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Preparing, Adapting, Reconstructing: actions to promote climate change adaptation and risk disaster resilience in Italian and Croatian sensitive ecosystems

Work Package 1 – Output 1.1

“Climate-resilient water ecosystems management scenarios”

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Contents

1. Introduction
2. Comparison of Water Ecosystem Management Policies and Climate Scenarios Across Target Areas: gaps and inputs for next project phases.
 - 2.1 Emilia-Romagna Region – Broader area of Ravenna and Ferrara provinces, including the Po River Delta (protected area)
 - 2.2 Marche Region – Province of Pesaro, Parco San Bartolo (protected area)
 - 2.3 Puglia Region – Province of Brindisi, Egnazia (archaeological site)
 - 2.4 Zadar County – Paklenica National Park (protected area)
 - 2.5 Split-Dalmatia County – Historic City of Trogir (UNESCO World Heritage Site)
 - 2.6 Dubrovnik-Neretva County – Neretva River Delta (protected area, Natura 2000 habitat)
3. Conclusion





1. Introduction

This document builds on the analysis and lessons learned throughout the project's first Work Package (WP1) and represents its final output. In particular, the purpose of this output is to examine the interplay between climate-related hazards and existing policy frameworks across the project's target areas, leveraging on the combined results of activity 1.1 and activity 1.2.

The analysis has two main objectives:

1. To systematically compare climate hazard scenarios - particularly those related to water ecosystem management - with the policies currently in place at the European, national, regional, and local levels.
2. To determine whether, and to what extent, these policies address the relevant hazards, while identifying regulatory gaps that may hinder effective climate risk management and adaptation.

By mapping hazards against the corresponding policies, the document provides:

- A comprehensive overview of how climate risks are currently regulated across multiple scales of governance.
- A gap analysis highlighting where specific hazards remain unaddressed or inconsistently managed

The outcomes of this work are intended to inform and support stakeholders by pointing out the areas where further policy development, integration, or adaptation is needed, preparing the ground for activities under WP2 and WP3 of the project. Indeed, this evidence-based approach provides targeted inputs for the next project phases and will help guide efforts to strengthen climate resilience, ensuring that local, regional, and national strategies remain aligned with European objectives.

2. Comparison of Water Ecosystem Management Policies and Climate Scenarios Across Target Areas: gaps and inputs for next project phases

This section cross-references climate hazards projected for the target areas (Figure 1) with existing policies to evaluate the extent to which risks are regulated or mitigated. For each area, the analysis identifies:

- Relevant policies and regulatory frameworks (EU, national, regional/local)
- Alignment or mismatch between policy measures and projected hazards
- Policy gaps
- Recommendations and inputs to guide stakeholders and inform subsequent project activities.



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TARGET AREAS:

Emilia Romagna Region
Dubrovnik-Neretva County
Zadar County
Marche Region
Puglia Region
Split-Dalmatia County

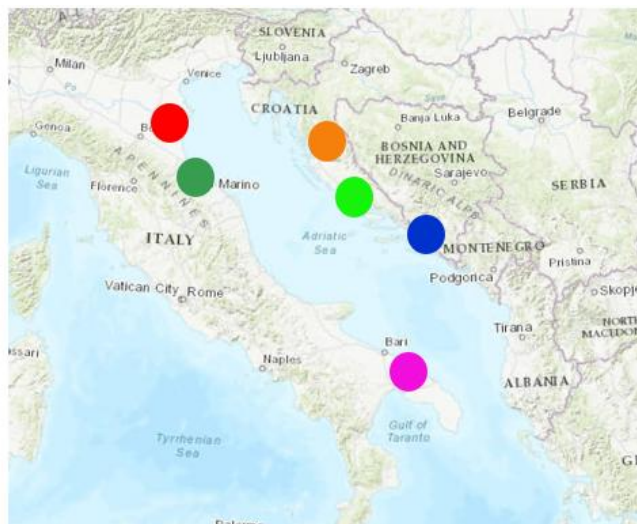


Figure 1: Target areas of the project

2.1 Emilia-Romagna Region – Broader area of Ravenna and Ferrara provinces, including the Po River Delta (protected area)

The eastern sector of the Po Valley (Figure 2), with particular reference to the Po Delta area, represents a notable example of how the morphological structure of a territory can be shaped by the dynamic interaction between natural factors and human interventions.

The formation of the current Po Delta began approximately 2,000 years ago through the gradual accumulation of sediments transported by the river. The process of delta progradation was particularly significant between the 16th and 19th centuries, driven by the substantial sediment load carried by the extensive Po River basin (approximately 71,000 km²).

Human activities have profoundly altered the area, accelerating the formation of the modern delta.

In recent years, the Po Delta area has been facing an increasingly complex environmental emergency, marked by the convergence of extreme hydrological and climatic events.

The dual threat of floods and droughts places significant pressure on both the territory and local communities, jeopardizing agriculture, tourism, biodiversity, and infrastructure.

Among the main critical factors identified are:

- Increasing frequency of concentrated intense precipitation causing river flooding
- Long periods of drought that significantly reduce river flow and water availability
- Coastal marine erosion and sea level rise
- Increased frequency and intensity of storm surges.



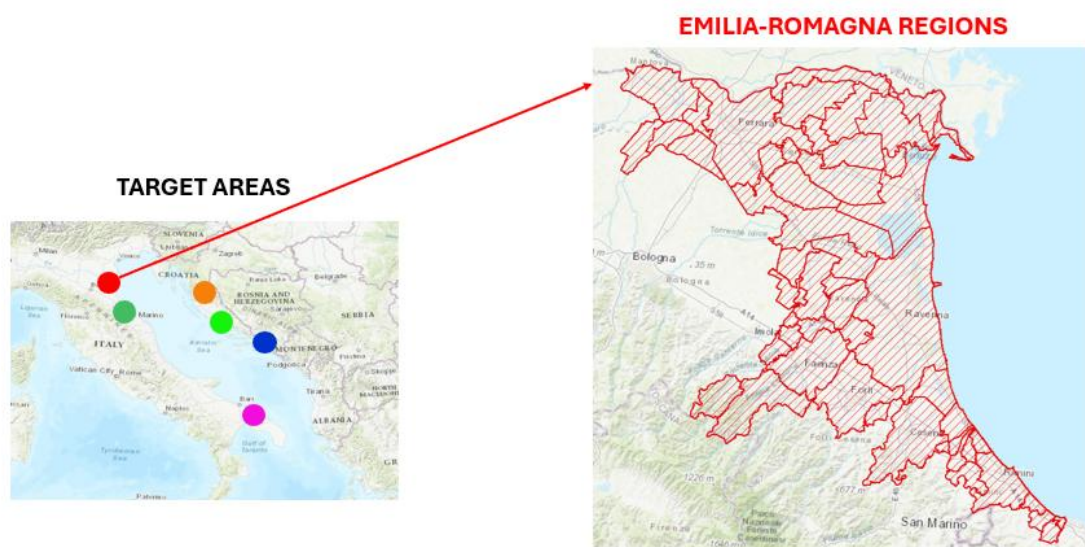


Figure 2: Italian target area: Emilia-Romagna Region – Broader area of the provinces of Ravenna and Ferrara, including the Po River Delta.

Considering this, understanding the characteristics of climate hazards is fundamental for a correct and adequate definition of adaptation strategies.

As already outlined in the document “*Strategy on scenarios of climate change related effects and risks and impacts on water landscapes*”, climate analyses were carried out in terms of climate indicators both for the study of the climate during the reference period (1981-2010) and for the expected climate (2036-2065).

On the reference period the total annual precipitation, calculated exclusively from days with a minimum of 1 mm of precipitation (**PRCPTOT**) show precipitation in the region ranges between 500 mm and 800 mm, with a gradient from the plains to the hills. Whereas considering rainfall intensity indicators (**SDII**), important in assessing how rainfall patterns are changing, higher values can be noted in the inner part of the region.

Instead, indicators linked to extreme temperatures (such as **HW**) show higher values in localized areas located mainly in the internal part of the region.

For the expected climate variations (2036-2065), the climate analysis reveals significant variations in precipitation and temperature patterns across different RCP scenarios. While total precipitation shows scenario-dependent trends (increases in RCP2.6/RCP8.5, heterogeneous patterns in RCP4.5 with coastal

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reductions affecting 3,148 km² of irrigated cropland), precipitation intensity consistently increases across all scenarios by 7-10 mm per rainfall event, creating flood risks particularly in 1,095 km² of below-sea-level areas. Temperature indicators demonstrate clear warming variations, with summer days (Daily maximum temperature >25°C) increasing by 18-24 days annually, intensifying toward coastal areas and affecting 163,361 buildings. Hot waves days (Daily maximum temperature >35°C) show a west-to-east gradient, with western areas experiencing up to 7 additional days under RCP2.6 and 13 days under RCP4.5—an 85% increase between scenarios. These findings underscore the need for targeted adaptation strategies addressing spatial heterogeneity of climate impacts, particularly in vulnerable coastal and western territories.

In response, **Emilia-Romagna Region** has implemented a comprehensive strategy to combat climate change, aiming to reduce greenhouse gas emissions by 80% by 2050. This strategy covers sectors like agriculture, energy, transport, and health, with a focus on sustainable water management through actions such as improving drainage networks, enhancing wastewater treatment, reducing water losses, and promoting water reuse (in line with the **European Adaptation Strategy and National Climate Change Adaptation Plan**). Moreover, the region has adopted different policy tools for climate adaptation and nature-based solutions: **sustainable drainage canal management** (2012), **flood risk mitigation and ecological restoration of watercourses** (2015), and **riparian vegetation management** (2019), **strategy for integrated management for coast defense and adaptation to climate change** (2014-2020), **flood risk management plan** (2021-2027). Though initially underemphasized, these measures gained relevance after the 2023 floods and were formally adopted by the Regional Government. On the other hand, key local initiatives include the **Sustainable Energy and Climate Action Plans** (PAESC) for municipalities like Cesena, Ravenna, Rimini, and Forlì, which focus on reducing water consumption, enhancing water resilience, and addressing flood risks through both green infrastructure and nature-based solutions.

However, a closer comparison between climate findings and existing policies reveals both progress and gaps. Flood risks from intense rainfall events are partly addressed by the Flood Risk Management Plan and river restoration initiatives, yet the urgency of implementation increased only after the 2023 floods, suggesting a reactive rather than proactive approach. Drought and water scarcity are tackled through water reuse, improved drainage, and reduced losses, but rising agricultural and tourism demands require more integrated, forward-looking solutions. Coastal risks—erosion and sea level rise—are considered in the integrated coastal strategy, though updates based on recent climate data and broader adoption of nature-based solutions remain necessary. Urban heat risks, projected to intensify substantially, are only partially covered by PAESC measures, with limited focus so far on public health and urban resilience. Overall, while Emilia-Romagna has established a comprehensive policy framework aligned with many of



Italy – Croatia



the identified climate risks, implementation speed, spatial targeting, and proactive adaptation remain key challenges.

2.2 Marche Region – Province of Pesaro, Parco San Bartolo (protected area)

The Parco Naturale del Monte San Bartolo, a coastal reserve in Italy's Marche region (Figure 3), exemplifies the delicate interplay between ecological richness and climate vulnerability. Projections from the Intergovernmental Panel on Climate Change (IPCC) highlight intensified hazards over the coming decades, with rising temperatures, erratic precipitation and sea-level rise amplifying environmental pressures across Parco San Bartolo.

Anthropogenic global warming is expected to alter atmospheric patterns, leading to changes in weather frequency, intensity, and duration. These shifts pose multiple threats to natural and cultural landscapes, including accelerated soil erosion, destabilized coastal defenses, and biodiversity changes. Heat waves and droughts particularly stress native vegetation like Spanish broom (valued for tourism) and disrupt wildlife migration patterns. Reduced freshwater availability threatens Mediterranean plant species and historic agricultural areas, including centuries-old olive groves and vineyards that now face combined pressures from soil degradation and changing water resources. Coastal erosion from climate extremes risks permanent damage to unique landscapes. These interconnected environmental challenges highlight the critical need for adaptive conservation strategies to protect both ecological systems and cultural heritage sites.

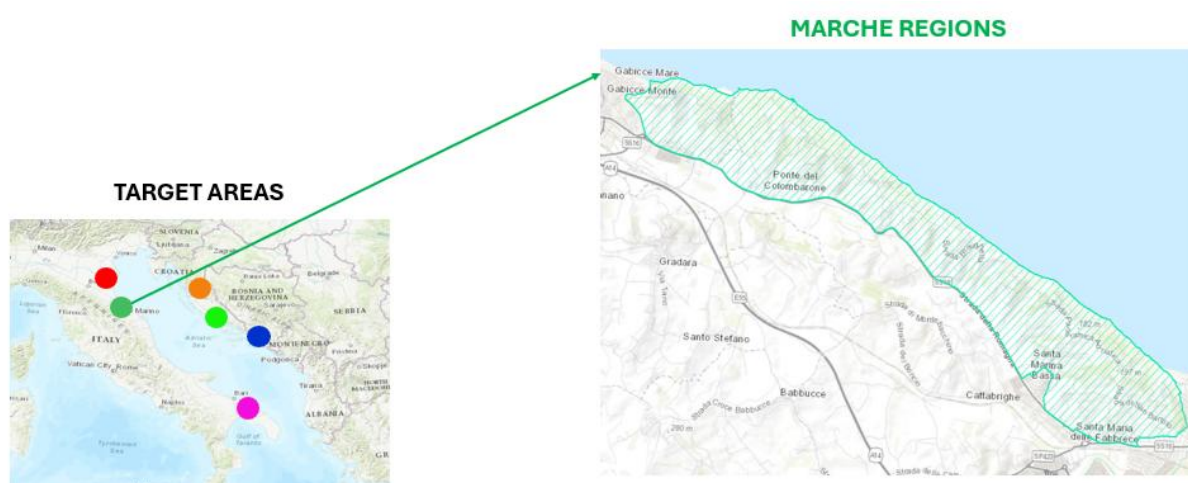


Figure 3: Italian Target area: Marche Region - Province of Pesaro, Parco San Bartolo (protected area).



Italy – Croatia



Given these considerations, comprehensively understanding climate hazard characteristics is essential for developing effective and appropriate adaptation strategies. As detailed in the **document** *“Strategy on scenarios of climate change related effects and risks and impacts on water landscapes”*, climate analyses were conducted using climate indicators to examine both the baseline climate conditions during the reference period (1981-2010) and projected future climate scenarios (2036-2065).

In the reference period the climate analysis of Parco San Bartolo reveals significant spatial variability in climate hazards, with the north-western area consistently showing the most extreme conditions across multiple indicators. Some results can be described as follows, the north-western zone experiences both intense rainfall events (**SDII** up to 8mm, high **R20/R50** values) and prolonged dry periods (high **CDD** values), creating a dual risk of soil erosion during heavy rains and vegetation stress during droughts. This same area shows an elevated number of summer days conditions (**SU** up to 100). Drought indicators (**PET**, **SPI**, **SPEI**) indicate potential water management challenges, particularly affecting native species like Spanish broom and potentially favoring invasive species.

Climate projections for 2036-2065 indicate substantial changes in precipitation and temperature patterns, with varying intensities across different RCP scenarios. In general it is possible to highlight an increase in the intensity of daily precipitation (moving from the RCP2.6 scenario to the RCP8.5 scenario) and an increase of the extreme events linked to extreme temperatures (significant increase in Summer Days indicator). Essentially under RCP8.5 scenario, the park faces compound risks from both intensified precipitation extremes and prolonged heat/drought conditions, requiring comprehensive adaptation strategies for ecosystem protection and visitor safety.

The **Marche Region** has implemented various strategic plans to address climate change and ensure sustainability at both regional and local levels. The **Regional Climate Change Adaptation Plan** outlines actions to strengthen climate resilience through transversal and sector-specific measures, focusing on water resource management, agriculture, ecosystems, and coastal resilience. It emphasizes efficient water use, improved distribution networks, and protection against coastal flooding. The **Regional Strategy for Sustainable Development** aligns with the UN’s 2030 Agenda, focusing on territorial resilience, climate action, equity, biodiversity protection, and sustainable economic development. It promotes water management, reuse, and coastal area preservation. The **Water Protection Plan** (aligning with both national and EU water management directives) addresses water quality, sustainable use, flood risk management, and ecological restoration, encouraging public participation in water resource management. The **Regional Water Supply Plan** ensures a sustainable water supply by optimizing resource use, improving efficiency, and upgrading infrastructure. The **Integrated Coastal Zone Management Plan** focuses on protecting coastal ecosystems, preventing erosion, and ensuring sustainable tourism while



Italy – Croatia

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engaging local communities. It also promotes innovative strategies for climate resilience, balancing natural coastal processes with human activities to prevent shoreline degradation and land loss.

At the local level, the **Municipality of Pesaro** has adopted a **Sustainable Energy and Climate Action Plan** to align with EU climate objectives while strengthening the city's resilience to climate change. The plan pursues multiple goals: reducing greenhouse gas emissions, improving energy efficiency, and expanding the use of renewable energy sources. A key priority is sustainable water management, with measures such as rainwater harvesting systems and water-saving technologies aimed at optimizing water resources and reducing overall consumption. Beyond mitigation, the plan emphasizes adaptation strategies to address climate-related risks including flooding, heatwaves, and hydrogeological instability. Particular attention is given to vulnerable areas such as **Parco San Bartolo**, where targeted interventions aim to protect both ecosystems and local communities. Importantly, the plan fosters community engagement to ensure that residents, businesses, and institutions actively participate in building a climate-resilient city. Despite this comprehensive policy framework, some aspects could be improved (Table 2). Ecosystem-specific adaptation strategies are not yet fully developed for biodiversity hotspots and cultural heritage assets particularly exposed to heat and drought stress. Likewise, drought risk projections are only partially integrated into water management planning, limiting the long-term resilience of water-dependent ecosystems and agriculture. While coastal management policies exist, they should be updated to reflect the most recent climate projections, especially concerning combined risks from sea-level rise, erosion, and storm surges. Overall, while Marche has laid strong policy foundations, implementation and alignment with future climate scenarios remain critical to ensure the protection of both natural ecosystems and cultural landscapes against compound climate risks.

2.3 Puglia Region- Province of Brindisi, Egnazia (archaeological site)

The Egnazia area (Figure 4), located in Puglia between Bari and Brindisi, is characterized by a typical Mediterranean climate with hot, dry summers (temperatures exceeding 30°C) and mild, wet winters (500-600 mm annual precipitation). The Adriatic coastal position benefits from sea breezes that moderate temperatures. Climate change projections indicate significant challenges ahead for the region. Rising temperatures are expected to intensify summer heatwaves, while precipitation patterns will shift toward more concentrated, intense events coupled with prolonged summer drought periods. These changes will create growing water stress that particularly threatens agricultural activities such as olive and grape cultivation, which are fundamental to the local economy. The changing climate conditions will also impact



Italy – Croatia



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Mediterranean biodiversity, as native species adapted to current warm-dry conditions may struggle to adapt to new environmental parameters.

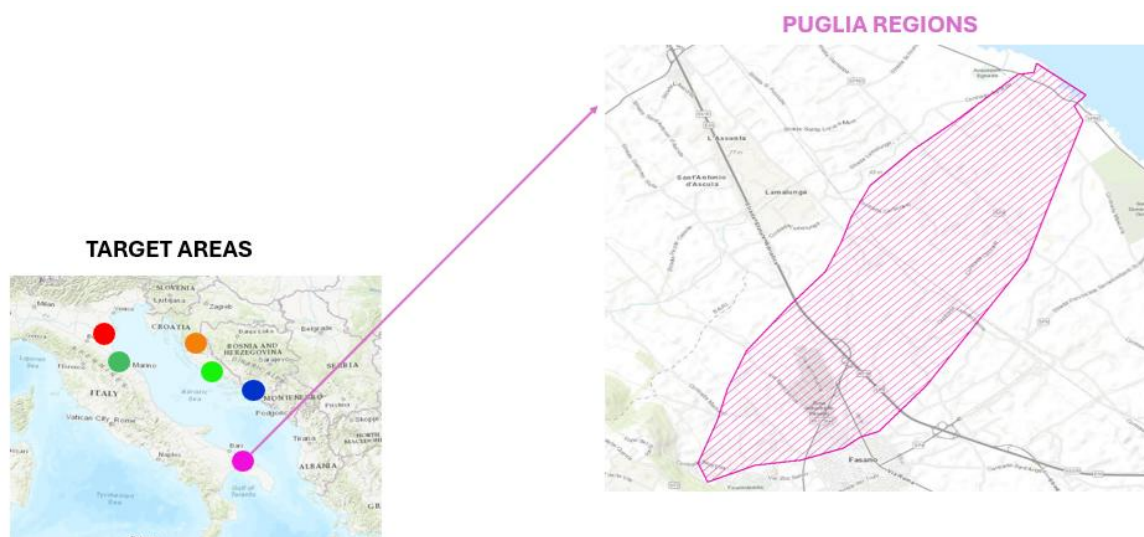


Figure 4: Italian target area: Puglia Region - Province of Brindisi, Egnazia (archaeological site).

In light of these considerations, a thorough understanding of climate hazard characteristics becomes fundamental for formulating effective and targeted adaptation strategies. Climate analyses utilizing specific indicators were therefore conducted to examine baseline climate conditions for the reference period (1981-2010) and to assess projected future climate scenarios (2036-2065), as outlined in document “*Strategy on scenarios of climate change related effects and risks and impacts on water landscapes*”.

On the reference period the analysis reveals significant spatial variations in precipitation patterns, with higher intensity values (up to 6 mm) observed in northern areas through the **SDII** indicator, while extreme precipitation events (**R20**, **R50**) and maximum daily/3-day precipitation (**RX1DAY**, **RX3DAY**) show relatively uniform distribution across the study area. Drought indicators (**SPI** e **SPEI**) consistently demonstrate higher values in the southwestern region, indicating favorable moisture conditions, while Potential Evapotranspiration (PET) peaks in the northeastern area. Temperature-related indicators reveal moderate thermal impacts across the region, with the southwestern area experiencing approximately 11 hot wave days (Maximum daily temperature >35°C) and the **Humidex 5** index showing uniform thermal discomfort effects. The Consecutive Dry Days (**CDD**) indicator suggests limited prolonged drought periods, while Summer Days (**SU**) display consistent warm weather patterns with slightly elevated values in the northeastern zone.



Italy – Croatia

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Future climate projections across RCP scenarios reveal intensifying precipitation patterns. Drought indicators present values increasing, with Consecutive Dry Days (**CDD**) increasing up to 4 additional days under RCP8.5, while both **SPI-12** and **SPEI-12** show positive percentage increases across all scenarios.

Temperature-related indicators show pronounced increases, with thermal discomfort effects intensifying particularly in the central and southern portions of the study area across all emission scenarios.

To address these challenges, **Puglia Region** has developed the **Guidelines for the Drafting of the Regional Strategy for Adaptation to Climate Change (SRACC)**, providing a framework for analyzing the past and present climate of the region. In particular, eight major climate hazards have been identified: floods, landslides, droughts, wildfires, water security, heat waves, and coastal erosion. The assessment, based on IPCC RCP4.5 and RCP8.5 scenarios for 2020–2050, 2045–2075, and 2070–2100, confirms significant temperature and rainfall anomalies, including reduced water availability for civil, urban, and industrial uses. To address water resource management challenges, the study aligns with the National Plan for Adaptation to Climate Change (PNACC) and classifies actions into three types: soft actions (enhancing governance and knowledge), green actions (nature-based solutions for sustainable water use), and grey actions (infrastructure improvements for water efficiency). Additionally, the **Interreg Italy-Croatia RESPONSE** project in the **Brindisi province** has established a climate change monitoring system, integrating adaptation measures into planning, assessing stakeholder perceptions, and developing monitoring tools to evaluate water management strategies.

Despite this multi-level policy architecture, several gaps remain evident. Cultural heritage sites like Egnazia lack tailored adaptation measures that directly address risks from combined heat, drought, and heavy rainfall impacts. Water resource management strategies require stronger coordination across governance levels to integrate the latest climate projections and ensure implementation aligns with long-term drought risk scenarios. Furthermore, measures addressing biodiversity loss under combined temperature and water stress conditions remain insufficient, particularly for ecosystems supporting both cultural landscapes and agricultural productivity. Overall, while Puglia has developed a strong strategic framework, future adaptation planning must focus on site-specific measures for cultural heritage, integrated water management under climate extremes, and ecosystem resilience to ensure effective protection against projected hazards.

2.4 Zadar County – Paklenica National Park (protected area)

The Paklenica National Park area (Figure 5), located in Zadar County along Croatia's Adriatic coast, is characterized by a relevant climatic variability across its elevational gradient. The **Summer days (SU)** are



Italy – Croatia



45-81 days annually, with coastal areas experiencing higher values. The park historically recorded zero **hot wave days (HW)** during 1981-2010, establishing a critical baseline. **Total precipitation (PRCPTOT)** ranges from 891-1263 mm annually, with higher totals in southern and central upland areas benefiting from orographic lifting around Velebit peaks. Lower totals appear in northwestern lowlands and exposed coastal ridges. The **Consecutive Dry Days (CDD)** indicator shows 27-33 consecutive dry days per year, with a clear north-south gradient where northern zones experience shorter dry spells (27-30 days) while southern areas face longer sequences (32-33 days). **Precipitation intensity (SDII)** varies from 5mm in southern parts to 8mm in northern areas, with surrounding zones reaching 10mm. **Potential Evapotranspiration (PET)** ranges from 550mm in higher karst ridges to over 700mm in southern coastal zones, directly correlating with vegetation types and drought vulnerability.

Climate change projections indicate fundamental shifts in the park's thermal regime. Specifically, the **Summer Days (SU)** shows moderate but consistent increases across scenarios: RCP2.6 projects up to 65 days (compared to current 45-81), RCP4.5 reaches 75-85 days in southern sectors, while RCP8.5 approaches or exceeds 90 days in exposed areas. Most significantly, the **Hot Waves days (HW)** transform from zero baseline to 1-3 days under RCP2.6 in southern zones, 2-4 days under RCP4.5 across central areas, and 3-4 days under RCP8.5 throughout the southern half of the park. **Precipitation intensity (SDII)** will increase consistently across scenarios: minimal changes (+1%) under RCP2.6, moderate intensification (+2-3%) under RCP4.5, and relevant shifts (+4-5%) under RCP8.5. This suggests future rainfall will occur less frequently but with greater intensity. **Potential evapotranspiration (PET)** increases uniformly: +6-7% under RCP2.6, +7-8% under RCP4.5, and +9-10% under RCP8.5, indicating growing atmospheric water demand across all park ecosystems. These changes particularly threaten thermally sensitive beech forests above 900m elevation and Dalmatian black pine stands on exposed slopes. The projected climate shifts will fundamentally alter ecosystem functioning, fire risk patterns, and visitor safety conditions within this protected karst landscape.



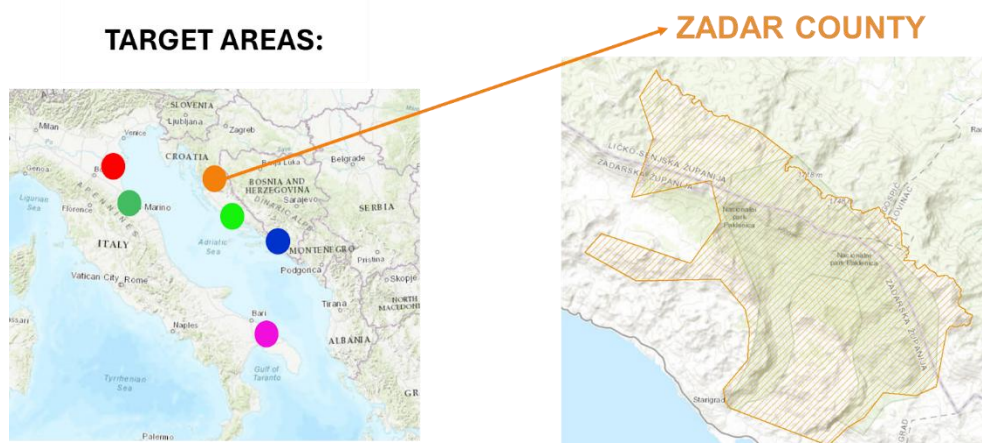


Figure 5: Croatian target area: Zadar County – Paklenica National Park (protected area).

In order to address these challenges there is a comprehensive policy framework that spans multiple governance levels. At the regional level regarding **Zadar County**, the **Sustainable Energy and Climate Action Plan (SECAP)** for Ličko-Senjska County (2022) and the **Program for Climate Change Mitigation, Adaptation, and Ozone Layer Protection in Zadar County** (2023) provide strategic frameworks for addressing climate risks such as extreme precipitation, temperature rise, droughts, and flooding. Key measures include promoting renewable energy, improving energy efficiency, sustainable transport, biodiversity conservation and enhanced flood protection. Implementation relies on collaboration with local governments, EU funding, and continuous monitoring. At the local level, the Implementation Program of the Municipality of Starigrad (2021–2025) focuses on fostering a sustainable economy, strengthening environmental protection, and improving social infrastructure. Measures include investments in renewable energy, biodiversity protection, and flood prevention, with stakeholder engagement and EU funding playing a crucial role. For conservation, the Forest Protection, Care, and Restoration Program for Paklenica National Park (2022–2031) aims to preserve forest ecosystems through sustainable management, pest control, wildfire prevention, and erosion control. Similarly, the Management Plan for Paklenica National Park (2023–2033), developed under the EU-funded Natura 2000 framework, focuses on biodiversity conservation, habitat restoration, and sustainable visitor management. Building on these regional conservation efforts, the Velebit Mountain Biosphere Reserve (BR) Management Plan (2018–2027) provides a broader strategic framework for the sustainable development of this UNESCO-designated area, which encompasses Paklenica National Park. It prioritizes forest ecosystem protection, sustainable land use, and biodiversity preservation through wildfire prevention, habitat restoration, and invasive species control. Additionally, it promotes eco-tourism and sustainable agriculture while emphasizing scientific research, environmental education, and stakeholder



Italy – Croatia



engagement. The plan aligns with the ongoing conservation initiatives in Paklenica and other protected areas, reinforcing regional resilience against climate change. Finally, the Sustainable Energy and Climate Action Plan (SECAP) for the City of Gospić (2024) addresses climate risks such as floods, droughts, and wildfires by promoting renewable energy, sustainable transport, flood defences, and wetland restoration.

Despite this robust policy architecture, some areas remain to be improved. Climate adaptation planning insufficiently integrates wildfire risk projections, despite clear evidence of increasing heat and drought stress. Moreover, water scarcity impacts on sensitive ecosystems and karst habitats are not fully reflected in current adaptation measures, limiting long-term ecological resilience. Finally, while visitor safety and infrastructure protection are acknowledged in management plans, updated climate projections need to be systematically embedded in tourism and disaster risk reduction strategies. Overall, while Zadar County and Paklenica National Park benefit from a comprehensive multi-level policy framework, proactive integration of climate projections into wildfire management, water resource planning, and ecosystem resilience measures remains essential to address future climate extremes effectively.

2.5 Split-Dalmatia County – Historic City of Trogir (UNESCO World Heritage Site)

The Historic City of Trogir (Figure 6), situated in Split-Dalmatia County on Croatia's central Adriatic coast, shows distinct climate patterns. The reference period (1981-2010) shows approximately 100 **Summer Days (SU)** and 47 **Tropical Nights (TR)** annually, with annual potential evapotranspiration around 800mm. Temperature extremes are moderate, with 90th percentile maximum temperatures reaching 22.8°C and minimum temperatures below 7.8°C for about 36 days yearly. The coastal location provides some thermal moderation, though the area experiences approximately 12 frost days annually.

Future climate projections reveal intensifying thermal stress across all scenarios. Summer days are expected to increase by 15-31 additional days depending on location and scenario, with island areas (Drvenik Veli and Mali) showing greater vulnerability than mainland areas. Specifically, Northern Trogir areas project increases of 15 days (RCP2.6), 23 days (RCP4.5), and 26 days (RCP8.5). Island areas (Drvenik Veli and Mali) demonstrate greater vulnerability with increases of 18 days (RCP2.6), 25 days (RCP4.5), and 31 days (RCP8.5). Tropical nights (TR) follow similar patterns with northern areas experiencing increases of 17 days (RCP2.6), 25 days (RCP4.5), and 31 days (RCP8.5), while islands face more severe impacts: 21 days (RCP2.6), 28 days (RCP4.5), and 34 days (RCP8.5). This pattern indicates accelerated nighttime warming, particularly affecting isolated island environments. Hot wave days (**HW**) will emerge where previously absent, with potential evapotranspiration rising 6-12% across scenarios. Drought indicators show increasing frequency across multiple timescales, while precipitation totals are projected to



Italy – Croatia



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decrease. The uniform warming pattern strains energy infrastructure through reduced winter heating needs but dramatically increased summer cooling demands. Tourism-dependent areas face particular challenges from extended hot periods and thermal discomfort. Islands demonstrate heightened vulnerability due to maritime heating effects and isolation from mainland adaptation resources.



Figure 6: Croatian target area: Split-Dalmatia County – Historic City of Trogir (UNESCO World Heritage Site).

The **Split-Dalmatia County** has developed a comprehensive approach to address climate change, aligned with national policies such as Croatia’s Low-Carbon Development Strategy (2021). The **Program for Mitigating Climate Change, Adapting to Climate Change, and Protecting the Ozone Layer of the Split-Dalmatia County (2023)** evaluates vulnerabilities across key sectors including water resources, fisheries, energy, tourism, and biodiversity, identifying major risks such as increasing droughts, extreme weather events, rising temperatures, sea-level rise, and biodiversity loss. The program emphasizes securing funding for mitigation and adaptation measures, raising public awareness, reducing carbon emissions, and promoting renewable energy and energy efficiency. At a more localized level, the Implementation Plan for flood defence, prepared by Croatian Waters, focuses on the southern Adriatic region, including small basins of the central Dalmatian coast and islands. It identifies flood-prone areas such as the Jadro and Žrnovnica Rivers and numerous torrential streams, highlighting risks from urbanization, sedimentation, and insufficient drainage. The plan defines responsibilities for Croatian Waters, Civil Protection, emergency services, and local authorities, outlining measures such as monitoring, early-warning systems, emergency response, river regulation, drainage maintenance, stormwater infrastructure, and improved flood forecasting to enhance resilience. The **city of Trogir** complements these efforts through its Spatial Plan, which integrates sustainable urban development with hydrological adaptation measures. The plan establishes flood risk and coastal buffer zones, enhances urban drainage



Italy – Croatia

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planning with nature-based solutions, and introduces guidelines for embankments, floodwalls, and erosion control, while also addressing emergency preparedness and inter-agency coordination.

The city's 2023 Sustainable Energy and Climate Action Plan (SECAP) further strengthens water resource management and climate resilience. It identifies key vulnerabilities including coastal flooding, sea-level rise, pluvial flooding, water scarcity, and biodiversity loss, emphasizing the impacts of extreme weather, heat, and prolonged droughts. Proposed measures include improved water supply and groundwater protection, implementation of early warning systems and flood zoning, and wetland restoration as a natural flood mitigation strategy. Collectively, these initiatives aim to safeguard biodiversity, enhance urban resilience, and ensure the sustainable development of Trogir.

Despite these efforts, key gaps persist. First, urban planning strategies require systematic integration of climate projections to ensure that infrastructure development, housing, and transport systems remain resilient to future heat extremes and drought conditions. Second, the tourism sector—critical to Trogir's economy—lacks targeted adaptation strategies to cope with extended periods of heat stress, rising cooling demands, and visitor safety concerns. Finally, small island communities remain particularly vulnerable due to geographic isolation and limited access to adaptation resources, necessitating specific policies for water supply security, emergency response capacity, and heatwave preparedness. Overall, while Split-Dalmatia County has made progress in coastal defense and water management, mainstreaming climate projections into urban planning, tourism resilience, and island adaptation strategies remains an urgent priority to safeguard cultural heritage, economic livelihoods, and public health in a warming climate.

2.6 Dubrovnik-Neretva County – Neretva River Delta (protected area, Natura 2000 habitat)

The Neretva River Delta area (Figure 7) in Dubrovnik-Neretva County exhibits typical Mediterranean lowland characteristics with significant thermal loading. **Hot wave days (HW)** are about 10 days annually while **Summer Days (SU)** reach approximately 123 days annually. The reference period shows **maximum daily precipitation (RX1DAY)** reaching 40mm, with **precipitation intensity (SDII)** averaging around 10mm on wet days. **Annual potential evapotranspiration (PET)** averages 850mm, reflecting the warm Mediterranean conditions. The delta's low-lying topography and proximity to both river and sea create distinctive microclimatic conditions.

Climate projections indicate relevant intensification of temperature extremes, with hot wave days (**HW**) increasing from 2-16 additional days and summer days rising by 12-27 days when comparing RCP2.6 to



Italy – Croatia



RCP8.5 scenarios. Precipitation patterns will shift toward greater intensity and variability, though uncertainty in precipitation projections remains high. The Simple Daily Intensity Index (**SDII**) and maximum daily precipitation (**RX1DAY**) show general increases, suggesting more concentrated rainfall events. Drought indicators (**SPI-3**) reveal increasing aridity, with homogeneous variations up to 2% expected across the study area under RCP8.5.

These changes pose particular challenges for the delta's wetland ecosystems, agricultural productivity, and flood management, as the combination of more intense rainfall, prolonged drought periods, and rising temperatures will stress both natural and human systems in this ecologically sensitive coastal region.



Figure 7: Croatian target area: Dubrovnik-Neretva County – Neretva River Delta (protected area, Natura 2000 habitat).

In order to address these challenges, in **Dubrovnik-Neretva County**, which includes the Neretva Delta, there are regional policies such as the Program for Mitigation of Climate Change, Adaptation to Climate Change, and Protection of the Ozone Layer (2023–2026) focus on tackling pressing issues like coastal erosion, rising sea levels, and extreme weather events. Since the Neretva region is an agricultural hub and a fragile ecosystem, special attention is given to monitoring climate-related risks and reducing greenhouse gas emissions while ensuring the sustainable use of natural resources. At the **local level**, adaptation strategies become even more targeted to address site-specific challenges. In the Neretva River Delta, one of Croatia's most ecologically sensitive areas and a designated Natura 2000 protected habitat, the



Italy – Croatia

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Adaptation Plan for Neretva River Delta lays out concrete steps to tackle the region's unique climate threats. Wetland restoration is a priority, as it helps mitigate flooding and supports biodiversity. Additionally, efforts to prevent soil salinization and improve irrigation systems are crucial for maintaining the area's agricultural productivity.

Nevertheless, **several adaptation gaps remain**. While general adaptation and mitigation strategies exist, integrated flood management addressing both riverine and coastal flooding under compound extreme events may need further strengthening. Specific strategies for **extreme heat impacts on human and natural systems could be strengthened**, as current measures do not fully address the direct effects of heatwaves on communities, agriculture, and ecosystems. Additionally, long-term monitoring of precipitation variability and drought impacts on agriculture and wetlands could be enhanced, and more detailed measures linking climate projections to specific land-use planning and water management strategies may be required to ensure resilience in this ecologically sensitive region.

3. Conclusion

The analysis conducted across the Italian and Croatian target areas highlights both the growing vulnerability of water-dependent ecosystems and cultural heritage sites to climate change and the existing policy frameworks aimed at enhancing adaptation and resilience. The comparative assessment reveals several key findings:

1. Increasing climate risks across all target areas:

All regions exhibit clear trends of rising temperatures, more frequent and intense heatwaves, shifts in precipitation patterns, and compounded risks from droughts and flooding. Mediterranean lowlands, deltas, and coastal zones—such as the Po Delta, Neretva River Delta, and Parco San Bartolo—are particularly exposed to extreme hydrological and thermal stresses, while upland and island areas, like Paklenica National Park and the Trogir archipelago, face growing wildfire, drought, and heat stress risks.

2. Policy frameworks are comprehensive but unevenly implemented:

European, national, and regional policies provide a solid foundation for climate adaptation through strategies such as the EU Adaptation Strategy, National Adaptation Plan for Italy (PNACC), Croatian Climate Change Adaptation Strategy, and regional/local plans (e.g., PAESC, SECAP). Measures include



sustainable water management, nature-based solutions, flood prevention, ecosystem restoration, and urban resilience. However, several gaps persist, including limited integration of site-specific climate projections, insufficient attention to compound hazards, and reactive rather than proactive implementation in response to extreme events.

3. Challenges in water resource management:

Across both countries, water scarcity, drought, and increasing precipitation intensity pose significant challenges for agriculture, ecosystem integrity, and cultural heritage protection. While some regions have implemented monitoring systems and integrated adaptation measures, coordination across governance levels and alignment with future climate scenarios remain critical for long-term resilience.

4. Ecosystem and cultural heritage vulnerabilities:

Protected areas, archaeological sites, and UNESCO heritage zones are highly sensitive to climate stressors. Heatwaves, droughts, and coastal erosion threaten both biodiversity and cultural landscapes. Adaptation strategies often lack detailed, ecosystem- and site-specific measures, highlighting the need for tailored interventions that address local environmental, social, and economic conditions.

5. Opportunities for proactive and integrated adaptation:

Effective climate resilience requires forward-looking strategies that combine “soft” measures (governance, planning), “green” measures (ecosystem-based solutions), and “grey” measures (infrastructure and technological interventions). Cross-border coordination, particularly in transboundary hydrological systems like the Neretva Delta, and strengthened alignment between climate projections and policy implementation, will be essential. Enhanced monitoring, stakeholder engagement, and nature-based solutions can further improve adaptive capacity.

Overall, the study underscores that while Italian and Croatian regions have made important strides in developing climate adaptation strategies, substantial work remains to ensure that ecosystems, cultural heritage sites, and local communities are resilient to projected climate extremes. Future efforts must focus on spatially targeted, proactive adaptation that integrates climate projections, addresses compound hazards, and fosters cross-sectoral collaboration to safeguard both environmental and socio-economic systems in these sensitive regions.

