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

Pilot site: Apulian Regional Natural Park

“Dune Costiere da Torre Canne a Torre San Leonardo” (southern Italy)

Version of 30/09/25

(PP7 contribution to Deliverable n. 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 pilot site of the Apulian Regional Natural Park "Dune Costiere da Torre Canne a Torre San Leonardo"** (hereinafter referred to as "Parco Dune Costiere"). Analyzes were 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, erosion, 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, in order 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 Parco Dune Costiere pilot site, within the framework of the "ACTION - Increasing coastal ecosystem resilience to climate change" project.
The pilot area, which is characterized by ecological fragility, socio-economic relevance, and exposure to multiple stressors, is particularly sensitive to the impacts of climate change. The aim of this analysis, coupled with the results of in situ surveys, 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 different contributions. This triangulation of inputs mitigated bias, enabled cross-sectoral comparisons, and ensured the legitimacy of the results.

For the analysis of hazards and threats and local scenarios of the Parco Dune Costiere pilot site, the following stakeholders were involved: i) UNIBA team, as research organization; ii) ASSET (*Agenzia regionale Strategica per lo Sviluppo Ecosostenibile del Territorio*) and Regione Puglia – Sezione Demanio e Patrimonio, as regional public administrations; and iii) Autorità di Bacino Distrettuale dell'Appennino Meridionale, as interregional management body.

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.

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. 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.

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.

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 and discussion

In the following subparagraphs, the description of the threats and impacts for each considered sector in the Pilot Area is provided. The results are obtained from the expert-based evaluation of each indicator proposed for the "Sensitivity analysis". They can be considered as the base for the analysis of the vulnerability. As shown in Annex 2, the sensitivity analysis of interactions between climatic drivers and geo-biodiversity components indicates that many threats define high sensitivity, especially threats directly associated with the temperature increase, change in hydrogeological patterns, and mass degradation. Considering the tourism sector, which takes into account infrastructure, services, attractions, economic development, and related employment, relevant impacts are defined for the processes associated with the temperature increase (mostly heat waves and wildfires) and with the increase of marine-related processes (coastal erosion, flooding, and sea level rise). Considering the agriculture sector, the highest values of sensitivity are associated with variations in temperature and pluvial patterns, as well as sea level rise and saltwater intrusion. Finally, the expected increase in the occurrence of heat waves represents the main threat also for the fishing and aquaculture sectors, which are also affected by sea acidification, sea level rise, and flooding processes.

3.1 Geo/biodiversity

The natural areas located in the pilot site are characterized by high geological and biological value. In fact, the Park is characterized by a high diversity of natural environments, which include beaches, coastal dune belts, wide back-dune wetlands (Fiume Piccolo, Fiume Grande, Fiume Morelli), fossil dunes, and part of karst valleys (Lamacornola, Lama Torre Bianca, Lama Defense of Malta, Lama Rosa Marina). From the ecological point of view, the high biodiversity of the park provides essential ecological functions, serving as a habitat for rare and endangered plant and animal species. It acts as a vital breeding ground and migratory stopover for numerous bird populations. The analysis shows an overall high level of sensitivity to natural and anthropogenic processes for all the aspects taken into account (area of protected habitats, species richness, ecosystem services). As in other parts of the Mediterranean, climate change is expected to amplify existing natural and anthropogenic pressures.

According to our analysis, all the aspects taken into consideration are highly sensitive to temperature increase, heat waves, and wildfires, which are expected to affect richness species due to the biological alterations and favour the distribution of invasive species. Furthermore, key coastal and backdunal habitats as well as wetlands are highly sensitive to wildfires, which are expected to destroy habitat structure, faunal shelters, and ecosystem integrity. Coastal natural environments, such as pinewoods and dunes, are particularly sensitive. By way of example, in wetlands, wildfires can burn reed beds and riparian vegetation, destroying nesting areas for waterbirds, reducing cover for amphibians and small mammals, and altering aquatic habitats that sustain fish and invertebrate communities.

Variations in wind regime are expected to affect mostly the habitat integrity since storms and extreme wind events cause coastal dune destabilization, sediment resuspension, and damage to nesting sites. Therefore, habitats show medium sensitivity, while species richness and ecosystem services can be considered less sensitive to the occurrence of wind storms, as the impacts tend to be localized.

As concerns the water-related threats, all the accounted aspects are considered highly sensitive to the direct and indirect effects of the variations in the hydrological regime. In fact, natural habitats and species

can be strongly affected by the alteration of precipitation and drought patterns. Similarly, highly sensitive values are associated with ecosystem services due to reduced water availability and loss of freshwater-dependent habitats.
Sea acidification threatens molluscs and other invertebrates, favours opportunistic and invasive species, and can alter trophic structures in lagoons (Range et al., 2012). By way of example, the invasive blue crab (Callinectes sapidus), increasingly recorded in Mediterranean coastal wetlands, including Parco Dune Costiere pilot site, can thrive under altered salinity and pH regimes, heavily preying on native bivalves and crustaceans, reducing mollusc populations and reshaping food web dynamics to the detriment of fish and waterbirds. Sensitivity is medium across all biodiversity dimensions, reflecting long-term risks to community composition.
Saltwater intrusion, sea level rise, and (coastal, pluvial, and fluvial) flooding processes are among the most severe threats in the pilot site. Saltwater intrusion alters plant community composition, promotes soil salinization, and diminishes soil fertility, while sea level rise and flooding are expected to favour beach and dune erosion, inundate wetlands and low-lying areas, and decrease the natural resilience of the mobile coastal systems. By way of example, prolonged saltwater intrusion in back-dune wetlands can cause die-off of reed beds and freshwater macrophytes, reducing spawning areas for amphibians and fish, and forcing waterbird populations to abandon traditional nesting and foraging grounds. 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.
At the same time, coastal erosion and soil degradation affect habitat quality and ecosystem functioning. Coastal erosion favours shoreline retreat and the loss of sediments, leading to the narrowing of beaches and the degradation of natural habitats, such as dunes and wetlands. It can also result in the exposure of natural and anthropogenic structures to wave action and storm surge, and in the increase of the risk of coastal flooding. By way of example, erosion of wetland margins leads to the collapse of nesting banks used by birds, while also reducing shallow-water nursery zones essential for juvenile fish and invertebrates.
Soil degradation and erosion reduce fertility, increase runoff, habitat productivity, and regulating services, and as a consequence, species richness is also rated as high sensitive.
Landslides are of minor relevance for the pilot area.
Finally, subsidence 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. Due to the average rate (<1mm/yr) estimated for the pilot area, all biodiversity components have a medium sensitivity.

3.2 Tourism

Tourism in the Parco Dune Costiere pilot site is strongly dependent on infrastructure and services, local economic development and employment, and the preservation of natural heritage. Due to its exposure to multiple climatic drivers, the pilot area remains highly vulnerable to climate-related pressures. The sensitivity analysis highlighted that

All tourism dimensions are characterized by high sensitivity values to rising temperatures and heat waves. Related impacts include reducing visitor comfort and safety, increasing costs for cooling and water provision, cancellation of outdoor events, and declining interest in outdoor activities during peak summer. These changes may influence the timing of peak tourist seasons, reduce aesthetic landscape appeal, and complicate the organization of travel packages and events. In the study area, cold and frost waves are associated with 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.

On the other hand, the occurrence of wildfires represents a high threat to infrastructure, services, attractions, as well as for economic development. They can destroy natural and anthropogenic assets, degrade air quality, and pose safety risks for visitors. At the regional scale, a recent example is provided by the wildfires occurred in the province of Lecce during the summer of 2025, which burned extensive areas of Mediterranean scrub and coastal pine forests, making it necessary to evacuate beaches, tourist accommodations, and holiday homes.

Accounting for the expected changes in wind regime and storms, a medium sensitivity value is associated with infrastructure and attractions, while a low value for economic activities. Main impacts include cancellations of outdoor events, damage to property, restricted access to natural areas, and the need for visitor safety measures. Furthermore, wind-dependent recreational activities (e.g., sailing, paragliding) are affected by changes in wind patterns. At the same time, all components are affected by the whirlwinds with a high sensitivity. 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's attractiveness. A representative case of such phenomena concerns the whirlwinds that occurred in the southern Apulia region in 2024 and 2025. These events caused damage to beach establishments, accommodation facilities, and beach equipment, causing inconvenience to tourists and panic among bathers.

Alterations in the hydrological regime (droughts, water stress, and irregular rainfall) show low sensitivity across the tourism sector.

Sea acidification is assessed as low sensitivity for infrastructure, but medium for and economy and 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 sensitivity for all the touristic dimensions since the decrease in freshwater availability may impact biodiversity in wetlands and freshwater-dependent areas.

Sea level rise and different flooding are among the most severe threats and therefore are considered as highly sensitive across all tourism dimensions. They cause direct and indirect impacts, including beach loss, relocation of coastal infrastructure, and degradation of coastal landscape. Consequences include higher insurance costs, conflicts over land and water use, and declining service quality. Furthermore, waves and extreme marine events cause direct physical damage, service interruptions, and long-term loss of tourism.

Finally, among the threats related to solid mass processes, coastal erosion represents the highest sensitivity threat for infrastructure and attractions, and a medium for the economy. It reduces beach

capacity, undermines protective structures, increases costs for adaptation, and threatens the competitiveness of seaside tourism.
Tourism is relatively sensitive to soil degradation and soil erosion. Their impacts are associated with gradual reductions in scenic quality and attractiveness, unless broader environmental degradation occurs.

3.3 Agriculture

Agriculture in the Apulian pilot site is a key socio-economic sector, strongly intertwined with land use patterns, rural employment, and the preservation of agro-biodiversity. Given its location, the coastal area is particularly vulnerable to climate-related stressors such as extreme temperatures, hydrological fluctuations, and changes in soil and landscape dynamics. Sensitivity assessments of the three agricultural components, land use and landscape, agricultural income and employment, and agricultural biodiversity, indicate that the highest sensitivity levels are linked to changes in temperature and precipitation patterns, as well as to sea level rise and saltwater intrusion.
The impacts of the temperature increase affect all the dimensions considered for the agricultural sector, since high temperatures and heat waves can alter the crop cycles, as they disrupt crop calendars, reducing yields in grapes, fruit trees, and vegetables. As a consequence, higher irrigation and plant protection treatments are required. Land use and landscape register medium sensitivity, as prolonged heat accelerates soil and water stress. Biodiversity is likewise medium sensitive, with risks to pollination timing, fruit set, and overall ecological balance. Cold waves and frost are assessed as highly sensitive for income and employment, since they can severely damage agricultural crops as orchards, vineyards, and olive trees. Sensitivity level is assessed as medium for land use, reflecting local disruptions, but low for biodiversity, as ecosystem structure is less directly affected.
High sensitivity level is associated with wildfires on land use and landscape, while income, with localized destruction of crops, greenhouses, and equipment, and indirect economic costs, has a medium value. Similarly, biodiversity has a mean sensitivity, since habitat degradation may occur.
All the components are associated with a medium sensitivity to changes in wind regimes and storms; main consequences are related to disrupted pollination, pest and disease spread, as well as direct crop and infrastructure damage. Whirlwinds generate more severe localized impacts, classified as high sensitivity for income and employment due to the destruction of crops, structures, and equipment. On the other hand, land use and biodiversity are associated with low sensitivity.
All the accounted aspects are considered highly sensitive to changes in the hydrological regime (drought, altered precipitation), as such processes can alter the irrigation scheduling, crop selection, and sowing/harvest reliability. Saltwater intrusion is also associated with high sensitivity across all the accounted components, since it strongly reduces irrigation water quality, drives soil salinization, and forces shifts in crop selection.
Sea level rise is one of the most critical pressures, with high sensitivity since it leads to salinization, drainage and nutrient losses, and long-term loss of cultivable areas. Biodiversity sensitivity is high, 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. Land use and biodiversity are characterized by a medium sensitivity,

given the recurrent degradation of soils and habitat conditions. Coastal erosion shows high sensitivity for land use and income, reducing available farmland and threatening protective structures. Given limited direct impacts on biodiversity, a medium sensitivity level is associated. Among the accounted marine-related processes, sea acidification is not relevant to agricultural systems.
Soil degradation and erosion are associated with a high sensitivity for land use and employment, due to fertility loss and nutrient imbalance, and medium sensitivity for biodiversity, undermining long-term productivity, raising fertilization costs, and disrupting ecosystem services.
The subsidence rates estimated for the pilot area allowed for assigning a medium sensitivity level to all the agricultural components. Finally, landslides do not affect the investigated site.

3.4 Fishing and Aquaculture

Fishing and aquaculture in the Apulia region 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).
Temperature increase 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), further exacerbate these impacts by preying on native resources and competing with commercial species, thus threatening both artisanal fisheries and aquaculture production. Additionally, “Multifunctionality” exhibits a medium sensitivity level, as ecosystem services are also influenced by temperature variations.
Cold waves and frost exert low sensitivity on resource use and employment, as they can trigger fish kills in shallow lagoons and damage aquaculture facilities. Wildfires have low sensitivity, with indirect impacts from ash and debris degrading water quality, occasionally affecting small or non-professional aquaculture facilities.
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 and employment, as they can inflict localized but intense damage on boats, onshore structures, and aquaculture systems.
Changes in the hydrological regime (drought and altered precipitation) have medium sensitivity for all the fishing components (resource use, employment, and multifunctionality). Variations in freshwater modify salinity and nutrient loads in coastal lagoons and retrodunal lakes, affecting breeding and juvenile survival of sensitive and migratory fish. Sea acidification has high sensitivity across all components, except for multifuntionality. Acidification weakens the shells of molluscs, disrupts food chains, and undermines aquaculture profitability. Saltwater intrusion raises salinity levels in lagoons, stressing freshwater and

brackish species and challenging aquaculture operations in low-lying areas. It registers high sensitivity in resource use and employment and medium sensitivity in multifunctionality.
Sea level rise and flooding are high-sensitivity drivers for all components, due to the relevant impacts in terms of inundation of aquaculture sites and infrastructure, reduction of freshwater inflows into lagoons, alteration of species composition, and increasing the risk of farm flooding. Furthermore, flooding events damage fish farms, tanks, and processing facilities, cause fish escapes, and interrupt fishing operations. Changes in salinity also affect fish abundance.
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. Multifunctionality has a high sensitivity, reflecting loss of ecological and cultural values. Soil degradation and erosion show medium sensitivity, as increased sediment loads degrade water quality and damage fish gills but do not fundamentally alter the resource base. As for the other accounted sectors, subsidence has a medium impact, affecting relative sea level rise. Finally, landslides are not relevant to professional fishing and aquaculture in the pilot area and remain low-sensitivity across all components.

ANNEX 1 - The sensitivity assessment, resulting from the integration of the analyses completed i) UNIBA team, as research organization; ii) Asset and Regione Puglia – Sezione Demanio e Patrimonio, as regional public administration; and iii) Autorità di Bacino Distrettuale dell'Appennino Meridionale, as management body, on threats and related impacts for the Parco Dune Costiere pilot site.

EVALUATION OF SENSITIVITY

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

AREA: GEO/BIODIVERSITY			Area of protected habitats	Species richness	Ecosystem services
CLIMATE FACTORS	*THREATS*	*IMPACTS*	*SENSITIVITY*	*SENSITIVITY*	*SENSITIVITY*
TEMPERATURE	Temperature increase, heat waves	Effects on metabolism, growth and reproduction; change in reproductive cycles (i.e. nest failure and migration timing for birds), biological cycles (i.e. increased metabolic rates with stress organism); alterations of survival of key species (higher mortality rates, particularly in larvae and juveniles of Amphibians, fishes and macro-zoobenthic taxa); altered predator-prey dynamics; increased vulnerability to disease outbreaks, mass mortality events and alien or invasive species; stress in pine forest ecosystem where canopy cover and water regulations are insufficient to buffer high temperature; reduced plant productivity	High	High	High

	Cold waves	Sensitive species (e.g., cold-water fish, wetland amphibians, reptiles, insects, temperature-dependent plants) are replaced by generalists or non-native species more tolerant to heat, reducing overall biodiversity; Carbon storage and nutrient cycling in wetlands may be impaired if plant productivity and microbial activity are reduced.	Medium	Medium	Low
	Wildfires	Destruction of the ecosystem (dune and backdune); destruction of habitat structure and faunal shelter	High	High	High
WIND	Changes in the wind regime, storms (rain-snow and wind)	Extensive habitat and coastal damage Potential impacts on dune dynamics and coastal vegetation. Soil erosion Coastal dunes and wetlands may experience blowouts, sand displacement, or saltwater intrusion due to storm surges driven by high winds. Backdune systems may see sediment resuspension and breaching of protective embankments. Nesting birds can lose breeding sites and suffer mortality during extreme wind events. Invertebrates and ground-dwelling species may be buried, displaced, or exposed.	Medium	Low	Medium

	Whirlwinds	Forested areas are highly vulnerable to windthrow (uprooting or breakage of trees), altering forest structure and canopy. Coastal dunes and wetlands may experience blowouts, sand displacement, or saltwater intrusion due to storm surges driven by high winds. Backdune systems may see sediment resuspension and breaching of protective embankments. nesting birds can lose breeding sites and suffer mortality during extreme wind events.	Medium	Low	Low
	Change in the hydrological regime (water stress, drougth) and type of precipitation	Change in seasonal cycles affecting habitat suitability and water-dependent species; Change in the hydrological cycle impacting wetland dynamics and aquatic habitats Reduced water availability for ecosystems, especially in summer; decrease in aquifer recharge (water deficit);	High	High	High
	Sea acidification	New potential dangerous species (e.g. non-native, pathogen) living our coastal environments; Lower carbonate ion levels causing difficulties in shell and skeleton formation for calcifying invertebrates.	Medium	Medium	Medium

WATER	Saltwater intrusion	decrease in freshwater availability; change in plant communities; soil salinization and decrease in soil fertility	High	High	High
	Sea level rise	Coastal erosion; dune destruction; saltwater intrusion and encroachment of marine water along the rivers and canals open to the sea; soil salinization; decrease of freshwater ecosystems	High	High	High
	Flooding (coastal, fluvial, pluvial, groundwater)	Flooding of habitats; erosion and sediment load impacting ecosystems; habitat loss	High	High	High
SOLID MASS	Coastal erosion	increase of exposure to storm surge, flooding, saltwater intrusion; destruction of coastal habitats;	High	High	High
	Soil degradation/erosion	decrease in fertility; increase in runoff	High	High	High
	Landslide	n/a for Parco delle Dune but maybe for the other PPs	Low	Low	Low
	Subsidence	Increase of pilot area vulnerability to flooding, salinization, coastal erosion; effects on ecosystem productivity and services	Medium	Medium	Medium

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 (beach resorts bnirdwacthing); higher operating costs for adaptation to hottest periods (e.g., air conditioning, insulation). Reduced tourist comfort and satisfaction; increased health risks (heatstroke, dehydration); potential declines in visitation during hot months. Unpredictable weather discourages bookings; difficulty in planning travel packages and events; risk to outdoor tourism reliability. Cancellation of outdoor events and activities; increased demand for cooling and water; health risks; lowered tourist satisfaction.	High	High	High
	Cold waves	Risk to transportation and accessibility; temporary closures of tourist services; increased heating costs.	Low	Low	Low

	Wildfires	Destruction of natural landscapes (coastal and historical pinewoods) and tourist attractions (demages in coastal pinewood and beach establishments); evacuation of areas; air quality issues; long-term damage to tourism brand.	High	High	High
WIND	Changes in the wind regime, storms (rain-snow and wind)	Altered patterns of wind-dependent activities (e.g., sailing, paragliding); discomfort for tourists; potential safety concerns. Event cancellations; damage to attractions and property; reduced safety and accessibility; increased maintenance costs.	Medium	Low	Medium
	Whirlwinds	Demages to transport infrastructure and services; long recovery periods; insurance challenges; safety concerns reduce demand.Demages also to private infrastructures; visitor panic and safety risks; reduced trust in safety of destination. Unpredictable water availability affects rural/ecotourism; problems for water sports and nature-based tourism.	High	High	High
	Change in the hydrological regime (water stress, drougth) and type of precipitation	Change in seasonality and reliability of tourism seasons (also extensione of the touristic season).	Low	Low	Low
	Sea acidification	New dangerous species (alloctonus) living our coastal environments	Low	Medium	Medium

WATER	Saltwater intrusion	Affects freshwater availability for hotels/resorts; deteriorates agricultural landscapes used for agritourism.	Medium	Medium	Medium
	Sea level rise	Loss of beaches; relocation of coastal infrastructure; increase in flooding of tourist areas; higher insurance costs. Conflict over water use between tourists and locals; reputational damage; reduced quality of service. Landscape degradation; fire risk increases; impacts on wildlife tourism; restrictions on water use. Infrastructure strain; flash floods; access limitations; damage to heritage sites and trails.	High	High	High
	Flooding (coastal, fluvial, pluvial, groundwater)	Direct damage to tourist areas; reduced tourist confidence; interruption of public services.	High	High	High
SOLID MASS	Coastal erosion	Beach loss; decline in coastal tourism; costly protective infrastructure investments; loss of tourism revenue. Need of rigid protection infrastructures	High	High	High
	Soil degradation/erosion	Degradation of scenic landscapes; reduced attractiveness of destination.	Low	Medium	Medium
	Landslide	n/a for Parco delle Dune but maybe for the other PPs	Low	Low	Low
	Subsidence	Beach loss; Structural damage to heritage buildings and accommodations; disruption in services and access.	Medium	Low	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; risk of early blooming followed by late frost damage. Stress on crops (e.g., grapes, fruit trees) and livestock; reduced agricultural yields. Affects pollination, fruit set, and overall crop quality. Risk of overripening or sunburn in fruit and vegetables; water stress and increased irrigation needs.	High	High	High
	Cold waves	Damages to spring crops (e.g., orchards); affects vines and olive trees.	Medium	High	Low
	Wildfires	Damage to rural lands and pastures; loss of forage, crops and fire risk to farm buildings.	High	Medium	Medium
WIND	Changes in the wind regime, storms (rain-snow and wind)	Impacts pollination; spreads pests and diseases; potential damage to greenhouses. Direct damage to crops (especially grapes, fruit, vegetables); increases insurance and production costs.	Medium	Medium	Medium
	Whirlwinds	Localized destruction of crops, greenhouses, and farm equipment.	Low	High	Low

WATER	Change in the hydrological regime (water stress, drougth) and type of precipitation	Altered irrigation scheduling; unpredictable sowing and harvest periods. Impacts on groundwater recharge and surface water availability for irrigation.	High	High	High
	Sea acidification		Low	Low	Low
	Saltwater intrusion	Affects water quality for irrigation in low-lying coastal areas; reduces crop yield.	High	High	High
	Sea level rise	Long-term threat to coastal farmland; soil salinization and drainage problems. Reduced availability of irrigation water; conflict between agricultural and urban uses. Crop failure, especially in water-sensitive crops; increased reliance on emergency irrigation. Soil erosion, nutrient leaching, waterlogging, and crop loss.	High	High	High
	Flooding (coastal, fluvial, pluvial, groundwater)	Loss of arable land and delayed or canceled planting; infrastructure damage.	Medium	High	Medium
SOLID MASS	Coastal erosion	Reduces usable farmland in coastal zones; threatens protective infrastructure.	High	High	Medium
	Soil degradation/erosion	Loss of soil fertility; impacts on long-term productivity and land management costs.	High	High	Medium
	Landslide	n/a for Parco delle Dune but maybe for the other PPs	Low	Low	Low
	Subsidence	Increase in flood risk in farmlands.	Medium	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. Some species may decline or disappear. Invasive species like blue crab (*Callinectes sapidus*) outcompete native species, disrupt food chains, and damage gear. High temperatures reduce oxygen levels in water; increased fish mortality and vulnerability to disease. Indirectly affects water temperature stability; stresses on shellfish and aquaculture operations. Mass mortality events in aquaculture due to oxygen depletion; algae blooms increase.	High	High	High
	Cold waves	Fish kills in shallow waters; damage to aquaculture facilities and equipment.	Medium	Medium	Medium
	Wildfires	Indirect effects through ash and debris entering water bodies, impacting water quality.	Low	Low	Low
WIND	Changes in the wind regime, storms (rain-snow and wind)	Alters upwelling and water circulation, influencing nutrient availability and fish distribution.	Low	Low	Low

		Disturb aquaculture infrastructure; limit fishing activity; risk of fish escape.			
	Whirlwinds	Can damage boats and onshore facilities; very localized impact.	Low	Medium	Low
WATER	Change in the hydrological regime (water stress, drougth) and type of precipitation	Affects salinity and nutrient load in coastal lakes; impacts fish species sensitive to water quality. Alters coastal lakes conditions; affects breeding of migratory and freshwater-dependent fish.	Medium	Medium	Medium
	Sea acidification	Threatens shellfish and mollusks by weakening shells; impacts food chains.	High	High	Medium
	Saltwater intrusion	Increases salinity in brackish lagoons; negatively affects freshwater species and aquaculture.	High	High	Medium
	Sea level rise	Inundates coastal infrastructure and brackish ecosystems. Reduces freshwater input into coastal lakes; imbalance in ecosystems and species decline. Decline in water levels and quality; increased salinity in coastal waters affecting species composition. Alters water chemistry; causes flooding of fish farms and infrastructure damage.	High	High	High

	Flooding (coastal, fluvial, pluvial, groundwater)	Physical damage to fish farms, tanks, and processing facilities; fish escapes.	High	High	High
SOLID MASS	Coastal erosion	Loss of coastal lakes and habitats vital for nursery areas; threats to aquaculture infrastructure.	High	High	High
	Soil degradation/erosion	Increased sediment load in water; impacts water quality and fish gills.	Medium	Medium	Medium
	Landslide	n/a for Parco delle Dune but maybe for the other PPs	Low	Low	Low
	Subsidence	Worsens flood risk in low-lying aquaculture zones; increases salinity intrusion.	Medium	Medium	Low

4. Conclusions

The sensitivity analysis conducted for the Parco Dune Costiere Pilot Area highlights a multifaceted and systemic vulnerability of the area to climate change. The evaluation of key investigated sectors (geo-biodiversity, tourism, agriculture, and fishing/aquaculture) reveals how climate drivers such as temperature increase, changes in precipitation and hydrological regimes, sea level rise, saltwater intrusion, and coastal erosion interact with ecological processes and socio-economic dynamics, resulting in widespread sensitivity across the system.

Geo-biodiversity components are highly sensitive to heat waves, wildfires, and water-related stressors, with significant risks for species richness, habitat integrity, and ecosystem services. The natural areas of the park, which play a critical role in biodiversity conservation and ecological connectivity, are especially exposed to compounding pressures that threaten their resilience and long-term functionality.

In the tourism sector, rising temperatures and extreme events such as wildfires, coastal flooding, and sea level rise pose direct threats to infrastructure, attractions, and seasonal activities, with cascading effects on local economies and employment. The degradation of natural landscapes, loss of beach areas, and increasing safety risks for visitors could alter the competitiveness and attractiveness of the area, particularly during peak tourist seasons.

Agriculture, a remarkable economic and cultural component of the pilot area, is similarly vulnerable. High sensitivity is recorded in response to temperature extremes, altered rainfall patterns, and soil and water degradation processes. These pressures negatively impact crop yields, farming practices, and rural livelihoods, while threatening the integrity of agro-ecosystems and biodiversity. Sea level rise and saltwater intrusion are particularly severe, as they compromise soil fertility and freshwater availability, leading to long-term productivity losses.

Finally, the fishing and aquaculture sectors are highly sensitive to the warming of marine and lagoon water, sea acidification, and increased flooding. These stressors affect species distribution, ecosystem balance, and the viability of aquaculture operations. Coastal erosion and habitat loss further reduce the ecological and economic sustainability of these sectors, with implications for both resource use and the multifunctional roles these activities play in the local context.

Overall, the results emphasize the interdependence between ecological integrity and socio-economic stability in the face of climate-related processes. The high sensitivity level across multiple sectors highlights the need for integrated adaptation strategies that address sector-specific vulnerabilities while also recognizing cross-sectoral interactions. Enhancing climate resilience in the pilot area will require coordinated planning, nature-based solutions, improved resource management, and the active involvement of local communities and stakeholders to safeguard the environmental and economic assets of the Parco delle Dune Costiere over the long term.

References

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Annexes

1 - The sensitivity assessment, resulting from the integration of the analyses completed by PP7 on threats and related impacts for the Parco Dune Costiere pilot site.