Deliverable Phase 1 – Climate risk assessment

ClimateSmart Pomorie: "Charting a Sustainable Future" (CSP-Future)

Bulgaria, Pomorie Municipality

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HORIZON-MISS-2021-CLIMA-02-01 - Development of climate change risk assessments in European regions and communities based on a transparent and harmonised Climate Risk Assessment approach

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Abbreviations and acronyms

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Abbreviation / acronym	Description
CRA	Climate Risk Assessment
DRR	Disaster Risk Reduction
NIMH	National Institute of Meteorology and Hydrology

Executive summary

Motivation

This report concludes the first phase of the multi-risk assessment for Pomorie municipality under the CLIMAAX ClimateSmart Pomorie: "Charting a Sustainable Future" project. It addresses the need for science-based climate risk evaluation in local adaptation planning. The document provides local decision-makers and stakeholders with a comprehensive analysis of coastal flooding hazards. The process of drafting of the report has served to increase risk knowledge and awareness while supporting local policies to enhance the climate resilience of Pomorie Municipality, focusing on multi-risk climate assessment and targeted adaptation strategies.

Main results and findings

The frequency of coastal flooding in Pomorie has increased in the last years as a result of climate change and sea level rise. According to data from the National Institute of Meteorology and Hydrology, over the past 50 years, 12 cases of coastal flooding have been recorded in the Pomorie area, indicating an average frequency of one flood every four years. Over the last 20 years, analyses show an increase in the magnitude of events—on average 1–2 significant floods per decade—with a clear trend toward higher frequency and intensity.

The accuracy of global flood maps for Pomorie municipality is limited by local geographic and infrastructural factors. Coastal dikes, levees, and drainage systems are not represented, potentially overestimating flooding in protected areas. Missing information includes detailed local topography, cadastral data, building types, and historical flood records, which would improve precision in economic damage calculations. The maps of coastal flood potential and associated damages reveal which areas, both in the main town and peripheral settlements, are most exposed, showing that risk is not uniform across the municipality.

Another finding is that the exposure and vulnerability interplay is critical: high-density urban areas and economically valuable infrastructure show higher potential losses even for moderate inundation scenarios. The workflow demonstrates how to access European-scale land use datasets, assign vulnerability curves and maximum damages to each land use category, and combine hazard, exposure, and vulnerability data to estimate economic impacts. The understanding where damage originates is critical for prioritizing preventive measures: areas with high exposure and vulnerability require urgent attention. This is especially important in the context of limited financial and human resources of a small municipality like Pomorie.

In conclusion, the results of this initial coastal flood risk assessment of Pomorie municipality provide a good basis for the local climate adaptation planning on municipality scale, considering the upcoming drafting of a municipal disaster risk reduction program for the period 2025-2030. The process of completing this first report supports the overall CLIMAAX objective - to develop harmonized, science-based climate risk assessments adapted to the needs of European regions and municipalities and to enhance their climate resilience and adaptive capacity.

1. Introduction

1.1. Background

Pomorie Municipality is part of Burgas Province, Bulgaria, and is located in the South-East economic region (NUTS 2 BG4) of the country. The municipality covers a territory of 413.2 km², lying between 42°53'55"N – 42°33'04"N and 27°25'07"E – 27°39'48"E. This area is situated by the eastern boundary of the Balkan Peninsula, along the Black Sea coast, in close proximity to the boundary between Europe and Asia (Figure 1-1). Most of the municipality's territory belongs to the continental-mediterranean climatic region of Bulgaria, while the northern and northeastern sectors of the municipality fall within a transitional zone toward the temperate-continental climate region. The dominant baric systems influencing the local climate are the Mediterranean cyclones, which are most active during the cold half of the year. Icelandic cyclones, which intensify during the warm half of the year, have a weaker impact in this part of the country. Under the moderating influence of the Black Sea basin, the climate in Pomorie Municipality is characterized by reduced annual and diurnal temperature amplitudes, milder winters with very rare snowfalls, and cooler summers, as well as a warmer autumn and a relatively cool spring.

The municipality's diverse relief, comprising lowlands, hilly terrains, and low mountain areas, creates additional local climatic specifics superimposed on the general regional pattern. The territory is divided into three local subregions — Southern (the Black Sea coast), medial (the Tundzha undulating plain), and northern (the Eastern Stara Planina mountain). From southeast to northwest the impact of altitude becomes more pronounced, while the maritime influence gradually diminishes. This is also reinforced by the prevailing west-east air transport in this part of the world, which blocks to a certain extent the spread of maritime influence westward, towards the interior of the territory. The mean annual air temperature is approximately 13.5 °C, with July averages of 23–24 °C and January averages of 2–3 °C. The average sea water temperature in the period June - September is above 21°C, and is suitable for swimmers until October. Annual precipitation is relatively low — around 500-550 mm, with a lower number of rainy days in warm part of the year, which combined with over 2300 hours of sunshine per year, and lots of sun in the summer, creates favorable conditions for recreational-tourist resort activities and viticulture.

An additional natural resource of economic and recreational importance is **Lake Pomorie** — an ultrasaline lagoon (≈8.5–10 km²), separated from the sea by a sand spit and an artificial embankment. The lagoon has been exploited for salt production for over 20 centuries and is also a source of healing brine and therapeutic mud used in balneotherapy. This area, designated as a protected zone since 2001, is a key stopover site along the Via Pontica migratory corridor, hosting more than 200 bird species, including wintering colonies of flamingos.

Climate change impacts on the territory of Pomorie Municipality are manifested through a positive temperature anomaly and decreasing precipitation totals (Figure 1-2). At the same time, extreme weather events — such as heat waves, droughts, heavy downpour of rain, floods, and storms — are increasing in frequency and intensity. Climate projections indicate a sea level rise of up to 0.5–0.8 m by 2100, which could result in significant losses of beach and dune areas — a critical factor for tourism, salt production facilities, and protected wetlands. The municipality's population is particularly vulnerable, with a pronounced aging structure (a significant proportion aged 65+), coupled with a relatively small younger cohort.

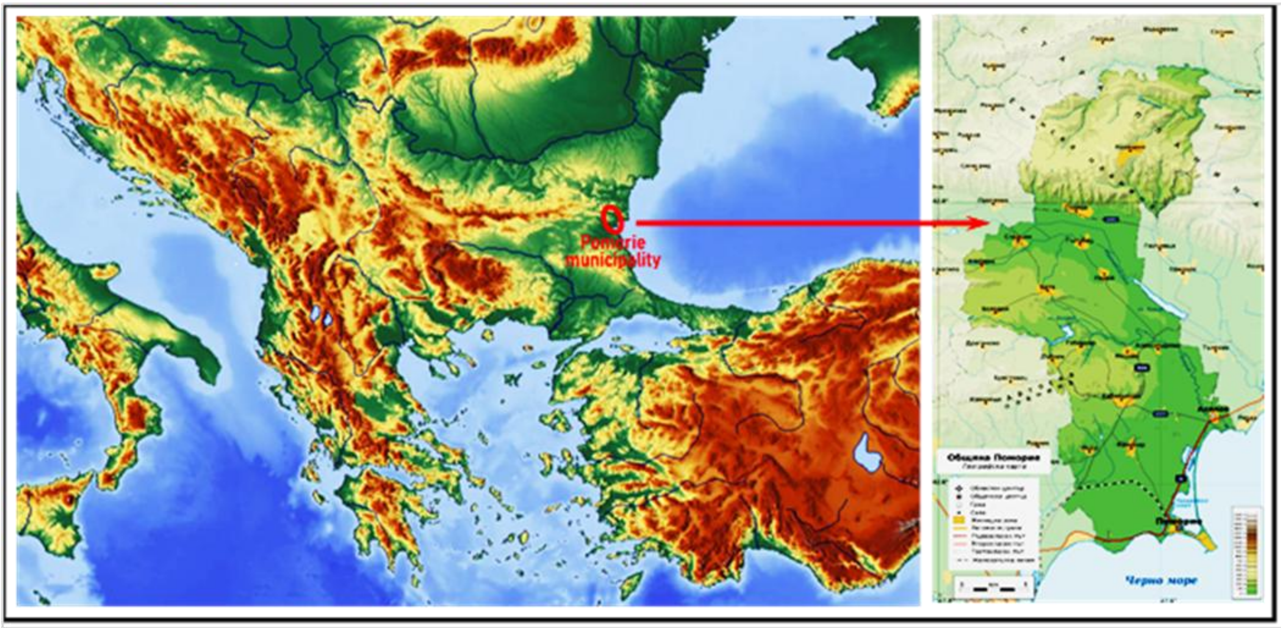

Figure 1-1 Geographical location of Pomorie municipality

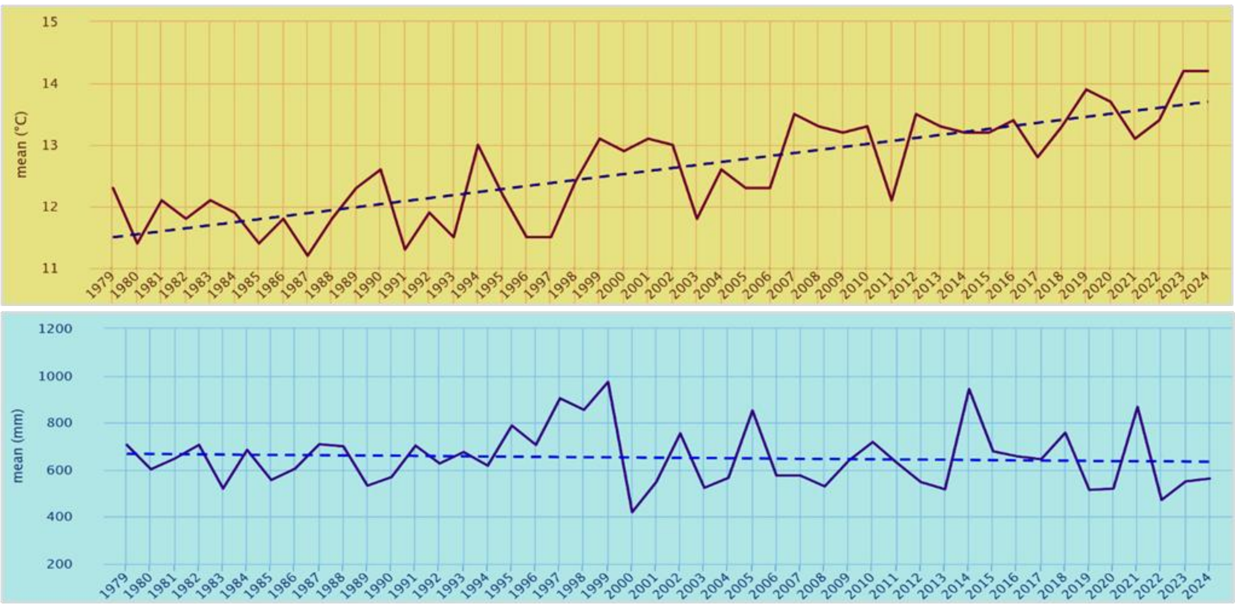

Figure 1-2 Mean annual air temperature (in yellow) and precipitation (in blue) in Pomorie – multi-annual courses and trends (1979-2024)

1.2. Main objectives of the project

The main objective of the ClimateSmart Pomorie project is to increase the knowledge and awareness about the climate risks and support local policies to enhance the climate resilience of Pomorie municipality, focusing on multi-risk climate assessment and targeted adaptation strategy. The specific objectives are:

- to improve the understanding and resilience to climate-related threats among residents, businesses, and policymakers to encourage proactive adaptation measures;
- to develop high resolution local data and climate models;
- to support climate-resilient policy development by providing evidence-based insights that inform and influence local policy-making, ensuring the integration of climate change considerations into urban planning, infrastructure development and disaster preparedness efforts.

The expected benefits of applying the CLIMAAX approach and Handbook are increased climate risk knowledge and awareness of the local authorities and population, e.g. by workshops and knowledge-sharing sessions with key stakeholders. A desired result will be a strengthened community resilience, stakeholder engagement and policy integration, incl. by collaboration with climate scientists, urban planners, and disaster management professionals to ensure scientific accuracy in risk assessments and development of policy recommendations and action plans for climate adaptation. The scientific and technical contributions by completion of a multi-risk climate assessment based on CLIMAAX methodology, high-resolution GIS maps and local datasets will enhance local capacity to analyse the climate risks and use climate models and scenario simulations to assess long-term impacts of climate change in Pomorie. This could lead to alignment of municipal climate adaptation planning with updated climate models and risk projections and identification of funding opportunities and mechanisms to sustain long-term climate resilience efforts.

1.3. Project team

The ClimateSmart Pomorie project’s team consists of experts who combine scientific and policy expertise with knowledge and understanding of the local circumstances. The team includes: Georgi Petkov - project manager responsible for overall project management, quality control and reporting functions; Dessislava Boneva - financial expert; environmental and climate expert - Plamen Peev (PhD); and municipal environmental experts responsible for data collection, communication activities, coordination of information with external services - Nadezda Ilieva and Marin Todorov. A public procurement procedure will be carried out to support the municipality in the next stages of the project.

1.4. Outline of the document’s structure

This document presents a climate risk assessment for Pomorie Municipality applying CLIMAAX methodology and focusing on coastal flooding. It presents first the main features of the project, including the project name, table of contents, lists of maps, figures, tables, abbreviations, and acronyms, followed by an executive summary that concisely outlines the assessment's key findings, methodology, and conclusions for stakeholders like the municipal government and fire department.

The report then covers an Introduction detailing background conditions of the municipality, the project objectives, the implementation team, and document structure. Chapter 2 is a key element of the report with Climate Risk Assessment, Phase 1, which defines the assessment's objectives, explores the hazards of coastal flooding, analyzes its risks, evaluates their severity, urgency, and existing capacity, and describes monitoring and evaluation methods. The report continues with Chapter 3 summarizing key findings and risk implications for Pomorie, and Chapter 4 on progress evaluation, setting the stage for future steps. Chapter 5 contains supporting documentation and references, and Chapter 6 lists sources, including academic literature, municipality reports.

2. Climate risk assessment – phase 1

2.1. Scoping

2.1.1. Objectives

Objective of the CRA

The overarching objective of the CRA is to increase climate risk knowledge and awareness in Pomorie Municipality, ultimately enhancing the region's capacity to anticipate, withstand, and adapt to the escalating impacts of climate change. This is achieved by conducting a multi-risk climate assessment and developing targeted adaptation strategies that bridge science, policy, and community engagement.

Purpose and Expected Outcome

The purpose of the CRA is to provide a robust evidence base for understanding both present and future climate-related risks in Pomorie—such as floods, droughts, heatwaves, storm surges, windstorms, and coastal erosion—through a detailed, data-driven, and participatory process. By evaluating the potential impacts of climate change on society, infrastructure, the local economy, and vulnerable communities, the assessment seeks to:

- Identify and estimate exposure to climate hazards across sectors (agriculture, water supply, tourism, health, infrastructure, ecosystem services).
- Forecast and prioritize the most significant and pressing risks for decision-makers.
- Support informed adaptation planning to safeguard livelihoods, assets, and essential services.

The expected outcomes include:

- Comprehensive risk profiles for key hazards, mapped and contextualized for Pomorie's socio-economic landscape.
- High-resolution local climate datasets and scenario analyses that project future trends and vulnerabilities;
- A prioritization of adaptation needs and feasible intervention points;
- Engaged stakeholders—from municipal officials to community groups—empowered with knowledge to take proactive measures;

- Tailored adaptation strategies and policy recommendations ready for implementation in local and regional planning frameworks;
- Policy and decision-making Integration.

The expected outcome is a robust climate risk profile for Pomorie, which feeds directly into municipal disaster risk protection plan and municipal disaster risk reduction program, adaptation strategies and urban, land use, and infrastructure development plans. The results of the climate risk assessment could be integrated in local strategic and operational documents, influencing development priorities and budget allocations. This product of the CRA will enable Pomorie's leadership to make evidence-based decisions about land use, investment, and infrastructure, adapt local governance strategies based on objective risk assessments, ensure compliance and alignment with Bulgarian, EU, and international climate policy standards.

The CRA's results are intended to feed directly into policy and decision-making by informing revisions of the municipal disaster risk reduction program, land use, and infrastructure plans. Guiding budgetary allocations for climate resilience actions. Ensuring that Pomorie's strategic documents incorporate up-to-date risk data, scenario modeling, and adaptation needs. Supporting alignment with national and EU climate policy and funding instruments.Providing evidence for applications to climate adaptation funds and for communication with higher-level governments and stakeholders.

Several limitations and boundaries are recognized, such as:

- Data availability and quality: high-resolution, long-term climate and vulnerability data are limited, which may constrain model precision and projections.
- Technical and financial resources: the municipality faces constraints in expert capacity, funding, and access to advanced analytic tools, which may limit the depth and scope of some risk analyses and adaptation planning;
- Stakeholder involvement: Time, logistical, and resource limitations may affect the ability to involve all relevant groups, especially marginalized or vulnerable communities, throughout every phase.

Worst-case scenarios: in the context of adaptation, certain hazards—such as catastrophic flooding or prolonged drought—might exceed local coping capacities, underscoring the need for regional and national support and the critical role of scenario planning.

The CRA objectives and outcomes are inherently linked: The assessment's scientific foundation and participatory process ensure that results are not only credible and actionable but also accessible to non-experts. This influences the communication strategy, enabling the translation of complex analyses into clear recommendations for decision-makers and awareness materials for the broader public. Regular workshops, a dedicated project webpage, and media outreach will ensure results inform both local action and broader regional discourse on climate resilience.

The implementation follows a structured, phased approach over 22 months:

Phase 1: Initial Risk Identification and Baseline Analysis (Months 1–6) included - Project kick-off, stakeholder engagement, and local data inventory.

Applying the CLIMAAX methodology for preliminary climate risk mapping. Deliverable: Baseline risk assessment report.

Phase 2: Detailed Multi-Risk Assessment and Scenario Planning (Months 7–16)

Collection and analysis of high-resolution local and regional data. Refinement of risk scenarios; in-depth vulnerability analysis for prioritized hazards and sectors. Extensive stakeholder workshops to validate findings. Deliverable: Advanced multi-risk assessment report.

Phase 3: Adaptation Strategy Development and Policy Integration (Months 16–22)

Drafting and revising adaptation actions and integrating them into municipal planning documents. Final community consultations and awareness campaigns. Deliverable: Final adaptation strategy and updated municipal risk management documentation.

Key stakeholders of the project include the administration and municipal council of Pomorie municipality, the relevant regional and national authorities, local businesses, NGOs, vulnerable groups, and community organizations, Research and expert organizations (e.g., NIMH, Bulgarian Academy of Sciences).

2.1.2. Context

Main Climate Hazards

Pomorie, located on the Bulgarian Black Sea coast, faces a variety of climate-related hazards:

- Flooding and coastal inundation: The area is increasingly vulnerable due to torrential rains, storm surges, and sea-level rise. Historical floods, such as those in November 2014, caused significant damage including river overflow leading to inundation and destruction of infrastructure and agriculture, with economic losses estimated in millions of euros. Coastal erosion and flooding risks are accentuated by the rising Black Sea levels (~3 mm/year) and extreme weather events.
- Drought and water scarcity: Recurrent prolonged droughts have intensified, reducing water availability significantly (e.g., a 40% drop in agriculture yield during 2020 drought). These droughts also increase fire risks and affect ecological balance, including salinity changes in the Pomorie lagoon impacting biodiversity and economic activities such as salt production.
- Extreme wind storms: Pomorie experiences frequent hurricane-force winds and associated storm damages. The 2022 windstorm caused damages estimated in millions of euros, including destruction of vineyards and infrastructure.
- Temperature extremes: Both heatwaves and cold spells affect the municipality. Heatwaves have increased in frequency, with temperatures above 40°C, raising public health issues and energy demand. Cold spells and snowstorms have also caused major disruptions.
- Other hazards: Increased risk from landslides and the spread of invasive species in the ecosystem further complicate local vulnerabilities.

These all affect direct economic losses due to crop and infrastructure damage. Disruption to tourism and agricultural livelihoods, which are mainstays of Pomorie's economy. Ecological degradation of lagoon habitats, with altered water salinity threatening biodiversity. Increasing social vulnerability due to impacts on public health and safety.The context of climate hazard, impact, and risk assessment in Pomorie Municipality is closely connected to both local realities and Bulgaria's broader national disaster risk reduction and climate adaptation policies. Below is a detailed analysis based on the provided documents.

Local Approaches in Pomorie.

Historically, Pomorie Municipality has confronted a range of climate-related hazards—including floods, coastal storms, droughts, heatwaves, strong winds, cold spells, and invasive species outbreaks. The local management of these hazards has primarily relied on: Reactive responses to extreme events (e.g., flooding, storm surges, prolonged drought) rather than proactive, integrated adaptation planning. Use of general municipal disaster risk reduction (DRR) plans and ad hoc technical interventions (repair of damaged infrastructure, emergency water supply provisions). Periodic participation in regional and national initiatives focused on risk prevention, but often as part of top-down mandates rather than as locally driven processes.

Nature of past assessments

Up to now, risk assessments in Pomorie have been constrained by several factors:

- Limited data availability and granularity: Access to high-resolution, up-to-date municipal climate, hydrological, and vulnerability data has been a continual challenge.
- Insufficient technical expertise and financial resources for sophisticated scenario modeling or vulnerability mapping at the municipal level;
- Lack of sustained community engagement and systematic public awareness campaigns, with most education occurring around or after emergencies;
- Existing plans and assessments have generally not incorporated the full spectrum of multi-risk, cross-sectoral, and climate change-driven threats, nor have they consistently used the latest methodologies required by EU policy and national regulations.

Regional/National Context

At the national level, Bulgaria has significantly upgraded its policies and institutional frameworks in recent years, adopting:

- The National Disaster Risk Reduction Program (2021–2025), which sets strategic and operational goals for DRR, climate adaptation, and sustainable development across all levels of governance.
- The National Strategy for Adaptation to Climate Change (2019+), which lays out priorities for sectoral risk management, scientific capacity building, and alignment with EU and international best practice.

Despite these advances, the translation of national strategies to actionable, data-driven, and community-embedded municipal plans has been incomplete, especially in resource-limited, medium-sized municipalities like Pomorie. The central problem targeted by the project is the limited ability of Pomorie Municipality to proactively anticipate, assess, and manage evolving climate risks in a way that is scientifically robust, locally relevant, and institutionally sustainable. This challenge is characterized by:

- Reactive risk management: Efforts have been more focused on post-event recovery, rather than on systematic risk identification, early warning, or prevention and adaptation.

- Data and expertise gaps: There is an absence of locally tailored, high-resolution climate risk and vulnerability information, partly due to lack of technical capacity, limited access to modern risk modeling tools, and underfunding of municipal adaptation efforts.
- Fragmented policy integration: Existing municipal plans have generally lagged in integrating climate adaptation systematically into urban planning, environmental protection, infrastructure development, agriculture, and public health strategies.

Placement in the Wider System (Regional/National Development)

National Policy Alignment

The project positions Pomorie at the forefront of efforts to harmonize local action with national and European Union policies:

- Directly addresses core objectives from the National DRR Program: reducing vulnerability, building institutional and technical capacity, and embedding risk management across municipal functions.
- Fills recognized gaps by providing locally adapted, actionable climate risk assessments using high-resolution data and participatory processes—as called for by both the National Strategy for Climate Change Adaptation and the EU Green Deal.

The project addresses key climate risks for the municipality, including in the context of regional and national development, since the powers of the municipality and the financial resources at its disposal are not always sufficient for planning and implementing climate adaptation measures. In this sense, cooperation with the regional administration, as well as with central government bodies such as the Ministry of Environment and Water, is of particular importance.

At the national level, the National Strategy for Adaptation to Climate Change and Action Plan to 2030 outlines the framework for actions and priority areas for adaptation to climate change by 2030. The Strategy covers various sectors, including agriculture, forestry, biodiversity, water, energy, transport, urban environment, health and tourism. An example of a specific activity that municipalities should undertake according to the Action Plan to the Strategy in the Urban Environment sector under Strategic Objective 1 Improving the policy and legal framework for mainstreaming climate change adaptation is the review and updating of the requirements for the scope and content of the main instruments such as regional and spatial development schemes and plans and detailed development plans.

Regional Development and Sustainability

Pomorie's CRA is tightly coupled with regional sustainable development strategies, including:

- Coastal zone management and flood prevention, reflecting the municipality's exposure to Black Sea hazards and low-lying topography.
- Risk-informed investment and planning, as advocated in both national and EU policy, with a focus on maintaining economic viability in tourism and agriculture—sectors that sustain municipal livelihoods but are highly climate-sensitive.
- Strengthening cross-sectoral cooperation (water management, health services, infrastructure) and encouraging innovation, capacity building, and public-private partnerships—all explicitly promoted in the National Program's operational objectives.

The project is essential for transforming Pomorie's approach from compliance-driven, siloed risk management to an integrated, anticipatory, and community-engaged climate adaptation paradigm. It sets a model for other Bulgarian municipalities facing similar constraints, helping to unlock national and EU support while making the region more resilient, sustainable, and inclusive in the face of escalating climate risks. By grounding the local CRA in both Pomorie's unique risk landscape and Bulgaria's evolving national strategy, the project responds to real gaps in knowledge, capacity, and governance—and provides a scalable, evidence-based pathway for sustainable, resilient development in the region.

The local Disaster Protection Plan of the Municipality of Pomorie was adopted in the first half of 2025 by representatives of the Municipal Council for Disaster Risk Reduction of the Municipality of Pomorie in compliance with the requirements of the Disaster Protection Act and in compliance with the requirements of the "Instructions for the Development and Readiness for the Implementation of Disaster Protection Plans" issued by the Disaster Risk Reduction Council to the Council of Ministers. The plans for specific hazards (e.g. floods) and other auxiliary plans have been prepared as separate parts of the plan. It lists prevention measures, activities and responsible institutions to reduce the significant risks identified in the risk profile Pomorie municipality. One of them is development of a municipal disaster risk reduction program for the period 2025-2030.

Relevant sectors in Pomorie municipality and climate change impacts

1. Agriculture

- Agriculture is highly significant due to the fertile soils and extensive farming activities including vineyards and sunflower cultivation.
- Climate risks such as prolonged droughts, increased temperatures, and irregular precipitation negatively impact crop yields, with documented reductions of 10-15% during drought years.
- Windstorms and hail damage further threaten crops; for example, over 1,500 hectares of vineyards were destroyed in recent severe wind and ice events, causing multimillion-euro losses.
- Water scarcity exacerbated by climate change impacts irrigation and soil moisture, increasing vulnerability to production losses and economic instability in this sector.

2. Tourism

- Tourism is a major economic driver, given Pomorie's coastal location and attractions such as the Black Sea and the Pomorie lagoon.
- Extreme weather events including heatwaves, storms, flooding, and coastal erosion can disrupt tourism seasons, damage infrastructure, and reduce visitor numbers.
- Sea-level rise and storm surges threaten coastal facilities and beaches, affecting the long-term sustainability of tourism.
- Heatwaves also pose health risks for residents and tourists alike, potentially reducing the attractiveness of the area.

3. Water Resources and Management

- Water supply is critical as the municipality faces increased water scarcity driven by decreasing annual precipitation and rising temperatures.
- Drought-induced reductions in water table levels threaten both public water supplies and ecological systems like the Pomorie lagoon.

- Flooding events from torrential rains and sea surges risk damaging water infrastructure, requiring resilient water management systems and flood defenses.

4. Infrastructure and Urban Development

- Roads, bridges, residential buildings, and other infrastructure are vulnerable to flooding, strong winds, and extreme temperature events.
- Floods and storm surges can cause damage and disrupt local services, requiring integrated climate-proofing of infrastructure.
- Urban planning needs to incorporate climate adaptation to reduce exposure and increase resilience.

5. Environment and Biodiversity

- The Pomorie Lagoon, wetlands, and forested areas are environmentally sensitive and threatened by climate-driven changes such as altered salinity from freshwater influx, drying from drought, and increased fires.
- Changes in ecosystem balance affect biodiversity and ecosystem services, which support agriculture, tourism, and community well-being.

6. Public Health and Social Services

- Increased frequency of heatwaves and cold spells poses public health risks, exacerbating vulnerabilities especially among elderly and sensitive groups.
- Heatwaves stress energy systems leading to blackouts and service disruptions.
- Disaster preparedness services, including emergency response to floods and storms, are critical to protect populations.

Key adaptation challenges for the municipality include:

- **Public health and population:** vulnerable groups, especially elderly residents, are at risk of severe stress during heat waves.
- **Tourism resilience:** coastal erosion and the loss of beach areas threaten the attractiveness and competitiveness of the resort sector.
- **Water resources and salt production:** changes in precipitation regimes and amounts, and sea level could alter the salinity and water balance of Lake Pomorie.
- **Energy and environmental sustainability:** there is a pressing need to adopt climate-smart practices in tourism, agriculture, and coastal zone management.

Adaptation intervention measures to address climate risks in the municipality include the conservation and restoration of dunes and wetlands (as natural buffers), integrated coastal zone management, enhanced meteorological-hydrological monitoring and early warning systems for heat waves, implementation of climate-smart viticultural practices (e.g., varietal selection, shading systems), and improvements in energy efficiency and urban greening.

2.1.3. Participation and risk ownership

The stakeholder involvement has been demonstrated by the process of developing the Disaster Protection Plan of the Municipality of Pomorie in the first half of 2025. For drafting of the plan a Municipal Council for Disaster Risk Reduction was established. Its members include representatives of the municipal administration and municipal council of Pomorie, representatives of the local division of Ministry of Internal Affairs, the District Fire Safety and Population Protection Service - Pomorie, the local hospital "MBAL - Pomorie" EOOD„ the Client Energy Center of Pomorie and the Water and Sanitation company “V&K" EAD Burgas - Pomorie region.

Other stakeholders include the state and regional authorities: the Ministry of Environment and Water, the Ministry of Regional Development and Public Works and the Ministry of Agriculture and Foods and the Burgas Regional Administration. From the academia & research institutions: National Institute of Meteorology and Hydrology, Climate, Atmosphere and Water Research Institute (BAS) and Bourgas Free University. The private sector is represented by agricultural associations, tourism industry stakeholders and local enterprises and business associations

Another group of stakeholders includes representatives of civil society and NGOs include regional & local NGOs (with environment and community focus), community-based organizations (vulnerable groups), community leaders and neighborhood representatives. The media is represented by local, regional and national news agencies.

The vulnerable groups who are mostly affected by climate risks are the elderly people, the low-income households, the residents of low-lying coastal zones, tourists with poor evacuation orientation, persons with limited mobility, people with chronic illnesses and seasonal tourism workers.

Risk ownership is designated for specific climate risks and adaptation actions, ensuring accountability throughout the CRA process and subsequent policy implementation. The first phase of Pomorie municipality’s CRA has established the necessary objectives, context, limitations, and stakeholder processes to build a locally robust, policy-integrated, and evidence-based climate adaptation framework, fully aligned with the CLIMAAX methodology and international best practice. The Climate Risk Assessment for Pomorie Municipality is closely aligned with the principles, strategic goals, and operational measures outlined in Bulgaria’s National Disaster Risk Reduction Program 2021-2025. This alignment ensures that local efforts reinforce national resilience-building, address climate change adaptation, and integrate disaster management into sustainable regional development.

2.2. Risk Exploration

Risk exploration is the starting point for understanding the climate-related challenges that are relevant for Pomorie Municipality. It provides a structured overview of hazards, exposures, and vulnerabilities, forming the evidence base for the subsequent risk assessment. The exploration process combines:

- Local knowledge and stakeholder input – highlighting issues of direct concern to municipal authorities, service providers, and citizens.
- Available municipal and scientific data – including past records of climate-related damages and monitoring datasets.
- European climate services and tools – in particular the Copernicus Climate Atlas and the CLIMAAX Toolbox, which provide consistent projections and indicators for the region of Southeast Bulgaria and the Black Sea coast.

This broad screening makes it possible to prioritise hazards that are both currently impactful and expected to intensify under climate change scenarios. It also ensures that the selected workflows respond to Pomorie's specific vulnerabilities, such as its low-lying coastal setting, reliance on agriculture and tourism, and concentration of elderly residents.

2.2.1. Screen risks (selection of main hazards)

The risk screening process has identified a set of key hazards for the municipality: coastal floods, drought and water scarcity, heatwaves, heavy rainfall extremes, and strong winds/storms. These hazards are consistent with both local experience and European climate projections.

- Floods are a recurring risk for Pomorie due to its exposed coastal location and low-lying urban areas. Recent events (e.g. 2014, 2021) caused severe damages to homes, roads, and the tourism infrastructure. The flood hazard is further aggravated by sea-level rise and storm surges in the Black Sea.
- Drought and water scarcity affect agriculture (vineyards, sunflowers), municipal water supply, and ecosystems such as Pomorie Lake. Severe droughts in 2020 and 2022 caused yield losses and stressed the saltworks and lagoon system.
- Heatwaves are becoming more frequent and intense, creating risks for human health (especially the elderly and outdoor workers), energy demand, and the comfort of tourists.
- Heavy rainfall events are increasingly observed, with more frequent short-duration downpours leading to pluvial flooding in urbanised areas and flash floods in river valleys.
- Strong winds and storms periodically cause damage to infrastructure, vineyards, roofs, and powerlines. Although projections for changes in storm intensity remain uncertain, their disruptive impacts on the coastal economy make them relevant for monitoring and preparedness.

The Copernicus Climate Atlas confirms the expected increase in hot extremes, lengthening of dry spells, and intensification of heavy rainfall events across Southeast Europe, while also pointing to ongoing sea-level rise in the Black Sea. These findings support the prioritisation of the hazards listed above as central to the risk profile of Pomorie Municipality.

2.2.2. Workflow selection

2.2.2.1 Workflow #1

After identifying the relevant hazards, the next step is to select workflows that structure the assessment of hazard–exposure–vulnerability–risk chains. Each workflow applies the CLIMAAX methodology to a specific hazard, using available data and stakeholder inputs to build a first-order risk assessment.

For Deliverable 1, the municipality has agreed to focus on coastal floods as the primary workflow. This choice reflects the high level of local concern, the significant historical damages, and the strong alignment with available datasets and Copernicus indicators. The flood workflow will provide a concrete demonstration of the CLIMAAX methodology, producing maps and hotspot analyses for Pomorie.

At the same time, other hazards (heavy rainfall, drought, heatwaves, strong winds) are also included in the risk exploration, with preliminary scoping of workflows. These will be further developed in subsequent phases (Deliverable 2 and beyond), ensuring that the overall assessment addresses the multi-risk context of the municipality.

Preliminary scoping of the other risks for Deliverable 2 phase:

2.2.2.2 Workflow #2 – Heavy Rainfall

Heavy rainfall events are already causing pluvial flooding and flash floods in Pomorie's urban and rural areas. They overwhelm the drainage system, damage roads, and disrupt transport and daily life. Vulnerable areas include densely built neighbourhoods, underpasses, and critical road links. Although strongly linked with flood risk, heavy rainfall is scoped as a separate workflow because it requires specific indicators (e.g. short-duration precipitation extremes, IDF curves) and local drainage data. Preliminary analysis will use Copernicus indices such as Rx1day and Rx5day, supplemented with local meteorological records.

2.2.2.3 Workflow #3 - Droughts

Droughts are a growing concern for Pomorie due to rising summer temperatures and longer dry spells. They impact agriculture (vineyards, sunflower fields), stress municipal water supply systems, and affect the ecological balance of Pomorie Lake and its saltworks. Vulnerable groups include farmers, the local water utility, and elderly residents affected by compound heat–drought events. Copernicus indicators such as Consecutive Dry Days (CDD) and drought indices (SPEI) confirm increasing risk trends for the region. This workflow will require additional local data on groundwater reserves, irrigation demand, and water use in agriculture and tourism.

2.2.2.4 Workflow #4 - Heatwaves

Heatwaves have become a frequent phenomenon in Southeast Europe, including the Burgas region. They pose risks to human health, especially the elderly and people with chronic illnesses, as well as outdoor workers and tourists. Infrastructure such as healthcare facilities and the energy grid are also vulnerable to extreme heat. Preliminary analysis will use indicators such as the number of hot days and tropical nights. Vulnerability mapping will focus on urban heat island areas, healthcare and eldercare facilities, and groups with limited adaptive capacity.

2.2.2.5 Workflow #5 – Strong Winds

Strong winds and storm events are periodic but damaging hazards in the Black Sea region. They cause roof damage, power outages, and disruptions to agriculture, particularly vineyards and greenhouses. The coastal tourism infrastructure is also exposed to storm-related damages. Although projections for future changes in storm frequency and intensity remain uncertain, the risk is recognised due to the high potential impact of single events. Vulnerable elements include powerlines, transport links, and coastal operations. This workflow will build on available climatological data, complemented with local incident records.

2.2.3. Choose Scenario

Introduction and purpose of the analysis

The coastal area of Pomorie Municipality is situated within a unique natural and socio-economic environment—a narrow and low-lying strip of land between the Black Sea and Lake Pomorie. This geographical setting creates exceptional opportunities for tourism, salt production, and fisheries, but simultaneously increases the risk of flooding in the event of sea-level rise and storm surges. The objective of this analysis is to identify the most suitable climate scenarios for the assessment of climate risk (CRA) with regard to this type of hazard, taking into account both global climate trends and the local specificities of the Pomorie coastline.

Why are Different Scenarios Used?

In climatology, a "scenario" represents a possible future state of the climate/sea level, depending on the extent of future greenhouse gas emissions and the corresponding responses of economies and ecosystems.

- SSP (Shared Socioeconomic Pathways) are scenarios that describe socio-economic trends—for example, whether the world will follow a sustainable and cooperative trajectory (SSP1) or pursue a pathway of high emissions and economic expansion (SSP5).
- RCP (Representative Concentration Pathways) are the previous generation of scenarios, based solely on greenhouse gas concentrations. In recent studies, SSP and RCP are applied in combination.
- Selecting several contrasting scenarios assists decision-makers to:
- Visualize conditions under moderate, high, and low risk;
- Assess which measures are "no-regret" (effective under all scenarios) and which are necessary only under more extreme conditions;
- Avoid over-reliance on an "average projection," which may either underestimate or overestimate the actual risk.

Appropriate Scenarios for Pomorie Municipality

Following an analysis of climate projections for the Black Sea and the characteristic features of the municipality, we recommend the application of three principal scenarios for coastal flooding:

1. SSP2-4.5 – Medium Scenario

- Reflects moderate economic and demographic growth, with moderate efforts at emission reduction
- By 2100, this scenario projects global sea-level rise of approximately 44–76 cm.
- Serves as a "baseline" scenario for planning investments in infrastructure, protection, and spatial development.

2. SSP5-8.5 – High Scenario

- It is applicable under the assumption that the world continues to rely heavily on fossil fuels and emissions continue to increase.
- By 2100, it projects a sea-level rise of approximately 63–101 cm, with the potential for even higher values under accelerated ice-sheet melting.
- It is used as a "stress test" for critical assets (dikes, roads, hospitals, salt pans), where failure would have severe consequences.

3. SSP1-2.6 – Low Scenario

- It assumes that the world rapidly transitions towards sustainable development and low emissions.
- By 2100, it anticipates sea-level rise of approximately 28–55 cm.
- It is useful for evaluating “no-regret” measures—those yielding benefits even under favorable climate outcomes.

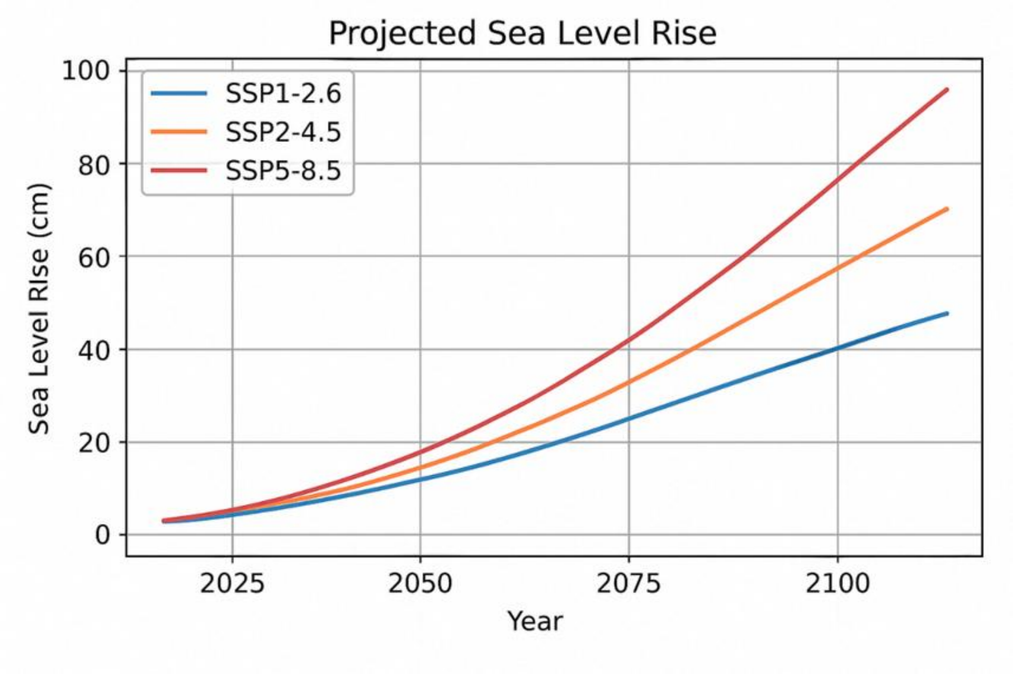

Figure 2-1 Projected sea level rise

Why This Choice of Scenarios is Appropriate for Pomorie

Geographical and Natural Characteristics

- The town and large portions of the coastal zone are at very low elevations—often below 2–3 meters above sea level.
- Dunes and beaches exist as natural protective barriers, yet these formations are being lost and fragmented due to urbanization and erosion.
- Lake Pomorie is connected to the sea through channels and sluices, meaning that elevated sea levels may cause backflow and internal flooding.

Historical Experience

- Documented storm surges in the region have impacted coastal streets, salt pans, and infrastructure.
- National studies identify Pomorie as a “hotspot” of risk from marine (coastal) flooding.

Socio-Economic Exposure

- The municipality has a population of approximately 26,600 residents, more than half of whom live in the coastal town of Pomorie.
- There is a pronounced seasonal increase in population during summer months—tourists and seasonal workers—raising the number of potentially affected individuals.

- Key economic activities such as tourism and salt production are directly dependent on the coastal zone and are highly sensitive to flooding.

Political and Governance Frameworks

- The municipality already possesses a Disaster Protection Plan and participates in national Flood Risk Management Plans.
- Protected areas within the municipality (Ramsar site, NATURA 2000) impose restrictions on construction and other activities, thereby influencing the selection of adaptation measures.

Practical Application of the Scenarios

The practical application of scenarios entails a phased approach through the following steps:

1. Identification of critical assets—roads, dikes, wastewater treatment plants, hospitals, tourist infrastructure.
2. Floodplain mapping—for each selected sea-level rise scenario and recurrence period (10, 50, 100 years).
3. Comparative analysis—assessment of inundated areas under low, medium, and high scenarios; evaluation of damages and disruptions.
4. Selection of measures—a combination of hard (dikes, breakwaters) and nature-based solutions (dune restoration, afforestation), in addition to spatial planning controls.
5. Updating and review—recommended every 5–6 years in line with new scientific evidence.
6. Conclusion

The application of three contrasting scenarios (SSP1-2.6, SSP2-4.5, SSP5-8.5) will provide Pomorie Municipality with a clear, realistic, and flexible foundation for coastal flood protection planning. This will enable:

- Preventive investment in measures effective under all scenarios;
- Stress testing of critical assets under extreme conditions;
- Improved communication with citizens and businesses through clear and comprehensible projections.

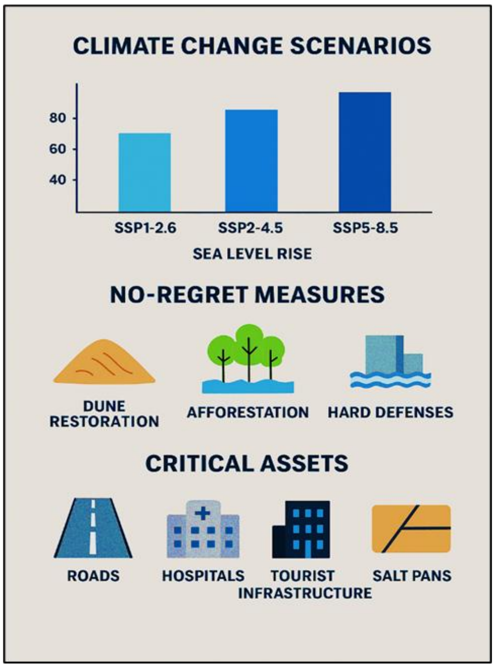

Figure 2-2 Infographic of climate change scenarios

The infographic above illustrates three main climate scenarios for the Pomorie Municipality coastline up to 2100: SSP1-2.6 (low), SSP2-4.5 (medium), and SSP5-8.5 (high). For each scenario, it shows:

- Projected sea-level rise – indicating the range of increase relative to current levels.
- "No-regret" measures – investments and actions that are effective under all scenarios, such as dune reinforcement and restoration of natural barriers.
- Critical assets for stress testing – infrastructure and key sites that require resilience checks under the most extreme scenario (SSP5-8.5), including roads, hospitals, tourist facilities, and salt pans.

This visualization aims to provide a clear and compact overview of coastal flooding climate risk, linking global scenarios to the local context. This allows us to make informed decisions for adaptation and protection of people and economic activities along the coast.

2.3. Risk Analysis

The primary objective of the climate risk assessment for Pomorie municipality is to rigorously evaluate the territory's vulnerability in relation to key climatic hazards, including coastal inundation, extreme precipitation events, prolonged droughts, high-intensity windstorms, and heatwave episodes. This assessment offers a comprehensive and integrated evaluation of potential impacts on populations, critical infrastructure, residential and commercial buildings, transportation networks, agricultural systems, and natural ecosystems. The analytical framework is grounded in the interrelation of hazard, exposure, and vulnerability, following the methodologies and protocols established in the CLIMAAX Handbook. This encompasses the use of multi-scale geospatial datasets, high-resolution land-use and land-cover information, and empirically derived damage functions for the quantitative economic estimation of losses. The results facilitate the spatial identification of high-risk areas and provide a robust foundation for the design of evidence-based, context-specific adaptation measures and comprehensive risk management strategies.

2.3.3. Workflow #1 Coastal Flooding

General context

Coastal flooding constitutes a significant risk for the Municipality of Pomorie due to its geographic positioning along the Bulgarian Black Sea coast. The principal determinants of this risk include:

- **Rising sea levels,** which amplify the probability of inland inundation.
- **Extreme meteorological phenomena**, such as storms and high-intensity waves, capable of triggering substantial flooding over short temporal intervals.
- **Intensive land use within coastal zones**, encompassing urbanized areas, tourist facilities, and industrial sites.

The purpose of this analysis is to systematically quantify both the potential hazard of flooding and the associated economic damages and infrastructural vulnerabilities across (flood risk) diverse coastal flood scenarios.

Table 2-1 Data overview workflow #1 Coastal flooding

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
Deltares Global Flood Maps (GFM) via Microsoft Planetary Computer: coastal flood depth rasters for 2018 and 2050 (RCP8.5), return periods 2–250 yrs; 30–75 m native resolution; reprojected to EPSG:3035 and clipped to Pomorie municipal boundary.	JRC vulnerability/damage curves and LUISA_damage_info_curves.xlsx adapted with Bulgaria GDP/capita (10,090 USD, per input), yielding max damage €/m² by land-use class.	JRC Land Use (100 m) for Europe (2018), clipped to Pomorie AOI; auxiliary layers: Natura 2000 Pomorie Lake; key assets (port/breakwater), transport corridors (context).	DamageScanner-based maps and summary tables of potential economic damage by scenario/return period and by land-use class; preliminary hotspots for Pomorie town spit/peninsula, Aheloy lowlands, Pomorie Lake fringes (subject to defense corrections). (climateknowledgeportal.worldbank.org, City Population, City Population, European Commission, CLI - Concrete Layer Innovations)

2.3.1.1. Hazard assessment – Coastal flooding

Introduction

Pomorie Municipality is located in the central part of the Bulgarian Black Sea coast, with 55 km of shoreline, including the Pomorie Peninsula, extensive sandy beaches, the Pomorie Lagoon, and several low-lying areas with a high concentration of urbanization, tourism, and industrial activities. Its geographical position, combined with dynamic marine hydrology and climate change, makes it particularly vulnerable to the phenomenon of coastal flooding. This is caused by extreme sea water levels, elevated during sea storms and further amplified by sea level rise.

Climate projections for the Black Sea indicate a future increase in the frequency and intensity of severe storm waves, combined with rising sea levels, which increases the risk to coastal infrastructure, natural resources, and the socio-economic stability of the municipality.

Key data for the territory of the municipality, in the context of coastal flooding hazard:

- Average elevation of the coastal strip: 0–5 m.
- Potential flood depth: 0.2–2.0 m (depending on scenario).
- The most vulnerable areas are the low-lying coastal zones, particularly near bays and the long-beach zone.
- A significant part of the coastal strip and adjacent urbanized areas (~15% of the total municipal area) are exposed to flood depths above 0.5 m under high-probability scenarios (100–250 year return periods).
- Sea dikes and other protection structures are absent in the global datasets, which may lead to an overestimation of the risk.

Methodological approach for assessing the coastal flooding hazard and data sources

Many different methodologies can be used to create a map of coastal flooding. In this workflow, we use the Global Flood Maps dataset openly available via the Microsoft Planetary Computer (Deltares). These are integrated with local plans and observations, including Disaster Protection Plans, Bulgarian Academy of Sciences analyses, regional climate assessments, as well as CLIMAAX guidelines.

The coastal hazard in Pomorie Municipality is assessed based on potential flood depth maps from the Global Flood Maps dataset, interpolated with local land-use data. The maps show potential inundated areas under different coastal flood scenarios with varying return periods (2, 5, 10, 50, 100, 250 years).

We present **global flood maps** available for two scenarios:

- Present-day climate (ca. 2018).
- Climate in 2050 under the RCP8.5 scenario.

The 2050 scenario assumes sea level rise as estimated under RCP8.5 (high-emission scenario).

Within each scenario, several flood maps are available, corresponding to extreme sea storms with different statistical occurrences (e.g., once in 5 years, once in 100 years, etc.). The dataset has a relatively high spatial resolution of 30−75 m (depending on latitude). The methodology behind this dataset is documented and can be accessed via the data portal. The dataset is based on the GTSMv3.0 (Global Tide and Surge Model), forced with the ERA5 reanalysis atmospheric dataset. Statistical analysis of the modelled data is used to estimate extreme water level values for different return periods. These values are then applied to calculate flood depths using a static inundation modelling routine ("bathtub" method, with simplified friction correction over land) over a high-resolution Digital Elevation Model (MERIT-DEM or NASADEM).

Several aspects must be considered when interpreting the flood maps:

- The dataset provides insight into coastal flood potential at a given location. However, it does not account for man-made coastal protections already present in populated regions (e.g., dams, storm barriers). Local conditions must therefore always be surveyed.
- While the dataset's resolution is very high on a global scale, performance decreases in complex local bathymetries (e.g., estuaries, semi-enclosed bays), and results should be interpreted with caution.
- The dataset uses static topography. In some coastal areas, flood risk may be increased by land subsidence. If subsidence is a known issue in the area, it must be considered when interpreting the maps.

For more accurate coastal flood risk estimates, it is recommended to perform local flood modelling, using the results of the global model as boundary conditions. Local models can take better account of complex bathymetry and topography, and incorporate local data and knowledge about e.g. flood protection measures.

In this workflow, we retrieve the relevant parts of the coastal flood hazard dataset and explore it in more detail for the region of interest, through the following steps:

1. Select area of interest - bbox = [27.400909,42.521264,27.686554,42.918778]; areaname = 'Pomorie'

2. Access and view the coastal flood map dataset

We open the global dataset. Since its extent is global, the number of points along latitude and longitude is very large. Therefore, the dataset needs to be clipped to our area of interest and reprojected to local coordinates (to display distances in meters rather than degrees).

We then clip the dataset to a wider area around the region of interest, and call it ds_local. The extra margin is added to account for reprojection at a later stage. The clipping of the dataset allows to reduce the total size of the dataset so that it can be loaded into memory for faster processing and plotting. We will convert the dataset to a geospatial array (with a reference to geographical coordinate system), drop the unnecessary coordinates, reproject the array to the projected coordinate system for Europe (in meters), and, finally, clip it to the region of interest using our bounding box.

The dataset can now be plotted for one scenario and return period. The colorbar bounds can be adjusted via the vmax variable (in meters).

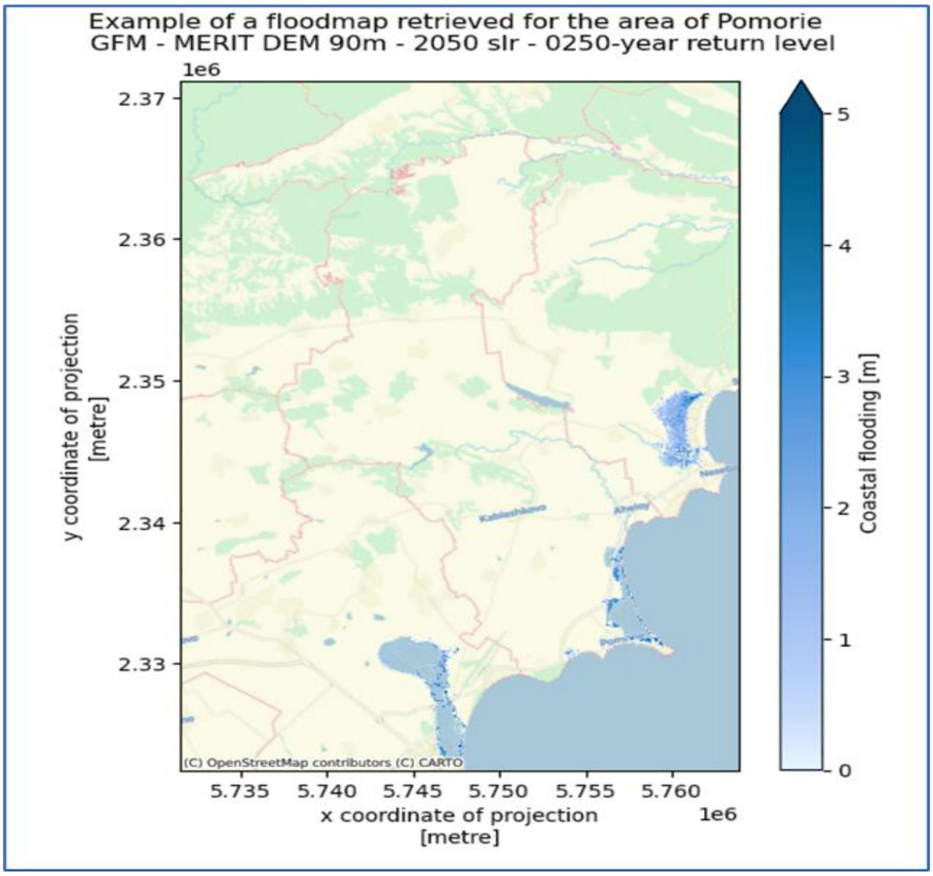

Figure 2-3 Example of a floodmap retrieved for the area of Pomorie

3. Download the coastal flood map dataset for different scenarios and return periods

For hazard and risk assessments, we need to compare flood maps for different scenarios and return periods. We therefore load and merge the datasets for multiple scenarios and return periods into one dataset. A function is defined to automate the processing of individual datasets.
We can now apply this function, looping over the two scenarios and a selection of return periods.
In the Global Flood Maps dataset there are two climate scenarios: present day (represented by the year 2018) and future (year 2050, with sea level rise corresponding to the high-emission scenario, RCP8.5). The available return periods range between 2 years and 250 years. Below we make a selection that includes 5, 10, 50, 100-year return periods).

4. Visualize coastal flood hazard dataset

Maps of flood potential across different scenarios and return periods can now be compared side by side.

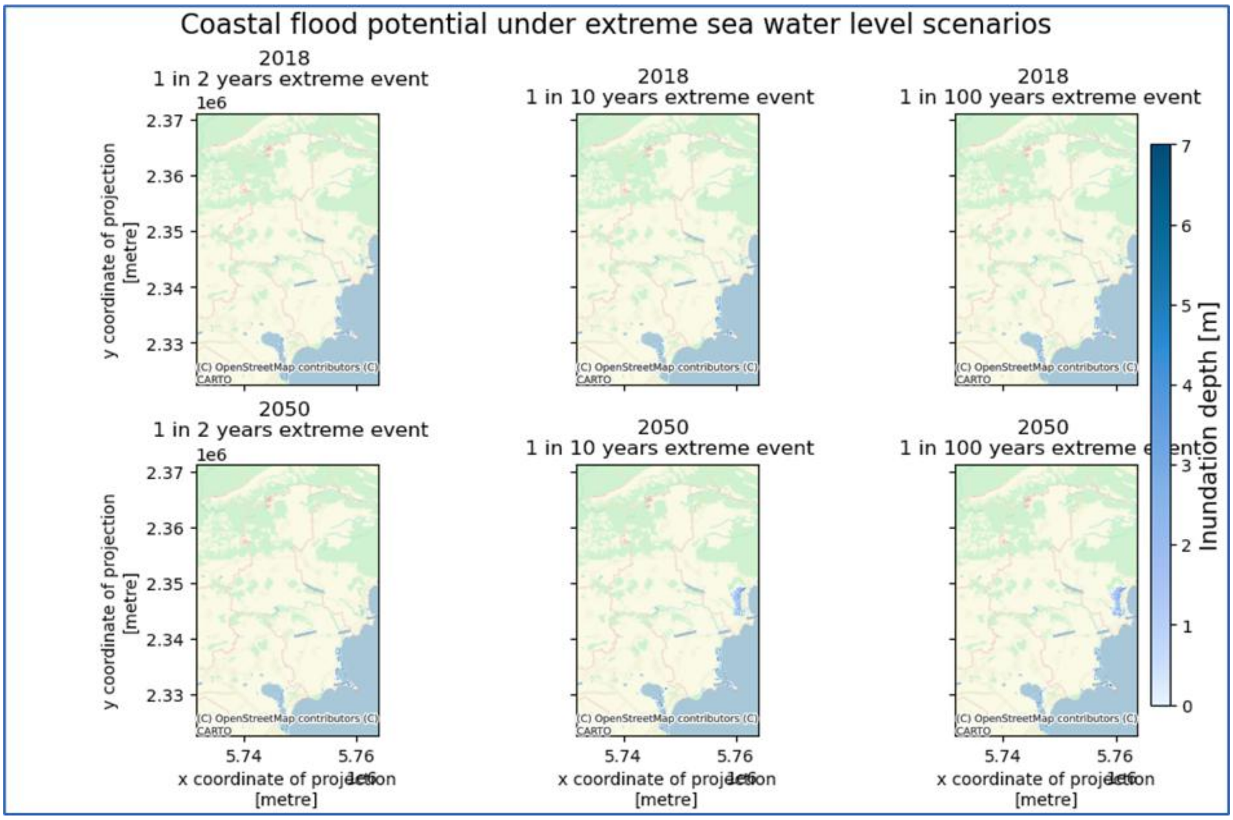

Figure 2-4 Coastal flood under extreme sea water level scenarios

By overlaying flood maps from 2018 and 2050 scenarios (e.g., 1-in-5-year and 1-in-100-year return periods), we can visualize the effects of sea level rise, which in 2050 is estimated at ~0.2 m compared to present day. While this increment is relatively small compared to extreme water levels, it still contributes to increased inundation.

Similarly, plotting flood extents for different return periods on top of each other illustrates how potential impacts scale with event rarity.

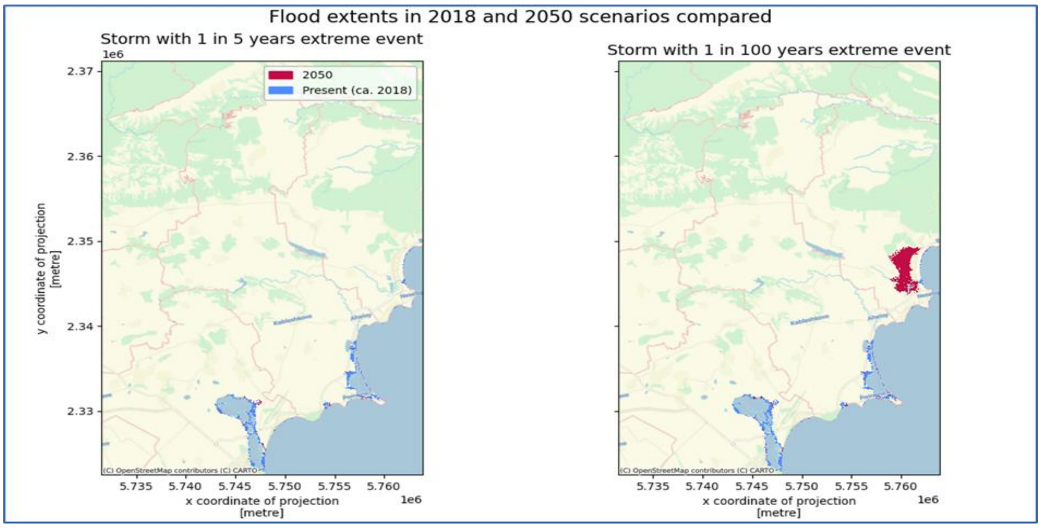

Figure 2-5 Flood extents in 2018 and 2050 scenarios compared

To understand the differences between the potential coastal flood extents corresponding to different return periods, we can also plot the flood extents for different return periods on top of each other below.

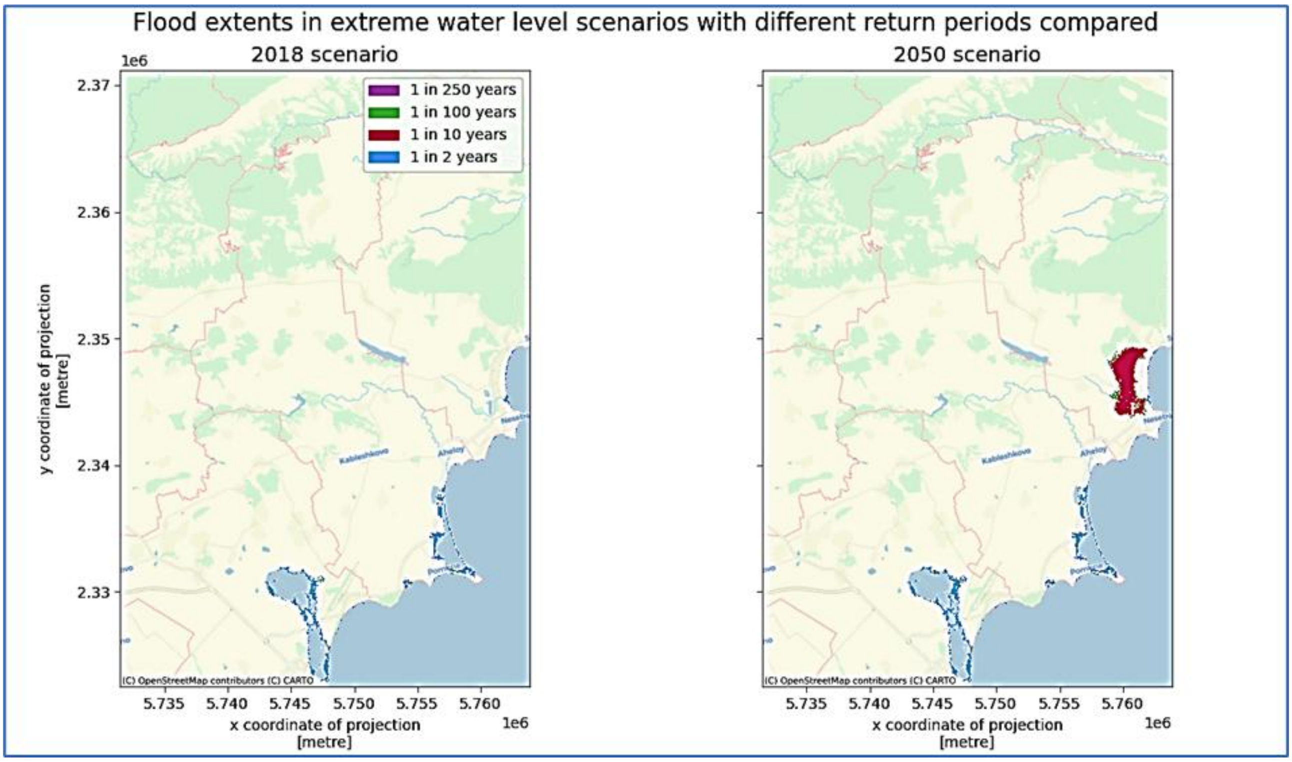

Figure 2-6 Flood extents in extreme water level scenarios with different return periods compared

5. Save dataset to a local directory for future access

Once the dataset is fully loaded, it can be saved either as a single netCDF file containing all scenarios, or as separate raster files (.tif).

Applying the hazard workflow – lessons learned

- How to retrieve coastal flood maps for a specific region.
- Understanding the accuracy and limitations of coastal flood maps in local contexts.
- Recognizing the differences between climate scenarios and return periods.

The coastal flood hazard maps retrieved and saved in this workflow will be further used in the coastal flood risk workflow (part of the risk toolbox).

2.3.1.2. Risk assessment

In this workflow we will visualize risks to build infrastructure presented by coastal flooding. The damages will be calculated using the methodology described in the risk workflow description of CLIMAAX CRA Handbook. We will use pre-processed coastal flood maps from the Global Flood Maps dataset and combine these with land use maps, as well as information on economic vulnerability (damage curves) to quantify the order of the damages in economic terms.

This methodology to calculating flood risk can also be used with other regional flood map datasets. In fact, for many locations the Global Flood Map dataset will not be accurate enough because it does not include coastal flood defenses (i.e. some areas may appear flooded, while in reality there are flood defenses in place to prevent that). But for initial understanding of how coastal flood risk can be estimated the global flood maps can be used.

Country-specific information is required to calculate the economic damages, which in this case is *Bulgaria 2024 GDP/capita = 10 090 USD*.

Flood risk assessment goes through the following steps:

1. Download and explore the data

Hazard data - coastal flood maps
As default option, we use the potential coastal flood depth maps from the Global Flood Maps dataset, that were downloaded using the hazard assessment workflow for coastal floods.

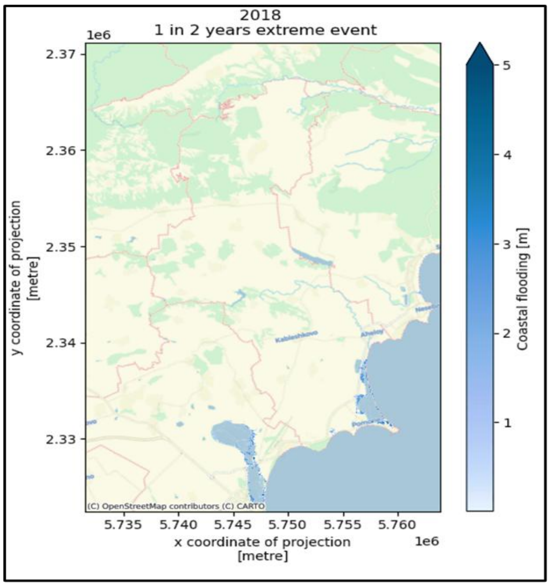

Figure 2-7 One in two years extreme event - 2018

2. Exposure - land-use data

Next we need the information on land use. We will download the land use dataset from the JRC data portal, a copy of the dataset will be saved locally for ease of access. In this notebook we use the land use maps with 100 m resolution. The land use maps can also be downloaded manually from the JRC portal.
The land use data is saved into the local data directory. The data shows on a 100 by 100 meter resolution what the land use is for Europe in 2018. The land use encompasses various types of urban areas, natural land, agricultural fields, infrastructure and waterbodies. This will be used as the first exposure layer in the risk assessment.
The land use dataset needs to be clipped to the area of interest. For visualization purposes, each land use type is then assigned a color. Land use plot shows us the variation in land use over the area of interest.

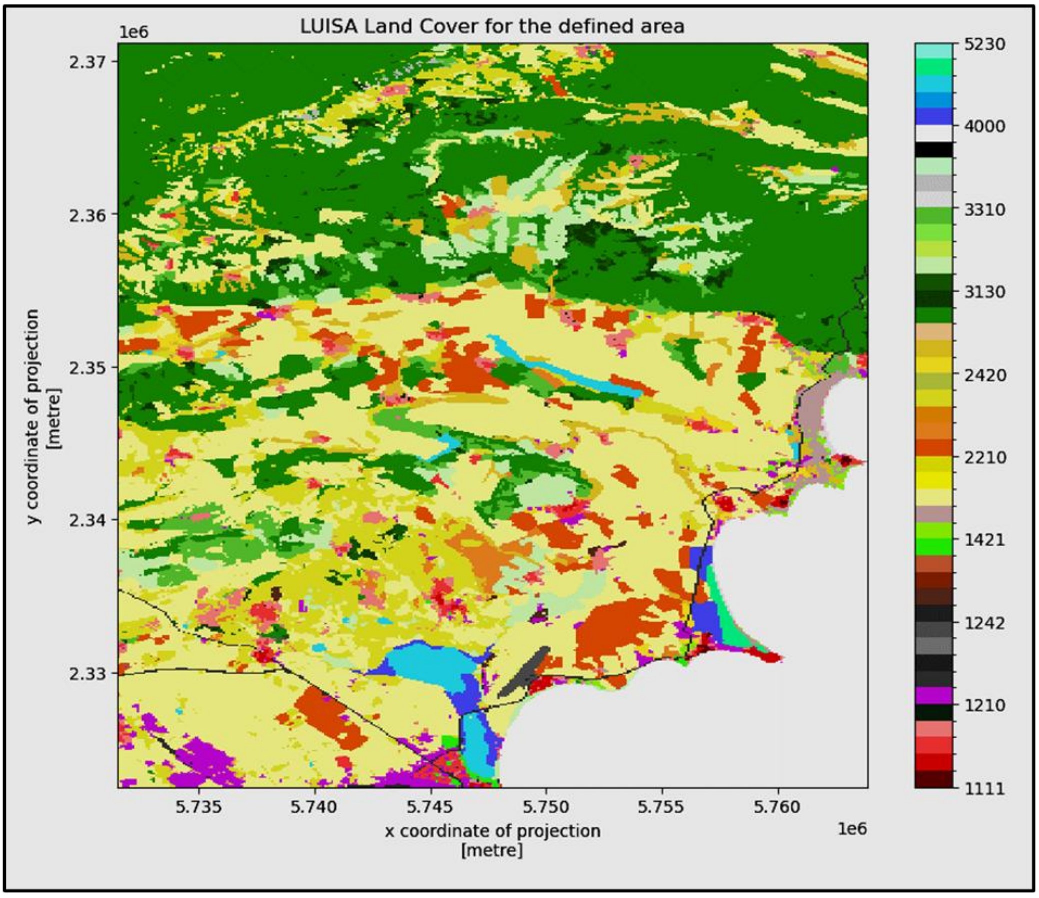

Figure 2-8 LUISA land cover for the defined area

3. Vulnerability - damage curves for land use

We will use damage curve files from the JRC that are already available in the GitHub repository folder. See the Handbook page on vulnerability curves for more information.

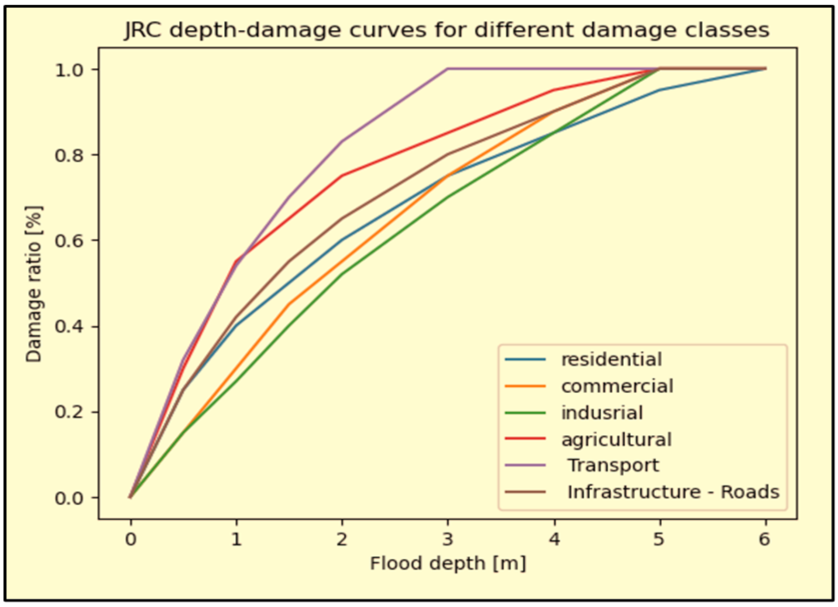

Figure 2-9 JRC depth-damage curves for different damage classes

4. Processing data

The maps of flooding and land use can be combined to assess multiple types of risk from coastal flooding in a region. This way we can estimate the exposure of infrastructure and economic assets to coastal floods. In this section we will align the resolutions of the datasets, prepare vulnerability curves and calculate the damage maps.

5. Combining datasets with different resolution

Before we can calculate risk indices, we will prepare the data by aligning the spatial resolution of the datasets and by calculating the vulnerability curves for economic damages based on specified information.

The flood and land use datasets have different spatial resolutions. Flood extent maps are at a resolution of 30-75 m (resolution varies with latitude), while land use data is at a constant 100 m (or 50 m) resolution. We can bring them to the same resolution. It is preferable to interpolate the flood map onto the land use grid (and not the other way around), because land use is defined in terms of discrete values and on a more convenient regularly spaced grid. We will interpolate the flood data onto the land use map grid in order to be able to calculate the damages.

We will save the resampled flood maps as raster files locally, so that we can more easily use them as input to calculate economic damages.

6. Linking land use types to economic damages

In order to assess the potential damage done by the flooding in a given scenario, we also need to assign a monetary value to the land use categories. We define this as the potential loss in €/m². The calculation of economic value for different land use types is made with help of an accompanying template (LUISA_damage_info_curves.xlsx).

Bulgaria 2024 GDP/capita = 10 090 USD

We go to the newly created file and adjust the information on the GDP per capita in the first line of the Excel sheet. From the Handbook page on maximum damage estimation we can see more information about the spreadsheet and calculations.

	Total €/m²
Land use code	
1111	390.283064
1121	268.631707
1122	159.395752
1123	46.001905
1130	0.000000
1210	272.851115

1221	27.731014
1222	388.234196
1230	166.386084
1241	388.234196

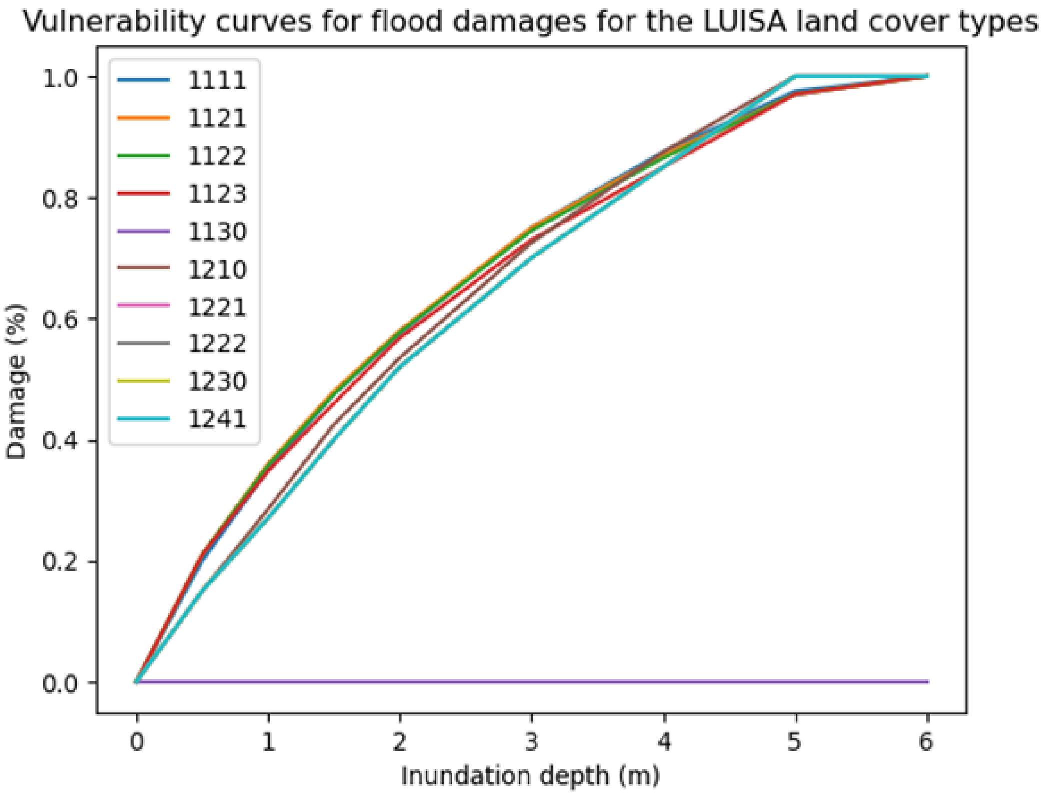

Figure 2-10 Vulnerability curves for flood damages - for LUISA land cover types

7. Calculate potential economic damage to infrastructure using DamageScanner

Now that we have all pieces of the puzzle in place, we can perform the risk calculation. For this we are using the DamageScanner Python library which allows for an easy damage calculation. The DamageScanner takes the following data:

- The clipped and resampled flood map
- The clipped land use map
- The vulnerability curves per land use category
- A table of maximum damages per land use category

We can perform the damage calculations for all scenarios and return periods now, which contains the results of damage calculations for all scenarios and return periods. We format this dataframe for easier interpretation:

	Description	2018_rp0002	2018_rp0005	2018_rp0010	2018_rp0050	2018_rp0100	2018_rp0250	2050_rp0002	2050_rp0005	2050_rp0010	2050_rp0050	2050_rp0100	2050_rp0250
2110	Non irrigated arable land	2.0	2.1	2.2	2.3	2.4	2.7	2.4	2.6	84.3	87.8	91.1	93.3
4000	Wetlands	42.7	43.4	44.0	45.4	46.2	47.0	46.0	46.7	47.4	49.2	50.0	51.1
1422	Sport and leisure built-up	9.8	10.0	10.1	10.4	10.6	11.2	10.6	10.8	43.3	45.2	46.1	47.3
1210	Industrial or commercial units	21.0	21.9	23.1	26.8	27.7	28.7	27.5	28.5	36.2	38.7	40.3	42.1
1330	Construction sites	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.1	16.4	16.5	16.7
2430	Land principally occupied by agriculture	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	10.6	11.1	11.3	11.5
1123	Isolated or very low density urban fabric	2.0	2.1	2.1	2.2	2.3	2.6	2.3	2.6	7.0	7.3	7.4	7.5
1121	Medium density urban fabric	4.5	4.7	4.9	5.2	5.4	5.6	5.4	5.6	5.7	6.0	6.1	6.3
1421	Sport and leisure green	1.8	1.9	1.9	2.1	2.1	2.2	2.1	2.2	5.1	5.4	5.6	5.7
1111	High density urban fabric	4.0	4.1	4.2	4.4	4.5	4.7	4.5	4.6	4.7	4.9	4.8	5.2

8. Plot the results

Now we can plot the damages to get a spatial view of what places can potentially be most affected economically. To do this, first the damage maps for all scenarios will be loaded into memory and formatted:

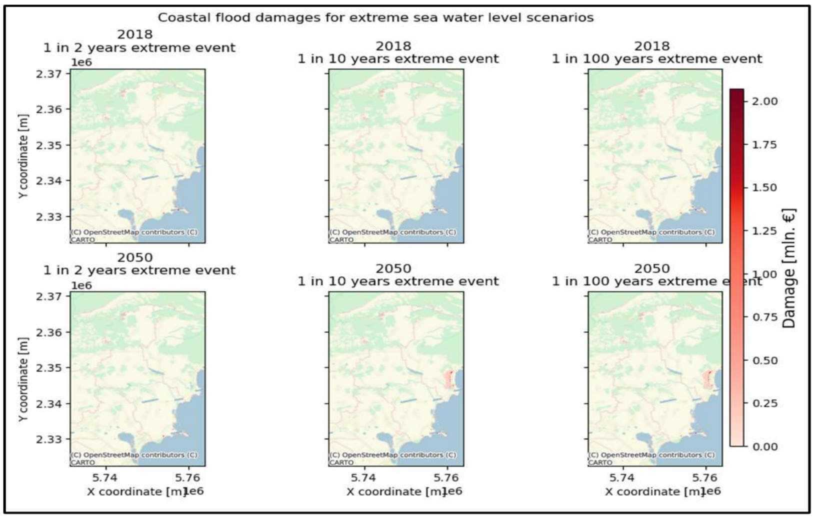

Figure 2-11 Coastal flood damages for extreme sea water level scenarios

To get a better indication of why certain areas are damaged more than others, we can also plot the floodmap and land use maps in one figure for a given return period.

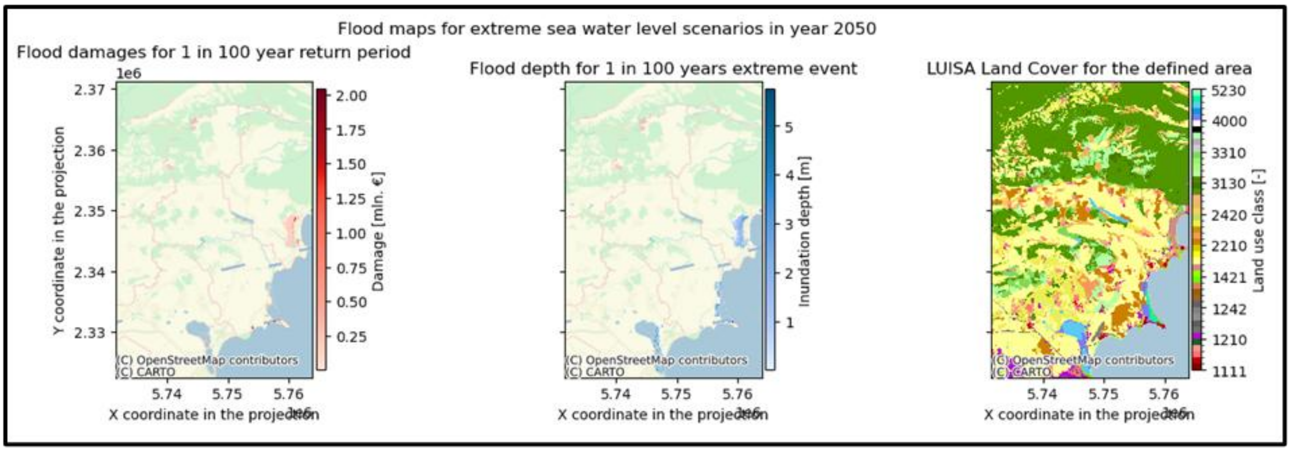

Figure 2-12 Flood maps for extreme sea water level scenarios in 2050

Here we see both the potential flood depths and the associated economic damages. This overview helps to see which areas carry the most economic risk under the flooding scenarios. The maps illustrate the patterns of coastal flood potential and identify areas likely to experience significant damage, serving as a starting point for informed decision-making and proactive risk management.

What we learned from the application of this risk workflow:

- How to access European-scale land use datasets.
- How to assign each land use with a vulnerability curve and maximum damage.
- Combining the flood (hazard), land use (exposure), and the vulnerability curves (vulnerability) to obtain an economic damage estimate.
- Understand where damage comes from and how exposure and vulnerability are an important determinant of risk.

2.4. Preliminary Key Risk Assessment Findings

The purpose of risk assessment is to identify it in terms of its severity, urgency, and the society's readiness/capacity to cope with it. *The severity* of the risk is determined by the potential magnitude of its impact – e.g., high human loss, large areas affected, massive financial damage, important sectors affected, roads blocked, cascading effects such as disease outbreak, social unrest, destruction of ecosystems and biodiversity, loss of agricultural land, etc. *The urgency* of the risk is determined by when actions are needed to minimize threats, whether it is related to sudden events (e.g., heavy rain) or slow onset processes (e.g., sea level rise), whether it is expected to worsen significantly in the near future, and so on. *The capacity* to cope with the risk depends on what management measures exist and whether they have already been implemented, taking into account different contexts – financial (available means to prepare and respond to the risk), social (social inclusion in DRM, equity, representation, favourable policy environment), human (awareness, knowledge, and learning), physical (ability to forecast and warn, provide critical infrastructure and services), and natural (resource management and ecosystem health).

The risk assessment process is in line with the IPCC Risk Propeller concept, combining different risk contexts and their projected future changes in order to build a strategic framework for climate risk management (CRM).

This requires active involvement of key stakeholders, experts, and priority groups through consultations, focus groups, or workshops. This includes gathering information regarding risk perceptions, historical observations, local disaster management practices, and potential impacts on populations, the economy, and ecosystems.

In the context of Pomorie Municipality, the identified climate risks include:

- Coastal flooding
- Heavy Rainfall
- Droughts
- Heatwaves
- Strong Winds

At this stage, the analysis focuses on the first and most critical risk – coastal flooding, while the other risks will be assessed later – in the next phase of the current project implementation.

2.4.1. Severity

The severity of climate risk assesses how strong are the potential physical, social, economic, and environmental consequences, as well as possible irreversible damages and cascading effects resulting from the impacts of site-specific climate hazards.

The determination of the degree of severity for Pomorie Municipality is based on the analysis and results from sections 2.3.1.1 and 2.3.1.2 of this report, as well as on local strategic documents, the Pomorie Municipality Disaster Protection Plan, the Integrated Municipal Development Plan, and statistical sources on historical events.

1. General description of coastal flooding in Pomorie Municipality

The coastal zone of Pomorie Municipality is highly sensitive to flooding caused by sea waves, storm surges, and potential sea level rise. The table below presents the main quantitative data for a coastal flooding event with a wave height of 0.5–2.0 m.

Table 2-2 Quantitative data for a coastal flooding event with a wave height of 0.5-2.0 m

Parameter	Value
Height of potential flooding	0.5 – 2.0 m above sea level
Affected area	500 – 800 ha in an extreme event
Population at risk	~8,000 – 10,000 inhabitants
Critical infrastructure	Ports, main roads, water supply and sewerage networks
Historical data	2–3 severe floods in the past 20 years
Economic damages	~EUR 2–5 million per event

Cartographic analyses indicate that with a floodwater level of 1.5 m, approximately 15% of the territory of Pomorie would be inundated, including parts of the historic center and the tourist zone. The areas of highest impact severity are concentrated around:

- The central part of Pomorie town, where high building density and economic activity amplify potential damages.
- The port zone and coastal tourist complexes, particularly in the southern part of the municipality.
- Peripheral settlements and agricultural lands, which, despite lower building density, are exposed to significant economic losses during larger flood events.

The frequency of coastal flooding in Pomorie is increasing as a result of climate change and sea level rise. According to data from the National Institute of Meteorology and Hydrology, over the past 50 years, 12 cases of coastal flooding have been recorded in the Pomorie area, indicating an average frequency of one flood every four years. Over the last 20 years, analyses show an increase in the magnitude of events—on average 1–2 significant floods per decade—with a clear trend toward higher frequency and intensity.

2. Impacts of coastal flooding in Pomorie Municipality

- **Social and health impacts:** Loss of human lives or injuries, deterioration of public health due to flooding, social tensions resulting from destroyed housing and services. A potential coastal flood could affect more than 3,500 residents, primarily in low-lying coastal zones, including residential, commercial, and tourist areas. Vulnerable groups such as the elderly and persons with limited mobility are at heightened risk.
- **Physical and infrastructural impacts:** Roads, bridges, port facilities, water supply and energy networks, residential and tourist sites in coastal areas, as well as industrial and commercial facilities, may be disrupted. This affects both the normal functioning of the city and emergency rescue operations. Predictive models indicate that with a 2 m floodwater level, more than 30% of the municipality's road network could be affected, including major roads and bridges.
- **Economic impacts:** Damages to the tourism sector, losses in agriculture, and degradation of farmland, with long-term financial consequences for the municipality. Expected damages to real estate, infrastructure, and tourist facilities may reach approximately EUR 50–60 million for a medium-scale event, while in extreme scenarios, losses could double or more. According to analyses by the Ministry of Tourism, a 1.5 m floodwater level may reduce tourist inflows by about 20% during the summer season, leading to financial losses of approximately BGN 2 million. Predictive models show that a 2 m flood could destroy up to 10% of farmland, including orchards and vegetable crops.
- **Environmental effects:** Potential saline intrusion and erosion of coastal territories (including beaches), degradation of coastal ecosystems, biodiversity loss, and impacts on protected natural areas, such as the Pomorie lagoon. At a floodwater level of 1.5 m, about 5 hectares of protected areas around Lake Pomorie may be affected, resulting in habitat loss for rare bird species. Predictive models further show that at 2 m, approximately 3 hectares of farmland could become salinized, reducing productivity for up to five years.
- **Cascading effects:** Long-term economic losses, social tensions, and potential migration, alongside prolonged environmental damages. Prolonged flooding is expected to increase unemployment by approximately 5% in affected areas due to business closures and reduced economic activity. Long-term floods could cause ecosystem degradation, declining water quality, and biodiversity loss, potentially irreversible without significant restoration measures.

3. Projections of coastal flooding risk across future time horizons

Projections of sea level rise:

- **Short-term horizon (by 2050):** According to World Bank data, global sea level rise is projected to reach 0.28–0.55 m under low emissions (SSP1-1.9) and 0.63–1.02 m under high emissions (SSP5-8.5) by 2100 (European Environment Agency).
- **Medium-term horizon (by 2100):** Studies suggest that sea level rise in the Black Sea may be more pronounced due to local climatic conditions and ocean current dynamics.
- **Long-term horizon (by 2150):** Some scenarios project up to 5 m of sea level rise under extreme glacier melt projections.

Projections of coastal flooding in Pomorie Municipality:

- **Scenario 1 (by 2050):** Increasing frequency and intensity of coastal flooding, affecting low-lying residential and tourist zones.
- **Scenario 2 (by 2100):** Permanent inundation of parts of the coastal zone, loss of beaches, and erosion of protective barriers.
- **Scenario 3 (by 2150):** Submergence of large land areas, population migration, and severe economic losses.

4. Severity assessment

According to the CLIMAAX CRA Handbook /fig. 26, severity is differentiated into four levels, each characterized by the following parameters (as applied to Pomorie Municipality):

- **Critical risk:**
  - Potentially affected settlements: Pomorie town (central area), “Northern Shore” district
  - Economic assets: tourist complexes, port, industrial zones
  - Infrastructure: main road arteries, electricity network, water supply
  - Ecosystems and agricultural lands: coastal dunes, protected zones, agricultural areas
- **Substantial risk:**
  - Potentially affected: peripheral neighborhoods of Pomorie, lower tourist areas
  - Economic assets: small businesses and coastal shops
  - Infrastructure: secondary roads serving adjacent settlements
  - Ecosystems: partially inundated coastal lagoons
- **Moderate risk:**
  - Areas with limited flooding during severe marine events
  - Economic and social damages: temporary service disruptions, minimal financial losses
- **Limited risk:**
  - Inland parts of the municipality and hilly areas, minimal exposure
  - Damages: negligible to none

Based on the results of sections 2.3.1.1 and 2.3.1.2 of this report, the severity level in Pomorie Municipality is as follows:

- **Regarding the PHYSICAL IMPACT:**
  - High risk to coastal infrastructure, including roads, sewerage, dikes, and tourist facilities.

- Likelihood of recurrent damages from storms and sea level rise.

Current severity level: *Substantial* → Future: *Critical*.

- **Regarding the SOCIAL IMPACT:**

Present (C):
Direct threat to human lives is more limited compared to river floods; however:
- Risks exist for vulnerable groups (elderly, tourists with poor evacuation orientation, persons with limited mobility).
- Impacts on housing and social infrastructure (schools, hospitals not in the lowest zones, but could be indirectly affected during severe events).

Present social impact: *Moderate–Substantial*.

Future (F):
- Sea level rise (as per IPCC and national assessments) combined with more frequent and intense coastal floods will affect an increasing number of residents in Pomorie's densely built-up coastal strip.
- Cascading effects: evacuations, temporary housing loss, social tensions from damages to the tourism sector, job losses, and migration.

Future social impact: *Substantial* (upper bound), unlikely to reach *Critical* due to limited expected fatalities, though socio-economic stresses will intensify.

- **Regarding the ECONOMIC IMPACT:**

Present (C):
- *Tourism:* Strong dependence on coastal tourism (beaches, balneology, salt pans). Flooding and erosion already affect the beach strip, reducing tourism capacity. Short-term floods result in financial losses for hotels, restaurants, and related businesses.
- *Agriculture:* Soil salinization and flooding threaten agricultural lands around Lake Pomorie. Risks exist for viticulture and winemaking—key sectors for the local economy.
- *Infrastructure and real estate:* Recurrent damages require periodic repairs, straining both municipal and private budgets. Insurance claims increase with each storm.

Present economic impact: *Substantial*.

Future (F):
- *Tourism:* Projected sea level rise and accelerated erosion will significantly reduce tourist inflows. Long-term reputational damages to Pomorie as a destination are likely.
- *Agriculture:* Persistent salinization and frequent flooding may render some farmland unusable. Disruptions to production and supply chains → loss of income.
- *Infrastructure and real estate:* Recurrent and long-lasting damages to roads, sewerage, and the port. In some areas, permanent property loss could occur, reducing asset values and burdening the local economy.

Future economic impact: *Critical*, as damages may become irreversible with long-term loss of assets, land, and key economic sectors.

Summary:

- *Physical impact:* Present – Substantial; Future – Critical
- *Social impact:* Present – Moderate-Substantial; Future – Substantial
- *Economic impact:* Present – Substantial; Future – Critical

Key Takeaways:

- Physical & Economic impacts: Strong increase toward Critical due to sea-level rise, storm surges, and recurrent damage.
- Social impacts: Moderate-to-substantial today, increasing to substantial in future as more residents face flooding and cascading socio-economic pressures.
- Overall Severity: Clear upward trend from Substantial to Critical highlights urgency for adaptation measures, resilience planning, and risk reduction strategies.

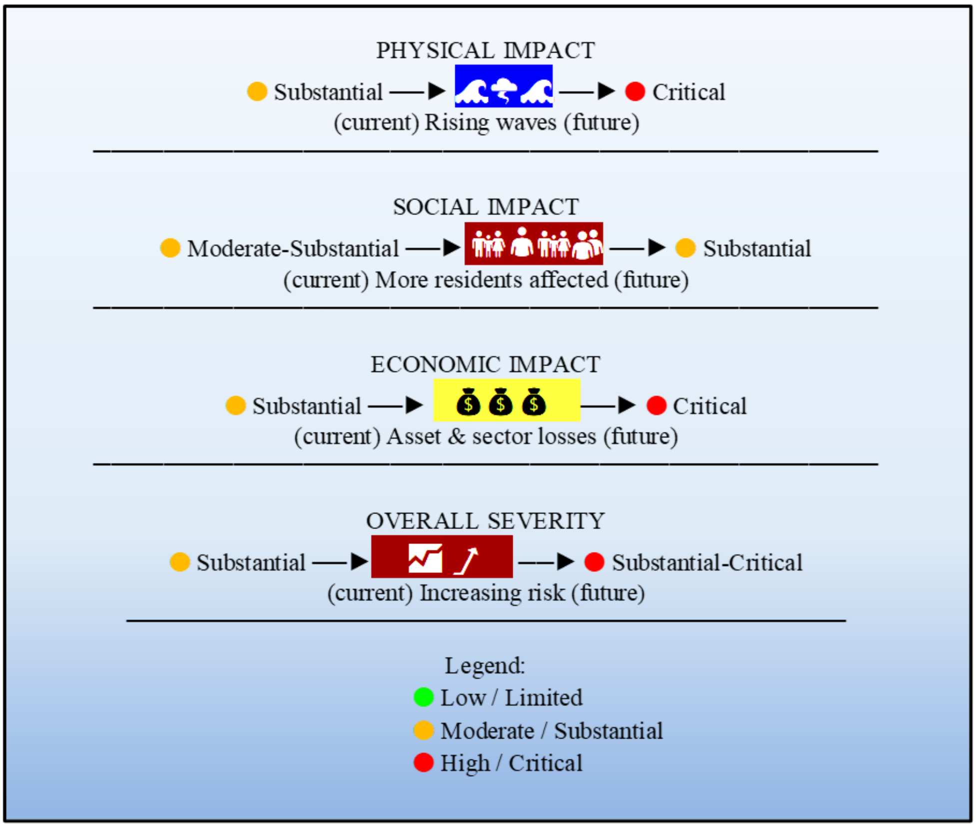

Figure 2-13 Infographic of Climatic Risk Severity in Pomorie Municipality

Overall Severity Summary for Pomorie Municipality:

The overall climate risk severity for Pomorie Municipality from coastal flooding is currently **Substantial**, driven by significant physical and economic vulnerabilities, while social impacts remain moderate to substantial. In the future, severity is projected to increase, with **Critical physical and economic impacts** due to sea-level rise and more frequent flooding, and **Substantial social impacts** from cascading effects such as evacuations, temporary housing loss, and socio-economic stress. Overall, the municipality faces a clear trend toward higher severity over time, emphasizing the need for adaptive measures and resilience planning.

2.4.2. Urgency

The urgency assessment aims to determine the necessity for immediate measures and the prioritization of adaptation actions to address climate risk, in this case – coastal flooding. The approach to defining urgency combines scientific evidence and practical risk management measures, thereby providing a more substantiated basis for municipal priorities. The urgency assessment regarding the risk of coastal flooding in Pomorie Municipality is based on an integrated approach recommended by the CLIMAAX CRA Handbook, which merges quantitative and qualitative indicators of impacts on the physical environment, infrastructure, health, the social sphere, and the economy.

Methodologically, the determination of urgency is based on:

- analysis of exposure and vulnerability of territories, infrastructure, and population (data from Sections 2.3.1.1 and 2.3.1.2);
- comparison of current and future coastal flooding scenarios (2050, RCP4.5 and RCP8.5);
- results and recommendations from the Pomorie Municipality Disaster Protection Plan;
- the Urgency scale recommended by the CLIMAAX CRA Handbook (Fig. 26), used to define the immediacy of adaptation measures.

1. Physical and Infrastructure Aspects

Exposure to Coastal Flooding:

- Current state: More than 60% of areas below 5 m elevation are exposed to floods >0.5 m. The probability of such events occurring within the next 5–10 years is estimated at 35–45%. This implies that a significant share of urbanized territories and agricultural land are directly threatened during extreme tides and storm surges.
- Future state (2050, RCP8.5): The projected sea level rise, combined with the increasing frequency of extreme storms, raises the probability to 60–70%. Areas affected by floods over 1 m are expected to expand by 20–25%. This significantly increases the urgency of protecting critical infrastructure and residential zones.

Table 2-3 Urgency Assessment of the Physical-Infrastructure Component

Physical Component	Current	Future	Remarks and recommendations
Urbanized areas	4	5	Immediate risk to buildings and roads; strengthening and evacuation routes needed.
Coastal dikes and defenses	4	5	Partially functional dikes; future floods require reinforcement and regular inspection.
Agricultural land & salinas	3	4	High exposure but partial protection; urgent measures can reduce economic losses.

Conclusion on the Physical-Infrastructure Component: The combination of physical exposure and infrastructure vulnerability determines a high level of urgency.

2. Health and Social Aspects
2.1. Health Risks

- **Current**: Risk of water contamination and infections in floods >0.5 m; 3–5 local incidents reported over the past decade. Potential for localized epidemiological incidents and the need for rapid response planning.
- **Future**: Increased frequency and intensity of floods → expanded health risks. Restricted access to medical services and greater likelihood of waterborne diseases.

Table 2-4 Urgency Assessment of the Health Component

Health Component	Current	Future	Remarks and recommendations
Drinking water	3	4	High risk during extreme events. Vulnerability of water supply system; urgent protection of water sources needed.
Emergency medical care	3	4	Limited access during floods. Critical need for mobile medical units.

2.2. Social Vulnerability

- **Current**: Vulnerable groups – elderly, low-income households, and residents of low-lying coastal zones. They are more exposed and have limited adaptive capacity.
- **Future**: Increased flood frequency → heightened social stress. An integrated evacuation and social support strategy is required.

Table 2-5 Urgency Assessment of the Social Component

Social component	Current	Future	Remarks and recommendations
Vulnerable groups	3	4	Immediate need for protection and evacuation. Greater demand for protective measures and social assistance.
Psychological stress	2	3	Affects quality of life; preventive social programs recommended.

3. Economic Aspects
3.1. Tourism

- **Current**: Potential losses of €5–10 million/year from floods of 0.5–1 m. Coastal beaches and hotels are exposed to immediate economic risk.
- **Future**: For floods >1 m, losses may reach €15 million/year. Rising losses increase the urgency for adaptive investments.

Urgency Assessment of the Tourism Component: 3 → 4

3.2. Agriculture and Salinas

- **Current**: 200–300 ha of salinas and cropland affected; 30–40% crop losses. Significant economic impact, requiring protective dikes and drainage systems.

- **Future**: With increased flood frequency → losses could reach 50–60%. Without measures, the economic urgency becomes critical.

Urgency Assessment of the Agriculture/Salinas Component: 4 → 5

4. Integrated coastal flood urgency assessment

Table 2-6 Integrated coastal flood urgency assessment in Pomorie municipality

Component	Current	Future	Remarks and recommendations
Physical & Infrastructure	4	5	Immediate risk to dikes, roads, buildings; reinforcement and maintenance plan urgently needed.
Health & Social	3	4	Vulnerable groups, potential health impacts; social programs and evacuation plans necessary.
Economic	3.5	4.5	Tourism and salinas at risk of losses; adaptive investments critical.
Overall Assessment	**3.5**	**4.5**	Combines physical urgency with socio-economic consequences.

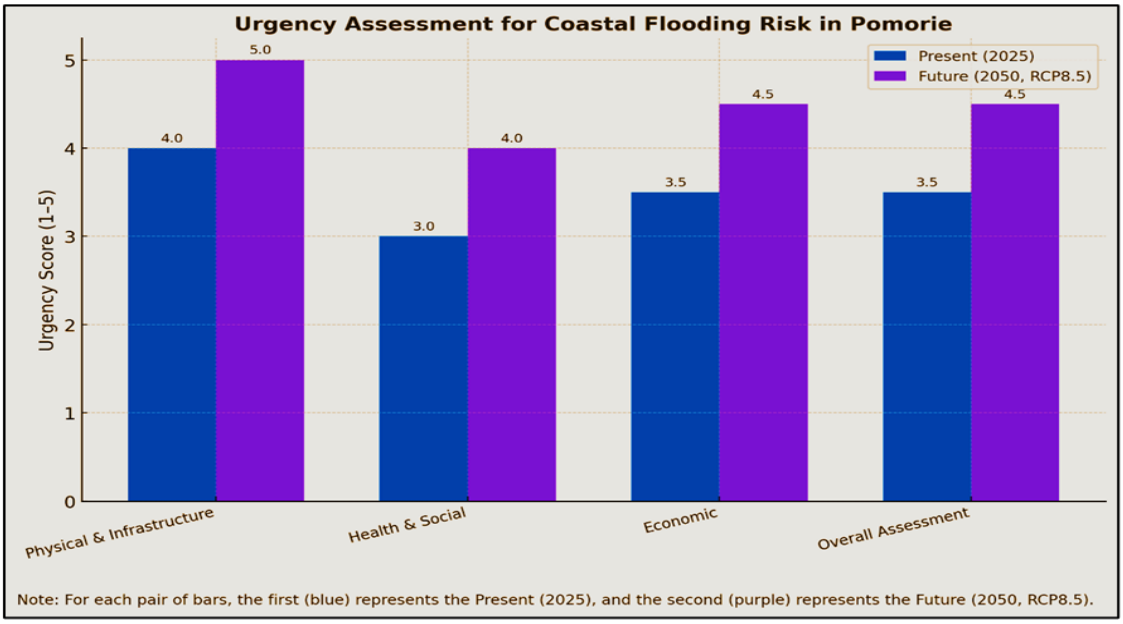

Figure 2-14 Urgency assessment for coastal flooding risk in Pomorie

From the table and the graphic above, it is evident that the **Urgency** of the risk of coastal flooding in Pomorie Municipality increases over time across all components – physical and infrastructure, health and social, as well as economic. This confirms that adaptation actions must commence immediately, with planning for escalation of measures in the long term.

In terms of Physical and Infrastructure Aspects (4 → 5):
The current assessment of "**High**" already indicates a serious threat to dikes, road infrastructure, and buildings in vulnerable areas. The projected increase to "**Critical**" underscores the urgency of strengthening and regularly maintaining protective structures, establishing buffer zones, and developing preventive engineering solutions. This is the most urgent component, dominating the overall Urgency assessment.

In terms of Health and Social Aspects (3 → 4):
Although the current risk is assessed as "Medium–High", its anticipated rise to "High" is highly concerning, particularly due to the presence of vulnerable groups (elderly individuals, people with chronic illnesses, seasonal tourism workers). Flooding can lead to respiratory and infectious diseases, psychological stress, and social disruption. The need to establish early warning systems, social programs, and effective evacuation plans is critical.
In terms of Economic Aspects (3.5 → 4.5):
The current value of "Medium–High" reflects the already existing risk of losses in key economic sectors – tourism and salinas, which form the backbone of the local economy. In the future, the assessment reaches "Very High", indicating potential significant financial damages, job losses, and reduced investment attractiveness. Mitigating these effects requires investments in adaptive infrastructure, insurance mechanisms, and economic diversification.
The overall urgency assessment (3.5 → 4.5) indicates that:
The combined trend from "Medium–High" to "Very High" indicates a serious urgency. It reflects both the physical vulnerability of coastal infrastructure and the severe socio-economic consequences. An increase of a full level emphasizes that any delay in action will lead to exponential growth in damages and recovery costs.
General conclusion: Based on the above, the analysis demonstrates that the urgency of adaptation measures for coastal flooding in Pomorie is already high and rapidly approaching critical levels. An integrated approach is required – engineering protection, social policies, economic incentives, and strategic planning. Timely implementation of structural and institutional measures can prevent escalation to a critical Urgency level in the future.
Integrated Urgency at different potential high of the wave
The table below demonstrates urgency levels across flood depths, integrating physical exposure with potential economic, health, and social impacts. Current values reflect risks under the present sea level and infrastructure, while future values account for sea level rise and extreme weather scenarios. The applied scale (low–medium–high–critical) visualizes the growing urgency of adaptation and the prioritization of measures.

Table 2-7 Urgency levels across flood depths: Integrated physical exposure with potential economic, health, and social impacts

Flood Height	Current	Future
<0.5 m	Medium	High
0.5–1 m	High	High–Critical
>1 m	High–Critical	Critical

The key observations on the latter table indicate the following:

Increasing Risk Over Time: For all flood levels, projections indicate a rising risk. For example, for minor flooding (<0.5 m), the current risk is Medium, whereas the future risk is High;

Escalation for Moderate and Major Floods: For 0.5–1 m floods, the current risk is High, while the future risk reaches High–Critical, indicating a substantial increase in potential hazard. For >1 m floods, the current risk is High–Critical, and the future risk becomes Critical – representing the maximum danger level;

Logical Sequence: Risk increases with water height (an evident correlation).Future assessments are always equal to or higher than current ones;

Final practical implications

- Even minor floods (<0.5 m) in the future can cause significant damage, so preventive measures should not be neglected.
- For moderate floods (0.5–1 m), it is recommended to plan additional protective measures, as the risk is approaching critical levels.
- For major floods (>1 m), the situation remains critical in the future, requiring a strategic approach to infrastructure, early warning systems, and evacuation planning.

2.4.3. Capacity

The municipality has recently installed a rainwater runoff cistern which proved to be effective in the drainage of recent intensive rains. The newly adopted disaster protection plan foresees some key disaster prevention measures like development of an annual work program of the municipal council for disaster risk reduction and attracting all stakeholders to participate in the council's activities and creation of a mechanism at the level of the Council for coordination of planning and implementation of disaster risk reduction measures in plans and programs at the municipal level. Other measures include: development of a municipal training program to build capacity for disaster risk management; regulating town planning in areas with significant potential flood risk through general and detailed development plans; cleaning and maintaining the conductivity of river beds in urbanized areas.

The initial expert assessment, later confirmed by the discussions at the workshop on adaptation and application of CLIMAAX methodology, Pomorie municipality lacks the capacity to address the respective climate risks, as demonstrated by the initial assessment of coastal flooding risk. There is no comprehensive financial capacity to prepare and respond to the risk since the municipal budget provides only small funding for technical design for new storm water sewers. Human capacity is also limited and the CLIMAAX project has been instrumental to raise the awareness of the administration about the CRA. The natural capacity and the physical capacity, esp. the ability to forecast and warn about rapid-onset climate events is lacking or limited. The social capacity is also limited since Pomorie is a small municipality with not very active civil society and NGOs.

2.5. Preliminary Monitoring and Evaluation

A key lesson from the first phase of the climate risk assessment is that the current municipal policies need to be adapted to the new realities of the climate risks for the municipality and the newly adapted disaster protection plan 2025 is the right step in this direction. Another conclusion relates to the need to enhance the reliability of flood maps for municipal-level planning and incorporate local hydrological and structural data. Additionally, collecting and integrating high-resolution datasets on buildings and infrastructure will allow for more precise estimates of exposure. The outputs of global flood maps should then be validated against historical flood events in Pomorie municipality, providing an opportunity to calibrate the models and ensure their accuracy.

These insights can subsequently inform local adaptation strategy and other strategic documents. Measures such as reinforcing protective structures, guiding land-use planning, and prioritizing emergency response efforts can all benefit from this refined understanding of local flood risks.

2.6. Work plan

The work plan for the remaining phases of the ClimateSmart Pomorie (CSP-Future) project is structured to build on the baseline risk assessment by refining risk knowledge, developing adaptation strategies, and strengthening policy integration for climate resilience.

Phase 2: Refinement of Multi-Risk Assessment

At this phase Pomorie will collect high-resolution data and make some analysis: The project team, in cooperation with external multi-risk assessment experts, will collect and analyze local climate data at a higher resolution to refine the initial risk assessment. This includes detailed studies of floods, droughts, heavy rainfall, strong winds, and heatwaves to better identify the municipality's most vulnerable sectors and populations.

We will do development of climate impact scenarios using predictive modeling to assess future risks, considering various plausible climate pathways and socioeconomic developments.

Pomorie Municipality will make an organization of workshops, expert consultations, and community meetings to gather input, validate results, and strengthen collaboration among all local actors.

Also report compilation and publication of a multirisk assessment report, providing evidence-based insights for the development of adaptation strategies.

These activities aim to deepen understanding of risks, enhance accuracy in vulnerability mapping, and support evidence-based policy actions tailored to Pomorie's specific climate threats. High-resolution data and scenarios directly inform decision-making for resilience investments and adaptation measures.

Phase 3: Adaptation Strategy Development and Policy Integration

Pomorie will review and update Strategic Documents: Systematic revision of municipal policies, risk reduction programs, and disaster management plans using the refined assessment results from Phase 2. Development of Climate Adaptation Strategy we will follow by drafting a comprehensive strategy and action plan, setting clear adaptation targets, timelines, responsible stakeholders, and monitoring mechanisms.

Pomorie will implement large-scale public awareness activities, educational campaigns, and final project conference to disseminate findings and encourage climate-resilient behaviors among residents, businesses, and authorities.

We plan to conduct two major workshops (local and international sharing of best practices) and a final conference to review accomplishments, transfer knowledge, and foster continued collaboration.

These actions ensure that the new knowledge and evidence from the project are effectively translated into municipal policy, local planning, and practical community adaptation measures supporting long-term resilience.

Aspects Not Studied and Rationale.

First are non-climate hazards. The project does not address non-climate-related risks such as technological accidents, earthquakes, or other geohazards, as the focus is specifically on climate change-driven risks (floods, droughts, heatwaves, storms, etc.).

Second is Sectoral Micro-Management. In-depth operational or technical interventions within specific sectors (e.g., detailed agricultural practices, energy grid management) are not included, as the project's scope is to inform strategic, multi-sectoral adaptation rather than provide sector-specific technical solutions.

Private Property Assessments: The project prioritizes public policy and communal risk mapping, not individual private property vulnerability studies, due to resource and data limitations.

This targeted approach enables Pomorie Municipality to allocate resources efficiently, addresses the most pressing and relevant risks, and ensures that project activities align directly with climate adaptation needs at the municipal scale.

3. Conclusions Phase 1- Climate risk assessment

The findings and conclusions at this phase of the project based on the CRA of coastal flooding are as follows:

Findings:

1. The accuracy of global flood maps for Pomorie Municipality is limited by local geographic and infrastructural factors. Coastal dikes, levees, and drainage systems are not represented, potentially overestimating flooding in protected areas.
2. Missing information includes detailed local topography, cadastral data, building types, and historical flood records, which would improve precision in economic damage calculations.
3. Maps of coastal flood potential and associated damages reveal which areas, both in the main town and peripheral settlements, are most exposed, showing that risk is not uniform across the municipality.
4. Exposure and vulnerability interplay is critical: high-density urban areas and economically valuable infrastructure show higher potential losses even for moderate inundation scenarios.

5. The workflow demonstrates how to access European-scale land use datasets, assign vulnerability curves and maximum damages to each land use category, and combine hazard, exposure, and vulnerability data to estimate economic impacts.
6. Understanding where damage originates helps prioritize preventive measures: areas with high exposure and vulnerability require urgent attention.

Conclusions:

- Global datasets are a useful starting point but require significant local adaptation for accurate coastal flood risk assessment.
- The workflow illustrates a systematic approach to combining hazard, exposure, and vulnerability information to quantify economic risks.
- Peripheral settlements contribute substantially to municipal-level risk and must be considered in planning.
- The exercise enhances understanding of the determinants of risk, showing that both the spatial distribution of assets (exposure) and their susceptibility (vulnerability) drive potential damages.
- These results can inform both short-term protective measures and long-term strategic planning, supporting climate adaptation and disaster preparedness.

1. Local accuracy considerations

Coastal flood maps provide a useful general overview of flood potential, but their accuracy for Pomorie may be affected by local geographical and infrastructural factors, such as:

- Shallow lagoons, estuaries, and the semi-enclosed Burgas Bay.
- Existing coastal protections (sea walls, embankments, drainage systems) not included in global models.
- Land subsidence in low-lying coastal areas and around Pomorie Lake.

2. Missing information for improved assessment

- Local tidal and storm surge measurements to validate global model outputs.
- Detailed DEMs with higher resolution than MERIT/NASADEM for Pomorie’s coastal zone.
- Updated data on urban expansion, tourism infrastructure, and industrial facilities along the coast.
- Records of historical flood events for calibration and validation of hazard assessments.

3. Insights from flood maps

- Global flood maps help identify areas with the highest flood potential under both present-day and 2050 RCP8.5 scenarios.
- Scenario comparison highlights the relative contribution of sea level rise versus extreme storm events.
- Overlaying flood maps with land-use data reveals which sectors (residential, agricultural, industrial, tourism) are most at potential risk.

4. Recommendations for local risk management

- Use global flood maps as boundary conditions for local hydraulic and hydrodynamic modeling of Pomorie’s coastal flood risk.

- Integrate local flood protection measures, bathymetry, and topography to refine risk estimates.
- Monitor sea level trends, land subsidence, and storm patterns regularly to update hazard assessments.
- Incorporate flood-prone zones into strategic planning for future development.

5. Key takeaways from the workflow

- Ability to retrieve and visualize coastal flood maps for Pomorie.
- Awareness of limitations in global datasets and the need for local calibration.
- Understanding differences between scenarios (present-day vs. 2050) and return periods (2–250 years).
- Identification of critical areas for further analysis in local risk workflows.

4. Progress evaluation and contribution to future phases

Table 4-1 Overview key performance indicators

Key performance indicators	*Progress*
Minimum 1 workflow successfully applied on Deliverable 1 – by the end of month 6	Deliverable 1 submitted on 5.9.2025
1 climate multirisk assessment report published – by the end of month 16	Pending
15 stakeholders involved in the activities of the project – by the end of month 22	Pending Kick-off meeting completed Workshop 1 completed
20 000 residents, key local and regional authorities and stakeholders reached through awareness campaigns – by the end of month 22	Pending Initial press-conference completed
1 awareness-raising campaign conducted – by the end of month 22	Pending Initial press-conference completed
4 articles in regional media mentioning the project	Pending Publications on municipality website
2 local workshops, one final conference and meetings conducted for decision-makers and stakeholders – meeting by the end of month 2, workshop on the adaptation and application – by mid-month 6, workshop with stakeholders – by the end of month 15, final conference – by the end of month 22	Pending Kick-off meeting completed Workshop 1 completed
2 international workshops for sharing of experience and best practices – by mid-2025 and end of 2026	Pending 1 international workshop in Barcelona completed

Key performance indicators	*Progress*
Municipal strategic documents regarding risk reduction, disaster and accidents management being revised – by the end of month 21	Pending

Table 4-2 Overview milestones

Milestones	*Progress*
M1: Successful Kick-off Meeting and Press Conference (Activity 1.1 and 1.3) – by the end of month 2 and end of month 5	Activity 1.1. completed in Month 5, Activity 1.3. completed in Month 6
M2: Completion of Inventory of potential hazards and policy context (Activity 1.2) – by the end of month 5	Activity 1.2. completed in Month 5
M3: Workshop on CLIMAAX Framework Application (Activity 1.4) – by mid-month 6	Activity 1.4. completed in Month 5
M4: Completion of CLIMAAX Framework Application Report (Activity 1.5) – by the end of month 6	Activity 1.5. completed in Month 6
M5: Completion of Data Collection and Research for Multi-Risk Assessment (Activity 2.1) – by the end of month 14	Pending
M6: Stakeholder Workshop on Multi-Risk Assessment (Activity 2.2) – by the end of month 15	Pending
M7: Attend the CLIMAAX workshop held in Barcelona – by mid-2025	Activity completed in Month 3
M8: Submission of Multi-Risk Assessment Report (Activity 2.3) – by the end of month 16	Pending
M9: Review and update of municipal strategic documents on climate risk, environmental and disaster management (Activity 3.1) – by the end of month 20	Pending
M10: Draft Climate Adaptation Strategy (Activity 3.2) – by the end of month 21	Pending
M11: Final Conference and Presentation of Project Results (Activity 3.3) – by the end of month 22	Pending
M12: Attend the CLIMAAX workshop held in Brussels – by the end of 2026	Pending

5. Supporting documentation (1-2 pages)

1. Main report (*.PDF format)
2. Generated output from the Floods workflow (*.ZIP archive)
3. Publicity about the project

Project contract announcement -

https://www.pomorie.bg/podpisan-e-dogovor-po-proekt-vklimatitchno-inteligentno-pomorie-kartirane-na-ustoytchivo-badeshtev

Kick-off meeting and initial press-conference -

https://www.pomorie.bg/provede-se-vstapitelna-preskonferentsiya-po-proekt-vklimatitchno-inteligentno-pomorie-kartirane-na-ustoytchivo-badeshtev

Workshop for Deliverable 1 - https://www.pomorie.bg/obshtina-pomorie-izpalnyava-proekt-vklimatitchno-inteligentno-pomorie-kartirane-na-ustoytchivo-badeshtev

6. References

1 *Aerts, J. C. J. H., Botzen, W. J. W., & van der Veen, A. (2008). Cost estimates for flood risk management strategies in the Netherlands. Journal of Flood Risk Management, 1(2), 99–111. https://doi.org/10.1111/j.1753-318X.2008.00014.x*

2 *BirdLife International. (2025). Important Bird Areas factsheet: Pomorie Lake. https://datazone.birdlife.org/site/factsheet/pomorie-lake-iba-bulgaria/text*

3 *Carleton College. (n.d.). Sea Level Rise and the Bulgarian Coast. Science Education Resource Center. Retrieved September 5, 2025, from https://serc.carleton.edu/vignettes/collection/31871.html*

4 *CityPopulation.de. (2025). Pomorie (Burgas, Bulgaria) – population statistics, charts, map and location. https://citypopulation.de/en/bulgaria/burgas/pomorie/57491__pomorie*

5 *CLIMAAX Consortium. (2023). CLIMAAX CRA Handbook: Climate Risk Assessment Guidelines. Horizon Europe.*

6 *CLIMAAX Consortium. (n.d.). CLIMAAX CRA Handbook: Climate risk assessment methodology for municipalities. CLIMAAX Project.*

7 *European Commission. (2020). EU strategy on adaptation to climate change. Directorate-General for Climate Action.*

8 *European Commission. (2025). Conservation of Pomorie Lake coastal lagoon (LIFE19-NAT-BG-000804). https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE19-NAT-BG-000804/conservation-of-pomorie-lake-coastal-lagoon*

9 *European Environment Agency. (2017). Climate change, impacts and vulnerability in Europe 2016: An indicator-based report. EEA Report No 1/2017.*

10 *European Environment Agency. (2024). Global and European sea level rise — EEA indicator assessment. Retrieved September 5, 2025, from https://www.eea.europa.eu/en/analysis/indicators/global-and-european-sea-level-rise*

11 *Frontiers in Marine Science. (2025). Innovative UAS-based photogrammetry for coastal dune mapping along the Bulgarian Black Sea coast. Frontiers in Marine Science. https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2025.1579724/full*

12 *Galabov, V., Kortcheva, A., & Staneva, J. (2015). Reconstruction of extreme Black Sea storms with numerical models. arXiv preprint arXiv:1509.08513. https://arxiv.org/abs/1509.085*

13 *Hallegatte, S., Green, C., Nicholls, R. J., & Corfee-Morlot, J. (2013). Future flood losses in major coastal cities. Nature Climate Change, 3(9), 802–806. https://doi.org/10.1038/nclimate1979*

14 *Hallegatte, S., Rentschler, J., & Rozenberg, J. (2019). Lifelines: The resilient infrastructure opportunity. World Bank.*
15 *Institute of Oceanology, Bulgarian Academy of Sciences. (2025). Oceanology, Volume 3 – Coastal erosion research. https://www.io-bas.bg/Oceanology_Volume_3_bg.html*
16 *Intergovernmental Panel on Climate Change (IPCC). (2014). Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.*
17 *Jonkman, S. N., & Vrijling, J. K. (2008). Loss of life due to floods: Impact of hazard, exposure and vulnerability. Natural Hazards, 46(3), 451–464. https://doi.org/10.1007/s11069-007-9195-5*
18 *Kundzewicz, Z. W., Mata, L. J., Arnell, N. W., Döll, P., Kabat, P., Jiménez, B., ... & Shiklomanov, I. (2007). Freshwater resources and their management. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), Climate change 2007: Impacts, adaptation and vulnerability.*
19 *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 173–210). Cambridge University Press.*
20 *LIFE for Pomorie Lagoon. (2025). Natura 2000 zones 3-38. https://lifeforpomorielagoon.eu/natura-2000-zones-3-38*
21 *LIFE Project (LIFE19-NAT-BG-000804). (2020). Conservation of Pomorie Lake coastal lagoon. Biodiversity Foundation. https://biodiversity.bg/Conservation-of-Pomorie-Lake-coastal-lagoon-LIFE-19-/-NAT-/-BG-/-000804-3-4171*
22 *Merz, B., Kreibich, H., Schwarze, R., & Thieken, A. (2010). Review article "Assessment of economic flood damage". Natural Hazards and Earth System Sciences, 10, 1697–1724. https://doi.org/10.5194/nhess-10-1697-2010*
23 *Ministry of Tourism, Republic of Bulgaria. (2023). The Salt Museum in Pomorie was visited by over 16,000 tourists last year. https://tourism.government.bg/en/kategorii/novini/salt-museum-pomorie-was-visited-over-16000-tourists*
24 *Municipality of Pomorie. (2019). Plan for Disaster Protection of Pomorie Municipality [План за защита при бедствия на Община Поморие]. Pomorie, Bulgaria.*
25 *Municipality of Pomorie. (2021). Sustainable Development and Environmental Protection Strategy 2021–2027 [Стратегия за устойчиво развитие и опазване на околната среда 2021–2027]. Pomorie, Bulgaria.*
26 *Peychev, V., Stancheva, M., & Palazov, A. (2021). Human-induced changes in sediment balance and shoreline dynamics along the Bulgarian Black Sea coast. Journal of Coastal Conservation, 25(2), 1–15. https://link.springer.com/article/10.1007/s11852-021-00841-4*
27 *Pomorie Municipality. (n.d.). Disaster protection plan of Pomorie Municipality. Pomorie Municipality.*
28 *Prodanov, B., Stancheva, M., Palazov, A., & Peychev, V. (2025). Sand dunes along the Bulgarian Black Sea coast. ResearchGate. https://www.researchgate.net/publication/290546143_Sand_dunes_along_the_bulgarian_black_sea_coast*
29 *Ramsar Convention Secretariat. (2002). Pomorie Wetland Complex (Ramsar Site no. 1229). Ramsar Sites Information Service. https://rsis.ramsar.org/ris/1229*
30 *Rijkswaterstaat. (2018). Flood risk management in coastal areas: Guidelines and best practices. Dutch Ministry of Infrastructure and Water Management.*
31 *TheMayor.eu. (2025). Pomorie: Information. https://www.themayor.eu/en/bulgaria/pomorie/info*
32 *UNISDR. (2015). Sendai framework for disaster risk reduction 2015–2030. United Nations Office for Disaster Risk Reduction.*
33 *Wikipedia contributors. (2025). Lake Pomorie. In Wikipedia. https://en.wikipedia.org/wiki/Lake_Pomorie*
34 *Wikipedia contributors. (2025). Pomorie Municipality. In Wikipedia. https://en.wikipedia.org/wiki/Pomorie_Municipality*
35 *Wikipedia contributors. (2025). Pomorie. In Wikipedia. https://en.wikipedia.org/wiki/Pomorie*
36 *World Bank. (2025). Climate Change Knowledge Portal: Bulgaria – Sea Level Rise Projections. Retrieved September 5, 2025, from https://climateknowledgeportal.worldbank.org/country/bulgaria/sea-level-projections*
37 *World Health Organization. (2019). Health emergency and disaster risk management: A global framework for action. WHO Press.*