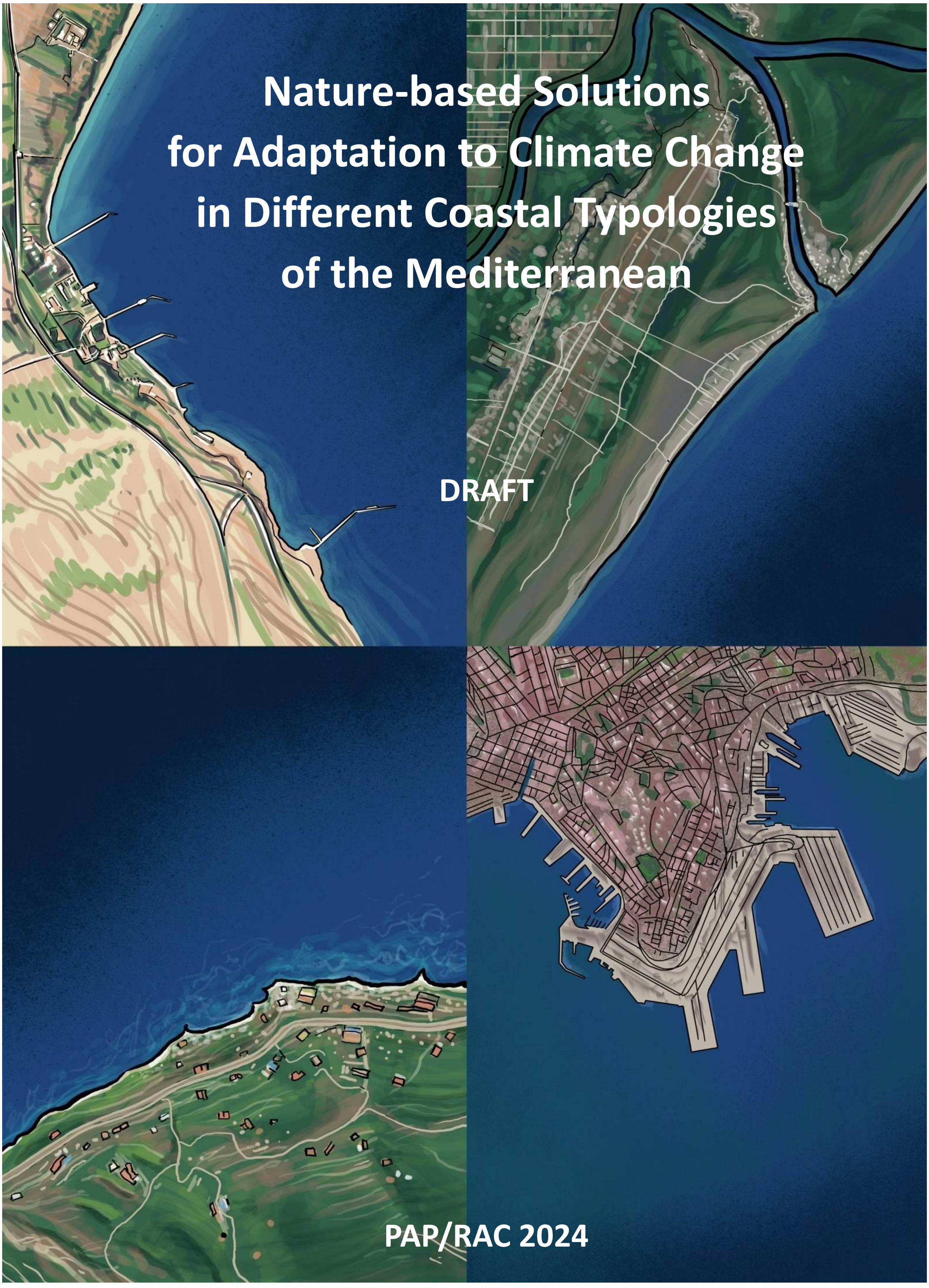
Nature-based Solutions for Adaptation to Climate Change in Different Coastal Typologies of the Mediterranean

DRAFT



PAP/RAC 2024

CONTENTS:

1. NBS FOR THE MEDITERRANEAN COASTS

1.1 THE COASTAL ZONE OF THE MEDITERRANEAN SEA

The Mediterranean Basin stands as one of the world's most esteemed and cherished seas, encompassing an extensive array of coastal and marine ecosystems that bestow valuable benefits upon its coastal communities. These diverse ecosystems include brackish water lagoons, estuaries, coastal plains, wetlands, rocky shores, sea grass meadows, coralligenous communities, frontal systems, upwellings, seamounts, and pelagic systems (UNEP/MAP, 2012). The Mediterranean Sea itself occupies a basin spanning nearly 2.6 million km², with a coastline extending 46,000 km and varying depths, with an average depth of 1500m.

Within the vast Mediterranean drainage basin, spanning over 5 million km², thrives a remarkable biodiversity that ranks among the world's richest. The basin teems with an abundance of flora and fauna, while its habitat diversity is nothing short of extraordinary. Climatically, the Mediterranean experiences warm temperatures, winter-dominated rainfall, dry summers, and a plethora of micro-climates, with temperature variations following a noticeable north-to-south gradient. However, this region, is facing unprecedented challenges and transformations. The coastal zone of the Mediterranean, a mosaic of marine and terrestrial ecosystems often found at ecological boundaries known as ecotones, is experiencing disruptions in its fragile equilibrium. These disruptions, propelled by population growth, changes in land and sea use, pollution, and invasive species, are further exacerbated by the impacts of climate change.

The Mediterranean's unique geopolitical landscape encompasses portions of Europe, southwestern Asia, and northern Africa, resulting in a densely populated and politically intricate region. Today, 21 countries with a collective population exceeding 500 million people border the Mediterranean Sea, each with its own distinct character and coastline (UNEP/MAP and PlanBleu, 2020). Despite growing recognition of the region's ecological importance, Mediterranean ecosystems continue to face threats. Fragmented planning systems and disjointed governance structures have hindered the formulation of cohesive responses to address these challenges. Existing policies and bodies govern various sectors within the Mediterranean, often lacking the holistic and cross-sectoral approaches essential for effective Nature-based Solutions (NbS) delivery (UNEP/MAP, 2012).

The future of the Mediterranean Sea coasts hinges on a complex interplay of environmental, social, and economic factors: in the future, climate change, biodiversity conservation, tourism, water resources, marine pollution, urbanization, cultural heritage preservation, and renewable energy will shape its coastal landscape. The path forward necessitates sustainability, resilience, and a dedication to preserving the region's natural and cultural heritage. International cooperation among the Mediterranean's diverse countries is vital to address shared challenges, while engaging local communities in coastal management and conservation efforts is equally imperative.

Our surroundings offer a multitude of means to protect, restore and regenerate natural systems, enhancing their potential for climate change mitigation and adaptation, biodiversity conservation and enhancement, erosion control, and more. This publication seeks to shed light on these solutions, advocating for a deeper understanding of the current state and the unlocking of nature's potential to address the complex challenges facing the Mediterranean Basin.

1.2 INTRODUCING NbS

The challenges of biodiversity loss and climate change are intricately intertwined. The recognition that these challenges must be addressed jointly, with nature offering solutions to problems arising from climate change, marks a crucial shift in our approach to environmental issues. NbS, as defined by the International Union for Conservation of Nature (IUCN), encompasses **actions aimed at protecting, sustainably managing, and restoring ecosystems in ways that effectively address societal challenges and deliver both human well-being and biodiversity benefits.**

NbS play a vital role in bolstering disaster and climate resilience. These solutions tackle societal problems in ways that benefit both human populations and the natural world. Natural habitats can serve as potent NbS for climate mitigation, whether by sequestering carbon and contributing to Net Zero targets, and by providing adaptation to climate change impacts, such as reducing impacts of flooding, protecting coastlines from sea-level rise, or creating cooler, greener spaces within cities. It's important to note that all habitats, from dense forests to coastal wetlands, can act as NbS, offering a helping hand in addressing the intertwined challenges of climate change and biodiversity loss.

While the definition of NbS is still evolving, this study takes a broad view, treating any nature conservation action as a form of NbS. This perspective is rooted in the recognition that biodiversity loss is a pressing challenge, and conservation actions typically yield multiple benefits. Nonetheless, achieving consensus on the precise definition and scope of NbS remains a work in progress. Effective communication is vital to overcome barriers often encountered in translating scientific research into policy and practice. This entails bridging the gap between academic language and public understanding, simplifying complex tools and models, and highlighting the intrinsic value of nature in economic models. Successful scientific assessments that influence policymaking embrace a multi-disciplinary approach, involve decision-makers and stakeholders, and clearly articulate the implications for human well-being. Effective communication, both direct and through the media, plays an important role in ensuring that scientific insights drive meaningful action.

Strategic and well-executed NbS initiatives yield a multitude of public goods, including valuable biodiversity benefits that can accelerate progress toward conservation targets while enhancing human health and well-being. However, it's crucial to emphasize that any intervention that adversely impacts climate, biodiversity, or local communities, even if beneficial in other aspects, cannot be classified as a true NbS. The scale of NbS implementation required to make a substantial difference demands investment from governments, along with changes in legislative and policy frameworks to encourage private sector participation, along with the intense involvement of civil society.

Albert Einstein's words, "**Look deep into nature, and then you will understand everything better**," resonate in the context of NbS. To replicate successful NbS initiatives and maximize their impact, it is imperative to outline their socio-economic and environmental performances. Local cooperation, partnerships, political commitment, and societal support are essential drivers of this replication process. Moreover, dedicated funding and human resources are critical to ensure the efficient transfer of NbS outcomes to other coastal and marine areas. Networking of NbS projects, facilitated by various stakeholders, further strengthens their integration and utilization across the Mediterranean basin.

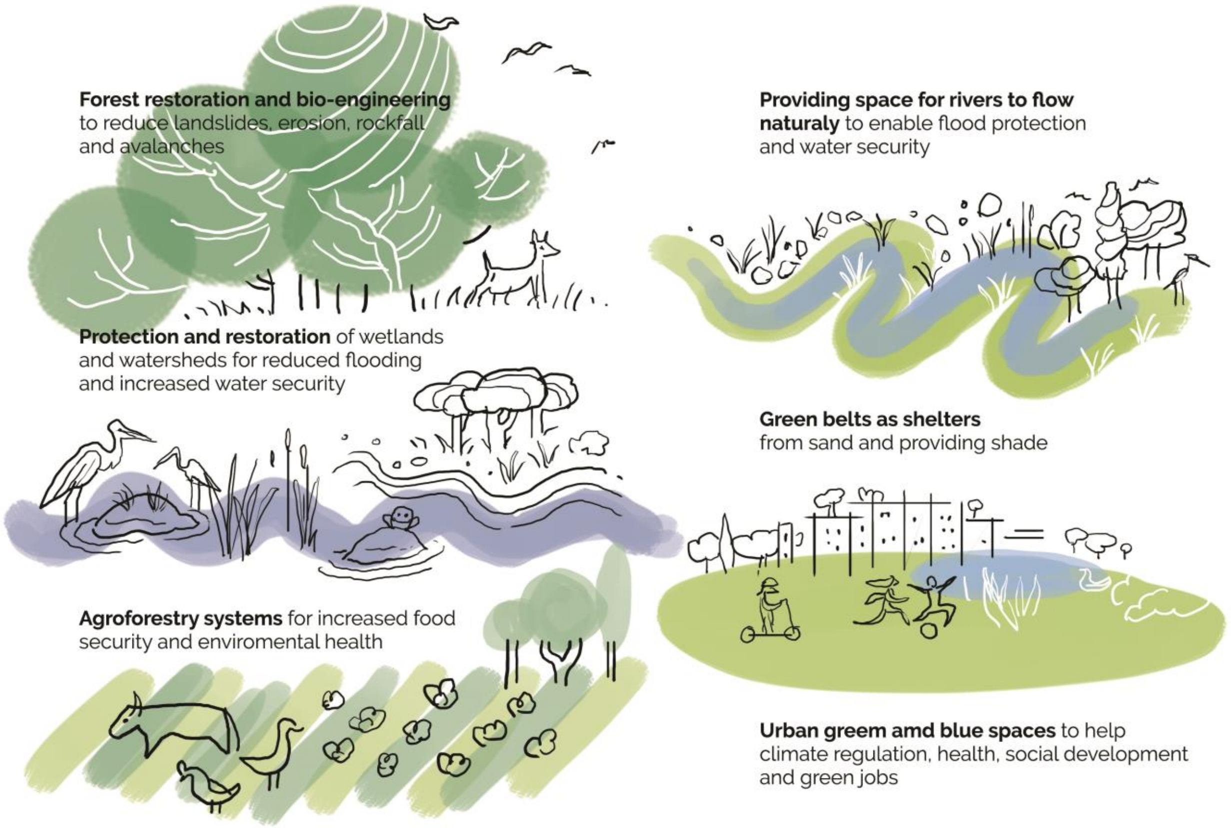


Figure 1: Benefits through NbS for humans and biodiversity

Practical examples of NbS abound, addressing a spectrum of challenges:

- Regenerative agriculture and agroecological approaches enhance food security, health, and sustainable livelihoods;
- Green infrastructure, such as native vegetation along road embankments, controls soil erosion and reduces water run-off;
- Landscape-scale watershed restoration improves regional water quality and availability;
- Urban green spaces and trees mitigate heatwaves, manage stormwater, and reduce pollution;
- Protecting or restoring coastal ecosystems shields communities and infrastructure from storm surges and erosion.

The concept of NbS has a rich history rooted in ecological and environmental sciences, evolving over time to address critical global challenges. The foundations of NbS can be traced back to early conservation movements that recognized the importance of preserving natural ecosystems for their intrinsic value and benefits to humanity. In the late 20th century, the concept of ecosystem services gained prominence. This framework highlighted the tangible benefits that ecosystems provide to humans, such as clean water, pollination, and climate regulation. It underscored the idea that healthy ecosystems are essential for human well-being. The oldest notion on such interconnections was given in 4th century BC, when Theophrastus postulated local climate change as an effect of trees being cleared around Philippi (near Kavala in Greece) causing the waters to dry up and the weather to become warmer.

Organizations like the International Union for Nature Conservation (IUCN) and The Nature Conservancy (TNC) introduced the concept of *ecosystem-based adaptation* (EbA) as a vital element of climate adaptation strategies under the UNFCCC. Ecosystem-Based Management (EbM) emerged as a holistic approach that treats human populations and economic systems as integral parts of ecosystems. It focuses on managing ecosystems to sustain the services they provide, recognizing that healthy ecosystems are essential for human well-being.

The impacts of climate change led to a growing recognition of nature-based approaches for climate adaptation. Natural features such as mangroves and coral reefs gained attention for their role in coastal protection against storms and sea-level rise worldwide. International agreements and conventions, including the Convention on Biological Diversity (CBD) and the UNFCCC, recognized the importance of ecosystems and biodiversity in addressing global challenges. The Aichi Biodiversity Targets and the Paris Agreement both acknowledged the significance of NbS. In 2020, the IUCN released its *Global Standard on NbS*, providing a framework for designing and verifying NbS interventions. This standard aims to guide practitioners in implementing NbS that address societal challenges effectively. In 2021, the United Nations launched the *Decade of Ecosystem Restoration*, emphasizing the role of NbS in restoring degraded ecosystems caused by human actions. This initiative promotes NbS as a key approach to address climate change and enhance biodiversity.

NbS has gained recognition and mainstream acceptance as a powerful approach for climate change mitigation and adaptation, biodiversity conservation, and sustainable development. It has been integrated into policies and planning across various sectors, including urban planning, agriculture, and disaster risk reduction. NbS represents a shift towards more holistic and sustainable approaches, emphasizing the importance of working with nature to create a resilient and harmonious future.

The connection between the Integrated Coastal Zone Management (ICZM) and NbS lies in their shared goal of promoting sustainable development and resilience in coastal zones, and ICZM often utilizes NbS as part of its approach to managing coastal sustainability.

1.3 CLIMATE CHANGE

The latest IPCC report (2023) underscores the profound impact of human-caused climate change on our planet, particularly in vulnerable areas like low-lying coastal regions, river estuaries, drylands, and permafrost areas. According to this report, climate change has also contributed to desertification and exacerbated land degradation. These changes have far-reaching consequences for ecosystems and human livelihoods.

Climate change is exacerbating disaster risks in many regions. There is a growing recognition of the importance of ecosystem-based approaches for disaster risk reduction (Eco-DRR) and climate change adaptation. These approaches leverage natural solutions, such as wetlands and coastal ecosystems, to provide protective buffers, support food and water security, and enhance resilience against disasters. They offer multiple socioeconomic benefits, including carbon storage, biodiversity conservation, and poverty alleviation. Coastal ecosystems, including wetlands and seagrasses, store significant amounts of organic carbon known as ***coastal blue carbon***. This carbon is sequestered and stored over thousands of years in these environments, making them critical in mitigating climate change and preserving biodiversity. In summary, the IPCC report underscores the urgent need for global action to mitigate the impacts of climate change, particularly in vulnerable coastal areas. Ecosystem-based approaches and the preservation of coastal ecosystems play a crucial role in building resilience and mitigating the consequences of a changing climate.

According to the MedECC-Report, the Mediterranean Basin is experiencing climate change at a faster rate than the global average, primarily due to anthropogenic greenhouse gas emissions. Land and sea temperatures in the region are already 1.5°C higher than pre-industrial levels, i.e. **0.4°C more than the global average change.** Future regional average warming will **exceed the global mean value by 20% on an**

Figure 2: Torrential flooding in a coastal zone of a Mediterranean city.

annual basis and 50% in summer. Sea surface temperatures in the Mediterranean are projected to continue rising during the 21st century, with an increase of 1 to 4°C depending on emissions scenarios. This warming trend has implications for marine ecosystems and biodiversity. Rising carbon dioxide (CO_2) concentrations are leading to seawater acidification, which can harm marine life and ecosystems. This negative trend is expected to continue.

The observed trends in land precipitation show variability, with a notable decrease in winter precipitation over central and southern areas since the second half of the 20th century. Models project a consistent decrease in precipitation throughout the 21st century, particularly in the warm season and winter for most of the Mediterranean, except for northern regions. The mean rate of land precipitation decrease is estimated to be 4% per degree of global warming, leading to a reduction of 4 to 22% by the end of the century. Future climate projections also suggest a shift towards higher interannual variability, increased intensity, and greater extremes in precipitation, with longer dry spells, especially in summer and southern areas.

Observations and model projections indicate a trend towards drier conditions over the Mediterranean Basin, particularly in the warm season and in southern areas. Net fresh water loss across the Mediterranean

Sea has increased since the last decades of the 20th century, primarily due to a rise in evaporation caused by local warming. This trend is expected to continue in the future, driven by a decrease in precipitation and river runoff and an increase in evaporation. In the 20th century, there has been a significant reduction in the area and volume of glaciers across high mountains in the Mediterranean. Deglaciation has accelerated in recent decades, and glaciers in the region are projected to continue losing mass throughout the 21st century, eventually leading to the disappearance of most mountain glaciers by the end of the century.

1.4 SUSTAINABLE DEVELOPMENT GOALS AND NBS

The integration of Nature-Based Solutions (NBS) into coastal management aligns with Sustainable Development Goals (SDGs), particularly those focusing on climate action, biodiversity conservation, and resilient infrastructure, to promote sustainable development along the Mediterranean coasts while enhancing ecosystem services and community resilience. Implementing NBS in Mediterranean coastal regions contributes to achieving SDGs by fostering biodiversity conservation, enhancing coastal resilience to climate change impacts, and promoting sustainable livelihoods for coastal communities.

Figure 3: SDGs and NbS in the mediterranean coastal zone.

2. COASTAL TYPOLOGY

The Mediterranean region has been inhabited continuously for the last 3000 years and, in particular, its coast have been the area which has received the most pressures due to defence from storm surges and population settlement history. In the last 500 years, most of the hinterland has been heavily transformed at water catchment level and hence it is significantly rare to find pristine land. High mountains and/or deserts around the Sea are the only territories that remain unoccupied, while some of today's semi-arid areas were once fertile valleys that thrived with human activities.

All of the above implies that coastal processes, both on land and in the nearshore are significantly transformed from their natural physiography and ecosystem functions. The 20th century, in particular, has witnessed an increase in human intervention to the extent that most coastal typologies can be classified, *senso stricto*, as Coupled Human-Natural Coastal Systems (CHANS).

On the other hand, within the context of the Barcelona Convention, the Protocol on Integrated Coastal Zone Management (ICZM) acknowledges the importance of safeguarding four distinct coastal ecosystems: wetlands and estuaries, marine habitats, coastal forests and woodlands, as well as dunes. It's crucial to note that the entire coastal zone functions as a vast transitional area:

Ecotones, as transitional zones between terrestrial and marine ecosystems, are critical for biodiversity and ecosystem health in coastal areas. These ecologically significant areas offer several key functions and benefits: they provide a wide range of habitats and microenvironments, making them hotspots of biodiversity. These transition zones allow for the coexistence of species from different ecosystems, contributing to overall species diversity. Many species, especially those with complex life cycles, rely on ecotones as migration corridors. These areas facilitate the movement of species between terrestrial and marine environments, supporting their life cycles and genetic diversity. Estuaries and coastal lagoons, serve as critical nursery habitats for numerous marine species, including commercially valuable fish and shellfish. These areas offer shelter, food, and suitable conditions for the early stages of marine organisms.

Already perceptible effects of climate change indicate that preparedness of coastal lands and waters to intensified weather phenomena will become a fundamental issue. Coastal flooding and erosion of low lying soft shores will be accelerated or defied to different degrees if the natural functioning of the ecosystems and its resources can exercise their high natural resilience. The opposite will be true of stressed environments where artificialisation had led to total disruptions of natural resources flow. In these latter scenarios, the system will be facilitated by human intervention on natural resources at a higher economic and environmental cost. It is thus of great interest to classify the coastal typology facing this situation to best stablish which NbS may be more suitable. Not all artificialisation of coastal stretches is complete and various typologies can be recognised in areas where land use corresponds to human needs and have been adapted from natural to human to some degree.

Fig. 3: Typology of the man-influenced mediterranean Coasts: A) Low density urbanised coast, **B)** moderately artificial coast, **C)** entirely artificial coasts and **D)**transitional coasts .

Understanding and managing coastal dynamics involves recognizing the biological-physical interactions that underpin coastal processes. These interactions include biostabilization versus biodestabilization, greenhouse gas regulation, root biostabilization, sediment deposition, moisture regulation, biogeochemical regulation, bed roughness, ocean chemistry regulation, canopy shading, and wave/current attenuation.

2.1. ENTIRELY ARTIFICIAL COASTS

Entirely artificial coasts are characterized by **intensive human intervention**, where natural coastal land and water resources are replaced or heavily managed for human purposes. This intervention often involves the creation of major harbour and port facilities, industrial zones, or energy infrastructure. These coasts rely on engineered resilience and require continuous maintenance to sustain their functionality. However, they face challenges such as environmental degradation, dependency on human systems, and limited effectiveness of NbS due to their extensive artificialization.

2.2. MODERATELY ARTIFICIAL COASTS

This type of coasts experiences **frequent human intervention** but to a lesser extent compared to entirely artificial coasts. These areas are often associated with tourism development and urbanization for tertiary purposes. While human activities such as water and shoreline management are prevalent, there is still a degree of natural resilience present. However, these coasts face challenges such as the need for continuous maintenance and potential negative impacts from industrial activities.

2.3. LOW-DENSITY URBANISED COASTS

Low-density urbanized coasts experience urbanization at a lower density compared to heavily urbanized areas. While urban sprawl poses a threat to natural ecosystems, low-density urban development can provide opportunities for promoting ecological corridors. Despite the challenges, there is potential for implementing NbS, especially in areas where urban sprawl is integrated with forests, or where planning practices allow for the preservation of natural features.

2.4. TRANSITIONAL COASTS

Transitional coasts reflect the interaction between natural coastal dynamics and human influences, including **both natural and artificial** stressors such as natural hazards or technological impacts. These areas are often managed as CHANS, presenting opportunities to apply NbS as part of the process of coastal recovery.

In the context of Coupled Human-Natural Coastal Systems coastal typology, each coastal type may encompass **fragments of specific coastal ecosystems**, highlighting the intricate interplay between human activities and the natural environment within diverse coastal landscapes.

3. SPECIFIC COASTAL ECOSYSTEMS

3.1 WETLANDS AND ESTUARIES

Mediterranean wetlands are a unique subset of global wetlands, characterized by a blend of European, African, and Asian influences. Located in a biodiversity hotspot, these wetlands experience seasonal variations with typically mild, wet winters and hot, dry summers. This climatic cycle, combined with their strategic position at the crossroads of migratory bird routes, makes wetlands crucial habitats for various flora and fauna (Sarà et al., 2023). Nearly 50% of coastal wetlands have been lost over the last century due to a combination of factors, including human pressures, sea-level rise, warming, and extreme climate events. Coastal wetlands are vital for biodiversity and act as buffers against coastal erosion and flooding.

They are home to many endemic species adapted to its unique conditions, plant communities, adapted to the region's salinity and water fluctuations, not only support wildlife but also help stabilize the soil and regulate the microclimate (Taylor et al., 2021). Beyond their ecological value, wetlands have significant economic and social implications. Acting as natural water purifiers, they save billions in water treatment costs annually. Their fertile grounds support agriculture, while the diverse fish species they host provide sustenance and livelihoods to millions, underpinning local and national economies. Wetlands also hold cultural and spiritual importance in many societies, playing roles in local myths, traditions, and ceremonies (Verschuuren, 2018). Furthermore, they offer recreation opportunities, fostering ecotourism and outdoor activities like birdwatching and fishing.

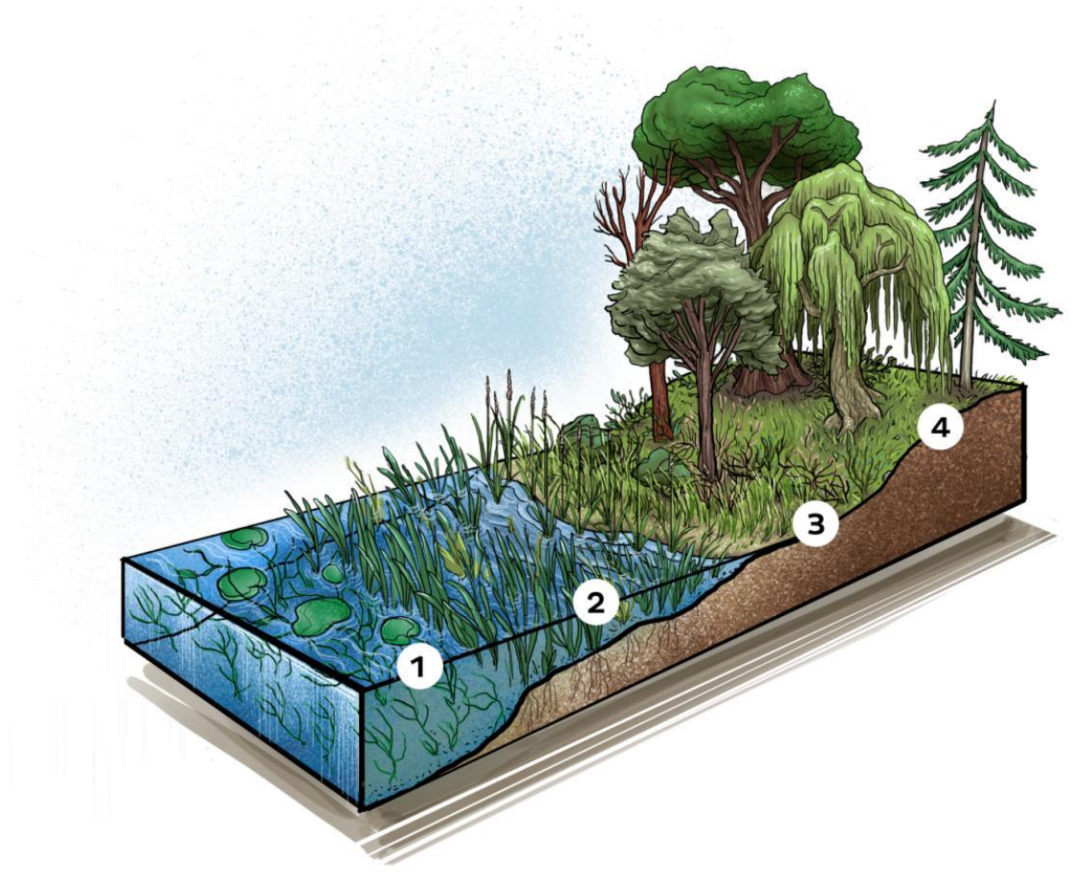


Figure 4: Zonation of a Wetland: 1) Intertidal, **2)** subtidal, **3)** saltmarsh and **4)** forested zones.

Despite their immense value, wetlands face multifaceted threats. Urbanization and the conversion of wetland areas for agriculture or infrastructure diminish their spatial expanse. Pollution, stemming from both point and non-point sources, degrades water quality, affecting both flora and fauna. Altered water regimes, whether from dam construction or water extraction, disrupt their natural functioning. Climate change, with its multifarious impacts, further compounds these threats. Sea-level rise, altered precipitation patterns, and increasing temperatures can irreversibly modify wetland ecosystems. Their degradation not only results in biodiversity loss but can also exacerbate climate change due to the release of stored carbon. While the Mediterranean basin occupies only 1.6% of the world's land surface, it has witnessed approximately 50% of wetland loss (Geijzendorffer, 2019). Unsustainable water extraction for agriculture, urbanization, and tourism development are key culprits. Climate change further exacerbates these threats, with rising temperatures leading to increased evaporation rates and altered precipitation patterns, impacting the hydrology and integrity of wetlands.

Wetlands are indeed powerhouses of ecosystem services. As highlighted by Mitsch (2015) wetlands are defined as kidneys of the landscape and are also called nature’s supermarkets because of the major roles they play in the landscape by providing unique ecosystem services.

3.1.1. SALTMARSHES

Saltmarshes are coastal ecosystems situated in the upper intertidal zone, characterized by the prevalence of halophytic vegetation, primarily consisting of salt-tolerant grasses and herbs. These unique environments play a crucial role in supporting various forms of wildlife and ecological processes. In the Mediterranean coastal zone, saltmarshes are particularly significant due to their biodiversity and ecological functions. They serve as important habitats for numerous species of birds, fish, and invertebrates, providing nesting sites, feeding grounds, and refuge areas. Additionally, saltmarshes contribute to coastal protection by buffering against erosion and attenuating wave energy. Their ability to trap sediments and nutrients also helps improve water quality and promote the productivity of adjacent marine ecosystems.

Saltmarshes are characterized as nearly horizontal platforms distinguished by a predominantly continuous cover of salt-tolerant vascular plants, including grasses, rushes, and shrubs. In the lower transition zones adjacent to mudflats, annual species may dominate the marsh canopy, while the upper terrestrial saltmarsh areas are typically dominated by perennial species. Adjacent tidal flats often support invertebrates with highly specialized adaptations, while the richness of invertebrate species on vegetated saltmarshes varies significantly and is sensitive to localized conditions. These ecosystems serve as crucial habitats for a diverse range of species, including breeding, feeding, and roosting birds—many of which are migratory—as well as fish and aquatic/marine invertebrates (Hudson, 2023).

3.1.2 COASTAL FRESHWATER PONDS

Coastal temporary ponds, also known as Mediterranean vernal pools or ephemeral pools, stand out as fascinating and ecologically significant environments. These seasonally flooded, shallow depressions undergo a cyclic transformation, filling with water during the wet season and often drying out completely during the dry season.

Mediterranean coastal temporary ponds are characterized by their dynamic nature, defined by the Ramsar Convention (2002) as small, shallow water bodies covering less than 10 hectares. They are isolated from permanent water sources, which makes them unique and ecologically intriguing. These ponds are highly sensitive to seasonal changes, responding to the rhythm of nature's cycles.

The defining feature of these ponds is their cyclic behaviour. During the wet season, typically in autumn and winter, rainfall and runoff from surrounding areas fill these depressions with water. The depth and extent of flooding can vary widely, but even in their fullest state, these ponds are relatively shallow. However, as the dry season approaches, the water gradually recedes, and many of these ponds may dry out completely, leaving behind only a memory of their watery existence. Despite their temporary nature, Mediterranean coastal ponds are biodiversity hotspots. These unique ecosystems support a rich array of plant and animal species specially adapted to the ponds' ever-changing conditions.

One of the most notable inhabitants of these ponds are amphibians, particularly frogs and toads. Many amphibian species rely on temporary ponds for breeding. The ephemeral nature of these ponds offers a predator-free environment for amphibian larvae, allowing them to develop without the constant threat of fish predation. For migratory birds traveling between Europe and Africa, Mediterranean coastal temporary ponds serve as essential stopover points. These ponds provide vital resources for birds, offering a source of food and rest during their long journeys. The combination of aquatic insects, small crustaceans, and aquatic plants makes these ponds attractive to a wide range of bird species.

While Mediterranean coastal temporary ponds are invaluable in terms of biodiversity and ecological functions, they face several conservation challenges: One of the primary threats to these ecosystems is habitat loss due to urbanization, agriculture, and infrastructure development. As human activities encroach on these areas, the ponds are drained or filled, disrupting their natural cycles. Invasive plant species, often introduced accidentally or intentionally, can out-compete native plants and disrupt the delicate balance of these ecosystems. Invasive animals, such as predatory fish, can decimate amphibian populations. Pollution from agricultural runoff and other sources can negatively impact water quality in these ponds, affecting both aquatic life and the plants that depend on clean water.

3.2 COASTAL MARINE HABITATS

Despite Mediterranean Sea is only covering 0.82% of the world’s ocean surface, it contributes to an estimated 4-18% of the world´s known marine species (SOED, 2020). Among the diverse ecosystems that thrive in the sea, *Posidonia oceanica*, stands as a vital keeper of the region's ecological health. This flowering plant species endemic to Mediterranean, often referred to as Neptune grass, reigns as the Mediterranean Sea's dominant seagrass.

These meadows, though covering a fraction of the Mediterranean's vast expanse, have achieved something remarkable — they have stored an estimated 11-42% of total CO_2 emissions from Mediterranean countries since the Industrial Revolution. Globally, seagrass meadows are responsible for more than 10 % of carbon buried in the ocean, even though they occupy just 0.2 % of the world's seafloor (Fourqurean et al., 2012). According to some estimations, seagrasses capture carbon up to 35 times faster than tropical rainforests (*www.wwf.org.uk*). This exceptional **carbon sequestration capability** positions *Posidonia oceanica* as a critical player in the fight against climate change.

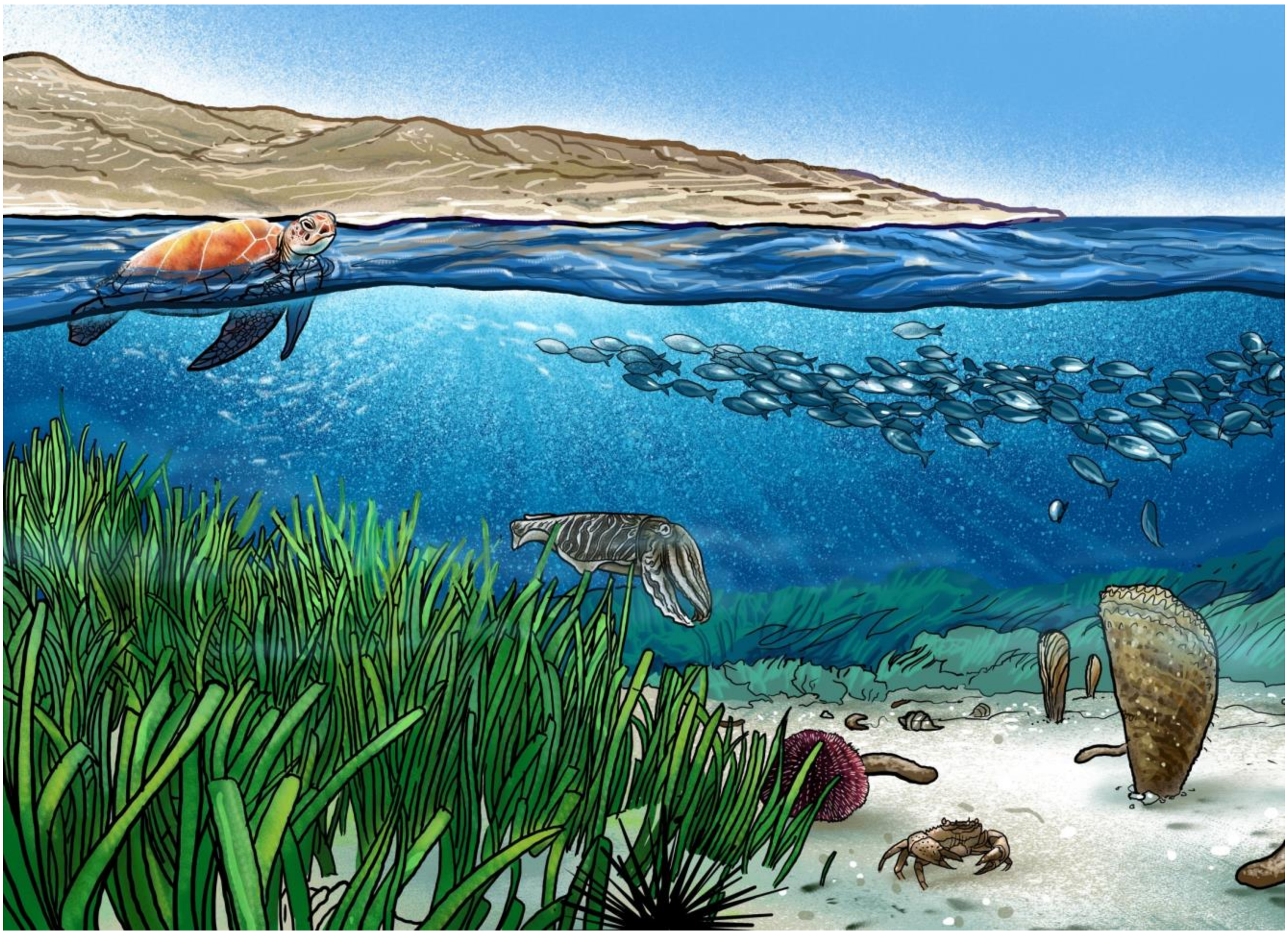


Figure 5: Benthic environment with Neptune grass meadows.

Beyond carbon dioxide, *Posidonia* meadows contribute significantly to sequestering particulate inorganic carbon in the form of calcium carbonate ($CaCO_3$). This carbon pool, originating from shells of organisms within the meadows and external sources, accumulates in the sediment. $CaCO_3$ burial isn't just an intriguing geological process; it also bolsters the role of *blue carbon* ecosystems in climate change adaptation. Beyond carbon dioxide, *Posidonia* meadows contribute significantly to sequestering particulate inorganic carbon in the form of calcium carbonate ($CaCO_3$). This carbon pool, originating from shells of organisms within the meadows and external sources, accumulates in the sediment.

These meadows rapidly accrete sediments, elevate seabeds, and thus mitigate the impacts of sea-level rise — a proof to their multifaceted ecological services. The preservation and restoration of blue carbon sinks offer an array of ecological and human co-benefits. These ecosystems serve as natural barriers against coastal storms, aiding in sediment stabilization and guarding against erosion intensified by rising sea levels. They also contribute to nitrogen fixation and oxygen production, supporting marine life and promoting recreational opportunities like underwater tourism. Additionally, they serve as crucial spawning and breeding grounds for marine species, providing habitat for approximately 20% of Mediterranean marine life.

Despite their resilience, *Posidonia* meadows face threats, with eutrophication topping the list. Eutrophication, characterized by an excessive influx of nutrients into aquatic ecosystems, leads to rapid phytoplankton growth. Algal blooms, an indication of eutrophication, disrupt the balance of marine ecosystems, affecting biodiversity. Fast-growing algal species outcompete slow-growing plants, depriving fish of cover, food, and substrate for invertebrates. Human activities exacerbate this natural process, highlighting the need for proactive conservation efforts. The benthic ecosystems of the world's oceans are under constant threat due to human activities, climate change, and pollution. Despite all these protection initiatives, a recent analysis of area coverage indicates a 34% decline in distribution area or degradation in the past 50 years in the Mediterranean Sea (Telesca et al. 2015).

Protecting benthic ecosystems like *Posidonia oceanica* transcends national and corporate boundaries. It requires a global effort to mitigate climate change, reduce nutrient pollution, and prioritize ecosystem preservation. Seagrasses also slow down the movement of ocean currents between the seabed and the tips of their leaves. Some recent studies have indicated that wave heights were 10-20 % lower in dense seagrass meadows, compared to a bare seafloor (*www.phys.org*).

3.3 COASTAL FORESTS AND WOODLANDS

Mediterranean coastal forests and woodlands are represented by the woody vegetation behind the sand-dunes and cliffs along the coast and they also characterize the sea-close part of thermo-Mediterranean forest vegetation zone. They form the transition from dune to inland zonal vegetation. Compared to the inland forests, they are open to storms and salt spray from the Mediterranean Sea. Their distributional zone is the areas where Mediterranean climate is felt most intensely, and summer drought is too intensive. These are the regions where the bedrock is often up to the surface, the soil is generally of shallow depth or poor in nutrients. All these factors together cause the constitution of extreme site conditions for forest occurrence and sustainability.

Mediterranean coasts have been intensively subjected to settlements and agriculture at early ages and not only agriculture but also heavy urbanization and tourism for the last decades, which causes a shrink in total coverage of coastal forests and woodlands, break in their structural characteristics, regression in physiognomy or conversion to other vegetation types. Many big cities in the Mediterranean are located by the sea and continue to grow especially in tourism, which can pose a risk for the future of coastal forests and woodlands. The decrease in total coverage, overgrazing, wood used as a fuel, and fires are the main reasons for structural degradation and regression. The changes in fire regime related to climate change increase the risk more on coastal forests and woodlands. Forest fires appearing more frequently and with much greater severity negatively affect the post-fire regeneration strategies of ecosystems causing the regression in vegetation composition and structure like the regression of pine forests to macchia and from macchia to gariques, phryganas and more dramatically to grasslands.

Figure 5: Akamas forest on Cyprus. Protected area in the rank of a national park, spanning across 230 square kilometers, boasting valleys, gorges, and wide sandy bays.

Floristically, they resemble the inner or higher elevated zonal forest vegetation of thermo-mediterranean belt (Kavgacı et al 2021), with different structural and growth characteristics. In addition to the extreme climatic, soil and bedrock characteristics, the special impact of sea sided wind may result in wind shaped form of forests and woodlands, but with heterogeneity in stand canopy and decrease in height and diameter growth. All these factors cause them to have a special place in terms of biodiversity within the landscape integrity.

These forests and woodlands are mainly dominated by pines and sclerophyllous species. The characteristic pine species of Mediterranean basin: Aleppo pine, Turkish red pine, stone pine and maritime pine are the essential coniferous species of this vegetation. While the western Mediterranean coastal pine forests are mainly represented by Aleppo pine and maritime pine, Turkish red pine appears at eastern Mediterranean basin. Although stone pine occurs at very large geography in Mediterranean, it shows local and narrow distributions including artificial plantings. Coastal forests and woodlands are mostly characterized by a dense shrub layer formed by sclerophyllous species. The high abundance and coverage of geophyte species increases the biodiversity value of these ecosystems. Sclerophyllous species dominated forests are also important element of Mediterranean forests and woodlands (Chytrý et al., 2022). Common olive, carob tree, strawberry tree, Greek strawberry tree, lentisk, mock privet and oak species like kermes oak, holm oak, ballota oak and cork oak are some of the dominant species of these forests. They geographically show different floristic composition resulted in high diversity of vegetation types. The appearance of endemic woody species dominated coastal sclerophyllous forests and woodlands like the boz pırnal oak ones at eastern Mediterranean makes (SW Türkiye and East Aegean Islands) an essential contribution to the biological richness of these forests.

It is possible to assess the high scrubs like maccia and low ones – garrique and phrygana located in the same distribution zone of Mediterranean coastal forests and woodlands in an integrated approach with the forests. Most of machia, gariques and phryganas were formed as a result of the degradation of pine and sclerophyllous forests in Mediterranean except the ones on less productive and xeric sites.

In addition to these zonal vegetation types, riparian woodlands dominated by species such as tamarix and oleander add a special value to the diversity of coastal forests and woodlands. Deciduous riparian forests dominated by species such as elm, alder and sweetgum increase the value of Mediterranean coastal forest diversity and reveal the importance of these forests in terms of nature conservation. Due to the reduced presence of palm species like Cretan date palm, a European endemic palm tree, coastal forests and woodlands are even more valuable and important for preservation.

Local and regional variations in floristic composition and structural characteristics cause coastal forests and woodland to have a high biological diversity especially within beta and gamma diversities and functional diversity. However, the presence of many local – regional endemic and rare species in the flora shows how sensitive this diversity is. In addition to their richness in terms of non-wood forest products due to many aromatic, medicinal and edible plants, they have important functions in supporting traditional land use with a controlled grazing and contributing to the local and regional economy.

Mediterranean coastal forests and woodlands protect the settlements and inland ecosystems from flooding and erosion by stabilizing the soil. They also create cooler climatic conditions for cities and carry out crucial functions in avoiding the polluting effects of floods and overflow to seas, reducing silt transport to lagoons and streams, and mitigating destructive effects on settlements.

3.4 COASTAL DUNES

Coastal dunes are aeolian formations formed by sand existing on coastlines as part of the ecosystems that constitute the spatial transition between continental/terrestrial and marine/aqueous environments. They occur where a sufficient amount of sand-sized material accumulates and circulates in a sedimentary cycle. It is dragged by the sea waves and deposited in the beach, then it is carried inland by coastal winds to form the dunes. In this dynamic sedimentary system, the beach is a severely disturbed habitat as it is submitted to the surfing dynamic, with the episodic inundation of waves with its energetic mechanical action and the high salinity of the seawater. The dunes, which lay along the coastal front, receive the sand from the beaches and are shaped by the wind. Its disturbance regime is lower: substrate mobility and wind intensity are variable, as well as salinity, which depends on the input of sea water droplets brought by the wind. Coastal dunes are present along all the world's coastlines, giving rise to a wide range of shapes and dimensions related to spatial and temporal variations in sediment input, wave energy and wind regimes.

Coastal dunes are ecosystems with a diverse and very specific flora, which is sorted into particular plant communities. They constitute an important element for biodiversity in the regions where they occur, basically in terms of beta and gamma. In particular, the Mediterranean coastal dune systems host a richer and more diverse flora and habitats in comparison to other areas of the world (Doing 1985). Coastal dune ecosystems are diversified into several typically arranged distinct zones along the shoreline–inland gradient, which are occupied by their particular plant communities (see figure). This gradient is determined by a number of abiotic factors such as wind, waves, tides, soil salinity, and sand grain size. That gradient determines that the zones have a typical dune morphology and are occupied by different plant communities, each of them having their particular structure, species composition and dynamics. These zones include the embryonic dunes, foredunes (shifting or white dunes), semi-fixed dunes and fixed dunes (stable or grey dunes) and palaeodunes. The embryonic and foredunes are more dynamic due to the stronger and more constant coastal winds and higher incidence of sea-water droplets; even they suffer occasional inundation by sea storms. Beyond the foredunes, sand becomes more stable, salinity decreases and ecological conditions are more benign, in a transition towards the normal inland conditions (Marcenò et al., 2018).

In addition to their biodiversity content, dune habitats provide other important ecosystem services, among which recreation stands out. Among these services, its ability to fix the sand stands out, since it subtracts part of it from its cycle of movement from the beach inland and stores it in the dune, cushioning its entry into the interior and protecting the habitats and species inland.

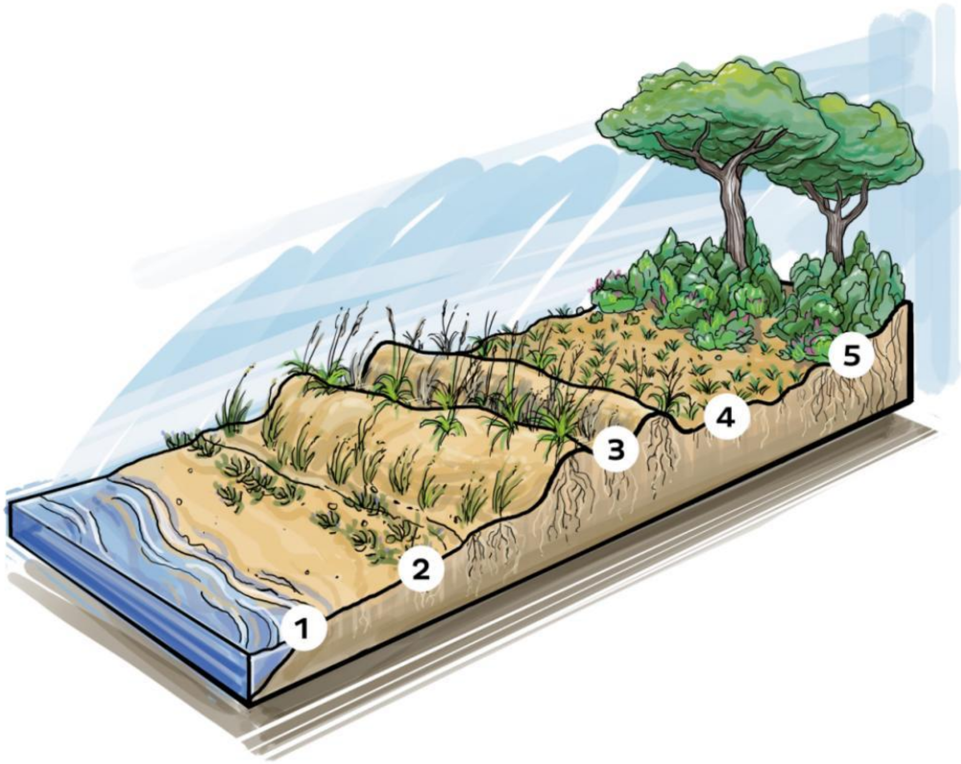


Figure 6: Idealized zonation of a Mediterranean coastal dune system:

1) Beach **2)** Foredune **3)** Crest dune **4)** Semifixed grey dune **5)** Fixed dunes and paleo-dunes

The coastal dunes have been profoundly altered by human activities. In many cases they have been completely and irreversibly degraded, as is the case of housing, infrastructure construction, etc., which entails the disappearance of irreplaceable ecosystems. Other widespread uses are those related to recreation, especially intense in the Mediterranean area and linked to tourist activity, more controllable, but which are also contributing to the disturbance of the coastal dune ecosystems. Important source of degradation of the Mediterranean dune ecosystem is also the invasion of exotic species, which alter the composition of plant communities, degrading the natural conditions of biodiversity (Giulio et al. 2020). Additionally, there are other threats of more global scope, for instance, those derived from climate change, entailing the sea-level rise, the higher incidence of extreme weather events, etc.

Conservation of coastal dunes is vital for multiple reasons, encompassing ecological equilibrium and storm protection. Serving as a primary natural barrier against storms and tides, coastal dunes play a pivotal role in shielding inhabited areas and coastal infrastructure from flooding and erosion. Recognized as an efficient mitigation strategy against the repercussions of climate change and rising sea levels, coastal dunes serve as an indispensable asset for coastal resilience and adaptation efforts (Massarelli, 2023)

3.5 COASTAL CLIFFS

Coastal cliffs, both sea cliffs (maritime cliffs) and inland cliffs, are distinctive geological features that play a crucial role in the biodiversity and ecology of coastal regions. While sea cliffs and inland cliffs may appear similar on the surface, they have unique characteristics related to their formation, plant and animal species, and ecological dynamics. Sea cliffs are primarily formed by the erosive action of water and waves. In contrast, inland cliffs result from the weathering of geological strata with varying hardness. Sea cliffs are more influenced by wave action, while inland cliffs depend on geological processes for their formation.

The ecological communities on sea cliffs are shaped by two key factors: salinity and rapid erosion due to wave action. These factors influence the types of plant and animal species that can thrive on sea cliffs. Inland cliffs, on the other hand, have distinct ecosystems adapted to their geological characteristics. Maritime plants on sea cliffs may be sensitive to cold temperatures, particularly during the seedling stage. This sensitivity limits their expansion to inland cliffs where temperature extremes are more pronounced. Plants adapted to sea cliffs may have lower competitive abilities compared to those adapted to inland cliffs. This competition factor contributes to the separation of species between these two types of cliffs (Bird, 2016)

Coastal cliffs, due to their partial inaccessibility, are among the least disturbed habitats globally, both on land and at the sea-shore. Their unique ecological conditions support a diverse range of plant and animal species, and they are invaluable habitats for biodiversity and ecosystem health. Cliffs serve as refuges from unfavourable climate changes, competition with aggressive ground-level vegetation, and grazing pressure. This preservation of habitat is critical for species survival. High rates of endemism are observed in cliff communities. Local extinctions and slow reinvasion rates, combined with cliff-specific adaptations, contribute to this endemism. The topography of cliffs creates microclimates that are more favourable for plant life than other stony habitats. Crevices accumulate soil and water, and the steep slopes reduce radiation input, minimizing evaporation.

Many sea cliffs worldwide support sea bird colonies. These cliffs offer proximity to the sea for food supply, updrafts for take-off and landing, and reduced pressure from predation. Coastal cliffs harbour a wide range of life forms, including mosses, lichens, algae, and various higher plants, both halophytic (salt-loving) and non-halophytic. Sea cliffs support salt-tolerant plant species typically found in saltmarsh habitats. These species are adapted to the saline conditions and thrive in the coastal environment.

In summary, coastal cliffs are dynamic and ecologically significant features in coastal regions. They support diverse ecosystems, provide refuge to unique species, and contribute to the overall biodiversity and ecological balance of these areas. Understanding the distinctions between sea cliffs and inland cliffs is essential for conservation efforts and protecting these valuable habitats.

3.6 COASTAL AQUIFERS

The availability and quality of freshwater resources is a critical issue for the growing population of the coastal areas in the Mediterranean basin. Water demand in the region doubled during the second half of the 20th century and is now an aggregate of 290 km3 per year. Coastal aquifers are of particular importance to respond to this increasing demand. They often represent the main source of freshwater for human uses including drinking, agriculture and industrial needs. However, these invisible key resources face numerous challenges such as growing pressure on groundwater supplies, saltwater intrusion, coastal aquifer salinization, and nutrient and contaminant transport.

As recognized by the Mediterranean Sea Transboundary Diagnostic Analysis (TDA) Coastal Aquifer Supplement of 2012, coastal aquifers contribute to the integrity and functioning of the coastal zone and marine ecosystems, and their degradation contributes to the major transboundary issues affecting the Mediterranean Sea Large Marine Ecosystem (LME). The regional picture that emerges from t he assessment of the current state of these critically important resources is one of environmental stress, generalized neglect and progressive degradation of coastal aquifers and coastal freshwater ecosystems along large sections of the Mediterranean coastline.

Coastal aquifers often support unique and diverse ecosystems, including wetlands, estuaries, lagoons, humid zones and other coastal habitats which are critical habitats for various plant and animal species. Some of these ecosystems which provide very valuable services and contribute to coastal livelihoods, are all in part or totally dependent on groundwater regimes. The services provided by GWDE include: freshwater, food, fibre, medicines, minerals, construction materials, improvement of water quality, regulation of climate, generation of tourism, economic resources, cultural values, etc. Coastal aquifers play a crucial role in adaptation to climate change, particularly in mitigating the impacts of rising sea levels and changing precipitation patterns. They also serve as natural storage systems for freshwater, and as climate change alters precipitation patterns, some coastal areas may experience increased droughts or shifts in rainfall intensity. Coastal aquifers can help to mitigate water scarcity by storing excess rainfall during periods of heavy precipitation and providing a reserve of freshwater during dry spells. This stored water can support various needs, including drinking water supplies, agriculture, and ecological habitats, thus enhancing the resilience of coastal communities in the face of changing climate conditions.

Although Submarine Groundwater Discharges (SGD) are large (>25%) in the Mediterranean, and in places superior to surface water inflows, they have not been sufficiently characterized and assessed in many coasts of the Mediterranean basin. Hence coastal aquifers contribute to, and sustain shallow marine water quality and ecosystems. Nutrients such as nitrates and phosphates in coastal aquifers are a serious concern in certain parts of the Mediterranean. Excess nutrients in water have led to water quality problems such as algal blooms, eutrophication in a number of surface water bodies, affecting living marine resources and human health.

4. CHALLENGES IN THE COASTAL ZONE

4.1 LOSS OF BIODIVERSITY

Biodiversity represents the remarkable variety of life forms on Earth. According to the Convention on Biological Diversity (1992), it encompasses "the variability among living organisms from all sources including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part." This definition includes diversity within species, between species, and of ecosystems. It is, in essence, the intricate tapestry of life that thrives on our planet. **Coastal ecotones** are particulary vulnerable to various threats, including habitat degradation, pollution, overfishing, and the impacts of climate change, such as sea-level rise and increased storm intensity. Urban and touristic development, as mentioned, can lead to the fragmentation and loss of these critical habitats.

Nowhere is the complexity and richness of biodiversity more evident than in the Mediterranean region, where coastal and marine biodiversity flourish. The Mediterranean basin is renowned for hosting some of the world's most diverse and fauna and flora (Mittermeier et al., 2011). The term "biodiversity hotspot" is aptly applied to the Mediterranean, as it represents one of the world's top 25 biodiversity hotspots. These areas are characterized by their rich biodiversity, a high number of endemic species unique to the region, and critical levels of habitat loss. Despite the ongoing challenges and pressures that the Mediterranean faces, such as pollution and overfishing, the region still boasts remarkable diversity. However, it is essential to recognize that some species, including reptiles, marine mammals, birds, fish, and pollinators are facing alarming declines in abundance. These declines serve as a stark reminder of the urgent need for conservation efforts to safeguard the Mediterranean's unique biodiversity.

One of the distinctive features of the Mediterranean is its combination of low biological productivity with high biodiversity. While the Mediterranean Sea itself may have relatively low levels of biological productivity, the surrounding lands and coastal areas exhibit a striking degree of biological diversity. The Mediterranean's habitat diversity is a consequence of various factors, including the steep depth gradient within the basin and the latitudinal range. These factors result in a wide range of climatic conditions, spanning from sub-tropical to temperate. Such diversity in environmental conditions gives rise to a wide variety of habitats, each hosting a unique set of species and ecological interactions.

The pollinator crisis: The IPBES report of 2019 emphasized the cultural and historical significance of pollinators. These remarkable creatures have been revered in the sacred texts of various religions, underscoring their profound importance to human societies throughout history. Preserving pollinators is not just a matter of ecological concern but also a cultural imperative. The bees and other pollinators have a critical role of in sustaining life on our planet. In the Mediterranean coastal zone, the preservation and restoration of these invaluable pollinators play an important role in rewilding efforts and maintaining ecosystem health. Bees and butterflies are among the charismatic pollinators that facilitate the reproduction of countless plant species, including many of our food crops. However, these insects are facing unprecedented challenges due to human activities.

One of the primary threats to pollinators is habitat loss. As urbanization and agriculture expand along the Mediterranean coast, natural habitats are being transformed or destroyed, leaving pollinators with fewer places to forage and nest. Intensive farming practices, which often rely on monocultures, have further diminished pollinator-friendly landscapes. Climate change adds another layer of complexity to the problem. Altered weather patterns disrupt the synchronized timing between plants and pollinators, affecting the availability of nectar and pollen. The consequences of these disruptions ripple through ecosystems, impacting not only pollinators but also the plants they support. Agrochemicals, particularly pesticides, have also taken a toll on pollinators. The widespread use of these chemicals in modern agriculture has resulted in the contamination of nectar and pollen, leading to harmful effects on bee colonies and other pollinator populations.

4.3 LAND-USE CHANGE

The Mediterranean coastal zone is undergoing rapid land-use change, primarily driven by urbanization, which poses significant challenges to the region's environment and sustainability. This section explores the complex dynamics of land-use change in the Mediterranean coastal zone, with a focus on the impact of urbanization on water resources, sand mining, food production, energy demand, and estuaries.

One of the most pronounced consequences of urbanization in the Mediterranean coastal zone is the increased demand for freshwater resources. Growing urban populations require water for household, industrial, and agricultural use. This heightened demand places significant pressure on groundwater resources, which are often over-exploited. The over-pumping of groundwater not only threatens its long-term sustainability but also leads to land subsidence, a phenomenon that can exacerbate coastal flooding risks. Urbanization places additional stress on the agricultural sector in the Mediterranean coastal zone. Increased water demand from urban areas can lead to water stress in agricultural regions, negatively impacting crop yields and food production. Salinization, resulting from seawater intrusion into groundwater, further challenges food security by rendering soils less fertile. Moreover, agricultural runoff, containing excess nutrients, can deteriorate water quality and harm marine biodiversity.

Rising urbanization coincides with a growing demand for energy in the Mediterranean coastal zone. As countries seek to transition away from fossil fuels, many are turning to hydroelectric dams to meet their energy needs. While these dams offer a cleaner energy source, they also disrupt local ecology and hydrological systems. The construction of dams alters water and sediment flow, impacting downstream ecosystems and potentially exacerbating coastal erosion. Estuaries are unique and ecologically vital coastal features, but they are particularly vulnerable to the impacts of land-use change and urbanization. As urban areas expand, estuary ecosystems often bear the brunt of habitat destruction and pollution. Changes in land use, such as deforestation and urban development, disrupt the delicate balance of sediment delivery to estuaries. This disruption can lead to coastal erosion and the loss of vital habitats.

The construction industry, closely linked to urbanization, drives the demand for sand and gravel in the Mediterranean coastal zone. Sand mining, a key source of these materials, has become a major concern. The extraction of sand from riverbeds and coastal areas can disrupt ecosystems, erode coastlines, and harm aquatic life. Additionally, unregulated sand mining contributes to habitat destruction and exacerbates the vulnerability of coastal communities to erosion and sea-level rise.

It is not only the current industry, but the dismissed industrial activities have also left an indelible mark on the Mediterranean coastal zone. Over the years, the long-term accumulation of xenobiotic contaminants in the environment has resulted in chronic pollution. These human-made chemicals find their way into the environment, often through industrial processes, and have adverse effects on ecosystems and human health. This chronic form of pollution represents a significant threat on multiple fronts: Contaminants from **brownfields** can leach into groundwater, posing risks to communities living in proximity to these sites. Exposure to pollutants can lead to a range of health issues, from respiratory problems to more severe conditions such as cancer. Brownfields are often devoid of native flora and fauna due to contamination. The loss of habitat and the presence of pollutants can disrupt local ecosystems and threaten indigenous species. Pollutants can alter the fundamental processes that support ecosystem health. From nutrient cycling to water purification, these disruptions can have far-reaching consequences.

4.4 COMPOUND FLOODING

The occurrence of compound flooding involves the presence of two or more flood hazards driven by a single weather event, such as terrestrial flash floods and marine storm surges happening concurrently during a single low-pressure episode. It presents a significant threat to coastal cities and settlements due to its potential to impact low-lying coastal areas and drainage systems. Surface and groundwater from surrounding coastal regions naturally flow towards the coast, ultimately discharging into the sea. This convergence of water exacerbates conditions during heavy rainfall, resulting in severe consequences for both inhabitants and the environment.

Coastal flooding presents a multifaceted challenge, particularly when considering the influence of inland waters, necessitating an integrated approach for effective mitigation. Despite the significance of the issue, there exists a scarcity of definitive rules or guidelines governing its management. While safeguarding against the 100-year coastal flood stands as a clear imperative, the precise definition and correlation of this event with inland water flow, specifically the 100-year large body of water from hinterlands to coastlines, remain largely ambiguous. Understanding the reliability of these metrics poses a formidable challenge, compounded by insufficient local research efforts. Furthermore, alongside evaluating the 100-year sea level, the determination of local 100-year sea and wave heights is indispensable, albeit intricate and resource-intensive. Complicating matters further, the fluctuating mean sea level (MSL) alters wave formation dynamics, rendering predictions elusive. (PAP/RAC, 2021)

Conventional solutions to coastal flooding involve implementing hard protection structures, elevating coastal land and building heights, and fortifying coastal infrastructure. However, these "grey" solutions may have limitations and environmental implications. A comprehensive strategy must consider nature-based solutions and sustainable practices to ensure long-term resilience against coastal flooding.

4.5 SEA-LEVEL RISE

Sea level rise is a pressing concern for coastal regions worldwide, and the Mediterranean coastal zone is no exception. As global mean sea levels continue to rise, the Mediterranean region faces unique challenges due to its diverse coastal typologies and the significant impact this phenomenon has on coastal communities, ecosystems, and infrastructure.

Global mean sea level rise is accelerating, primarily due to the effects of climate change. The Intergovernmental Panel on Climate Change (IPCC) has provided projections indicating that by 2100, **global mean sea levels could rise between 29 and 110 cm compared to levels at the end of the previous century.** Since 1900, sea levels have already risen by an average of 20 cm. The Mediterranean mean sea level has risen by 6 cm in the past two decades. This trend is likely to accelerate and could reach a global rate of 43 to 84 cm by 2100. In the event of further ice-sheet destabilization in Antarctica, sea level rise could exceed 1 meter. Namely, recent scientific studies have raised concerns about the stability of parts of the Antarctic ice sheet (Naughten et al., 2023). If these unstable sections were to collapse, it could lead to even more substantial sea level rise. This potential catastrophic scenario underscores the importance of immediate and effective climate mitigation efforts to reduce greenhouse gas emissions.

Predicting the exact rate of future sea level rise remains highly uncertain. Several factors contribute to this uncertainty, including the progress made in mitigating greenhouse gas emissions, the complexity of forces driving sea level rise, and the unknown timing of potential tipping points in the climate system. Therefore, it is essential to take a precautionary approach and prepare for a range of sea level rise scenarios.

The Mediterranean coastal zone, with its diverse landscape and human settlements, is particularly vulnerable to sea level rise, that contributes to increased coastal erosion, threatening infrastructure and property along the coast. Low-lying coastal areas, including urban centers, agricultural lands, and wetlands, are at risk of inundation during high tides and storm events. Higher sea levels can lead to saltwater intrusion into groundwater, rendering freshwater sources brackish or undrinkable. Coastal habitats, including beaches, dunes, and salt marshes, face degradation and loss due to sea level rise, impacting biodiversity. Coastal communities may be forced to relocate as their homes become uninhabitable due to sea level rise and associated hazards.

Additionally, management frameworks for **coastal groundwater** are absent, and in many cases these resources are not formally recognized as critical for the sustainability of coastal developments, and as being highly vulnerable. Unregulated exploitation is common, and no quality-quantity safeguards exist or are applied. Conflicts among uses (agriculture, domestic, tourism, environment, energy…) are common and potentially disruptive. Additionally, scientific knowledge and public awareness of coastal aquifers are scanty or non-existent in most countries. Monitoring is occasional at best, but lacks modern technologies and strategic, multi-purpose design.

4.6 COASTAL EROSION

Soil erosion is a long-standing issue in the Mediterranean region, with complex historical and environmental factors contributing to this problem. The impacts of erosion extend to coastal ecosystems, posing threats to soil health, water resources, biodiversity, and beach dynamics.

Erosion in the Mediterranean region has deep roots, with evidence of Late Pleistocene erosion associated with climatic changes and sparse vegetation cover. During this period, a cooler and drier climate led to increased sediment yield from catchments. However, the debate regarding erosion history during the Holocene is more complex, with arguments over timing and causal factors. Some attribute erosion to climate changes, while others point to anthropogenic causes. For example, dams in upstream river reaches trap sediment, preventing its supply to estuaries and coastal zones. This sediment is essential for counteracting sea-level rise and land subsidence in these areas. The decreasing sediment input into estuaries and coastal zones exacerbates coastal erosion and land loss.

Erosion has far-reaching consequences for coastal ecosystems in the Mediterranean region. These impacts include the destruction of soil surface layers, groundwater pollution, dune degradation leading to desertification, reduced biodiversity, altered beach dynamics, decreased sedimentary resources, and soil and groundwater salinization. Coastal ecosystems are intricately linked to land processes, making erosion a critical concern.

4.7 INVASIVE ALIEN SPECIES

The term "biological invasion" is used to describe the process involving transport or movement of a species (animals, plants, and other organisms) outside its natural range by human activities and its introduction to new regions, where it may become established and spread (IPBES, 2023). In contrast to native species, non-indigenous species are introduced to new regions by humans that play a key role in this process. Invasive alien species represent a subset of aliens known to have established and spread with negative impacts on biodiversity or on nature's contributions to people such as ecosystem goods and services and good quality of life (IPBES, 2023). Invasive alien species can be introduced unintentionally. For example, many alien invertebrates entered the littoral and sublittoral Mediterranean waters through vessels transiting the Suez Canal (Galil, 2008).

However, others have been intentionally introduced, often for their perceived benefits without consideration or knowledge of their potential negative impacts. The European grass *Ammophila arenaria* has been introduced in many coastal areas around the world to promote the stabilization of dunes, but soon became invasive with serious consequences to the local biodiversity (Pickart, 2021). Similarly, the South African succulent *Carpobrotus edulis/acinaciformis* has been introduced as an ornamental species in many coastal areas of the world and now is one of the most widespread alien plants in the Mediterranean coastal ecosystems, and a severe threat to their fragile biodiversity (Campoy et al. 2018).

Invasive alien species are recognized as one of the five major direct drivers of change in nature globally, alongside land- and sea-use change, direct exploitation of organisms, climate change, and pollution. Invasive alien species cause dramatic and, in some cases, irreversible changes to biodiversity and ecosystems, resulting in adverse and complex outcomes across all regions of Earth, including local and global species extinction (IPBES, 2023).

Mediterranean coastlines are dynamic landscapes influenced by many natural factors such as the salinity, substrate composition and wind action that change along the sea–inland transition. Additionally, they are also strongly affected by human activities. In most cases, these activities are related to touristic exploitation and infrastructure development which has contributed to the establishment and spread of many aliens. Specifically, Mediterranean coastal zones, have been reported to harbour many alien species (Chytrý et al., 2008). In coastal ecosystems, such as sandy coastal habitats, alien species are typically generalists. They often exhibit ruderal traits or are more commonly found in disturbed semi-natural or human-made habitats (Giulio et al, 2020) which leads to habitat homogenization and simplification.

Alien species are being introduced by human activities to all regions and biomes of the world at unprecedented rates. The Mediterranean Basin, a well-known biodiversity hotspot, is also threatened by alien species moved around by long-distance trade exchanges (Seebens et al., 2015) and is considered at high risk of new invasions in the future (Cao Pinna et al. 2020). In Mediterranean coastal zones, despite the presence of numerous habitats considered as priorities for international conservation goals, many ecosystems have undergone consistent transformations, and the majority of habitats are currently highly endangered. Mediterranean shifting coastal dunes, Mediterranean dune scrubs, Mediterranean coastal dune grasslands (grey dunes), Mediterranean temporary waterbodies (Jenssen et al. 2016) and *Posidonia* beds in the infralittoral zone have been highlighted among the most vulnerable habitats (Gubbay et al. 2016). Despite the various threats affecting these habitats, the impact of invasive plants has been identified as one of the most relevant ones.

4.8 URBAN HEAT ISLANDS

Urban heat islands (UHIs) are a growing concern in urbanized areas across the Mediterranean coastal zone. Urban areas experience significantly higher temperatures than their surrounding rural or natural counterparts. Urbanization and the Mediterranean climate create a potent combination that exacerbates the UHI effect. This phenomenon is driven by various human activities and urban characteristics, making it crucial to address the well-being of the coastal urban population.

Highly built areas characterized by heat-absorbing infrastructure and materials, such as asphalt and concrete, are particularly susceptible to UHIs. The Mediterranean climate, known for its hot, dry summers, further intensifies the heat island effect. UHIs impact human health (heat-related illnesses and increased mortality rates), energy consumption (e.g. increase in air conditioning), and overall urban resilience to climate change. UHIs lead to increased economic costs (such as increased infrastructure maintenance costs) and increased environmental degradation (effect on urban ecosystems, plants and wildlife).

4.9. MARINE HEAT WAVES

Marine heat waves (MHWs) in the Mediterranean have become in general longer and more intense. Since the beginning of the 1980s, average Mediterranean Sea surface temperatures have increased throughout the Mediterranean basin, but with large sub-regional differences between +0.29 and +0.44°C per decade (MedECC, 2020), with stronger trends in the eastern basins (Adriatic, Aegean, Levantine and north-east Ionian Sea). Marine heat waves in the Mediterranean will very likely increase in spatial extent, become longer, more intense and more severe than today. These are expected to occur in the Mediterranean from June to October and to affect the whole region at their peak (UNEP/MAP and Plan Bleu, 2020).

MHWs can cause immediate shifts in the distribution of (mobile) species, and cause local extinctions, indicating that many, marine ecosystems may not be resilient to extreme events. One of the first documented mass mortalities in rocky benthic communities was from the north-western Mediterranean Sea during the summer of 2003: several thousand kilometres of coastline were affected by a MHW with temperatures of 1-3 °C above the climatic values, which caused the mass mortality (up to 80 % of the population) of at least 25 species of soft corals (e.g. sea fans) and sponges.

4.10 WILDFIRES

Wildfires are an integral factor in most terrestrial biomes but fire frequencies vary widely. In Mediterranean-type climates wildfires occur especially in the dry summer season and recur usually only once within decades or more rarely. Wildfire resilience is a common feature in plants of Mediterranean environments and is expressed very clearly by the ability to resprout from dormant buds at plant structures at ground-level or below-ground that survived the fire, such as lignotubers. Other fire-related plant adaptations include serotiny, where fire triggers the release of the seeds, and the persistence of seeds in the soil. After a fire, the soil is bare of litter, fertilized from ash, freed from competitive plant cover, and the seedlings have perfect growth conditions. The germination of the seeds may even be triggered by heat or chemical substances in smoke or ash. Pine cones release seeds usually in periods of drought, and some open only at temperatures reached with wildfires.

Although the proportion of plant species specifically adapted to wildfire in the Mediterranean Basin may not reach those of some other Mediterranean-climate regions such as Southwest Australia and the Cape region of South Africa, the resistance of numerous plant species in the European-North African Mediterranean Basin to fire and other disturbances involving plant biomass loss is well-known and scientifically proven (Pausas et al. 2008; Ne’eman et al., 2012).

Many regions throughout the Mediterranean Basin suffered in recent years from unprecedented wildfires that destroyed settlements, cultivated and wooded areas alike. They have also taken a toll on human lives. Wind gusts, scorching temperatures, and the longer drought season with dry vegetation have led to spread of wildfires that got out of control in several countries. The monitoring by the European Union Joint Research Center (JRC 2023) showed a total burnt area of 135,000 hectares in the Mediterranean countries of Algeria, Greece, Italy and Tunisia in just 12 days in July 2023. This figure includes over 20 000 hectares of Natura 2000 protected areas in Italy and Greece. Over 120,000 people inhabiting areas that were burnt by wildfires have been immediately affected in this short period in the four countries (JRC 2023), while an additional unknown number of people suffered the effects of the fires, such as smoke pollution, evacuations, etc.

The rise in the number of fires, their frequency of occurrence, duration, extent, destroyed values and costs involved are almost certainly a consequence of global warming. It is likely, therefore, that the annually burned area will increase further in the coming years and decades. A robust projection by Turco et al. (2018) concluded that the higher the warming level, the larger will be the increase of burned area. Wildfire prevention measures in sensitive regions in the Mediterranean Basin are therefore increasingly of importance.

5. SOLUTIONS

When analysing the challenges, identifying risks and planning NbS, it is essential to consider the social and environmental context of the area or landscape where the action will be implemented. This understanding helps in assessing how biodiversity and ecosystems contribute to ecosystem services and climate adaptation. Some of the important considerations would be the following:

- Describe the environmental characteristics of the area, including habitat types, topography, and ecosystem services it provides.
- Understand the current use of the area, including who uses it and for what purposes.
- Identify the stakeholders involved, such as landowners, residents, and interest groups.
- Assess whether there are existing climate adaptation targets for the area.

The IUCN Standard consists of 8 Criteria and 28 Indicators to evaluate the effectiveness, sustainability, and adaptability of NbS interventions. Criteria include addressing societal challenges, considering scale, achieving a net gain in biodiversity, economic viability, inclusive governance, balancing trade-offs, adaptive management, and sustainability.

Potential risks and challenges: Guard against "greenwashing" and ensure NbS efforts align with decarbonization goals. Focus on protecting and restoring existing habitats and ecosystems instead of solely tree planting. Avoid overlooking adaptation, biodiversity, and social benefits by presenting NbS primarily as a climate change mitigation tool. Be cautious about potential harm to marginalized indigenous peoples and local communities and avoid land appropriation. Consider the negative outcomes that may result from NbS projects, such as planting non-native trees in biodiversity-rich areas. Address unsustainable production and consumption practices, especially in food and agriculture sectors, to ensure long-term benefits of NbS.

Example of best practice: The restoration of Camargue's former saltworks serves as an example of assessing NbS effectiveness in a coastal area. The project aimed to restore natural hydrological processes, reconnect lagoons, and address climate change challenges. Objectives included improving conservation, restoring coastlines, and facilitating sustainable development. Therefore, a comprehensive understanding of the environmental and social context, coupled with careful planning and evaluation, is crucial for the successful implementation of NbS while avoiding potential risks and challenges.

Table 1: A simplified summary of potential Nature-based Solutions (NbS), highlighting their relevance to various coastal types and environmental challenges within the Mediterranean coastal zone. The colors assigned to coastal types indicate their general level of naturalness (though these colors may vary locally). Additionally, icons representing each solution are included to address specific identified challenges. The sequencing of both colors and icons is intended to establish connections between priority areas/types and the corresponding solutions to challenges.

5.1 PROTECTION OF SPECIFIC COASTAL ECOSYSTEMS

Conserving and managing **coastal ecotones** is imperative for preserving the ecological vitality of coastal regions and ensuring the sustainability of vital ecosystem services, including fisheries. A comprehensive and integrated approach is necessary, considering the interconnections between terrestrial and marine ecosystems and involving local communities and stakeholders in conservation endeavors. Safeguarding and rehabilitating these transitional zones are pivotal for bolstering the overall health and resilience of coastal ecosystems.

Moreover, ecotones play a pivotal role in enhancing the resilience of coastal areas to the impacts of climate change. They serve as effective buffers against storm surges, offering natural shoreline stabilization that mitigates coastal erosion. Additionally, coastal ecotones function as natural filtration systems, enhancing water quality by capturing sediments and pollutants from upstream areas before they reach the marine environment. These transitional zones offer a myriad of ecosystem services, including recreational opportunities, cultural significance, and support for traditional livelihoods such as fishing.

Amidst growing global concerns about biodiversity loss and the depletion of marine ecosystems, the "30 by 30" initiative has emerged as a ray of optimism. Originating from the COP15 meeting of the Convention on Biological Diversity in 2022, this global mission aims to designate 30% of Earth's land and ocean area as protected areas by 2030. Embedded within the Kunming-Montreal Global Biodiversity Framework, this ambitious target underscores the urgent need to conserve and manage critical ecosystems. Biodiversity loss stands as one of the most pressing threats to both our planet's ecological health and global economic prosperity. Acknowledging this, international bodies such as the World Economic Forum and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) have underscored the urgency of addressing this crisis.

The initiative assumes significant importance in safeguarding coastal marine ecosystems, with **MPAs** playing a crucial role in preserving and revitalizing marine life, ensuring sustainable fisheries, and bolstering the resilience of seas and oceans. These areas serve as vital sanctuaries for threatened species and as centers for scientific research on marine biodiversity. However, expanding global networks of MPAs faces complexities and requires collective efforts from countries, communities, and organizations, while respecting the needs and rights of local communities and indigenous peoples dependent on these coastal ecosystems. Balancing conservation with sustainable use is paramount.

Establishing MPAs can offer refuge for *Posidonia* meadows by restricting harmful activities and providing a safe environment for these critical benthic ecosystems to thrive. Collaborative efforts at various levels are necessary for the restoration and conservation of *Posidonia* meadows. Addressing climate change through greenhouse gas emission reduction is crucial for the long-term survival of these ecosystems, as it helps maintain suitable conditions for their growth and distribution. Furthermore, implementing sustainable coastal management practices, such as regulating nutrient inputs, protecting coastal habitats, and reducing pollution, is essential for the conservation of *Posidonia* meadows.

As the world unites to combat biodiversity loss through the "30 by 30" initiative, the Mediterranean emerges as a microcosm of global biodiversity challenges. Its coastal regions, teeming with unique ecosystems, demand our unwavering attention and conservation commitment. The "30 by 30" mission presents an opportunity for the Mediterranean to showcase its ecological richness and commitment to sustainability. By fostering collaborative partnerships, respecting indigenous rights, and integrating conservation into broader landscapes, the Mediterranean can serve as a model for achieving this critical global target.

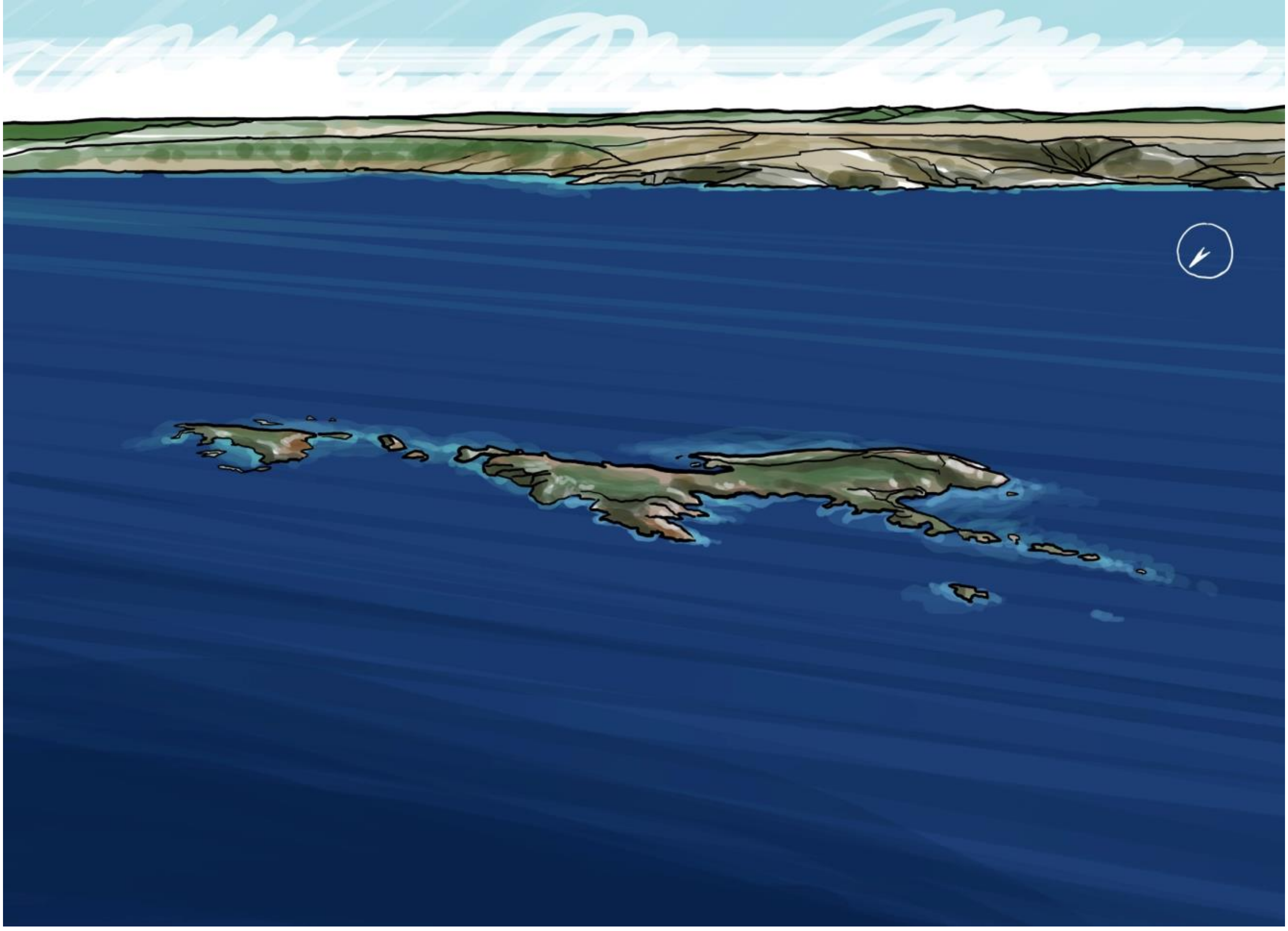


Figure 7: Habibas islands, Algeria. The archipelago of Habibas Islands is an emblematic and the first Algerian Marine Protected Area with a legal status acquired on 2004 and also the first legal Algerian SPAMI (Special Protected Area with Mediterraean Importance) under Barcelona Convention.

In the Mediterranean, the need for NbS is critical, and **wetlands** offer huge potential in this respect. To harness the potential of wetlands as NbS, a two-pronged approach is essential: conservation of existing wetlands and restoration of degraded ones. Local communities, often the first stewards of these ecosystems, must be at the heart of these efforts, blending traditional knowledge with modern conservation practices. Stricter regulatory frameworks are vital. This includes designating more wetlands under the Ramsar Convention, implementing buffer zones around critical wetlands, and enforcing stricter pollution controls. But policies alone will not suffice. Raising awareness, promoting research, and fostering collaborations between governments, NGOs, and the private sector are equally important. The ongoing challenges of urbanization, climate change, and resource extraction necessitate adaptive management strategies that are responsive to changing conditions. Such strategies should be holistic, integrating wetland conservation into broader landscape and watershed management plans.

Effective management of Mediterranean **saltmarshes** involves balancing conservation efforts with sustainable use practices. Strategies may include habitat restoration, invasive species management, community engagement initiatives, and the protection of existing saltmarshes. Saltmarsh conservation should prioritize the protection of existing habitats, as their ecological values are often underestimated. Preservation efforts can include establishing protected areas, implementing regulations to prevent habitat destruction, and monitoring programs to assess ecosystem health. Additionally, public awareness campaigns and educational initiatives can help highlight the importance of saltmarsh ecosystems and garner support for conservation measures.

Despite the importance of **coastal forests and woodland** in terms of ecosystem goods and services, their narrowing in distributional range and floristic and structural regression make them an immediate subject of restoration studies. Sustainability of already protected ones should be a priority and they should be used as a reference plot in restoration. Alien and invasive species must be avoided and seeds and seedlings with certified local origin must be used. Special attention should be given to the protection of biodiversity and to the prevention of soil loss in planting and soil mechanization. To reduce the fire risk, changing the fire regime should be taken into consideration by favouring the constitution of a more fire-resistant landscape. All, in final, should be related to the mitigation of the negative effects of climate change. Urbanization and tourism are still common phenomena in the Mediterranean, but they should be planned by considering the value and importance of coastal forests and woodlands.

The conservation management of the **coastal dunes** and their restoration must be done helping the natural processes that operate in the ecosystem and not ignoring them, much less going against them. This implies that the flows of the sedimentary system, both wind and aquatic, must always be assured and never interrupted. The works that imply the construction of permanent solid elements, such as houses, roads, etc., that suppose the burying of the dune, must be totally prevented.

Safeguarding the **coastal aquifers**' health and productivity can be done by implementing ICZM practices, such as the regulation of land use, the implementation of best management practices, and the establishment of buffer zones, in order to minimize the potential risks of contamination. Another significant linkage between coastal aquifers and coastal zone management is the mitigation of coastal hazards. Coastal areas are prone to natural disasters, including storm surges, flooding, and sea-level rise. These events can have detrimental impacts on coastal aquifers, leading to salinization and intrusion of saltwater into freshwater aquifers. Proper coastal zone management approaches, such as the construction of protective structures like seawalls, dikes (as grey measures), and recharge basins (as a NbS), can help reduce the vulnerability of aquifers to these hazards. Additionally, preserving and restoring natural coastal ecosystems, such as wetlands and dunes, can provide natural buffers that protect aquifers from the impacts of extreme weather events.

ICZM practices that promote the conservation and restoration of these ecosystems contribute to the protection of aquifer recharge areas and the maintenance of groundwater quality. By recognizing the interdependencies between coastal aquifers and ecosystems, coastal zone management can adopt an integrated approach that ensures the long-term health and resilience of both.

As global temperatures rise, sea levels are increasing, posing a significant threat to coastal communities and ecosystems, coastal aquifers also contribute to the maintenance of coastal ecosystems by sustaining groundwater flow to support vegetation and maintain ecological balance. Preserving and restoring these coastal ecosystems through adaptive management practices can help enhance their resilience and contribute to climate change adaptation efforts. Seawater intrusion is the movement of seawater into freshwater aquifers due to natural processes or human activities. Seawater intrusion is caused by decreases in groundwater levels or by rises in seawater levels. Intrusion affects the quality of water and the health of groundwater dependent ecosystems. Coastal aquifers play a role in reducing the impacts of saltwater intrusion. Rising sea levels can lead to the intrusion of saltwater into freshwater resources, making them unsuitable for consumption or irrigation. However, coastal aquifers act as a natural barrier against saltwater intrusion, maintaining a freshwater lens beneath the land surface. By carefully managing groundwater extraction and implementing measures to prevent over-pumping, such as implementing water-use efficiency practices, coastal communities can preserve the integrity of their aquifers and ensure a reliable supply of freshwater.

5.2. RESTAURATION OF SPECIFIC COASTAL ECOSYSTEMS

Ecosystem restoration involves reversing ecosystem degradation to improve their ecological functionality. Restoration can include natural regeneration of overexploited ecosystems or planting trees and other plants. Consider ecological engineering and ecological restoration as part of the restoration process. Ecosystem restoration in Mediterranean coastal areas involves aiding the recovery of ecosystems that have suffered degradation or destruction, while also safeguarding those that remain intact. Healthier coastal ecosystems, marked by increased biodiversity, offer numerous benefits, including improved soil fertility, enhanced yields of timber and fish, and heightened resilience to climate change.

Various strategies can be employed for ecosystem restoration along the Mediterranean coast, ranging from active interventions such as planting to allowing natural recovery by reducing external pressures. However, achieving a balance between human activities, such as agriculture and infrastructure, and ecological conservation is crucial. It is not always feasible or desirable to return a coastal ecosystem to its original state. Instead, coastal ecosystems, like societies, must adapt to changing climates while emphasizing sustainable practices for a resilient and harmonious coexistence along the Mediterranean coastline.

The restoration of **wetlands** in the Mediterranean coastal zone is a critical initiative aimed at rehabilitating and conserving these vital ecosystems. Wetlands play a crucial role in supporting biodiversity, regulating water flow, and providing various ecosystem services. In the Mediterranean context, where wetlands face threats from urbanization, agricultural expansion, and climate change, restoration efforts focus on re-establishing the natural balance and functions of these sensitive coastal areas.

For wetlands to be effective as NbS in the Mediterranean, it is crucial to integrate wetland protection, restoration, and sustainable management into regional and national climate change adaptation strategies. Policies that support the conservation of existing wetlands, restoration of degraded ones, and the sustainable use of wetland resources are also critical. The Ramsar Convention on Wetlands provides an international framework for the conservation and wise use of wetlands, which could be leveraged to promote wetland conservation and restoration in the Mediterranean as part of climate change adaptation strategies.

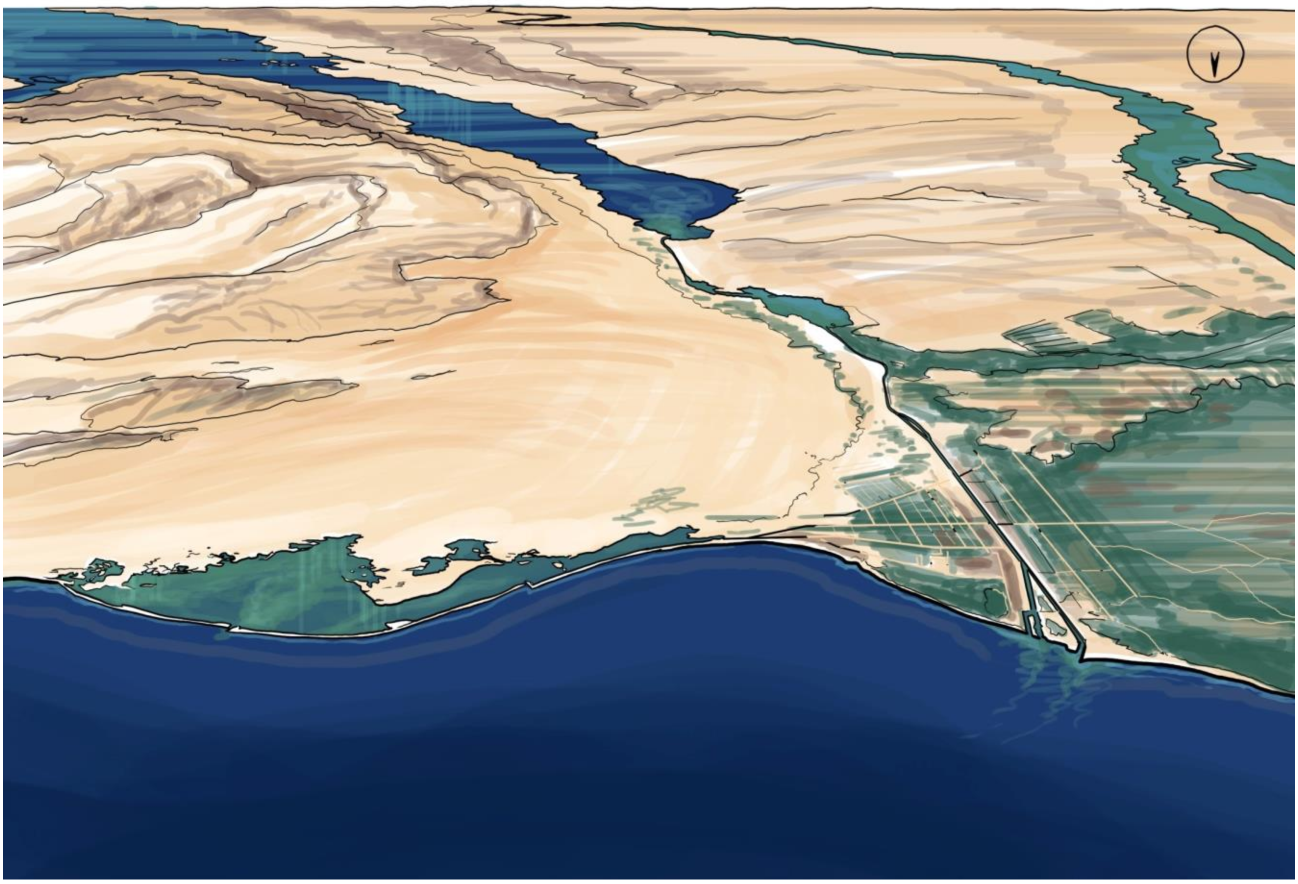


Figure 8: Lake Bardawil, Egypt. Example of a wetland restoration - the ambitious project aims to restore the wetlands in the northern part of the Sinai Peninsula, reviving the ecosystem and reintroducing native species.

The importance of wetlands as NbS becomes increasingly evident. By prioritizing their protection and restoration, we not only safeguard their inherent values but also harness their potential in addressing some of the most pressing environmental and climate challenges. Given the multiple benefits that wetlands offer in terms of biodiversity conservation, flood control, coastal protection, carbon sequestration, water quality improvement, and livelihood support, they are indeed valuable NbS for adaptation to climate change in the Mediterranean basin and elsewhere. Integrated and sustainable management approaches are vital to maximizing these benefits and ensuring the resilience of wetland ecosystems. Efforts like the Mediterranean Wetlands Initiative (MedWet) underscore the regional focus on conserving these invaluable ecosystems. Integrating local communities into conservation strategies, promoting sustainable agricultural practices, and fostering transboundary collaboration are essential. Moreover, given the intricate socio-ecological fabric of the region, strategies must account for both ecological and cultural restoration.

Restoration initiatives aim to enhance **biodiversity** by reintroducing native plant species, creating habitats for aquatic and terrestrial fauna, and fostering ecological resilience. Efforts are made to restore natural water flow patterns, control water quality, and prevent excessive sedimentation. Restoring hydrological processes is crucial for the overall health of wetland ecosystems. Restoration projects often focus on establishing connectivity between fragmented wetland areas. This facilitates the movement of species and promotes genetic diversity, contributing to the overall health of the ecosystem. Involving local communities in restoration projects is essential for their success. Community participation not only contributes to the sustainable management of wetlands but also raises awareness about the importance of these ecosystems.

Conservation efforts aimed at protecting Mediterranean **coastal temporary ponds** are gaining momentum. Here are some strategies being employed to safeguard these unique ecosystems: Restoration projects focus on recreating or enhancing these ponds in areas where they have been lost or degraded. By recreating the natural hydrology and plant communities, restoration efforts aim to bring back the essential features of these ecosystems. Raising public awareness about the ecological importance of these ponds is crucial.

Figure 9: Comino, Malta. Restauration project for coastal freshwater ponds.

Education programs and community engagement can help garner support for conservation initiatives and encourage responsible land use practices. Some ponds have received legal protection through national and international conservation agreements. The Ramsar Convention, for instance, recognizes the ecological significance of these ponds and promotes their conservation. Efforts to control and manage invasive species in and around these ponds are essential to maintaining the integrity of these ecosystems. This may involve the removal of invasive plants or the establishment of barriers to prevent the introduction of invasive species. Implementing measures to reduce pollution and maintain water quality in these ponds is vital. Sustainable agricultural practices, buffer zones, and pollution control measures can all contribute to healthier pond ecosystems.

Seagrass restoration projects aim to reestablish seagrass habitats and to promote the recovery of associated marine species. Efforts are being made to restore *Posidonia* meadows through seagrass transplantation. This involves carefully uprooting healthy seagrass shoots from donor meadows and transplanting them to areas where seagrass has been lost. In the face of mounting challenges, the Red Eléctrica Marine Forest emerges as a pioneering initiative. Located in Majorca, this project aims to restore *Posidonia oceanica* seagrass meadows—an endeavour of global significance. Its objectives are multifaceted: the conservation of biodiversity, the promotion of research and development, and a commitment to climate change mitigation. The project aligns perfectly with Red Eléctrica's 2030 Sustainability Commitment, highlighting the corporate world's growing involvement in safeguarding these vital ecosystems.

In restoration projects for **dunes**, only the species belonging to natural communities should be used, which must always have the certification of origin that guarantees their geographical proximity. Never use exotic species or plants native to distant places or regions. The settlement of native communities will promote the natural stabilization of the dune. A notable example of dunes restoration one can find in Italy, in the Bevano River mouth area. The results demonstrate the effectiveness of dune fencing in promoting sand deposition and vegetation growth, reducing blowout features and erosion while enhancing overall coastal resilience (PAP/RAC, 2021).

Invasive alien species and their negative impact can be prevented or mitigated through timely monitoring and effective management. Nowadays, there are many decision frameworks and approaches for supporting management of invasive aliens at all stages of the biological invasion process (IPBES, 2023). However, no doubt that prevention is the best and most cost-effective option. A risk assessment in line with a precautionary approach can also be effective to guide management actions, including the use of novel, and emerging and environmentally sound technologies. Early detection, eradication, containment and control are also effective in specific contexts (IPBES, 2023). In coastal ecosystems, all these stages can be particularly challenging when they are in proximity or connected with the sea, as marine-transported alien propagules have the potential to continuously arrive. Furthermore, in particularly fragile ecosystems like coastal dunes, eradication efforts could prove largely ineffective, as the loose sandy substrate may "conceal" numerous alien propagules. Eradication has been successful, especially for small and slow-spreading populations of invasive alien species, especially in isolated ecosystems such as Mediterranean islands. Very importantly, consistent and long-term site monitoring plays a vital role in early detection of invasive alien species, including instances of re-invasion, and can guide subsequent management actions.

5.3. COASTAL PLANS

The implementation of ICZM strategies, such as setback zones and sustainable land-use planning, can serve as effective measures to safeguard natural coastal features and mitigate uncontrolled development in hazard-prone areas. Addressing the challenges posed by land-use change and urbanization in the Mediterranean coastal zone requires a multi-faceted approach that balances urban development with environmental conservation:

Implementing **sustainable urban planning** practices can help minimize the ecological footprint of cities. Compact, well-designed cities can reduce the demand for land and resources. **Integrated water resource management** is essential to ensure the sustainable use of freshwater and the prevention of groundwater overexploitation. This includes the implementation of water-efficient technologies and conservation measures. Governments and authorities should also regulate and monitor **sand mining activities** to minimize environmental impacts. Sustainable alternatives to traditional sand mining should also be explored. Furthermore, **agricultural innovations** should be promoted: water-efficient and salt-tolerant crop varieties, along with improved irrigation techniques, can enhance food production while minimizing environmental harm. Developing a **diverse energy** portfolio that includes renewables, such as solar and wind power, can reduce the dependence on hydroelectric dams while mitigating ecological disruption.

Protecting and restoring estuary ecosystems is crucial. This includes preserving natural sediment transport processes, managing land use in delta areas, and controlling pollution. **Restoring natural dunes** and beaches can act as a buffer against coastal erosion and inundation. **Planting native vegetation** helps stabilize these ecosystems. **Wetland restoration** along coastlines can absorb excess water, reduce wave energy, and provide vital habitat for coastal species. **Living shorelines** incorporate natural materials like oyster reefs, seagrass beds, and salt marshes to stabilize coastlines and provide habitat while absorbing wave energy. Planned relocation of vulnerable coastal communities away from hazard-prone areas can reduce risks and promote long-term resilience. **Reforesting riparian zones** along rivers and streams can reduce sediment runoff and flooding, improving water quality and resilience.

Effective management of **entirely artificial coasts** requires long-term environmental strategies coupled with strong political and socio-economic commitment. Mitigation efforts should focus on addressing negative impacts such as soil sealing, pollution, and disruption of coastal ecosystems. While integrating NbS may face challenges, efforts should still be made to incorporate nature-based elements where feasible.

By implementing targeted management strategies and incorporating NbS, stakeholders can work towards enhancing the sustainability of **moderately artificial coastal areas**. For instance, restoration of nearshore and benthic communities would require water quality measures which is frequently affected by industrial uses negatively. *Posidonia* and other species that stabilize the near-shore environment can help mitigate the occurrence of algal blooms in these regions.

Low-density urbanized coasts require effective management, which involves recognizing the potential for ecological corridors within dispersed urban development. NbS can be integrated into planning practices to promote environmental sustainability. Examples include areas where low-density urban sprawl is integrated with forests, providing opportunities for preserving natural ecosystems and promoting biodiversity corridors. By implementing targeted management strategies and incorporating NbS, stakeholders can work towards enhancing the sustainability of these coastal areas.

Acknowledging the dynamic interplay between natural processes and human activities is essential for effectively managing **transitional coasts**. Strategies may include interventions that work with nature's resilience to restore functioning natural systems, such as beach nourishment or habitat restoration. Examples include coastal areas where natural processes are managed in response to changing environmental conditions or coastal hazards. By implementing adaptive management strategies and integrating NbS, stakeholders can enhance the resilience and sustainability of these dynamic coastal environments.

Sea level rise in the Mediterranean coastal zone presents a multifaceted challenge that requires immediate action and a comprehensive approach. NbS offer a promising avenue for mitigating the impacts of rising sea levels while enhancing the resilience of both natural and human systems. To safeguard the Mediterranean's diverse coastal typologies, it is imperative to integrate NbS into regional and national strategies and collaborate across borders to address this shared concern. By embracing NbS and committing to ambitious climate mitigation efforts, the Mediterranean region can work towards a sustainable and resilient future in the face of sea level rise.

The Mediterranean coastal zone is at a critical juncture, facing the challenges of urbanization, land-use change, and their far-reaching environmental consequences. Achieving a balance between urban development and conservation is essential to ensure the region's sustainability and resilience. Through sustainable urban planning, responsible resource management, and a commitment to preserving natural ecosystems, the Mediterranean coastal zone can thrive while protecting its unique environment for future generations.

The concept of **coastal setback**, a strip along the coastline where construction is either prohibited or heavily restricted, is a fundamental aspect of the Integrated Coastal Zone Management (ICZM) Protocol. It serves to uphold the Protocol's objectives, including preserving coastal nature and landscape integrity, mitigating risks from natural processes like erosion and climate change, and ensuring public access to coastal areas for recreational activities. In the context of climate change and rising sea levels, coastal setback emerges as a crucial "low-regret" measure. These measures are relatively inexpensive to implement and yield substantial social benefits. By guiding new development away from flood-prone areas, coastal setbacks not only contribute to climate change adaptation but also generate multiple economic and social advantages.

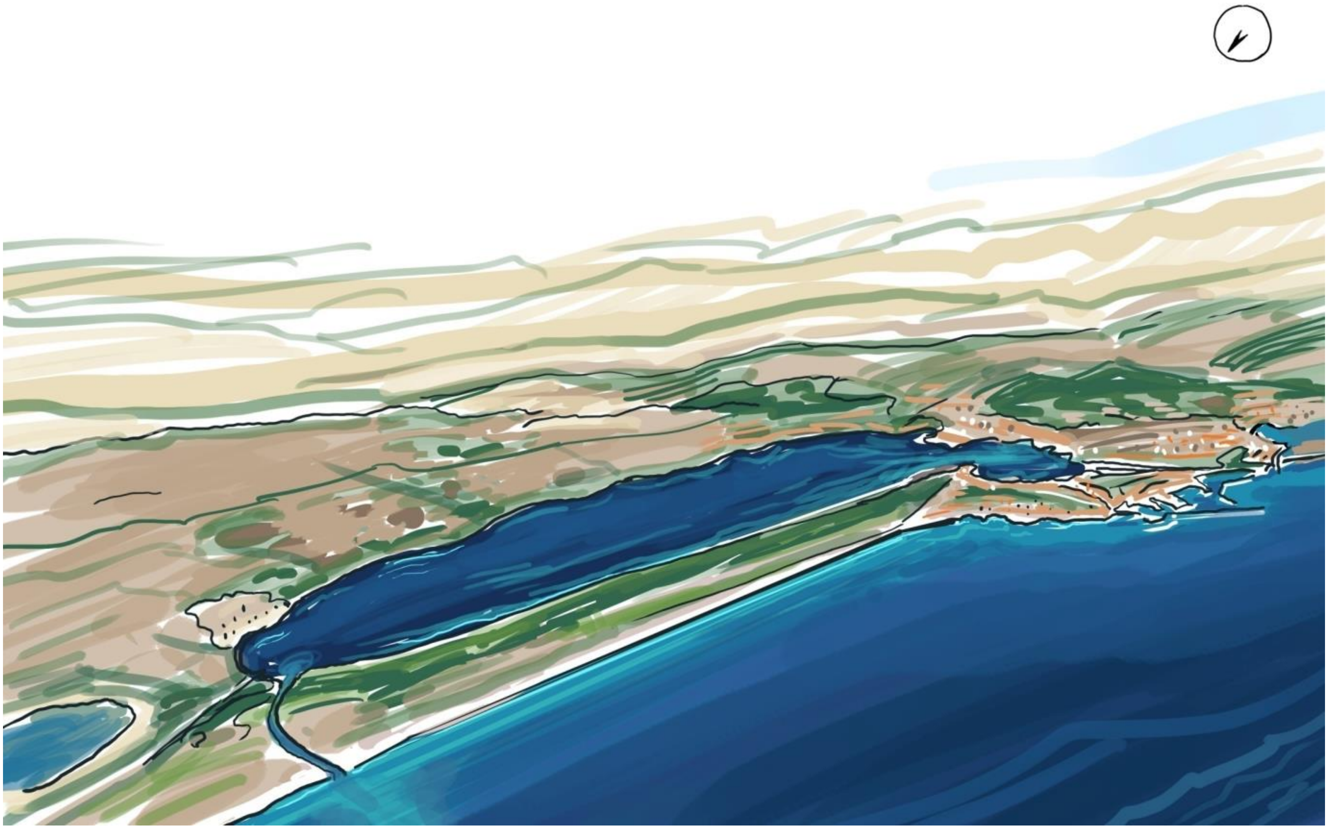


Figure 10: The littoral between Sète and Marseillan, France. A crucial project involves managed retreat of the coastal road and restoration efforts for beaches and dunes to address current and future erosion, preserving the ecological balance of this fragile coastal system.

Implementing coastal setbacks enhances safety, expands beach capacity, and fosters economic activities, thereby serving as a valuable resource for both local populations and tourism. Moreover, coastal setbacks improve tourism offerings, potentially increasing overall revenue, while also benefiting hinterland residential and tourist capacities by providing convenient access to public facilities along the coast. The creation of a green belt along the beach further enhances comfort amid rising temperatures, offering open spaces for locals and visitors alike to enjoy. In essence, coastal setbacks represent a win-win solution, balancing environmental preservation, risk reduction, and socio-economic development along coastal areas.

5.4 INNOVATIVE SOLUTIONS FOR AGRICULTURE

The Mediterranean region faces a multitude of challenges in agriculture, exacerbated by climate change, population growth, contamination, and land degradation. To address these challenges and promote sustainable agriculture, innovative planning approaches are imperative. This segment explores the unique agricultural challenges in the Mediterranean coastal zone and outlines best practices and future strategies, including diversified crop cultivation, soil conservation, regenerative agriculture, agroforestry, organic farming, and water management. It emphasizes the importance of integrating agroecological principles and traditional knowledge to ensure long-term agricultural sustainability.

The Mediterranean coastal zone is a region of immense ecological and agricultural significance. However, it is beset with a host of challenges, including water scarcity (agriculture is the largest consumer of water in the Mediterranean), groundwater salinization, soil degradation, resource depletion (e.g. the issue of phosphorus) and climate change impacts. In the face of these pressing issues, innovative planning in agriculture is essential to ensure food security, environmental preservation, and the well-being of local communities.

To address all these challenges, innovative planning strategies are crucial. Moving away from monoculture towards **diversified crop cultivation** reduces the risk of pests and diseases, enhances soil health, and improves overall resilience. Implementing reduced tillage, cover cropping, and organic matter addition practices helps improve soil fertility, structure, and moisture retention. Efficient water storage and distribution systems, coupled with the use of drought-resistant crop varieties, are vital for sustainable **water management**. Prioritizing **organic farming** practices improves soil health, reduces synthetic inputs, and supports biodiversity. Promoting **agroecology** principles, including minimal soil disturbance, crop residue retention, and carbon sequestration, supports sustainable agriculture and biodiversity. One crucial observation is that natural ecosystems typically maintain **soil cover** with living or dead biomass. This practice sustains humus-rich, living soil and protects it from harsh climatic conditions, reducing soil disturbance, erosion, and degradation. Integrating tree planting and **agroforestry** systems into agriculture enhances soil quality, provides shade, and increases biodiversity. Also, agroforestry systems have proven to be more resilient to climate change impacts, adapting better to temperature fluctuations, droughts, and biotic stresses. They contribute to enhanced sustainability and resource efficiency in agriculture. Implementing **erosion control** measures, such as terracing and vegetation planting, prevents soil erosion and land degradation.

Finally, it is equally important to enhance the **capacity building**, i.e., providing farmers with access to information, climate-resilient technologies, and market insights enhances their knowledge and skills in sustainable agriculture. To foster innovative planning in Mediterranean agriculture, policymakers should consider these policy recommendations: promoting agroecology principles and soil regeneration;

encouraging the use of drought-resistant indigenous or traditional plant varieties; supporting farmers transitioning to organic agriculture; strengthening small farmers' livelihoods for food security; incorporating traditional knowledge into agricultural management; enhancing multidisciplinary research on sustainable agriculture; facilitating cross-sectoral and international cooperation.

Example: Within innovative initiatives, one can mention the Tour du Valat's agro-ecological project in the Gard Camargue that exemplifies innovative planning. It combines agro-ecology and permaculture principles to reduce chemical inputs, promote renewable resources, and enhance water use efficiency. The project monitors its impact on biodiversity, soil quality, carbon sequestration, and economics, emphasizing a holistic approach to sustainability.

The Mediterranean coastal zone is characterized by its unique blend of natural beauty, rich biodiversity, and cultural heritage. However, it is also a region susceptible to **desertification**, especially in areas where environmental stressors converge. Desertification, the process by which fertile land becomes desert due to various factors such as climate change, deforestation, and unsustainable land management, poses a significant threat to the Mediterranean coastal zone. This complex and multifaceted issue is influenced by a range of factors, including climate variability, land management practices, population pressure, and more. In the Mediterranean region, desertification and land degradation are most active or pronounced in specific areas that are particularly vulnerable to these processes. Here are some of the key factors contributing to desertification in the Mediterranean coastal zone:

Climate variability, including prolonged droughts and irregular rainfall patterns, exacerbates soil erosion and land degradation. The Mediterranean region is known for its semi-arid to arid climate, characterized by hot, dry summers and relatively mild, wetter winters. **Unsustainable land management practices**, such as overgrazing, deforestation, and improper agricultural techniques, contribute to soil depletion and erosion. **Rapid population growth** and urbanization in the coastal areas put additional pressure on the land and its resources. Increased construction, water demand, and tourism development can lead to habitat destruction and soil degradation. **Erosion**, a natural process, becomes problematic when it exceeds the soil's ability to regenerate. Coastal areas, with their fragile ecosystems, are particularly vulnerable to erosion caused by heavy rains and storms. The introduction of **invasive plant species** can disrupt native ecosystems, outcompeting native vegetation and contributing to land degradation.

To combat desertification in the Mediterranean coastal zone, a holistic approach that incorporates NbS is gaining momentum. NbS are sustainable land management practices that harness the power of nature to restore ecosystems, improve resilience, and mitigate the impacts of desertification. Here are some NbS strategies that can be employed in this region:

Reforestation and Afforestation: Silvicultural interventions involving the planting of native trees and shrubs can help restore degraded coastal areas. These trees provide essential ecosystem services, such as stabilizing soil, preventing erosion, and enhancing biodiversity.

Agroforestry: Integrating trees into agricultural landscapes through agroforestry practices can improve soil fertility, increase water retention, and provide farmers with additional income sources.

Sustainable Grazing: Implementing rotational grazing practices and restoring native grasslands can prevent overgrazing and soil compaction, thus preserving soil health.

Soil Conservation: Employing erosion control measures, such as terracing, contour farming, and planting cover crops, helps safeguard against soil erosion and land degradation.

Water Management: Implementing sustainable water management practices, including rainwater harvesting and the construction of check dams, can improve water availability and recharge aquifers.

Biodiversity Conservation: Protecting and restoring native ecosystems, such as coastal wetlands and dune systems, supports biodiversity and enhances ecosystem resilience.

Community Engagement: Involving local communities in sustainable land management practices and raising awareness about the importance of combating desertification is crucial for the success of NbS.

To effectively combat desertification, monitoring and assessment of land degradation processes and the impact of NbS are essential. Remote sensing technologies, Geographic Information Systems (GIS), and field surveys play a crucial role in evaluating the success of NbS interventions.

5.5 MITIGATING EROSION

Mitigating erosion in the Mediterranean coastal zone can be achieved by using NbS. Some of the strategies may include: restoring native vegetation cover helps stabilize soil, prevent erosion, and enhance biodiversity. Coastal forests and woodlands act as windbreaks, protecting against aeolian erosion. Further on, regulations play a crucial role: Enforce zoning and land-use regulations that protect coastal dunes and limit construction and development in vulnerable areas. Implement beach management practices that restrict access to dune areas and discourage activities like off-road vehicle use and sand mining, which exacerbate aeolian erosion.

Raise awareness among local communities and tourists about the importance of dune protection and responsible beach behaviour to prevent unnecessary disturbance. Continuously monitor coastal conditions and the effectiveness of erosion control measures. Adapt strategies as needed based on changing environmental factors.

Banquettes of *Posidonia* serve as nature-based coastal defences that enhance dune formation, stabilize coastlines, support biodiversity, and minimize beach erosion. However, these valuable ecosystems are often removed due to mismanagement practices and aesthetic concerns, despite their significant benefits.

5.6 REWILDING

Rewilding in the terrestrial part of the Mediterranean coastal zone represents a multifaceted conservation approach aimed at restoring natural habitats, reestablishing ecological processes, and enhancing biodiversity. This abstract explores the principles and practices of rewilding in this unique ecosystem, highlighting its potential to mitigate habitat degradation, promote species resilience, and foster sustainable land management practices. By reintroducing native species, managing ecosystems dynamically, and engaging local communities, rewilding initiatives in the Mediterranean coastal zone contribute to the preservation of biodiversity and the promotion of resilient ecosystems in the face of ongoing environmental challenges.

Figure 11: The coastal line of Scerni, Italy. It is a home to many plant species which have become rare on the rest of the Adriatic coast due to extensive urbanisation, habitat fragmentation and alteration. Recent rewilding projects to preserve endangered species and ecosystems and promote an eco-friendly tourism to rediscover, understand and conserve the genius loci - i.e., the innermost identity characteristic of the territory.

The Mediterranean coastal zone, with its captivating beauty and ecological significance, has long been a hub of human activity and industrialization. While these activities have brought economic growth, they have also left a trail of environmental degradation in their wake. Dismissed industrial activities have led to persistent pollution, posing threats to human health, biodiversity, and ecosystem functioning. However, in the spirit of rejuvenating these once-degraded landscapes, **brownfield reuse** has emerged as a promising solution.

Once perceived as liabilities, brownfields are now seen as opportunities. The concept of brownfield reuse entails repurposing these abandoned or underutilized industrial sites for new, sustainable uses. This approach not only reclaims land but also revitalizes communities and ecosystems. While brownfields reuse offers hope and opportunity, the success of these projects hinges on the integration of restoration plans. These plans serve as roadmaps for ecosystem revival, ensuring that the reclaimed land thrives as a healthy and functional habitat.

Environmental remediation and restoration are imperatives, and addressing the legacy of contamination in the Mediterranean coastal zone is a pressing need. Environmental remediation practices are essential to mitigate the immediate threats posed by brownfields. Remediation may involve soil and groundwater cleanup, containment of contaminants, and risk reduction measures to protect human health. However, a comprehensive approach extends beyond remediation. Restoration plans play a crucial role in reversing the degradation trend and restoring the ecological balance of these areas. Restoration aims to breathe new life into these landscapes, transforming them into vibrant and healthy ecosystems that can provide valuable goods and services to both nature and society.

Two prominent examples of brownfields reuse in the Mediterranean coastal zone can be mentioned. Barcelona’s iconic waterfront was once home to industrial facilities. Today, it has been transformed into a thriving cultural and recreational district, serving as a testament to the potential of brownfields reuse. The industrial legacy of Marseille's harbour has also been reimagined through ambitious urban renewal projects. These efforts have not only cleaned up polluted areas but have also given rise to innovative urban spaces.

5.7 NBS FOR CITIES

NbS are highly relevant and beneficial for coastal cities, as they provide effective ways to address various challenges associated with urban coastal areas. Two of the most widely applicable and impactful NbS for coastal cities are:

Natural Infrastructure: This approach supports natural systems and features to provide solutions for coastal flooding, erosion, and runoff. It often includes the protection and restoration of critical natural features like wetlands and sand dunes. Natural infrastructure mimics natural processes, such as the ability of wetlands to absorb and slow floodwaters, making it a cost-efficient and environmentally friendly way to safeguard coastal communities. As an example, wetlands can act as natural sponges, absorbing excess water during storms and helping to reduce flooding in urban areas.

Green Infrastructure involves the strategic planning and management of natural and semi-natural areas within urban environments to deliver a wide range of ecosystem services. This approach extends beyond traditional parks and green spaces to include features like porous pavements, green roofs, rain gardens, vegetated swales, and more. Green infrastructure helps manage stormwater, reduce urban heat island effects, improve air quality, and enhance overall urban resilience. It promotes the integration of nature within the urban fabric and fosters a more sustainable and liveable urban environment. Using this instance as a model, Alexandria implemented an extensive 70-kilometer-long belt of reeds.

Both NbS approaches align with the principles of sustainability and resilience, addressing not only environmental challenges but also improving the quality of life for urban residents. They contribute to the protection of biodiversity, enhancement of ecosystem services, and the creation of more accessible and enjoyable natural spaces within cities. In coastal cities, these NbS can play a crucial role in mitigating the impacts of climate change, including sea-level rise and increased storm events, while simultaneously enhancing the urban environment and the well-being of residents.

The United Nations Human Settlements Programme (UN-Habitat) plays an important role in promoting sustainable urbanization and addressing urban challenges in cities worldwide, including those situated along the Mediterranean coast. One of the critical strategies employed in this endeavour is the concept of green infrastructure, a thoughtfully designed network of natural and semi-natural areas integrated with environmental features.

This network is meticulously planned and managed to provide an array of ecosystem services, including water purification, air quality improvement, recreational spaces, climate change mitigation and adaptation, and effective management of wet weather impacts, all of which yield substantial community benefits.

Given that many urban areas are situated on low-lying coasts, higher dikes and seawalls are essential, though they may impact the landscape; repurposing them for everyday use, such as boardwalks or platforms, offers a pragmatic approach. Integrating green and blue solutions, tailored to local conditions, becomes crucial for managing water-related issues in coastal urban areas, contributing to flood resilience and minimizing structural damage caused by flooding. Techniques like flood proofing for new structures, while incurring higher costs, are deemed insignificant compared to the total cost of construction. Overall, long-term, persistent efforts are necessary to minimize risks and damages, considering the baseline level will be higher than the current level, including the groundwater level.

Figure 12: Barcelona, Spain: The municipality of Barcelona is actively promoting significant transformations in urban and natural spaces by utilizing a range of tools aimed at enhancing urban ecology and bolstering biodiversity within the city. This strategic initiative seeks to fortify Barcelona's network of urban green spaces and enhance its resilience.

Green infrastructure offers an effective solution to mitigate the **urban heat island effect** in coastal cities. This approach involves the strategic integration of natural elements into urban areas to create a more sustainable and resilient environment. Greened surfaces have a higher albedo (20-30 %) than artificial surfaces (5 %), contributing to reducing the UHI effect by reflecting more light (Castellari and Davis, 2021). Introducing parks, green corridors, public gardens and urban forests into urban landscapes provides areas for shade and reduces the UHI effect. These spaces offer residents respite from high temperatures and enhance the overall quality of life in cities.

Installing **green roofs**, covered with vegetation and soil, on buildings helps reduce heat absorption and provides insulation. Green roofs can significantly lower indoor temperatures, reduce energy consumption for cooling, and extend the lifespan of roofing materials. Choosing heat-tolerant and drought-resistant plant species for landscaping can reduce the need for excessive watering and maintenance, promoting sustainability.

The incorporation of green infrastructure into urban planning fosters biodiversity in cities. Green spaces, particularly those enriched with a diverse range of trees and plants, serve as vital habitats for various species. These green corridors offer connectivity for wildlife, facilitating movement and promoting genetic diversity. Thus, urban greening has the power to transform concrete jungles into vibrant ecosystems teeming with life.

A notable example of how a national park can adjoin a large city and provide valuable natural habitats and experiences for urban populations can be found in the Calanques National Park in France. Such urban protected areas play a unique role in connecting people to nature and promoting conservation in an urban context.

5.7.1 SOLUTIONS FOR RAINWATER IN CITIES

As noted by famous roman naturalist Pliny two millennia ago, when watersheds were deforested, the result was ruinous: "Often indeed devastating torrents unite when from the hills has been cut away the woods that used to hold the rains and absorb them." In recent years, an increasing collection of evidence has pointed to floods and flood-related disasters as the most frequent and destructive forms of catastrophes affecting economies and communities worldwide, surpassing other types of natural disasters (EEA, 2012; EEA, 2016; IPCC, 2012). Historically, responses to these challenges have primarily centred on the deployment of conventional, hard, or engineered solutions, collectively referred to as *grey infrastructure*. These solutions encompass a spectrum of measures, including the construction of pipes, canals, tunnels, dikes, and similar physical structures designed to mitigate flood risks.

While grey infrastructure has been the preferred method and a common choice for flood management, there is a growing recognition that its reliance on hard-engineered materials has fostered a deceptive sense of security. Many governments and communities have come to place complete reliance on these structures, assuming they provide infallible protection against floods. Unfortunately, when these engineered solutions falter, communities often find themselves inadequately equipped to contend with the consequences. A multitude of scientists and experts have precisely examined the efficacy of such infrastructure and arrived at a sobering conclusion: the prevailing grey infrastructure approaches have proven inadequate in delivering the level of flood protection required. Beyond their inefficiency, they have raised concerns regarding cost-effectiveness and environmental sustainability. As we dive into this chapter, we will explore the need for a fundamental shift in our approach to flood management, one that embraces innovative, sustainable, and holistic solutions in place of the traditional grey infrastructure paradigm.

Mitigating water challenges and promoting resilience: The rapid urbanization of coastal Mediterranean cities has led to the widespread use of concrete and asphalt, covering natural soil and disrupting the natural flow of water. Rainwater, often perceived as a nuisance, is hastily channelled into underground systems, thereby missing the opportunity to serve as a valuable resource. It is important to address the challenges posed by traditional rainwater management practices, the potential losses incurred, and the alternative approach of **Sustainable Urban Drainage Systems (SUDS)** in the coastal Mediterranean context.

Urban expansion, particularly in unplanned cities, has resulted in the replacement of natural landscapes with impermeable surfaces. This shift prevents water from penetrating the ground and disrupts the delicate balance between surface and groundwater. The prevailing tendency is to swiftly remove rainwater from urban areas, effectively cutting short its journey through the environment. However, this approach raises several critical questions: What are the consequences of prematurely ejecting water from our surroundings? How can we manage excess rainwater when our drainage systems are overwhelmed? Are there cost-effective alternatives to conventional "grey" infrastructure solutions, both in construction and maintenance?

SUDS offer a compelling solution to these challenges by encompassing a range of practices and infrastructure designs specifically tailored to urban and suburban areas. Their primary objective is to manage surface water runoff effectively while simultaneously reducing the risks associated with flooding, erosion, and water pollution. What sets SUDS apart is their commitment to mimicking natural drainage processes, thereby promoting sustainability and environmental protection.

A fundamental principle of SUDS is promoting the use of permeable surfaces. These include permeable pavements, porous asphalt, and gravel, all designed to enable rainwater to infiltrate into the ground rather than rapidly running off into stormwater drains. By facilitating the natural process of water absorption by the soil, SUDS reduce the volume and speed of surface water runoff, mitigating the risk of flooding during heavy rain events. Rain gardens and similar features in SUDS act as retention basins, temporarily holding rainwater before releasing it slowly. In cases where the subsoil is already saturated or the water table is elevated due to previous precipitation, these retention features ensure that excess water is held back. Once the subsoil can accept more water, the stored rainwater is gradually released, reducing the burden on drainage systems.

The coastal Mediterranean region faces unique water challenges. Increasingly unpredictable weather patterns and the impacts of climate change have brought about more intense rainfall during the winter months. This presents an opportunity to leverage SUDS in a region where water scarcity is a recurrent issue. Coastal cities in the Mediterranean are prone to heat islands, areas with significantly higher temperatures compared to their surroundings. SUDS can play an important role in addressing this problem by helping to regulate temperature differences between day and night. Rainwater, when retained and used for irrigation or cooling purposes, can help reduce excessive heat, creating a more comfortable urban environment.

SUDS also contribute to biodiversity conservation in urban areas. By creating permeable surfaces and green spaces, SUDS offer habitats for various plant and animal species. These areas can act as refuges for urban wildlife, providing breeding grounds, feeding opportunities, and migration corridors. Successful implementation of SUDS relies on community engagement and stewardship. Local authorities, communities, and organizations all have a role to play in monitoring, maintaining, and enhancing these systems. Educational programs and cleanup initiatives can foster a sense of ownership and responsibility, ensuring the long-term sustainability of SUDS.

5.7.2 OLD TREES PROTECTION

Trees are forms of plants that are currently some of the largest living species on this planet. Over millennia, for approximately 390 million years, they have constantly been adapting and co-evolving through many demanding epochs in the Earth’s history. Throughout the more recent history of humankind, trees have been perceived as a sacred element but also as a means of survival in hostile environments as people used trees as a source of food and construction material, as well as heating resources. By accommodating their specific needs, humans might have suppressed the features that could be important in future environmental adaptation processes. Current practice in tree management raises awareness of the previously often-neglected functions that trees provide, and with an understanding of how trees interact with the broader environment, we can support both natural processes and an array of beneficial interactions and incite these positive attitude changes within our communities and widespread society (Lonsdale (Ed.), 2013).

Throughout history, forests and trees have shown remarkable potential for adaptation to harsh and often unforgiving environments. Winds, frosts, fires, earthquakes, human activity, and water (San-Miguel-Ayanz, de Rigo, Caudullo, Houston Durrant, & Mauri, (Eds.), 2016) are among the main driving forces behind this diversity and alongside many other powerful natural disturbances, they play important role in shaping the face of our planet. Variety in landscape diversity sustains an array of specific niches that were consequently inhabited by various organisms and these cohabitations have had both positive and negative influences on the inhabiting specialised micro stands. That interaction in a vast landscape resulted in a dynamic mosaic that has shaped tree species, companion species but also the wider ecosystem as well.

The natural balance among species relies on fulfilling essential functions intertwined in a complex web of reciprocal needs. Trees exemplify this, appearing solitary but actually engaging in numerous interactions above and below ground. Recent attention has focused on interactions among trees, roots, and soil organisms, particularly via mycorrhizal fungi connections. Interactions between soil bacteria, wood-decomposing fungi, nematodes, and other beneficial microorganisms consist specific food chain (Elevitch, 2004) that makes it possible for the soil to accumulate organic matter, capture carbon, and also build the soil structure which is essential for wellbeing of plants. In the same way, disturbances that are altering the growing conditions in the soil can induce oxygen deficiencies and support different sets of microbial activity that can affect trees in a detrimental way of water or sugar insufficiency, irreversible damage and consequently death (Hirons & Thomas, 2017).

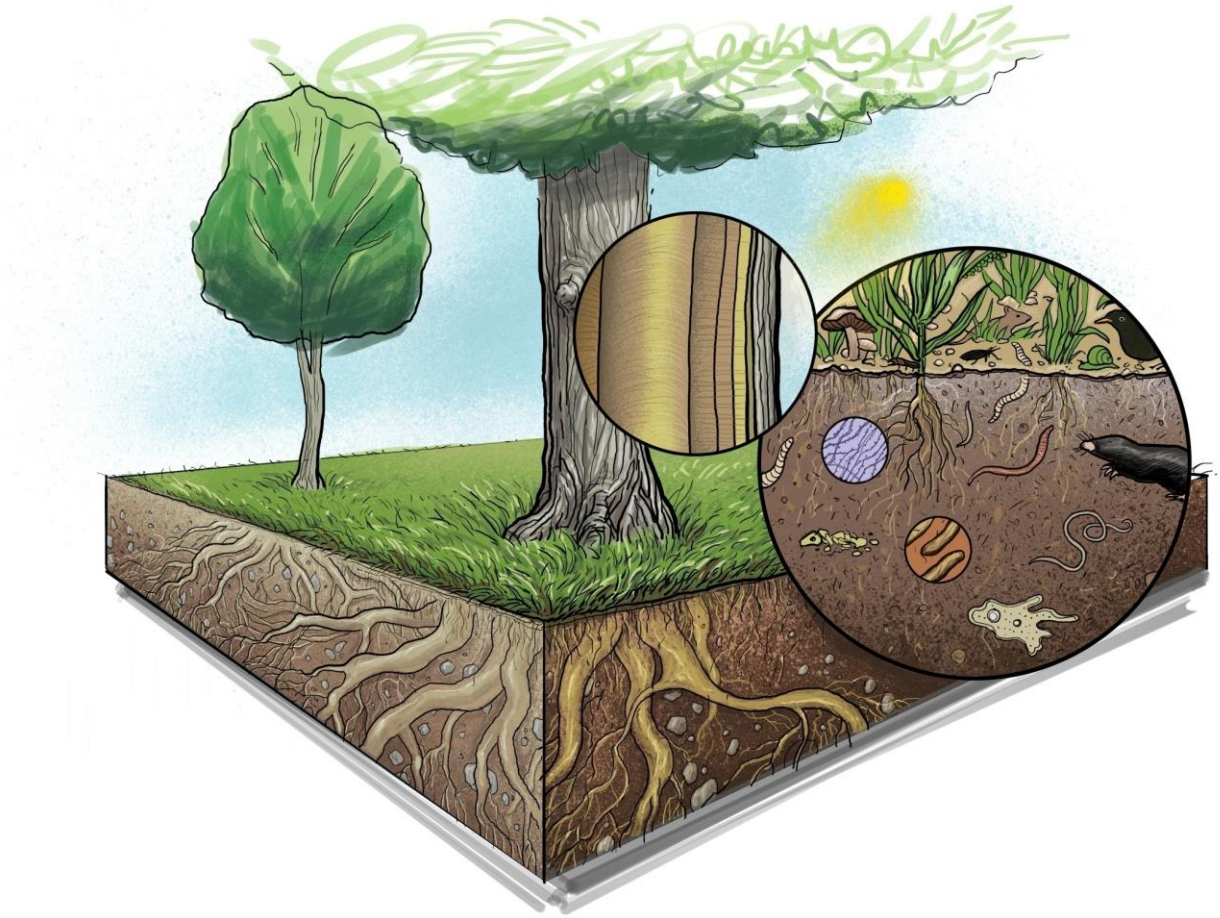


Figure 13: Natural equilibrium is sustained by the intricate interconnectedness of various species, exemplified by tree interactions above and below ground. Recent focus on root interactions highlights the active support trees provide through root leaching, fostering dynamic relationships with soil microorganisms, ultimately contributing to essential habitats and ecosystems.

Below-ground interactions are indeed essential for tree longevity but above-ground interactions with the microbiome are equally important. Recent studies reveal that microbes reside not only on but also within wood tissues, transitioning between latent and active states based on environmental conditions (Boddy, 2021). While some interactions may be pathogenic, many are chronic, fostering complex cohabitations that create essential habitats over long periods. (Read, 2000). For instance, the metabolic processes of heart rot fungi facilitate the formation of cavities, which become homes for rodents and birds. These creatures then aid in seed dispersal and introduce bacteria necessary for seed dormancy removal, vital for new tree establishment. Disrupting any link in this chain can have far-reaching consequences, highlighting the interconnectedness of ecosystems. (Colak, Kirca, & Rotherham (Eds.), 2023).

In order to understand all these interactions, we should more thoroughly examine the longstanding cohabitation patterns and correlated factors that promote typical behaviour between different species. Moreover, recent studies have unveiled that recorded interactions between organisms are changing under the influence of the changing environment. Therefore, it is of utmost importance to prevent untested means and *ad hoc* management methods. To minimise the potential negative impact that management approach can have on a wide-scale ecosystem, it is essential to focus even on the smallest details as they can sometimes be the key to long-term success in ecosystem restoration.

Soil compaction and pavement/asphalting induce strong negative influence on soil biological activity. Both of those interventions negatively impact oxygen, nutrient, and water inflow in deeper rhizosphere zone what results in altering the microbiome species composition, their interactions and metabolic activity around plant roots. As a mitigation measure, especially with highly valuable trees, along with de-paving practice, it is advisable to establish a mulching zone in the tree crown projection area. Mulching zone should be 8 -10 cm in total thickness and 10 cm offset from the tree bark. In an ideal scenario, depending on tree species, mulch should consist of local and same species chopped leaves and small shoots (15 -35 % of absolute mulch volume) and the rest volume of wood chips. This practice could prevent further compaction and cover diverse food sources for wide array of specialised beneficial microorganisms.

5.7.3 INTENTIONALY UNMANAGED AREAS

Intentionally unmanaged green areas, often referred to as "wild" or "natural" spaces, are ecosystems left to evolve without direct human intervention. These areas provide crucial ecological benefits, including habitat preservation, carbon sequestration, and recreational opportunities. However, they also present challenges such as invasive species and wildfire risk. Striking a balance between conservation and safety is essential, with local communities and organizations playing a vital role in their stewardship. In an increasingly urbanized world, the value of intentionally unmanaged green areas cannot be overstated. These spaces, where ecosystems are allowed to thrive without intensive human control, serve as vital reservoirs of biodiversity and provide numerous ecosystem services.

One of the primary ecological roles of intentionally unmanaged green areas is their contribution to biodiversity conservation. These spaces provide a refuge for a wide range of plant and animal species, many of which may not thrive in heavily managed or urbanized environments. By allowing natural processes to occur, such as plant succession and ecological interactions, unmanaged green areas become critical habitats for native flora and fauna. In some instances, such areas can also become part of ecological restoration efforts. These spaces may have been previously disturbed or degraded by human activities, and allowing them to return to a more natural state is essential for ecosystem recovery. Ecological restoration often involves the removal of invasive species, the reestablishment of native vegetation, and the promotion of natural ecological processes, all of which can be facilitated in unmanaged areas.

The benefits of these areas extend beyond their immediate boundaries. They provide critical ecosystem services, such as carbon sequestration, air and water purification, and support for pollinators and wildlife, services that can contribute to improved air quality, climate regulation, and overall ecological health. They also act as natural buffers, enhancing the resilience of surrounding ecosystems and urban areas. Incorporating unmanaged green areas into urban planning can create natural oases within cities. Moreover, such areas require minimal maintenance compared to manicured landscapes, reducing the need for resource-intensive practices such as mowing and pesticide use.

While the ecological benefits of unmanaged green areas are substantial, they present specific challenges: Unmanaged areas may be susceptible to the encroachment of invasive species, which can threaten native flora and fauna. Vigilant monitoring and management efforts are necessary to control invasive species and prevent their establishment. Further, the accumulation of biomass in such areas can increase the risk of wildfires, posing a threat to nearby communities and ecosystems. Fire management strategies must be employed to mitigate this risk while respecting the natural role of fire in certain ecosystems. Rapid urban development can also represent a significant threat to unmanaged green areas as it can encroach upon them, reducing their size and ecological value. Effective land-use planning and conservation efforts are essential to safeguard these spaces.

One promising avenue for promoting **pollinator conservation** in the Mediterranean coastal zone is the integration of urban biodiversity initiatives. Urban areas, often characterized by concrete jungles, have untapped potential to contribute to pollinator-friendly habitats. Planting melliferous plants in public green spaces is one such strategy. These plants, which produce nectar and pollen, attract pollinators and create a network of sustenance within urban environments. Additionally, the presence of pollinators indirectly draws other organisms that feed on them or the plants themselves, enriching urban biodiversity. Urban green spaces that support pollinators also exhibit increased resilience to environmental stressors. These spaces are better equipped to withstand weather extremes, resist plant diseases, and control the spread of invasive species.

Thus, nurturing urban biodiversity pays dividends beyond pollinator conservation. When planning urban landscapes, several factors should be considered to maximize their pollinator-friendly potential. These include selecting native plant species whenever possible, avoiding the planting of invasive species, and accounting for the dimensions and water needs of mature plants. Prioritizing native flora not only benefits pollinators but also reduces the need for intensive maintenance, irrigation, and pesticide use. Maintaining existing landscape features is equally important. Old trees, hedges, drystone walls, and water elements are essential components of urban biodiversity. Preserving these features fosters a sense of continuity with the natural world and supports diverse ecosystems within urban areas. The preservation of pollinators in the Mediterranean coastal zone is a vital component of rewilding efforts and broader biodiversity conservation initiatives.

Local communities and organizations play a pivotal role in the stewardship of intentionally unmanaged green areas. Their involvement through monitoring, cleanup efforts, and educational programs is crucial for the preservation and responsible management of these ecosystems. Community engagement fosters a sense of ownership and responsibility, ensuring that these areas continue to thrive for generations to come. Unmanaged green areas offer valuable educational and recreational opportunities for the public. People can visit these spaces to observe natural processes, learn about local ecosystems, and connect with the environment. They serve as outdoor classrooms where individuals, particularly children, can develop a deeper appreciation for nature and conservation. Additionally, these areas provide opportunities for hiking, birdwatching, and other recreational activities that promote physical and mental well-being.

5.7.4 GREEN, BROWN AND BIODIVERSE ROOFS

In the quest for sustainable urban development, innovative solutions continue to emerge, reshaping the way we view and utilize rooftops. **Green roofs**, often referred to as vegetated roofs or living roofs, are a remarkable fusion of architecture and ecology. These rooftop ecosystems are intentionally designed to support a thriving layer of vegetation, which can include grasses, sedums, or other low-maintenance plants. Green roofs are not just patches of greenery; they are precisely crafted systems with several key components. First, a robust waterproof membrane forms the foundation of the green roof, ensuring that moisture does not penetrate the building. Above this membrane lies the drainage layer, which facilitates the controlled flow of excess water, preventing waterlogging. A specialized growing medium, essentially a carefully engineered soil substitute, provides essential nutrients and support for the rooftop vegetation. Finally, the rooftop is adorned with a carefully curated selection of plants that can thrive in this unique environment.

In contrast to the planned green roofs, **brown roofs** take a more *laissez-faire* approach to rooftop ecosystems. These roofs are designed to develop and evolve naturally over time, with minimal human intervention. Initially, they may consist of a simple substrate, often gravel or crushed brick, with little to no vegetation. The life-secret of brown roofs lies in their organic transformation as nature reclaims these spaces. Brown roofs may start as barren expanses, but they gradually become biodiverse spots as seeds are carried by wind or birds, taking root and colonizing the substrate. In essence, brown roofs are blank canvases upon which nature paints, with each rooftop taking on a unique character. What truly sets brown roofs apart is their low maintenance requirements. Unlike green roofs, which necessitate regular care and maintenance, brown roofs are left to their own devices, requiring minimal human intervention. This makes them a cost-effective and sustainable option for building owners who prefer a more hands-off approach to rooftop ecology.

Biodiverse roofs represent the culmination of rooftop habitat creation. These specialized roofing systems are precisely designed to maximize biodiversity and provide a thriving habitat for a wide range of species. They go beyond the traditional green or brown roof by incorporating an extensive array of planting materials, including native plants, wildflowers, and even small trees. The key goal of biodiverse roofs is to mimic natural ecosystems in urban settings. By carefully selecting plant species that attract pollinators, insects, and birds, these roofs become thriving biodiversity hotspots. The variety of plant life, combined with the intentional design of these roofs, fosters a diverse range of species and ecological interactions. Biodiverse roofs not only contribute to urban biodiversity but also provide valuable ecosystem services. They enhance pollination, support beneficial insects, and can even offer green spaces for city residents. These multifaceted benefits make biodiverse roofs a powerful tool for urban sustainability and ecological conservation.

Vegetated roofing systems are transforming urban landscapes by integrating nature into the built environment. Green roofs provide a controlled oasis of greenery, brown roofs allow nature to reclaim urban spaces, and biodiverse roofs maximize biodiversity and ecological interactions. Each of these systems represents a step toward a more sustainable and harmonious coexistence between cities and the natural world.

5.8 SOLUTIONS FOR WILDFIRE PREVENTION

Despite the resilience of many Mediterranean plants, the habitats are to a lesser or greater degree affected by increasing fire frequencies. It is therefore imperative to define the fire vulnerability of the different habitats in a region; develop fire risk and action planning in all lowland and other populated areas; and reduce the imminent danger in high-risk environments by appropriate landscape management and settlement development, awareness raising, surveillance, and provision of fire protecting and fighting equipment as well as controlled burning knowhow.

Fire prevention measures must target all sectors of the population and all landscapes. Most serious fires occur in the wildland-urban interface, where built settlements are either inside or adjacent to wildland vegetation. The population in such areas is most affected by and at high risk of, wildfires. Landscape monitoring is essential to determine wildfire hazards, areas in need of controlled burning, and regeneration success of burnt areas. Natural regeneration is to be promoted and, when necessary, seeding or planting should be performed with material collected locally from native tree populations.

Targeting woodlands of native tree species for multipurpose use as a substitute for plantations with pines or exotic trees should imply various native oak species in Mediterranean lowlands. Oaks should be selected from the local species pool, to ensure genetic resources of well-adapted local tree populations. The area's vegetation history in the recent past may yield basic information. It would therefore be advisable to develop regionalized nurseries for the tree species of Mediterranean woodlands to conserve the species' genetic variability and to make them available for local-scale restoration purposes whenever needed.

A vegetation mosaic of groves, structurally diverse cropland, coppice woods and half-open land developed and maintained as wood pasture can be achieved by silvicultural measures, taking into consideration local ecological factors (i.e., soil, geomorphology). Such vegetation mosaics prevent the spread of fires and at the same time enhance biodiversity. Woodland management planning involving fire prevention must take into consideration social preferences and local land-use practices (Varela et al. 2014, 2018). Forest management aiming at the reduction of fuel biomass and promoting traditional practices such as wood pasture is to be encouraged. Political agendas should motivate land management, not land abandonment; rural land-use, not land consumption. This involves reasonable agriculture, multiple-use forestry, agro-tourist policy where possible, and maintenance of inland and groundwater resources.

Mediterranean habitats most sensitive to wildland fires are those with high amounts of combustive material and with limited resilience. The degree of combustibility depends largely on the accumulation of dry litter and plant biomass. This is particularly high in coniferous woodland and plantations as well as in unmanaged sclerophyllous shrubland. Woodlands of pine (*Pinus*) species are fire-prone but may regenerate after burning by reseeding from a cone seed bank, provided that seedlings in their first years are sufficiently water-supplied. Successful fire prevention in the Mediterranean depends much on inland waters, such as streams, water springs and seasonal pools, and on groundwater resources. Such wetlands provide an array of different habitats, all of which being less sensitive to wildfires. In the lowlands and especially in wildland-urban interface regions the effects of groundwater drawdown and dumping of small water-bodies have led to more serious fire hazards. Conservation targets regarding habitats close to populated areas must include the reduction of litter accumulation which in rural areas includes the support and revival of traditional pastoralist systems. Fire-prone tree plantations of pines, cypresses and exotic trees have to be replaced by open Mediterranean oak woodland, especially in peri-urban areas. Woodlands with ancient oaks combine fire resistance with biodiversity promotion (Bergmeier et al. 2021).

5.9 CITIZEN SCIENCE and NbS

NbS are a flexible and innovative approach to addressing various societal challenges, drawing inspiration from nature's resilience and adaptability. They encompass concepts such as 'ecosystem services' and 'blue-green infrastructure,' offering sustainable solutions for environmental and biodiversity issues. Citizen science, on the other hand, engages ordinary citizens in scientific research and data collection, leveraging their enthusiasm and dedication to contribute valuable data to various scientific studies and environmental monitoring efforts. This chapter explores the intersection of citizen science and NbS, highlighting their collaborative potential in advancing environmental conservation and achieving Sustainable Development Goals (SDGs).

Citizen science empowers individuals, communities, and organizations to actively participate in scientific research and environmental monitoring. Volunteers, often with limited scientific backgrounds, become citizen scientists, taking an active role in data collection, analysis, and the creation of a collective body of knowledge. This inclusive approach has significant implications for environmental conservation and sustainable development.

Citizen science encompasses a wide range of activities related to environmental and biodiversity monitoring. Volunteers can engage in various projects, including:

Citizen scientists can **monitor local ecosystems**, tracking changes in plant and animal populations, habitat conditions, and biodiversity levels. Volunteers can **measure air and water quality parameters**, identify ollution sources and contribute to environmental health assessments. They can also help **track wildlife migrations**, behaviour patterns, and population dynamics, contributing essential data for conservation efforts. Volunteers can actively **participate in restoration projects**, assessing the success of reforestation, wetland restoration, and other NbS initiatives.

The engagement of citizens in scientific research aligns with several SDGs related to environmental conservation and sustainable development:

SDG 13: Climate Action: Citizen science supports climate action by gathering data on climate change impacts, local weather patterns, and carbon sequestration in natural habitats.

SDG 14: Life Below Water and **SDG 15**: Life on Land: Monitoring aquatic and terrestrial ecosystems helps protect biodiversity and preserve marine and terrestrial life.

SDG 6: Clean Water and Sanitation: Citizen science contributes to clean water initiatives by monitoring water quality and identifying pollution sources.

SDG 11: Sustainable Cities and Communities: Engaging citizens in urban biodiversity projects fosters community involvement in sustainability efforts, promoting healthier and more sustainable urban environments.

Citizen science is particularly valuable in the planning and implementation of NbS:

Volunteers can help with **site identification**, i.e., by identifying suitable locations for NbS interventions, such as tree planting, wetland restoration, or green infrastructure projects. Citizen scientists play a crucial role in **monitoring** the progress and success of NbS initiatives. They track changes in biodiversity, ecosystem health, and the impact of NbS on local communities. Citizen science projects **raise awareness** about environmental issues and promote public engagement in sustainability efforts. This increased awareness often translates into stronger support for NbS and related SDGs. Data collected through citizen science can inform policy decisions at local, national, and international levels, thus contributing to **evidence-based policy.** Policymakers can use this evidence to make informed choices about NbS implementation and its alignment with SDGs.

Citizen science and NbS are powerful allies in the quest for environmental conservation and sustainable development. By engaging citizens in scientific research and data collection, citizen science harnesses the collective knowledge and enthusiasm of volunteers. This approach supports NbS by identifying suitable sites, monitoring progress, raising awareness, and contributing to evidence-based policymaking. Together, citizen science and NbS form a dynamic partnership that empowers communities and fosters a sense of ownership and responsibility for local ecosystems, ultimately advancing the achievement of SDGs related to environmental protection and climate action.

CONTRIBUTORS:

Coastal Typology – Gonzalo Malvarez
Wetlands – Alessio Satta
Dunes – Javier Loidi
Forests and Woodlands – Ali Kavgaci
Coastal Aquifers – Jose Luis Bordes
Urban heat islands, marine heat waves – Ivan Sekovski
Invasive species – Alicia Acosta
Wildfires – Erwin Bergmeier
Old trees protection – Fran Poštenjak

6. KEY REFERENCES

Acosta, A., Ercole, S., Stanisci, A., Pillar, V. D. P. & Blasi, C. 2007. Coastal vegetation zonation and dune morphology in some Mediterranean ecosystems. *Journal of Coastal Research* 23(6), 1518-1524.

Bergmeier E., Capelo J., Di Pietro R., Guarino R., Kavgacı A., Loidi J., Tsiripidis I. & Xystrakis F. 2021: 'Back to the Future'—Oak wood-pasture for wildfire prevention in the Mediterranean. Plant Sociology 58(2): 41–48. DOI 10.3897/pls2021582/04

Boddy, L., 2021: "Fungi and Trees: Their complex relationships", Arboricultural Association, Stroud, 306 pp

Bonari, G., Fernández-González, F., Çoban, S., Monteiro-Henriques, T., Bergmeier, E., Didukh, Y.P. *et al.* (2021) Classification of the Mediterranean lowland to submontane pine forest vegetation. *Applied Vegetation Science*, 24, e12544. https://doi.org/10.1111/avsc.12544

Cao Pinna, L., Axmanová, I., Chytrý, M., Malavasi, M., Acosta, A. T. R., Giulio, S., Attorre, F., Bergmeier, E., Biurrun, I., Campos, J. A., Font, X., Küzmič, F., Landucci, F., Marcenò, C., Rodríguez-Rojo, M. P., & Carboni, M. 2020. The biogeography of alien plant invasions in the Mediterranean Basin. Journal of Vegetation Science, 32(2), e12980

Campoy, J.G, Acosta A.T.R, Affre L., Barreiro R., Brundu G., Buisson E., et al. 2018. Monographs of invasive plants in Europe: Carpobrotus. Botany Letters 165(3–4): 440–475.

Čarni, A., Matevski, V., Kostadinovski, M., Ćušterevska, R. (2018) Scrub communities along a climatic gradient in the southern Balkans: maquis, pseudomaquis and shibljak. *Plant Biosystems*, 152, 1165–1171. https://doi.org/10.1080/11263504.2018.1435567

Castellari,S and Davis, M (2021). "Global and European policy frameworks" Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction. EEA Report No 1/2021.

Chytrý, M., Tichý, L., Hennekens, S.M., Knollová, I., Janssen, J.A.M., Rodwell, J.S. *et al.* (2020) EUNIS habitat classification: Expert system, characteristic species combinations and distribution maps of European habitats. *Applied Vegetation Science*, 23, 648–675. https://doi.org/10.1111/avsc.12519

Cohen-Shacham, E., Walters, G., Janzen, Cutard Maginnis, S. (eds.) 2016.. Nature based solutions to address global societal challenges. Gland, Switzerland: IUCN

Colak, H., A., Kirca, S., Rotherham, D., I. (Eds.), 2023, "Ancient Woods, Trees and Forests: Ecology, History and Management", Pelagic Publishing, London, 488 pp

Díez-Garretas, B., Asensi, A. & Gavilán, R. 2003. Sabulicolous therophytic plant communities in the Mediterranean Region: a proposal of phytosociological synthesis. *Phytocoenologia* 33 (2-3): 495-526.

Doing, H. 1985. Coastal fore-dune zonation and succession in various parts of the world. In *Ecology of coastal vegetation: Proceedings of a Symposium, Haamstede, March 21–25, 1983* (pp. 65-75). Springer, Netherlands.

Elevitch, R., C., (Ed.), 2004: "The Overstory Book (2nd Edition): Cultivating Connections with Trees" Permanent Agriculture Resources, 548 pp

European Environmental Agency (EEA) (2019), 'Marine Messages II – Navigating the course towards clean, healthy and productive seas through implementation of an ecosystem-based approach'. EEA Report No 17/2019, at 34–44.

Giulio, S., Acosta, A.T.R., Carboni, M., Campos, J.A., Chytrý, M., Loidi, J., Pergl, J., Pyšek, P., Isermann, I., Janssen, J.A.M., Rodwell, J.S., Schaminée, J.H.J. & Marcenò, C. 2020. Alien flora across European coastal dunes. *Applied Vegetation Sci*ence 23: 317–327. https://doi.org/10.1111/avsc.12490

Gubbay, S. Sanders, N. Haynes T., Janssen J.A.M., Rodwell J.R., Nieto A., et al. 2016. European Red List of Habitats. Part 1. Marine Habitats. Luxembourg: Publications Office of the European Union.

Hirons, D., A., Thomas., A., P., 2017: "Applied Tree Biology", Willey Blackwell, Oxford, 411 pp

IPBES (2019): The Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Brondizio, E. S., Settele, J., Díaz, S. and Ngo, H. T. (eds.). IPBES secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.3831673

Janssen JAM, Rodwell JS, García Criado M, Gubbay S, Haynes T, Nieto A, et al. 2016. European Red List of Habitats. Part 2. Terrestrial and Freshwater Habitats. Luxembourg: Publications Office of the European Union.

JRC (European Union Joint Research Centre) 2023: Wildfires in the Mediterranean: monitoring the impact, helping the response. https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/wildfires-mediterranean-monitoring-impact-helping-response-2023-07-28_en.

Kavgacı, A, Balpınar, N, Öner, H. H., Arslan, M., Bonari, G., Chytrý, M., Čarni, A. 2021: Classification of forest and shrubland vegetation in Mediterranean Turkey. Applied Vegetation Science 24:e12589. https://doi.org/10.1111/avsc.12589

Lonsdale, D. (Ed.), 2013: "Ancient and other veteran trees: further guidance on management", The Tree Council, London, 212pp

Mediterranean ecosystem restoration sites, Interreg Mediterranean Biodiversity Protection Community project, 2023, PlanBleu

Marcenò, C., Guarino, R., Loidi, J., Herrera, M., Isermann, M., Knollová, I., Tichý, L., Tzonev, R.T., Acosta, A.T.R.,

PAP/RAC (2021) "Coastal Resilience Handbook for the Adriatic", INTERREG AdriAdapt project, Split

FitzPatrick, Ú., Jakushenko, D., Janssen, J.A.M., Jiménez-Alfaro, B., Kącki, Z., Keizer-Sedlákova, I. Kolomiychuk, V.,

Rodwell, J.S., Schaminée, J.H.J., Šilk, U. & Chytrý, M. (2018). Classification of European and Mediterranean coastal dune vegetation. *Applied Vegetation Science* 21(3): 533-559. https://doi.org/10.1111/avsc.12379

MedECC (2020) Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report [Cramer, W., Guiot, J., Marini, K. (eds.)]. Union for the Mediterranean, Plan Bleu, UNEP/MAP, Marseille

Mittermeier, R.A., Turner, W.R., Larsen, F.W., Brooks, T.M. and Gascon, C. (2011) Global biodiversity conservation: the critical role of hotspots. In: Zachos, F.E. & Habel, J.C. (Eds), Biodiversity Hotspots. Heidelberg: Springer, pp. 3–22.

Mucina, L., Bültmann, H., Dierßen, K., Theurillat, J.P., Raus, T., Čarni, A. *et al.* (2016) Vegetation of Europe: Hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. *Applied Vegetation Science*, 19, 3-264. https://doi.org/10.1111/avsc.12257

Ne’eman G., Lev-Yadun S. & Arianoutsou M. 2012: Fire-related traits in Mediterranean Basin plants. Israel Journal of Ecology & Evolution 58:177-194.

Pausas J.G., Llovet J., Rodrigo A. & Vallejo, R. 2008: Are wildfires a disaster in the Mediterranean basin? - A review. International Journal of Wildland Fire 2008, 17, 713–723. DOI: 10.1071/WF07151.

Read, H., 2000: ”Veteran Trees: A guide to good management”, English Nature, London, 176 pp

San-Miguel-Ayanz, J., de Rigo, D., Caudullo, G., Houston Durrant, T., Mauri, A. (Eds.), 2016: “European Atlas of Forest Tree Species”, Publication Office of the European Union, Luxembourg, p- 5 - 36

Seebens, H., Essl, F., Dawson, W., Fuentes, N., Moser, D., Pergl, J. et al. (2015) Global trade will accelerate plant invasions in emerging economies under climate change. Global Change Biology, 21(11), 4128– 4140.

Turco M., Rosa-Cánovas J. J., Bedia J., Jerez S., Montávez J. P., Llasat M. C. & Provenzale A. 2018: Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with nonstationary climate-fire models. Nature Communications 9:3821. DOI: 10.1038/s41467-018-06358-z

UNEP/MAP 2012: State of the Mediterranean Marine and Coastal Environment, Athens

UNEP/MAP and Plan Bleu 2020: State of the Environment and Development in the Mediterranean, Nairobi

Varela E, Jacobsen JB, Soliño M (2014) Understanding the heterogeneity of social preferences for fire prevention management. Ecological Economics 106: 91–104. https://doi.org/10.1016/j.ecolecon.2014.07.014

Varela E., Górriz-Mifsud E, Ruiz-Mirazo J, López-i-Gelats F (2018) Payment for targeted grazing: integrating local shepherds into wildfire prevention. Forests 9(8): 464. https://doi.org/10.3390/f9080464

Zahran, M.A.; Willis, A.J. (2008). The Vegetation of Egypt. Springer Science & Business Media