

D.1.4.1

Report on the local scenarios

Neretva estuary pilot site

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Index

Abstract.....	4
1. Introduction.....	5
2. Methodology.....	6
2.1. Sheet 1 – Qualitative Sensitivity analysis.....	6
2.2. Sheet 2 – Exposure analysis	10
2.3. Sheet 3 – Adaptation analysis	12
2.4. Sheet 4 – Residual vulnerability assessment	15
3. Results and discussion	17
3.1. Exposure.....	17
3.2. Adaptation Strategies and Adaptation Capacity.....	22
3.2.2. Tourism	23
3.2.3. Agriculture	25
3.2.4. Fisheries and Aquaculture.....	26
3.3. Residual vulnerability assessment	27
4. Conclusion.....	29
References.....	30
Annexes	31

Abstract

This assessment explores the vulnerability and climate change exposure of the Neretva Estuary, focusing on four key sectors: biodiversity, tourism, agriculture, and fisheries/aquaculture. Each sector is evaluated in terms of its sensitivity to climate stressors and the practicality of implementing adaptation strategies, considering local environmental, socio-economic, and governance factors. The analysis uses two climate scenarios outlined by the IPCC: SSP2-4.5 (moderate emissions) and SSP5-8.5 (high emissions). Findings suggest that the Neretva Estuary faces considerable challenges, with increasing threats from hydrological, hydrogeological, and temperature-related risks across all four sectors. Moreover, under both scenarios—particularly SSP5-8.5—the estuary becomes increasingly vulnerable to strong winds and extreme weather events, adding to the already complex climate risk landscape. In the high-risk SSP5-8.5 pathway, the capacity for adaptation weakens significantly, pushing all observed sectors into a state of high vulnerability. This trajectory points to a concerning future for the region if no substantial action is taken. Given the estuary’s role as an ecological and economic hub, it is now considered a climate impact hotspot, where immediate, coordinated adaptation efforts are essential. Protecting ecosystems, maintaining agricultural productivity, safeguarding infrastructure, and supporting local livelihoods will require integrated and cross-sectoral responses in the face of accelerating climate pressures.

1. Introduction

This report presents a structured methodology for assessing climate vulnerability and resilience in the Neretva Estuary pilot area, as part of activities aimed at strengthening the resilience of coastal and near-coastal ecosystems to climate change.

The Neretva Estuary, with its diverse mosaic of wetlands, rivers, and agricultural habitats, is one of the most ecologically valuable regions in Croatia. The Neretva River mouth is part of the Natura 2000 ecological network, and certain sections of the wetlands are also designated as special ornithological reserves. This area provides critical habitats for numerous bird species, especially migratory birds, and supports a high level of biodiversity. However, this ecological richness has already been partially degraded due to a combination of natural vulnerability, growing anthropogenic pressures, and the impacts of climate change — with long-term threats continuing to escalate.

As in other parts of the Mediterranean, climate change in the Neretva Estuary is expected to intensify existing pressures, including rising temperatures, more frequent and severe heatwaves, prolonged drought periods, and increasing intrusion of saltwater into freshwater systems, particularly during the summer months.

Agriculture is the most important economic sector in the region, largely due to the fertile soils of the alluvial estuary. Traditional farming practices and the area's rich agrobiodiversity are a key part of the Neretva Estuary's cultural heritage, while also playing a crucial role in preserving landscapes and associated ecological values. In addition to agriculture, the region experiences strong seasonal tourism growth, driven by its natural heritage, cultural traditions, and the Neretva River itself. Although commercial fishing is limited, both fishing and aquaculture remain important to the local community and have potential for development through specialised tourism.

This study applies a shared vulnerability assessment matrix, developed in collaboration with project partners, which integrates three key components: sensitivity, exposure, and adaptive capacity. The assessment focuses on four sectors — biodiversity, tourism, agriculture, and fisheries/aquaculture — and considers two climate scenarios:

- SSP2-4.5 — a moderate emissions reduction scenario, and
- SSP5-8.5 — a high-emissions pathway, in which adaptive capacity becomes increasingly constrained and ineffective.

This integrated approach enables the identification of the most critical climate risks across sectors and provides a solid foundation for defining and prioritising adaptation measures at the local level — with the aim of protecting ecosystems, reducing socio-economic losses, and enhancing community resilience.

2. Methodology

The methodology adopted in this study is based on a framework provided by the European Commission's *Technical Guidance on Sustainability Verification for the InvestEU Fund* (EU, 2021) and it is adapted to a local scale by integrating ecological, socio-economic, and governance dimensions.

The assessment combines:

- **Qualitative Sensitivity analysis** (Sheet 1 of attached file): evaluating how system components respond to climate threats.
- **Exposure analysis** (Sheet 2 of attached file): assessing expected impacts under climate projections.
- **Adaptation analysis** (Sheet 3 of attached file): identifying the capacity to mitigate risks through available measures.
- **Residual vulnerability assessment** (Sheet 4 of attached file): integrating the above to provide risk-based prioritization.

This multi-layered approach ensures a structured and transparent methodology for identifying climate-related risks and adaptation needs. Hazards and threats are identified based on the probability of occurrence (low, medium, high); expected severity of impact on ecological and socio-economic systems, and relevance at seasonal and long-term scales.

To ensure a more robust and representative assessment of the levels of environmental sensitivity/criticality, it was foreseen that for each pilot area the matrix would be compiled in at least three separate versions, each by a subject with a complementary perspective:

- A research organization, to ensure a scientific and technical analysis.
- A local government/public administration to integrate aspects of planning, governance and political feasibility.
- A representative from a protected area or environmental management body, to bring the operational and territorial point of view, rooted in concrete knowledge of the natural context.

A final matrix will be put together merging the three different contributions. This triangulation of inputs mitigated bias, enabled cross-sectoral comparisons, and ensured legitimacy of the results.

For the analysis of hazards and threats and local scenarios of the Po Delta and Lamone River pilot site the following stakeholders were involved: i) PP3 UNIBO, as research organization; ii) the LM Ravenna Municipality, as local public administration; and iii) the PP2 PDP, as environmental management body.

2.1. Sheet 1 – Qualitative Sensitivity analysis

The goal of this evaluation is to identify how climate threats affect the components of each thematic area based on their inherent characteristics and role in the socio-ecological system.

The assessment is applied to four selected sectors that characterize the context of the pilot areas, each broken down into three key components (Fig. 1):

1. **Biodiversity** (protected habitats, species richness, ecosystem services).
2. **Tourism** (infrastructure and services, economic development and employment, cultural/natural attractions).
3. **Agriculture** (land use and landscape, agricultural income and employment; agricultural biodiversity).
4. **Fishing & Aquaculture** (resource use, income and employment, multifunctionality).

These four selected sectors represent both ecological and socio-economic pillars of coastal systems. They were selected for their high exposure to climate threats and their relevance for local communities.

Each component is assessed against four climate factors:

- **Temperature** (increase, heat/cold waves, wildfires),
- **Wind** (changes in the wind regime, storms; whirlwinds),
- **Water** (change in the hydrological regime and type of precipitation; sea acidification; saltwater intrusion; sea level rise; flooding.),
- **Solid Mass** (coastal erosion; soil degradation/erosion; landslide; subsidence).

These four climate factors allow for a comprehensive capture of different stressors. These categories encompass both gradual processes (e.g., sea level rise, acidification) and extreme events (e.g., storms, heat waves, floods).

Each key component is assigned a sensitivity level for each threat, ranging from ‘low sensitivity’ (score 1) to ‘high sensitivity’ (score 3).

EVALUATION OF SENSITIVITY

OUTPUT: inviduating the sensitivity of the components of each area to climatic factors

This analysis aims to:
 * Analyse how climate factors translate into climate threats and hazards.
 * Identify the impacts of these threats for the area of reference.

Guide for compilation:
 * Do not add rows, insert the info in the rows provided
 * Select the level of sensitivity from the drop-down menu in the respective cell

AREA: BIODIVERSITY			Area of protected habitats	Species richness	Ecosystem services
CLIMATE FACTORS	THREATS	IMPACTS	SENSITIVITY	SENSITIVITY	SENSITIVITY
TEMPERATURE	Temperature increase, heat waves				
	Cold waves, frost				
	Wildfires				
WIND	Changes in the wind regime, storms (rain-snow and wind)				
	Whirlwinds				
WATER	Change in the hydrological regime (water stress, drought) and type of precipitation				
	Sea acidification				
	Saltwater intrusion				
	Sea level rise				
SOLID MASS	Flooding (coastal, fluvial, pluvial, groundwater)				
	Coastal erosion				
	Soil degradation/erosion				
	Landslide				
	Subsidence				

AREA: TOURISM			Tourism infrastructure and services	Economic development and employmen	Preservation of tourist attractions
CLIMATE FACTORS	THREATS	IMPACTS	SENSITIVITY	SENSITIVITY	SENSITIVITY
TEMPERATURE	Temperature increase, heat waves				
	Cold waves, frost				
	Wildfires				
WIND	Changes in the wind regime, storms (rain-snow and wind)				
	Whirlwinds				
WATER	Change in the hydrological regime (water stress, drought) and type of precipitation				
	Sea acidification				
	Saltwater intrusion				
	Sea level rise				
SOLID MASS	Flooding (coastal, fluvial, pluvial, groundwater)				
	Coastal erosion				
	Soil degradation/erosion				
	Landslide				
	Subsidence				

AREA: AGRICULTURE			Land use and landscape	Agricultural income and employment	Agricultural biodiversity
CLIMATE FACTORS	THREATS	IMPACTS	SENSITIVITY	SENSITIVITY	SENSITIVITY
TEMPERATURE	Temperature increase, heat waves				
	Cold waves, frost				
	Wildfires				
WIND	Changes in the wind regime, storms (rain-snow and wind)				
	Whirlwinds				
WATER	Change in the hydrological regime (water stress, drought) and type of precipitation				
	Sea acidification				
	Saltwater intrusion				
	Sea level rise				
	Flooding (coastal, fluvial, pluvial, groundwater)				
SOLID MASS	Coastal erosion				
	Soil degradation/erosion				
	Landslide				
	Subsidence				

AREA: FISHING AND AQUACULTURE			Use of resources	Income and employment	Multifunctionality
CLIMATE FACTORS	THREATS	IMPACTS	SENSITIVITY	SENSITIVITY	SENSITIVITY
TEMPERATURE	Temperature increase, heat waves				
	Cold waves, frost				
	Wildfires				
WIND	Changes in the wind regime, storms (rain-snow and wind)				
	Whirlwinds				
WATER	Change in the hydrological regime (water stress, drought) and type of precipitation				
	Sea acidification				
	Saltwater intrusion				
	Sea level rise				
	Flooding (coastal, fluvial, pluvial, groundwater)				
SOLID MASS	Coastal erosion				
	Soil degradation/erosion				
	Landslide				
	Subsidence				

Fig. 1 – Structure and input fields for the qualitative sensitivity analysis.

2.2. Sheet 2 – Exposure analysis

The goal is to assess how climate risks are expected to affect the pilot site over time, based on global scenarios, local projections and seasonal variability.

Two IPCC Shared Socio-economic development Pathways (SSPs) were selected (IPCC, 2023):

- **SSP2-4.5 (“Middle of the Road”)**: an intermediate scenario where socio-economic and technological trends follow historical trajectories, without major shifts in development, leading to medium-level warming. CO₂ emissions remain roughly stable until mid-century before declining, but they do not reach net zero by 2100. This pathway results in a projected global warming of about 2.7 °C by 2100 (relative to 1850–1900), with a likely exceedance of 1.5 °C between 2021 and 2040.
- **SSP5-8.5 (“Fossil-Fueled Development”)**: a high-emission pathway characterized by energy-intensive growth driven by intensive fossil fuel use and reliance on technological progress, resulting in severe warming and associated impacts. Under this pathway, CO₂ emissions roughly triple by 2075, leading to a projected global warming of about 4.4 °C by 2100 (range 3.3–5.7 °C). In this scenario, exceeding 1.5 °C of warming in 2021–2040 is very likely, with severe consequences for ecosystems, societies, and economies.

These scenarios enable comparison of vulnerabilities under both realistic and extreme climate futures, highlighting the range of possible risks and adaptation needs.

The four climate factors from sheet 1 are converted into risk factors (Fig. 2):

- **Thermal risk and climate extremes** ← Temperature
- **Hydraulic and hydrogeological risk** ← Water
- **Wind and weather storm risk**
- **Geological and land degradation risk** ← Solid Mass

For each season (spring, summer, autumn, winter) and for each risk factor, an exposure level is assigned, ranging from ‘low exposure’ (score 1) to ‘high exposure’ (score 3).

Each risk is assessed for its probability and expected impact, establishing a baseline (current state) and projected future conditions under 2 selected IPCC climate (SSP2-4.5 and SSP5-8.5).

EVALUATION OF EXPOSURE

OUTPUT: Identification of the climate risk factors of the location/area under consideration at present and in the two scenarios

This analysis assesses future exposure to climate risks with reference to the location of the pilot action (macro-climatic area), using the climate projections available according to the latest IPCC Report, choosing scenarios SSP2-4.5 and SSP5-8.5. The expected seasonal climate variations and the resulting impacts in terms of risks for the pilot area are qualitatively assessed.

Current climate exposure				
Season	Thermal risk and climate extremes	Hydraulic and hydrogeological risk	Wind and weather storm risk	Geological and land degradation risk
Spring				
Summer				
Autumn				
Winter				
Future climate exposure: SSP2-4.5 scenario - "Middle of the Road" world where trends largely follow their historical patterns				
Season	Thermal risk and climate extremes	Hydraulic and hydrogeological risk	Wind and weather storm risk	Geological and land degradation risk
Spring				
Summer				
Autumn				
Winter				
Future Climate Exposure: Scenario SSP5-8.5 - Fossil-fueled Development "Taking the Highway", a world characterised by rapid and unlimited growth in economic production and energy use				
Season	Thermal risk and climate extremes	Hydraulic and hydrogeological risk	Wind and weather storm risk	Geological and land degradation risk
Spring				
Summer				
Autumn				
Winter				

LEGEND

HIGH: High probability of occurrence with potential significant impacts
 MODERATE-HIGH
 MODERATE: Medium probability of occurrence with manageable impact
 MODERATE-LOW
 LOW: Limited probability and low impacts

Fig. 2 – Structure and input fields for the exposure analysis.

2.3. Sheet 3 – Adaptation analysis

This sheet evaluates the adaptive capacity of each area, focusing on strategies to mitigate or buffer impacts from the exposure risks (Fig. 3), such as:

- **Infrastructural** (e.g., barriers, drainage),
- **Managerial** (e.g., land use planning, irrigation solutions),
- **Formative** (e.g., awareness and training campaigns),
- **Ecosystemic** (e.g., wetland restoration, green infrastructure).

Capacity is scored qualitatively as High (robust systems in place, good governance, financial/technical resources - score 3), Medium (partial coverage, possibility for improvement - score 2), or Low (limited or no capacity, lack of awareness/tools/resources - score 1), reflecting governance, resources, and technical feasibility.

Adaptation analysis

OUTPUT: Adaptation strategies of the components examined for each area in relation to climate risks

Overall objective: Compile a vulnerability assessment for the future for each thematic area, identifying:
 1. The adaptation measures needed for each component of the scope.
 2. The level of adaptive capacity (High, Medium, Low) with respect to different types of climate risks.

For each component and type of risk, identify specific and concrete mitigation/prevention actions, e.g.:
 * Infrastructural (e.g. barriers, shelters, drainage)
 * Managerial (e.g. planning, monitoring, soil/water management)
 * Formative (e.g. capacity building, vocational training)
 * Ecosystemic (e.g. nature-based solutions)

Assign a level of adaptive capacity for each combination.

LEGEND:
 * High: if effective measures already exist or the context is favourable (resources, governance, awareness).
 * Medium: if supportive actions are needed but there is some operational scope.
 * Low: if tools, resources, knowledge or political will are lacking.

AREA: BIODIVERSITY					
Component	Scenario SSP2-4.5	Adaptation to thermal risk and climate extremes	Adaptation to hydraulic and hydrogeological risk	Adaptation to wind and weather storm risk	Adaptation to geological and land degradation risk
Area of protected habitats	Measures	List potential adaptation/prevention measures and their level			
	Adaptive Capacity				
Species richness	Measures	List potential adaptation/prevention measures and their level			
	Adaptive Capacity				
Ecosystem services	Measures	List potential adaptation/prevention measures and their level			
	Adaptive Capacity				
AREA: TOURISM					
Component	Scenario SSP2-4.5	Adaptation to thermal risk and climate extremes	Adaptation to hydraulic and hydrogeological risk	Adaptation to wind and weather storm risk	Adaptation to geological and land degradation risk
Tourism infrastructure and services	Measures				
	Adaptive Capacity				
Economic development and employment	Measures				
	Adaptive Capacity				
Preservation of tourist attractions	Measures				
	Adaptive Capacity				

AREA: AGRICULTURE					
Component	Scenario SSP2-4.5	Adaptation to thermal risk and climate extremes	Adaptation to hydraulic and hydrogeological risk	Adaptation to wind and weather storm risk	Adaptation to geological and land degradation risk
Land use and landscape	Measures				
	Adaptive Capacity				
Agricultural income and employment	Measures				
	Adaptive Capacity				
Agricultural biodiversity	Measures				
	Adaptive Capacity				
AREA: FISHING AND AQUACULTURE					
Component	Scenario SSP2-4.5	Adaptation to thermal risk and climate extremes	Adaptation to hydraulic and hydrogeological risk	Adaptation to wind and weather storm risk	Adaptation to geological and land degradation risk
Use of resources	Measures				
	Adaptive Capacity				
Income and employment	Measures				
	Adaptive Capacity				
Multifunctionality	Measures				
	Adaptive Capacity				

Fig. 3 - Structure and input fields for the adaptation analysis.

2.4. Sheet 4 – Residual vulnerability assessment

The goal is to quantify residual vulnerability after adaptation is considered, allowing for risk-based planning. Residual vulnerability provides a prioritization tool for identifying critical areas requiring urgent adaptation measures.

Residual vulnerability is automatically calculated using the formula:

$$\text{Residual Vulnerability} = \text{Sensitivity} * \text{Exposure} / \text{Adaptation Capacity}$$

Under SSP2-4.5, adaptation capacity is considered active, while under SSP5-8.5 it is fixed at 1, reflecting the nullification of adaptation in extreme scenarios. Final residual vulnerability (Fig. 4) is scaled from 1 to 9, where higher values indicate greater climate risk, based on the following categories:

- o 1–2: Low residual vulnerability
- o 3–5: Moderate vulnerability
- o 6–9: High residual vulnerability which suggest need of critical intervention.

Residual vulnerability analysis

OUTPUT: weighted assessment of sensitivity and exposure and how adaptation measures can reduce the impacts of risks

On the basis of the matrices in the previous sheets, a summary is made to allow verification of the impact of the different types of risks for each area. If every part is compiled correctly, the table below will automatically upload and it will not be necessary to insert any input

AREA: BIODIVERSITY	Scenario	Sensitivity	Exposure	Adaptation	Residual vulnerability
Thermal risk and climate extremes	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D
Hydraulic and hydrogeological risk	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D
Wind and weather storm risk	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D
Geological and land degradation risk	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D

AREA: TOURISM	Scenario	Sensitivity	Exposure	Adaptation	Residual vulnerability
Thermal risk and climate extremes	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D
Hydraulic and hydrogeological risk	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D
Wind and weather storm risk	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D
Geological and land degradation risk	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D

AREA: AGRICULTURE	Scenario	Sensitivity	Exposure	Adaptation	Residual vulnerability
Thermal risk and climate extremes	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D
Hydraulic and hydrogeological risk	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D
Wind and weather storm risk	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D
Geological and land degradation risk	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D

AREA: FISHING AND AQUACULTURE	Scenario	Sensitivity	Exposure	Adaptation	Residual vulnerability
Thermal risk and climate extremes	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D
Hydraulic and hydrogeological risk	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D
Wind and weather storm risk	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D
Geological and land degradation risk	SSP2-4.5	#N/D	#N/D	#N/D	#N/D
	SSP5-8.5	#N/D	#N/D	1.00	#N/D

Sensitivity: the sensitivity to climate factors is averaged for each area, evaluated as a number from 1 (low sensitivity) to 3 (high sensitivity)

Exposure: the exposure to the individual risks in the case of SSP2-4.5 and SSP5-8 is evaluated as a number from 1 (low exposure) to 3 (high exposure)

Adaptation: averaged over the effectiveness of the adaptive capacity of the measures that can be implemented in the SSP2-4.5 scenario (=1, i.e. null, in case of SSP5-8.5), evaluated as a number from 1 (low mitigation/adaptation capacity) to 3 (high capacity)

Residual vulnerability: calculated as the product of sensitivity and exposure, divided by the effectiveness of adaptation

Fig. 4 - Structure and input fields for residual vulnerability assessment.

3. Results and discussion

3.1. Exposure

As described in performance document D.1.3.1, the Neretva Estuary pilot area is a sensitive region where the main challenges in preserving natural values stem partly from its natural characteristics and partly from increasing anthropogenic pressures, while climate change further exacerbates the risks associated with both factors.

Due to its geomorphology, low altitude, and proximity to the sea, the Neretva Estuary is a highly vulnerable coastal freshwater and agricultural ecosystem. The area is characterized by an extensive network of canals, bays, and wetlands, as well as intensive land use for conventional agriculture. Even without additional anthropogenic influences, this system is sensitive to changes in freshwater flow and seawater intrusion, which has serious consequences for agriculture, biodiversity, and water supply.

The most significant anthropogenic influences result from river flow regulation, embankment construction, wetland drainage, and the expansion of agricultural areas that rely on the use of chemicals (fertilizers and pesticides). These substances enter water systems through erosion and leaching, causing eutrophication and chemical contamination, especially during the intense irrigation season.

Additional pressure comes from high water use for irrigation, which reduces the natural supply of freshwater to riverine and underground systems and increases the risk of seawater intrusion. This problem is particularly evident during the summer months, when tributary flows and the water level of the Neretva are lowest and agricultural water demand is highest.

Climate change—particularly warmer and drier summers, reduced precipitation, increased evaporation, and rising sea levels—further exacerbates the risk of salinization of soil and water. The consequences include habitat degradation, loss of agricultural productivity, and damage to freshwater-dependent ecosystems.

Changes to the hydrological regime, including prolonged droughts and shifts in seasonal precipitation patterns, also affect aquatic ecosystems, cause habitat instability, and increase salinization. In this context, the Neretva Estuary demonstrates high vulnerability of ecosystems and the ecosystem services it provides, including biodiversity, drinking water supply, agricultural production, and flood protection.

Combined pressures can, in the long run, lead to deterioration of soil and groundwater quality, increased irrigation costs, and undermine the sustainability of local water resource management systems.

Climate aspect

The analysis of the climatic characteristics of the Neretva Estuary is based on the processing of multi-year meteorological data from stations near Metković and Ploče (DHMZ). The dataset covers the period 1990–

2023, with average monthly and annual values for air temperature (°C), precipitation (mm), and climate extreme indicators.

The results confirm the pronounced Mediterranean climatic characteristics of the area, with warm, dry summers and mild winters.

The lowest temperatures were recorded in January and February (7–9 °C), while the highest were recorded in July and August (25–27 °C).

Linear trends show an increase in average annual temperature, consistent with global warming.

Reduced precipitation in the summer months further increases the risk of drought, fires, and lack of irrigation water.

The Neretva Estuary is under significant pressure from cumulative natural, anthropogenic, and climatic influences, which together lead to reduced ecosystem resilience and an imbalanced relationship between natural resource use and protection. Comprehensive adaptation measures are needed, particularly in the agricultural sector, water resource management, and biodiversity conservation.

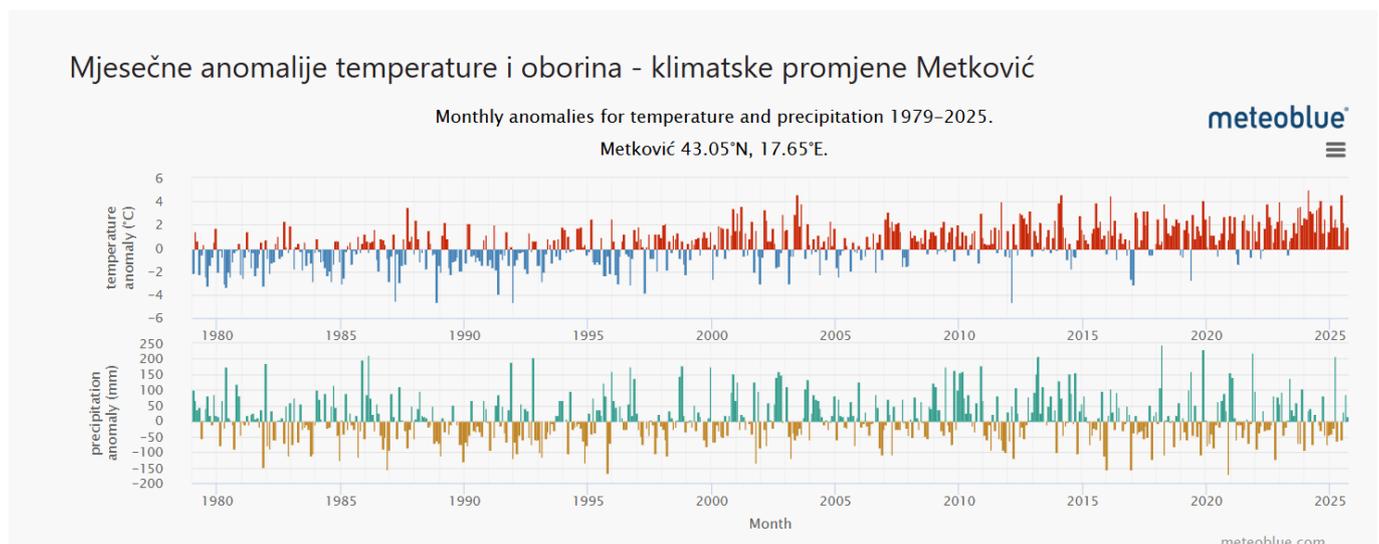


Fig.5 Monthly anomalies for temperature and precipitation 1979-2025

The chart presents monthly temperature and precipitation anomalies for the Metković area during the period 1979–2025, relative to the reference climate period 1980–2010.

The upper panel illustrates air temperature anomalies. Positive values (red) represent months with higher-than-average temperatures, whereas negative values (blue) indicate colder-than-average periods. The analysis reveals a notable increase in the frequency of warmer months after 2000, suggesting a gradual rise in mean air temperatures and confirming the presence of a locally pronounced warming trend, consistent with global climate change patterns. Negative anomalies predominated during the 1980s and early 1990s, while positive anomalies have become dominant over the last two decades.

The lower panel shows monthly precipitation anomalies. Green bars indicate months with above-average rainfall, while brown bars represent drier-than-average conditions. In contrast to temperature anomalies, precipitation does not display a clear long-term trend of increasing or decreasing totals. However, there is evidence of enhanced interannual variability, characterized by more frequent extreme wet and dry months, which may be attributed to changes in atmospheric circulation patterns associated with global climate change.

Overall, the results indicate a significant increase in air temperatures and greater variability in precipitation patterns in the Metković area over recent decades. These trends are consistent with regional and global climate assessments, which confirm the ongoing warming process and an increase in the frequency of extreme weather events across the Mediterranean region.

Figure 5 shows the **annual average values of air temperature and total precipitation**, together with corresponding trends, for the **Neretva Estuary** during the period **1990–2023** (source: DHMZ).

The obtained results confirm the globally observed patterns of **increasing average temperatures**, which drive **climate change** and enhance the **frequency of extreme climatic events** (IPCC, 2023).

In the Neretva Estuary, climate change has multiple consequences:

- **Natural habitats** show greater sensitivity to **forest and vegetation fires**, as well as accelerated **grassland overgrowth** due to altered heat and moisture conditions.
- **Agriculture** faces increased exposure to **droughts during the growing season**, a greater **need for irrigation**, and a **higher risk of flood damage** following intense precipitation.
- **Water resources** are experiencing **changes in groundwater and surface water levels**, linked to altered precipitation distribution and **increased evapotranspiration**.

These findings highlight the importance of **continuous meteorological monitoring** and the **integration of climate data into land-use planning and water resource management**. Climate trends in the Neretva Estuary call for **adaptive management measures** targeting **agriculture, ecosystem conservation, water management, and spatial planning** (Beta, 2025).

SSP2-4.5 Scenario (“Middle of the Road”)

This scenario assumes the **continuation of current global policies** without a significant intensification of mitigation efforts or a dramatic increase in emissions.

CO₂ emissions stabilize around current levels and begin to decline by mid-century, but do not reach net zero by 2100.

According to IPCC projections, **global warming** under this scenario is expected to reach approximately **2.7 °C** by 2100 (uncertainty range: **2.1–3.5 °C**).

For the **Croatian Adriatic region**, including the Neretva Estuary, SSP2-4.5 projects an **increase in temperature of 2–3 °C by 2100**, more **frequent and intense heatwaves**, **longer dry periods**, and a **sea-level rise of 30–65 cm**.

Seasonal precipitation patterns are expected to change, with **drier summers** and **wetter autumn and winter seasons**.

These trends increase the risk of **drought stress**, **reduced river discharge**, **greater irrigation demand**, and **saltwater intrusion** into the lower parts of the estuary, potentially affecting **agriculture, ecosystems, tourism, and infrastructure** (MINGOR, 2020).



The SSP5-8.5 scenario assumes **rapid economic growth** driven by **fossil fuel use**, accompanied by a continuous rise in emissions. CO₂ emissions are projected to **double by mid-century** and **triple by 2100** relative to present levels. Under this pathway, **global warming** reaches approximately **4.4 °C** (uncertainty range: **3.3–5.7 °C**), leading to **extreme risks** — including **very high temperatures, rapid sea-level rise (up to 83 cm)**, and more **frequent and intense extreme weather events** such as **droughts, floods, and wildfires** (IPCC, 2023).

For the **Neretva Estuary**, this scenario implies a **significant intensification of marine influence** on low-lying areas, **more frequent flooding, soil erosion, loss of agricultural productivity**, and a **high risk of saltwater intrusion** into both surface and groundwater systems.

Such changes would disrupt the **ecological balance, drinking water supply, and ecosystem functioning**, and some impacts could become **irreversible without robust adaptation measures** (MINGOR, 2020).

Based on projections from scenarios SSP2-4.5 and SSP5-8.5, the **key climate-related risks** for the Neretva Estuary include:

- **Thermal risks and climatic extremes:** rising temperatures, heatwaves, and physiological stress on crops and ecosystems.
- **Hydraulic and hydrogeological risks:** droughts, changes in rainfall regimes, water stress, flooding, and saltwater intrusion.
- **Wind and storm risks:** increased frequency of extreme winds and storm systems, particularly during transitional seasons.
- **Geological risks and soil degradation:** erosion, sediment deposition, and loss of soil fertility.

Under the **SSP2-4.5 scenario**, these risks remain **moderate and manageable**, but require **systematic adaptation planning**, particularly in agriculture and water management.

In contrast, the **SSP5-8.5 scenario** foresees a **substantial increase in exposure** throughout the year, with pronounced **thermal, hydrological, and geological stress**, necessitating **immediate and comprehensive mitigation measures**.



The **summer months** are particularly critical, when **thermal and hydraulic risks** are most pronounced — consistent with the **analysis of climatic anomalies (1979–2025)**, which indicates both **rising temperatures** and **increased precipitation variability** across the region.

3.2. Adaptation Strategies and Adaptation Capacity

The analysis of adaptation strategies in the Neretva Estuary highlights both the ecological sensitivity of the area and the heterogeneous level of preparedness to cope with climate-related risks. Across all thematic areas, adaptation capacity under the SSP2-4.5 scenario is uneven: some measures are already in place, but persistent gaps remain in funding, institutional coordination, and public awareness.

3.2.1. Biodiversity

Biodiversity adaptation strategies in the Neretva Estuary adopt multifunctional, ecosystem-based approaches that combine habitat restoration with climate risk management. Key strategies include:

Planting of trees and riparian buffers along canals, rivers, and agricultural parcels, serving multiple functions: reducing water temperature, providing wind protection, improving water quality, creating habitats for birds and aquatic species, and limiting soil erosion. These interventions simultaneously contribute to microclimate regulation, flood mitigation, and soil stabilization.

Restoration of coastal and wetland habitats, including floodplain meadows and marshes, enhances ecosystem resilience by improving habitat quality, supporting natural water purification, regulating water levels, and stabilizing soils. These measures mitigate hydrological and geological risks while increasing biodiversity and ecosystem services.

Water regime management, including the use of movable dams and retention zones in coastal areas, balances flood control, water availability, and habitat maintenance, supporting multiple climate adaptation objectives.



Monitoring of climate parameters and species status, providing essential data for adaptive management, ecosystem restoration, invasive species control, and maintenance of ecosystem health.

Erosion control and sediment retention measures, protecting soil and water quality, reducing geological risks, and supporting overall ecosystem functioning.

These multifunctional strategies illustrate an ecosystem-based approach that strengthens biodiversity conservation, water resource management, and climate resilience in the Neretva Estuary. They form the core of effective, integrated adaptation planning. Adaptive capacity under SSP2-4.5 is generally assessed as medium, reflecting the availability of technical knowledge and management tools, alongside a continued reliance on financial and institutional resources for successful implementation.

3.2.2. Tourism

Adaptation strategies for tourism in the Neretva Estuary under the SSP2-4.5 scenario aim to strengthen resilience to a range of climate risks while promoting sustainable development. The main multifunctional approaches include:

Establishing tree belts along rivers, canals, and recreational paths to provide shade, create habitats, and serve as windbreaks. These interventions reduce heat stress, support biodiversity, mitigate storm and wind damage, and enhance the aesthetic and recreational value of tourist sites.

Adapting tourism schedules and services to seasonal climate variations to sustain economic viability during hotter or wetter periods, while ensuring visitor safety and comfort.

Deploying early warning systems and monitoring climate indicators to provide real-time information on natural hazards, improving preparedness for tourists and service providers alike.



Restoring wetlands and floodplain areas as natural buffers, which help reduce flood and hydraulic risks, enhance water quality, and contribute to the conservation of key tourism attractions.

Promoting sustainable water use and quality through the establishment of protected water zones and ensuring accessible sources of potable water, which are essential for visitor health and satisfaction.

Implementing energy-efficient and nature-based construction techniques to adapt to heat extremes while minimizing environmental impacts.

Adaptive capacity is generally high for most aspects of tourism, although hydraulic and hydrogeological risks to infrastructure remain more challenging. Economic development and employment show medium to high capacity, while adaptation measures for preserving tourist attractions are generally medium to high, particularly concerning heat stress and extreme climate events.

These strategies combine ecosystem restoration, hazard management, and visitor services, demonstrating effective approaches to tackle complex climate risks while maintaining the economic, social, and ecological functions of tourism. Some measures are long-term, requiring multi-level decision-making and stakeholder engagement, which can limit rapid implementation, while others, like tree planting, are low-cost, highly adaptable, and can deliver immediate benefits.

Overall, the strategy emphasizes integrated, multifunctional approaches that combine ecosystem-based restoration, disaster preparedness, and sustainable resource management to ensure the long-term resilience of tourism in the Neretva Estuary under changing climate conditions.



3.2.3. Agriculture

The agricultural sector in the Neretva Estuary is highly exposed to climate risks, including heat stress, flooding, wind damage, and soil degradation, with overall adaptation capacity remaining relatively low. This highlights the urgent need for targeted support and the implementation of effective adaptation measures.

Recommended multifunctional strategies for this sector include:

- **Agroforestry and shaded crop systems**, which help mitigate heat stress on crops while enhancing biodiversity and improving soil moisture retention.
- **Land-use adjustments**, such as integrating pastures or cover crops, which improve soil health, limit erosion, and support the regulation of water cycles.
- **Restoration and protection of wetlands and riparian areas**, which stabilize hydrological processes, reduce flood risk, and provide habitats that benefit agricultural biodiversity.
- **Upgrading drainage systems and designating flood-resilient crop zones**, which reduce hydraulic risks, while buffer strips along waterways help manage runoff.
- **Protective belts and windbreaks**, which decrease wind damage, limit pesticide runoff, and maintain stable microclimates.
- **Soil stabilization and reforestation projects**, which combat land degradation, protect soil fertility, and contribute to carbon sequestration.

Despite these options, the sector's adaptive capacity is limited by resource availability, technical capacity, and governance challenges. Coordinated programs combining farmer training, technical support, financial incentives, and ecosystem-based approaches are essential to strengthen resilience and maintain sustainable agricultural production in a changing climate.

Agriculture in the Neretva Estuary remains one of the most vulnerable sectors under the SSP2-4.5 scenario. Adaptation capacity varies across risk types, with medium to low capacity for some hazards. Many measures, including wetland restoration, movable water-control structures, improved drainage, and agroecological practices, require significant financial and human resources. Effective implementation



also depends on monitoring climate and ecological indicators, managing water systems, and controlling invasive species—tasks that demand technical expertise, scientific knowledge, and stakeholder capacity building.

Fragmented land ownership and governance structures further complicate coordinated adaptation, as unclear responsibilities or uncoordinated management can hinder planning, regulation enforcement, and landscape restoration. Environmental constraints, such as the complex karst hydrology, may also limit certain measures. These challenges emphasize the need for **integrated management, capacity building, financial support, community engagement, and adaptive governance frameworks** tailored to the specific environmental and socio-economic context of the Neretva Estuary.

3.2.4. Fisheries and Aquaculture

The fisheries and aquaculture sector in the Neretva Estuary demonstrates moderate adaptive capacity to thermal and hydraulic risks, reflecting the availability of practical ecosystem-based and technical measures, such as invasive species management and water level control. Adaptation capacity for windstorm and geological risks remains limited due to localized impacts, limited infrastructure, and lower economic incentives.

Multifunctional measures in fisheries and aquaculture strategies serve multiple purposes, including ecological restoration, economic benefits, and recreational use. These integrated approaches enhance resilience by mitigating climate risks while supporting broader sectoral objectives, making them essential for coordinated adaptation planning.

Key measures and examples include:

Restoration of submerged and emergent vegetation along canals, riverbanks, and wetland areas, which stabilizes fish habitats, improves water quality, and supports ecosystem services, including recreational fishing and biodiversity conservation.



Development of natural filtration and multifunctional aquaculture infrastructure, integrating fish farming with wetland and canal conservation, creating facilities that support fisheries, tourism, and environmental monitoring.

Management of water levels across the network of channels and flooded fields, reducing hydraulic risks while maintaining suitable habitats for fish and other aquatic species.

Adaptive capacity under the SSP2-4.5 scenario is moderately high for thermal risks and extreme climate events, with resource use, income, and multifunctional benefits generally performing better under these conditions. Hydraulic and hydrogeological risks show medium capacity for resource use but lower capacity for income and multifunctional outcomes. Windstorm and storm risks, as well as soil and sediment degradation, present low to medium adaptive capacity.

Local fish communities in the Neretva Estuary include species popular with anglers, such as carp, catfish, pike, and other non-native species, while native species face pressures from habitat alteration and competition. Introduced species have changed community structure, sometimes displacing native populations, and sediment-dwelling carp may accelerate eutrophication in canals and floodplains.

Fisheries management is primarily carried out by local communities, fishing associations, and private operators, particularly in recreational fishing areas. Strengthening governance, technical capacity, and financial support is critical for maintaining sustainable fisheries and aquaculture while preserving ecological integrity. The sector's resilience depends on coordinated water management, habitat restoration, and monitoring of aquatic species, ensuring both ecological and economic sustainability in the face of climate change.

3.3. Residual vulnerability assessment

The assessment of residual vulnerability in the Neretva Estuary highlights sector-specific sensitivities under the SSP2-4.5 and SSP5-8.5 climate scenarios. Residual vulnerability reflects the combined effect of sensitivity, exposure, and adaptation capacity for each sector.



Biodiversity shows high residual vulnerability under high-emission conditions (SSP5-8.5), particularly for thermal risk and climate extremes (7.64) and hydraulic and hydrogeological risks (8.20). This is due to high exposure—such as temperature increases, drought, and salinization—combined with limited adaptive capacity, emphasizing the vulnerability of local ecosystems. Biodiversity is moderately sensitive to wind and weather risks (4.17) and geological and land degradation (6.65) under SSP5-8.5, while under SSP2-4.5, residual vulnerability is significantly lower, ranging from 1.61 to 4.51 across risk types.

Tourism exhibits moderate residual vulnerability. Under SSP5-8.5, thermal risk and climate extremes have a residual vulnerability of 5.19, hydraulic and hydrogeological risks 6.00, and geological and land degradation 4.81. Wind and weather storm risk remains relatively low (1.69). Under SSP2-4.5, residual vulnerability is much lower for all risks (1.62–3.75), reflecting lower exposure and higher adaptation capacity.

Agriculture remains one of the most vulnerable sectors under SSP5-8.5. Thermal risk and climate extremes show a residual vulnerability of 5.50, hydraulic and hydrogeological risk 5.80, and geological and land degradation 5.27. Windstorm risk is lower at 4.58. Under SSP2-4.5, residual vulnerability is moderate across all risks, ranging from 2.06 to 3.19. This indicates that while adaptation measures exist, they are unevenly implemented, and smallholder farms remain particularly exposed.

Fisheries and aquaculture show moderate residual vulnerability. Under SSP5-8.5, hydraulic and hydrogeological risks present the highest vulnerability (6.20), while thermal risks and climate extremes have a residual vulnerability of 4.89, and windstorm and geological risks are lower (3.19 and 5.04, respectively). Under SSP2-4.5, residual vulnerability is generally lower, ranging from 1.50 to 2.84, reflecting better adaptation capacity relative to exposure.

Overall, the assessment highlights that **thermal risks, extreme climate events, and hydraulic/hydrogeological risks** are the main drivers of residual vulnerability across sectors in the Neretva Estuary. Biodiversity and agriculture are particularly sensitive under high-emission scenarios, while tourism and fisheries show moderate vulnerability. Strengthening adaptive capacity through targeted interventions, coordinated management, and financial and technical support will be essential to reduce residual vulnerability under projected climate scenarios.



4. Conclusion

The assessment of the remaining vulnerability of the Neretva Estuary highlights significant sector-specific weaknesses in the context of predicted climate change, particularly when comparing scenarios SSP2-4.5 and SSP5-8.5. The highest residual vulnerability is associated with thermal and climate extremes and hydraulic and hydrogeological risks under scenario SSP5-8.5. These results reflect the combined effects of increased drought exposure, soil salinization, and more frequent climatic extremes, alongside insufficient adaptive capacity, particularly in the biodiversity and agriculture sectors. In high-emission scenarios, the ecosystems of the Neretva Estuary show acute vulnerability as their adaptive capacity is inadequate in relation to increased climate pressures.

Biodiversity in the Neretva Estuary is most at risk and highly sensitive to thermal and hydraulic risks under SSP5-8.5, while it is moderately sensitive to wind and storm risks. Even under scenario SSP2-4.5, biodiversity remains moderately vulnerable to hydraulic and hydrogeological threats, indicating a constant need for conservation and adaptation.

Tourism, although vulnerable to climate change, shows the greatest vulnerability to thermal extremes, while hydraulic and wind/storm risks are moderate, particularly under SSP5-8.5. Overall, tourism in the Neretva Estuary does not exhibit a critical vulnerability comparable to that of biodiversity or agriculture.

Agriculture, a key activity in the Neretva Estuary, shows very high sensitivity to thermal extremes and significant vulnerability to hydraulic risks under SSP5-8.5, while under moderate climate change (SSP2-4.5), it shows moderate sensitivity to wind and storm risks. Existing adaptive capacity in agriculture is fragmented, with limited resources and uneven sector protection, especially for small and medium-sized farms.

Fisheries and aquaculture in the Neretva Estuary are also very sensitive to hydraulic and hydrogeological risks, mainly due to salinization and eutrophication, which favor the spread of invasive species. At the same time, these sectors show moderate sensitivity to thermal and storm risks under SSP5-8.5.

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Annexes

Compiled matrix (final version resulting from the analysis of three different stakeholders (.xls file)

1 - The working Excel file used to perform Exposure, Adaptation and Risk assessments for the different local climate scenarios.

2 - The Exposure, Adaptation and risk assessments, resulting from the integration of the analyses completed by PP8 for the Neretva Estuary pilot site.



Current climate exposure				
Season	<i>Thermal risk and climate extremes</i>	<i>Hydraulic and hydrogeological risk</i>	<i>Wind and weather storm risk</i>	<i>Geological and land degradation risk</i>
<i>Spring</i>	Moderate	High	Moderate-High	Moderate-High
<i>Summer</i>	High	Moderate-High	Low	Moderate
<i>Autumn</i>	Moderate-Low	High	Moderate-High	Moderate-High
<i>Winter</i>	Moderate-Low	Moderate-High	High	Moderate

Future climate exposure: SSP2-4.5 scenario - "Middle of the Road" world where trends largely follow their historical patterns				
Season	<i>Thermal risk and climate extremes</i>	<i>Hydraulic and hydrogeological risk</i>	<i>Wind and weather storm risk</i>	<i>Geological and land degradation risk</i>
<i>Spring</i>	Moderate	High	Moderate-High	Moderate-High
<i>Summer</i>	High	Moderate-High	Low	Moderate
<i>Autumn</i>	Moderate-Low	High	Moderate-High	Moderate-High
<i>Winter</i>	Moderate-Low	Moderate-High	High	Moderate

Future Climate Exposure: Scenario SSP5-8.5 - Fossil-fueled Development "Taking the Highway", a world characterised by rapid and unlimited growth in economic production and energy use				
Season	<i>Thermal risk and climate extremes</i>	<i>Hydraulic and hydrogeological risk</i>	<i>Wind and weather storm risk</i>	<i>Geological and land degradation risk</i>
<i>Spring</i>	High	High	High	High
<i>Summer</i>	High	High	Low	Moderate-High
<i>Autumn</i>	Moderate-High	High	High	High
<i>Winter</i>	Moderate-High	High	High	Moderate-High

AREA: BIODIVERSITY					
Component	Scenario SSP2-4.5	Adaptation to thermal risk and climate extremes	Adaptation to hydraulic and hydrogeological risk	Adaptation to wind and weather storm risk	Adaptation to geological and land degradation risk
Area of protected habitats	Measures	Increase forest canopy Create water retention ponds Control water releases to match phenology of species Monitor climatic conditions	optimize hydrological network and water management; fix hydraulic infrastructure (i.e. sluice gates) Buffer zones to slow runoff and collect water Reduce artificial drainage in sensitive zones	Maintain and restore coastal dune Reinforce embankments in wetlands and lagoons	Stabilize and revegetate eroding shorelines; Promote sediment trapping measures; Reduce land subsidence through sustainable groundwater and gas extraction;
	Adaptive Capacity	Medium	Medium	High	Medium
Species richness	Measures	Adjust management of breeding timing and habitat water levels Monitor indicator species' stress responses	Restore water connectivity between wetland units	Monitor vulnerable nesting sites Avoid forest over-fragmentation to reduce blowdown risk	Create refuges or corridors for species migration; Restore degraded habitats to support ecosystem resilience
	Adaptive Capacity	Medium	Low	Low	Medium
Ecosystem services	Measures	Protect wetland buffer vegetation Avoid land change and consumption Encourage agroecological practices in buffer areas	Improve drainage systems - Enhance water storage capacity during wet seasons - Apply water-sensitive agriculture	Grow natural windbreaks and vegetative buffers to reduce storm damage; Diversify agroecosystem functions including long rotation crops	Prevent soil compaction and erosion in agricultural and wetland areas; Apply conservation tillage and native vegetation cover
	Adaptive Capacity	Medium	Medium	High	Medium

AREA: BIODIVERSITY	<i>Scenario</i>	<i>Sensitivity</i>	<i>Exposure</i>	<i>Adaptation</i>	<i>Residual vulnerability</i>
Thermal risk and climate extremes	SSP2-4.5	2,78	2,00	2,00	2,78
	SSP5-8.5	2,78	2,75	1,00	7,64
Hydraulic and hydrogeological risk	SSP2-4.5	2,73	2,75	1,67	4,51
	SSP5-8.5	2,73	3,00	1,00	8,20
Wind and weather storm risk	SSP2-4.5	1,67	2,25	2,33	1,61
	SSP5-8.5	1,67	2,50	1,00	4,17
Geological and land degradation risk	SSP2-4.5	2,42	2,25	2,00	2,72
	SSP5-8.5	2,42	2,75	1,00	6,65



AREA: TOURISM					
Component	Scenario SSP2-4.5	Adaptation to thermal risk and climate extremes	Adaptation to hydraulic and hydrogeological risk	Adaptation to wind and weather storm risk	Adaptation to geological and land degradation risk
Tourism infrastructure and services	Measures	Increase shading vegetation along nature trails; Improve microclimatic resilience of protected coastal areas; Adjust timing of tourist access based on seasonal extremes. Implement rapid alert systems to inform tourists of real-time natural hazards.	Restore wetlands as natural buffers; Improve infrastructure to cope with flooding in natural parks and lagoon trails; Maintain boardwalks and elevated paths in vulnerable areas. Implement rapid alert systems to inform tourists of real-time natural hazards.	Strengthen natural dune systems protecting visitor areas; Design wind-resistant structures for info points and shelters. Implement rapid alert systems to inform tourists of real-time natural hazards.	Stabilize hiking paths and coastal lookout points; Control tourist access in erosion-prone zones; Manage compaction and footpath erosion
	Adaptive Capacity	High	Low	Medium	Medium
Economic development and employment	Measures	Regulate tourist access based on forecasts of extreme weather events. Educate visitors about newly introduced or dangerous species, and increase the availability of potable water sources.	Increase connectivity of habitats to preserve mobile species (e.g., birds, amphibians) as well as, restore and maintain small freshwater bodies within tourist nature parks. Implement rapid alert systems to inform tourists of real-time natural hazards. Establish safety points in elevated areas to minimize flood risks for both tourists and employees.	Implement rapid alert systems to inform tourists of real-time natural hazards. Develop resilient infrastructure in tourist areas to protect both visitors and employees from major storms and extreme weather events.	Rehabilitate degraded tourist natural sites and maintain the existing one to increase attractiveness; Monitor and manage human impact on touristic ecosystems.
	Adaptive Capacity	Medium	Low	Medium	Low
Preservation of tourist attractions	Measures	Introduce heat-resilient vegetation in and around attractions; Use reflective or breathable materials in conservation areas; Limit access during extreme heat conditions.	Develop water drainage systems near historical/cultural sites; Protect attractions from floods with barriers and water diversion methods; Elevate or relocate vulnerable features.	Use wind-resistant barriers and shelters to protect open-air attractions; Stabilize structures and artifacts exposed to windstorms; Use temporary covers during extreme weather.	Restore eroded landscapes and features; Restrict access to fragile geological formations; Use sustainable materials and techniques in conservation to minimize human impact.
	Adaptive Capacity	Medium	Low	Medium	Low

AREA: TOURISM	<i>Scenario</i>	<i>Sensitivity</i>	<i>Exposure</i>	<i>Adaptation</i>	<i>Residual vulnerability</i>
Thermal risk and climate extremes	SSP2-4.5	1,89	2,00	2,33	1,62
	SSP5-8.5	1,89	2,75	1,00	5,19
Hydraulic and hydrogeological risk	SSP2-4.5	2,00	2,75	1,00	5,50
	SSP5-8.5	2,00	3,00	1,00	6,00
Wind and weather storm risk	SSP2-4.5	1,50	2,25	2,00	1,69
	SSP5-8.5	1,50	2,50	1,00	3,75
Geological and land degradation risk	SSP2-4.5	1,75	2,25	1,33	2,95
	SSP5-8.5	1,75	2,75	1,00	4,81



AREA: AGRICULTURE					
Component	Scenario SSP2-4.5	Adaptation to thermal risk and climate extremes	Adaptation to hydraulic and hydrogeological risk	Adaptation to wind and weather storm risk	Adaptation to geological and land degradation risk
Land use and landscape	Measures	Promote agroforestry and shaded cropping systems; Shift sowing and harvesting calendars; Introduce heat-resilient crops; Expand use of mulching and precision irrigation.	Restore and conserve wetlands to regulate water cycles; Design flood-tolerant cropping zones; Create buffer zones near water bodies as flooding areas; Improve and maintain drainage infrastructures.	Use shelterbelts and windbreaks; Apply storm-resilient land zoning practices; Reinforce protective field infrastructure like greenhouses and fencing.	Enforce zoning in erosion-prone areas; Implement soil stabilization and reforestation projects. Increase the carbon storage against soil erosion.
	Adaptive Capacity	Medium	Medium	High	Medium
Agricultural income and employment	Measures	Provide subsidies for climate-resilient farming; Support income diversification (e.g., agritourism); Develop early warning systems for heatwaves and crop loss.	Promote insurance for flood-related crop loss; Offer financial aid for farm recovery; Train farmers on adaptive irrigation methods and water conservation.	Strengthen access to social safety nets post-storm events; Provide infrastructure protection grants; Support local cooperatives for emergency response.	Invest in land reclamation programs with labor components; Encourage sustainable farming to prevent land degradation; Fund educational programs for soil health practices.
	Adaptive Capacity	Low	Low	Medium	Medium
Agricultural biodiversity	Measures	Conserve and promote drought- and heat-tolerant crop varieties; Enhance seed banks with local species; Support mixed cropping and polyculture systems.	Protect wetland and riparian habitats for wild species; Maintain genetic diversity of flood-tolerant crops; Promote landscape connectivity for agro-ecosystems.	Establish emergency seed reserves post-storm events; Enhance resilience through crop diversification; Design biodiversity corridors protected from storm damage.	Prevent monoculture in erosion-prone areas; Encourage crop rotation to maintain soil structure and species richness; Restore degraded agro-ecosystems with native species. Encourage the use of shelterbelts as biodiversity hot spot.
	Adaptive Capacity	Medium	Medium	Low	Medium

AREA: AGRICULTURE	<i>Scenario</i>	<i>Sensitivity</i>	<i>Exposure</i>	<i>Adaptation</i>	<i>Residual vulnerability</i>
Thermal risk and climate extremes	SSP2-4.5	2,00	2,00	1,67	2,40
	SSP5-8.5	2,00	2,75	1,00	5,50
Hydraulic and hydrogeological risk	SSP2-4.5	1,93	2,75	1,67	3,19
	SSP5-8.5	1,93	3,00	1,00	5,80
Wind and weather storm risk	SSP2-4.5	1,83	2,25	2,00	2,06
	SSP5-8.5	1,83	2,50	1,00	4,58
Geological and land degradation risk	SSP2-4.5	1,92	2,25	2,00	2,16
	SSP5-8.5	1,92	2,75	1,00	5,27

AREA: FISHING AND AQUACULTURE					
Component	Scenario SSP2-4.5	Adaptation to thermal risk and climate extremes	Adaptation to hydraulic and hydrogeological risk	Adaptation to wind and weather storm risk	Adaptation to geological and land degradation risk
Use of resources	Measures	Shift toward farming thermally resilient species; Adjust fishing seasons and times to avoid heat stress; Monitor oxygen levels and harmful algal blooms in aquaculture sites.	Improve lagoon and estuarine management to prevent salinity intrusion; Install water-level regulation systems; Create buffer zones around aquaculture sites.	Reinforce fishery structures and aquaculture tanks against storm surges; Design floating or submersible aquaculture systems; Create mobile units for harvesting.	Prevent overexploitation of benthic habitats; Promote sustainable dredging practices; Monitor seabed and lagoon floor erosion.
	Adaptive Capacity	Low	Medium	Medium	Medium
Income and employment	Measures	Provide financial incentives for species diversification; Offer training in climate-resilient fishing and farming practices; Promote cold storage and processing infrastructure to reduce heat-related losses.	Establish insurance schemes for damage; Support emergency income programs; Diversify livelihoods linked to wetland-related processing.	Provide risk reduction training for fishers; Develop storm compensation funds; Support collective safety nets for fishery workers.	Invest in skills transition toward sustainable marine practices; Support circular economy initiatives to reduce resource pressure; Introduce land-sea integration planning for employment security.
	Adaptive Capacity	Low	Low	Medium	Medium
Multifunctionality	Measures	Encourage integration of aquaculture with renewable energy (e.g., floating solar); Promote recreational and educational uses of aquaculture systems that are heat-resilient.	Develop nature-based solutions (e.g., aquaculture-wetland integration); Use multi-use platforms combining flood mitigation and fish farming; Restore natural filtration ecosystems.	Promote marine ecotourism with storm-resilient infrastructure; Create multipurpose docks and floating hubs that combine fishing, tourism, and monitoring.	Support erosion-resilient multifunctional areas (e.g., oyster reefs); Integrate aquaculture with dune or sediment stabilization efforts; Use multifunctional coastal zones to reduce degradation pressure.
	Adaptive Capacity	Medium	Medium	Medium	High

AREA: FISHING AND AQUACULTURE	<i>Scenario</i>	<i>Sensitivity</i>	<i>Exposure</i>	<i>Adaptation</i>	Residual vulnerability
Thermal risk and climate extremes	SSP2-4.5	1,78	2,00	1,33	2,67
	SSP5-8.5	1,78	2,75	1,00	4,89
Hydraulic and hydrogeological risk	SSP2-4.5	2,07	2,75	2,00	2,84
	SSP5-8.5	2,07	3,00	1,00	6,20
Wind and weather storm risk	SSP2-4.5	1,33	2,25	2,00	1,50
	SSP5-8.5	1,33	2,50	1,00	3,33
Geological and land degradation risk	SSP2-4.5	1,83	2,25	2,33	1,77
	SSP5-8.5	1,83	2,75	1,00	5,04