalmatas	Peligrosidad 6
59	Madeira Centro	Peligr. Geomorf.
60	Marina	Peligr. Geomorf.
61	Melia Benidorm	Peligr. Geomorf.
62	Palm Beach	Sin Peligrosidad
63	Princesa	Sin Peligrosidad
64	Riviera	Peligrosidad 6
65	Royal	Peligr. Geomorf.
66	Sandos Monaco	Peligr. Geomorf.
67	Sol Costa Blanca	Peligr. Geomorf.
68	Victoria	Peligr. Geomorf.
69	Deloix Aqua Center	Peligr. Geomorf.
70	Mediterraneo	Peligr. Geomorf.
71	Agua Azul	Peligr. Geomorf.

Figure 27: Flooding hazard on the hotels in Benidorm CCLL. Source: Climate Change Adaptation Plan of Benidorm municipality.

Accordingly, the risk of the hotels of Benidorm is scored in a low-medium-high scale. The results are presented in Table 31, showing that the hotels at higher risk are Ambasador Playa I, Ambasador Playa II, Calypso, Magic Villa de Benidorm, Rialto, Ruidor, Rosamar, Sol Orcas, Sol Pelicanos and Flash.

Table 31: Flooding risk on the hotels of Benidorm CCLL. From: Climate Change Adaptation Plan of Benidorm municipality.

No.	Hotel	Risk	No.	Hotel	Risk
1	Palm Court	Low	31	Rosamar	High
2	Acapulco	Low	32	Sol Orcas	High
3	Bermudas	Medium	33	Sol Pelicanos	High
4	Joya	Low	34	Venus	Medium
5	Perla	Low	35	Agir	Low
6	Rio Park	Low	36	Belroy Palace	Low
7	Los Alamos	Low	37	Benidorm Centre	Low
8	Ambasador Playa I	High	38	Benidorm Plaza	Low
9	Ambasador Playa II	High	39	Brisa	Medium
10	Benikaktus	Low	40	Castilla	Low
11	Benilux Park	Low	41	Cimbel	Low
12	Caballode Oro	Low	42	Corona del Mar	Low
13	Calypso	High	43	Diplomatic	Low
14	Gala Placida	Medium	44	Don Pancho	Medium
15	Helios	Medium	45	Dynastic	Medium
16	Jaime I	Low	46	Flamingo Oasis	Low
17	Magic Villa de Benidorm	High	47	Flash	High
18	Mont Park	Medium	48	Les Dunes Comodoro	Low
19	Nadal	Low	49	Levante Club	Low
20	Nereo	Medium	50	Los Dalmatas	Medium
21	Orange	Low	51	Madeira Centro	Low
22	Poseidon	Low	52	Marina	Low
23	Poseidon Palace	Low	53	Melia Benidorm	Low
24	Poseidon Playa	Low	54	Riviera	Medium
25	Presidente	Medium	55	Royal	Low
26	Arcos	Medium	56	Sandos Monaco	Low

No.	Hotel	Risk	No.	Hotel	Risk
27	Pueblo Benidorm	Low	57	Sol Costa Blanca	Low
28	Regante	Medium	58	Victoria	Low
29	Rialto	High	59	Deloix Aqua Center	Low
30	Riudor	High	60	Mediterraneo	Low

Similarly, a number of campsites are in flood-prone areas, as shown in Figure 28. Most of the campsites are occupying a space with runoff hazard, with the exception of Camping Villasol, which is located in the southernmost sector and is also in the area corresponding to the flooding event of 500-year return period and water depth of 0.8 m. Table 32 shows the assignation of risk to the campsites potentially affected by flooding.

Table 32: Flooding risk on the campsites of Benidorm CCLL. From: Climate Change Adaptation Plan of Benidorm municipality.

No.	Campsite	Risk
1	Camper Park Terra Natura	Low
2	Camping Villasol	Medium
3	Camping Arena Blanca	Low
4	Camping Benidorm	Low
5	Camping Villamar	Low
6	Camping Benisol	Low
7	Robin Hood	Low

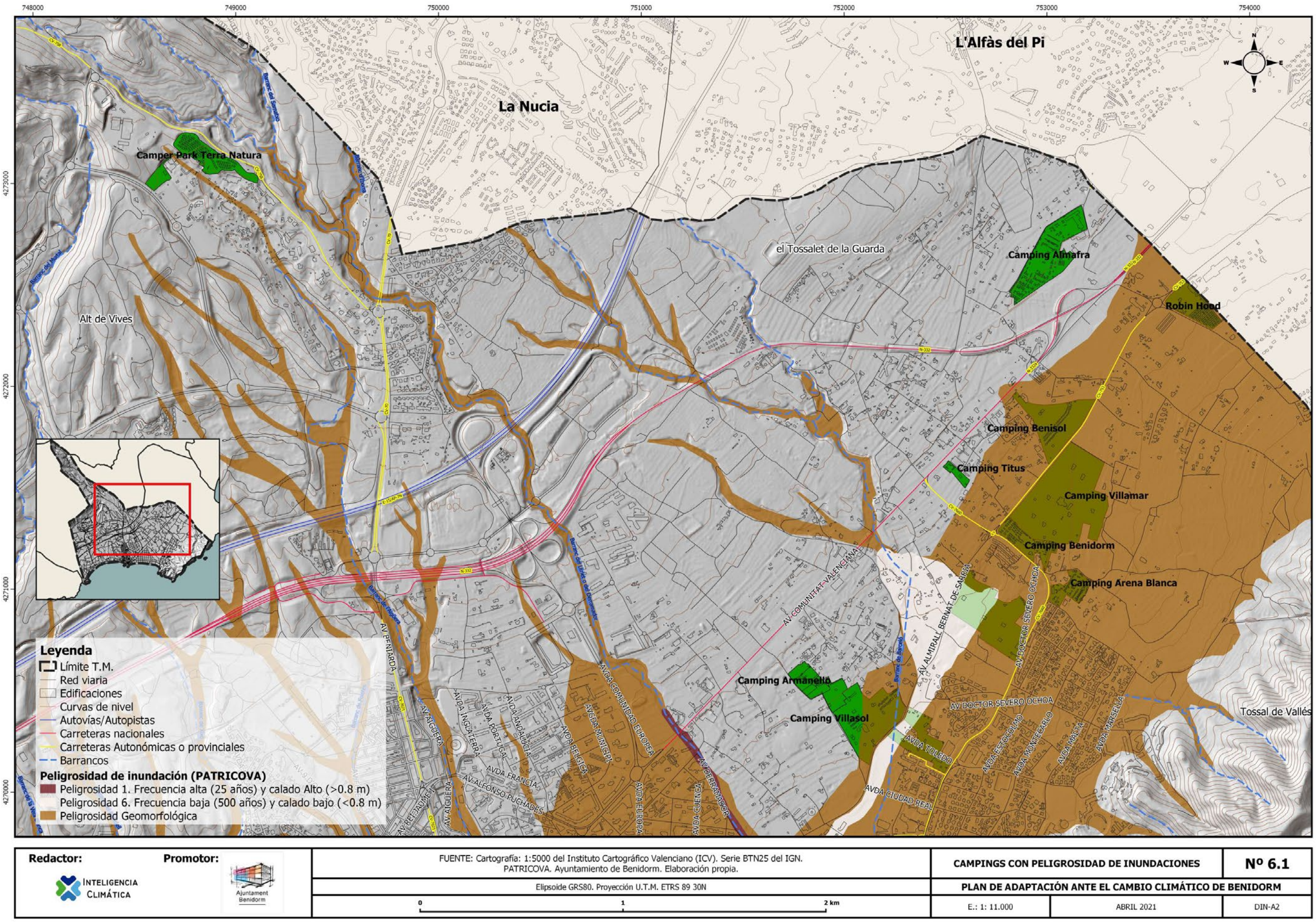


Figure 28: Flooding hazard on the campsites in Benidorm CCLL. Source: Climate Change Adaptation Plan of Benidorm municipality.

The map showing the traffic infrastructure at risk of flooding is presented in Figure 29. The flood hazard concentrates backwards Levante Beach, especially in the east part of the beach, where the streets of Av. Derramador, Avda. Mediterraneo, Avda. Madrid, Av. Castellon and Av. Almeria are affected by the flooding episode of 100-year return period and water depth of 0.8 m. Other streets in the area are also occupying the areas associated to the flooding episode of 500-year return period and 0.8 m of water depth, including Avda. Filipinas, Av. Juan Fuster Zaragoza, Av. Ametilla de Mar, Avda. Roma and Avda. Paris.

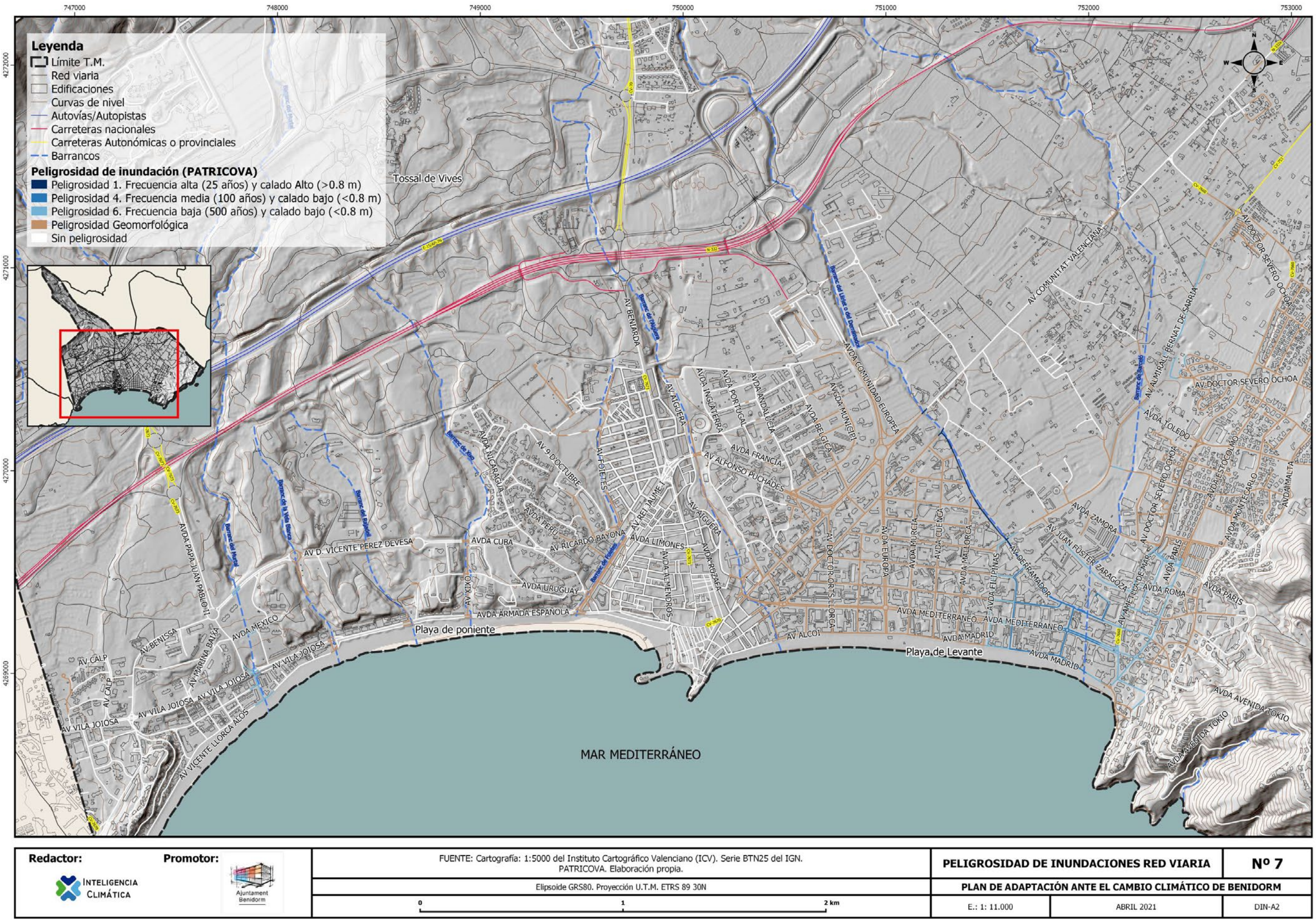


Figure 29: Flooding hazard on the traffic infrastructure in Benidorm CCLL. Source: Climate Change Adaptation Plan of Benidorm municipality.

4.5.4. Final considerations

In summary, the land flooding hazard concentrates in the downstream areas of the ravines of Lliret–Derramador and Barcelo, which is a very densely populated area. It has been shown how a number of critical elements are included within this area, including hotels, campsites, traffic infrastructure, green areas and residential and commercial buildings, as well as the Levante Beach and its associated services. In addition, compound flooding due to the interaction of land and coastal flooding is possible in this area. For these reasons, the area has been defined as a hot spot of risk.

Table 33: High-level risk characterisation in Benidorm CCLL.

Risk element	Coastal erosion	Coastal flooding	Land flooding
Population	Low	Low	Medium
Residential building	Low	High	High
Commercial building	Low	Low	Low
Industrial use	Low	Low	Low
Agriculture	Low	Low	Low
Beach areas	High	High	Medium
Critical infrastructure	Low	Low	Medium

Risk element	Coastal erosion	Coastal flooding	Land flooding
Areas of high ecological value	High	High	Medium

4.6. Oarsoaldea

Coastal and land flooding and landslides are the key climate-related hazards identified in Oarsoaldea CCLL.

4.6.1. Coastal flooding

The coast of Pasaia is characterized by rugged cliffs, rocky outcrops, few small beaches and several natural bays and inlets. The most notable among them are the three main bays of Pasaia Donibane (San Juan), Pasaia San Pedro, and Pasaia Trintxerpe. These bays provide sheltered areas for harbours and marinas, which the ports of Pasaia Donibane and Pasaia Trintxerpe are important hubs for fishing and commercial and recreational maritime activities.

The exposure of Oarsoaldea to coastal flooding is potentially limited in extent (LECZ area represents 1.1% of the total municipality area), but high in the rest of the parameters measured (relative sea-level changes, mean significant wave height and tidal range of 1.5 mm/year, 2.4 m and 1.4 m, respectively) (Table 34). Coastal flooding mainly affects the port and railway areas and residential areas. The port of Pasaia is the only port of national significance in the province (Gipuzkoa) and the residential areas host 27.8% of the CCLL population. Coastal flooding also affects a considerable extent of the rocky coast of Pasaia (13.0% of LECZ area), including the coast of the Natura 2000 site Jaizkibel.

Table 34: Summary of the indicators assessing coastal flooding risk in Oarsoaldea CCLL.

Indicator	Value	Threshold	Score
Relative sea-level changes (mm/year)	1.5	(0.5; 1.0)	High
Mean significant wave height (m)	2.4	(1.5; 2.5)	Medium
Tidal range (m)	1.4	(0.5; 1.0)	High
LECZ area (%)	1.1	(10; 25)	Low
LECZ / Coastline (ha/km)	6.3	(50; 150)	Low
LECZ population (%)	27.8	(10; 25)	High
Most vulnerable population (age) (2020) (%)	11.02	(9; 11)	High
Area of residential land use within the LECZ (%)	21.7	(10; 25)	Medium
Area of industrial/ commercial land use within the LECZ (%)	0.2	(5; 10)	Low
Area of agriculture land use within the LECZ (%)	0.2	(20; 40)	Low
Area of beaches, dunes, and sand plains within the LECZ (%)	0	(5; 10)	Low
Area of critical infrastructure within the LECZ (%)	64.9	(5; 10)	High
Presence of railway within the LECZ	Yes	(No; Yes)	High

Indicator	Value	Threshold	Score
Presence of port within the LECZ	Yes	(No; Yes)	High
Presence of airport within the LECZ	No	(No; Yes)	Low
Areas of high ecological value within the LECZ (%)	13.0	(10; 25)	Medium
Local coastal adaptation planning	Yes	(No; Yes)	Low
National sea level rise preparedness	Reasonably well	(Not well; Reasonably well; Well/very well)	Medium
MSL rise scenario scale	National	(Local; Regional; National)	High

4.6.2. Land flooding

The extents of the flood-prone areas are very limited, encompassing the downstream of the Oiartzun river around Gabierrota-Larzabal (Errenteria) and the westernmost area around the GI-636 road in Oairtzun and the locality of Altzibar-Karrika in Oiartzun. These areas mainly include residential and industrial/commercial uses and areas of railway. Although the sensitivity scores for these indicators are high, the overall risk scores have been reduced to medium due to the low exposure of the hazard considering the total municipality area.

Table 35: Summary of the indicators assessing land flooding risk in Oarsoaldea CCLL.

Indicator	Value	Threshold	Score
Flood-prone area (%)	0.3	(10; 25)	Low
Flood-prone area population (%)	0.4	(10; 25)	Low
Most vulnerable population (age) (2020) (%)	11.02	(9; 11)	High
Area of residential land use within the flood-prone area (%)	39.0	(10; 25)	High
Area of industrial/ commercial land use within the flood-prone area (%)	21.0	(5; 10)	High
Area of agriculture land use within the flood-prone area (%)	0	(20; 40)	Low
Area of beaches, dunes, and sand plains within the flood-prone area (%)	0	(5; 10)	Low
Area of critical infrastructure within the flood-prone area (%)	14.5	(5; 10)	High
Presence of railway within the flood-prone area	No	(No; Yes)	Low
Presence of port within the flood-prone area	No	(No; Yes)	Low
Presence of airport within the flood-prone area	No	(No; Yes)	Low
Areas of high ecological value within the flood-prone area (%)	18.6	(10; 25)	Medium
Local coastal adaptation planning	No	(No; Yes)	High

4.6.3. Landslides

Spain does not have a continuous plan to prevent and mitigate the risk of landslides. The Autonomous Regions are the responsible for the management of the landslide risk, with substantial differences between the different regions.

According to the Geological and Mining Institute of Spain, Spain is in a medium-low position in Europe in relation to its strength in dealing with this hazard. In Gipuzkoa, multiple landslide occurrences are triggered by extreme convective rainfall (Rivas et al., 2020).

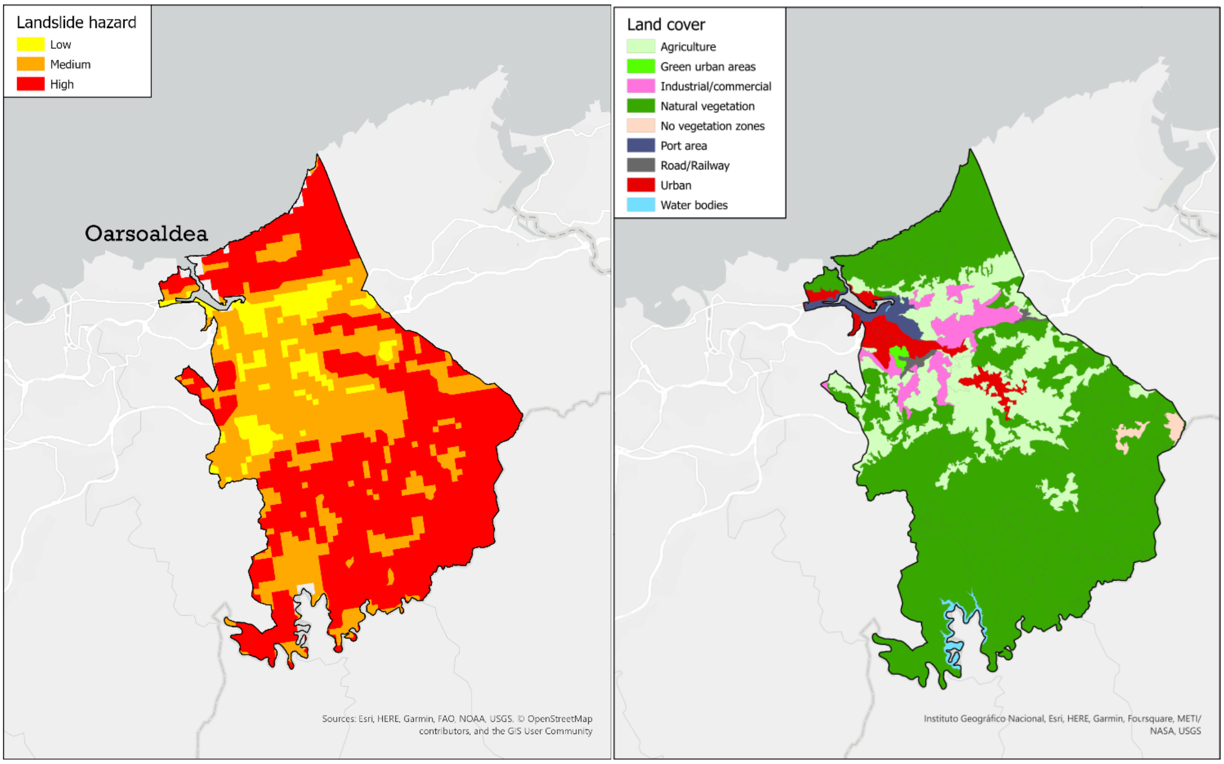


Figure 30: Distribution of landslide hazard and land cover in Oarsoaldea CCLL.

In Oarsoaldea, the landslide hazard is generally high (56.3% of total CCLL area is under high landslide hazard), according to the data from Günther et al. (2014) and Wilde et al. (2018) (Table 36). Fortunately, the residential areas are mainly located in areas of low and medium hazard and the total residential area of the CCLL is relatively low (3.4% of the total CCLL area). The distribution of the industrial, commercial and agricultural uses is similar to the distribution of the residential uses. All are concentrated in the areas of low and medium hazard (especially in the low-hazard area), but the total extent of the areas varies, especially in the case of agricultural areas (19.4% of total CCLL area). Although slightly, part of the areas of port and railway lye within the area of high hazard (also in the areas of low and medium hazard). Most of the high-hazard areas are concentrated in the municipalities of Pasaia and Oiartzun and are covered by areas of natural vegetation.

Table 36: Summary of the indicators assessing landslide risk in Oarsoaldea CCLL.

Indicator	**Total**	**Low hazard**	**Medium hazard**	**High hazard**
Landslide-prone area (%)	98.5	7.1	35.1	56.3
Landslide-prone area population (%)	5.7	-	-	-
Most vulnerable population (age) (2020) (%)	11.02	-	-	-
Area of residential land use within the landslide-prone area (%)	3.4	9.4	6.5	0.6
Area of industrial/ commercial land use within the landslide-prone area (%)	4.1	13.0	7.8	0.7

Indicator	Total	Low hazard	Medium hazard	High hazard
Area of agriculture land use within the landslide-prone area (%)	19.4	44.6	33.3	7.5
Area of beaches, dunes, and sand plains within the landslide-prone area (%)	0.0	0.0	0.0	0.0
Area of critical infrastructure within the landslide-prone area (%)	0.5	2.3	0.6	0.1
Presence of railway within the landslide-prone area	Yes	Yes	Yes	Yes
Presence of port within the landslide-prone area	Yes	Yes	Yes	Yes
Presence of airport within the landslide-prone area	No	No	No	No
Areas of high ecological value within the landslide-prone area (%)	18.6	18.0	50.5	89.7
Local coastal adaptation planning	No	-	-	-

In general, natural areas and residential areas are highly sensitive to landslide hazards. In the case of natural areas, due to their undisturbed state, delicate ecological balances, and susceptibility to habitat destruction, soil erosion, and loss of biodiversity. The density of population and infrastructure in residential areas increases the risk of loss of life, property damage, and displacement. Transportation infrastructure, including roads, railways, bridges, and tunnels, and industrial areas, comprising factories, warehouses, and other facilities, have a moderate sensitivity to landslide hazards. In this sense, disruptions in connectivity, traffic congestion, and increased vulnerability are common consequences of landslides. While not directly affected as frequently as the previous elements, industrial areas are at risk of infrastructure damage, interruptions in production, and environmental hazards. On the other hand, agricultural areas and the general population have a relatively lower sensitivity to landslide hazards. While crop loss, soil degradation, and contamination can occur, immediate risks to human life and critical infrastructure are generally lower. The sensitivity of population varies depending on the proximity to the landslide-prone areas and the level of preparedness and response mechanisms in place.

4.6.4. Final considerations

The elements most exposed to risk are the port of Pasaia and railway areas and the natural areas, including the Jaizkibel Natura 2000 site (Table 37). Other elements to be considered are the residential areas adjacent to the port, which can be potentially affected by coastal flooding and some residential and commercial/industrial areas in the downstream of the Oiartzun river within the land-flooding-prone areas. In general, landslides pose risk in practically the entire municipality, especially to the natural areas and the critical infrastructure.

Table 37: High-level risk characterisation in Oarsoaldea CCLL.

Risk element	Coastal flooding	Land flooding	Landslides
Population	Medium	Low	Low
Residential building	Medium	Medium	Medium
Commercial building	Low	Medium	Low
Industrial use	Low	Medium	Low

Risk element	Coastal flooding	Land flooding	Landslides
Agriculture	Low	Low	Medium
Beach areas	Low	Low	Low
Critical infrastructure	High	Medium	High
Areas of high ecological value	High	Low	High

4.7. Oeiras

In D1.2, coastal and land flooding were identified as the key climate-related hazards in Oeiras CCLL.

4.7.1. Coastal flooding

The shoreline of Oeiras consists primarily of cliffs, rocks, and artificial structures, interspersed with small beaches. This coastal area accommodates the urban landscape and important facilities such as roads, ports, defence equipment, and basic sanitation infrastructure, which make it more susceptible to oceanographic influences. Concerning the beaches, they make up approximately 30% of the total coastline length. Out of the twelve beaches in Oeiras, five are classified as urban bathing beaches that experience high levels of activity. Similar to the majority of Oeiras' coastline, rigid structures are present, and their ability to adapt to changes in external forces is extremely limited.

The exposure to coastal flooding in comparison to the other CCLLs is high according to the parameters measuring the relative sea-level rise (1.5 mm/year), mean significant wave height (2.7 m) and the tidal range (1.1 m). However, the indicators measuring the geometry of the LECZ show low values (LECZ area corresponding to 1.7% of total area and 9.2 hectares per kilometre of coastline). The population living in the LECZ is also one of the lowest between the CCLLs, 1.2%, with a medium percentage of population identified as vulnerable according to their age (9.79%). The existence of a coastal adaptation plan increases the adaptive capacity of the CCLL to the impacts of climate change, although the projections of sea-level rise can be improved to local or regional scale.

Table 38: Summary of the indicators assessing coastal flooding risk in Oeiras CCLL.

Indicator	Value	Threshold	Score
Relative sea-level changes (mm/year)	1.5	(0.5; 1.0)	High
Mean significant wave height (m)	2.7	(1.5; 2.5)	High
Tidal range (m)	1.1	(0.5; 1.0)	High
LECZ area (%)	2.6	(10; 25)	Low
LECZ / Coastline (ha/km)	9.2	(50; 150)	Low
LECZ population (%)	1.2	(10; 25)	Low
Most vulnerable population (age) (2020) (%)	9.79	(9; 11)	Medium
Area of residential land use within the coastal-flooding-prone areas (%)	24.8	(10; 25)	Medium
Area of industrial/ commercial land use within the coastal-flooding-prone areas (%)	18.6	(5; 10)	High

Indicator	Value	Threshold	Score
Area of agriculture land use within the coastal-flooding-prone areas (%)	4.4	(20; 40)	Low
Area of beaches, dunes, and sand plains within the coastal-flooding-prone areas (%)	0.9	(5; 10)	Low
Area of critical infrastructure within the coastal-flooding-prone areas (%)	7.2	(5; 10)	Medium
Presence of railway within the coastal-flooding-prone areas	Yes	(No; Yes)	High
Presence of port within the coastal-flooding-prone areas	Yes	(No; Yes)	High
Presence of airport within the coastal-flooding-prone areas	No	(No; Yes)	Low
Areas of high ecological value within the coastal-flooding-prone areas (%)	37.9	(10; 25)	High
Local coastal adaptation planning	Yes	(No; Yes)	Low
National sea level rise preparedness	Reasonably well	(Not well; Reasonably well; Well/very well)	Medium
MSL rise scenario scale	National	(Local; Regional; National)	High

The areas of exposure of coastal flooding assessed for the rest of indicators are those corresponding to the detailed study performed in the document *Oeiras Climate Vulnerabilities Assessment for the Municipal Climate Adaptation Plan, 2020*. The extent of these areas, of around 10 ha, corresponding to the coastal flooding event of 100-year return period and current climatic conditions (2020) is similar but reduced compared to the LECZ (Figure 31).

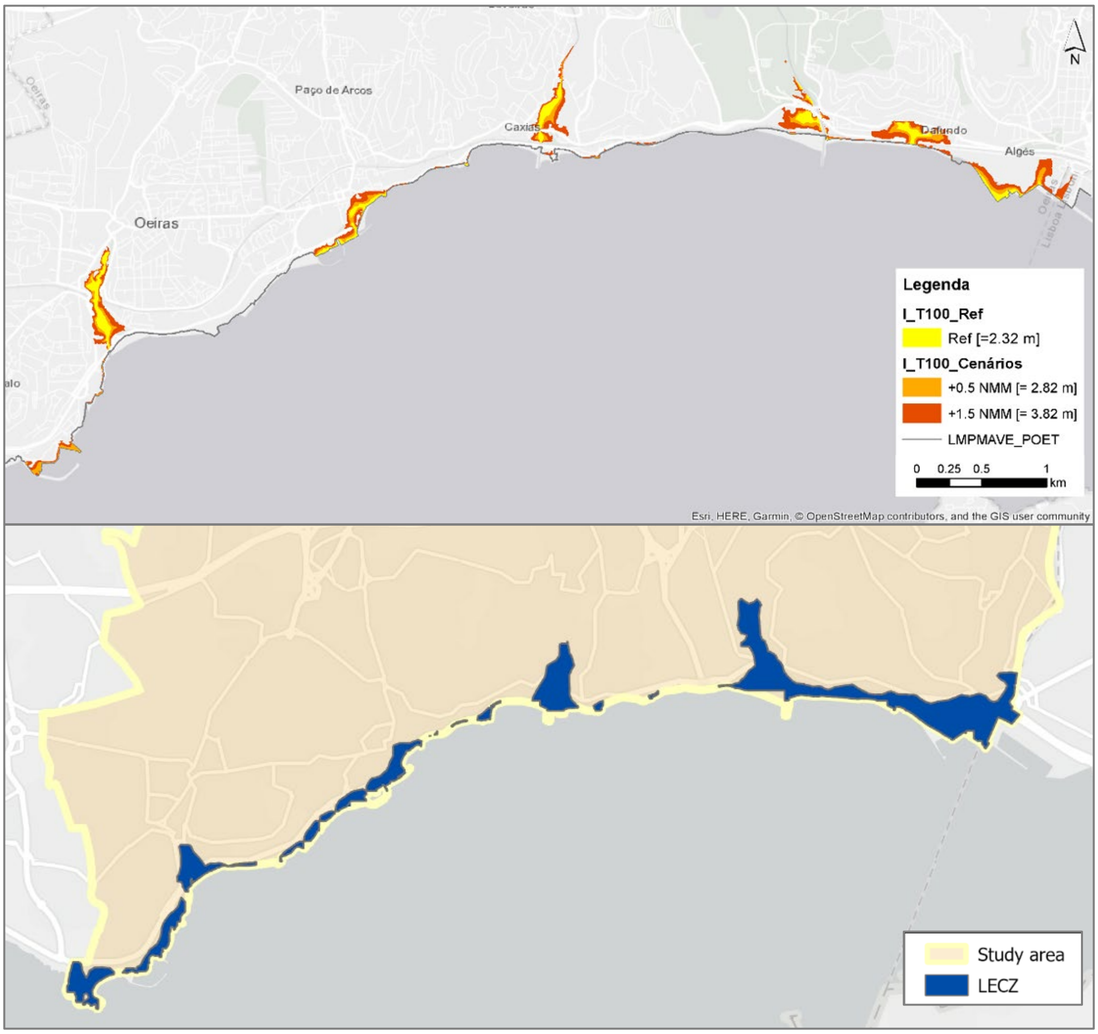


Figure 31: Top: Coastal-flood-prone areas for the 100-year return period in Oeiras under current climatic conditions (yellow), +0.5 m MSLR (orange) and +1.5 m MSLR (red) scenarios, according to Oeiras Climate Vulnerabilities Assessment for the Municipal Climate Adaptation Plan, 2020. Bottom: LECZ in Oeiras.

The land uses affected by the areas potentially affected by coastal flooding are detailed in Table 39. The industrial/commercial areas and the aeras of high-ecological value are within the most affected lands (18.6% and 37.9%, respectively). The areas corresponding to critical infrastructure have a medium score, but they include port and railway infrastructure. The beach areas and the areas intended to agricultural uses are relatively small (0.9% and 4.4%, respectively).

Table 39: Distribution of land cover/uses within Oeiras CCLL coastal flood-prone areas. Adapted from: Oeiras Climate Vulnerabilities Assessment for the Municipal Climate Adaptation Plan, 2020.

Land cover	Flooded area for the 100-year return period scenario (ha)	%
Port area	0.74	7.19
Culture assets	0.00	0.00
Defence assets	0.61	5.93
Education assets	0.13	1.26
Leisure assets	0.00	0.00
Health assets	0.00	0.00

Land cover	Flooded area for the 100-year return period scenario (ha)	%
Water treatment assets	0.00	0.00
Sport assets	0.12	1.17
Urban green areas	2.99	29.06
Natural vegetation	0.70	6.80
Industrial/Commercial	1.30	12.63
No vegetation zones	0.22	2.14
Beaches, dunes, and sand plains	0.09	0.87
Agriculture	0.45	4.37
Transportation network	0.52	5.05
Urban	2.42	23.52
Bare rock	0.00	0.00
Total	10.29	100.00

4.7.2. Land flooding

As it was discussed in D1.3, the flood maps from Dottori et al. (2021) do not display any information in Oeiras. However, the document *Hydrological and Hydraulic Study of the Oeiras Watersheds for the elaboration of a map of areas subject to flooding in accordance with Decree-Law No. 115/2010* delimitates the flood-prone areas and their corresponding maximum flood depths for different return periods for the Jamor river basin, including the watercourses of Laje, Porto Salvo, Barcarena and Alges (Figure 32).

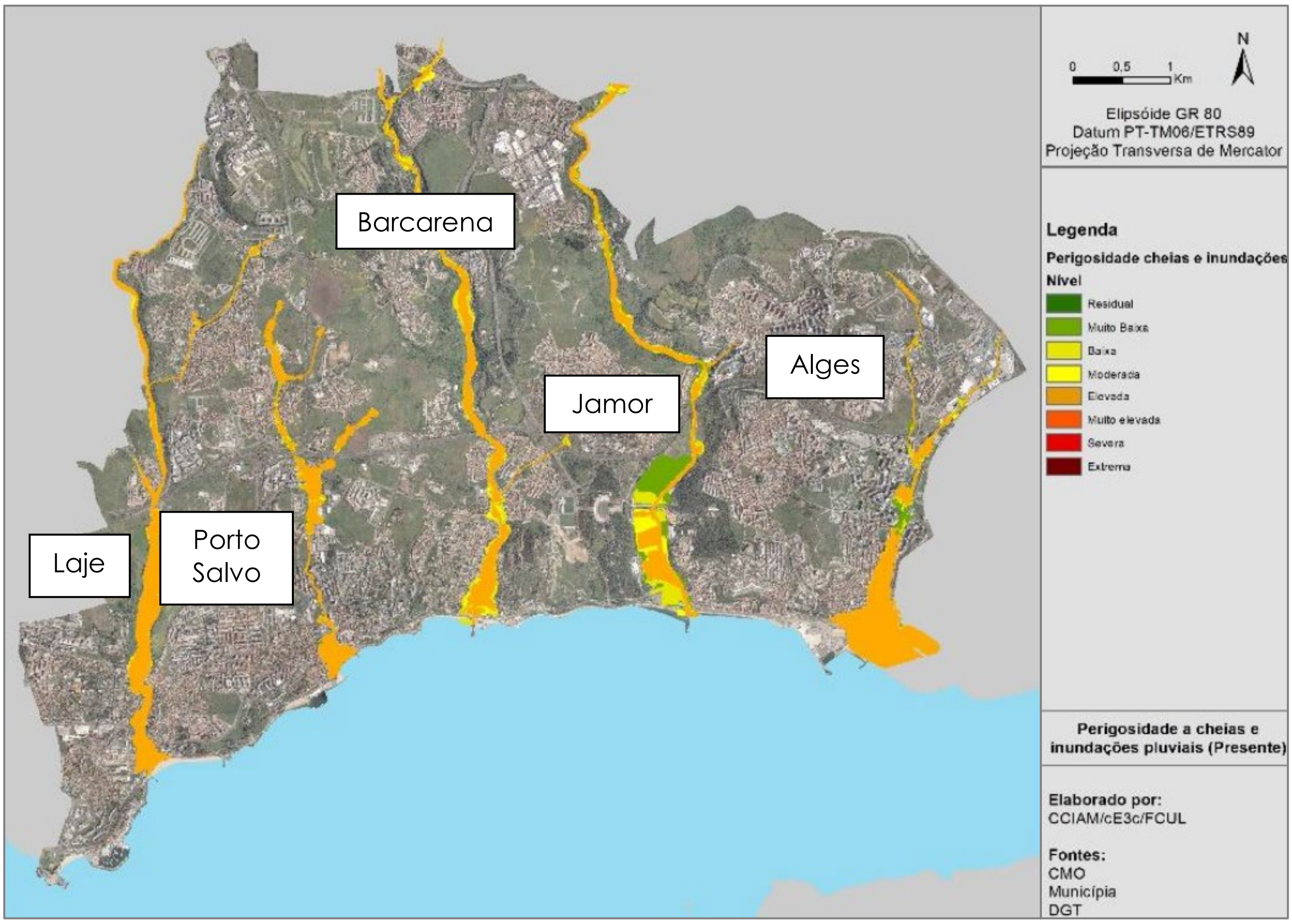


Figure 32: Land flooding hazard in Oeiras in current climatic conditions. Source: Hydrological and Hydraulic Study of the Oeiras Watersheds for the elaboration of a map of areas subject to flooding in accordance with Decree-Law No. 115/2010.

The degree of hazard is generally between medium and high, with the exception of the areas associated to the Jamor river. The downstream areas coincide with the areas affected by coastal flooding previously shown. These areas are especially sensitive because they are areas with high urban density (e.g., downtown Algés, Paço de Arcos). The vulnerability of the flood areas is assessed in the document *Municipal plan for adaptation to climate change in Oeiras*, whose main results are summarised for each parish in Table 40.

Table 40: Vulnerability to land flooding in Oeiras CCLL. Adapted from: Municipal plan for adaptation to climate change in Oeiras.

Area (Parish)	Transportation network	Agriculture	Economic activity	Tourism	Critical assets
Algés, Linda-a-Velha e Cruz Quebrada-Dafundo	High	Low	High	High	High
Carnaxide e Queijas	Medium	Low	High	Medium	Medium
Barcarena	High	High	Medium	Medium	Medium
Porto Salvo	High	Low	Medium	Low	Low
Oeiras e São Julião da Barra, Paço de Arcos e Caxias	High	Low	Low	Medium	Low

Almost the entire garden area of Pedreira Italiana is in a zone of moderate to very high danger. With regard to the transport sector and communication routes, the vulnerability of the transport infrastructure network to floods is high for all the parishes with exception of Carnaxide e Queijas, where is estimated as medium. In general, the North-South orientation of the numerous rivers existing in Oeiras and their related floodplains expose the transportation network as these could generate generalised traffic constraints, especially at the intermodal station (including railway) in downtown Algés.

The parishes of Barcarena and Porto Salvo stand out for having an area of green spaces greater than the area occupied by the urban fabric, according to the Urban Atlas classification (Table 41). Within these spaces, associations of herbaceous vegetation stand out, scattered throughout the Municipality, with greater emphasis in the parishes of Barcarena, and in the Union of parishes of Carnaxide and Queijas.

Table 41: Green areas in Oeiras CCLL. Adapted from: Municipal plan for adaptation to climate change in Oeiras.

Area (Parish)	Green areas (%)	Urban (%)	Road (%)	Total (%)	Exposure
Algés, Linda-a-Velha e Cruz Quebrada-Dafundo	32.6	52.3	15.1	100	Low
Carnaxide e Queijas	40.1	49.3	10.6	100	Medium
Barcarena	55.4	35	9.6	100	High
Porto Salvo	49.2	41.3	9.5	100	High
Oeiras e São Julião da Barra, Paço de Arcos e Caxias	32.1	52	15.9	100	Medium

4.7.3. Final considerations

The risk associated to coastal flooding has been indicated as medium in the beach areas due to the high impact of the services sector in the region (86.5% of the GDP), despite the low relative area of these areas. Contrarily, the risk of the industrial/commercial areas has been scored as medium, taking into consideration the low size of the LECZ and the contribution of the industry in the GDP of Lisboan compared to the other CCLLs.

The high exposure to land flooding and the variable relevance of the economic sectors considered (agriculture, industry and services) have been fundamental in the risk characterisation. Moreover, the distribution of the different watercourses across the municipality cut the transportation network in multiple points.

The flood hazard concentrates in the downstream areas of the various watercourses considered, mainly residential, where coastal flooding and land flooding hazards superpose.

Table 42: High-level risk characterisation in Oeiras CCLL.

Risk element	Coastal flooding	Land flooding
Population	Low	Medium
Residential building	Medium	High
Commercial building	Medium	Medium
Industrial use	Medium	Medium
Agriculture	Low	Low

Risk element	Coastal flooding	Land flooding
Beach areas	Medium	Medium
Critical infrastructure	Medium	High
Areas of high ecological value	High	High

4.8. Massa

4.8.1. Coastal erosion

The coastal area of Massa stretches along the Tyrrhenian Sea, featuring a number of sandy beaches and access to the Mediterranean waters. The beaches are a major attraction, drawing both locals and tourists during the summer months. These beaches are well-maintained and offer various amenities such as beach clubs, restaurants, and water sports activities. Some popular beaches in Massa include Marina di Massa, Ronchi, and Cinquale.

Figure 33: Overview of the coastal area of the city of Massa, featuring various sandy beaches. Source: Google Earth.

The indicators measured in D1.3 and summarised in Table 43 show that the exposure to coastal erosion is lower than in other CCLLs. The area of beaches within the LECZ is small (2% of the LECZ area), however the beaches cover practically the totality of the shorefront. Considering the importance of the services sector on the province of Massa-Carrara, that the beaches are one of the main attractions for tourism and that the resilience of the CCLL has been scored as low, the risk on the beaches has been scored as medium.

Moreover, although the indicator “Areas of high ecological value within the LECZ (%)” has been scored of high, the sensitivity of the natural areas can be considered lower than in other CCLLs. For example, there has not been found any natural protected area along the coastline of Massa CCLL and the ecosystems of the coast can be considered already altered by the intense urban pressure in the area.

Table 43: Summary of the indicators assessing coastal erosion risk in Massa CCLL.

Indicator	Value	Threshold	Score
Relative sea-level changes (mm/year)	1	(0.5; 1.0)	Medium
Mean significant wave height (m)	0.7	(1.5; 2.5)	Low
Tidal range (m)	0.2	(0.5; 1.0)	Low

Indicator	Value	Threshold	Score
Lithotype hardness	Medium	(Hard; medium; soft)	Medium
Area of beaches, dunes, and sand plains within the LECZ (%)	2.0	(5; 10)	Low
Areas of high ecological value within the LECZ (%)	32.5	(10; 25)	High
Local coastal adaptation planning	No	(No; Yes)	High
National sea level rise preparedness	Not well	(Not well; Reasonably well; Well/very well)	High
MSL rise projections spatial scale	National	(Local; Regional; National)	High

4.8.2. Coastal flooding

Although the indicators measuring the sea-level rise, the wave energy and the tidal range show low scores, the area of the LECZ is of medium size when compared to the municipality area (18.8%) and of high size when compared to the length of the coastline (186.2 ha/km), indicating medium values of exposure to coastal flooding. The areas potentially affected by coastal flooding cover high extents of residential and industrial/commercial uses and areas of high-ecological value, including the beach areas. The population living in the LECZ is also high, approximately 34.1% of the total municipality area, with a high percentage of vulnerable people according to their age. Conversely, the agricultural land is scarce in the LECZ, as well as the area of critical infrastructure.

Table 44: Summary of the indicators assessing coastal flooding risk in Massa CCLL.

Indicator	Value	Threshold	Score
Relative sea-level changes (mm/year)	1	(0.5; 1.0)	Medium
Mean significant wave height (m)	0.7	(1.5; 2.5)	Low
Tidal range (m)	0.2	(0.5; 1.0)	Low
LECZ area (%)	18.8	(10; 25)	Medium
LECZ / Coastline (ha/km)	186.2	(50; 150)	High
LECZ population (%)	34.1	(10; 25)	High
Most vulnerable population (age) (2020) (%)	13.02	(9; 11)	High
Area of residential land use within the LECZ (%)	34.8	(10; 25)	High
Area of industrial/ commercial land use within the LECZ (%)	13.5	(5; 10)	High
Area of agriculture land use within the LECZ (%)	3.4	(20; 40)	Low
Area of beaches, dunes, and sand plains within the LECZ (%)	2.0	(5; 10)	Low
Area of critical infrastructure within the LECZ (%)	0.2	(5; 10)	Low
Presence of railway within the LECZ	Yes	(No; Yes)	High

Indicator	Value	Threshold	Score
Presence of port within the LECZ	No	(No; Yes)	Low
Presence of airport within the LECZ	No	(No; Yes)	Low
Areas of high ecological value within the LECZ (%)	32.5	(10; 25)	High
Local coastal adaptation planning	No	(No; Yes)	High
National sea level rise preparedness	Not well	(Not well; Reasonably well; Well/very well)	High
MSL rise scenario scale	National	(Local; Regional; National)	High

4.8.3. Landslides

Massa is known for its historical and cultural landmarks situated along the coast. One notable site is the Malaspina Castle, a medieval fortress overlooking the sea. Moving inland from the coast, Massa transitions into the foothills of the Apennine Mountains. These foothills form a hilly landscape with gentle slopes and undulating terrain. The hills are covered with vegetation, including Mediterranean shrubs, forests, and cultivated fields. The northern part of the municipality of Massa is dominated by the Apuan Alps. The Apuan Alps rise dramatically from the surrounding plains, reaching heights of over 2,000 meters. The peaks are characterized by rugged and rocky formations, including marble quarries that have been actively mined for centuries. The Apuan Alps provide a picturesque backdrop to the municipality and offer excellent opportunities for mountaineering, trekking, and enjoying panoramic views of the surrounding area. Heavy precipitation oftenly leads to dangerous landslides in these areas (Amponsah et al., 2016; D'Amato Avanzi et al., 2013; Nardi & Rinaldi, 2015).The areas representing the landslide hazard in Figure 34 corresponds to the maps from the document "Plan on landslide and geomorphological risk" at 1/10,000 scale for the susceptibility levels of "high" and "very high", similar to the high-hazard scenario used in Oarsoaldea CCLL.

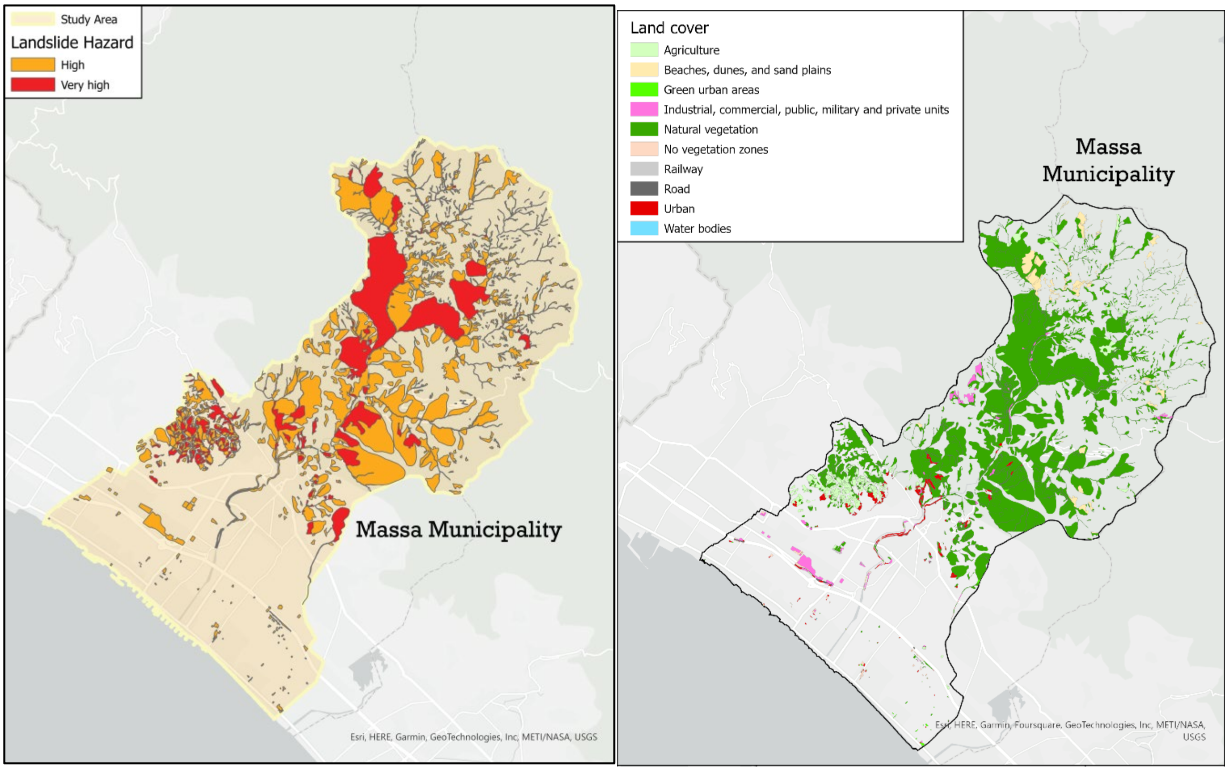


Figure 34: Areas affected by landslide hazard in Massa CCLL (left) and land cover within these (right).

The landslide hazard mainly covers areas corresponding to the natural areas within the hilly and the mountain areas of the city (86.5%) (Table 45). The exposure to landslides in Massa CCLL measured as the percentage of high hazard area over the total CCLL area is lower compared to Oarsoaldea CCLL, approximately the half. In this case, any element of risk is especially affected, with the exception of the areas of high-ecological value.

Table 45: Summary of the indicators assessing landslide risk in Massa CCLL.

Indicator	Total (high hazard)
Landslide-prone area (%)	27.0
Landslide-prone area population (%)	6.0
Most vulnerable population (age) (2020) (%)	13.02
Area of residential land use within the landslide-prone area (%)	2.3
Area of industrial/ commercial land use within the landslide-prone area (%)	2.3
Area of agriculture land use within the landslide-prone area (%)	6.3
Area of beaches, dunes, and sand plains within the landslide-prone area (%)	4.1
Area of critical infrastructure within the landslide-prone area (%)	2.0
Presence of railway within the landslide-prone area	Yes
Presence of port within the landslide-prone area	No
Presence of airport within the landslide-prone area	No
Areas of high ecological value within the landslide-prone area (%)	86.5
Local coastal adaptation planning	No

4.8.4. Final considerations

Coastal flooding poses the major risks to the CCLL of Massa, especially to population, residential and commercial building and industrial uses in one of largest LECZ between of the CCLLs. The combination of coastal flooding and coastal erosion can impact the coastal area of the city, mainly formed by a series of sandy beaches of high value for tourism. The landslides principally affect the hilly and mountain areas of the north half of the CCLL, where some historic values can experience risk in the natural protected area of the Apuan Alps.

Table 46: High-level risk characterisation in Massa CCLL.

Risk element	Coastal erosion	Coastal flooding	Landslides
Population	Low	High	Low
Residential building	Low	High	Low
Commercial building	Low	High	Low
Industrial use	Low	High	Low
Agriculture	Low	Low	Low

Risk element	Coastal erosion	Coastal flooding	Landslides
Beach areas	Medium	Medium	Low
Critical infrastructure	Low	Low	Low
Areas of high ecological value	Medium	Medium	High

4.9. Piran

4.9.1. Coastal flooding

The LECZ extent reaches 30.7% of the municipality area in Piran CCLL (Figure 35), suggesting that coastal flooding can affect a considerable extension of the territory. The impacts of a flooding episode of 1 m along the Slovenian coast, in terms of land exposure, buildings affected and population, are studied in Kovačič et al. (2016) and Brečko Grubar et al. (2019). The results confirm that great urban areas are potentially affected by coastal flooding, including the old city centre of Piran. In fact, it was shown in D1.1 that coastal flooding affected the Tartini Square (Piran) in November 2019, damaging infrastructure, leading to road cut-offs and isolating some citizens. 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.

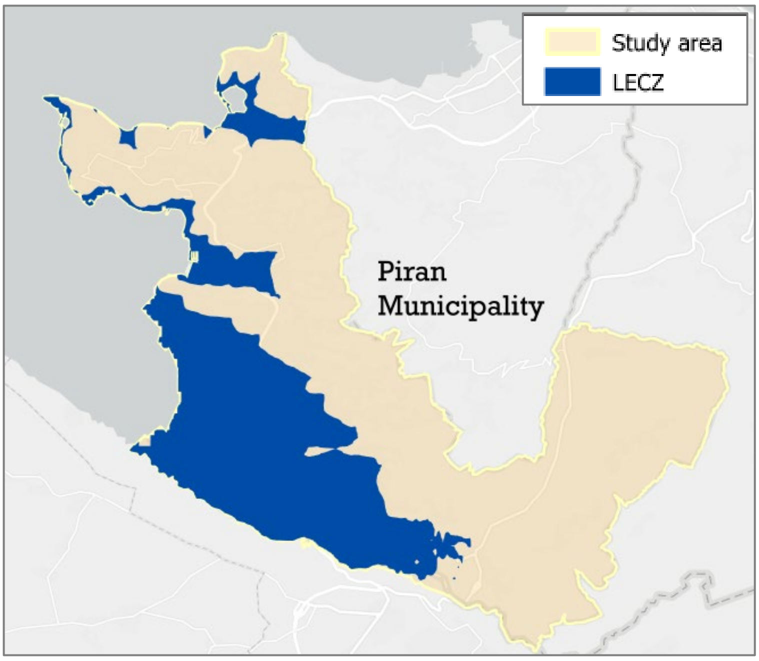


Figure 35: LECZ in Piran CCLL.

The analysis of the indicators developed in D1.3 (Table 47) shows that the population, the critical infrastructure and the areas of high-ecologycal value can be especially affected by coastal flooding. The most vulnerable population in terms of age reaches a high percentage of the total municipality population (11.01%) and the estimation of population living in the LECZ is of about 34.3% (circa 20,000 inhabitants).

Table 47: Summary of the indicators assessing coastal flooding risk in Piran CCLL.

Indicator	Value	Threshold	Score
Relative sea-level changes (mm/year)	1	(0.5; 1.0)	Medium

Indicator	Value	Threshold	Score
Mean significant wave height (m)	0.7	(1.5; 2.5)	Low
Tidal range (m)	0.2	(0.5; 1.0)	Low
LECZ area (%)	30.7	(10; 25)	High
LECZ / Coastline (ha/km)	67.1	(50; 150)	Medium
LECZ population (%)	34.3	(10; 25)	High
Most vulnerable population (age) (2020) (%)	11.01	(9; 11)	High
Area of residential land use within the LECZ (%)	7.7	(10; 25)	Low
Area of industrial/ commercial land use within the LECZ (%)	0	(5; 10)	Low
Area of agriculture land use within the LECZ (%)	36.4	(20; 40)	Medium
Area of beaches, dunes, and sand plains within the LECZ (%)	0	(5; 10)	Low
Area of critical infrastructure within the LECZ (%)	5.3	(5; 10)	Medium
Presence of railway within the LECZ	No	(No; Yes)	Low
Presence of port within the LECZ	Yes	(No; Yes)	High
Presence of airport within the LECZ	Yes	(No; Yes)	High
Areas of high ecological value within the LECZ (%)	50.5	(10; 25)	High
Local coastal adaptation planning	No	(No; Yes)	High
National sea level rise preparedness	Not well	(Not well; Reasonably well; Well/very well)	High
MSL rise scenario scale	National	(Local; Regional; National)	High

Coastal flooding can have severe consequences for critical infrastructure, including utility systems and transportation networks. The port of Piran (close to the historic center of Piran), Marina Portorož (situated in the nearby town of Portorož) and Marina Lucija (near Portorož) are are some of the main ports and marinas in the Piran municipality lying within the LECZ. Also, the Portorož Airport (located in the village of Sečovlje, which is approximately 7 km south of Piran) is a small international airport that primarily serves general aviation and charter flights, which can be potentially affected by coastal flooding. In addition, electrical substations, sewage treatment plants, and pumping stations located in low-lying or flood-prone areas may be vulnerable to flooding, resulting in power outages, wastewater discharge, and disruption to essential services.

Piran municipality encompasses diverse ecosystems, influenced by its coastal location along the Adriatic Sea and its proximity to the nearby countryside. More than 50% of the LECZ is covered by areas of high-ecological value. The coastal area includes seagrass meadows, underwater rocky reefs, sandy beaches, rocky shores, coastal cliffs, salt marshes, lagoons, estuaries and salt pans. For instance, the Sečovlje Salina Nature Park, located close to the airport, is known for its extensive salt pans and wetlands. Coastal flooding can have adverse effects on the local ecosystems and biodiversity. Wetlands, marshes, and coastal habitats in and around Piran may experience saltwater intrusion, which can harm sensitive plant and animal species. Flooding can disrupt nesting grounds for migratory birds and affect fish populations, leading to ecological imbalances and potential long-term environmental damage.

Figure 36: City of Piran. Photo by Indriany Lionggo during the SCORE workshops[16].

Moreover, coastal flooding may pose other significant risks to the waterfront and coast of the municipality of Piran. For instance, Piran is known for its rich historical and cultural heritage, including ancient buildings, churches, and monuments. Coastal flooding can damage or degrade those elements of cultural heritage located in close proximity to the waterfront. Other vulnerable structures, such as buildings, promenades, and infrastructure along the waterfront, may be at risk of damage or collapse too. Furhtermore, low-lying parts of the city located in the immediate vicinity of the shoreline, such as the marinas of Piran and Portoroz, ground-level shops, residential areas, restaurants, hotels, recreational facilities and parking lots are also susceptible to flooding. Streets and public spaces in these areas may experience temporary or prolonged inundation, leading to disruptions in transportation and services.

The absence of local coastal adaptation increases the overall risk to climate change in Piran CCLL. Adequate planning and implementation of adaptation strategies are crucial for reducing the observed risks, protecting communities, infrastructure and ecosystems, and building resilience.

The assigment of risk presented in Table 48 summarises the previous results. These results show that the major risks are those faced by the population, the critical infrastructure and the areas of high-ecological value. The city centre of Piran has been identified as a hot spot of risk, due to the impact of coastal flooding into the historic centre and the concentration of population in the area.

Table 48: High-level risk characterisation in Piran CCLL.

Risk element	Coastal flooding
Population	High
Residential building	Medium
Commercial building	Low

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[16] https://www.ihs.nl/en/news/score-road

Risk element	Coastal flooding
Industrial use	Low
Agriculture	Medium
Beach areas	Low
Critical infrastructure	High
Areas of high ecological value	High

4.10. Gdańsk

4.10.1. Coastal flooding

The LECZ of Gdańsk city is the largest between of the ten CCLLs (Table 49). Coastal flooding has the potential to affect significant areas of industrial and commercial uses of land adjacent to the western branch of the Vistula River (former Leniwka), especially those included in the Port of Gdańsk, and areas of high-ecological value (Figure 37). In this sense, the city of Gdańsk encompasses several coastal ecosystems hosting biodiversity and of environmental significance, including extensive sand dunes, coastal forests (pine, oak and birch), salt marshes, coastal lagoons and the Vistula Estuary. These areas provide habitats for diverse plant and animal species, act as natural barriers against erosion and storms stabilizing the coastline, contribute to the purification of the air, help maintaining the ecological balance of the area in general and provide recreational opportunities for residents and visitors.

Moreover, all the beach areas from the border of Sopot to Sobieszewo, including the popular Jelitkowo, Brzeźno and Stogi lye within the LECZ. In this sense, coastal flooding put at risk different values, such as the coastal landscape, promenades, the water supply sector, the service sector and various amenities such as cafes, restaurants, and recreational facilities (e.g., beach bars, volleyball courts and water sports activities) (Staudt et al., 2006).

Figure 37: View of Stogi beach, port of Gdańsk and adjacent forest areas, including accesses, recreational facilities and residential buildings. Source: Google Earth.

The estimate of population living in the LECZ is high (circa 37% of total population). The sea-level rise and coastal flooding can deteriorate historic townhouses along the waterfront and the old city centre (Stare Miasto), but also apartment buildings, modern housing developments and villas and mansions.

A more detailed quantification of the economic impact of a scenario of sea-level rise of 5 m is provided in Paprotny & Terefenko (2017). This study uses detailed cartographic materials, including the majority of flood defences in the area and calculates the exposure of land, population and assets. Results show that flood hazard concentrates in the Vistula estuary (Gdańsk).

Table 49: Summary of the vulnerability/exposure indicators in Gdańsk CCLL for coastal flooding, as reported in D1.3.

Indicator	Value	Threshold	Score
LECZ area (%)	46.7	(10; 25)	High
LECZ / Coastline (ha/km)	361.0	(50; 150)	High
LECZ population (%)	36.8	(10; 25)	High
Most vulnerable population (age) (2020) (%)	8.91	(9; 11)	Low
Area of residential land use within the LECZ (%)	8.0	(10; 25)	Low
Area of industrial/ commercial land use within the LECZ (%)	14.4	(5; 10)	High
Area of agriculture land use within the LECZ (%)	35.4	(20; 40)	Medium
Area of beaches, dunes, and sand plains within the LECZ (%)	1.3	(5; 10)	Low
Area of critical infrastructure within the LECZ (%)	5.3	(5; 10)	Medium
Presence of railway within the LECZ	Yes	(No; Yes)	High
Presence of port within the LECZ	Yes	(No; Yes)	High
Presence of airport within the LECZ	No	(No; Yes)	Low
Areas of high ecological value within the LECZ (%)	33.2	(10; 25)	High
Local coastal adaptation planning	Yes	(No; Yes)	Low
National sea level rise preparedness	Reasonably well	(Not well; Reasonably well; Well/very well)	Medium
MSL rise scenario scale	National	(Local; Regional; National)	High

4.10.2. Land flooding

The areas exposed by river flooding (100-year return period event) are similar to the LECZ, mainly excluding some natural vegetated areas between the western branch of the Vistula River and the shorefront. For this reason, the risks associated to river flooding are similar to those previously described. The city of Gdańsk has implemented various measures to protect against flooding and strengthen its river embankment protection system, improving its resilience to flood events (Figure 38). However, it is important to note that the effectiveness and adequacy of the flood defence system can be influenced by the increasing scale and intensity of flooding events. In the event of extreme precipitation, there may still be areas or aspects of the river embankment protection system that require further improvement or reinforcement, especially the areas where embankment walls are smaller than 1 m (Staudt & Kordalski, 2005).

Figure 38: Długie Pobrzeże street, Gdańsk, 2013-05-20. Source: photo by Diego Delso[17].

As shown in the maps (Figure 39), coastal and river flooding concentrate in the eastern half of the city, and pluvial flooding[18], in the western half (Marosz, 2007; Paprotny & Terefenko, 2017). Consequently, especially attention should be considered to the potential risk of compound coastal and land flooding, mainly caused by the combined action of intense rainfall, thaws and ice jams on the Vistula River, storm surges from the sea and anthropogenic-related causes (damage to flood protection or anti-storm protection facilities, breakage of embankments, etc.), as seen in D1.2.

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[17] https://creativecommons.org/licenses/by-sa/3.0/

[18] Data for more than five hundred (500+) pluvial flooding notifications in Gdansk for the years 2010-2017 and historical floods during 1829-1992 made available by the Regional Water Management Board Gdańsk (Regionalny Zarząd Gospodarki Wodnej Gdańsk).

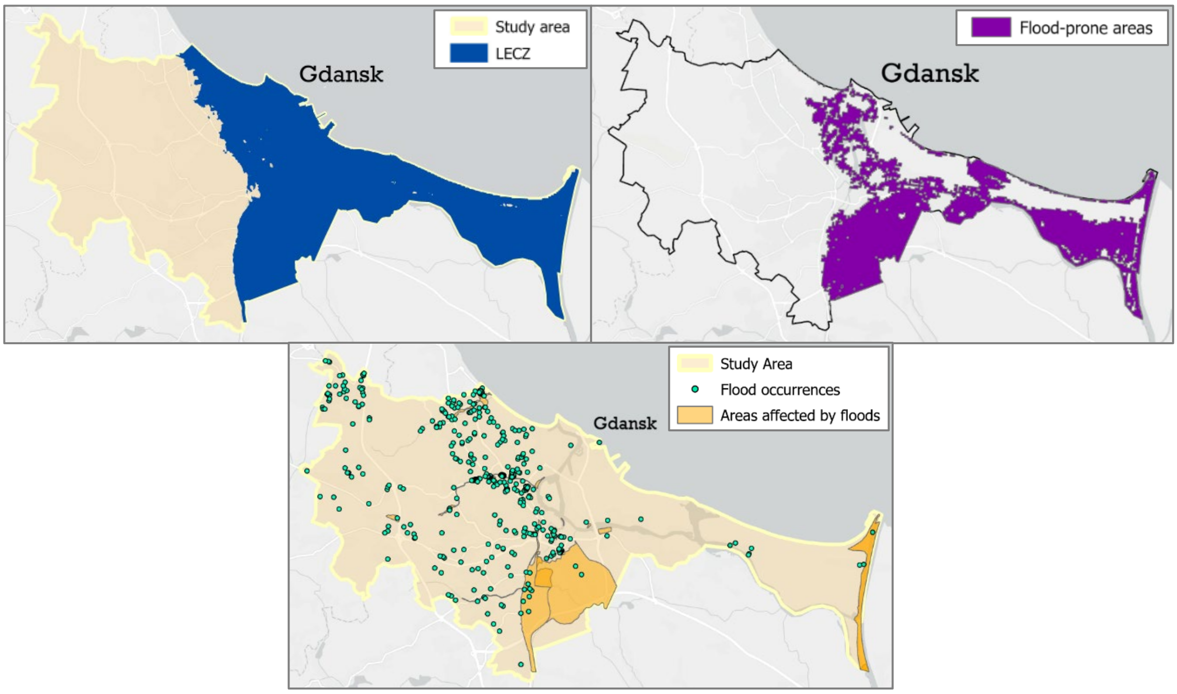

Figure 39: Low-elevation coastal zone (top left), extents of the 100-year return period river flooding event (top right) and geographical distribution of the flood notifications between 1829-2017 (bottom) in Gdańsk.

The summary of the indicators measuring the land flooding risk provided in Table 50 show similar scores to the equivalent indicators used to assess coastal flooding risk. However, in this case, land flooding concentrates in land intended to agriculture between Orunia and Rudniki and transportation infrastructure, also including the Port of Gdańsk and railway areas.

Table 50: Summary of the vulnerability/exposure indicators in Gdańsk CCLL for land flooding (T = 100 years), as reported in D1.3.

Indicator	Value	Threshold	Score
Flood-prone area (%)	26	(10; 25)	High
Flood-prone area population (%)	16.5	(10; 25)	Medium
Most vulnerable population (age) (2020) (%)	8.91	(9; 11)	Low
Area of residential land use within the flood-prone area (%)	4.4	(10; 25)	Low
Area of industrial/ commercial land use within the flood-prone area (%)	11.2	(5; 10)	High
Area of agriculture land use within the flood-prone area (%)	52.8	(20; 40)	High
Area of beaches, dunes, and sand plains within the flood-prone area (%)	1.5	(5; 10)	Low
Area of critical infrastructure within the flood-prone area (%)	6.1	(5; 10)	High
Presence of railway within the flood-prone area	Yes	(No; Yes)	High
Presence of port within the flood-prone area	Yes	(No; Yes)	High
Presence of airport within the flood-prone area	No	(No; Yes)	Low
Areas of high ecological value within the flood-prone area (%)	18.6	(10; 25)	Medium

Indicator	Value	Threshold	Score
Local coastal adaptation planning	Yes	(No; Yes)	Low

More details on the analysis of the risks arisen from sea-level rise, land and coastal flooding hazard and storm surges, in Gdańsk due to climate change are analysed in the document *Plan of adaptation to climate change in the city of Gdańsk until 2030*. For this reason, Gdańsk CCLL has been considered to be more resilient than other CCLLs with no local coastal adaptation planning.

4.10.3. Final considerations

In summary, the impacts of both coastal and land flooding are similar in Gdańsk, as the exposed areas are closely related. Table 51 summarises how risk has been interpreted for the different elements considered. In general, the risk associated to both hazards has been considered higher than in other CCLLs, due to the large values of exposure. Moreover, the flooding hazards are likely to occur simultaneously, increasing the overall risk.

Table 51: High-level risk characterisation in Gdańsk CCLL.

Risk element	Coastal flooding	Land flooding
Population	High	Medium
Residential building	Medium	Medium
Commercial building	High	High
Industrial use	High	High
Agriculture	Medium	High
Beach areas	Medium	Low
Critical infrastructure	High	High
Areas of high ecological value	High	Medium

4.11. Samsun

4.11.1. Coastal erosion

The measurement of the indicators of *Relative sea-level change (mm/year)*, *Mean significant wave height (m)*, *Tidal range (m)* and *Lithotype hardness* were omitted in the comparative analysis performed in D1.3 for Samsun CCLL, as it has the status of Fellow and no data were available from the datasets utilised for this city. However, information on the two first parameters can be found in the publication *The Black Sea coastline erosion: Index-based sensitivity assessment and management-related issues*. As it was seen in D1.2, In this article, Tătui et al. (2019) computed a Coastal Sensitivity Index (CSI) at 1-km spatial scale for more than 4,000 geographical sectors around the Black Sea through the following parameters: shoreline changes in the last 33 years, type of coast (coastal geomorphology and lithology), coastal slope (from shoreline to 20 m depth), wave incidence, significant wave height during storm conditions and relative sea level rise. More details on how the parameters have been derived can be found on the publication.

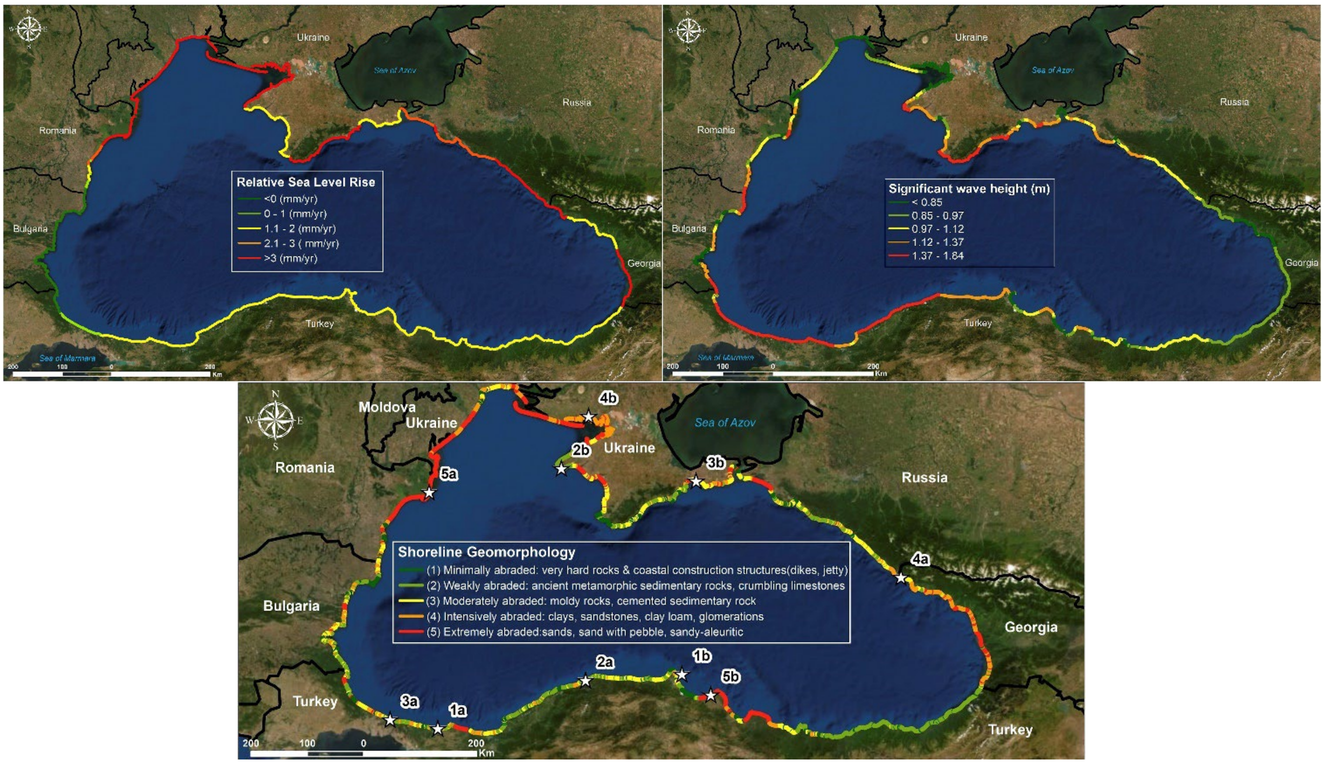

Figure 40: The relative rankings of the relative sea-level rise (top left), the significant wave height and the geomorphology parameters for the Black Sea coasts. Source: (Tătui et al., 2019).

Representative values of the indicators *Relative sea-level change (mm/year)*, *Mean significant wave height (m)* and *Lithotype hardness* have been measured from the previous source and scored according to the thresholds developed in D1.3. Regarding the parameter *Tidal range (m)*, it is widely known that the Black Sea has a very weak tidal range of less than 20 cm, mainly for being an enclosed sea. The results of the calculations of these parameters are summarised in Table 52, including the rest of indicators assessing coastal erosion.

Table 52: Summary of the indicators assessing coastal erosion risk in Samsun CCLL.

Indicator	Value	Threshold	Score
Relative sea-level changes (mm/year)	2.0	(0.5; 1.0)	High
Mean significant wave height (m)	1.4	(1.5; 2.5)	Low
Tidal range (m)	0.2	(0.5; 1.0)	Low
Lithotype hardness	Soft	(Hard; medium; soft)	High
Area of beaches, dunes, and sand plains within the LECZ (%)	2.7	(5; 10)	Low
Areas of high ecological value within the LECZ (%)	23.4	(10; 25)	Medium
Local coastal adaptation planning	No	(No; Yes)	High
National sea level rise preparedness	Not well	(Not well; Reasonably well; Well/very well)	High
MSL rise projections spatial scale	National	(Local; Regional; National)	High

The coastline of the province of Samsun is mainly shaped by the Kızılırmak Delta, with the plains of Bafra and Çarşamba and the city of Samsun between them. To Samsun's west, lies the Kızılırmak River (Bafra plain), to the east, lies the Yeşilırmak river (Çarşamba plain) and the Mert river reaches the sea at the city. The erosion of this deltaic region, including its lagoons, has been widely studied by the scientific community (Görmüş et al., 2021; Tătui et al., 2019; Allenbach et al., 2015; Ozturk et al., 2015; Ozturk & Sesli, 2015; Cüneyt et al., 2014; Faik & Sesli, 2010; Kökpinar et al., 2007). The shoreline changes in the delta have been determined in Ozturk et al. (2015) and Ozturk & Sesli (2015) between 1962-2013, showing that the dams built on the Kızılırmak River and close to the delta have significantly increased the erosion of the delta, especially near the river mouth. The spurs, which were built to prevent coastal erosion and provide partial protection, were found to be unable to fully prevent erosion.

Coastal erosion significantly affects the plains of Bafra and Çarşamba, whereas the coastline of the city of Samsun is less exposed. These areas are important centres of agricultural production, as well as home of diverse ecosystems and rich biodiversity, as it will be discussed in the next point.

4.11.2. Coastal flooding

The geographical extension of the province of Samsun is the largest between the coastal areas studied, with 9579 km^2, approximately, where about 10% of the area is under 10 m and connected to the sea. The length of the coastline of Samsun CCLL is of around 235 km, the second largest after Dublin CCLL (318 km). However, the relationship between the area of the LECZ and the length of the coastline is of 410 ha/km, which is the largest between the 10 CCLLs. According to the results from D1.3 (Table 53), approximately three quarters of the LECZ correspond to agricultural land (72.1%) and one quarter (23.4%), to areas of high-ecological value.

Table 53: Summary of the indicators assessing coastal flooding risk in Samsun CCLL.

Indicator	Value	Threshold	Score
LECZ area (%)	10.1	(10; 25)	Medium
LECZ / Coastline (ha/km)	410.0	(50; 150)	High
LECZ population (%)	18.2	(10; 25)	Medium
Most vulnerable population (age) (2020) (%)	8.38	(9; 11)	Low
Area of residential land use within the LECZ (%)	2.3	(10; 25)	Low
Area of industrial/ commercial land use within the LECZ (%)	1.1	(5; 10)	Low
Area of agriculture land use within the LECZ (%)	72.1	(20; 40)	High
Area of beaches, dunes, and sand plains within the LECZ (%)	2.7	(5; 10)	Low
Area of critical infrastructure within the LECZ (%)	0.7	(5; 10)	Low
Presence of railway within the LECZ	Yes	(No; Yes)	High
Presence of port within the LECZ	Yes	(No; Yes)	High
Presence of airport within the LECZ	Yes	(No; Yes)	High
Areas of high-ecological value within the LECZ (%)	23.4	(10; 25)	Medium
Local coastal adaptation planning	No	(No; Yes)	High

Indicator	Value	Threshold	Score
National sea level rise preparedness	Not well	(Not well; Reasonably well; Well/very well)	High
MSL rise scenario scale	National	(Local; Regional; National)	High

The main areas of high-ecological value encompass the deltas of Kızılırmak, Yeşilırmak and Terme, including the plains of Bafra and Çarşamba and the sandy beaches, rocky shores and coastal cliffs of Terme Coastline. The Kızılırmak Delta is recognized as a Ramsar site and is known for its rich biodiversity and diverse ecosystems, including wetlands, salt marshes, and lagoons. The Terme Delta is another significant wetland area and is a popular location for birdwatching and ecotourism due to its diverse avian population, including flamingos, herons, and other waterbirds. Coastal flooding can lead to the erosion and alteration of habitats within these ecological areas, the displacement and disruption of the natural movement and distribution of species, the introduction of pollutants and sediments and the inundation of nesting sites of birds and sea turtles within these ecological areas. In last term, coastal flooding can disrupt and destroy sensitive ecosystems, affect the breeding, feeding and migration patterns, and lead to population declines and reduced biodiversity.

The Bafra Plain is characterized by its significant agricultural productivity, including crops of grains, vegetables, fruits, and tobacco, by being a popular tourist destination, offering sandy beaches and green landscapes and by the growth of industrial zones and urban areas in recent years. The Çarşamba Plain is another agriculturally significant region known for its rice production and picturesque landscapes. Coastal flooding can produce damage to the crops or related infrastructure (e.g., irrigation systems), affecting the production and the contribution of agriculture to the economy and food security of Turkey.

Around the city of Samsun, the main risks identified are the presence of railway, port and airport infrastructure within the LECZ. In addition, the lack of coastal adaptation planning and the low scores of other parameters of adaptive capacity, show that improving the resilience is a critical issue in Samsun CCLL in the event of a coastal flooding episode.

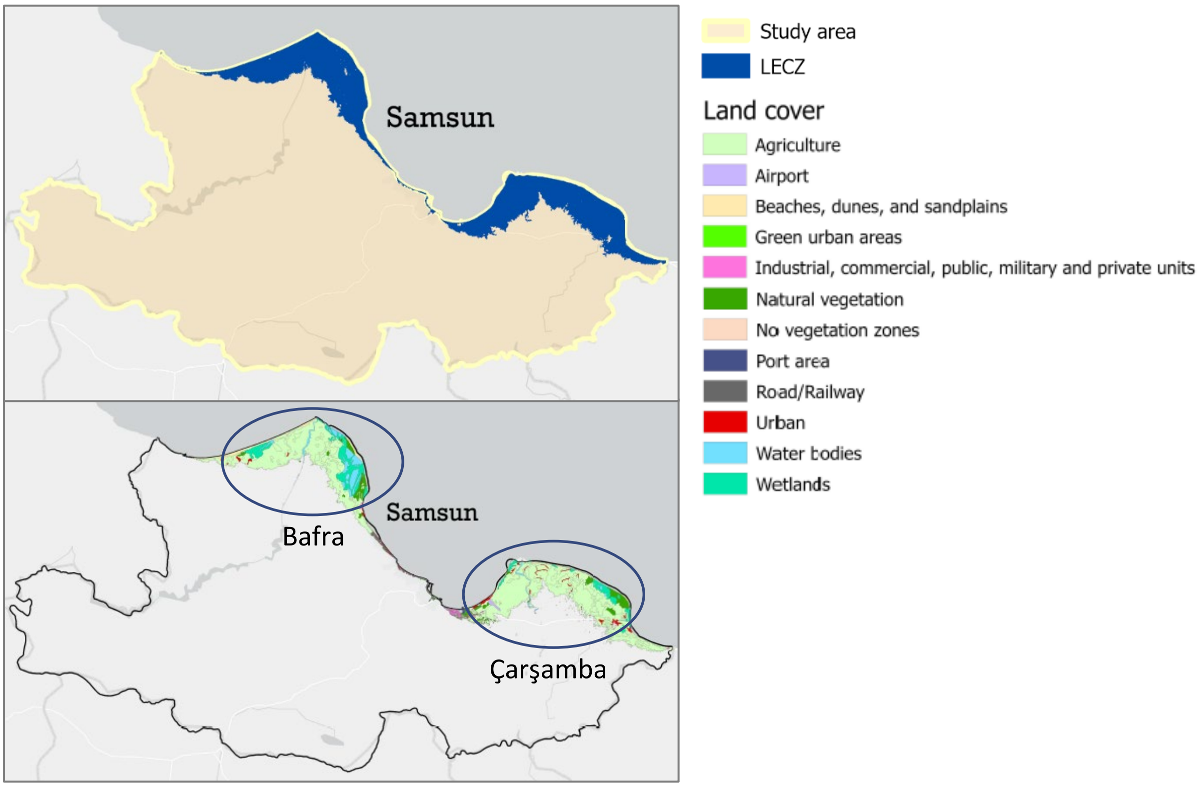

Figure 41: Samsun CCLL LECZ and its land cover.

4.11.3. Land flooding

The areas affected by land flooding are similar to the LECZ, putting at risk considerable areas of agriculture and high-ecological values (Table 54). The adaptive capacity is again seen as low, increasing the risk. Regarding the critical infrastructure, the airport is not included in the flood-prone areas. Moreover, it is observed that the areas potentially affected by land flooding are very similar to the LECZ (Figure 42). For this reason, the risk of compound flooding is perceived as notably high in Samsun CCLL.

Table 54: Summary of the indicators assessing land flooding (100-year return period) risk in Samsun CCLL.

Indicator	Value	Threshold	Score
Flood-prone area (%)	7.6	(10; 25)	Low
Flood-prone area population (%)	7.4	(10; 25)	Low
Most vulnerable population (age) (2020) (%)	8.38	(9; 11)	Low
Area of residential land use within the flood-prone area (%)	1.3	(10; 25)	Low
Area of industrial/ commercial land use within the flood-prone area (%)	0.2	(5; 10)	Low
Area of agriculture land use within the flood-prone area (%)	60.1	(20; 40)	High
Area of beaches, dunes, and sand plains within the flood-prone area (%)	2.8	(5; 10)	Low
Area of critical infrastructure within the flood-prone area (%)	0.1	(5; 10)	Low
Presence of railway within the flood-prone area	Yes	(No; Yes)	High
Presence of port within the flood-prone area	Yes	(No; Yes)	High
Presence of airport within the flood-prone area	No	(No; Yes)	Low

Indicator	Value	Threshold	Score
Areas of high ecological value within the flood-prone area (%)	37.4	(10; 25)	High
Local coastal adaptation planning	No	(No; Yes)	High

Moreover, land flooding affects the city of Samsun when the Mert River overflows. In this sense, it was shown in D1.2 that the total number of land flooding events between 1963-2012 was of eleven and that the greatest discharge value was produced in the Yılanlı Stream in the fourth of July in 2012, reaching a peak discharge of 710 m^3/s. These events have the potential to produce the lost of human lives and damage to the shopping centres, residential buildings, industry and other facilities such as the stadium of the city.

Demir & Kisi (2016) produced flood hazard maps of the Mert River basin using GIS and HEC-RAS for floods of different return periods (10, 25, 50, 100, and 1,000 years). The flood maps show that some areas are highly affected from the 10-year return period event. Under this scenario, the maximum depth reached is of 6.2 m and the flood area is of approximately 30% in the downstream of the Mert River. Around 650 houses are potentially affected by this flood. The comparison of the results with the flooding event occurred in 2012 shown similarity between them. The key result is that the flood-prone area generally covers industrial and residential areas and that it was seen that floods can be prevented in this region by adding levee and regulation of river bottom.

The risk associated to land flooding for population, industrial uses and residential buildings have been increased from low to medium considering the results of the previous study, as shown in Table 55.

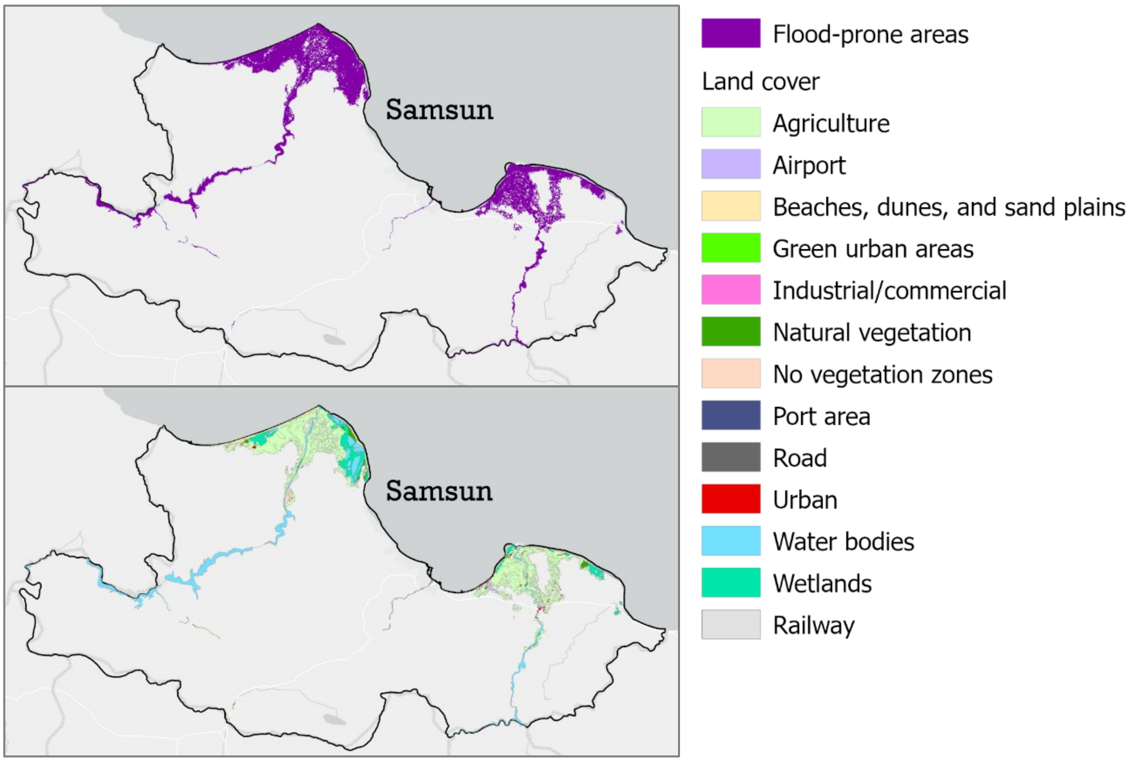

Figure 42: Samsun CCLL flood-prone areas (100-year return period) and their land cover.

4.11.4. Final considerations

The characterisation of risk considering coastal erosion, coastal flooding and land flooding and including the elements of population, residential buildings, commercial buildings, industrial uses, agriculture, beach areas, critical infrastructure and areas of high-ecological value is summarised in Table 55. The agricultural areas and ecosystems of the coastal plains of Bafra and Çarşamba are the main places at risk from the three hazards which are important centres of agricultural production of the country and a Ramsar site. Coastal erosion also affects a considerable extension of sandy beaches along the coastline of the province. Coastal flooding can affect key railway, port and airport infrastructure within the Samsun CCLL LECZ. Land flooding of the Mert River in Samsun can put at risk population, residential buildings and industrial uses. Finally, there is a considerable risk of compound flooding due to the similarity of the LECZ and the areas prone to land flooding.

Table 55: High-level risk characterisation in Samsun CCLL.

Risk element	Coastal erosion	Coastal flooding	Land flooding
Population	Low	Low	Medium
Residential building	Low	Low	Medium
Commercial building	Low	Low	Low
Industrial use	Low	Low	Medium
Agriculture	High	High	High
Beach areas	Medium	Low	Low
Critical infrastructure	Low	High	Medium
Areas of high ecological value	High	High	High

5.CONCLUSIONS

This report performs a high-level characterisation of risk in the ten coastal cities of Sligo (Ireland), Dublin (Ireland), Vilanova i la Geltrú (Spain), Benidorm (Spain), Oarsoaldea (Spain), Oeiras (Portugal), Massa (Italy), Piran (Slovenia), Gdańsk (Poland) and Samsun (Turkey) to the climate-change-related hazards identified in the document *D1.2 - Map and report of key climate-change hazards* in the context of the SCORE project, including coastal erosion, coastal flooding, land flooding, landslides, strong winds, forest fires and heat waves.

Baseline risk has been scored in a low-medium-high scale for population, residential areas, industrial and commercial uses, agriculture, beach areas, critical infrastructure and natural areas based in a series of indicators of vulnerability previously developed in the document *D1.3 - Map and report of baseline exposure and vulnerability*. Hot spots of risk have been identified after the study of the confluence of the different hazards in particular areas of the CCLLs and the complementary information provided by other assessments of risk and the results of the literature review developed in the document *D1.1 – Literature review report*.

This work constitutes the completion of the baseline risk analysis and mapping of extreme climate impacts and sea level rise in WP1, and the results provide an initial understanding of what are the main risks that the CCLLs face. These results will be exploited by the CCLLs, the rest of WPs and other stakeholders to help building climate resilience through EBAs and sophisticated digital technologies. In particular, a subsequent quantitative analysis of risk under climate change conditions will be carried out in WP6.

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APPENDIX I – INFORMATION SOURCES

Table 56: Summary of maps produced and data sources– Part I.

CCLL	Coastal erosion	Coastal flooding	Land flooding	Heat wave	Landslide	Forest fire	Strong winds
Sligo	Eurosion Database; European Landslide Susceptibility Map version 2 (ELSUS v2); Irish Coastal Protection Strategy Study – Phase V; Coastal Flood and Erosion Risk Management Study - Rosses Point/Drumcliff Bay (2016)	MERIT DEM; Corine Land Cover 2018; Strategic Flood Risk Assessment	River flood hazard maps for Europe and the Mediterranean Basin region (Dottori et al., 2021); Corine Land Cover 2018; Strategic Flood Risk Assessment	-	-	-	-
Dublin	Eurosion Database; European Landslide Susceptibility Map version 2 (ELSUS v2); https://www.floodinfo.ie; Climate Ireland; National Risk Assessment of Impacts of Climate Change: Bridging the Gap to Adaptation Action	MERIT DEM; Urban Atlas 2012; https://www.floodinfo.ie	River flood hazard maps for Europe and the Mediterranean Basin region (Dottori et al., 2021); Urban Atlas 2012	-	-	-	-
Vilanova i la Geltrú	-	MERIT DEM; Corine Land Cover 2018; Areas of periodic flooding (Vilanova i la Geltrú CCLL)	Corine Land Cover 2018; Areas of periodic flooding (Vilanova i la Geltrú CCLL)	European Climate Assessment & Dataset platform; Climate Change Adaptation Plan of Vilanova i la Geltrú	-	Corine Land Cover 2018; European Climate Assessment & Dataset platform; Climate Change Adaptation Plan of	Corine Land Cover 2018; CCLL partners

						Vilanova i la Geltrú	
Benidorm	Eurosion Database; European Landslide Susceptibility Map version 2 (ELSUS v2); CCLL partners	MERIT DEM; Urban Atlas 2012; CCLL partners	Urban Atlas 2012; Climate Change Adaptation Plan of Benidorm; Floods and Adaptation to Climate Change in Tourist Areas: Management Experiences on the Coast of the Province of Alicante (Spain); PATRICOVA	-	-	-	-
Oarsoaldea	Eurosion Database; European Landslide Susceptibility Map version 2 (ELSUS v2)	MERIT DEM; Corine Land Cover 2018	River flood hazard maps for Europe and the Mediterranean Basin region (Dottori et al., 2021); Corine Land Cover 2018	-	European Landslide Susceptibility Map version 2 (ELSUS v2); Corine Land Cover 2018	-	-
Oeiras	-	MERIT DEM; CCLL partners; Oeiras Climate Vulnerabilities Assessment for the Municipal Climate Adaptation Plan (PMAACO), 2020	CCLL partners; Oeiras Climate Vulnerabilities Assessment for the Municipal Climate Adaptation Plan (PMAACO), 2020; Hydrological and Hydraulic Study of the Oeiras Watersheds for the elaboration of a map of areas subject to flooding in accordance with Decree-Law No. 115/2010	-	-	-	-

Massa	Eurosion Database; European Landslide Susceptibility Map version 2 (ELSUS v2)	MERIT DEM; Urban Atlas 2012	-	-	European Landslide Susceptibility Map version 2 (ELSUS v2); Urban Atlas 2012	-	-
Piran	-	MERIT DEM; Corine Land Cover 2018	-	-	-	-	-
Gdańsk	-	MERIT DEM; Urban Atlas 2012; Plan of adaptation to climate change in the city of Gdańsk until 2030	Urban Atlas 2012; River flood hazard maps for Europe and the Mediterranean Basin region (Dottori et al., 2021); Plan of adaptation to climate change in the city of Gdańsk until 2030; Regional Water Management Board Gdańsk - pluvial flooding notifications; Regional Water Management Board Gdańsk - historical flooding events	-	-	-	-
Samsun	Spatiotemporal Analysis of Shoreline Changes of the Kızılırmak Delta; Shoreline change analysis of the Kızılırmak Lagoon Series; The Black Sea coastline erosion: Index-based sensitivity assessment and management-related issues	MERIT DEM; Urban Atlas 2012; Corine Land Cover 2018	River flood hazard maps for Europe and the Mediterranean Basin region (Dottori et al., 2021); Urban Atlas 2012; Corine Land Cover 2018	-	-	-	-

APPENDIX II – CALCULATIONS

Coastal erosion

Table 57: Scoring of risk to coastal erosion.

Indicator	Weighting	Sligo CCLL		Dublin CCLL		Benidorm CCLL		Massa CCLL		Samsun CCLL	
		Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score
Relative sea-level changes (mm/year)	10.00	High	10.00	Low	2.50	Medium	5.00	Medium	5.00	High	10.00
Mean significant wave height (m)	10.00	High	10.00	Low	2.50	Low	2.50	Low	2.50	Low	2.50
Tidal range (m)	10.00	High	10.00	Medium	5.00	Low	2.50	Low	2.50	Low	2.50
Lithotype hardness	20.00	Low	5.00	Medium	10.00	High	20.00	Medium	10.00	High	20.00
Area of beaches, dunes, and sand plains within the LECZ (%)	15.00	Medium	7.50	Low	3.75	High	15.00	Low	3.75	Low	3.75
Areas of high ecological value within the LECZ (%)	15.00	High	15.00	High	15.00	High	15.00	High	15.00	Medium	7.50
Local coastal adaptation planning	10.00	High	10.00	Low	2.50	Low	2.50	High	10.00	High	10.00
National sea level rise preparedness	5.00	Medium	2.50	Medium	2.50	Low	1.25	High	5.00	High	5.00
MSL rise projections spatial scale	5.00	High	2.50	High	5.00	Medium	2.50	High	5.00	High	5.00
Score	**100**		**72.50**		**48.75**		**66.25**		**58.75**		**66.25**

Coastal flooding

Table 58: Scoring of risk to coastal flooding. CCLLs of Sligo, Dublin, Vilanova i la Geltrú, Benidorm and Oarsoaldea.

Indicator	Weighting	Sligo CCLL		Dublin CCLL		Vilanova i la Geltrú CCLL		Benidorm CCLL		Oarsoaldea CCLL	
		Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score
Relative sea-level changes (mm/year)	5.0	High	5.00	Low	1.25	Medium	2.50	Medium	2.50	High	5.00
Mean significant wave height (m)	5.0	High	5.00	Low	1.25	Low	1.25	Low	1.25	Medium	2.50
Tidal range (m)	5.0	High	5.00	Medium	2.50	Low	1.25	Low	1.25	High	5.00
LECZ area (%)	10.0	Low	2.50	Low	2.50	Low	2.50	Low	2.50	Low	2.50
LECZ area per coastline length (m2/km)	5.0	Low	1.25	Low	1.25	Low	1.25	Low	1.25	Low	1.25
LECZ population (%)	5.0	Medium	2.50	Low	1.25	Low	1.25	Low	1.25	High	5.00
Most vulnerable population (age) (2020)	2.5	Medium	1.25	Medium	1.25	Medium	1.25	High	2.50	High	2.50
Area of residential land use within the LECZ (%)	5.0	Low	1.25	Medium	2.50	High	5.00	High	5.00	Medium	2.50
Area of industrial/ commercial land use within the LECZ (%)	5.0	Low	1.25	Medium	2.50	Medium	2.50	Low	1.25	Low	1.25
Area of agriculture land use within the LECZ (%)	5.0	High	5.00	High	5.00	Medium	2.50	Low	1.25	Low	1.25
Area of beaches, dunes, and sand plains within the LECZ (%)	5.0	Medium	2.50	Low	1.25	Low	1.25	High	5.00	Low	1.25

Area of critical infrastructure within the LECZ (%)	2.5	Low	0.63	Low	0.63	High	2.50	Low	0.63	High	2.50
Presence of railway within the LECZ	2.5	High	2.50	High	2.50	High	2.50	Low	0.63	High	2.50
Presence of port within the LECZ	2.5	High	2.50	High	2.50	High	2.50	High	2.50	High	2.50
Presence of airport within the LECZ	2.5	High	2.50	Low	0.63	Low	0.63	Low	0.63	Low	0.63
Areas of high ecological value within the LECZ (%)	12.5	High	12.50	High	12.50	Low	3.13	High	12.50	Medium	6.25
Local coastal adaptation planning	15.0	High	15.00	Low	3.75	Low	3.75	Low	3.75	High	15.00
National sea level rise preparedness	2.5	Medium	1.25	Medium	1.25	Low	0.63	Low	0.63	Low	0.63
MSL rise projections spatial scale	2.5	High	2.50	High	2.50	High	2.50	Medium	1.25	High	2.50
Total	**100.0**		**71.88**		**48.75**		**40.63**		**47.50**		**62.50**

Table 59: Scoring of risk to coastal flooding. CCLLs of Oeiras, Massa, Piran, Gdańsk and Samsun.

Indicator	Weighting	Oeiras CCLL		Massa CCLL		Piran CCLL		Gdańsk CCLL		Samsun CCLL	
		Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score
Relative sea-level changes (mm/year)	5.0	High	5.00	Medium	2.50	Medium	2.50	Medium	2.50	High	5.00
Mean significant wave height (m)	5.0	High	5.00	Low	1.25	Low	1.25	Low	1.25	Low	1.25
Tidal range (m)	5.0	High	5.00	Low	1.25	Low	1.25	Low	1.25	Low	1.25
LECZ area (%)	10.0	Low	2.50	Medium	5.00	High	10.00	High	10.00	Medium	5.00
LECZ area per coastline length (m2/km)	5.0	Low	1.25	High	5.00	Medium	2.50	High	5.00	High	5.00
LECZ population (%)	5.0	Low	1.25	High	5.00	High	5.00	High	5.00	Medium	2.50
Most vulnerable population (age) (2020)	2.5	Medium	1.25	High	2.50	High	2.50	Low	0.63	Low	0.63
Area of residential land use within the LECZ (%)	5.0	Medium	2.50	High	5.00	Low	1.25	Low	1.25	Low	1.25
Area of industrial/ commercial land use within the LECZ (%)	5.0	High	5.00	High	5.00	Low	1.25	High	5.00	Low	1.25
Area of agriculture land use within the LECZ (%)	5.0	Low	1.25	Low	1.25	Medium	2.50	Medium	2.50	High	5.00
Area of beaches, dunes, and sand plains within the LECZ (%)	5.0	Low	1.25	Low	1.25	Low	1.25	Low	1.25	Low	1.25
Area of critical infrastructure within the LECZ (%)	2.5	Medium	1.25	Low	0.63	Medium	1.25	Medium	1.25	Low	0.63

Presence of railway within the LECZ	2.5	High	2.50	High	2.50	Low	0.63	High	2.50	High	2.50
Presence of port within the LECZ	2.5	High	2.50	Low	0.63	High	2.50	High	2.50	High	2.50
Presence of airport within the LECZ	2.5	Low	0.63	Low	0.63	High	2.50	Low	0.63	High	2.50
Areas of high ecological value within the LECZ (%)	12.5	High	12.50	High	12.50	High	12.50	High	12.50	Medium	6.25
Local coastal adaptation planning	15.0	Low	3.75	High	15.00	High	15.00	Low	3.75	High	15.00
National sea level rise preparedness	2.5	Medium	1.25	High	2.50	High	2.50	Medium	1.25	High	2.50
MSL rise projections spatial scale	2.5	High	2.50	High	2.50	High	2.50	High	2.50	High	2.50
Total	**100.0**		**58.13**		**71.88**		**70.63**		**62.50**		**63.75**

Land flooding

Table 60: Scoring of risk to land flooding. CCLLs of Sligo, Dublin and Vilanova i la Geltrú.

Indicator	Weighting	Sligo CCLL		Dublin CCLL		Vilanova i la Geltrú CCLL	
		Score	Weighted score	Score	Weighted score	Score	Weighted score
Extent of flood-prone area (%)	30.0	Low	7.50	Low	7.50	Low	7.50
Flood-prone areas population (%)	5.0	Low	1.25	Low	1.25	Low	1.25
Most vulnerable population (age) (2020)	2.5	Medium	1.25	Medium	1.25	Medium	1.25
Area of residential land use within the flood-prone areas (%)	5.0	Low	1.25	Low	1.25	High	5.00
Area of industrial/ commercial land use within the flood-prone areas (%)	5.0	Low	1.25	Low	1.25	High	5.00
Area of agriculture land use within the flood-prone areas (%)	5.0	High	5.00	High	5.00	Medium	2.50
Area of beaches, dunes, and sand plains within the flood-prone areas (%)	5.0	Low	1.25	Low	1.25	Low	1.25
Area of critical infrastructure within the flood-prone areas (%)	2.5	High	2.50	Medium	1.25	Medium	1.25
Presence of railway within the flood-prone areas	2.5	High	2.50	High	2.50	High	2.50
Presence of port within the flood-prone areas	2.5	Low	0.63	High	2.50	High	2.50
Presence of airport within the flood-prone areas	2.5	Low	0.63	High	2.50	Low	0.63
Areas of high ecological value within the flood-prone areas (%)	12.5	Medium	0.00	Medium	0.00	Low	0.00
Local coastal adaptation planning	10.0	High	10.00	Low	2.50	Low	2.50
National sea level rise preparedness	5.0	Medium	2.50	Medium	2.50	Low	1.25
MSL rise projections spatial scale	5.0	High	5.00	High	5.00	High	5.00
Total	**100.0**		**42.50**		**37.50**		**39.38**

Table 61: Scoring of risk to land flooding. CCLLs of Oarsoaldea, Gdańsk and Samsun.

Indicator	Weighting	Oarsoaldea CCLL		Gdańsk CCLL		Samsun CCLL	
		Score	Weighted score	Score	Weighted score	Score	Weighted score
Extent of flood-prone area (%)	30.0	Low	7.50	High	30.00	Low	7.50
Flood-prone areas population (%)	5.0	Low	1.25	High	5.00	Medium	2.50
Most vulnerable population (age) (2020)	2.5	High	2.50	Low	0.63	Low	0.63
Area of residential land use within the flood-prone areas (%)	5.0	High	5.00	Low	1.25	Low	1.25
Area of industrial/ commercial land use within the flood-prone areas (%)	5.0	High	5.00	High	5.00	Low	1.25
Area of agriculture land use within the flood-prone areas (%)	5.0	Low	1.25	High	5.00	High	5.00
Area of beaches, dunes, and sand plains within the flood-prone areas (%)	5.0	Low	1.25	Low	1.25	Low	1.25
Area of critical infrastructure within the flood-prone areas (%)	2.5	High	2.50	Medium	0.63	Low	0.63
Presence of railway within the flood-prone areas	2.5	Low	0.63	High	2.50	High	2.50
Presence of port within the flood-prone areas	2.5	Low	0.63	High	2.50	High	2.50
Presence of airport within the flood-prone areas	2.5	Low	0.63	Low	0.63	Low	0.63
Areas of high ecological value within the flood-prone areas (%)	12.5	Medium	0.00	Medium	0.00	High	0.00
Local coastal adaptation planning	10.0	High	10.00	Low	2.50	High	10.00
National sea level rise preparedness	5.0	Low	1.25	Medium	2.50	High	5.00
MSL rise projections spatial scale	5.0	High	5.00	High	5.00	High	5.00
Total	**100.0**		**44.38**		**64.38**		**45.63**

Landslides

Table 62: Scoring of risk to landslides.

Indicator	Weighting	Oarsoaldea CCLL		Massa CCLL	
		Score	Weighted score	Score	Weighted score
Extent of the landslide-prone areas (%)	30.0	Medium	15.00	Medium	15.00
Landslide-prone areas population (%)	5.0	Medium	2.50	Medium	2.50
Most vulnerable population (age) (2020)	2.5	High	2.50	High	2.50
Area of residential land use within the LECZ within the landslide-prone areas (%)	5.0	Low	1.25	Low	1.25
Area of industrial/ commercial land use within the landslide-prone areas (%)	5.0	Low	1.25	Low	1.25
Area of agriculture land use within the landslide-prone areas (%)	5.0	Low	1.25	Low	1.25
Area of beaches, dunes, and sand plains within the landslide-prone areas (%)	5.0	Low	1.25	Low	1.25
Area of critical infrastructure within the landslide-prone areas (%)	2.5	Low	0.63	Low	0.63
Presence of railway within the landslide-prone areas	2.5	High	2.50	High	2.50
Presence of port within the landslide-prone areas	2.5	High	2.50	Low	0.63
Presence of airport within the landslide-prone areas	2.5	Low	0.63	Low	0.63
Areas of high ecological value within the landslide-prone areas (%)	12.5	High	0.00	High	0.00
Local coastal adaptation planning	20.0	High	20.00	High	20.00
Total	**100.0**		**51.25**		**49.38**

Forest fires

Table 63: Scoring of risk to forest fires.

Indicator	Weighting	Vilanova i la Geltrú CCLL	
		Score	Weighted score
Extent of the forest-fire-prone areas (%)	30.0	Medium	15.00
Forest-fire-prone areas population (%)	5.0	Low	1.25
Most vulnerable population (age) (2020)	2.5	Medium	1.25
Area of residential land use within the forest-fire-prone areas (%)	5.0	Low	1.25
Area of industrial/ commercial land use within the forest-fire-prone areas (%)	5.0	Low	1.25
Area of agriculture land use within the forest-fire-prone areas (%)	5.0	Medium	2.50
Area of beaches, dunes, and sand plains within the forest-fire-prone areas (%)	5.0	Low	1.25
Area of critical infrastructure within the forest-fire-prone areas (%)	2.5	Low	0.63
Presence of railway within the forest-fire-prone areas	2.5	Low	0.63
Presence of port within the forest-fire-prone areas	2.5	Low	0.63
Presence of airport within the forest-fire-prone areas	2.5	Low	0.63
Areas of high ecological value within the forest-fire-prone areas (%)	12.5	Medium	6.25
Local coastal adaptation planning	20.0	Low	5.00
Total	**100.0**		**37.50**

Strong winds

Table 64: Scoring of risk to strong winds.

Indicator	Weighting	Vilanova i la Geltrú CCLL	
		Score	**Weighted score**
Extent of the strong-wind-prone areas (%)	30.0	Medium	15
Strong-wind-prone areas population (%)	7.5	Medium	3.75
Most vulnerable population (age) (2020)	2.5	Medium	1.25
Area of residential land use within the strong-wind-prone areas (%)	5.0	High	5
Area of industrial/ commercial land use within the strong-wind-prone areas (%)	5.0	Low	1.25
Area of agriculture land use within the strong-wind-prone areas (%)	5.0	Medium	2.5
Area of beaches, dunes, and sand plains within the strong-wind-prone areas (%)	5.0	Low	1.25
Area of critical infrastructure within the strong-wind-prone areas (%)	2.5	Low	0.625
Presence of railway within the strong-wind-prone areas	2.5	High	2.5
Presence of port within the strong-wind-prone areas	2.5	High	2.5
Presence of airport within the strong-wind-prone areas	2.5	Low	0.625
Areas of high ecological value within the strong-wind-prone areas (%)	10.0	Medium	5
Local coastal adaptation planning	20.0	Low	5
Total	**100.0**		**46.25**

Heat waves

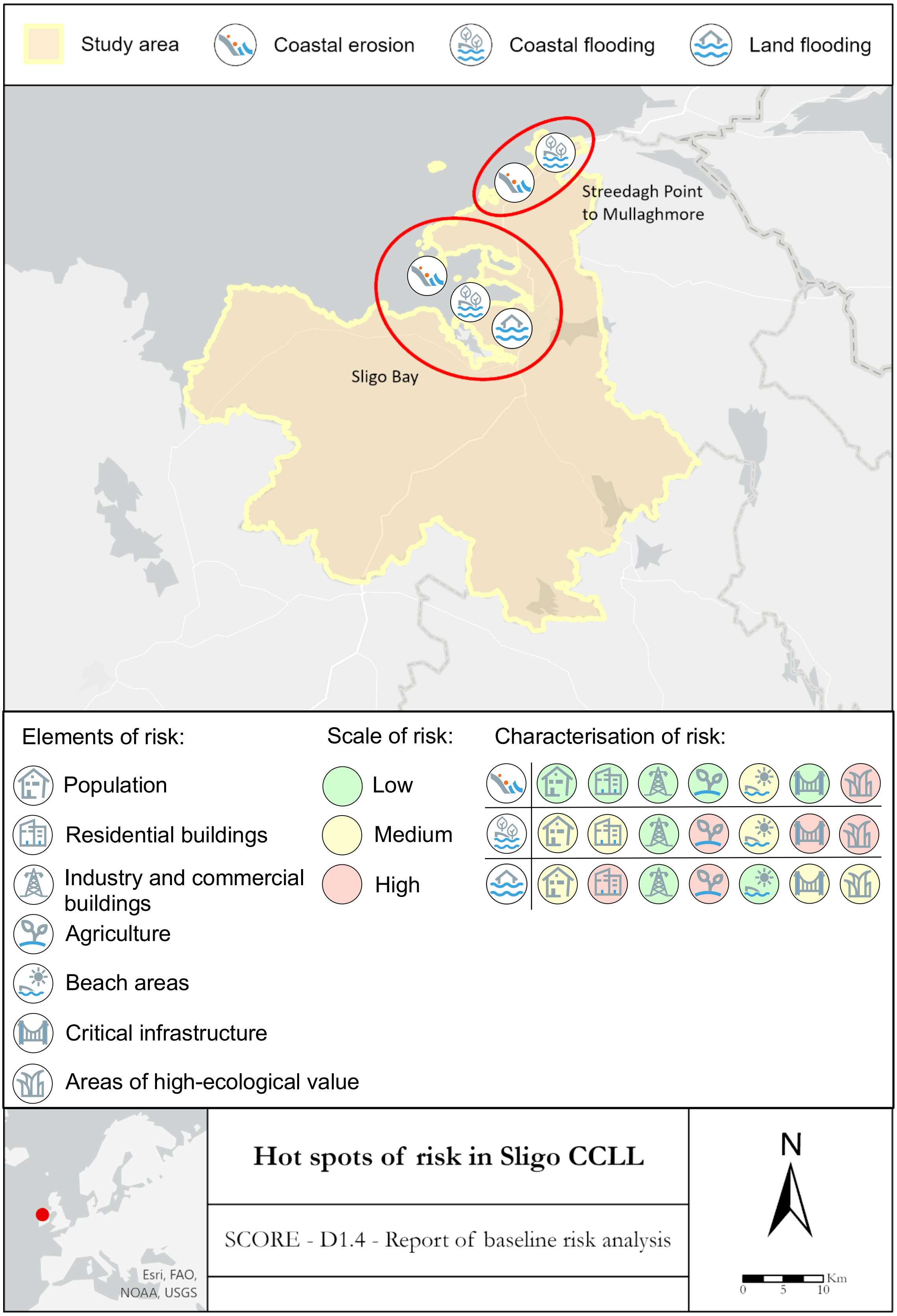
Table 65: Scoring of risk to heat waves.

Indicator	Weighting	Vilanova i la Geltrú CCLL	
		Score	Weighted score
Exposure to heat waves	30.0	High	30
Sensibility of population	7.5	High	7.5
Sensibility of residential land uses	5.0	High	5
Sensibility of economic activities	15.0	Low	3.75
Sensibility of critical infrastructure	10.0	Low	2.5
Sensibility of areas of high ecological value	12.5	Medium	6.25
Local coastal adaptation planning	20.0	Low	5
Total	**100.0**		**60.00**

APPENDIX III – MAPS

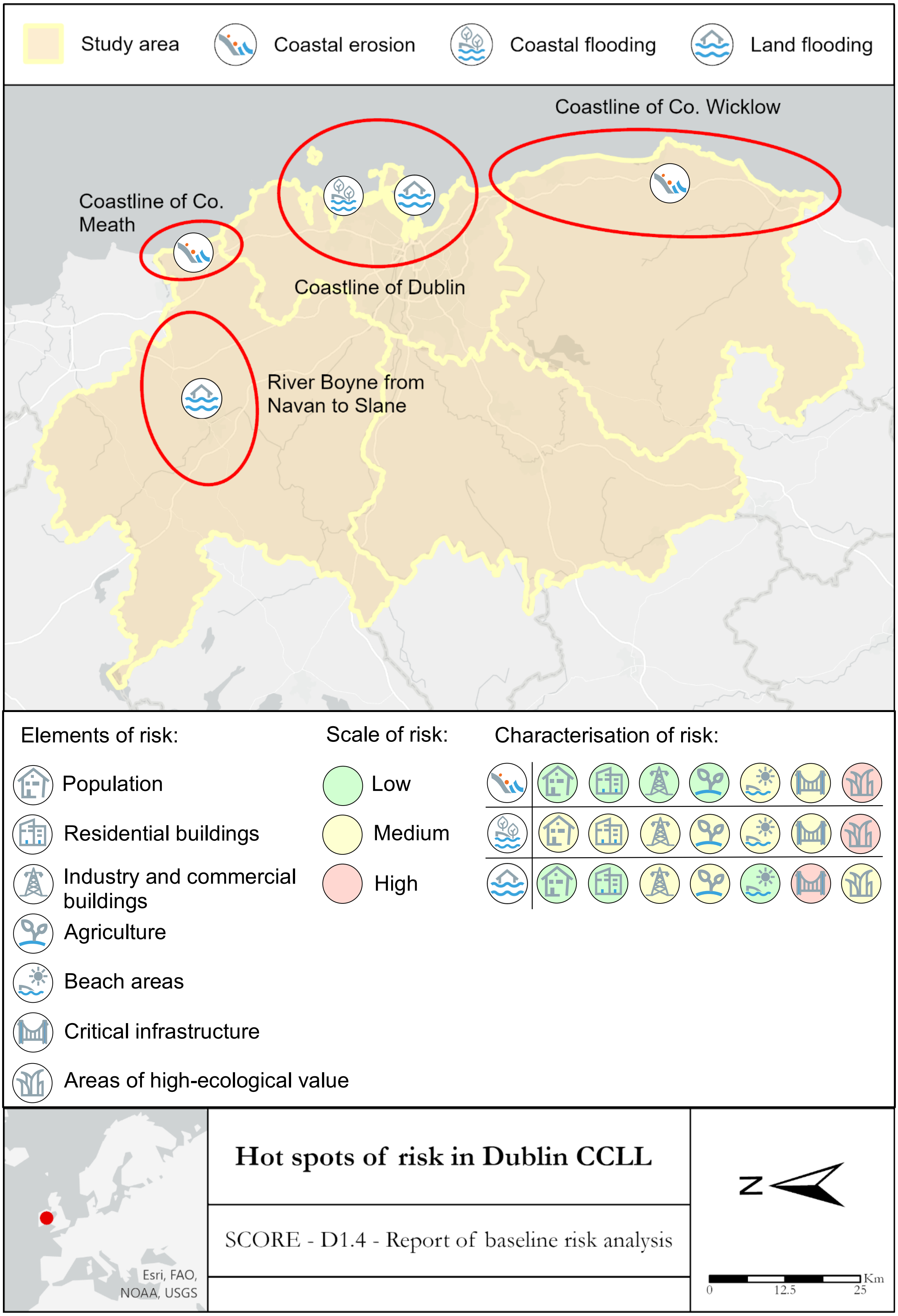
Sligo CCLL

Figure 43: Risk map of Sligo CCLL.



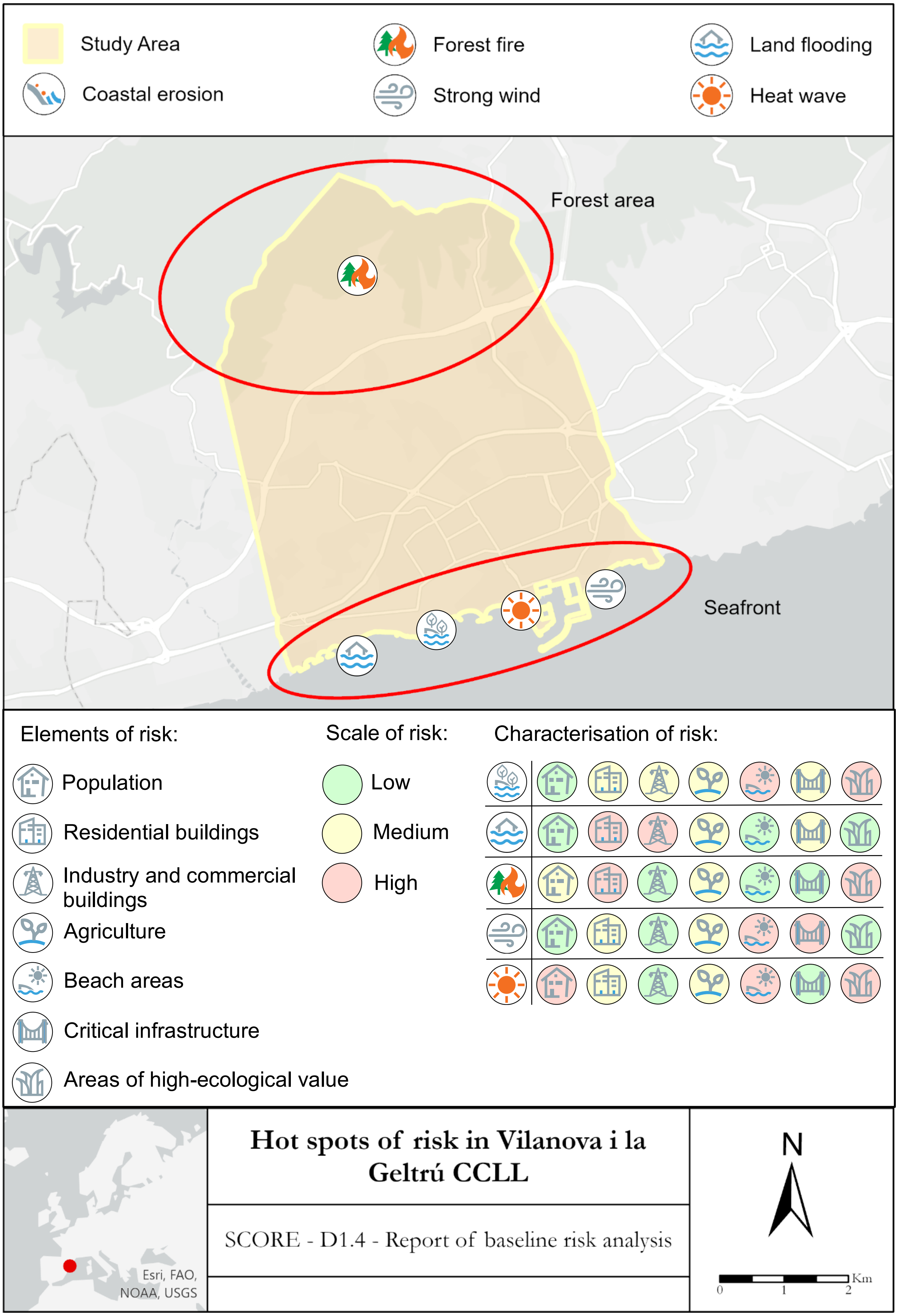
Dublin CCLL

Figure 44: Risk map of Dublin CCLL.



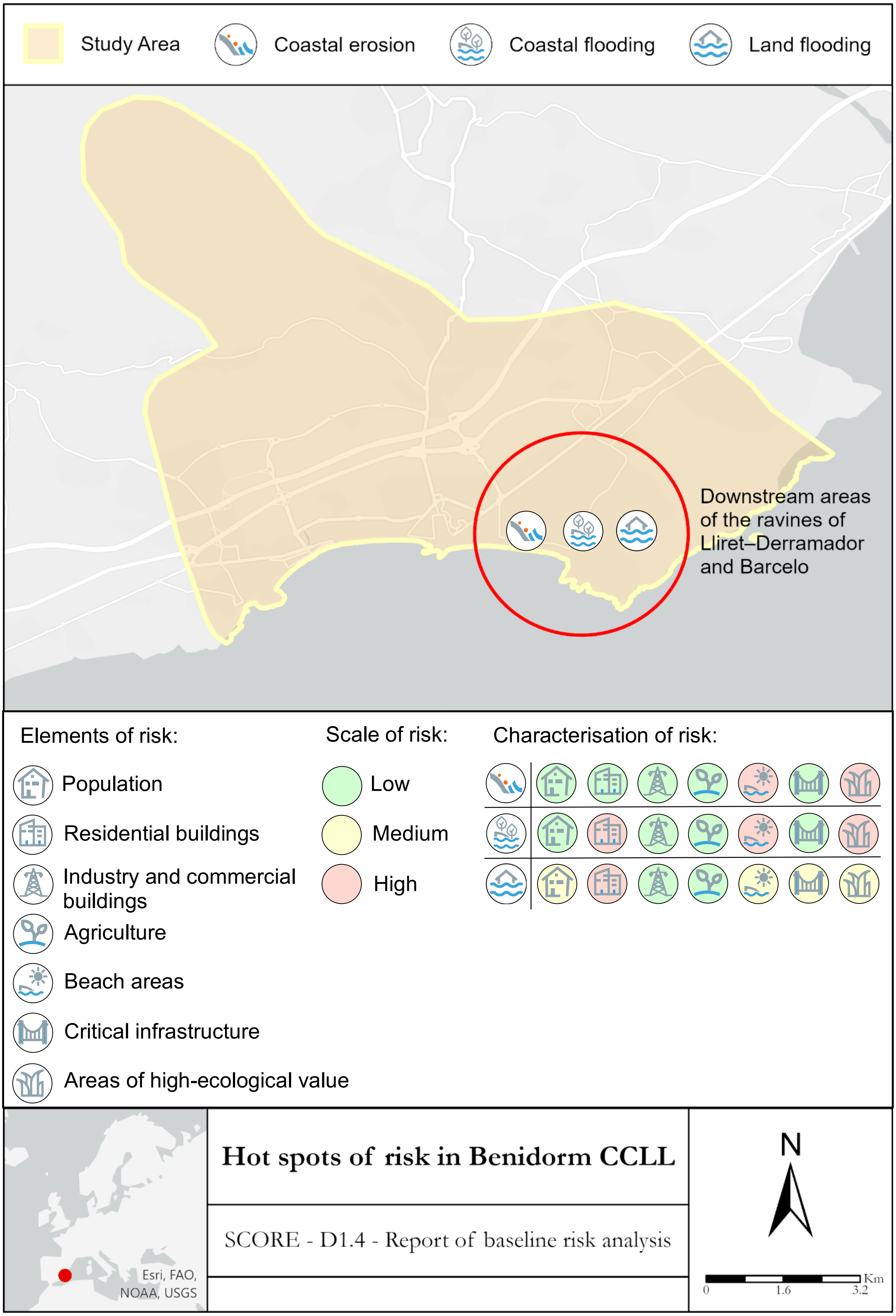
Vilanova i la Geltrú CCLL

Figure 45: Risk map of Vilanova i la Geltrú CCLL.



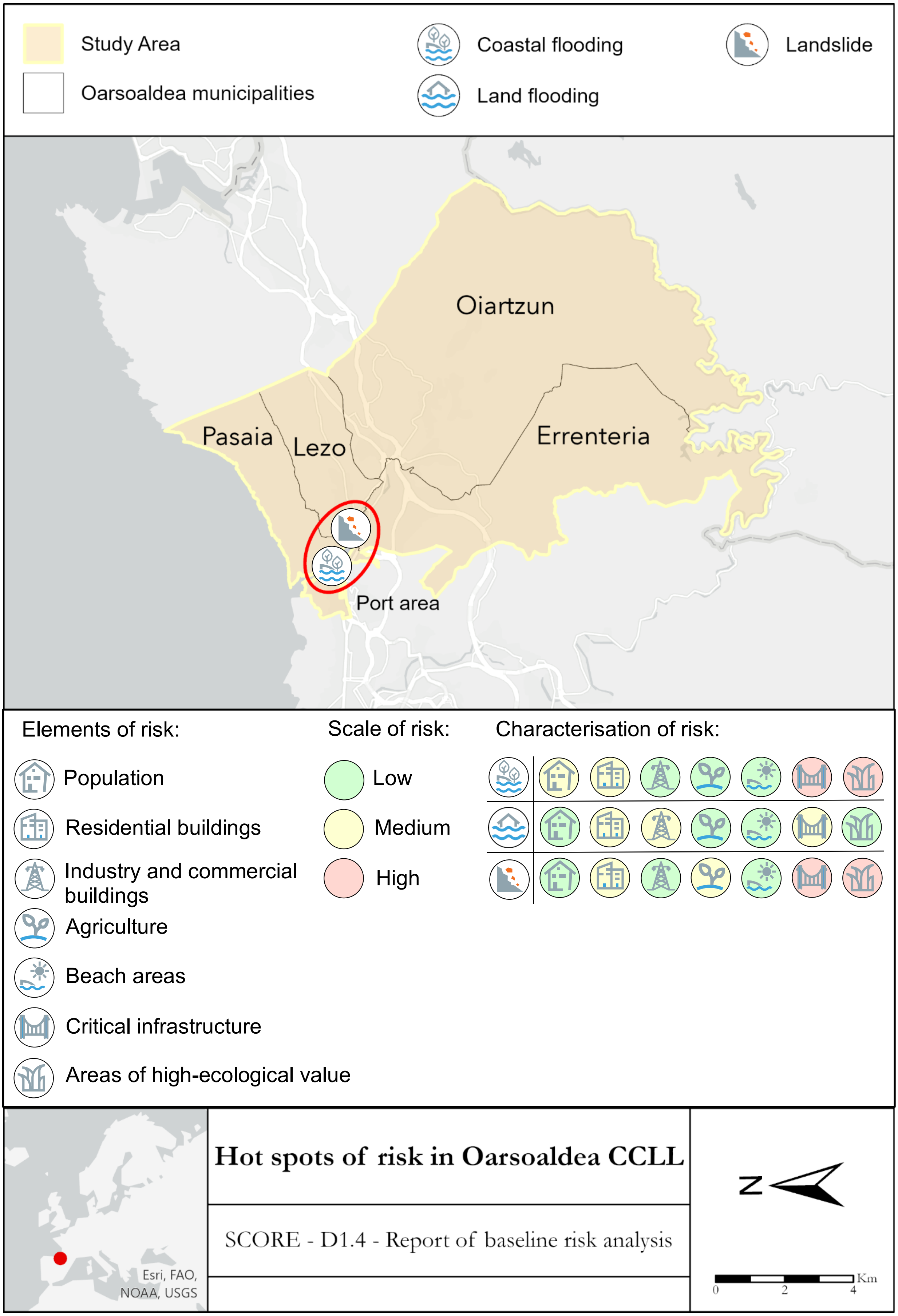
Benidorm CCLL

Figure 46: Risk map of Benidorm CCLL.



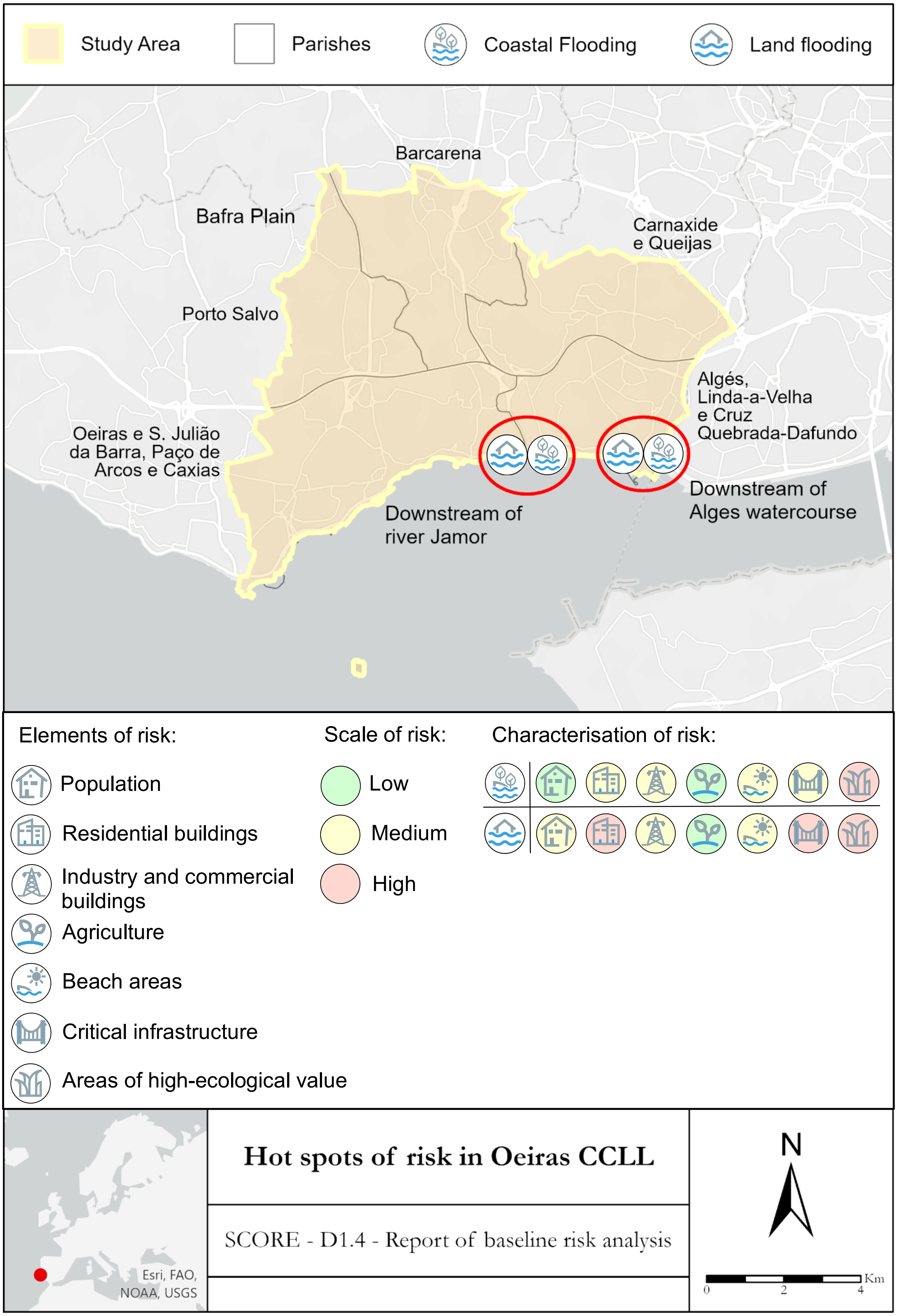
Oarsoaldea CCLL

Figure 47: Risk map of Oarsoaldea CCLL.



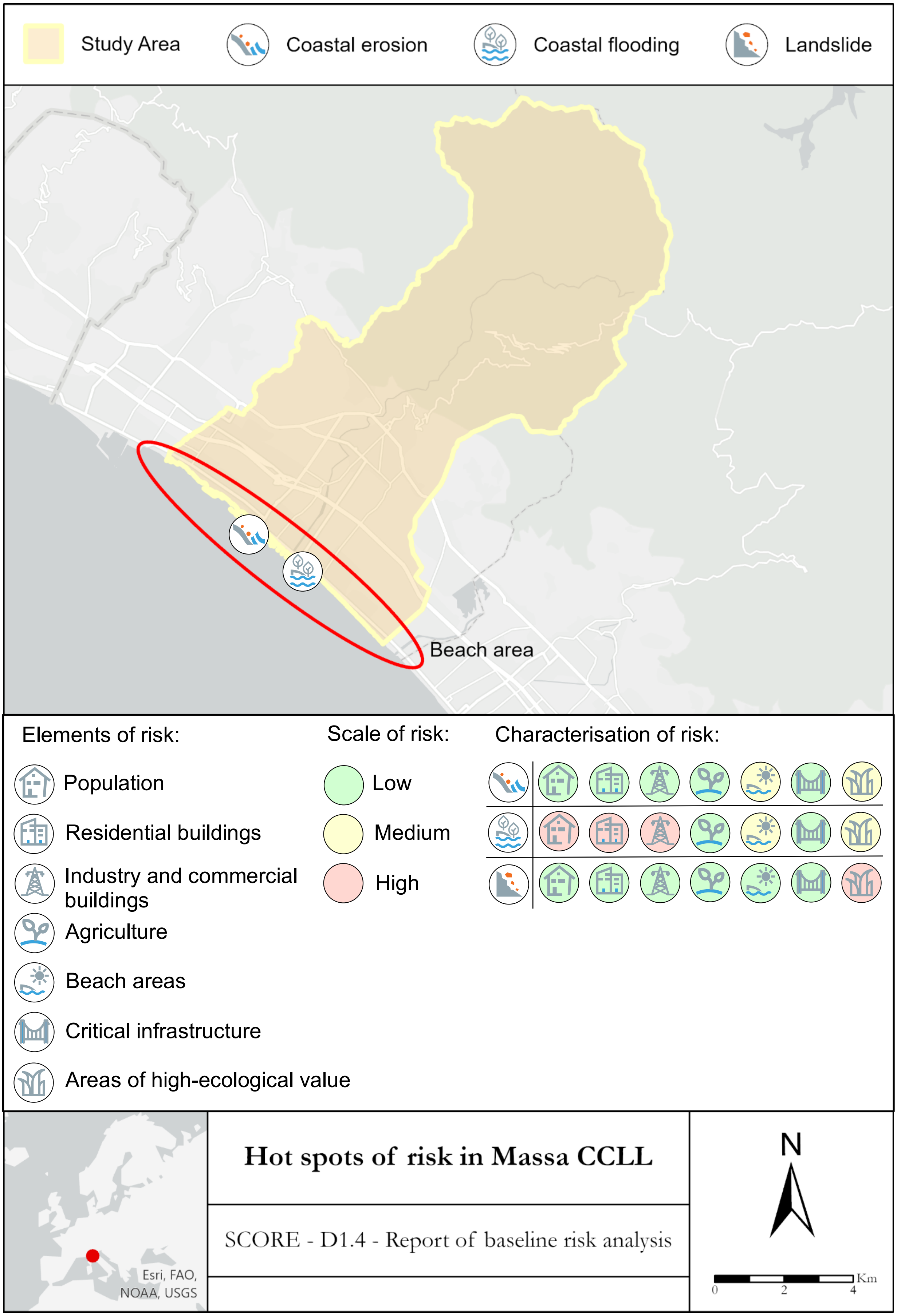
Oeiras CCLL

Figure 48: Risk map of Oarsoaldea CCLL.



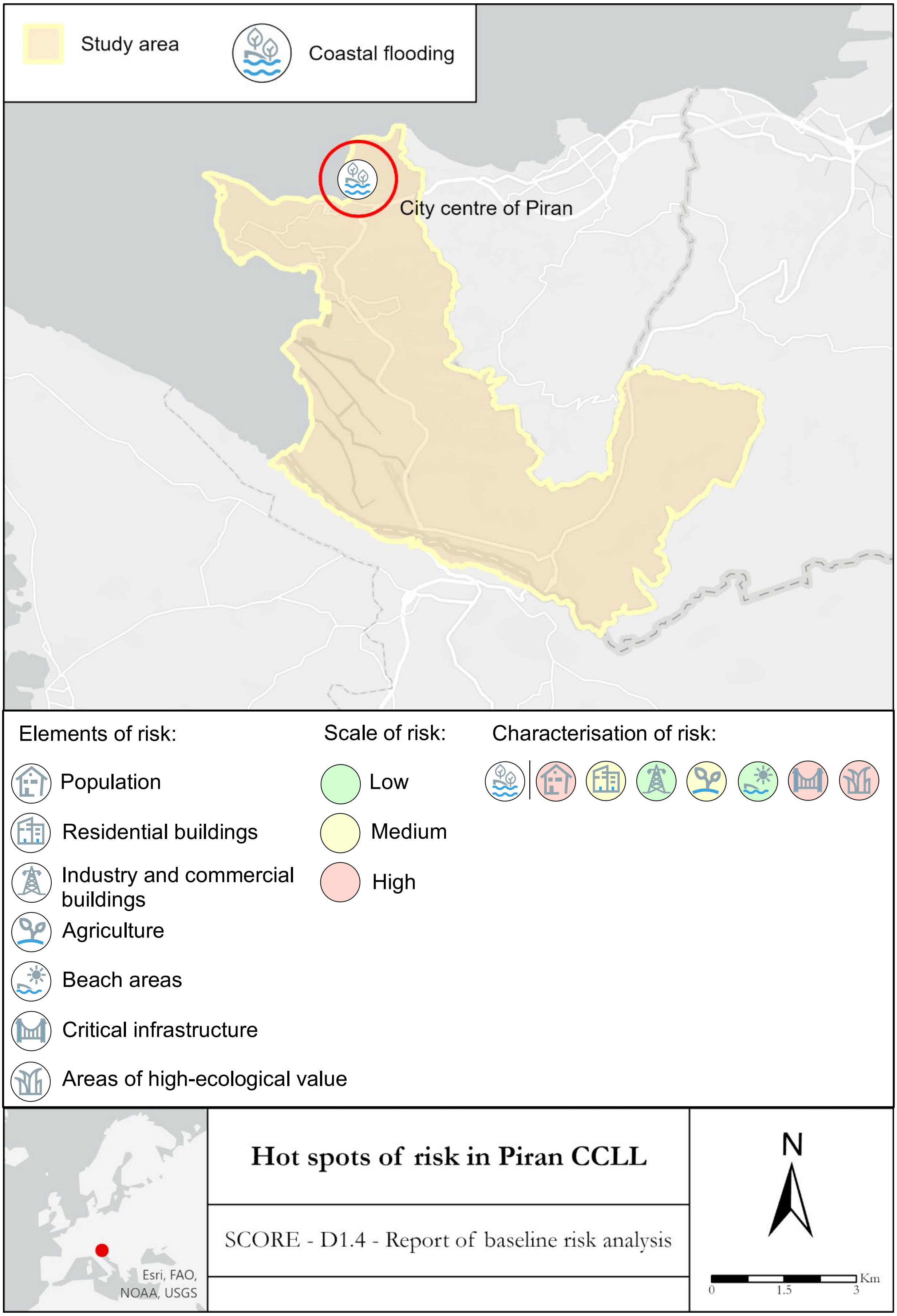
Massa CCLL

Figure 49: Risk map of Massa CCLL.



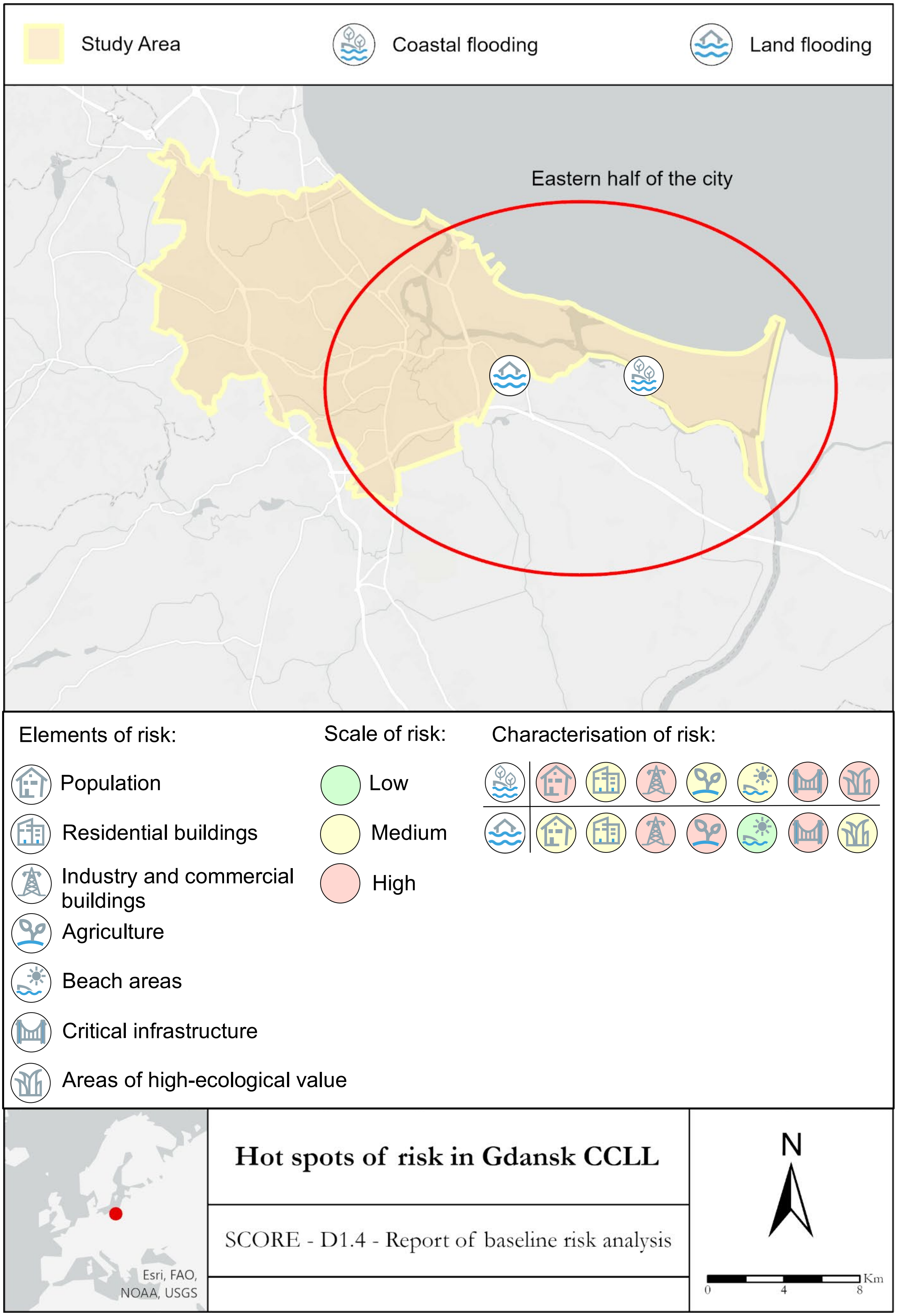
Piran CCLL

Figure 50: Risk map of Piran CCLL.



Gdańsk CCLL

Figure 51: Risk map of Gdańsk CCLL.



Adapted from: Urban Atlas 2012

Samsun CCLL

Figure 52: Risk map of Samsun CCLL.