Interreg Co-funded by the European Union
Italy – Croatia
ACTION

D.1.3.1

Report on the hazards and threats of the pilot areas in the medium and long term

Po Delta and Lamone River pilot site

Version of 26/09/2025

(PP3 UNIBO, PP4 IDECO, LP MR, and PP2 PDP contribution to Deliverable Number D.1.3.1)

Project acronym	ACTION
Project ID Number	ITHR0200390
Project Title	Increasing coastal ecosystem resilience to climate change
Programme priority	Green and resilient shared environment
Specific objective	1.2: Ecological and socio-economic analyses
Work Package Number	1
Work Package Title	Analysis of Pilot areas
Activity Number	1.3
Activity Title	Identification of hazards and threats at medium and long term
Partner in charge	PP3 UNIBO
Partners involved	PP3 UNIBO, PP4 IDECO, LP MR, and PP2 PDP
Status	Final
Distribution	Internal partners repository

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Abstract

This report analyzes the main **hazards and threats related to climate change in the Po Delta and Lamone River pilot site**, based on a shared methodology developed among scientific, administrative, and management partners. The approach combines sensitivity, exposure, adaptive capacity, and residual vulnerability assessments to evaluate risks for key sectors – biodiversity, tourism, agriculture, fisheries, and aquaculture – in the medium and long term. Results show that the area is highly vulnerable to sea level rise, subsidence, saltwater intrusion, heatwaves, and flooding, which generate cross-cutting and systemic impacts. These findings confirm the urgent need for integrated adaptation strategies, based on ecosystem-based and multi-sectoral approaches, to strengthen the socio-ecological resilience of the territory.

1. Introduction

This report presents a structured methodology for assessing climate vulnerability and resilience in the Po Delta and Lamone River pilot site, within the framework of the ACTION – Increasing coastal ecosystem resilience to climate change project.
These coastal zones, characterized by ecological fragility, socio-economic relevance, and exposure to multiple stressors, are particularly sensitive to the impacts of climate change. The aim of the analysis is to identify the main climate-related risks, sectoral vulnerabilities, and systemic interlinkages, thereby supporting the design of targeted adaptation measures and integrated planning.
The study adopts a common assessment matrix, agreed upon by project partners, which considers medium- and long-term hazards and threats and prioritizes them across relevant sectors (biodiversity, tourism, agriculture, fisheries and aquaculture).
The report thus provides a scientific and operational basis for the development of local scenarios and adaptation solutions, which will be discussed in detail in deliverable D.1.4.1.

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, drougth) 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: 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, drougth) 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: 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, drougth) 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, drougth) 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 (Calvin et al., 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. CO_2 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, CO_2 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 impac
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*	*List potential adaptation/prevention measures and their level*	*List potential adaptation/prevention measures and their level*	*List potential adaptation/prevention measures and their level*
	Adaptive Capacity				
Species richness	**Measures**	*List potential adaptation/prevention measures and their level*	*List potential adaptation/prevention measures and their level*	*List potential adaptation/prevention measures and their level*	*List potential adaptation/prevention measures and their level*
	Adaptive Capacity				
Ecosystem services	**Measures**	*List potential adaptation/prevention measures and their level*	*List potential adaptation/prevention measures and their level*	*List potential adaptation/prevention measures and their level*	*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:

*Residual Vulnerability = Sensitivity * Exposure / 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:

- 1–2: Low residual vulnerability
- 3–5: Moderate vulnerability
- 6–9: High residual vulnerability which suggest need od 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: 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: 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: 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

Following the description and discussion of the threats and impacts for each considered sector in the Pilot Area.

3.1. Biodiversity

The natural areas around Ravenna, included in the Po Delta Regional Park, represent a biodiversity hotspot within a highly urbanized coastal region. As in other parts of the Mediterranean, climate change is expected to amplify existing natural and anthropogenic pressures. The sensitivity analysis of interactions between climatic drivers and biodiversity components (protected habitats, species richness, and ecosystem services) indicates that most threats cause high sensitivity, particularly in terms of habitat conservation and species diversity (Annex 2). Ecosystem services, while impacted, often exhibit slightly lower sensitivity due to compensatory functions and adaptive capacities of some systems.

Temperature-related threats

Rising temperatures and recurrent heat waves significantly affect metabolism, growth, reproduction, and survival of key species, particularly amphibians and fish. These conditions destabilize predator–prey dynamics, increase vulnerability to disease, and favour invasive species. Protected habitats and species richness are highly sensitive, given the risk of mortality events, habitat degradation, and altered biological cycles. Ecosystem services are rated high in sensitivity due to impacts on water regulation, vegetation cover, and carbon storage, with some short-term buffering possible.

Cold waves and frost primarily affect temperature-dependent species (amphibians, reptiles, cold-water fish, and certain plants), often allowing generalist or non-native species to replace them. Mortality events and disrupted reproductive cycles make species richness highly sensitive, while habitats and ecosystem services remain moderately affected due to partial resilience in nutrient cycling and carbon storage.

Wildfires destroy habitat structure, faunal shelters, and ecosystem integrity, resulting in high sensitivity across habitats, species richness, and ecosystem services, including carbon storage, cultural values, and recreational opportunities.

Wind-related threats

Storms, changes in wind regime, and extreme wind events cause coastal erosion, dune destabilization, sediment resuspension, and damage to nesting sites. Habitats and species richness show medium sensitivity, while ecosystem services are slightly less affected, as impacts tend to be localized. Whirlwinds exert broader pressure, particularly on forested areas such as the San Vitale and Casalborsetti pinewoods, where uprooting alters canopy structure, and on lagoon systems through sediment resuspension and embankment breaches. Sensitivity across habitats, species richness, and ecosystem services is medium, reflecting the wider ecological repercussions of these disturbances.

Water-related threats

Changes in the hydrological regime, including prolonged droughts (as happened during summer 2022 in the whole Po Delta area) and altered precipitation patterns, reduce wetland suitability, alter aquatic ecosystems, and decrease aquifer recharge (Bonaldo et al., 2023; Montanari et al., 2023). Habitats and species richness exhibit high sensitivity, while ecosystem services are also highly sensitive due to reduced

water availability, loss of freshwater-dependent habitats, and decreased buffering against salinization (Luo et al., 2024).
Sea acidification threatens molluscs and other invertebrates, favours opportunistic and invasive species, and can alter trophic structures in lagoons. Sensitivity is medium across all biodiversity dimensions, reflecting long-term risks to community composition.
Saltwater intrusion, sea level rise, flooding, and coastal erosion are among the most severe threats to the Ravenna coastal system (Del 1.2.1.) (Giambastiani et al., 2021, 2017). Saltwater intrusion alters plant community composition, promotes soil salinization, and diminishes soil fertility, while sea level rise and flooding erode dunes, inundate wetlands. These pressures reduce freshwater availability, compromise terrestrial and aquatic habitats, and disrupt species richness and ecosystem service provision. Sensitivity is high across all dimensions, indicating systemic vulnerability.

Solid mass and soil threats

Landslides are of minor relevance for the Lamone basin but could pose localized risks elsewhere, primarily through flooding if embankments collapse. Subsidence, however, is a critical factor, exacerbating exposure to flooding, salinization, and coastal erosion. It amplifies the impacts of sea level rise and storms, compromising ecosystem functioning and services such as flood protection and productivity. Sensitivity is high across all biodiversity components.
Soil degradation and erosion reduce fertility, increase runoff, and threaten habitat quality and ecosystem functioning. Habitat productivity and regulating services (e.g., nutrient cycling) show high sensitivity, while species richness is rated medium due to partial resilience of opportunistic species.

3.2. Tourism

Tourism in the Po Delta and Lamone River pilot site is strongly dependent on climate-sensitive assets, including infrastructure and services, local economic development and employment, and the preservation of cultural and natural heritage. Due to its geographical location and exposure to multiple climatic drivers, the area remains highly vulnerable to climate-related pressures. The main different impacts and sensitivities on the tourism sector deriving from the most relevant threats, are reported in the Annex 2 and summarized below.

Temperature-related threats

Rising temperatures and recurrent heat waves exert medium sensitivity across all tourism dimensions. Impacts include reduced visitor comfort and safety (e.g., heatstroke, dehydration), increased operating costs for cooling and water provision, cancellation of outdoor events, and declining interest in outdoor activities during peak summer. These changes may shift the timing of peak tourist seasons, reduce aesthetic landscape appeal, and complicate the organization of travel packages and events.
Cold and frost waves register low sensitivity. They can cause temporary disruptions such as transport difficulties, higher heating costs, visitor discomfort, and occasional cancellations, but without lasting structural consequences for tourism systems.
Wildfires, by contrast, represent a high sensitivity threat for attractions and infrastructure, and medium for economic development. They destroy natural landscapes and heritage sites, degrade air quality, and

pose safety risks for visitors. Long-term reputational damage to the destination and the loss of iconic natural environments (e.g., pinewoods, dunes) are particularly critical.

Wind-related threats

Changes in wind regime and storms show medium sensitivity for infrastructure, but low for economic activity and attractions. While impacts include cancellations of outdoor events, damage to property, restricted access to natural areas, and the need for visitor safety measures, they tend to be episodic and localized.

Whirlwinds, however, carry medium sensitivity across all components. They may damage transport infrastructure, tourist facilities, and green areas, disrupt services, and create safety concerns for visitors. Their unpredictability can impact tourist confidence and negatively affect the area attractivity.

Water-related threats

Alterations in the hydrological regime (droughts, water stress, and irregular rainfall) show medium sensitivity across the tourism sector. Reduced water availability constrains rural/ecotourism, lowers the appeal of wetland-based destinations, and creates planning difficulties for operators. Violent rains may also damage infrastructure and disrupt tourist flows.

Sea acidification is assessed as low sensitivity for infrastructure and economy, but medium for attractions. The arrival of invasive or dangerous species could alter coastal ecosystems, undermining biodiversity-related tourism.

Saltwater intrusion presents low sensitivity for infrastructure, but medium for economic activities and attractions; the decrease of freshwater availability impact biodiversity in wetlands and freshwater-dependent areas.

Sea level rise is among the most severe threats, rated high sensitivity across all tourism dimensions. It causes beach loss, forces relocation of coastal infrastructure, increases flooding, and degrades landscapes. Consequences include higher insurance costs, conflicts over land and water use, and declining service quality.

Flooding is also highly disruptive, with high sensitivity for infrastructure and economic activity (Valente et al., 2025), and medium for attractions. It causes direct physical damage, service interruptions, and long-term loss of tourism.

Solid mass-related threats

Coastal erosion represents a high sensitivity threat for infrastructure and attractions, and medium for the economy. It reduces beach capacity, undermines protective structures, increases costs for adaptation, and threatens the competitiveness of seaside tourism.

Tourism is relativity low sensitive to soil degradation and soil erosion. Their impacts are limited to gradual reductions in scenic quality and attractiveness, unless broader environmental degradation occurs.

Subsidence demonstrates high sensitivity for infrastructure, and medium for economy and attractions. It causes beach loss, increase damages to cultural heritage and buildings, and disrupts accessibility and service continuity, while amplifying the risks posed by sea level rise, storm surge, flooding, and extreme events.

3.3. Agriculture

Agriculture in the Ravenna pilot site represents a strategic socio-economic sector, closely linked with land use patterns, rural employment, and agro-biodiversity conservation. Due to its low-lying coastal position, the system is highly exposed to climatic stressors such as extreme temperatures, hydrological variability, and soil and landscape dynamics. The results of the sensitivity assessment for three key agricultural components — land use and landscape, agricultural income and employment, and agricultural biodiversity — against the most relevant climate threats affecting the area are reported in the Annex 2.

Temperature-Related Threats

Temperature increase and heat waves show high sensitivity for agricultural income and employment, as they disrupt crop calendars, reduce yields in grapes, fruit trees, and vegetables, increase livestock stress, and elevate risks of harvest loss (Straffelini and Tarolli, 2023). They also require higher irrigation and plant protection treatments, raising costs and insurance exposure (Villani et al., 2011). Land use and landscape register medium sensitivity, as prolonged heat accelerates soil and water stress. Biodiversity is likewise medium sensitivity, with risks to pollination timing, fruit set, and overall ecological balance. Cold waves and frost are assessed as high sensitivity for income and employment, since they severely damage orchards, vineyards, and olive trees, particularly when preceded by early warming. Sensitivity is medium for land use, reflecting local disruptions, but low for biodiversity, as ecosystem structure is less directly affected. Wildfires exert medium sensitivity on land use and income, with localized destruction of crops, greenhouses, and equipment, and indirect economic costs. Biodiversity remains low sensitivity, though habitat degradation may indirectly occur.

Wind-Related Threats

Changes in wind regimes and storms exert medium sensitivity on land use and income, through disrupted pollination, pest and disease spread, and direct crop and infrastructure damage. Biodiversity remains at low sensitivity. Whirlwinds generate more severe localized impacts, classified as high sensitivity for income and employment due to destruction of crops, structures, and equipment. Land use is medium sensitivity, with biodiversity again low sensitivity.

Water-Related Threats

Changes in the hydrological regime (drought, altered precipitation) are high sensitivity for income and employment, as they undermine irrigation scheduling, crop selection, and sowing/harvest reliability. They also raise competition for scarce water and increase production costs. Land use and biodiversity show medium sensitivity, due to altered water balances and habitat stress. Sea acidification is not relevant to agricultural systems. Saltwater intrusion is medium sensitivity across all components, reducing irrigation water quality, driving soil salinization, lowering yields, and forcing shifts in crop selection.

Sea level rise is one of the most critical pressures, with high sensitivity for land use and income, since it leads to salinization, drainage and nutrient losses, and long-term loss of cultivable areas. Biodiversity sensitivity is medium, reflecting stress on water-sensitive crops and soils. Flooding (coastal, fluvial, pluvial, groundwater) is high sensitivity for income and employment, causing arable land loss, infrastructure

damage, planting delays, and long-term soil contamination (Cesco et al., 2024; De Feudis et al., 2025). Land use and biodiversity are medium sensitivity, given the recurrent degradation of soils and habitat conditions. Coastal erosion shows medium sensitivity for land use and income, reducing available farmland and threatening protective structures. Biodiversity is low sensitivity, given limited direct impacts.

Solid Mass-Related Threats

Subsidence is high sensitivity for land use, as it exacerbates flood risks and soil degradation, and medium sensitivity for income and biodiversity, given its effects on aquifers, saltwater intrusion, and pedological profiles. Landslides are low sensitivity, with impacts largely negligible in the Lamone basin except where they affect river embankments and exacerbate flood risk. Soil degradation and erosion are high sensitivity for income and employment, undermining long-term productivity, raising fertilization costs, and disrupting ecosystem services. They register medium sensitivity for land use and biodiversity, due to fertility loss and nutrient imbalance.

2.1. Fishing and aquaculture

Fishing and aquaculture in the Ravenna coastal area are important to local livelihoods, food supply, and cultural identity. These activities are strongly tied to the stability of aquatic ecosystems and are therefore highly exposed to climatic stressors. The analysis below evaluates the impacts of major climate drivers — temperature, wind, water-related processes, and solid mass dynamics — on three critical components: resource use, income and employment, and multifunctionality (ecological services, cultural values, and tourism–fisheries interlinkages). The result table is showed in the Annex 2.

Temperature-related threats

Temperature increases and heat waves are among the most critical pressures, with high sensitivity for both resource use and employment. Rising water temperatures alter fish reproduction, migration, and metabolism, causing species decline and shifts in community composition (Gavioli et al., 2024). Invasive species, such as the blue crab (*Callinectes sapidus*), thrive in warmer waters, disrupting food chains and damaging fishing gear. Reduced oxygen levels increase mortality in both wild stocks and aquaculture, triggering mass mortality events, while shellfish are stressed by algal blooms (Alvisi and Cozzi, 2016; Zoffoli et al., 2025). Multifunctionality shows medium sensitivity, since ecosystem services are disrupted but not entirely lost. Cold waves and frost exert medium sensitivity on resource use and employment, as they can trigger fish kills in shallow lagoons and damage aquaculture facilities. Impacts on multifunctionality remain low. Wildfires have only low sensitivity, with indirect impacts from ash and debris degrading water quality, occasionally affecting small or non-professional aquaculture facilities.

Wind-related threats

Changes in wind regimes and storms show low sensitivity across all components. Altered upwelling and circulation may influence nutrient availability and fish distribution, while aquaculture facilities, boats, and embankments may suffer episodic damage. However, impacts are short-lived, mostly interrupting fishing activity rather than resource stability. Whirlwinds cause medium sensitivity for resource use and

employment, as they can inflict localized but intense damage on boats, onshore structures, and aquaculture systems. Effects are similar to storms but more concentrated.

Water-related threats

Changes in the hydrological regime (drought and altered precipitation) have medium sensitivity for resource use and employment. Variations in freshwater inflow modify salinity and nutrient loads in coastal lagoons (e.g., Piallassa Baiona), affecting breeding and juvenile survival of sensitive and migratory fish. Multifunctionality shows low sensitivity, as ecosystem processes continue despite changes in species composition. Sea acidification has medium sensitivity across all components. Acidification weakens shells of molluscs, disrupts food chains, and undermines aquaculture profitability. Saltwater intrusion registers medium sensitivity in all three dimensions. It raises salinity levels in lagoons, stressing freshwater and brackish species and challenging aquaculture operations in low-lying areas.

Sea level rise is a high-sensitivity driver for resource use and employment. It inundates aquaculture sites and infrastructure, reduces freshwater inflows into lagoons, alters species composition, and increases the risk of farm flooding (Lanzoni et al., 2022). Multifunctionality is medium sensitivity, since brackish habitat loss also undermines cultural and ecological services. Flooding produces medium sensitivity across all components. It damages fish farms, tanks, and processing facilities, causes fish escapes, and interrupts fishing operations. Changes in salinity also affect fish abundance.

Solid mass-related threats

Coastal erosion is another high-sensitivity factor for resource use and employment. It reduces lagoon nursery habitats, threatens aquaculture infrastructure, and may lead to transformations of lagoons (e.g., Piallassa Baiona becoming small bay if unprotected). Multifunctionality is medium sensitivity, reflecting loss of ecological and cultural values. Soil degradation and erosion show low sensitivity, as increased sediment loads degrade water quality and damage fish gills but do not fundamentally alter the resource base. Subsidence is a structural pressure with medium sensitivity across all dimensions. It lowers land elevation, amplifies flood risk in low-lying aquaculture zones, and accelerates salinity intrusion and sea ingression, thereby compounding the effects of sea level rise.

Landslides are not relevant to professional fishing and aquaculture in the pilot area and remain low sensitivity across all components.

3. Discussion

The sensitivity analysis across biodiversity, tourism, agriculture, and fisheries/aquaculture in the Po Delta and Lamone River pilot site reveals a shared exposure to multiple climate drivers, with temperature extremes, hydrological variability, sea-level rise, flooding, subsidence, and coastal erosion emerging as the most disruptive. While each sector demonstrates specific vulnerabilities linked to its ecological or socio-economic structure, the results highlight a high degree of systemic interdependence: degradation of natural habitats undermines cultural and recreational values, while changes in freshwater and marine ecosystems affect agricultural productivity, tourism attractiveness, and fisheries sustainability.

Temperature-related threats are prevalent across all sectors. Heat waves consistently register high sensitivity in biodiversity, agriculture, and fisheries, where they disrupt species physiology, crop yields, and aquaculture stability. Tourism shows medium sensitivity to heat, reflecting its capacity to reorganize seasonality, but remains indirectly dependent on the integrity of natural landscapes. Cold waves, by contrast, are generally of lower importance, though still critical for perennial crops and lagoon ecosystems. Wildfires represent another transversal high-sensitivity driver, particularly affecting biodiversity, cultural landscapes, and tourism attractions.

Hydrological changes and sea-level dynamics stand out as the most critical climate pressures. Droughts, change in precipitation pattern, and reduced freshwater availability trigger agriculture and biodiversity, while fisheries show medium but structural exposure due to lagoon salinity shifts. Sea-level rise, flooding, and saltwater intrusion represent the strongest common denominator across sectors, consistently rated high sensitivity for land use, infrastructure, economic activity, and ecosystem services. Subsidence amplifies these threats, making the Ravenna coastal plain particularly vulnerable to multiple events.

Wind-related threats (storms, whirlwinds) are more localized but still relevant, with medium sensitivity for infrastructure (tourism, agriculture, fisheries) and natural areas. Their impacts tend to be episodic, but cumulative damages—particularly to green areas, pinewoods, and aquaculture sites—can undermine resilience in the longer term.

Soil degradation and erosion exert high sensitivity in agriculture and biodiversity, but more marginal impacts in tourism and fisheries. Their gradual nature makes them less visible than extreme events, yet their long-term consequences on productivity, fertility, and landscape quality are profound.

3.1. Sectoral specificities

Biodiversity emerges as the most uniformly sensitive sector, with high ratings across most climate drivers. Ecosystem services show some buffering capacity, but systemic threats such as wildfires, hydrological changes, sea-level rise, and subsidence challenge the stability of habitats and species richness.

Tourism shows a differentiated sensitivity profile: direct exposure to sea-level rise, flooding, and coastal erosion is very high, while temperature and wind-related pressures are moderate. The sector's adaptive capacity—through seasonality shifts, diversification, and infrastructural protection—may offset some impacts, but reputational and long-term attractiveness risks remain significant.

Agriculture is highly sensitive to temperature extremes, decrease in freshwater availability, water regime alterations, soil degradation, and sea-level rise, directly linking climatic changes to productivity and rural livelihoods. Cold waves are particularly damaging for perennial crops, while salinization and flooding undermine long-term viability of low-lying farmland.

Fishing and aquaculture show the strongest link to water-related pressures. Heat waves, invasive species, salinity shifts, sea-level rise, and coastal erosion heavily affect stocks and facilities. While storms and

whirlwinds are disruptive, the most profound risks are structural, threatening the sustainability of lagoon-based systems and aquaculture zones.

3.2. Systemic risks and cascading effects

The results emphasize that climate threats do not operate in isolation. Compound and cascading effects—such as heat waves combined with drought, or subsidence exacerbating sea-level rise—can rapidly overwhelm sectoral coping capacities. Moreover, impacts in one sector often reverberate across others: biodiversity loss reduces ecosystem services critical to agriculture, fisheries, and tourism; agricultural soil degradation influences water quality, sediment dynamics affect lagoons; and flooding damages infrastructure essential for both tourism and aquaculture.

This interconnected vulnerability suggests that sectoral adaptation in isolation will be insufficient. Cross-sectoral strategies, ecosystem-based approaches, and integrated coastal zone management are required to address systemic risks.

4. Conclusions

The sensitivity assessment confirms that the Ravenna coastal system is a climate hotspot, where natural, socio-economic, and cultural values are simultaneously exposed to multiple drivers. While individual sectors show differentiated vulnerabilities, the most severe risks—sea-level rise, flooding, subsidence, and temperature extremes—are transversal and systemic. The combination of fragile ecosystems, intensive land use, and socio-economic reliance on climate-sensitive activities underscores the urgency of proactive adaptation solutions.

Future strategies should adopt integrated, multi-sectoral, and ecosystem-based approaches that strengthen both ecological and socio-economic resilience. Protecting biodiversity, securing water resources, and addressing structural risks are prerequisites for safeguarding tourism, agriculture, and fisheries in the Po Delta and Lamone River pilot site. In this context, the results provide a scientific foundation for local adaptation planning and broader Adriatic coastal governance.

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Annexes

1 - The working Excel file used to perform the analysis of hazards and threats under different local climate scenarios.

2 - The sensitivity assessment, resulting from the integration of the analyses completed by PP3 UNIBO, LP MR, and PP2 PDP on threats and related impacts for the Po Delta and Lamone River pilot site.

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ANNEX 2- The sensitivity assessment, resulting from the integration of the analyses completed by PP3 UNIBO, LP MR, and PP2 PDP on threats and related impacts for the Po Delta and Lamone River pilot site.

The matrix below shows the results of the sensitivity analysis examining the interactions between climatic drivers and the sectors of Biodiversity, Tourism, Agriculture, and Fisheries & Aquaculture.

EVALUATION OF SENSITIVITY
OUTPUT: assessing 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.
* Assess the sensitivity of the areas' components to these threats.

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	Alteration of metabolism, growth, reproduction and biological cycles (e.g. mismatches in migration or nesting periods for birds, pollination, flowering). Increased mortality in key species (especially amphibian and fish larvae/juveniles). Altered predator–prey dynamics. Higher vulnerability to disease outbreaks and invasive species. Stress in pine forest ecosystems (insufficient canopy cover and water regulation). Reduced plant productivity. Anoxia events in water bodies due to reduced mixing. Loss of food resources (e.g. berries for birds). Impaired amphibian reproduction and metamorphosis.	High	High	High

		Better adaptation of tropical/exotic species. Greater risk of management failure: increased risk of botulism in freshwater; lower success of restoration/plantings; increased water demand and pond loss.			
	Cold waves, frost	Mortality of sensitive species (cold-water fish, amphibians, reptiles, insects, temperature-dependent plants). Replacement by generalist or non-native species → reduced biodiversity. Reduced plant productivity, carbon storage and nutrient cycling in wetlands. Following early warm periods: plant growth interruption and fruiting failure; decline in arthropod populations; failure of first broods in amphibians and birds.	Medium	High	Medium
	Wildfires	Destruction of ecosystems and habitat structure. Loss of faunal shelter and nesting sites. Disruption of species' biological cycles. Destruction of protected sites and landscape alteration.	High	High	High
WIND	Changes in the wind regime, storms (rain-snow and wind)	Damage to habitats, dunes, coastal vegetation and soils (erosion, blowouts, displacement). Lagoon systems: sediment resuspension, embankment breaching (e.g. Piallassa Baiona). Nesting bird mortality and breeding failure during extreme winds. Invertebrates and ground-dwelling fauna (e.g. amphibians) buried or displaced. Storms: treefall and habitat damage; higher management costs due to damage to infrastructure; faster erosion of lagoon embankments; sudden water level rise in wetlands; mortality of adult waterbirds. Wind regime change: greater pressure on inadequate coastal protections; intensified coastal erosion and shoreline retreat.	Medium	Medium	Medium
	Whirlwinds	High vulnerability of pine forests (e.g. San Vitale, Casalborsetti): uprooting, breakage, canopy alteration. Damage to dunes, wetlands and lagoons (as above, but more localized). Loss of nesting sites and mortality in birds. Localized, severe impact compared to storms.	Medium	Medium	Medium
	Change in the hydrological regime (water stress, drougth)	Altered seasonal cycles affecting habitat suitability and aquatic ecosystems. Reduced water availability and aquifer recharge. Decline in freshwater quality and buffering capacity against saltwater intrusion. Habitat loss for freshwater-dependent species.	High	High	High

	and type of precipitation	Increased mortality (e.g. due to hail). Prolonged droughts altering plant community composition.			
	Sea acidification	Loss of autochthonous species, emergence of invasive/non-native species. Mortality of mollusks and invertebrates; impaired biological cycles. Damage to biogenic coastal barriers (e.g. seagrass, reefs).	Medium	Medium	Medium
WATER	Saltwater intrusion	Reduced freshwater availability. Soil salinization and fertility decline. Habitat loss in wetlands and meadows. Transformation of landscape through species succession.	High	High	High
	Sea level rise	Coastal erosion, dune destruction and saltwater encroachment. Salinization of rivers, canals and wetlands. Loss of freshwater ecosystems. Sediment alteration (chemical, biological). Degradation of coastal geomorphology and lagoon infrastructure.	High	High	High
	Flooding (coastal, fluvial, pluvial, groundwater)	Habitat loss and flooding of ecosystems. Sediment deposition and erosion. Pollution from surrounding anthropic areas. Temporary alteration of habitats and seasonal dynamics. Damage to embankments, bridges, floodgates.	High	High	High
SOLID MASS	Coastal erosion	Increased exposure to storm surges, flooding and saltwater intrusion. Destruction and loss of coastal habitats. Inland habitat salinization. Higher financial costs for protection infrastructure.	High	High	High
	Soil degradation/erosion	Loss of fertility, increased runoff. Habitat degradation and disruption of trophic networks.	High	Medium	High
	Landslide	Not relevant for Lamone basin but possible in other pilot areas. Risk of flooding if embankments collapse.	Low	Low	Low
	Subsidence	Increased vulnerability to flooding, salinization and erosion. Loss of ecosystem productivity and services. Destruction of shallow-water habitats (reedbeds, seagrass). Loss of bird nesting and stopover sites. Amplification of other threats (saltwater intrusion, sea level rise, soil erosion).	High	High	High

AREA: TOURISM			Tourism infrastructure and services	Economic development and employment	Preservation of tourist attractions
CLIMATE FACTORS	***THREATS***	***IMPACTS***	***SENSITIVITY***	***SENSITIVITY***	***SENSITIVITY***
TEMPERATURE	Temperature increase, heat waves	Shift in peak tourism seasons; loss of appeal in seasonal destinations Higher operating costs for adaptation (air conditioning, insulation) Reduced tourist comfort and satisfaction; increased health risks (heatstroke, dehydration) Difficulty in planning travel packages and events; risk to outdoor tourism reliability Cancellation of outdoor events; increased demand for cooling and water Increased requests for shaded/covered resting areas and refreshment points Loss of interest in outdoor activities during hot months Loss of aesthetic appeal of the landscape; lower general satisfaction	Medium	Medium	Medium
	Cold waves, frost	Risk to transportation and accessibility; temporary closure of tourist services Increased heating costs Visitor discomfort; booking cancellations; general loss in turnout	Low	Low	Low
	Wildfires	Destruction of natural landscapes and tourist attractions Evacuation of areas; air quality issues Long-term damage to tourism brand and natural heritage Potential danger for tourists; decreased air quality	High	Medium	High
WIND	Changes in the wind regime, storms (rain-snow and wind)	Altered patterns for wind-dependent activities (sailing, paragliding); safety concerns Event cancellations; damage to attractions and property; reduced accessibility Storm-specific: Cancellation of events and visits Inaccessibility of natural areas during/after storms Need for visitor safety interventions and first aid Wind regime-specific: negligible impact	Medium	Low	Low
	Whirlwinds	Damage to transport infrastructure, services, and tourist facilities Long recovery periods; insurance challenges; safety concerns; reduced demand	Medium	Medium	Medium

		Interruption of communications Unpredictable water availability affects rural/ecotourism and water sports Severe damage to trees and plant coverage Event cancellations for extended periods Danger to visitors in outdoor conditions General fear and doubts in potential visitors			
WATER	Change in the hydrological regime (water stress, drougth) and type of precipitation	Changes in seasonality and reliability of tourism seasons Loss of aesthetic appeal in humid natural areas during droughts Difficulty in programming trips due to unreliable forecasts Violent rains and storms causing damage and inconveniences	Medium	Medium	Medium
	Sea acidification	Introduction of new dangerous species affecting coastal environments	Low	Low	Medium
	Saltwater intrusion	Affects freshwater availability for hotels/resorts and agricultural landscapes Restrictions on freshwater use; impacts agrotourism activities Reduced biodiversity of freshwater-related flora and fauna	Low	Medium	Medium
	Sea level rise	Loss of beaches; relocation of coastal infrastructure; increased flooding; higher insurance costs Conflicts over water use; reputational damage; reduced service quality Landscape degradation; increased fire risk; impacts on wildlife tourism Infrastructure strain; flash floods; access limitations; damage to heritage sites/trails Reduction of maritime/seaside and environmental tourism due to coastal impacts	High	High	High
	Flooding (coastal, fluvial, pluvial, groundwater)	Direct damage to tourist areas; reduced confidence Temporary unavailability of tourist sites; permanent loss of infrastructure Interruption of public services and communications Potential loss of visitor trust; general sense of danger	High	High	Medium
	Coastal erosion	Beach loss; decline in coastal tourism; costly protective measures; loss of revenue Reduction in maritime/seaside and environmental tourism due to coastal impacts	High	Medium	High

SOLID MASS	Soil degradation/erosion	Degradation of scenic landscapes; reduced attractiveness of destination Limited impact unless general aesthetic appeal is affected	Low	Low	Low
	Landslide	Not applicable for tourists in Po Delta Park area	Low	Low	Low
	Subsidence	Beach loss; structural damage to heritage buildings and accommodations Disruption in services and access Limited direct tourist impact but aggravates water-related risks	High	Medium	Medium

AREA: AGRICULTURE			**Land use and landscape**	**Agricultural income and employment**	**Agricultural biodiversity**
CLIMATE FACTORS	***THREATS***	***IMPACTS***	***SENSITIVITY***	***SENSITIVITY***	***SENSITIVITY***
TEMPERATURE	Temperature increase, heat waves	Alters crop cycles and calendars; risk of early blooming followed by late frost. Stress on crops (grapes, fruit trees) and livestock; reduced yields. Affects pollination, fruit set, and overall crop quality. Risk of overripening or sunburn in fruits and vegetables; increased irrigation demand. Timing mismatch between pollinators and flowers. Increased incidence of plant diseases, requiring more chemical/physical treatments. Increased risk of harvest loss.	Medium	High	Medium
	Cold waves, frost	Damages spring crops, orchards, vines, and olive trees. Severe impact when following early warm periods; affects flowers and fruits.	Medium	High	Low
	Wildfires	Localized destruction of crops, greenhouses, and farm equipment. Amplified damage compared to regular storms.	Medium	Medium	Low
WIND	Changes in the wind regime, storms (rain-snow and wind)	Impacts pollination and spreads pests/diseases. Direct damage to crops (grapes, fruits, vegetables) and agricultural structures. Decreased efficiency of agricultural chemicals. Increased insurance and production costs.	Medium	Medium	Low
	Whirlwinds	Localized destruction of crops, greenhouses, and farm equipment. Damage as described above, though of higher magnitude and on a more localized scale.	Medium	High	Low

WATER	Change in the hydrological regime (water stress, drougth) and type of precipitation	Alters irrigation schedules and sowing/harvest periods. Reduces groundwater recharge and surface water availability. High competition for water among farmers and with natural areas. Difficulty selecting crop types suitable for changing climate. Increased insurance costs; crop damage from extreme events (e.g., hail).	Medium	High	Medium
	Sea acidification	Not applicable	Low	Low	Low
	Saltwater intrusion	Reduces water quality for irrigation; soil salinization. Lowers crop yields; may force field abandonment. Limits choice of cultivars; freshwater scarcity and competition with urban/industrial uses.	Medium	Medium	Medium
	Sea level rise	Long-term threat to coastal farmland; soil salinization and drainage issues. Reduced irrigation water availability; conflicts with urban uses. Crop failure in water-sensitive crops; increased reliance on emergency irrigation. Soil erosion, nutrient leaching, waterlogging; loss of cultivable areas.	High	High	Medium
	Flooding (coastal, fluvial, pluvial, groundwater)	Loss of arable land; delayed or cancelled planting. Infrastructure and farm damage; loss of crop access due to road blockages. Soil pollution from drainage water; long-term soil recovery costs. Increased insurance costs.	Medium	High	Medium
SOLID MASS	Coastal erosion	Loss of cultivable areas and farmland usability. Threatens protective infrastructure.	Medium	Medium	Low
	Soil degradation/erosion	Loss of soil fertility; reduced long-term productivity. Increased costs for fertilization and land management. Water nitrification affecting ecosystem balance.	Medium	High	Medium
	Landslide	Not directly applicable to agriculture, except as increased flood risk when river embankments are affected.	Low	Low	Low
	Subsidence	Lowers land level and increases flood risk. Impacts aquifers through saltwater intrusion. Changes pedological profile; reduces soil depth.	High	Medium	Medium

AREA: FISHING AND AQUACULTURE	**Use of resources**	**Income and employment**	**Multifunctionality**

CLIMATE FACTORS	THREATS	IMPACTS	SENSITIVITY	SENSITIVITY	SENSITIVITY
TEMPERATURE	Temperature increase, heat waves	Alters water temperature, affecting fish reproduction, migration, and metabolism. Decline or disappearance of some native species; invasive species (e.g., blue crab) may proliferate, disrupt food chains, and damage fishing gear. Reduces dissolved oxygen; increases fish and shellfish mortality and vulnerability to disease. Mass mortality events in aquaculture due to oxygen depletion. Promotes algae blooms in nutrient-rich waters. Stresses shellfish and aquaculture operations.	High	High	Medium
	Cold waves, frost	Fish kills in shallow waters. Damage to aquaculture facilities and equipment.	Medium	Medium	Low
	Wildfires	Indirect impacts through ash and debris entering water bodies, affecting water quality. Potential threat to private or non-professional aquaculture structures.	Low	Low	Low
WIND	Changes in the wind regime, storms (rain-snow and wind)	Alters upwelling and water circulation, affecting nutrient availability and fish distribution. Damages aquaculture infrastructure, boats, nets, and embankment of enclosed basins. Interrupts fishing and aquaculture activities.	Low	Low	Low
	Whirlwinds	Localized, intense damage to boats and onshore facilities. Effects like storms but more concentrated.	Medium	Medium	Low
WATER	Change in the hydrological regime (water stress, drougth) and type of precipitation	Alters salinity and nutrient load in coastal lagoons, impacting sensitive fish species. Modifies estuarine and lagoon conditions; affects breeding and juvenile survival of migratory and freshwater-dependent fish. Reduction of freshwater influx (Pialassa Baiona) may disturb brackish water balance.	Medium	Medium	Low
	Sea acidification	Weakens shells of shellfish and mollusks; affects metabolism. Disrupts food chains.	Medium	Medium	Medium
	Saltwater intrusion	Increases salinity in brackish lagoons; negatively impacts freshwater species and aquaculture.	Medium	Medium	Medium
	Sea level rise	Inundates coastal aquaculture sites and infrastructure. Reduces freshwater input into lagoons; alters species composition and	High	High	Medium

		ecosystem balance. Causes flooding of fish farms and damages infrastructure. Changes tide levels and timing in lagoons.			
	Flooding (coastal, fluvial, pluvial, groundwater)	Physical damage to fish farms, tanks, and processing facilities; risk of fish escapes. Interruption of fishing and aquaculture activities. Changes in salinity affecting fish abundance.	Medium	Medium	Medium
SOLID MASS	Coastal erosion	Loss of coastal lagoons and nursery habitats. Threats to fish farm infrastructure. Potential transformation of lagoons (e.g., Piallassa Baiona) into small bays if unprotected.	High	High	Medium
	Soil degradation/erosion	Increases sediment load in water, affecting water quality and fish gills.	Low	Low	Low
	Landslide	Not relevant for professional fishing or aquaculture in the pilot area.	Low	Low	Low
	Subsidence	Increases flood risk in low-lying aquaculture zones. Facilitates salinity intrusion and sea ingression; amplifies impacts of sea level rise.	Medium	Medium	Medium