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Coastal Resilience **Handbook** for the Adriatic

PAP/RAC

Coastal Resilience Handbook for the Adriatic

Note:

This handbook was prepared in 2021 within the framework of the INTERREG AdriAdapt project (www.adriadapt.eu) to provide local and regional authorities from the Croatian and Italian side of the Adriatic with ideas, solutions and measures that will help strengthen coastal resilience.

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Contents

List of figures

List of tables

List of boxes

Foreword

This handbook is a deliverable for the Interreg CBC Italy – Croatia project "AdriAdapt", which aims to provide recommendations, guidelines and practical advice for taking action in response to climate change impacts in coastal areas, cities and villages along the Adriatic coast. Given that such and similar challenges will become more intense in the coming years – investing in stronger resilience is the best investment in coastal areas.

Through the "AdriAdapt" project, the Priority Actions Programme/Regional Activity Centre (PAP/RAC) was given the opportunity to elaborate recommendations for strengthening resilience made in 2015 for the "Coastal Plan of the Šibenik-Knin County", prepared by Jure Margeta and Gojko Berlengi within the framework of the Global Environment Facility "MedPartnership" project. It was the first coastal plan focusing on climate change that was prepared after the Protocol on Integrated Coastal Zone Management in the Mediterranean[1] (ICZM Protocol) entered into force. The idea of the "AdriAdapt" project is to further expand and deepen the acquired insights and adapt them to the needs of local and regional governments across the Italian and Croatian side of the Adriatic coast. The Adriatic coastlines in Italy and Croatia are characterised by different morphological, geological, oceanographic, hydrological, ecological and socio-economic systems. This is why this handbook needs to be used according to the local characteristics of the natural and built environment. One of the most important differences between the Croatian and Italian coastlines is erosion, which has been a major problem on the Italian side of the Adriatic for decades. This is how Italy has gained extensive and valuable experience in the field, which will be beneficial to everyone, because those who have never faced coastal erosion before will have to face it at some point due to rising sea levels. During the preparation of the Coastal Plan – fires turned out to be the most immediate threat, as concluded at the series of workshops. The area of Šibenik-Knin County is specific because it is rich in vegetation, and because the fire spread rate is much faster. However, after the 2019–20 Australian bushfire season and as the World Meteorological Organization announced the higher risk of fires due to rising temperatures and droughts in January 2020, looking at the 2020 fire season as well as the one in 2021, we have every reason to believe that this danger should be particularly taken into consideration. One of the most important reasons for the poor response in dealing with fire that claimed 102 lives in the Greek coastal region of Attica in 2018 was informal construction that blocked escape routes. Many coastal areas along the Adriatic share this problem, as investors in tourist facilities tended to act faster than services in charge of controlling the implementation of spatial plans.

One of the biggest challenges in the future will likely be flooding, both from the sea and in combination with torrential floods and hinterland waters. An assessment of possible damage caused by sea level rise in the Republic of Croatia was made within the "MedPartnership" project. Problems related to asset flooding on low-lying shores are the result of the sea and other waters action, along with informal construction in flood-exposed areas that are left without adequate protection. Therefore, the problem should be addressed in an integrated way, through spatial management measures and the application of protection measures to mitigate the impact of the sea and inland waters. Furthermore, research has shown that the areas most at risk are not the most populated ones.[2] It is considered that the reason for this lies in the fact

[1] The Coastal Plan was adopted at the session of the County Assembly in April 2016. In 2019, at the largest European conference in Lisbon, Šibenik-Knin County was awarded the Mediterranean Adaptation Award for its Coastal Plan as the best project for adaptation to climate change in the Mediterranean. In the same year, Kaštela adopted its coastal plan, Split-Dalmatia County and the town of Vodice started the process, and Primorje-Gorski Kotar County announced it would start to prepare its coastal plan.

[2] The greatest damage is expected in the areas that have the highest concentration of real estate, regardless of whether they are residential properties or second homes for tourism.

that a large share of the property is not primarily built for housing, but rather for tourism, and that it is only used for a few months a year. It is difficult to give a clear answer on how to prioritise climate adaptation investments.

Dramatic flooding in Venice in November 2019, when more than 80% of the city was under water, as well as flooding in several areas along the Adriatic coast, keep warning us that we must start adaptation planning now.

It is also important to bear in mind that our failure to reduce greenhouse gas emissions may hinder the success of climate change adaptation. Therefore, each proposed measure has been considered from different angles in order to ensure that any action towards adaptation will simultaneously reduce emissions by means of an integrated approach and lead the way towards the only solution – the overall green transition of society.

1 Adriatic coast

The Adriatic Sea is the northernmost section of the Mediterranean Sea. It is surrounded by coasts of six countries: Albania, Bosnia and Herzegovina, Croatia, Italy, Montenegro and Slovenia. The coastlines of Croatia and Italy make around 90 percent of Adriatic coastline's length. While Croatian Adriatic coastline is the longest, extending 6,278 kilometres in length, of which the island part is 4,398 kilometres long (Duplančić *et al.*, 2004), the Italy's Adriatic coastline ranks second extending 1,272 kilometres in length (Blake *et al.*, 1996).

1.1 Geography, geology, nature and natural processes

The Croatian, eastern part of the Adriatic has the second most indented European coastline (Pikelj and Juračić, 2013). Most of its coast is characterised by karst topography and hydrology systems, with high and rocky coast, steep seabed and deep sea, almost devoid of beaches, especially sandy beaches. After the last Ice Age, melting of ice caused sea level to rise around 120 meters, which partially submerged the karst landscapes, and the "peaks" of what once were mountains became today's islands (Surić *et al.*, 2005). The Adriatic Sea contains more than 1,300 islands and islets, most of which in Croatia, with 1,246 counted (Duplančić *et al.*, 2004).

Unlike the Croatian part, the Italian western part of the Adriatic coast is relatively low-lying, smooth (with very few ledges and islands coastwide) and regular, especially in the northern part of the basin, whereas the coastal area south of the Gargano peninsula up to Otranto is dominated by rocks. The northern and central Adriatic seabed sediments are predominantly sandy–muddy, influenced predominantly by the sedimentary flux of the Po River and other, yet smaller streams. This is why the wider area of the Po River delta is known for subsidence, which means the sinking of the ground surface and seabed, not only due to natural causes but also because of groundwater and underwater gas exploitation (Teatini *et al.*, 2005). Since almost 70% of the entire territory of Adriatic coastal municipalities in Italy consists of flat formations (wetlands and different types of coastal plains), low and sandy beaches and flat hinterland, the area was considered attractive for building infrastructure and human settlements (Romano and Zullo, 2014).

As part of the Mediterranean, the Adriatic coastline has been praised for its high biodiversity value. More than 30,000 different wild plant species thrive in the Mediterranean, while at the same time more than 10% of the total number of these species grow along the coasts of the Adriatic basin, in the Mediterranean and sub-Mediterranean areas. Among the major threats to coastal ecosystems are urbanisation pressure, coastal erosion and invasive species. Due to the further rise in temperature, potential novel habitats may become a suitable host of some of the invasive species, while storms and sea level rise will increase coastal erosion and pose growing threat to urbanized coasts.

1.2 Demography, coastal urbanisation, coastal landscapes and seascapes, typology

Along the Adriatic Sea coastline, there are many settlements and large cities. Nine out of ten largest cities on the Adriatic coast are either in Italy (Bari, Venice, Trieste, Rimini, Pescara, Ancona, Pesaro) or in Croatia (Split, Rijeka). In both countries, people find the coast quite attractive. In Italy, the Adriatic municipalities cover only 3.2% of the entire national territory while having almost 6% of the entire Italian population recorded in the 2011 census (Romano et Zullo, 2014).

Since the early 1960s, the Croatian coast has been experiencing a dramatic urban growth and the accompanying environmental pressures. Around 120-150 kilometres of the coastline was urbanised in 1960, while in 2010 the urbanised coast accounted for 1033 kilometres. Meanwhile the population size in Croatia remained approximately constant: most of the new development accounted for second homes or tourist apartments. However, the latest county spatial plans envisage further urbanisation. According to the data available at the coastal county institutes for physical planning, if all the plans come true, around 1,562 kilometres of the Croatian coastline will be further urbanised (MCPP, 2013). Coastline tends to be less urbanised on the islands.

As depopulation took its toll in the hinterland and on the islands (especially those remote and hard-to-reach), this led to mostly heterogeneous population density on the coast. The population is concentrated on the coastal belt, the overall urban population rate declined, whereas the coastal urbanisation without urbanity has been one of the key threats to the coastal zone for decades.

In Italy, the urbanisation pressure on the Adriatic coast has not been any different. Between the 1950s and 2001 there was a fourfold increase in urban development in coastal municipalities (Romano and Zullo, 2014). Over the past 50 years, the foregoing developments have fostered an extraordinary transformation, which has turned this part of the coastline, together with the Po valley, into one of the most artificialized and congested places in Italy. A conurbation stretching along 55 kilometres from Lido di Classe to Cattolica is a perfect example of this. Today, less than 30% of the Adriatic coastline in Italy is free from urbanisation, but it is faced with serious issues of territorial organisation, control and recovery of its residual ecosystem and landscape qualities (Romano et Zullo, 2014).

1.3 Human activities and impacts

Key economic activities along the entire Adriatic coast are tourism, fisheries, aquaculture and maritime transport. Industry is vitally important on the Italian side. As we saw in the previous chapter, an increase in tourism transformed Adriatic coastal landscapes in both Croatia and Italy, exerting urbanisation pressures. In Croatia, coastal tourism is the only sector that has been exhibiting a steady growth even in the midst of the economic crisis that has affected almost every other sector. However, the seasonal character of tourism is still a challenge: Croatia attracts 84% of total overnight stays between June and September, while it attracts about 58% of total overnight stays only during the 'peak' season in July and August (based on Ministry of Tourism data, 2019). The current dominance of the Croatian private accommodation sector is among root causes for seasonality. The lack of off-season offer further adds to the problem. The seasonal character of tourism puts the utility infrastructure under tremendous pressure, including water supply, sewage system, transport, electricity consumption and waste management. Summer pressures on healthcare services and urgent and emergency care system have also been reported in some coastal towns.

The Italian side of the Adriatic also relies heavily on seasonal tourism, especially on the northwestern Adriatic coast, which is home to some of the longest beaches in Europe. Indeed, the Adriatic region Emilia Romagna attracted more than 40 million overnight stays, while Veneto region attracted more than 60 million overnight stays in 2018 (*istat.it*). In comparison, the whole region of Adriatic Croatia attracted a little less than 85 million overnight stays (Croatian Bureau of Statistics, 2019) in 2018.

Maritime transport is another significant branch of the area's economy – there are 19 Adriatic Sea ports with more than a million tonnes of cargo per year. The cruise industry has seen significant growth in both countries, but a significant number of cruise vessels in recent decades have been raising serious concerns over their impact on the marine environment in terms of waste, hazardous emissions (bilge water, ash, pollutant emissions into the atmosphere), wastewater, ballast water, biocidal products, physical damage/collision; noise pollution and light pollution.

Marine fisheries remained part of the culture and tradition in many Italian and Croatian coastal settlements. Nowadays, even if they are known for different main target species (anchovies in Italy and sardines in Croatia) both countries are still experiencing a decrease in catches[3,4].

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3 https://www.eurofish.dk/croatia
4 https://www.eurofish.dk/italy

1.4 Coastal typologies

In order to offer solutions for enhancing coastal resilience to the impacts of climate change, we decided to distinguish between several categories of coastal zones with similar characteristics, those that have similar problems and those to which specific similar solutions apply. Then it will be easier to structure and prioritize topics and areas that are directly affected by climate change. In order to achieve this, we compared it against the underlying principles of Articles 8 and 10 of the Integrated Coastal Zone Management (ICZM) Protocol, which distinguishes the following categories of coastal zones:

- urban coastal zone;
- coastal areas with the linear urban development;
- more or less natural open coast areas in which urban development is restricted, but without any level of protection under environmental laws;
- protected areas; and
- backshore areas.

Urban coastal zones include compact cities and settlements, mostly with semi-circular layout, which are well connected with the hinterland and islands and meet the optimal population density and urbanism requirements. Coastal towns and settlements are mainly maritime-oriented, i.e. centered on their coastline; more recently, they are often built as a stage for a performance in which the *sea* plays a starring role. The land-sea relationship shapes social and economic development. For this reason, the most valuable urban areas, as well as cultural and historical heritage, are mostly located very close to the sea, in close proximity to the shoreline. They will therefore be the first ones affected by the expected sea level rise, 'rogue' waves and high tides.

Coastal areas with the linear urban development consist of a concentration of properties and permanent residents along the coasts, which is a phenomenon common in regions with pleasant climate and warm sea, such as the Mediterranean. In tourist coastal areas, there are often more development than permanent residents. The proximity to the beach with a sea view is one of the main priorities of tourist facilities and one of the strong drivers of urbanisation, which consists of one or more rows of houses by the sea stretching on for miles along the eastern, but also western coast of the Adriatic. Sometimes these zones are just neighbourhoods and settlements, suburban or informal development, and sometimes they are separate administrative units. This type of urbanisation is problematic since urban infrastructure is expensive and encourages extensive personal car use, as low population concentration makes efficient public transportation impossible. This type of urbanisation is also problematic from the point of view of the potential for funding coastal flooding and coastal protection projects.

Open coasts are defined in Article 8.3.a of the ICZM Protocol as coasts without any designation of protected area, which highlights the importance of their conservation by protecting them from urban development and other human activities. There appears to be fewer open coastal areas due to littoralisation and linear development along the coast. As set out in Article 10 of the ICZM Protocol, it is important to protect specific coastal ecosystems, such as wetlands, estuaries, marine habitats, coastal forests, woods and dunes, especially those located outside protected areas. As set out in Article 11, the same is required for valuable coastal landscapes.

Protected areas are usually sea or land areas that remained largely intact and preserved their naturalness. Considering the importance of each area – and indirectly the level of protection given to them – according to the common national categorisation, they are divided into strict nature reserves, national parks and nature parks, protected landscapes and natural monuments or features. They have several roles: they need to preserve the complexity of natural structures within the catchment area, maintain the ideals of the intact (even if there is no such thing as a completely intact ecosystem in Europe), but also serve as a litmus test for changes that are difficult to detect in other areas. In addition to the usual national protection, the world's largest *new* protection network has been established in Europe over the last three decades to include marine and land habitats, as well as areas of great importance for birds.

Hinterland areas are extremely important for the sustainable development of coastal regions. At times, this is where measures need to be taken to enable balanced development, and to offer a model where narrow coastal zones would serve as a driver of regional growth, and not only for private investor interests. Since the mid-twentieth century, the eastern Adriatic has seen a trend of migration of population to coastal cities and towns and depopulation of the hinterland. This imbalance is one of the key obstacles to sustainable development. Climate change adaptation makes these areas even more important. On the one hand, they are the first line of defence against torrential floods and fires, but also a valuable area that can provide opportunities for managed retreat.

In view of the characteristics and use of the Adriatic coastal area, as well as in accordance with the ICZM Protocol, the following territorial division will be used in this publication:

- the coastline defined by the Republic of Croatia and the Italian Republic;
- setback zone, as defined in Article 8 of the ICZM Protocol, which may not be less than 100 meters in width;
- a narrow coastal belt (up to 300 metres on both sides of the coastline);
- a narrow coastal zone (up to 1000 metres on both sides of the coastline);
- coastal zone (including coastal towns and municipalities) and its seaward limit which shall be the external limit of the territorial sea; as well as
- wider coastal area (coastal regions, including counties and provinces) to the outer limit of the territorial sea.

2 Climate change in the Adriatic coastal zone

2.1 Climate change data and projections

All climate projections are mainly characterised by the uncertainty of the scale of change. The climate is the result of a whole range of natural and anthropogenic hardly predictable factors for which it is difficult to accurately predict how they will change, both globally and locally. The uncertainty of scenarios, or future emissions and atmospheric concentrations of greenhouse gases and their complex impact on the climate resulting from human behaviour cannot be prevented. In addition, the climate system also has its own internal variability. Seemingly small changes can lead to strong impacts. For the time being, however, there is one thing we know for sure - and that is the trend of change. It is important that we get adequately prepared for the trends that are coming, as well as for the worst case scenarios. Possible solutions should be adaptable to different stages and feasible for all scenarios.

According to the latest Intergovernmental Panel on Climate Change reports (IPCC), in recent decades, in addition to the increase in mean air temperature, the intensity, frequency and duration of heat waves as well as extreme rainfall events and droughts increased too (IPCC, 2019). The IPCC recognised the Mediterranean as one of the climate change hotspots, because it is heating up faster than the rest of the planet, and this has been confirmed by the latest MedECC report – the one delivered by the network of Mediterranean Experts on Climate and Environmental Change (MedECC, 2020).

According to the 2019 IPCC Special Report on the Ocean and Cryosphere (IPCC, 2019), rising mean sea levels will contribute to the risk of coastal flooding along the coasts and on islands (Table 1).

Box 1. Who can we trust?

Created in 1988 by the UNEP and WMO, the objective of the IPCC is to provide decision makers with the best scientific input that they can use to develop planning and management policies. Since 1990, every 6 years, the IPCC has been publishing its regular assessment reports, which are prepared by thousands of scientists. In addition to regular reports, the IPCC also prepares special reports on request of the governments.

Table 1. Key parameters for coastal areas from the IPCC report (2019)

Expected global changes in key parameters for coastal areas by 2100		
Parameter	Expected value RCP 4.5	Expected value RCP 8.5
Mean global surface temperature deviation compared to 1850-1900 (in °C)	2.5 (1.7-3.3)	4.3 (3.2-5.4)
Global average sea level rise compared to 1986-2005 (in meters)	0.55 (0.39-0.72)	0.84 (0.61-1.10)
The rate of global sea level rise (in mm/year)	7 (4-9)	15 (10-20)

However, in addition to rising sea levels, which are relatively slow to change, it is important to keep in mind extreme weather conditions. During stormy weather, mostly with strong and long-lived stormy *scirocco* wind and low pressure, high tide and rogue waves hit the coast. As these are mostly cyclones, they are often accompanied by heavy rains. In combination with other factors, those events can cause significant coastal flooding, especially in low-lying coastal areas and those where land subsidence occurs. This happened in Venice in December 2019, when the measured sea level reached 187 cm above the usual. Many cities along the Adriatic coast were affected by floods. Although the cause of this flooding was a relatively rare specific weather condition, it is worth noting that the highest sea level in Split was measured only a few weeks earlier.

Within the AdriAdapt project, climate data and projections covered the period between 1986 and 2100. The data followed the historical forcing up to 2005 and two different future emission scenarios up to 2100: a moderate one (RCP4.5), which includes a future world where considerable efforts have been put into mitigation policies, and a high emissions one (RCP8.5), which includes a future world without climate mitigation policies. Simulations were made for the area covered by the AdriAdapt project, which stretches along the northern coast of Italy and most of the Croatian coast (Figure 1).

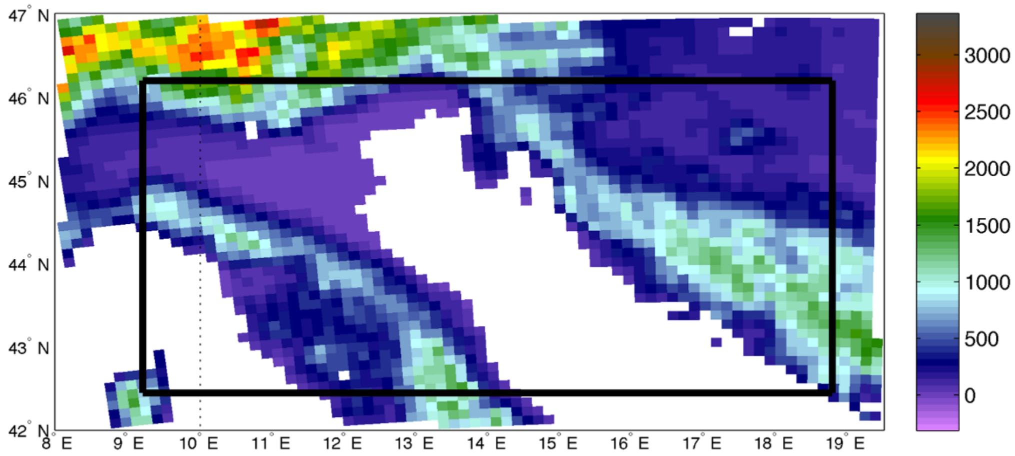


Figure 1. AdriAdapt area in which the simulations were carried out

The main conclusions of the AdriAdapt project regarding the future climate change in the Adriatic are as follows:

- An **increase in seasonal and annual mean air temperature** is expected by 2100; the strongest changes can occur in summer, increases of mean temperature by 2°C for RCP4.5 and 4.5°C for RCP8.5 could be reached by the end of the century.
- An **increase in both maximum and minimum air temperature** is expected by 2100; the annual maximum temperature is expected to increase more than annual minimum temperature; changes up to 3.3°C for RCP4.5 and 6.5°C for RCP8.5 are expected to affect the annual maximum temperature by the end of the century.
- A shift of the overall distribution of minimum and maximum air temperature is predicted to move towards warmer values in all seasons with peak intensity in summer.
- A **decrease in the number of frost days** is projected to occur in winter, spring and autumn; significant decreases are expected in the plains and locally with the tendency to complete disappearance of frost days especially for RCP8.5 and towards the end of the century. In winter, when frost days are most common, the expected change in the middle of the century is about 7.5 days less per season (December to February) compared to

the baseline period when up to 30 frost days are expected, for both emission scenarios. At the end of century, the RCP4.5 scenario predicted that there would be around 12.5 frost days less, whereas under RCP8.5 scenario the figure would be as low as 25 days less than the one compared with the baseline period; locally the signal could be even more intense.

- The **increase is expected during the seasonal heatwave** for both emission scenarios across the region by 2100; the peak signal is found in the urban pilot areas, especially in summer.
- Furthermore, the **number of tropical nights** is expected to **increase** throughout the area, with high intensity in urban areas, especially in summer (June to August); projections indicate a possible increase of about 20 tropical nights for RCP4.5 and 30 tropical nights for RCP8.5 by the end of the century, which is twice the baseline; changes projected locally could be even more intense.
- Projected **precipitation** amounts are not homogeneous for the whole area. The signal of the projected changes is very weak **in winter** for the moderate emission scenarios (RCP4.5), while a slight increase in precipitation may occur in the northeastern part of the region in the high emission scenario (RCP8.5). **Summer** precipitation is projected to decrease significantly by the end of the century.
- Projections of **intense and extreme precipitation** are in line with the signal of change in total precipitation; **in winter, intense precipitation will increase the most** for scenario RCP8.5 – along the eastern side of the Adriatic (but also in the Croatian inland) it will be by about 4 mm per day and about 10 mm per day in mountainous areas in the case of extreme precipitations. The opposite signal can be expected **in summer** when the **decrease in intense precipitation** will be up to 4 mm per day along the eastern part of the Adriatic coast and the inland of the southern Italy, at least for RCP8.5. Summer extreme precipitation does not show a clear pattern of change, in either of the two scenarios.
- The climate projections suggest increases in the **maximum number of consecutive dry days**, seeing a peak in the summer months.

2.2 Observed impacts of climate change in the Croatian and Italian cities along the Adriatic coast

A survey was conducted among local administrations in Croatia and Italy as part of the AdriAdapt project. Respondents were asked to complete the survey online from April to November 2019. The observed impacts of climate change in responses ranked by frequency are shown in Table 2.

Table 2. The results of the survey on the observed impacts of climate change in the Adriatic regions, cities and municipalities

Adriatic regions, cities and municipalities: the observed impacts of climate change (responses ranked by frequency)
Flooding caused by rainfall: 31
Damage caused by extreme weather events (ranked by frequency: trees, roofs, roads, cars, waterfronts, beaches, boats, landslides): 30
Flooding of houses and other facilities for residential purposes and tourism: 25
Coastal flooding due to extreme weather events: 24
Increase in the number of wildfires: 19
Increased deterioration of coastal infrastructure due to extreme weather events: 17
Lack of water for irrigation of agricultural areas: 17
Influence of temperature and/or precipitation change on the arrival of tourists in pre-season and post season: 17
Increased number of people seeking emergency medical care due to weather conditions: 16
Changes in the number of pests and invasive species: 16 (the Mediterranean bark beetle in Croatia: 8)
Increased unpleasant odour intensity in summer due to temperature increase (sewage, landfills, etc.): 16
Inadequate supply of drinking water in summer: 16
Reduced cropping yields and decline in soil quality caused by droughts: 15
Increasing damage to agriculture caused by extreme weather conditions: 15
Changes in the life cycle of vegetation: 15
Increase in infrastructure decay due to extreme weather events: 14
Voltage dips due to increased energy consumption: 13
Invasive species: 13
Changes in coastal morphology due to erosion of beaches and coasts: 12
Changes in the rate of fire spread and intensity: 12
Decline in commercial catches: 11
Increase in the number of termophilic fish and other species: 11
Increased degradation of trees: 10
Drought-related decay in native vegetation 10
Reported bathing water quality on the decline: 10
Lack of capacity to help everyone who seeks medical care in peak season: 8

As can be seen from the results, the most commonly observed impact is flooding caused by rainfall, damage caused by extreme weather events and coastal flooding. Flooding is the result of the weather condition (climate), but also the quality of urbanisation and topographical features of the built-up coast (and its height), as well as the condition and effectiveness of existing coastal defences, if any. Climate change is not the only factor to blame, though, it is a good indicator of the changing trends that will take place on some coasts.

Some of the observed impacts shown in the above table are significantly more prevalent in Croatia, such as the increased unpleasant odour intensity in summer, the Mediterranean bark beetle attacks, changes in the rate of fire spread and intensity, and all negative impacts related to agriculture. Some other impacts have been reported too, but in less than five responses, which is why they are not shown in the above table. Interestingly, among them is salt water intrusion into drinking water sources, which has been observed in four cities. Given that this is an important impact, the reported cases are not negligible. Erosion of the burned soil has been observed in seven local administration units.

Indeed, the most important impacts on the natural and built coastal environment are coastal flooding and coastal erosion. On the Italian side of Adriatic, especially in its northern low-lying part, coastal erosion poses a serious threat because of fine and unconsolidated sediments, contributing to frequent coastal flooding due to rising sea level and storm surges. Around the beaches in the area around the Po River delta, but also beaches around smaller deltas (e.g. Biferno, Trigno and Metaurno rivers), the erosion rates can reach up to 10 meters/year (Pranzini, 2013). In a recent study, scenarios for extreme wave heights for 2070-2100 period forecast "very high" wave hazards for the area from Venice to the Po River delta, especially in the winter trimester (January/February/March) (Torresan *et al.*, 2019; Gallina *et al.*, 2019).

In Croatia, an increased risk of coastal flooding due to storm surges, as well as dry land loss due to increased coastal erosion caused by sea level rise (SLR), was estimated by applying the DIVA (Dynamic Integrated Vulnerability Assessment) tool in 2015 (UNEP MAP PAP/RAC, 2015). The assessment showed that the impacts of sea level rise in Croatia will be substantial in the 21st century if no adaptation measures are taken. The area of Croatian coastal zones exposed to the 1-in-100 year coastal extreme water level will increase from the current 240 km^2 to 320-360 km^2 in the late 21st century. The expected number of people exposed to flooding each year will increase from 17,000 in 2010 to 43,000-128,000 in 2100. This study revealed many interesting insights: for example, in Croatia, the areas with high asset exposure to coastal flooding are not necessarily those with high population exposure, and vice versa.

Even if the problem of coastal erosion is not as severe in Croatia compared with Italy, it still can be observed in certain areas: e.g. on soft flysch coasts of the island of Rab; pocket beaches between Split and Ploče (partly influenced by construction of the Adriatic motorway that cut the layers of flysch deposit) and the area of the Neretva river delta (Pikelj and Juračić, 2013). Finally, the problem of coastal erosion is increasingly pronounced on the new coastal extensions, built in order to meet the needs of the tourism industry.

Growing **wildfire** danger in Croatia is mostly there due to the hinterland depopulation and abandoned agriculture and livestock farming in these areas, which started in the second half of the 20th century, which then led to the flourishing of maquis, garigue vegetation and pine forests – which are highly flammable. Mean temperatures increase, while drought periods for an extended period of time prolong and exacerbate the fire season, and the current trend will only worsen in the future. Fires contribute to a loss of carbon storage, produce a large amount of toxic gases and lead to erosion and desertification. In addition, costs associated with putting out a wildfire can be very high.

All other impacts of climate change observed by local administrations in Croatia and Italy (e.g. flooding caused by rainfall, a decrease in precipitation regime and the occurrence of drought, changes in the number of pests, etc.) served as a guideline in the development of this document, and they helped determine priority climate change impacts as well as the adaptation options that this publication will address.

3 Resilience

3.1 Resilience - definition

This handbook outlines *resilience* and *adaptation* as its key terms. The question is what resilience really refers to: resilience to adverse processes and situations in coastal zones caused by climate change and its consequences for people, settlements and the living world. The concept of resilience dates back to the 1970s and stems from ecology, referring to the capacity of the system to absorb disturbances and still retain the same structure and functions, in other words, to recover. Since then, the reflection on resilience has spread to different areas and has become particularly important in the area of climate change adaptation.

In order to be able to work on improving the resilience of coastal areas, we need to understand the processes that occur on the coast given the impacts of climate change. Vulnerability of coastal areas and all dimensions of living on the coast, along with its natural, social and economic subsystems, needs to be analysed. For this purpose, different methods of vulnerability assessment are used, providing insight into the vulnerability, exposure and resilience to the impacts of climate change. By analysing adaptation capacities, we are also looking at how to increase this capacity, reduce vulnerability and strengthen resilience.

As we continue to examine the concept of resilience of coastal areas to the negative impacts of climate change, we take into account phenomena such as coastal flooding, flash floods, drought, increased risk of wildfires, increase in infections caused by pathogenic organisms, disturbances caused by non-indigenous species, urban heat islands, and similar phenomena. Impacts are observed in the whole area including the coast, hinterland areas, sea and islands (in accordance with Article 3 of the ICZM Protocol) and humans and the accompanying socio-economic system. If we look at the coastline, which is the most resilient when it is natural, the interpretation of resilience will be completely different.

Box 2. Resilience

Resilience – the ability of a system and its components to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including ensuring the preservation, restoration, or improvement of its essential basic structures and functions.

Source: IPCC

Coastal resilience means the ability of a system and its socio-economic and natural components to anticipate, absorb, accommodate, or recover from the effects of a hazardous event and climate change in a timely and efficient manner. For this to be possible, coastal areas response needs to be systematic, planned, guided and managed. Therefore, an integrated adaptation planning in coastal areas is proposed as a precondition required to ensure resilience of the inhabited coastal area.

There are many reasons why we call for the cooperation between all groups of actors, starting from the scale of the challenges we have to face to the associated uncertainties. Uncertainty may be the most difficult aspect of facing climate change.[5] It is not so much a question of if this will happen, but rather more a question of exactly when and how this will happen and how many people and to what extent they will be affected by climate change. Different aspects of uncertainty are shown in Box 3.

[5] Change scenarios depend on human behaviour around the globe. In addition, concerns were also raised about tipping points, impact chains, feedback loops and other irreversible changes.

Box 3. Coping with uncertainty

- Uncertainty in climate projections
- Uncertainties associated with impacts on the biophysical systems
- Technical uncertainty
- Socio-economic uncertainty
- Political uncertainty
- Financial and economic uncertainty

Source: UNEP-WCMC and UNEP, 2019

When implementing solutions, it is important that they are progressively **adaptable** in the future, any changes, conditions and causes must be continuously monitored, and we must be able to react swiftly in case of moving away from the desirable state of the environment. This means that the management system needs to be adaptive, responsive, capable to deal with problems, foster constant learning, constant innovation, and respond to problems. This kind of a system can only be the one that encompasses large amounts and diversity of social, economic, physical, and natural capital (Chapin *et al.*, 2009).

The quality of our response to climate change depends entirely on the cooperation and networking of skilled, adequate and well-trained social strengths and available resources. Climate change affects all aspects of our lives, so changes and solutions are needed to address each and every one of them. Society divided into sectors with narrow sectoral focus that achieved an increase in efficiency (doing things the right way), but not in effectiveness (doing the right things) is often more of an obstacle rather than a virtue when responding to comprehensive challenges. Integrated solutions, synergies and a holistic approach are inevitable for achieving quality responses to climate change as the biggest challenge we are facing right now.

3.2 Climate resilient pathways

Climate change pushes us further to use sustainable development approach and to fully consider complex interrelations in the systems of climate, society and the natural environment. Climate resilient pathways are development trajectories that combine adaptation and mitigation to achieve the goal of sustainable development (IPCC, 2019). Figure 2 shows the global projected emissions of carbon dioxide (CO_2) based on the planned production of fossil fuels. It can be observed that at this point there is a considerable gap between the planned production and production agreed in the Paris Agreement, but the production projections for 2030 or 2040 look even worse. For now we are heading to worst case scenarios.

The integrated approach that is currently being advocated in coastal area management aims to integrate different planning and management systems, such as spatial, regional, social, ecological systems into a single system, in the same way as the habitat – *oikos* serves as the integration of living organisms and the natural environment (Filipić et Šimunović, 1993).

Adaptation is a strategy that helps us anticipate and mitigate climate change impacts that cannot be (or have not been) avoided under different climate change scenarios. It is clear that the adaptation process runs more smoothly the closer we get to sustainable development, or lags behind if we do not make an effort to mitigate climate change and keep moving away from sustainable development. The integrated approach encompasses both climate change adaptation and mitigation. Every decision we make has an impact on the position we have on our path to resilience; it can boost our motivation and bring us closer to our goal or steer us away from it. This situation is shown in Figure 3.

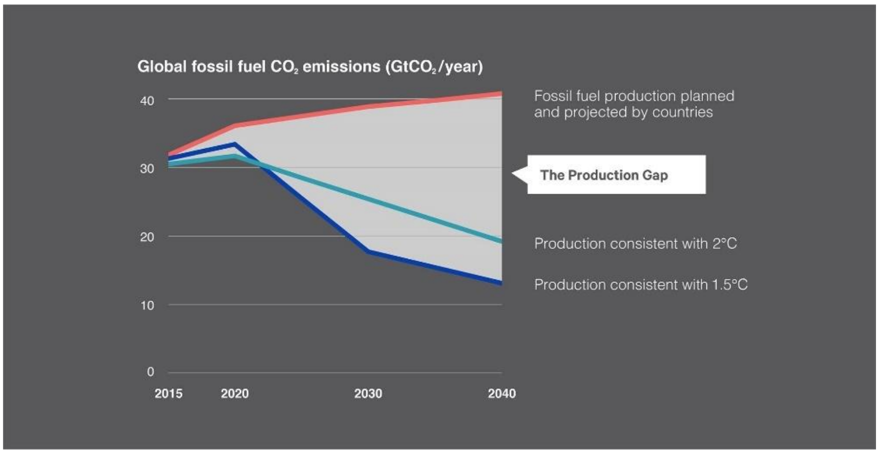


Figure 2. Forecast of carbon dioxide (CO_2) emission worldwide based on the planned fossil fuel production (Source: UN Environment. Global goals for sustainable development. http://productiongap.org/)

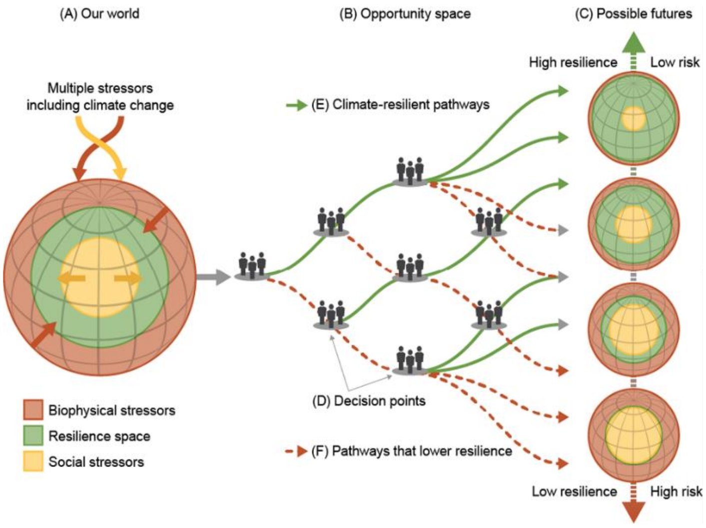


Figure 3. Implications of decision-making on climate resilient pathways. (Source: IPCC, The Fifth Assessment Report (AR5))

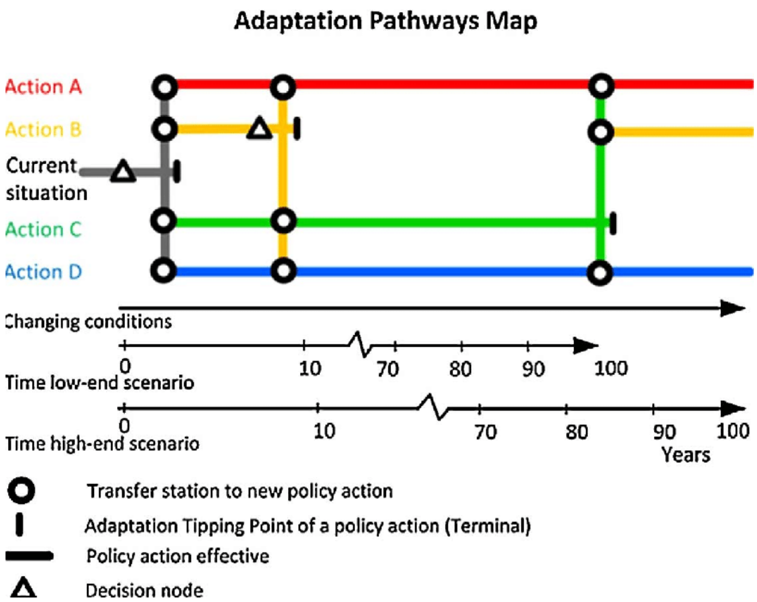


Figure 4. Adaptation pathways are presented in the original concept by Haasnoot with four different types of actions and tipping points in decision-making and low and high emission scenarios on the x axis (Haasnoot et al., 2013)

We may not be able to stop rising sea levels, even if we achieve the best case scenario, but we still have a chance to slow them down. Therefore, adaptation of inhabited low-lying and unprotected coastal areas is imperative. There is still just one question: how much is the sea level going to rise, and how fast will that happen? Therefore, the planning proposal is based on developing adaptation plans in coastal areas to ensure that different measures are taken at the right time and in the appropriate circumstances. The proposed solutions should be implemented in stages, in accordance with the latest developments and identified needs.

Principles and guidelines for strengthening resilience, shown in Box 4, will contribute to better understanding and use of the concept of resilience.

Box 4. Principles of resilience building

- Maintain diversity and redundancy, allowing for some components of the social-ecological system to compensate for loss or failure of others.
- Manage connectivity and promote flexibility, allowing for well-connected systems that more quickly overcome and recover from disturbances
- Manage slow variables and feedbacks, counteracting disturbance and change so that the social-ecological system recovers and keeps providing the same ecosystem services
- Foster complex adaptive systems thinking, acknowledging that social-ecological systems are based on a complex web of connections and interdependencies.
- Encourage learning, ensuring that different types and sources of knowledge are valued and considered when developing solutions.
- Broaden participation, actively engaging relevant stakeholders in order to build trust and expand knowledge needed in decision-making processes.
- Promote polycentric governance systems, where multiple government bodies interact to achieve action in the face of disturbance and change.

UNEP-WCMC and UN Environment. (2019) Guide to Ecosystem-based Adaptation in Projects and Programmes

3.3 Choosing appropriate response

In order to successfully support a given area on the road to resilience, different adaptation measures need to be taken. Adaptation measures presented in this handbook are divided into three categories: measures relating to society (societal measures), ecosystem-based adaptation (green measures) and engineering (grey) measures. All three categories of adaptation measures will be discussed in detail in the following chapters. Measures can also be hybrid or combined. The choice of measures that will be taken depends on a number of factors. Taking a staged implementation approach is hereby suggested, taking into account the latest scientific knowledge regarding the pace and scale of change and the use of the adaptation pathways, such as those shown in Figure 4.

The issue of strengthening resilience in the conditions of sea level rise is particularly challenging for low-lying coastal areas. Slowing down sea level rise would happen long after reducing greenhouse gas emissions. It is certain that sea level rise will continue in the coming decades, but forecasting how much and how soon the mean sea level will rise will need to be subject to further research. However, small rises in the mean sea level will lead to a multifold increase in the frequency of coastal flooding. The SROCC report (IPCC, 2019) defines six possible global responses to the sea level rise that need to be adapted to the local situation in terms of coastal exposure and sensitivity. When selecting adaptation measures, waters from the landward side and waters flowing from impermeable surfaces of the urban environment must be taken into account. Considering these impacts is crucial for choosing the appropriate response.

Responses to sea level rise shown in Figure 5 will be discussed in the following chapters. All of them (except for the last one) serve as measures that can strengthen the resilience of the coastal area. Coastal protection measures are generally costly and depend substantially on the desired and planned level of protection (for example, the 50-year, 100-year or 500-year flood).

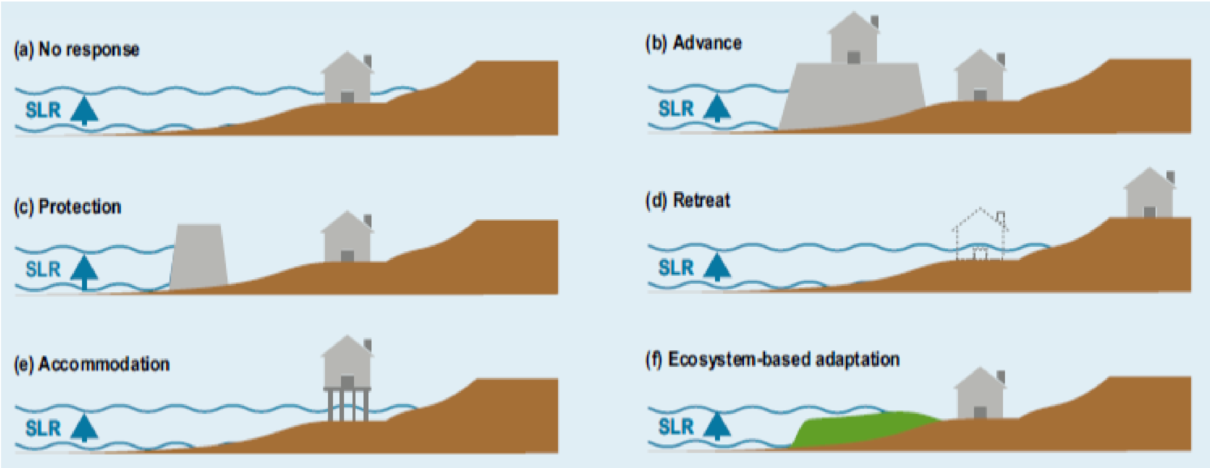


Figure 5. Responses to sea level rise (Source: IPCC, 2019)

As a rule, more densely populated areas, which generate higher revenues per kilometre of the coast, will be able to finance more reliable and better coastal protection. Which response will eventually be chosen will depend on the extent of potential damages over a specific period of time in accordance with the designed coastal defence, the number of people at risk, the natural configuration and characteristics of the coast, the length of the built-up coastline, the economic power of the population and its preferences, and on the other hand, the level of exposure to sea action (flooding). In the case of highly urbanised, densely populated coastal areas and a built-up coastline, the so-called grey – engineering measures such as those marked with letters (*b*), (*c*) or (*e*) shown in the figure above may be the best choice. Factors such as shoreline/ coast topography and seabed bathymetry will also play a role in choosing the right response. For some coastal cities, especially those in the areas of shallow waters, ecosystem-based solutions are becoming increasingly likely (*f*). Certainly, in areas around estuaries and deltas and low-lying coastal areas, this kind of solutions can at least delay coastal flooding. Finally, managed retreat (*d*) will sometimes be the most cost-effective solution. This strategy will help move towards creating plans for the cities and coastlines of the future.

Coastal protection costs in Croatia due to sea level rise were assessed twice based on the DIVA model. The 2020 study (Lincke *et al.*, 2020) has shown that the future cost of coastal flooding can be reduced by up to 39% if protection structures and setback zones are combined. However, combining protection structures and managed retreat can reduce the future cost of coastal flooding by up to 93%. The 2015 study (Hinkel *et al.*, 2015) did not take into account setback zones or managed retreat. This study showed that the areas with the highest percentage of vulnerable populations did not fully correspond with the areas with the highest percentage of vulnerable assets. Interestingly, the 2015 study was based on the assumption that coastal segments must be protected if their population density exceeded 30 inhabitants/km^2; while the new study took over the UK model according to which areas with benefit-cost ratio greater than 5 must be protected. These studies have clearly demonstrated how important decisions that will need to be taken really are: what population or built-up area density we will protect; which cost-benefit ratio we will apply, how to determine the value of historical and cultural heritage – these will be strategic and political decisions that we will have to make in the near future. It is safe to assume that densely populated areas, structures and environments will probably be defended by a set of engineering measures and other solutions. Assessments, plans and decisions will need to be made. We will need to find answers to questions such as: How to help people who live in areas that will eventually be flooded? How to take care of the area after it has been abandoned? How to deal with new challenges regarding the preservation of water quality after coastal flooding occurs? In addition to the above considerations, soon we may be dealing with issues that we have not even considered yet.

4 Societal adaptation measures

Societal measures or measures for society (the Latin word '*societas*') are measures taken by social actors concerning decision-making activities related to development, planning and development management, legislation, institutions, education and raising awareness, etc. Based on a comprehensive review of the literature on climate change adaptation, they are often referred to as *soft* measures. This wording completely limits the potential on the one hand and the complexity of the successful application of these measures on the other hand. For this reason, much more attention has been paid to these measures because we believe that they are the most important and the only ones that can actually lead to a complete transformation of society, necessary to successfully tackle climate change and the future of humanity and life on Earth.

These measures relate to the UN Sustainable Development Goal 17, which stands for "Partnerships for the Goals". It may be last, but not least, some would say, but on this occasion it needs to be emphasized that this goal could become a real game changer - this is why it plays a central role in the first group of measures.

In the section on societal measures, the following factors will be presented:

1. *governance*;
2. planning and management, including specific management and early warning systems for tackling the upcoming crises (fire, floods, etc.);
3. land-use planning/ spatial planning, including the setback zone, a strip along the narrow coastal belt where development activities are prohibited, and managed retreat in response to sea level rise;
4. social measures such as education, raising awareness and individual behaviour change.

4.1 Governance

A simple definition of *governance* would be – who holds *de facto* power, authority and responsibility to make and implement decisions; how those decisions are made, how effective and efficient they are, and how account is rendered. This concept still does not have the appropriate equivalent in the Croatian or in Italian language. The key to understanding the difference would be to find the answer to the following questions – who is responsible for the rule of law, and who is to blame for the lawlessness. This compares to understanding the concept of *genius loci*, which encompasses different layers of material and immaterial; the invisible experience of the place created in the human mind (Vecco, M., 2019).

Governance consists of the relationship between institutions, processes and customs that determine the way in which power is exercised, how decisions are made on matters of public and private interest, as well as how citizens and other actors make their voices heard. In other words, *governance* draws on who has power, who makes decisions, how stakeholders make their voices heard and how account is rendered.[6] *Governance* also encompasses the question of how decisions are implemented, in other words, tangible and intangible ways and processes needed to make *governance* operational. *Governance* is, in essence, also made up of different governance bodies and committees, because they provide the best opportunity to connect with management.

The reality of *governance* is also about the complex web of local conditions, of understandings and misunderstandings, of communication and miscommunication, along with the allocation (or misallocation) of power and resources - all of which are combined to create both matches and mismatches between policy and practice. The aim must be to maximise the former and minimise the latter (PAP/RAC, 2019). *Governance* is definitely not

[6] https://iog.ca/what-is-governance/

a short-term project. ***Governance* is all about the long-term; building trust, relationships, community support, and delivering action plans and programmes, but also building consensus that will not be affected by potential changes in government, it is all about a common and stable platform for building trust and partnership.**

Strengthening *governance* for climate action is a task that goes beyond the management structures established by the state, whereas its successful implementation requires a broad social partnership. The scale and uncertainty of the challenges posed by climate change requires a profound transformation of society that can only be achieved by changing lifestyles, the rule of knowledge, cooperation and planning, and embracing sustainability and resilience as the most important common goals. Given the complexity of the challenge, science needs to be at the centre of the actions that must be taken. The cooperation between decision-makers and scientists is one of the key preconditions for the successful climate change adaptation, as well as for the fight against climate change. Strengthening *governance* for climate action will be best achieved through the creation of relevant governing bodies that will deal primarily with these tasks. They should ensure continued cooperation between decision-makers and scientists, therefore, their institutional framework and human resources must live up to their ambitions. As climate action mainly takes place at local and regional levels, besides decision-makers, a network of centres is required to jointly implement adaptation and low-carbon development activities in cities and regions.

4.2 Planning and management

Coastal zone management is defined by the ICZM Protocol, which has been ratified by the European Union and the Republic of Croatia, but has yet to be ratified by Italy. However, in 2008, Italy signed a decision on the Protocol, showing its commitment to non-violation of the Protocol's provisions and undertaking obligations under the Protocol as an EU member state, given that the EU ratified the Protocol in 2010.

Under the Protocol, integrated coastal zone management (ICZM) means a dynamic process for the sustainable management and use of coastal zones, taking into account at the same time the fragility of coastal ecosystems and landscapes, the diversity of activities and uses, their interactions, the maritime orientation of certain activities and uses and their impact on both the marine and land parts. The Protocol was prepared and negotiated as a legal basis applicable to all Mediterranean countries, which is why it has relatively broad foundations, so decisions on specific matters can be made at the country level. One of these questions is figuring out who is responsible for managing the coastal zone as an area of great value with complex and overlapping interests and competences. Therefore, delineation of responsibilities is one of the most important issues, whereas effective organizing and integration management are inevitable in this process.

Planning as a method for determining the future and as a basis for management is of utmost importance for coastal zones. Adding climate change into the equation, which makes the future even more uncertain, the plan becomes a crucial tool for sustainable development. The complexity of coexistence in the coastal zone should be approached through an integrated, systematic approach and interaction between nature, society and the economy. The plan sets out how we will agree on the future we want for our coastal areas and help us carefully select measures and activities that will lead us to the desired future through joint action of all competent and responsible stakeholders.

A coastal plan, or coastal management plan, or an ICZM plan shall be based on Article 18 of the ICZM Protocol. Among good examples of such a plan is the Coastal Plan for the Šibenik-Knin County[7], which received the award in 2019 as the best adaptation to climate change action in the Mediterranean. This coastal plan was prepared with the approach typical for the integrated coastal zone management, placing a special emphasis on climate change. Another publication, "Integrating Climate Change Adaptation into Coastal Planning" focuses on planning, so the details regarding the planning process will not be discussed here. As we

[7] https://iczmplatform.org/storage/documents/WXMq1FV13VtV5aa919SW3iss18eMem5nZoBxsulx.pdf

face the growing flood risks in the coastal areas amid climate change, this handbook will place more emphasis on this topic.

4.2.1 Coastal risk management

Coastal risks must be managed given the increasing climate and anthropogenic pressures on the coast. To be managed effectively, they need to be identified, understood, and predicted as accurately as possible. This requires knowing when, where and how they normally affect the coast, the natural and built environment. Trends should be identified and analysed, looking at the drivers, pressures, current situation and impacts of climate change. To this end, a vast array of activities have been implemented:

- field analyses, including video monitoring, hydrographic surveys using a tide gauge, etc., data processing and the use of data for calibration and verification of models and calculations;
- assessments based on software/computer modelling to predict future hazardous events and/or coastal erosion rates based on expected climate change and sea conditions trends;
- statistical analysis and analysis of trends and changes, correlation between the process and interrelationships;
- producing flood maps;
- identification of areas at risk that overlap with spatial plans;
- producing coastal erosion maps.

The results of the coastal hazard analysis serve as the basis for effective coastal management, which will help protect the environment and the natural dynamics of this important economic resource. Effective coastal management requires:

- relevant field research;
- identification, analysis and mapping of vulnerable areas, with the incorporation of these findings into spatial plans;
- assessing vulnerability to climate change and the impacts of sea and land waters, as well as human activity along the coast;
- educating the local population, local and regional administrations and other stakeholders;
- setting up public information systems;
- setting up an efficient emergency alert and early warning system;
- adopting appropriate building regulations, guidelines, construction work bans, etc.
- developing local and regional climate change adaptation strategies, and meeting the requirements listed in adaptation strategies at the national, EU and Mediterranean levels;
- regular exchange of data and experiences between institutions and regions and participation in joint coastal management and coastal risk management projects.

Coastal risk management is a complex and costly set of tasks that must be constantly carried out to strengthen the safety of natural and built coastal environments by ensuring the sustainability of good environmental, living and working conditions status in coastal areas.

An increased risk of fire is a constant threat. Europe has recently highlighted the importance of shifting focus from fire suppression to fire prevention and recovery, suggesting integration of pre-fire and post-fire management to minimize risks of wildfire and negative effects once fires do occur. Unfortunately, the reality of the disaster preparedness at the front lines is not so rosy, as only 2% of funds are invested in prevention in Croatia, while 98% is spent on operational capacities for disaster response (Government of the Republic of Croatia, 2019).

4.2.2 Early warning systems

Among the early warning systems, two examples of good practice deserve special attention, specifically those set up in Venice and Šibenik-Knin County. The former refers to high tides and high water levels in the Venetian lagoon and the latter refers to the fire alarm and warning system. Both systems are of utmost importance in reducing the risk to human lives, and at the same time they can, at least to some extent, mitigate material damage. These measures are extremely important today, when we are not yet prepared for the challenges of climate change, but they still have a very limited reach.

4.3 Spatial planning

In coastal areas, space is one of the most valuable assets. For this reason, the importance of spatial planning and all of its instruments in achieving adaptation, resilience and sustainable development is underlined. Spatial planning is also very important for reducing the risk of disasters, starting from the risk of coastal flooding that will be further examined in the next chapter, but also for reducing the risk of stormwater or surface water runoff, firebreaks, corridors, heliports and access to strategic infrastructure, to name but a few.

4.3.1 Coastal setback

Coastal setback means a strip along the coastline, in which construction is not allowed or is significantly restricted. The concept of coastal setback and obligation to implement it is one of the most important provisions of the ICZM Protocol. The reasons for prescribing setbacks are the objectives and general principles of the Protocol set out specifically in Articles 5 and 6, including:

1. Preservation of the integrity of coastal nature and landscape and the overall natural dynamics of the area;
2. Avoiding risks for the coastal area, in particular avoiding damages resulting from natural processes such as erosion, natural disasters and climate change;
3. Providing for freedom of access by the public to the sea and along the shore, including, depending on local conditions, allowing acceptable recreational activities.

In the context of rising sea levels, this measure is found to be one of the *low-regret* measures, defined as measures that are relatively low-cost and provide relatively large social benefits. Besides the fact that coastal setback is a measure of adaptation to climate change in steering new development in flood hazard areas, it is also an important *win-win* measure, which means that it produces multiple economic and social benefits. Figure 6 shows a brief overview of the socio-economic effects of the development in a coastal settlement adjacent to the beach for the coastal type "a", where coastal setbacks were not imposed, and for the coastal type "b", where a coastal setback was implemented. The coastal type "b" offers a better safety from marine flooding for houses in the first row to the sea, potentially tripling beach capacity and provides more room for different economic activities and supporting facilities. In addition to serving as a resource that improves the quality of life for the local population, it is also an essential tourism asset.

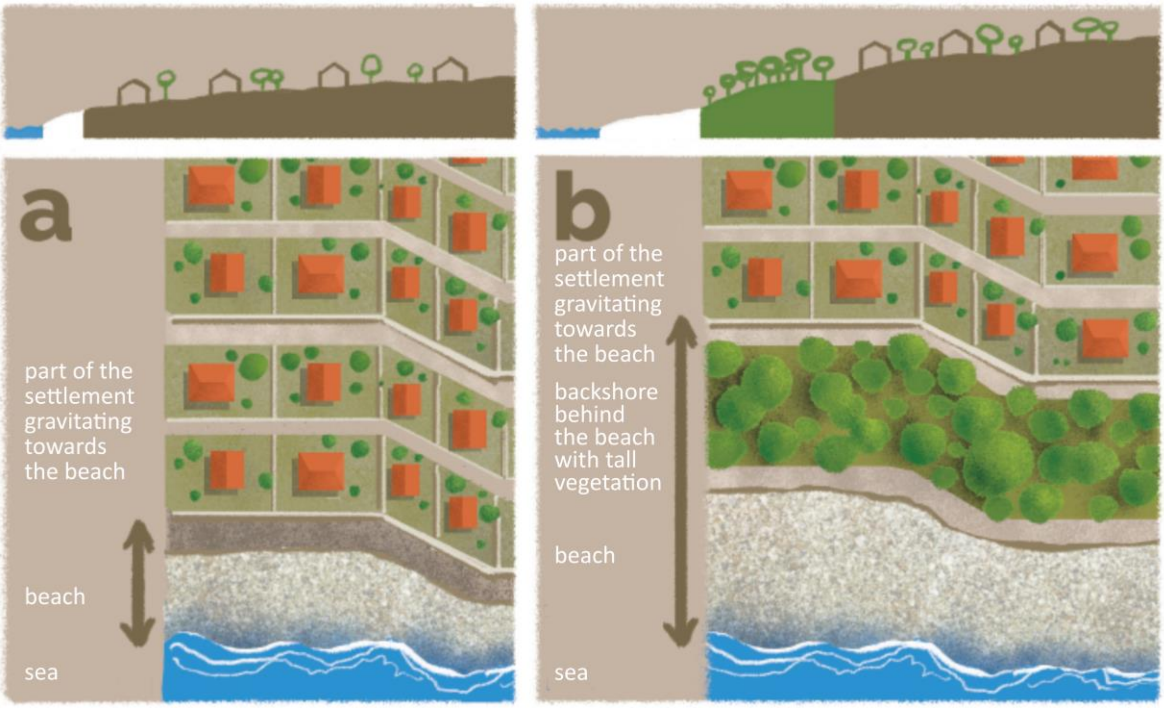


Figure 6. Schematic representation of the coastal setback

Figure 7. An example of a commercial tourist zone in which implementing a coastal setback encouraged the construction of the coastal promenade and a green belt at the back of the beach with recreational facilities that contributed immensely to the quality of the tourism offer and the overall quality of life in this area (Bol, the island of Brač).
(Source: Gojko Berlengi)

A large set of – beach, recreational and other – ancillary services for which coastal setback is required increase the quality of the tourism offer (potentially increasing total revenue from tourism), but also improve residential and tourist capacities in the hinterland, because everyone will conveniently want to use public facilities in their coastal area. The green belt along the beach offers all the more comfortable stay on the beach, especially in a very likely scenario of rising mean temperatures during summer's months on the Adriatic coast. Speaking of social implications, the coastal town gets a beach and other public spaces and amenities open and accessible to all the locals, and not only to those living in houses in the first row to the sea. Speaking of the economic implications, the setback zone and its public amenities tend to become an important asset that, while contributing to the quality of life of local people and visitors, help increase the property value. In terms of urban development, they also result in the expansion of settlements in depth, perpendicular to the coastline. On the other hand, the linear expansion of settlements along the coast, without providing adequate setbacks, results in a significant reduction in the capacity of the beach and *de facto* privatising the coast, while the number of potential beach visitors per unit of the coastline length decreases significantly.

Implementing this measure can become a difficult endeavour given the resistance of landowners (especially in case of the highly fragmented parcelling of land) who lose the right to build on their own land, which puts them at a huge disadvantage compared to the rights of landowners whose land is outside the coastal setback zone. This problem can be addressed by some of the instruments, such as a transfer of development rights, planned land redistribution, or urban land replotting. This is the most important land management instrument, which is used to transform the land passing from one generation to the next into building plots. Throughout the process, steps need to be taken to make sure that that the rights to build are **distributed fairly**. At the same time, urban land replotting helps to make possible that all public amenities (streets, squares, green surfaces, community playgrounds, etc.) are built at no cost to the local authority. The root of the problem of the dysfunctional areas across towns and villages lies with the lack of this kind of instrument. The instrument has been successfully used in, for example, Germany since 1902, as well as in other developed countries, including those with fundamentally different spatial planning policies and cultures, such as Japan or Korea, among many others. An adapted specific example of the Japan International Cooperation Agency (JICA) is shown below.

Figure 8 provides a specific example of the use of a specific land policy instrument – **urban land redistribution**. The top row shows a typical situation of unsound initial urban land distribution, where only the narrowest coastal strip is left for public use. Once that the land has been converted into building land, new buildings are built along the minimum maritime domain and the inadequate road, resulting in a typical longshore linear construction. Beach width is minimal, sufficient for one or at most two rows of buildings, which only encourages further expansion of the same type of construction.

The land distribution done in a way shown in the figures below makes it possible to implement a coastal setback for the buildings in the first row to the sea, which in turn helps create first-class public facilities, beaches, and recreational and other ancillary services. Beside the higher quality of the tourism offer (potentially increasing total revenue from tourism), this solution can also improve overall residential and tourist capacities in the hinterland, as all of them will want to use public facilities available in their coastal area. Land redistribution is done in such a way that all landowners are required to comply with the setback zone and other public use areas requirements and give up the equal percentage share of their land. In this case, the front row plots will remain in the newly formed plot category (which remains applicable to the landowners in the next rows), while retaining equal land distribution and spatial relations.

By resorting to this solution, everyone in the area contributes in a proportionate manner to the overall urban functioning and more affordable utilities, beach attractiveness with abundant tall coastal greenery, a promenade, a bike path, and other recreational facilities. Although all newly formed construction plots are slightly smaller, their total market value is greater than the value of the plots shown in the previous figures. This solution, which helps prevent the *de facto* privatization of the shores and their linear overexploitation, also contributes to better resilience to sea level rise, especially in low-lying coastal areas, making any beach stay much more comfortable, given the inevitable scenario in which average summer temperatures in Croatia and Italy are expected to rise.

Interestingly, this is a widely accepted instrument of land policy in many developed countries around the world. The UN HABITAT programme and its documents, in which the Republic of Croatia and the Italian Republic take an active role, further emphasize the importance of this instrument. Besides the obligation to ensure coastal setback, the importance of land policy instruments for the development of coastal settlements is also emphasized by the ICZM Protocol, which has been ratified by the Republic of Croatia and the EU.

Figure 8. Schematic representation of the land redistribution that allows designing a coastal setback regime (Adapted from JICA)

4.3.2 Managed retreat

Managed retreat is an adaptation option for built coastal environments in which the economic case for constructing expensive coastal protection structures is difficult to justify. This adaptation option helps mitigate coastal risks by relocating exposed people, assets and human activities outside the coastal risk zone. Managed retreat is a measure that implies an initiative taken by the national, regional or local authorities, which has so far been focused on smaller locations and communities (Hino *et al.*, 2017; Mortreux *et al.*, 2018; IPCC, 2019). For example, this is already happening on the south Wales coast and in France. In longshore linear development, this kind of a situation is often likely to happen. Timely managed retreat is critical for ensuring less damage and better adaptation, most importantly, it will reduce the possibility of impacts, including loss of human lives[8] and damage to valuable property. Managed retreat schemes will therefore help create better living conditions for future generations. Managed retreat will also be a good choice for stand-alone buildings on natural shores. Over the past few decades, coastal urbanisation has been following a less favourable trend in both countries, as developers continue to build along the coast, followed by inadequate beach maintenance or extension. This is a specific problem that will be complex and costly to solve, especially on the low-lying coasts directly exposed to the sea action.

If organised properly, managed retreat will help achieve that abandoned coasts are rehabilitated. This is just when the new transitional areas will be able to mitigate wave energy, protect against flooding and turn into valuable habitats, recreational areas and tourist facilities. Furthermore, these zones will then serve as carbon and methane sinks which, in addition to contributing to the safety of the population, also contribute to the fight against climate change. Such areas can also help maintain water quality, as well as reduce the risk of soil salinization caused by inadequate land use (Zhu *et al.*, 2010).

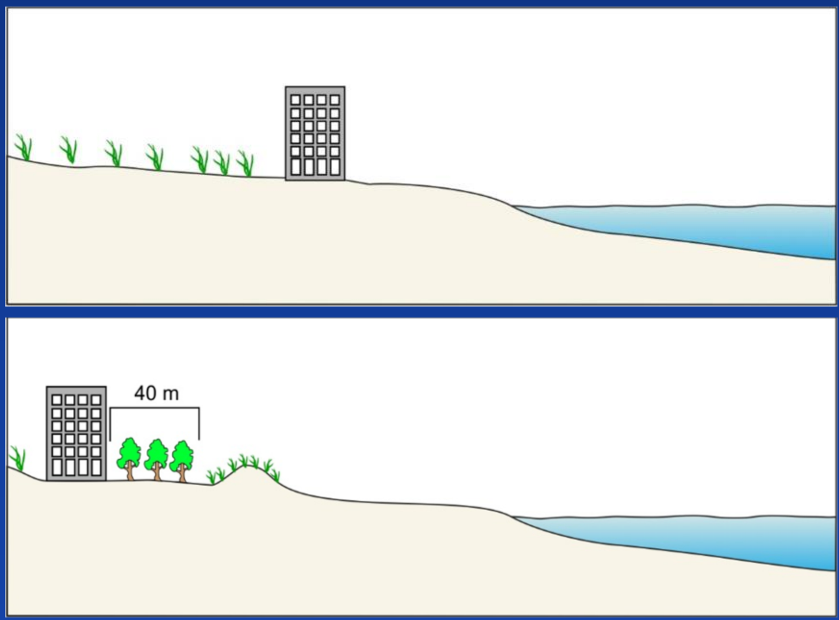
[8] In February 2010, the storm Xynthia flooded the low-lying coastal areas in Vendée and Charente-Maritime on the French Atlantic coast as 41 people lost their lives. In the aftermath of the catastrophe, the French Government set different criteria for flood risk assessment. This zone was declared extremely vulnerable to flooding, homes in the area were bought up by the government and gradually demolished.

Box 5. Impacts of Hurricane Irma on Varadero

The first tourist facilities in Varadero (Cuba) were built at the end of the 19th century as close as possible to the coast as possible. Private homes and hotels continued to spread along the coast until 1959, when most of them became public property.

In the late 1980s, large four and five star hotels were built to accommodate foreign tourists, and the international travel and tourism industry accounted for a significant share of the Cuban GDP.

From 1987 to 2012 the coast of Varadero was artificially nourished with a total volume of 3.4 M m^3 of sand quarried on the continental shelf; this allowed to maintain the beach without hard structures notwithstanding the erosion caused by several hurricanes. At the same time, strategic retreat, demolition of structures and their construction into the inland started, at least 40 meters behind the reconstructed dune. Hotels and beaches are connected by wooden, commonly elevated walkways.



Hurricane Irma ravaged the coast in Varadero, leaving different extent of damage in the areas subjected to coastal retreat and those that remained in their original configuration: the former did not suffer significant damage, while the latter suffered significant environmental and economic damage.

Managed retreat was also carried out on two roads in the Mediterranean, in France, between Sète and Marseille, as well as in Slovenia, where the road between Koper and Izola was pulled inland. Both cases are presented on the AdriAdapt Adaptation Knowledge Platform.

4.4 Sustainable spatial development in coastal areas

The rates of residential and tourist development in the narrow coastal zone and the expected sea level rise further emphasize the importance of managing spatial development. Given the importance of the landscape and environmental values of the coastal area, three topics will be particularly addressed: rational use of the coastal areas, maintaining integrated landscape values and improving quality in the built environment.

4.4.1 Rational use of the coastal space

The use of coastal land can be observed based on:

- total anthropogenic land use, in particular as a result of the expansion of construction sites, and exploitation of coastline resources (colloquially known as coast covered in concrete and apartments);

- irrational use of large construction sites, especially through dispersed construction that is not followed by adequate community infrastructure.

Coastal space consumption is a good indicator of unsustainable coastal spatial development, specifically given the speed and the increasing coastal urbanisation, as illustrated by the example of the Croatian coast. The figure below shows the trends in the use of the Croatian coast, showing that over the past 40 years one generation occupied four times as much coast as all the generations before them.

If this trend is compared to population growth, it may be observed that this area saw a population growth by about 25% between 1961 and 2011, while the urbanized coastal built-up area increased by almost 500% in the same period. This extent of coastal land use obviously goes far beyond the needs of the local population, the main reasons being tourism development and mass coastal development of second homes. Accepting the reality that tourist facilities and infrastructure built in the coastal zone make tourism one of the country's most important industries (just under 20% of Croatia's GDP), a high price tag on the impacts of coastal land use, primarily for second homes, must not be forgotten either. Likewise, there is a significant lack of uniformity in the design and functionality of the coastal settlement structures, with rampant illegal construction along valuable coastal areas.

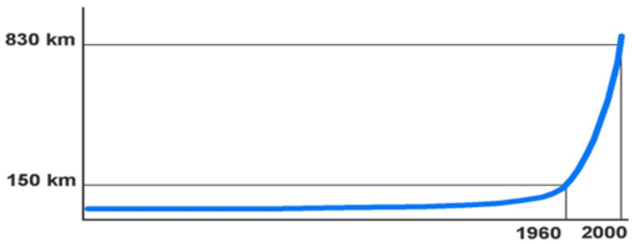


Figure 9. Trends in the use of the Croatian coast as a result of the construction of anthropogenic structures in the narrow coastal belt (Source: Gojko Berlengi, based on data from the Report on the Spatial Situation in the Republic of Croatia in 2003)

The most important recommendation regarding the spatial development in the coastal zone is the obligation of more responsible planning of future land use for the development of settlements and other purposes, and especially more responsible construction in the narrow coastal zone, which has been defined by the Physical Planning Act in Croatia as the area within 1 kilometre from the coastline. Besides granting a derogation with regard to the obligatory setback, the above mentioned Act does not impose any topographic restrictions on land-use practices, including those that relate to managing future coastal flood risks, so a large share of responsibility for spatial planning falls on local administrations.

In relation to excessive use of the narrow coastal belt, it is particularly important to refrain from longshore construction. The scope of this issue is set out in Article 8.3 of the ICZM Protocol, as well as in the Croatian Physical Planning Act. Unfortunately, these provisions do not work in practice, as no indicators have been set to monitor their implementation. From the point of view of coastal protection against floods caused by rising sea levels and extreme weather events, this is probably the least rational form of coastal spatial planning. The conclusions of the "Assessment of cost of sea-level rise in the Republic of Croatia including cost and benefits of adaptation" (Hinkel *et al*., 2015) further emphasize the importance of limiting further coastal urbanisation. Taking into consideration the cost-effectiveness of coastal protection measures at the level of coastal segments, the study suggests that it comes to light that protection measures are cost-effective only for large urban areas with high population and property density. Analysing this allows us to conclude that the narrow urbanised coastal belt cannot generate sufficient demand for safety, i.e. sufficient number of natural and legal persons ready to cover the cost of coastal protection measures. These measures are very expensive, however, managed retreat is an expensive alternative too. In this case, prevention is the best and wisest choice, as well as strict implementation of the law and the avoidance of further linear urbanisation of the coast. To promote more effective performance monitoring, a new target indicator of the rational use of the coastline was introduced within the Coastal Plan for the Šibenik-Knin County.

Another consideration that is worth a glimpse is the unreasonable use of construction areas, especially through dispersed development.

Dispersed development translates into large-scale construction projects and poor sustainability in terms of local spatial development, as well as the failure of local administration to guide the process and identify the most appropriate areas for this kind of projects. This results in the usurpation of coastal land and the absence of a coherent typology of a settlement, unnecessary loss of natural or cultivated landscape, expensive or unachievable communal, public and social facilities, as well as unnecessary pressures on the environment. This is particularly important in relation to cars and other modes of transportation, given the need to reduce CO_2 emissions to mitigate climate change. In the long run, this problem will most likely be effectively tackled only by imposing carbon taxes. This will significantly increase the cost of traffic, and people living in those areas might be cost burdened even more they are now.

Figure 10. Cases of the linear urbanisation along the coast as an example of unreasonable development by which the natural coast, an important public good and an essential component of the tourism industry, is slowly, but irreversibly 'worn away'. Clearly, it may be rather difficult to find funds for coastal flood defence schemes to protect such a small number of properties, scattered along the long Croatian coastline. Besides protecting the real property, appropriate measures to minimize marine pollution after a flood will need to be taken, as well as appropriate recovery efforts. (Source: Google Earth)

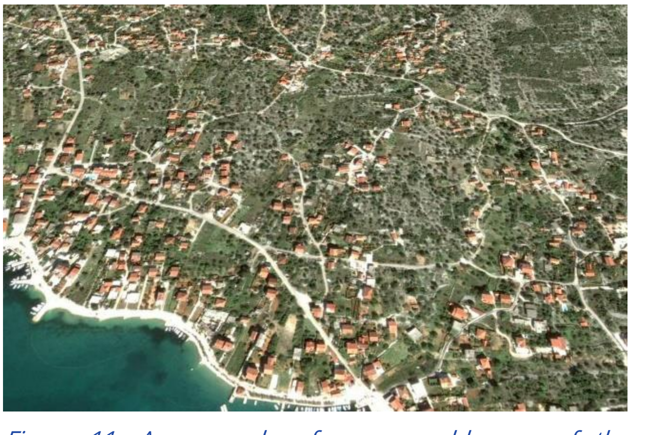


Figure 11. An example of unreasonable use of the construction area in the settlement through dispersed development, without an adequate basic street network and basic elements of the urban system (partly due to illegal construction). This is an area that would require urban recovery measures that would help create a more acceptable settlement pattern and contribute to its overall functionality through a more rational street network and overall municipal infrastructure. (Source: Google Earth)

4.4.2 Protecting coastal landscape values

There are multiple causes of threats to coastal landscape values. This is often the result of inappropriate construction and land use, including construction works outside dedicated construction areas that could threaten the preservation of valuable coastal areas, especially cultural landscapes. The cumulative impact of numerous and spatially dispersed, albeit small interventions on valuable natural landscapes can be devastating in the long run. This is the greatest challenge for local and regional governments - how to encourage and enable development on the one hand and preserve and improve inherited values on the other hand. At the same time, it is critical to understand that protecting the landscape and environmental values will also mean increasing the economic value of assets and businesses, since the market recognizes and appreciates them. Spatial plans that recognize landscape values and establish appropriate conditions for their protection and sustainable use, taking into account the risks posed by climate change, are the most important tools needed for achieving these goals.

Degradation of valuable agricultural cultural landscapes seems to be particularly harmful for the preservation of integrated landscape values. There are several reasons why they seem to be degraded or disappearing, starting with the depopulation of rural areas, the neglect of traditional agriculture, but also the conversion of agricultural land into construction sites.

Rural depopulation is a complex challenge requiring a systematic response. To be preserved, agricultural cultural landscapes require traditional agricultural activities. On the other hand, those are less favoured areas which require additional incentives to approach cost-effectiveness. Among other things, shortening supply chains, or in other words, product placement where these are produced, would help contribute to this goal, especially as part of an integrated tourism service (agritourism). It is also important to focus on indigenous varieties and breeds, as well as on organic production as a way of adding value to local products. Most northern Mediterranean countries are faced with this problem, integrating different successful solutions. Depopulation and neglect of agricultural activities may have important consequences for this area, which tend to become overgrown with maquis and forest-clad (mostly pine), as well as exposed to growing wildfire risks. This is why it is even more important to stop rural depopulation. In all of this, systematic incentives and coordination of agriculture, tourism, environmental protection, cultural heritage and fire protection sectors are a necessity.

Figure 12 A good example of how rational expansion of a settlement that follows compact settlement patterns can be achieved, striving to avoid longshore expansion and coastal development, which in turn helps establish more green spaces and recreational facilities for the public. (Source: Google Earth)

Figure 13. An example of preserved cultural landscapes with organic farming and tourism offer (Source: Gojko Berlengi)

Figure 14. The vegetation helped prevent fires from spreading. (Source: Nikola Tramontana)

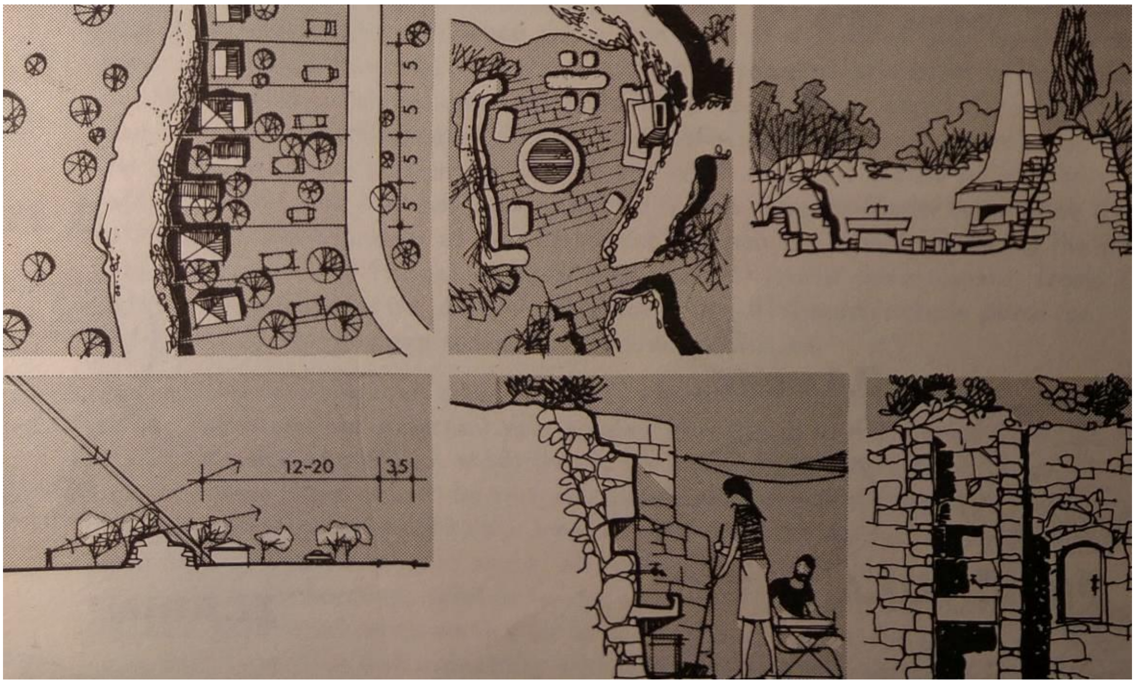


Figure 15. An example of the camp project (Physical development plan for the South Adriatic region, UNDP, 1971) in which the existing landscape structures (drywall network) were maintained as authentic local landscape elements, contributing to the overall functioning through the creation of private micro units and landscaping details.

4.4.3 Improving quality of the built environment

The quality of the built environment means functional and physiognomic morphological characteristics of the built environment, as well as the available municipal infrastructure. The system of public areas, facilities and equipment is a key element of the settlement functionality and the built environment. The built environment physiognomy and morphology mean the quality of space design, composition values of the settlement matrix, respect for the existing landscape values and valuable elements of the local traditional settlement typology. The examples of good and bad settlement practices are shown below, keeping in mind that some of the bad practices keep occurring more or less due to illegal construction.

An overview of green spaces, specifically deemed as public goods (parks, roadside trees) and an important element of functional spatial planing, good design and environmental protection in the settlement is provided in Chapter 5. Finally, the architectural design of individual buildings and their immediate environment is also important for the assessment of the quality of the built environment.

Traditional settlements in the attractive intact, natural environment near the coast with unrivalled sea views are particularly exposed to pressures caused by new construction projects. In the planning of constructional interventions in traditional areas, the system tends to rely on the guidelines set forth in spatial plans, including conservation requirements. Design guidelines can also be an important instrument that has been used worldwide, especially in the contexts of strategically robust spatial planning systems. "Lessons from the heritage for building on the Croatian Adriatic coast" (2007), the manual intended to improve the culture of the Croatian construction industry, especially for properties in or near protected areas is an example of this kind of instrument, albeit non-binding. As its title suggests, this manual is intended to provide a ready reference to areas that share common building traditions, rather than discussing specific spatial planning document. The ultimate objective is to give a clear account through a series of photographs, drawings and examples of good (as well as bad) practice highlighting how to run a successful intervention in heritage environments and how to respond to modern methods of construction and their specific requirements in the context of the traditional building practice.

Field huts in rural areas should be located along the edge of the plot, on grounds unsuitable for cultivation. Examples and guidelines from "Lessons from the heritage for building on the Croatian Adriatic coast" (Belamarić J. *et al.*, 2007) reflect the relationship between settlements and arable land.

Hence it is possible to develop specific guidelines at the county and regional levels for investors and entrepreneurs that would take into account both local traditional architecture and climate change.

Figure 16. Examples of inappropriate practices and substandard solutions to spatial planning in coastal regions. A lack of conceptual clarity is observed in the design of the physical structure of the settlement, as well as the absence of a setback that would allow any kind of public use and access to the coast, inadequate street network and inconsistent adherence to the urban development policies and spatial order rules. (Sources: Google Earth and Gojko Berlengi)

Figure 17. An example of spatial planning details in the same coastal settlement reflecting care for public spaces, use of local and traditional materials (underpinning walls, paving material), relationship to the environment (absorbent surfaces) and the existing green spaces, as well as abundant private and public green spaces. Another example of good practice is parking lot landscaping for 'visual relief' (along with the amount of shade provided) with trees and shrubs distributed throughout the parking area. All of these good practices of spatial design are at the same time considered excellent adaptation measures to climate change impacts, such as heat islands or extreme precipitation that cannot be drained properly through the drainage system. (Source: Gojko Berlengi)

Figure 18. Medov dolac, Raosi village. The village is located between two sinkholes cultivated by the local population.

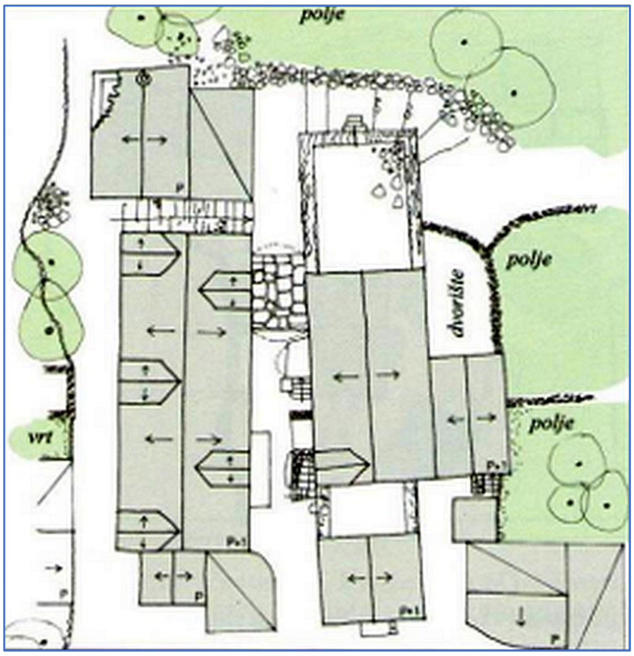


Figure 19. Drašnice, Alači village. Residential buildings and outbuildings are located along the edge of the field. The practice of terracing and dry stone walling as a method of enclosing fields has been employed to reduce slope steepness.

Box 6. Spatial planning and fire safety

Spatial planning has traditionally been considered a powerful mechanism for the prevention of fire risk. In Croatia, the regulation that would include specific reference to fire risk prevention in spatial plans is still expected to come into force. The spatial plan must include strategic policies to address the need for strategically located, sufficiently wide and well-maintained firebreaks and forest tracks, heliport facilities, bodies of water and access roads to critical infrastructure and forest facilities.

4.5 Social measures

As part of societal measures, social measures focus on:

- Enabling local people living in the coastal areas to co-create their future environment;
- Creating favourable psychosocial environment for building and developing resilience to the impacts of climate change. There is a plethora of awareness raising activities for local people living in the coastal areas that help people understand the impacts of climate change, as well as advocacy campaigns that help them find solutions. A fundamental task is to offer modern, attractive, hands-on and cause-oriented education to the general public about sustainability and resilience in the context of global warming and its impacts on coastal areas;
- Encouraging behaviour change: helping individuals take a step away from intentional or unintentional contribution to increasing concentrations of anthropogenic GHGs and their impacts caused by their lifestyle, transportation and work choices and become environmentally conscious individuals that actively make great strides to reduce greenhouse gas emissions.

Who do the resilience-building measures apply to?

1. territories (some countries or regions), settlements (ranging from large towns and cities to small settlements);

2. centres of research and knowledge creation (universities, institutes...);
3. governmental systems and organizations, managing authorities for social, spatial, environmental and other matters;
4. entrepreneurial systems and organisations in goods-producing and service industries;
5. civil society organisations, and
6. citizens who live in coastal regions.

From a slightly different angle, resilience-building measures in this handbook apply to:

- people who live in coastal regions;
- people who do not live, but work in the coastal area in goods-producing and service industries;
- people responsible for managing narrow administrative units along the Italian and Croatian coastlines and in the hinterland, and
- people who are mindful of the future of the coastal areas (education, science).

Based on a set of sociological insights, it could also be argued that people mostly perceive climate change as a distant problem: they know little to nothing about global warming and climate change. A lot of people think that we will not bear the brunt of climate change until much later, and that it is just one of many other issues. This is certainly wrong on all counts, and it does not help build resilience to climate change – here and now.

4.5.1 Giving local people living in coastal areas a chance to co-create their future living environment

The Adriatic coast has been shaped by the centuries-long work of its population, who created their living environment, built their settlements, working space, ships and vessels, their way of life. Coastal areas and its population will need to adapt to the climate change challenges and possibly growing problems ahead. A sharp decline in greenhouse gas emissions in the modern consumerist world is highly unlikely. Greenhouse gas emissions will probably continue to grow for a few more years. In addition, rising sea level is one of the slow onset effects of climate change that would likely continue to rise even after emissions of greenhouse gases were stopped. Living and creating one's living environment along the Adriatic coastline requires taking unprecedented action to build resilience. The necessary change does not only require a slight adjustment to climate change impacts, but changing our patterns in terms of the way we live, travel, produce goods and services and protect flora and fauna that give us food and life. Co-creating our future environment will be a daunting task that would take decades to complete. It is going to be a brand new world.

4.5.2 Raising awareness and providing systematic education for people in coastal communities and beyond

The temperature on Earth has been steadily rising for years. Climate change as a result of global warming is already pervading our daily lives, activities, space. This pattern may suggest its intensification – making fires, floods, melting ice, changes in flora and fauna more frequent and intense. There are observed effects on people and their environment. Populated, low-lying coastal areas around the world are particularly sensitive.

Given the above, a number of things is called into question. What human and social tools can we use to reverse the harmful effects of climate change? What political and administrative decisions do we need to make? What financial and investment opportunities, projects, funds are available to invent new – environmentally and climate friendly – technologies? What new models of resilience-building activities and actions could be taken at regional and local levels? From the point of view of social measures, we believe that investing in systematic education of today's and future generations about climate change is paramount at this stage of awareness and knowledge in modern society. An ill-informed person, ignorant of the facts of climate change, can neither understand nor change something for the better.

What systematic activities can we provide to raise awareness, share information, spread the knowledge about the causes and consequences of climate change in modern countries and societies? Have we done enough to systematically teach primary and secondary school students, who will probably be the ones to face serious issues due to the climate and ecological emergency, about sustainable development, global warming and climate change? So far very little has been done in practical terms.[9] On average, people know very little about the patterns and consequences of climate change. Many of them perceive climate change as a distant problem. Media are the primary sources of information related to shocking climate change events, and people tend to deal with this subject occasionally and superficially. We tend to become aware of the consequences of climate change as we learn about the terror of the Australian or Californian bushfire, fire fighters battling flames on the outskirts of Split in Croatia, storm surge crushing coastal towns around the globe, the entire towns being wiped off the map by a tornado in the US, or when enormous chunks of ice breaks off from the Arctic and Antarctica.

If so, the most important social measures, targeted to people, their awareness, knowledge and their willingness to take action include:

- awareness-raising activities for different population groups;
- systematic education for public servants responsible for the urgent transformation of society;
- education system for young generations; and
- innovation, through courses, seminars, lectures, etc. – citizenship education for different categories of the adult population.

In other words, the starting point is systematically raising people's awareness about current problems caused by climate change, and systematic efforts for increasing the public's climate literacy in modern societies. Speaking of this project, AdriAdapt is all about improving the climate literacy of the population on both sides of the Adriatic coast.

National educational authorities should be in charge of the systematic climate change education that takes years to complete. Local and regional coastal areas alone are unable to start something of that kind because the lack of funds, and a lack of infrastructure and human resources is only storing up more trouble. Climate change education should include local problems and difficulties related to climate change, their causes and consequences, etc.

Specifically, a climate-literate person:

- understands the essential principles of Earth's climate system;
- knows how to assess scientifically credible information about climate change;
- communicates about climate and climate change in a meaningful way; and
- is able to make informed and responsible decisions with regard to actions that may affect climate at both the local and global levels.

Do people living on the Adriatic coasts in Italy and Croatia know enough about climate change? It seems like the right time to think hard about this. How far would you get in climate literacy challenge?

4.5.3 How to encourage individual change

How to harness individual behaviour to address climate change and its impacts? Raising awareness and promoting education and understanding climate change is the first step in the process. A person is willing to change his or her views based on their interest in a specific issue, one of which is the climate change impact on the Adriatic coast. People need to be interested and motivated to learn more on this topic. This is why active, systematic encouragement is so important. Unfortunately, climate change impacts will show us a thing or two on how much climate change can affect our lives, with extreme weather events ravaging our property, homes, agricultural lands, coasts and boats. Coastal flooding caused by a specific set of tidal and wind-related events will become more common, as well as flash floods, coastal erosion, and creeping hazards such as sea level rise, as residential and tourism facilities and roads adjacent to such instabilities are being threatened. Given the widespread violent and greedy coastal development and the practice commonly known as 'covering coasts in concrete' that keeps going ahead despite the existing spatial plans, putting an end to this will be a welcome change.

[9] In November 2019, Italy announced that the course "Sustainable Development and Climate Change" would be introduced to Italian schools in autumn 2020. This was the initiative of the Ministry of the Environment, supported most prominently by the Minister himself. In Croatia, the first initiative of this kind has yet to be discussed.

Final considerations on social measures

Let us imagine that, in the coming years, people acquire knowledge on causes and impacts of climate change on the Adriatic coast, through climate change education in schools, as well as NGOs and climate change campaigns. People also learn from the struggles they went through in the past. The experience leaves them thinking hard about what can be done to prevent this happening again. Politicians and entrepreneurs are taking certain steps, they invest in prevention and coastal protection to fight against coastal flooding, coastal wildfires, and harmful construction projects along the coast.

However, climate resilient coastal protection schemes at the national, regional and local levels are still lacking. What kind of a cognitive bias has been hindering us from taking this approach?

Now, let us imagine that the Croatian and Italian governments, Croatian counties and Italian communes and provinces decided to establish Climate Action Centres in 2020. What would these centres do?

- They would conduct regular monitoring of processes caused by climate change at the regional and local levels;
- They would analyse activities, technologies and behaviours that contribute to global warming and climate change; analyse and endorse activities, technologies and behaviours that help reduce greenhouse gas emissions, and issue warnings and recommendations to reduce the former and encourage the latter;
- They would continuously carry out a systematic analysis of local cases of environmental threats caused by climate change and their types;
- They would establish early warning systems for climate change hazards and climate-related threats to people and assets;
- They would help build a bridge between institutions and local people in an emergency to contribute to the rescue efforts or help affected people, families, homes and areas;
- They would help tackle local climate change impacts on human health and assets in a coordinated way;
- They would make recommendations regarding construction, agricultural and other activities in the future in terms of risks, inherent uncertainty and potential levels of damage that may affect the specific local coastal area as a result of climate change.

Societal measures have the potential to help the countries establish centres for climate change and promote innovative governance, in which social measures and their educational dimension play a vital part.

5 Green measures

Green measures, i.e. nature-based solutions, imply an array of adaptations to climate change that integrate the ecosystem-based approach.

Considering the coastal areas, green measures include topics such as ecological conservation and ecological restoration, and planning and management measures for conservation and restoration. The topics outlined in this chapter include ecological conservation and restoration in the context of coastal cities and villages, shoreline urbanisation, hinterland areas, natural coasts, coastlines and coastal waters. Our discussion on coastal cities particularly focuses on green and blue infrastructure and other green solutions that can help prevent floods and urban heat island effect. In addition to floods, wildfires present a substantial risk to the backshore areas too. The most important factors of the intact coastal regions are conservation and restoration. Therefore, green measures have high potential for climate change mitigation. The eastern and western Adriatic coasts are quite different. Given the difference of coastal types, we will be looking at coastal erosion protection measures along the western Adriatic coast. We will also discuss green measures that apply to coastal waters, known as "blue" measures, which help prevent coastal erosion, but also play a major part in the fight against climate change. Finally, we will look at aquifer protection and conservation measures. The main partners for implementing these measures are usually local, regional, or even national governments. The success of their implementation relies on the cooperation of a variety of authorities involved.

Green measures can play a major role in any coastal setting, including coastal cities, shoreline urbanisation, backshore areas, while they are the most cost-effective solution used to protect natural coasts. The coastal area, as the place where the sea meets the land, stretching along two different ecosystems and landscapes[10] has an exceptional value. The biological perspective illustrates that this is a transitional area characterized by a large number of plants and animals, which therefore has an outstanding ecological value. From the landscape perspective, the place where two completely different landscapes meet brings to life rich experiences and an abundance of opportunities. This is true for both sides of the Adriatic, reflected in high population density, an abundance of activities, including development, mostly in the near shore area. The greatest threats to this zone come both from the sea and from the land. In the coastal area, water is a key resource for the safety of the natural environment. Any change in the characteristics and availability of water inevitably changes the natural environment, as well as the living conditions and resources. Those measures aim to reduce the risk of disasters in the cities, especially floods and heat waves, and urban heat islands, but also to enhance quality of life by securing clean air, clean water, and the capability to live a comfortable life. Green measures all contribute to the fight against climate change, which makes them more sustainable, robust, and generally more cost-effective than engineering measures. This provides an opportunity to reconsider the importance of preserving and restoring existing vegetation and ecosystems in coastal areas, including in the coastal waters.

5.1 Coastal towns, cities and settlements measures

In coastal towns, cities and settlements, the sea is a key element of the urban ecosystem that needs to be integrated with the land elements of the system into a specific coastal urban ecosystem. As an element of the ecosystem, water plays an important part in its safety and sustainability. Along with food and energy, water is one of the existential resources in any natural system, including the urban systems. Any urban planning efforts must take this into account if they aim to design green, healthy and safe cities. To make our

[10] This zone is called – an ecotone

cities green, we have to think blue to provide enough water for biocenosis. Climate change has altered precipitation regimes. It left its mark on biocenosis, too. The so-called blue urban infrastructure (local urban hydrological restoration strategy) will need to boost water management in urban areas to support the safety of biocenosis and improve overall resilience. This chapter will address the measures and instruments that can help us achieve this. It should not be forgotten that the coastal waters and coastal processes are also important here.

Green measures are particularly important for cities and settlements as they come with a whole host of benefits. Features of urban coastal areas generally include a significantly higher percentage of built-up, hard, horizontal or near-horizontal areas and, to a large extent, hard vertical shores. In the former group, it is all about soil sealing, that is, covering the soil surface by materials such as concrete and asphalt, or surfaces covered with gravel or compacted soil – surfaces with minimal green cover. As for the latter group, a modified wave reflection system can be observed, completely different than it was before the intervention. Sealed surfaces and green spaces in coastal towns also significantly condition the quality of the coastal waters.

The questionnaire completed by the local governments in Croatian and Italian cities as part of the AdriAdapt project revealed that **floods** were recognised as the most common negative impact of climate change, with stormwaters on the one hand and the sea on the other hand. Cities and settlements are vulnerable to surface runoff due to the share of the built-up area, with very few soakaways.

In addition, we are increasingly faced with extreme weather conditions, along with heavy and abundant rainfall. The existing drainage systems in most cases fall short of current requirements. Furthermore, there are very few soakaways, which leads to a condition called waterlogging and flooding that can have devastating effects on buildings and other property. As stormwater makes its way to the sea, coastal waters quality may be compromised too.

On the other hand, when little or no rain falls in summer, but also in other dry periods, cities can also expect **stormwater running** along streets, rooftops, parking areas or other developed land. This is how we lose water that could be used for many other purposes, and an important natural resource that could help cities make the most of green infrastructure. This is not so much about losing potentially potable water, an extremely important natural resource, as it is about fast flowing water that could attenuate **temperature fluctuations** by evaporation. Based on the above, it is safe to assume that urban areas are ill-equipped for the periods of below-normal rainfall.

Either way, solutions can be found, but the success of implementation depends on whether the administration really understands the adaptation needs, as well as on the robustness of physical planning instruments. In both cases, it is important to commit to unsealing sealed areas by turning them into pervious surfaces, which will not only support soil respiration, but also add a multi-layered structured green superstructure. As for the rapid surface runoff, the drainage system should be based on above-ground water retention solutions. We also tend to protect ourselves from urban floods through the implementation of solution-oriented spatial plans for wider areas. Based on past experience and specific data on the damage incurred – **retention areas** appear to be a solution (the example of Curitiba, a city in Brazil, reveals that this approach can make transformation efforts much easier). This is another task where the quality of cooperation between regional and local authorities determines how successful flood protection measures will be.

Urban green spaces also help in the fight against air pollution, which has even greater impact on human health due to high temperatures. This is particularly dangerous for children, starting from the impact on their development, to allergies and respiratory diseases. Apart from the fact that those of us living in the cities mostly have less of them than necessary, urban green spaces certainly need to be better maintained. In fact, the AdriAdapt questionnaire for local governments has shown that the incidence of damage to tangible property due to fallen trees or branches, and sometimes even the loss of human lives, is rather high. Therefore, companies tasked with urban green space management need to intensify their efforts in this respect, too. Monitoring the health of trees and replacing them regularly in new climate conditions will be an increasingly challenging task.

The negative impacts described above are largely caused by poor decisions in our social systems, spatial and urban plans, or poor plan implementation, the absence of the necessary coastal infrastructure and inability to understand the importance of sustainable development goals. Consequently, as mentioned earlier in the chapter on societal measures, spatial planning, but also many other measures have tools through which these negative impacts can be significantly reduced. In addition, in a very short period since urban ecology has emerged as a new discipline, thanks to the tools of landscape architecture and the related disciplines of urban forestry and engineering ecology, these findings have encouraged positive reactions worldwide, allowing us to enjoy the green spaces design solutions for water retention in small city parks, mini retention zones along the roads and parking lots, as well as targeted water retention in underground reservoirs - so that it is released to nourish tree roots in a given interval. The application of horizontal and vertical landscaping practices creates the favourable microclimate conditions and increases the energy efficiency of buildings, thereby increasing their market value.

Figure 20. Examples of good practice in urban vegetation and landscape planning, which are also important adaptation measures related to the impacts of climate change in settlements. These are the so-called multiple win-win measures that not only improve air quality, but also increase the share of permeable surfaces that reduce pressure on stormwater drainage systems, and due a higher share of green areas, they reduce heat island formation. (Photos: Gojko Berlengi and Daria Povh Škugor)

Coastal flooding poses a particular risk to coastal cities and settlements because it may directly affect all unprotected low-lying coastal areas, and even drainage systems. Surface and groundwater flows from the wider coastal area towards the coast and flows into the sea. The area where surface and groundwater flows into the sea is the narrow coastal belt. This interaction and adding up the effects of these waters during heavy rains in the coastal zone creates extremely difficult conditions, as well as significant negative consequences for people and their environment. On the eastern side of the Adriatic Sea, due to the steep slopes of the Croatian coastal areas, there are enormous amounts of the hydrodynamic water energy, so rainwater in the urban coastal area has an extremely rapid and strong impact. Pressures and consequences will increase in the future, as climate change tends to cause more of these events, as well as sea pressures (waves) and large quantities of coastal water. Flooding will become a major problem, a climate hazard for coastal towns and settlements on both sides of the Adriatic, but the contribution of rainwater from the east will be crucial.

As for the urban coastline and its fresh, new look covered with asphalt, it is rather difficult to find meaningful green measures. In this case, engineering or grey solutions will offer more options that should be applied in combination with green solutions whenever possible. The soft shorelines on the western side of the Adriatic, along the urban beaches, and future shoreline extensions will pave the way for the application of green measures. Likewise, looking at the 100 metre setback zone according to Article 8 of the ICZM Protocol, especially in projections of the future, there will be more room for green measures to enrich coastal towns and villages in any way they can. Finally, green measures can be applied to the sea itself, as well as to the remaining parts of natural coastlines in cities where conservation of the existing ecosystems, and restoration when necessary, has become an increasingly important task.

Without a doubt, cities are generators of specific urban **biodiversity;** they are home to more animal and plant species than their surroundings. Herbert Sukopp, one of the doyens of urban ecology, once said that the old town centres had a high degree of biodiversity (we can call them green islands), so special attention should be given to their preservation. This proved to be correct on both sides of the Adriatic. Since the role of urban green spaces was mostly aesthetic, at least until recently, little attention has been given to naturalness and other positive impacts on people and the natural environment. The role of urban green spaces has not been frequently considered in terms of the need to combat heat islands, air pollution or flooding. Today these disasters impose a different definition of green space and its function in cities. Vegetation is essential for maintaining humidity levels, oxygen and carbon dioxide balance in the atmosphere and serves as an exceptionally supportive environment for fauna development. Given the biodiversity status, greenery is not the only thing that matters, but also all the animal species that could enrich the cities and help establish a natural balance in coexistence with humans to strengthen the safety in the natural environment and promote sustainable living. The creation of **ecological corridors** in the cities enables the continuous and active transfer of genetic material needed for the restoration of life potential. The aim is to integrate as much greenery as possible into the city's urban tissue, to help the city areas connect through ecological corridors, and especially connect them with the natural environment outside the city itself. **Urban green infrastructure** needs to consist of near-natural and built-up areas, planned and maintained in such a way that the entire infrastructure offers top quality in terms of utility, biodiversity and appearance, while delivering a large number of ecosystem services. Regardless of their ownership or origin, all types of sites and individual elements characterized by vegetation or water can become parts of the green infrastructure.

Figure 21. An example of valuable "neglected" salt tolerant greenery (Photo: Igor Belamarić)

Figure 22. Multiple functions of urban green infrastructure (Photo: Igor Belamarić)

The great potential lies in the seemingly neglected urban spaces. On both sides of the Adriatic, there are areas that 'have not yet come into use'. Sometimes they are intended for greenery, sports, sometimes they are peripheral zones, or something of this kind. Vegetation flourishes in these areas – particularly those natural parts that, in combination with planted greenery, facilitate the organization of ecological corridors in the cities. Birds, insects, squirrels, hedgehogs and the like can often be spotted in these areas. This is a huge opportunity and the city authorities and plant care businesses can and must make the most of it. In order to be successful in carrying out these tasks, the municipal companies must empower their employees for this.

A modern local government understands the new role of nature in cities and, through the inclusion of green infrastructure in spatial plans and through enhanced maintenance and planting plans, it will support the transformation of their city into a place where people want to live. There is an extensive body of literature on nature-based solutions for cities and towns. The EU Green Infrastructure Strategy has paved the way to the widespread application of these solutions, which are expected to become a standard element of spatial development across the EU by being integrated into other EU regulations. The inclusion of green infrastructure and nature-based solutions in climate change adaptation plans is one of the essential steps. In this respect, one of the key tasks for local government is to reduce impervious surfaces to provide sufficient moisture for plants. It is necessary to build structures that provide enough sunlight, or implement LID techniques[11] that use or mimic natural processes and create infiltration, evapotranspiration or use rainwater to preserve water quality and water-dependent habitats. All these green measures can also help improve the quality of the built environment, one of the important characteristics of coastal cities where tourism plays an important role, as pointed out in the chapter on spatial planning.

Within the framework of the AdriAdapt project, a detailed modelling of the impact of climate change on the quality of the coastal waters was carried out in Šibenik, Tribunj, Vodice and Srima. One of the recommendations for strengthening the resilience of sea quality is that the share of impermeable surfaces in these cities must be reduced by at least 50% (Ružić, I. *et al.*, 2021).

As discussed in the previous chapter, the involvement of the local community is crucial, both in cities and in the whole coastal area, regardless of administrative boundaries or level of technical expertise. Local governments should encourage desirable behaviour patterns through all available instruments, such as economic incentives (for example, variable utility charges for those who choose to contribute to environmental goals); through joint cooperation and awareness-raising actions. Planting initiatives (such as the "Plant a tree, don't be a stump!" initiative in Croatia, 'adopt a tree' initiatives, etc.) or actions seeking to engage citizens in citizen science (such as the iNaturalist application) develop and raise awareness of the importance of nature and biodiversity and help make room for nature in cities. New industries, such as artificial intelligence and gamification offer tremendous opportunities for modern administrations. At the higher level, activities of this kind could increase the overall value of ecosystem services. However, perhaps the most important thing that will result from this kind of involvement in the cities will be citizen participation and transformation of citizen awareness, a better understanding of the importance of nature and all ecosystem services and, finally, understanding how dependent we are on healthy ecosystems.

5.2 Measures for areas subject to coastal linear urbanisation

This specific form of urbanisation also has its specific challenges related to adaptation to climate change. As opposed to, for example, soft sandy beaches in Thailand and Malaysia, green measures only will not be enough to help the rocky limestone karst coasts along the Eastern Adriatic adapt to the changing climate conditions. This kind of urbanisation on steep coasts, such as those in the

[11] Low Impact Development (LID) techniques

eastern Adriatic, is an obstacle to sediment transport, which used to contribute to beach nourishment, mostly gravel in this case, before the construction project started.

As for suburban and urban linear sprawls, their natural watercourses are mostly organised as channels, sometimes with a solid concrete vault, while the coastline usually contains a more or less fixed, built front. The third major component of the system consists of fragmented parts that in many ways resemble the more natural areas that will be discussed in the following chapters.

The old watercourse maps should be revised given that there is a possibility of renaturation. The gradual implementation of such a project would bring different benefits to the watercourse and its surroundings. Preventing rapid runoff will again have a beneficial impact on the climate by turning the area into a habitat for lost flora and fauna, so the impact of the site on biodiversity will be significant. The European experience has shown a relatively rapid return of those at the top of the food chain, which is generally considered indicative of a habitat in good condition.

The eastern coast of the Adriatic has undergone many transformations, turning from open space into an area subject to linear extensions, which largely depended on the geomorphology and specific terrain layout. As a side effect of a possible long-term stay (dwelling) in the narrow coastal belt, overhanging embankments, mostly formed over the last forty years, are often found in the area. Their role in the local ecology can be interpreted in two ways: during and after backfilling, soil erosion (mineral and organic matter humus, and to a certain extent, crushed rock) occurs, which needs to be avoided for different reasons - because Posidonia leaves get covered in mud and because of the indirect threat to the fish spawning areas. On the other hand, this is where the so-called *secondary habitats* emerge, very important human-made *habitats* that support new settlements and serve as a safe haven for endangered species (for example, coast barbgrass *Parapholis incurva*). These areas should be systematically subject to greening, preferably by using perennial plants that will certainly help reduce erosion in the future.

5.3 Hinterland area measures

Hinterland areas are extremely important for the sustainable development of coastal regions. Key activities of the first line of defence against (surface) runoff flooding (especially relevant for the steep slopes of the eastern Adriatic) are often needed, as well as fire prevention and protection activities.

Coastal defence starts in the hinterland of coastal towns and settlements, i.e. in the associated coastal catchment area. The hinterland may be within the administrative boundaries of the city, but this is often not the case. Cooperation with the regional level is necessary, which means cooperation at the level of the ecosystem – body of water.

Surface water solutions can be divided into three basic categories:

- conserve and retain water in the catchment area;
- safely transport water from the hinterland through the settlement to the sea, preferably using bypasses and green infrastructure to regulate flows; and
- a combination of both measures, along with controlled water retention and retention of water in settlements and the hinterland.

Water retention in the catchment areas and settlements should be based on the so-called green and blue solutions. Green solutions are related to the water transport through the process of evapotranspiration to the atmosphere, and blue solutions consist of strengthening natural processes of water movement in the local hydrologic cycle. These solutions are environmentally friendly, efficient, flexible and inexpensive, but can only be successfully implemented by appropriate purpose and spatial development planning. Their main feature is that they are climate resilient and adapt well to climate change. For example, increased precipitation means more surface water, but at the same time, evaporation rates are higher as temperature increases, so the water balance remains unchanged or changes only slightly.

Other standard measures such as surface retention ponds, drainage channels, surface and underground outlets are equally effective, but also less flexible, more expensive to build and maintain, visible in space and less environmentally friendly. They are more difficult to adapt to climate change and their planning may become uncertain because the scale of climate change is still not reliable enough for their scaling. If they are overestimated, the financial resources are unnecessarily spent, i.e. unnecessary loans are taken and it is more difficult to maintain them, and if they are underestimated, they will not be efficient in protecting the coastal areas. Details related to the construction of these structures can be found in the standard hydrotechnical literature.

As for **increasing resilience to fire,** there are primarily preventive activities, specifically, selecting fire resistant species in all afforestation, restoration, renaturalization activities, etc. and strategically distributed, sufficiently wide and well maintained firebreaks and trails, natural and artificial bodies of water, access routes to critical infrastructure and forest facilities. On both sides of the Adriatic, pine forests are the most prevalent, with the Aleppo pine (*Pinus halepensis*) as the most abundant conifer species. The stone pine (*Pinus pinea*) generally thrives on the Italian side because it prefers acidic and sandy soils. Many areas have been recolonized with the Aleppo pine as a pioneer species, either to restore ecosystems that have been disrupted by fire or those affected by other disturbances. Its true benefits include pioneering soil stabilisation and protection against erosion. However, in many places, the disadvantages of such monoculture plantations have been revealed, ranging from low levels of biodiversity to an even bigger problem, the uncontrolled spread of this pyrophytic – highly flammable – species in large numbers of abandoned fields and vineyards. The pine trees were planted mainly with the aim of building layers of substrate that would then serve as a basis for a better quality forest stand, mixed forests with a Mediterranean element of holm oak or pubescent oak (*Quercus ilex* or *Quercus pubescens*), together with deciduous and evergreen shrubs and low trees. However, after the initial planting, the routine checkups are rarely carried out, while the targeted additional planting is usually carried out even less, as well as the preservation of the dendroflora species that have meanwhile appeared in the fields, such as the oriental hornbeam, the manna ash and other components of the original forest stand that was supposed to be imitated. Given that fires are frequent in pine forests, pine trees will use their dominance for even denser growth, which will subsequently lead to a decrease in biodiversity. In this way many other components of the native flora will be suppressed, while the degree of exposure to disease or pest infestation (as in the case of the bark beetle outbreaks), and especially the risk of fire, gets extremely high.

In order to establish more valuable forest stands, it is important to take advantage of the natural elements of dendroflora, by adding as many species as possible. Positive experiences – for example, those including carob and other broadleaf evergreen trees – point to the need to better protect and use them more often in silviculture. Larger complexes of pine forest should be intersected by zones covered by less flammable vegetation and adequate firebreaks, bodies of water and access routes. It is difficult to expect these measures will ever be implemented if they are not included in spatial planning plans.

Controlled burning is used as a step to prepare for the fire season, to prevent larger combustible mass units from coming into contact, and to bring wildfires under control as quickly and efficiently as possible. This reduces possible damage caused by large wildfires, preserves and enhances habitats, and restores natural ecosystems. However, it only makes sense when applied over relatively small areas.

On the eastern coasts of the Adriatic, soil erosion after a wildfire is particularly dangerous, when soil leaching occurs due to heavy rainfall on steep slopes. This is why post-fire tree regeneration is extremely important. It has already been pointed out that no serious scientific research has been conducted in the Republic of Croatia on the vegetation succession after a wildfire, nor on the various effects of fire on specific large categories of vegetation (maquis, shrubs, dry grassland, etc.) regarding its intensity and burning rate. This knowledge would certainly contribute to the development of simulations and models to predict the fire propagation process and, ultimately, a better control of this risk. In addition, planting and reforestation issues should be regulated, by sustaining from planting pyrophytes and insisting on more consistent use of plants that will ignite slow burning due to their habitus and biomass chemical composition. This issue calls for better cooperation between the scientific community and decision-makers.

5.4 Natural shorelines measures

Natural coastal areas are particularly important as transitional areas in ecology. They often differ from adjacent, intact ecosystems, and this is reflected in a number of plant and animal species. This kind of peripheral biotopes is healthy for the environment, so their number determines the overall landscape assessment in terms of its value and protection-related needs. Coastal landscapes in the Adriatic often serve as a basis for tourism development. Landscape conservation is also an extremely important task for coastal administrations. The diversity of landscape components ultimately has an impact on the overall diversity of flora and fauna, whereas humans, by opening up new spaces (e.g. through deforestation), have long been involved in the co-evolution of life on Earth. Human activities have not always had a negative impact on the environment – on the contrary – they have kept pace with nature for thousands of years, while things took a wrong turn only a little over a hundred years ago. Based on the accumulated knowledge of our time, if there had not been so much of the human activity, the Mediterranean belt would have mostly been covered with holm oak forests (*Quercus ilex*), except for narrow lines along the sea and river coastlines. However, due to the degraded vegetation cover and its use for timber production, or as a result of wildfires and other impacts, different forms of vegetation have developed in this area: e.g. rocky grasslands, shrubs, maquis, etc. In the absence of fertile soil that was washed away by erosion, the holm oak reached the point of no return and many different plant species took its place. According to the underlying logic, the most important thing is to protect the areas whose structure and elements mostly resemble to the holm oak or pubescent oak forests. The future environmental protection efforts need to try and use ancient and traditional methods in combination with modern methods based on new scientific knowledge, taking into account climate change.

In order to be able to meet the objectives of Articles 8, 10 and 11 concerning the preservation of **the open coast** and **coastal landscapes**, we will first need to understand the concept of natural coast. As the meaning of those terms may sometimes be ambiguous, landscape architecture helps us understand how it works. The level of negative human impact on a specific part of the landscape can be quantified in different ways, and one of the most important ones is the assessment through the degree of naturalness (the scientific term is ‘the hemeroby scale’). Directly connected with habitat classification, a rating (1-natural to 9-almost artificial) is assigned on the basis of field research and analysis by methods of vegetation ecology. This is a detailed interpretation of the current state of vegetation, based on which general characteristics can be observed, as well as any specific deficiencies within natural structures. The degree of naturalness can help local governments identify natural coastal and landscape areas of high value outside protected areas and to ensure their survival by banning construction in these areas, leaving them just as they are – an exceptional social and tourist resource that can be used to improve the quality of life and tourism offer.

Vegetation cover is a key factor in **ecological conservation** of natural areas. Vegetation is crucial for maintaining humidity levels, oxygen and carbon dioxide balance in the atmosphere, serving as a stronghold for fauna development; therefore, the entire habitat classification is mainly based on vegetation science. A high percentage of building density along the Adriatic coast puts the vegetation cover and the safety in nature at risk. Because of their volume, mature forests are much more efficient at absorbing carbon than young ones. Likewise, mature native vegetation is far more resistant to weather extremes than the young vegetation.

Lately, large-scale tree mortality caused by a sharp increase in pest populations has been recorded. Climate and environmental change can affect range expansion of the disease and alter the seasonal phenology of pests, which results in faster development and increased food consumption, and has a direct negative impact on the health of forest ecosystems. In the new Climate Change Adaptation Strategy, exceptional bark beetle outbreaks are cited as negative impacts of climate change (EC, 2021). The sharp increase in the population of the Mediterranean bark beetle (*Orthotomicus erosus*) in Croatia and the enormous damage that it has done (Pernek *et al.*, 2019) is a recent example of a series of unfortunate events associated with climate change. In such conditions, the biology and population of pests is changing in unknown ways and their spread keeps endangering the forest ecosystem. In addition, a new complex disease associated with climate change has recently been recorded on holm oak (*Quercus ilex*), given the oak jewel beetle (*Agrilus* sp.) outbreaks associated with bacteria. The disease spreads territorially and is a threat to native holm oak forests. The negative impacts that environmental and climate change have on forests also trigger the physiological changes in trees, weakening their defence ability.

As such phenomena are new and unexplored, the lack of information and knowledge is a major problem, which is why the response is slow and taking action delayed. The negative impact on Mediterranean forests is likely to accelerate with increasing temperature, as well as with the increasing frequency and intensity of drought with an extended vegetation period. Even a slight increase in temperature can trigger changes in insect development rate, number of generations, population density, size, genetic constitution, scope and patterns of host plant use, and longitudinal and latitudinal distribution (Lieutier and Paine, 2016). Invasive species constitute a completely different group of harmful organisms (Jactel *et al.*, 2020) that are not necessarily associated with climate change, however, they have the potential to cause serious damage to forests and should be taken into account at the stage of monitoring. They are mainly under the supervision of the National Plant Protection Organizations (NPPOs), but a growing number of weaknesses has also been revealed.

Early detection of harmful organisms is critical to suppress or mitigate adverse effects after the outbreak. Although there is a pest monitoring system in forests at the state level, none of those measures have been taken at the local level. Involving a local expert who has basic knowledge of the symptoms of the presence of harmful organisms is one of the possibilities for more swift reaction to sudden outbreaks. Seasonal forest inspection and sample analysis, as well as verification with a relevant scientific institution, should be the basis for quick processing of the information regarding new damage, identifying the problem and determining containment measures. In addition to the above-mentioned active supervision, 'passive' supervision has lately been increasingly used, whereby citizens report observed symptoms on dedicated platforms, using their smartphones and gadgets (*citizen science*). It has been shown that this can significantly increase the likelihood of early pest detection (Baker *et al.*, 2018). Another possibility is to identify the problem through applications available to the general public that record unusual changes and activate the pest identification mechanism.

The most endangered protected areas within our coastline are certainly reedbeds, rushes and sedges. In addition to the species mentioned in the previous chapters, dry grasslands are extremely important for this area, as they are at risk and susceptible to overgrowth in other plant formations (e.g. maquis) due to people's lifestyle changes, so they must be protected, and landscape conservation measures – removal of some of the more durable and robust plants must be taken. This is one of the most dynamic and changing biocenoses in the world, whose floral diversity within these plant communities is the result of long-term migrations and adaptations of species to dramatic changes in soil quality and climate change. There is a strong connection between human activity in the environment and the expansion of areas covered by dry grasslands, so we can rightfully speak of cultural and natural heritage, i.e. the heritage of traditional culture that has been developed over ten thousand years. It is therefore necessary to systematically implement measures to maintain this habitat, which, among other things, provides shelter for numerous orchid species, many of which are protected by law. The biggest threat and pressure for this type of green cover are mainly changes in cultivation practices – in this case, abandonment of grazing (in some other areas, it is rather the intensification of agricultural production), which directly leads to the overgrowth by the longest-living and hardiest species.

Ecological restoration is the process of rebuilding a degraded, damaged or destroyed coastal system by restoring lost structures. This should include the functional unit of the ecosystem, i.e. a dynamic community of plants, animals and microorganisms interconnected with the physical environment and climate. Many scientists point out **reforestation** as potentially the most powerful and cost-effective tool for carbon storage. A study published last year at the Swiss University ETH Zurich has shown that afforestation and reforestation were by far the most powerful tool to combat climate change (Bastin *et al.*, 2019). Another study analysed the potential for carbon sequestration and concluded that species-rich forests can take up twice as much carbon as monocultures (Liu *et al.*, 2018). Based on these studies, many relevant institutions have recommended that reforestation should be encouraged, by using mixed species, preferring fast-growing, indigenous species, and taking into account the expected climate change. The increasing fire risk should always be kept in mind in species selection and land use planning.

Renaturation is the implementation of knowledge-based ideas in the field of applied biology. It contributes significantly to the conservation of biodiversity, and as such showcases the best of the culture of the administration and communities that implement it. Renaturation can be implemented more easily using the scale of naturalness. Finally, the success of the intervention can be assessed by the overall assessment *of naturalness*. The lower the score, the more challenging the intervention will be: how to "renature" the damaged ecosystem within the *Posidonia*-dominated area that got the lowest possible ratings? While the land areas, due to the lack of intact oak forests in some areas, can get a minimum score of 3, those areas normally get an even lower score. Therefore, the level of naturalness of the sea floor in the areas covered by Posidonia is higher than those in the *most natural* land parts.

Freshwater units, particularly wetlands and estuaries, are at high risk, especially in areas close to cities. The courses of streams and rivers are mostly regulated by solid barriers that accelerate the flow of water, while their very construction tends to wipe out wider, *more natural* banks that are more stable in the long run. Instead of creating an impenetrable barrier that prevents contact of roots with water, in order to renature the stream, the riverbed needs to be cleaned and strengthened with green structures that correspond to the area where the intervention is carried out. In general, running waters need enough space to successfully restore the dynamics of their flow, as opposed to straight channels.

The creation of green spaces should follow the guidelines of ecological restoration to get us closer to helping rebuild the destroyed ecosystem. In this case, the creation of monotonous plantations hosting few species is avoided due to exposure to the identical reaction in the event of a disaster. Given the abiotic factors and the overall situation, the plan envisages the creation of thematic zones, and contains a list of necessary species divided according to the main layers of vegetation. The plan is elaborated in stages and attempts are made to model it on a 10-year or 20-year plan. All plans must take into account the expected climate change.

Individual management and adaptation plans are needed to better understand the current situation with all its attributes. For a holistic approach, which is particularly effective in the coastal area, Geographic Information Systems – GIS and the integrated maps, as well as the thematic map layers shown in GIS are considered to be an important tool. Management plans are also used as a guide for future activities that need to be centered on improving the overall situation in a specific area and strengthening resilience to climate change.

5.5 Narrow coastal belt measures

Particular attention should be paid to nature-based solutions for the narrow coastal belt. Those measures protect the coast and:

- attenuate waves and, in the case of wetlands, serve as obstacles and retention areas in the event of storm surges;
- reduce the erosion rate by capturing and stabilising coastal sediments, as well as by

accumulating organic matter and debris, and raise the seabed levels (in the case of Posidonia) and coastal soil (in the case of coastal wetlands).

Even though erosional processes are more characteristic for the "sandy" Italian side of the Adriatic, the Croatian side also needs to be better prepared for this phenomenon caused by the rising sea level along the low-lying coasts. Green solutions for the narrow coastal belt often include artificial nourishment and are used to maintain adequate beach width. The cost-effectiveness is guaranteed by its primary purpose of attracting tourists, however, it is necessary to ensure the proper preparation and implementation of this kind of intervention.

Narrow coastal belts also include areas that are rare and vulnerable even without climate change impacts, such as wetlands and estuaries. Renaturation is an opportunity to strengthen natural defences that need to be further explored in the coastal areas.

5.5.1 Making more space for greenery along the coast

Making more space for greenery along the coast is a way of mitigating harmful effects of sea level rise. The original and intact parts of the coastline contain various natural structures characterised by organisms perfectly suited to their environment and harsh conditions, including exposure to sun, wind, waves and salt sediment (e.g. sea fennel, sea lavender, tamarisk). In the narrow coastal belt, along with benefits for microclimate conditions (a decrease in temperature and shading), vegetation belt is expected to encourage water loss through evapotranspiration, one of the essential plant features. As shown in the chapter on societal measures, coastal setback provides an opportunity to grow a planned, multi-layered green cover both for the sake of people staying in the accommodation in the first row to the sea and for the benefit of the local people and tourists. Making sure that local community understands those reasons is key to establishing a setback zone. Human presence affects changes in the structure of green cover to a greater or lesser extent, in the absence of its main components it makes them more vulnerable, or more susceptible to further degradation, especially within a complex network of ecosystem connections (some of which still remain unknown). The elimination or disruption of one part of the ecosystem may adversely affect other components and, ultimately, compromise the functioning of the overall ecosystem.

5.5.2 Dune construction and strengthening

Dune erosion is a natural phenomenon resulting from wind and wave action that can be worsened by human activities such as dune flattening to build urban settlements, parking lots, promenades, etc. This contributes to the deficit of beach sediment needed to overcome periods of intense storms, as dunes form sand reservoirs on the coast. In addition, eliminating dune vegetation or allowing inappropriate access to the beach can have a detrimental effect on dunes.

Dune construction and restoration are among the most important techniques in fighting coastal erosion and sea level rise impacts on sandy beaches, and preserving the dune functions, not only as sand reservoirs, but also as important ecosystems. Dune construction involves engineering artificial dunes by reproducing the natural dune forms, often in a chain-like fashion. Dune strengthening methods include grass planting on the surface of the dune (to trap and hold sand that helps stabilise dunes and protect them against storm damage); dune thatching (covering the face of the dune with plant debris and branches to stabilise sand, encourage the accretion of sand, and protect dune vegetation); and dune fencing (to encourage deposition of transported sediment, and create barriers that mitigate wind and wave impacts).

Figure 23. Dune construction and strengthening in Ravenna coastal area (Bevano Sud, Emilia Romagna, Italy) (Photo: Beatrice Giambastiani)

Figure 24. An example of a soft solution minimally invasive that facilitates access and allocates coastal space for appropriate use (Photo: Gojko Berlengi)

Dune strengthening and construction techniques can combine coastal defence with other benefits, such as habitat, biodiversity preservation and ecotourism. Interventions on dunes are more effective when integrated with the restoration or construction of the entire coastal belt.

The concept of coastal dune strengthening and construction near Ravenna has been discussed on the adaptation knowledge platform AdriAdapt, as a real-life example.

5.5.3 Coastal wetlands protection and restoration

Coastal wetlands provide a natural defence against coastal flooding and storm surges primarily by dissipating wave energy. They are one of the most effective natural coastal habitats to reduce wave heights (Seddon *et al.*, 2020). By stabilizing shore sediments, coastal wetlands also reduce coastal erosion, acting as retention areas. Healthy coastal wetlands come into play as one the most efficient carbon sinks on the planet, hosting different species such as birds, molluscs and fish, and contribute significantly to water purification.

The remaining coastal wetlands should be **protected** from any type of degradation, especially bearing in mind that drainage and conversion into agricultural land have reduced the wetland area in Europe by approximately 60% (EC, 2007). On the other hand, the **restoration** of already degraded coastal wetlands aims at restoring the natural functions of degraded wetland areas. One way to restore coastal wetlands is to add sediment to raise the land above the water level and allow the colonization of wetland plant species. Another coastal wetlands restoration method is to restore humidity in drained coastal wetlands by blocking drainage and reducing groundwater extraction (this is an effective restoration technique for brackish wetlands). A more resource-intensive technique would be the transplantation of vegetation coming from healthy wetlands or specialised nurseries. The managed realignment of coastal wetlands is a technique of setting back the line of hard flood defences to a new line, further inland and/or on elevated ground to recreate intertidal habitats between the old and the new defences. The wetland will then serve as a buffer zone that will help attenuate storm surges. Managed realignment helps rebuild important habitats and preserve biodiversity and can also be used for recreation and ecotourism.

5.5.4 Artificial reefs

The prefabricated elements for the construction of artificial reefs were initially built to create conditions for fish farming in deeper waters and to prevent trawling. In addition, they were used in the construction of coastal submerged breakwaters filled with cracks that serve as a shelter for fish or encourage the settlement of marine plants and animals.

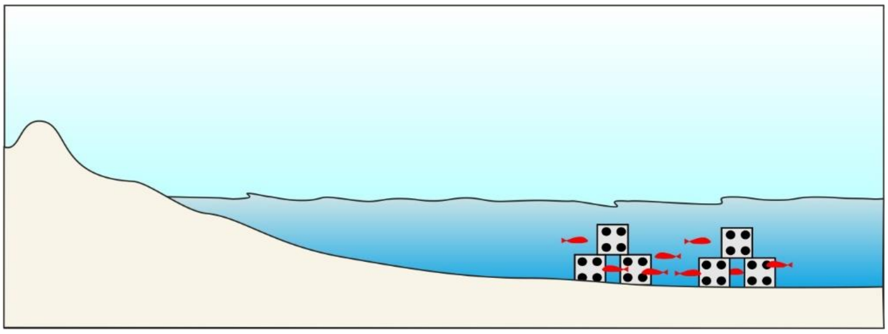


Figure 25. A schematic representation of an artificial reef

From the hydraulic point of view, they are not conceptually different from traditional rock structures, which are possibly more transparent and discontinuous, but they always must be classified as hard structures. They are easily and quickly colonized, creating a sort of living reef that can possibly be used as a tourist attraction. Artificial reefs reduce wave energy and protect the beach from erosion. They are considered to be less intrusive and, depending on orientation, can have less impact on the longshore processes. Very few independent monitoring surveys have been carried out so far to assess their efficiency in coastal protection.

5.5.5 Beach dewatering

Beach dewatering is a method that has been applied in different countries for the last 20 years. Water infiltration in the swash zone reduces backwash and, therefore, sediments shift offshore. Draining the beach can increase infiltration and relevant devices have been developed to this end, and applied in different countries, so far with controversial results. The advantages include zero environmental impact and zero impact on the beach quality and their use; the disadvantages include maintenance costs and questionable to moderate efficiency – especially during severe storms.

5.5.6 Management and protection of rocky coasts (and cliffs)

Rock coasts are less impacted by sea level rise and increased frequency of extreme events. However, coastal management cannot neglect this issue, among other things, because this type of coast is extremely common along the Adriatic Sea (especially along its eastern coast) and all its typologies are represented. Plunging cliffs (Figure 27A), with the sea so deep that the sediment transport by waves is virtually impossible, which is why the rate of erosion is very slow, will not change their dynamics due to the predicted sea level rise; this is the case in Southern Puglia, Southern Dubrovnik – Neretva county, several Croatian islands, and some parts of the Istrian peninsula.

In case that there is a platform (Figure 27B), the rate of erosion will be higher at the foot, the notch (where present) will grow in height, but cliff retreat rate will not increase significantly. With oblique cliffs (Figure 27C), the coastal response will be influenced by the slope profile, but no significant changes are expected, and evolutionary trends will be regulated by wave energy and the current rock strength. Situation is completely different with dead cliffs (Figure 27D), as they are protected by a broad beach, they are no longer subject to wave attacks; in this case, waves could again reach the rock slope, triggering a more rapid evolution, which could in turn cause the collapse of buildings and structures placed at the top.

Figure 26. A coastal cliff protected by a net on the Firule beach in Split (Photo: Ivan Sekovski)

Coastal cliff stabilisation techniques (such as revegetation and coastal belt nourishment) are "green" measures used to reduce coastal cliff erosion and its consequences – landslide, collapse, and falling of rocks.

On the other hand, there are many compact solutions that can help protect rocky coasts and cliffs, such as the construction of buttress and riprap strips, protective structures with different elements placed at the foot (concrete walls, rocks, finished blocks, gabion retaining walls, etc.), and/or cliff stabilization using all traditional and innovative geotechnical solutions developed for consolidation (cliff reshaping/profiling, cliff drainage; rock bolting/pinning; concrete buttress and riprap strips; geogrid reinforcement and pinned nets are used to reduce cliff erosion).

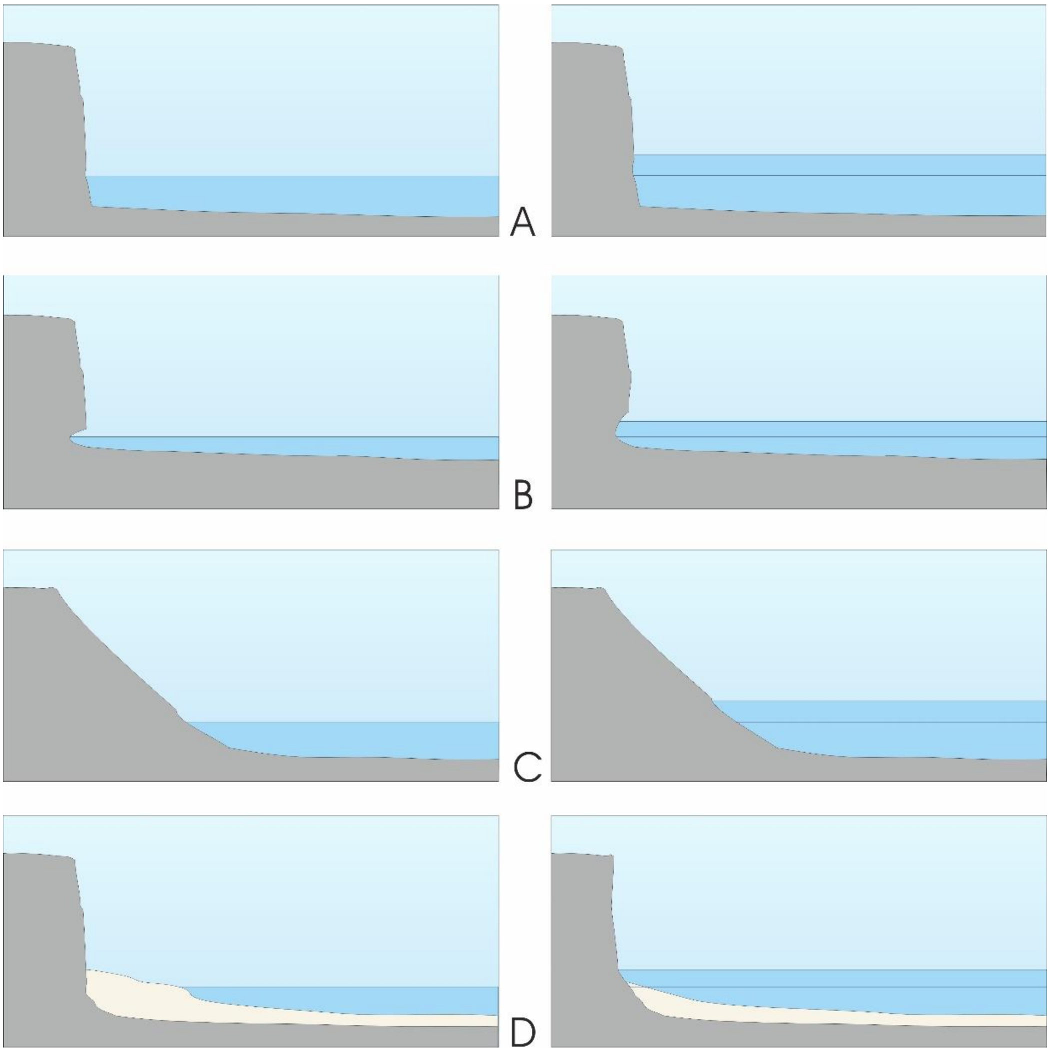


Figure 27. The evolution of the rocky coast as the sea level rises

5.5.7 The role of seagrass in curbing erosion

In case of beach/coastal erosion, seagrass meadows play an important defence role. They entrap sediment, stabilize the seafloor and prevent coastal erosion. As they entrap the sediment, the seabed gets shallower, and the waves break further away from the shoreline, mitigating coastal erosion during storms. Seagrass meadows slow down the movement of ocean currents between the seabed and the tips of their leaves. Recent studies have shown that wave heights were 10-20% lower in dense seagrass meadows, compared to a bare seafloor[12].

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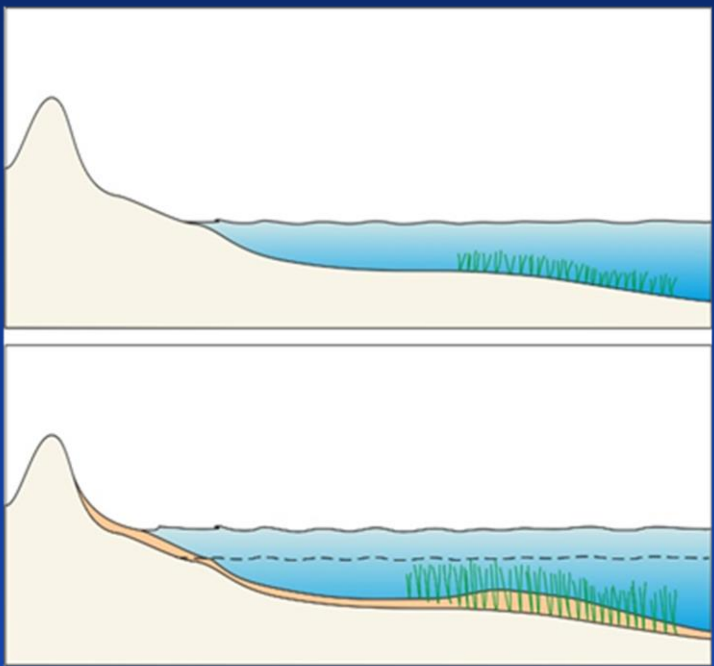
[12] https://phys.org/news/2016-06-seagrass-crucial-weapon-coastal-erosion.html

Seagrass meadows also play an important role in climate change mitigation as they have considerable potential for carbon storage, both through their own biomass and by filtering out fine organic material from the surrounding water. Globally, seagrass meadows are responsible for more than 10% of carbon burial in the ocean, even though they occupy just 0.2% of the world's seafloor (Fourqurean *et al.*, 2012).

In the Adriatic Sea, there are four species of seagrass, the most widespread of which is *Posidonia oceanica*. The meadows of Posidonia seagrass are an extremely valuable habitat for the Adriatic, and it is therefore essential to guarantee its protection. At the same time, the meadows of Posidonia are endangered in areas directly subjected to human activities such as anchoring, smothering and increased turbidity caused by material used in coastal construction, eutrophication and other types of contamination; improper fishing that employs seines, trawlers and bottom-dragging tools; and the spread of invasive species. Posidonia also grows extremely slowly (only 1 cm per year in height). Due to their slow growth, the recovery of the damaged Posidonia settlements is a lengthy process. Several projects of Posidonia planting have been carried out in the Mediterranean with varying degrees of success. Replanting may require considerable costs and be labour-intensive; therefore, seagrass protection is by far more cost-effective measure. The importance of seagrass protection is widely recognised on more than one level: Posidonia is included in Habitats Directive and Natura 2000 network of nature protection areas as a priority habitat. In Croatia, the Areas of Special Conservation Interest (ASCI) are established (based on the Berne Convention) for all seagrass species, as part of the "Emerald Network". In Croatia, all seagrass species are protected at the national level as strictly protected native taxa by the Nature Conservation Act. Italy also ratified a number of international regulations (such as the Berne Convention, the Habitats Directive, the Water Framework Directive, the Marine Strategy Framework Directive) in order to protect the Posidonia meadows and other seagrass species.

Until recently, seagrass protection has not been motivated by their role in coastal protection or carbon storage. This actually represents a new challenge for the local and regional administrations in charge of the coast.

Box 7. Seagrass and coastal adaptation



Seagrass meadows dissipate wave energy and reduce cross-shore and longshore transport; in addition, they host a rich community of carbonate sand producers.

Their roots create a close net, and while the system grows vertically (it can reach up to several meters of thickness), it forms a sort of natural reef (matte), which persists for a long time, even after the prairie death, and protects the coast.

Plants grow to take up the sea level rise and keep their protective function. Seagrass protection is one of the greenest strategies to mitigate the storm surges.

5.6 Coastal aquifers – groundwater

It is essential to use nature-based solutions to protect **coastal aquifers.** The situation is different for different types of coastal environment, the east coast being dominated by karst and the west coast by sandy beaches.

The rocky karst coasts along the eastern Adriatic are dominated by karst hydrogeological runoff processes in which the groundwater flows from the hinterland to the sea. They are rapid and pass through numerous cracks and openings. This is why karst aquifers get quickly filled with water in winter (rainy season of the year) and then they get pumped out, so they are mostly emptied by summer. There is very little rain in summer, and the area has a drop in water availability, especially on the islands. In some parts of the east coast, along which extends an impermeable flysch barrier, significant body of groundwater and water sources are formed in the hinterland (Ombla, Jadro, etc.). The aquifers are in contact with the sea through submarine and coastal springs, and small cracks and openings. The contact mostly remains spotty. Right off the coast there are local aquifers in a backwater area that are significantly more in contact with the sea (both spotty and linear) and their capacities are mostly very limited. Saltwater intrusion naturally occurs, increasing the salinity, which in turn diminishes their quality. On the west coast of the Adriatic, the hydrogeological conditions are different and this is where aquifers come into contact with saltwater of different characteristics, with a predominantly linear contact along the sandy coasts, and with a larger capacity.

Due to the difference in freshwater and saltwater densities, the lighter freshwater rises up and over the denser saltwater; as for the aquifer under the dune, for every meter of freshwater above sea level, there will be forty meters of freshwater in the aquifer below sea level (Ghyben–Herzberg principle – Figure 28). Lowering of dune, or even intersecting the passage, will cause a significant loss of water resources, which is crucial for different activities carried out along the coast, with their seasonal fluctuations.

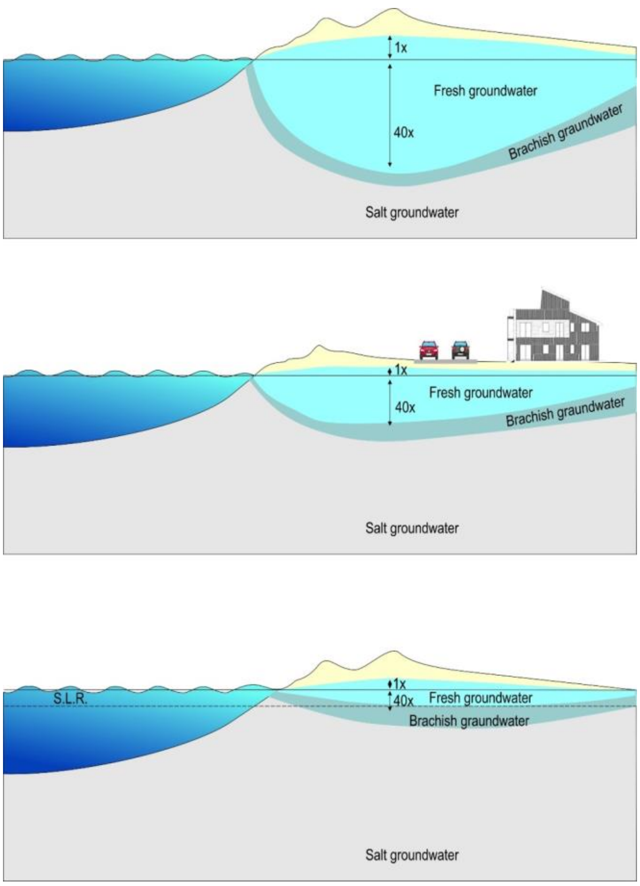


Figure 28. Sea level rise and coastal aquifers

Fresh water floats over saltwater (with a brackish water level in between) thanks to its lower specific weight (density). The Ghyben and Herzberg model shows the true course of events, with a buoyancy ratio of 1:40 (for every metre of water above sea level there will be forty metres of groundwater). Lowering the dune by one metre causes the loss of 40 metres of water. The same is true of the sea level rise, which poses a threat to the coastal freshwater stock.

Land surface impermeabilisation near the coast, due to urban expansion, reduced the infiltration of water, which is frequently directed to the beach through a series of outfall pipes: this has been proved to be among the causes of beach and dune erosion on urban beaches. An increase in extreme rainfall will only accelerate this process. Permeable paving for roads, sidewalks, car parks and playgrounds will promote water infiltration, and recharge groundwater. Runoff should be directed to new ponds, where phytoremediation could help increase water stock for non-sanitary use.

A decrease in annual precipitation along the Mediterranean coast may be followed by extreme events; in that case, the wide and high dunes, characterised by high porosity and permeability all the way to the phreatic, will resemble a sponge that can absorb large amounts of water and reduce flooding in the coastal plain.

Given the karst hydrogeological conditions prevailing on the east coast, this effect is very limited. The penetration of saltwater into streams and surface aquifers leads to their salinisation, which results in soil salinisation and exacerbates problems in agriculture. In Croatia, soil salinity is seen as particularly important:

- in the lower Neretva Valley in Dubrovnik-Neretva County;
- in the area of Vransko Polje in Zadar County;
- in the Mirna Valley in Istria County.

The salinity changes across space and time, depending on the sea level changes, distance from the sea, hydrological regime, and intensity of water use for irrigation. Monitoring has shown that continued salinisation may lead to crop failure, permanent loss of agricultural land and, eventually, depopulation. A change in habitat may also take place, as well as the change in characteristics of biocenosis – the ecosystem. The expected rise of the average and extreme sea levels will only accelerate these negative processes. Sudden penetration of the sea caused by weather and climate changes (low pressure, high tides, storm surges) will have the same negative effect. Another problem will be the projected more frequent and severe summer droughts and increased freshwater exploitation followed by higher air and sea/water temperatures accelerating biochemical processes in the soil, which will in turn cause gradual subsidence. When subsidence occurs, the area may become more vulnerable to sea and surface water action, which will only accelerate a downward trend.

6 Grey measures

Coastal infrastructure must provide its primary and secondary functions adequately over a reasonable lifetime and at a reasonable cost. Climate change will affect the functional and structural adequacy of such infrastructure, the durability and maintenance costs of the existing structures, and the design of new structures. Due to flooding and erosion caused by climate change, structures need to be adapted to new conditions, and new structures should be planned and designed according to new conditions in order to meet the objectives of their construction and meet the desired criteria.

Grey adaptation measures include technological and engineering solutions intended to improve the adaptation of territory, infrastructures and people to the climate change impacts. For coastal cities with artificial coast, responding to sea level rise and storm surges with engineering solutions will often be the best choice that can prevent the inland propagation of the sea. Technological and engineering solutions are essential for the protection and adaptation of the coastline. Engineering solutions are needed even when we choose managed retreat or the ecosystem-based adaptation, whereas the existing coastal structures should not be abandoned, but safely taken care of. Examples of grey measures include coastal protection, defence against flooding, raising and extending coastal land, adaptation of community coastal infrastructure and other technological and engineering solutions to ensure the resilience of coastal urban communities.

6.1 Coastal flooding and management

Certain areas, especially on the northern Adriatic coast, are below the sea level and protected by seawalls/dikes. However, when planning coastal defence against flooding, taking into account sea level rise alone is not enough. Extreme weather events, such as storm surges or flash floods, both bring additional trouble to urbanised coasts. When considering high tides, low atmospheric pressure, wind, waves, storm surges, and torrential waters, there can be dramatic changes in flooding compared to rising sea levels alone. All this should be taken into consideration when planning coastal defence against flooding.

Rising sea levels cause not only flooding of the coastline and coastal structures, but also have negative impact on the system of hinterland waters drainage and the associated flooding. Coastal flooding normally does not last long, but it develops quickly. It normally occurs when there are high tides caused by low pressure and strong winds blowing towards the coast. Due to the climate change impacts, flooding may become more frequent and severe, and the damage is even more serious when sea level rise and heavy rainfall interact, as well as in case of rising groundwater levels and surface water runoff towards the coast. Rising sea levels and strong winds blowing towards the coast cause seawater to splash deep into the land part of the coast, which results in damage to the coastal structures. This situation intensifies coastal erosion, which is why low-lying coasts appear to be at higher risk because subsidence and sliding of structures towards the sea, i.e. their collapse, can occur. Breakwaters and seawalls can stop wave action on the coast, but they cannot have any impact on the rising sea level and the impact of wind on waves crashing against the coast.

Some of the coastal defence options that recently came into spotlight include the storm surge gates and barriers. These are fixed installations that allow water to pass in normal conditions, and have gates or bulkheads that can be closed against storm surges or spring tides to prevent flooding. They are built to protect urban areas and infrastructure in areas where storm surges and sea flooding could have a major impact. Due to their costs and potential impacts, storm surge gates/flood barriers are relatively rare. On the Adriatic coast, the most prominent examples include the Venice Barriers ('Mose' system) which is the largest construction of this type, but also "Porte Vinciane" mobile barriers in the coastal area of Cesenatico. On the Croatian coast, such measures do not currently exist, mainly due to different geological characteristics of the soil, considerably lower subsidence levels, and less severe coastal flooding.

Coastal flooding is a complex problem, especially when the impact of inland waters is taken into account, so it needs to be considered and addressed in an integrated way. There are very few clear rules or guidelines. One of the clear rules that must be applied is the protection against the 100-year coastal flood. However, the question is what a 100-year flood or the 100-year large body of water flowing from the hinterland towards the coast really is. The correlation between the two values is still mostly unknown, and measuring their reliability remains a difficult task. In most cases, those issues have not been researched locally and have therefore remained largely unknown. In addition to the calculation of the 100-year sea level, the local 100-year sea and wave height also need to be calculated. It is a complex and expensive task. The mean sea level (MSL) rise changes the conditions of forming waves and they are difficult to predict.

The following grey solutions are mostly used:

- construction of hard protection structures around the protected area, along with a drainage system;
- raising coastal land and the height of coastal buildings by changing the urban plan and other relevant documents; and
- stabilisation of coastal structures (deeper foundations, and other similar measures).

In general, a set of different measures needs to be applied and long-term and persistent efforts must be made to minimise the risk and damage. Protection of low-lying coast must be done in an integrated way, along with the drainage of surface waters flowing towards the coast, considering that the baseline level will be higher than the current level, including the groundwater level.

Considering that many urban areas are located on low-lying coasts and subsiding alluvial plains, higher dikes and seawalls will be necessary, but they will also have an impact on the landscape, limiting the access and obstructing the sea view. Since their main function will be required for a few days a year, they could be used for multiple purposes: as a boardwalk, staircase, platform, or a pier. Overwash will be prevented by a concave profile and a drainage system will redirect water to the sea. Flood-proofing techniques must be applied to reduce the structural damage caused by flooding. *Higher costs needed to flood-proof new structures are assumed to be insignificant compared to the total cost of new construction* (Kirshen *et al.*, 2008). Finally, green and blue solutions are highly desirable in coastal urban areas, especially for water-related issues, as they can help in the situations ranging from water infiltration to surface runoff, depending on local conditions and needs (see Chapter 5).

6.2 Coastal protection and defence structures

Coastal protection and defence structures are widely spread across the western Adriatic coast, but lately they have been increasingly built around the eastern Adriatic coast. This kind of structures ensured livelihood security for millions of people living on the coast, as well as the functional communication channels and coastal protection of large agricultural areas, at a time when the coast was not believed to be important for ecology and tourism. Since beach tourism has started to flourish, coastal areas began to be considered a "golden goose", the use of facilities increased dramatically and all of their negative impacts eventually came to light. Given that every beach is different, solutions for the specific locations must be tailored according to their specific needs, taking into account morphology, sedimentology, wave energy, cultural, social and economic circumstances. However, the long history of coastal protection along the Mediterranean coast and the variety of measures applied, as well as the experiences of individual countries (which have had the misfortune to face this type of problem first) are a good opportunity to learn from the past experiences and mistakes.

Given the impending sea level rise, more solid coastal defence structures are expected to be built, at least in densely populated coastal cities. It is therefore important for decision-makers to become aware of the way in which these constructions work, with all the positive and negative effects that have emerged over the decades or even centuries of their implementation. Regardless of their differences in terms of form, location, and mode of operation, they have two things in common:

- they substantially reduce the coastal resilience when built on the intact coast;
- opinions among coastal communities are divided over whether they are environmentally friendly and whether this is an appropriate way to access and use the beach and sea. A homogeneous strategy needed to address coastal flooding and erosion in the context of climate change must be based on common goals, protocols and participatory processes and must strongly consider the environmental, social and economic disparities across different coastal areas.

Climate scenarios for sea level rise and extreme weather conditions may lead to a review of safety requirements and building new protection structures or heightening, strengthening and reshaping existing coastal defence structures.

All of the above is even more relevant to the western Adriatic coast, which is characterised by a shallow sea and long, low-lying sandy shores. In the built-up areas along the east coast, the seawalls made of different materials and for different purposes are more commonly used, as well as the breakwaters that shelter ports and harbour facilities from the bursts of wave energy. However, some of the coastal defence structures tend to be used more frequently in certain places in order to protect the new beaches.

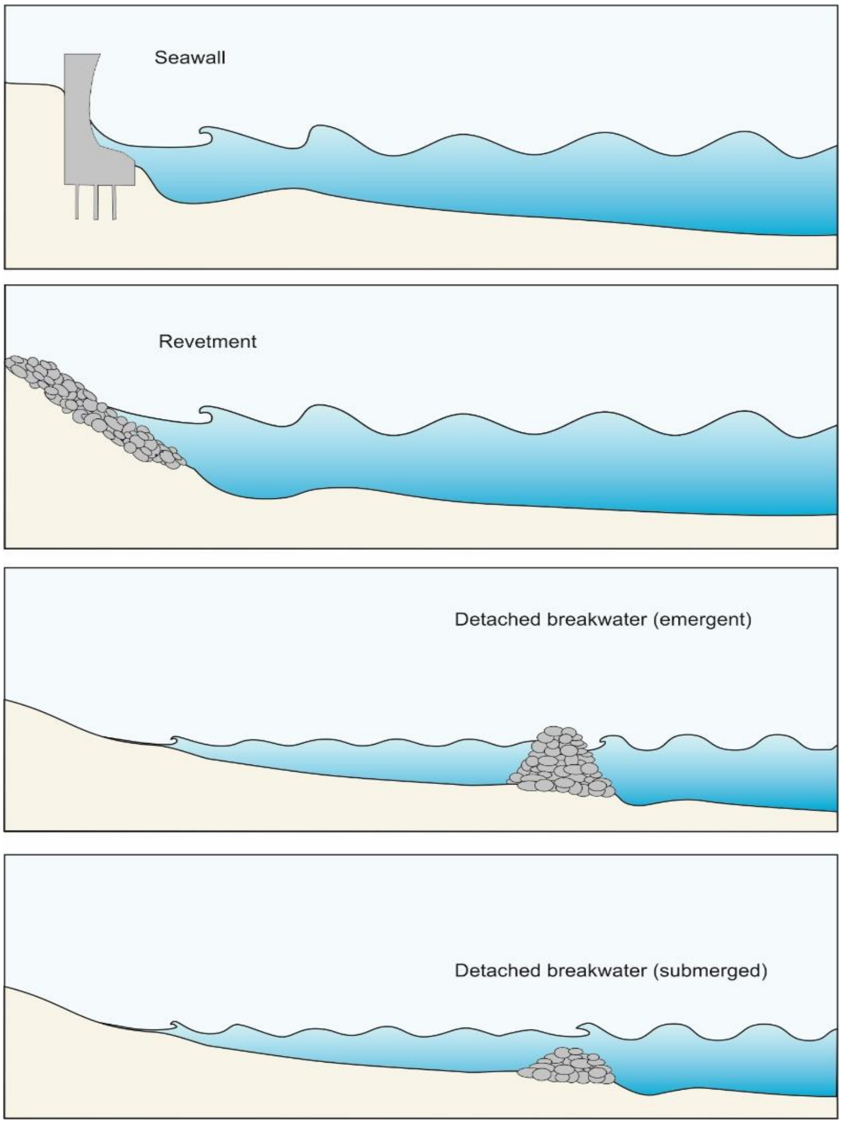


Figure 29. Examples of traditional coastal defence structures

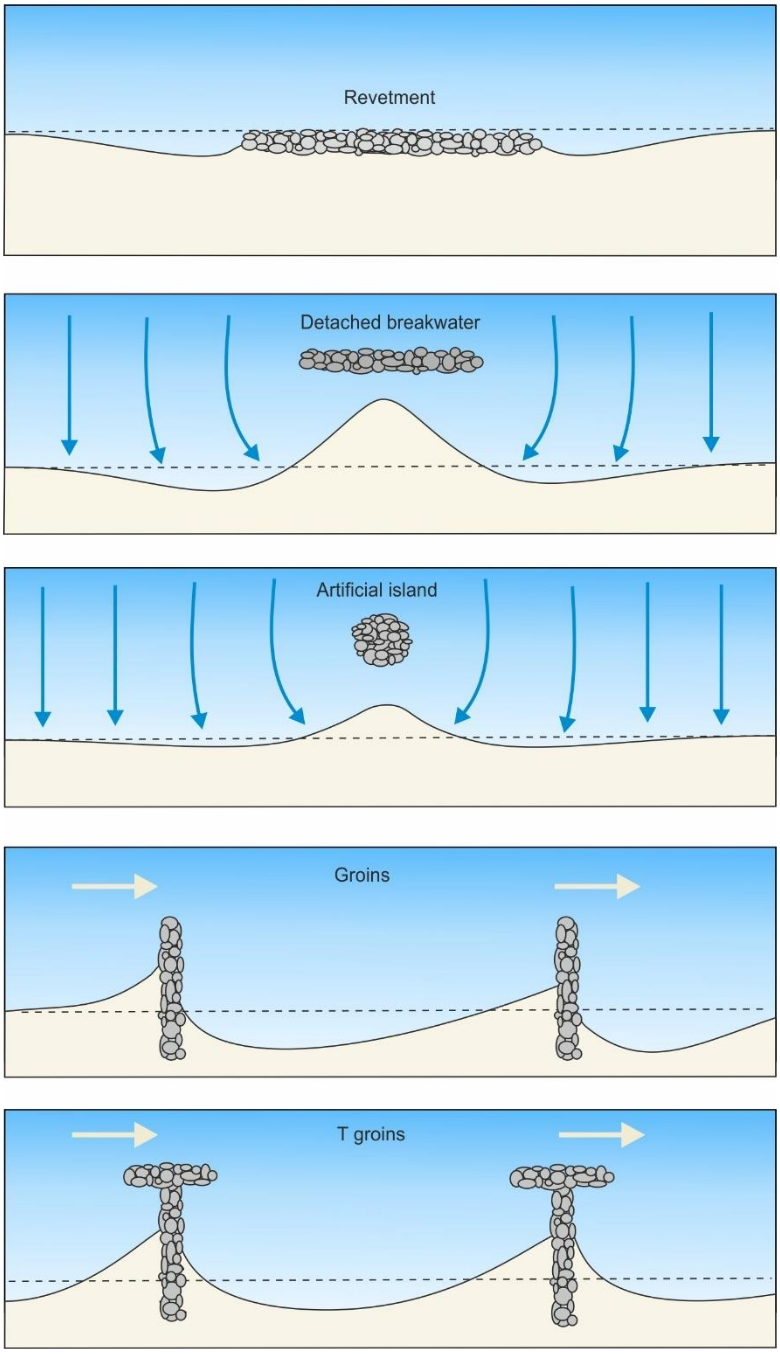


Figure 30. An example of a coastal protection structure and the appropriate beach response

6.2.1 Seawalls, quays and similar structures (ripraps, revetments, rubble mound breakwaters)

Seawalls are structures made of hard material (e.g. stones, concrete, masonry or sheet piles), built to protect the inland area against wave action and to prevent coastal erosion. Seawalls also serve to stabilize eroding cliffs and to protect coastal roads and settlements. They are built parallel to the shore at the transition between the beach and the mainland or between the beach and dunes.

Seawalls are usually massive structures, often concave and tall enough to protect the land against wave overtopping, with a 'thorny' surface to reduce the backwash velocity. Staircase profile is sometimes used to reduce the backwash velocity, but also to accommodate sunbathers, coastal paths, or bike routes. For example, a bike route was built on a revetment protecting the railway in Pedaso (Marche).

Figure 31. The seawall between Miramare and Trieste (Photo: Enzo Pranzini)

These structures can be found in almost all countries along the Adriatic coast, but their height and extensions are generally limited due to the low wave energy in the Adriatic Sea. The Venetian Murazzi, now converted into complex structures with a beach in front of them, were considered a masterpiece of traditional coastal engineering know-how. Along the Adriatic coast, small revetments have mostly been built to protect roads or houses close to the sea. In coastal villages and towns located within the bay, **quays** are commonly built, mostly on the Croatian side of the Adriatic. These structures are built to protect coastal communities from wave action, and they are normally slightly lower than "traditional" seawalls. They are built to serve as protection of houses, promenades and roads; and in some cases as docks for mooring small boats.

Figure 32. A quay on the waterfront in Split, Croatia (Photo: Ivan Sekovski)

Construction costs are high but seawalls are usually a low-maintenance option. Construction costs vary depending on the shape of seawall structures, but also on the type of construction, dimensions, availability and proximity of construction materials, anticipated rates of future erosion and wave loads, facilities such as walkways and steps or slipways.

Seawalls and quays often interfere with natural processes such as migration of intertidal organisms, causing the reduction of intertidal habitats. Although they prevent dune and hinterland erosion, vertical seawalls often reflect wave energy instead of dissipating it, which makes the shoreline in front of the seawall prone to erosion. Therefore, many seawalls have recently been built in such a way as to integrate slopes. As seawalls regularly get overtopped (in heavy storms) the water can wash away the soil or sand holding the wall together and weaken it. Also, continued erosion may undermine the foot of the structure and threaten its stability.

Seawalls and quays have many major benefits. They take up less space than other coastal defences, such as dikes. From a climate change adaptation perspective, seawalls have the advantage of a gradual upgrade by increasing the height of the structure in response to rising sea levels. It is important, however, to ensure that the seawall upgrade does not compromise the integrity of the structure. The high level of security provided by a seawall/quay can foster the development of the hinterland. The crest of the seawall often extends into stone-covered areas of the coastline, serving to a different function, such as a road, promenade or car park.

As for the above mentioned impact on intertidal habitats, prefabricated blocks with rough and hollow surfaces have been produced and installed recently to help marine plants and animals attach firmly to rocks.

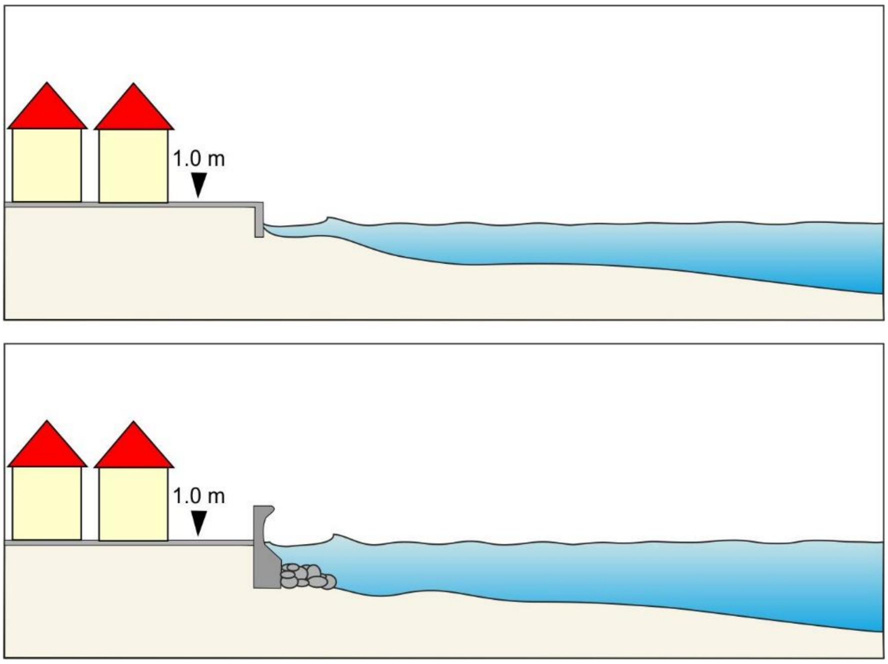


Figure 33. A new seawall, the height of which depends very much on local conditions

6.2.2 Detached breakwaters (emerged and submerged)

Detached breakwaters are the most common coastal defence structures along the Adriatic coast, but almost exclusively on the Italian side. In some parts of Italy, detached breakwaters are quite common: for example, in the north near Porto Garibaldi (Emilia Romagna) 74 separate breakwaters stretch over 9 kilometres of coastline, while between Porto San Giorgio and Casabianca (Marche) 61 elements protect 5.5 kilometres of beaches, while Pescara (Abruzzo) sets a record with 243 breakwaters covering more than 23 kilometres of coastline.

Figure 34. Breakwaters on Torre Mucchia beach, Italy (Photo: Enzo Pranzini)

By interrupting the longshore current, a breakwater can sometimes affect water quality. A recently invented alternative includes submerged breakwaters, which have limited impact on the landscape and considerably improve water quality. The water penetrates through the gaps between the breakwaters, which can in turn result in a creation of strong rip currents that may lead to fatalities, even if swimmers and divers tend to believe that the Mediterranean coast is completely safe. The environmental impact is another disadvantage of breakwaters.

In any case, a longshore current is present between the beach and detached breakwaters, which can help carry sand out of the protected area. For this reason, submerged groynes are frequently added to prevent this. The 8-kilometre-long defence project near Pellestrina (Veneto) is based on this scheme, featuring groynes with submerged extensions every 550 metres.

Both emerged and submerged detached breakwaters can be made of natural stones, concrete elements or geotextiles. Larger concrete structures in urban areas can be connected to the land with piers to transform them into a promenade or sunbathing platform. Lower wave energy behind the breakwater and a converging sediment transport induced by wave diffraction at their tips can trigger formation of a salient. In the case of extended structures or structures near the shore, salients can build up and form a tombolo that will connect the breakwater to the mainland coast.

6.2.3 Groynes (emerged and submerged)

A **groyne** is a coastal defence structure perpendicular to the shoreline to reduce the longshore drift and collect sediment. Since groynes induce an updrift beach expansion, and trigger a downdrift erosion, a series of groynes acting together to protect a beach ("groyne system") is often needed, due to this domino effect. The more offshore they extend, the more efficient groynes will be; in case that sediment movement along the shoreline crosses the protection line, almost all of them will be trapped. In order to maximize the benefits of this coastal defence, it is desirable to add a beach nourishment intervention.

Groynes are usually built on the western side of the Adriatic, and they are much more common there compared to the east coast, although they have started emerging lately in Croatia too. Groynes are among the most popular coastal protection structures among stakeholders, as they do not interfere with fishing and sunbathing. Such functions can be improved by building a walkway at the top, possibly protected by railings or stones (as it has been done in Cavallino, Veneto and Pescara, Abruzzo), and smaller platforms at the top. However, caution is urged while using groynes, especially large ones, because they have long-term and often unclear impacts on coastal processes.

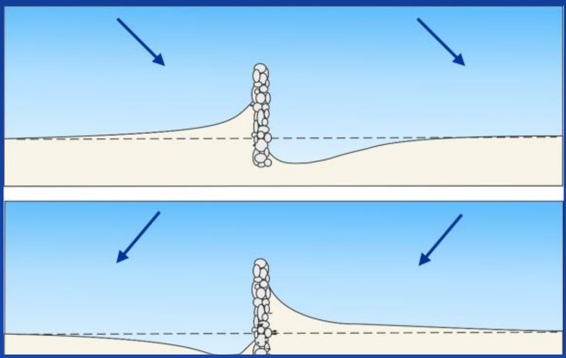
A more recent alternative involves submerged groins, which have limited impact on the landscape and allow sediments to pass over them after the formation of a ramp. These sediments are deposited downdrift since the rate of velocity decreases after passing over the crest. Along the Adriatic coast, this solution is not used, but submerged segments are added as extensions to traditional groynes, such as in the area south of Eraclea Mare. More frequently, they reach emerged or submerged breakwaters and create a sort of a "basin". Some of the prominent examples include Pellestrina (Veneto), Punta Marina (Emilia-Romagna) and Fano (Marche).

Jetties do not constitute an adaptation measure *per se*, but can be combined with seawalls or other hard coastal defence infrastructure. Even if coastal protection is not their main function, they do have an impact on sediment transport along the coast and on ecological processes: the longer a jetty, the stronger its impact on neighbouring areas.

Figure 35. Groynes in Misano, Italy (above) and Supetar, Croatia (below) (Photos: Enzo Pranzini and Ivan Sekovski)

Box 8. Inversion of the longshore sediment transport due to wind and wave rotation

Climate change is not only about rising temperatures, changing precipitation patterns and rising sea levels; wind direction and intensity change too, there is a 'reversal' in longshore sediment transport; signs of which have already been found. All coastal structures can be modified and the effect of coastal protection structures can be reduced, increased and even reversed. For this reason, new coastal protection structures must be very flexible and adaptable to future conditions. The problem may not be as serious for the groyne fields, but it will appear with extended individual structures. The same could happen both upstream and downstream of breakwaters and harbours.



6.2.4 Beach nourishment

Beach nourishment is artificial placement of sand/ gravel on the eroded shore in order to keep the material on the shore, mitigate the effects of erosion, and protect the area against storm surges. In addition, it also has the objective of maintaining or extending the width of the beach for tourism and recreational purposes (for more details, see Chapter 6.3).

Nourishment activities need to be carefully planned. Beach nourishment material, considering most of its characteristics (colour, mineral composition, grain size, etc.) must closely match the natural features on the native beach. Sediments with the same grain-size distribution, mineral composition, colour etc. as the native material are expected not to change the quality of the beach because the profile shifts offshore, and retains the same slope. As for the beach nourished with finer sediments than the original material, most of the sand will deposit nearshore, with limited benefit to the dry part of the beach. If finer material is easily accessible, its higher longshore and offshore dispersion can be compensated by more frequent fills, which is more relevant to the Italian side of the Adriatic considering the specific type of beaches. Care must be taken when implementing this option, as finer sediments can cause smothering of marine habitats by silt and increased turbidity. However, not all the material will deposit nearshore; some of the material will drift away and "nourish" the neighbouring beaches. On the other hand, coarser sediments are more stable under higher wave energy and produce a steep profile, so most of the fill will remain ashore. Special considerations need to be taken into account, due to potential impacts on coastal and marine environment.

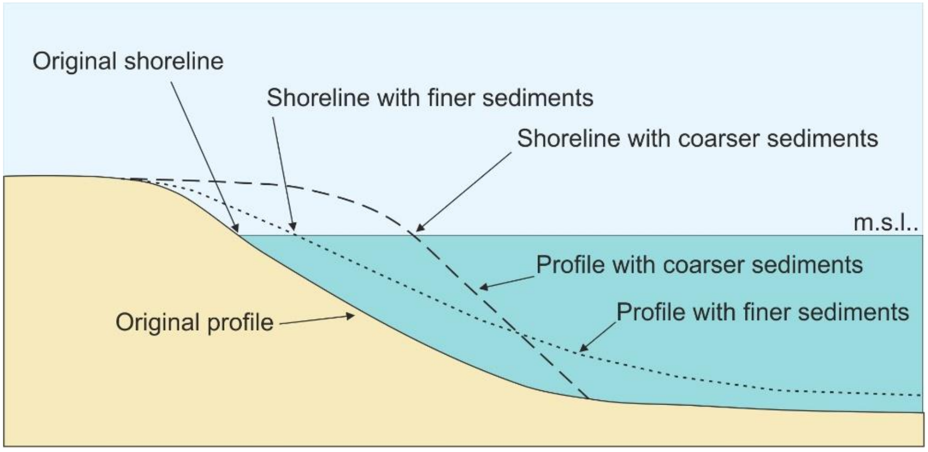


Figure 36. Beach profile response to nourishment

On the western side of the Adriatic Sea, characterised by long sandy beaches and high erosion rates, large projects can be managed, using sand and/or gravel, as both materials are largely available. In Marche region, a large part of the beach nourishment has been done with gravel, whereas in Abruzzo, Emilia Romagna and Veneto regions sand was used almost exclusively.

On the eastern side of the Adriatic, beaches are smaller with slower retreat, and suitable marine sediment is not available due to the naturally lower sediment transport rate by rivers into the sea. Gravel is most commonly used in these areas, partly because it is more similar to the native beach sediments.

Beach nourishment needs to be carried out on a regular basis. Sea level rise and extreme weather events can lead to a shorter expected duration of the beach nourishment project.

In beach nourishment projects, there are specific limiting and success factors.

Limiting factors:

- Beach nourishment can have different impacts on marine ecosystems, causing habitat change and affecting the inhabiting organisms, from small interstitial organisms to large mobile organisms, at various trophic levels. The negative effects on benthic organisms (macrobenthos, meiobenthos and microbenthos) can manifest themselves as significant changes in the composition of the assemblages, species abundance and biodiversity. Moreover, beach nourishment has directly or indirectly affected commercial species (such as bivalves, crustaceans, sponges, demersal fish, etc.).
- Adverse effects may include the burial of biota and the loss of habitats in sandbars and on the seabed. In addition, attention must be paid to finer sediments, as they might generate turbidity and smothering with slit: clogging of fish gills, adverse impacts on planktonic larvae, molluscs, etc. According to some studies, particles smaller than 0.063 mm that float and cover a large area around the beach can have a particularly harmful impact.
- Beach nourishment activities should be limited in areas where they may have a significant impact on protected species (such as *Pinna nobilis*) and important marine habitats (such as the *Posidonia oceanica* meadows).
- The right timing also plays its part – each spring, after the winter storms, the beaches most affected by erosion need to be immediately nourished so they can be ready for use at the beginning of the summer.
- Beach nourishment is usually an ongoing process, which leads to higher costs and recurrent ecosystem disturbance.
- Finding a source with sufficient quantities and good-quality sand can be challenging. The dredged sand should match the sand present on the site in terms of grain size, colour, and mineral composition.

- Sediment availability could be an issue if coupled with an increase in demand for nourishment projects. Offshore sand deposits may be limited, which is the case, for example, along the eastern coast of the Adriatic Sea. Beach nourishment, in a long-term perspective, must be integrated within a wider approach, such as managed realignment, setback definition, re-planning and zoning of coastal areas, etc. This is why is needs to be carefully planned.

Success factors:

- Beach nourishment is a flexible and fast method of coping with coastal erosion compared to hard structures and easily adapts to changing conditions.
- This is a measure that does not require high costs, as the long-term planning criteria are rarely taken into account (as opposed to the installation of hard structures): if the situation deteriorates, periodic 'top-ups' can be simply added.
- Beach nourishment can complement other grey measures, such as seawalls or groynes, and be used in conjunction with green measures, such as dune strengthening. Constructed and reinforced dunes can even act as sand reservoirs, and improve beach nourishment results.
- If beach nourishment provides flood and erosion reduction benefits, it can also serve to encourage coastal tourism and recreational activities.
- In some cases, material extracted for another purpose can be used for beach nourishment, allowing it to be productively reused and to keep costs at a reasonable level. In this case care must be taken when reusing dredge material since it can contain high levels of pollutants or be otherwise inappropriate for beach nourishment.

Figure 37. Beach extension alternative on the rocky coast. (Photo: Gojko Berlengi)

6.3 Coastal advance – raising and extending coastal land

The creation of new seaward and elevated land reduces the risk of flooding impacts due to sea level rise and storm surges. Coastal land extension makes sense in urbanised areas, where public space around the waterfront is still non-existent (Figure 38). Given this state of affairs, it is more likely to gain public support. However, when implementing coastal heightening and expansion projects, special care must be taken because of their impacts on the coastal and marine ecosystem. Land extension on the pristine, natural coasts makes them more vulnerable and degrades their environmental and landscape qualities; therefore, such practice should not be considered in these areas. This is specifically emphasized in Article 8, paragraph 3 of the ICZM Protocol according to which open areas where urban development and other activities shall be restricted or, if necessary, prohibited must be identified for the sake of sustainable use of coastal zones.

Coastal advance can also include beach extension. Beach extension should not be confused with beach nourishment: nourishment includes replacement of beach material taken away (due to the action of the sea and wind) from within the pre-determined beach borders, while advance extends the beach material beyond the dimensions of the existing beach.

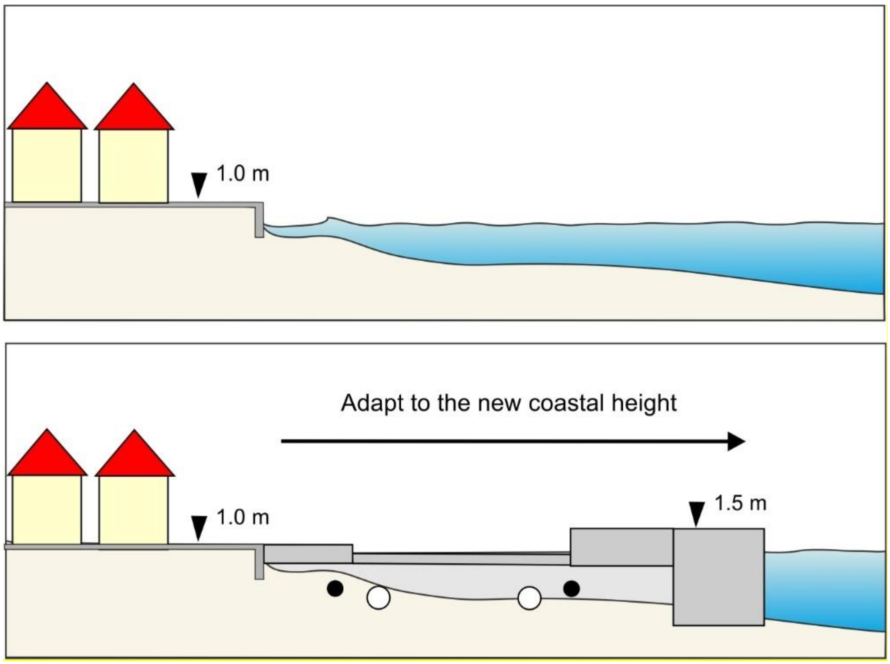


Figure 38. Construction of the new coastline and extension of the coastal belt

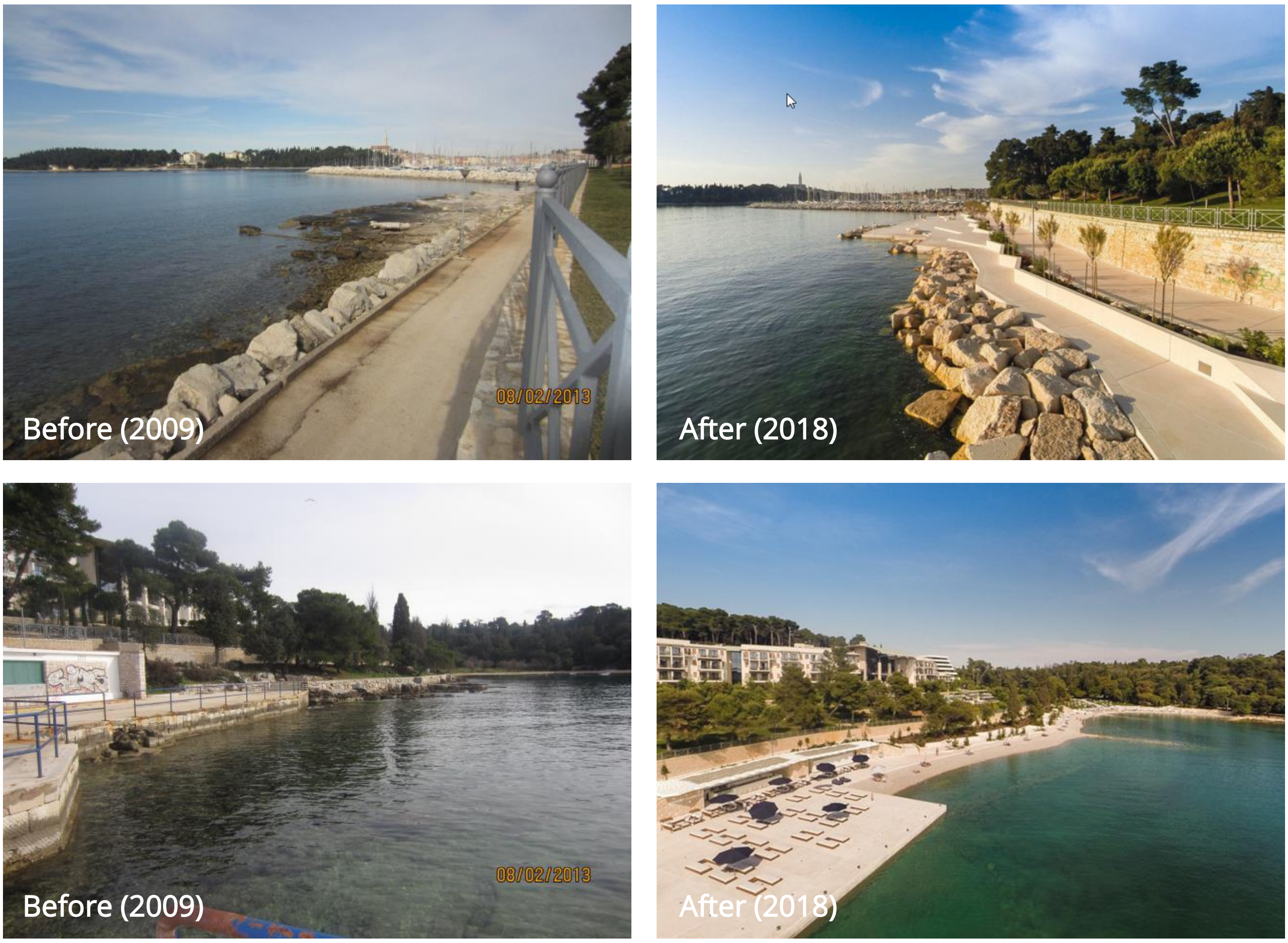


Figure 39. Coastal extension in Lone Bay, near Rovinj (Croatia) – the situation before the extension in 2009 (left) and the situation after the extension in 2018 (right). Photo courtesy by: Dalibor Carević (Beachex project – http://grad.hr/beachex)

In more recent times, tourism development reignited beach extension practice to accommodate new tourism infrastructure. Although both practices represent transformation of natural coasts, when driven by tourism, people may want to preserve the features of the landscape and the beautiful atmosphere of the space, beaches and biodiversity to become more competitive in the tourism sector. Unfortunately, many such actions are carried out without a plan or permission, especially in the cases of individual buildings, which has significantly reduced the landscape value of the coast.

Today, the decision about the coastal advance/ heightening should be taken on a different ground, starting from the growing negative impacts caused by climate change, i.e. sea level rise and storm surges. Given the relatively high economic costs of undertaking such actions and their maintenance, it needs to be considered only when a densely populated coast, or cultural property, must be protected from the risk of flooding. In the Coastal Plan of Kaštela from 2019, the envisaged future raising and extension of coastal land was accompanied by seawalls/breakwaters (Figure 40). More recently, a concept of floating houses is recognized as a part of flood-resilient architecture (e.g. in Amsterdam, Hamburg, Copenhagen), and may be considered as an alternative to land expansion in coastal areas sheltered from the wave action. Along the same line, alternative beaches can be considered too (Figure 41).

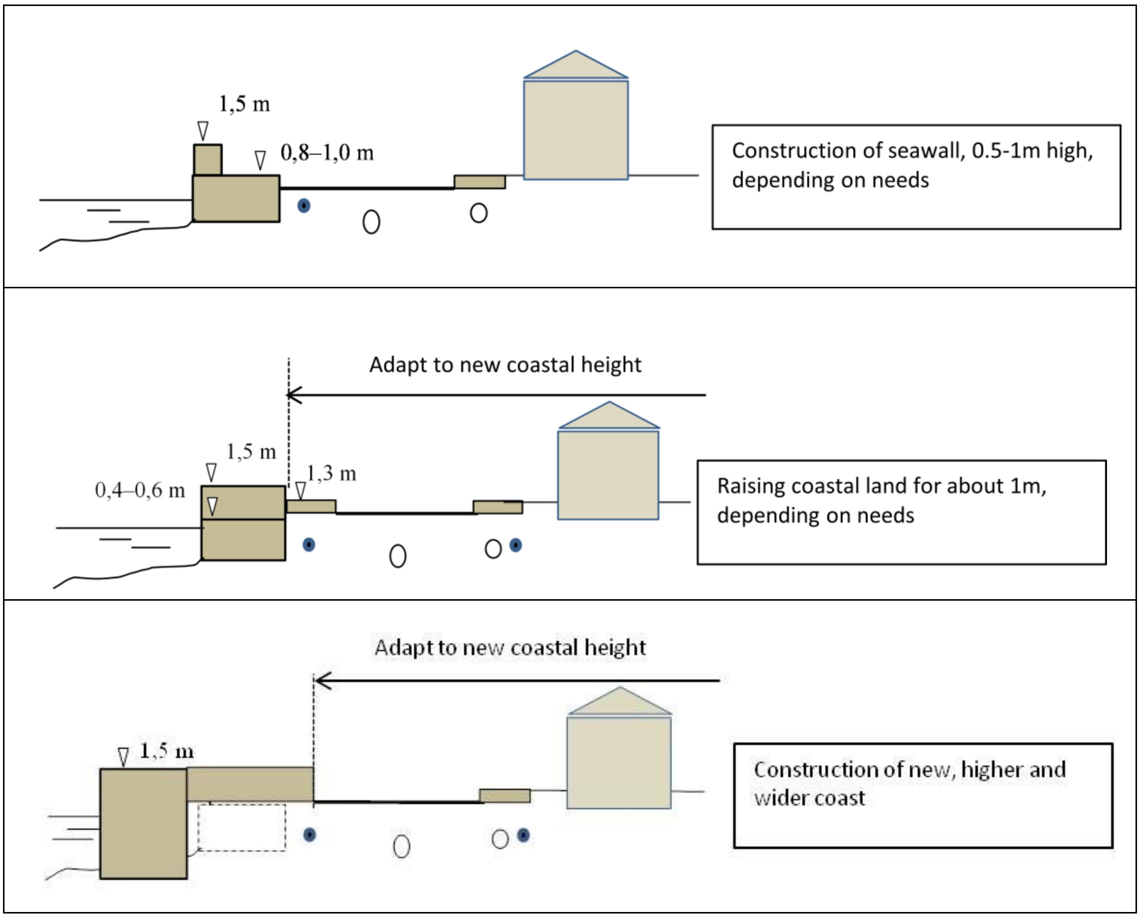
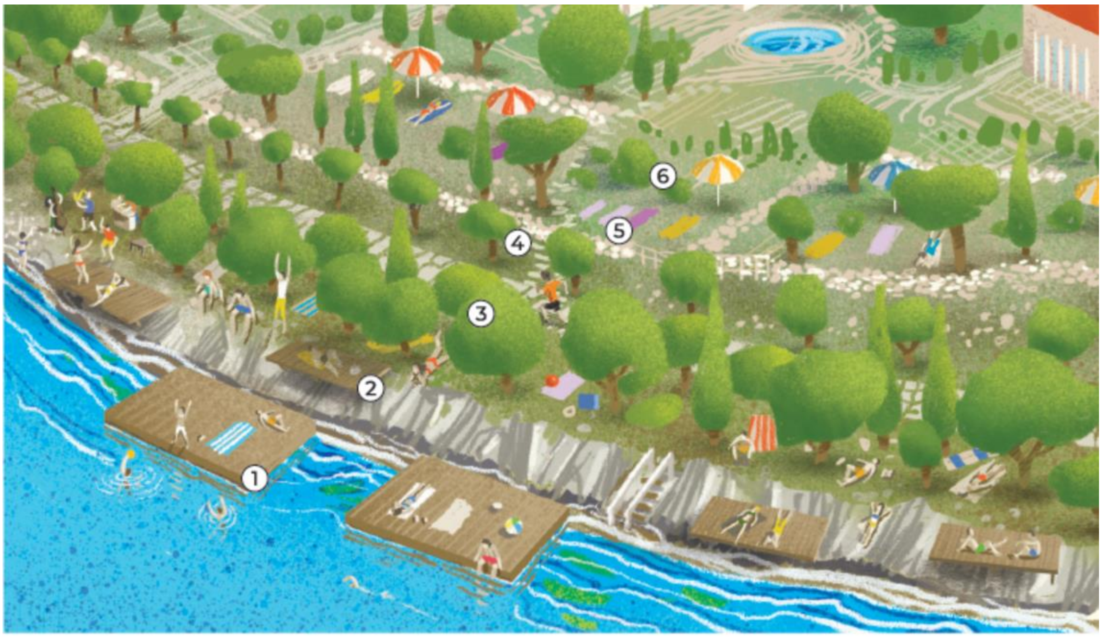


Figure 40. Examples of potential future coastal land-use solutions for Kaštela (examples taken from the Coastal Zone Management Plan. Author: Jure Margeta)



(1) Floating pontoons - sunbathing areas
(2) Prefabricated wooden platform
(3) Near-shore forest belt
(4) Tree line along the coastal path
(5) Porous paths and dry stone walls
(6) Sunbathing areas - native vegetation

Figure 41. Alternative beaches on rocky coasts (Author: Luka Duplančić)

6.4 Municipal coastal infrastructure adaptation

Climate change results in mean sea level rise, considerable sea level fluctuations, higher waves, and the dynamic impacts of the sea on the coast and coastal landscapes. Coastal infrastructure is directly affected by the sea, for example, through discharges and overflows, or indirectly through groundwater flows along the coast. In fact, the sea penetrates land and fills the spaces in the ground, depending on the sea level status. This means that any coastal area below the mean sea level will be constantly submerged in seawater, while everything above the mean sea level will be submerged occasionally during high tide and storms. This means that some of the municipal infrastructure will certainly be flooded at some point.

Rising sea levels and a consequential groundwater rebound in the coastal area will lead to the infiltration of water into septic tanks, inspection pits, wastewater treatment plants and other sewage facilities, as well as into the channels. This will lead to a rise in the salinity of the wastewater and cause corrosion and deterioration of materials and parts of the system.

Furthermore, coastal infrastructure will be adversely affected by the expected changes in air temperature and rainfall intensities. Higher temperatures will pose additional stress on the material, accelerate biochemical processes in drainage systems, cause corrosion damage, major system failures and other difficulties. Consequently, these changes will result in accelerated deterioration and reduced efficiency and reliability of coastal infrastructure. Deterioration will lead to sewage leaks into the environment and contaminate groundwater and coastal waters. This will lead to disruptions in the operation of the biological wastewater treatment plants. When storms and winds hit, strong waves are thrown against the coastline, which puts additional burden on drainage systems and further submerges and humidifies infrastructure and all coastal surfaces, causing corrosion and deterioration of materials and facilities.

Appropriate measures should be taken to prevent leaks of sewage in urban areas. One of the most important measures is to divide the combined sewer system into separate sewer system (rainwater/wastewater). Special care must be taken to make sure that roof drainage systems really prevent rainwater from entering the sewerage system. Due to climate change and the increase of short-lived bursts of intense rain and days of consecutive heavy rainfall, larger amounts of rainwater will need to be managed. Another important measure is the length of sewage channels permanently below the groundwater and sea level. Their length shall not be excessive. On submerged sections, groundwater infiltration into the sewage system may happen due to bolted joints loosening over time (5,000-50,000 l/ha/day, or 500-5,000 l/km/day, or 25-50 l/day per inspection pit).

Adaptation to climate change in urban coastal areas requires risk analysis that will help achieve the required standards of coastal zone development in the operation of urban water services and other infrastructure, and help prepare a contingency plan. Risk assessment in the coastal zone and cities can be carried out at different processing levels, from simple qualitative analysis to more complex quantitative analysis. They can be conducted taking into account different factors. In addition to the impact of extreme rainfall and extreme sea levels, there are also risks related to the functioning of drainage systems and other infrastructure.

Special attention must be paid to the water regime in urban areas and the environment, bearing in mind that the greatest damage and problems are expected from surface water flooding. Damage caused by higher sea levels, i.e. flooding can be divided into three categories:

- direct damage – normally damage caused by submersion, a certain level of water or water flow;
- indirect damage – for example, motor vehicle accidents associated with wet and slippery road surfaces, traffic disruptions and losses, the increase of labour costs, production losses, etc.
- social damage – negative long-term impacts on the economy, such as loss of asset value in floodplains, a slowdown in economic growth, etc.

The advantage of risk analysis is that all causes of flooding can be identified and evaluated so that appropriate sustainable solutions can be applied.

The objectives that must be taken into account in the analysis of flood damage are as follows:

- Prevent the population from coming into contact with a mix between the wastewater and the rainwater due to a sewage spill/overloaded sewage treatment system;
- ensure continuity of vital municipal functions, such as power supply, water supply, communications with hospitals, etc., when flooding strikes;
- ensure a minimum number (and surface area) of floodplains and facilities;
- ensure the minimum length of electrical cables, as well as other submerged infrastructure;
- ensure that traffic flows smoothly.

Problems caused by flooding are complex and infrastructure-specific. It is hard to offer a one-size-fits-all solution. The next section will therefore focus on coastal water infrastructure and associated guidelines.

6.4.1 Water infrastructure management options

Solutions to reduce the negative impacts of climate change and strengthen the resilience of coastal infrastructure depend on the type of infrastructure and its characteristics. The following two recommendations are universal:

- Infrastructures should be moved as far away as possible from the shoreline;
- Infrastructures should be moved as high as possible above mean sea level.

The question is how far from the shoreline and how high above mean sea level the infrastructure needs to be moved. The distance from the shoreline needs to prevent the sea and waves from having a direct impact on the infrastructure and the depth should be at least one metre above mean sea level. Whether this will be enough depends on how exposed the coastline is to the open sea and to wave action, urban planning in coastal areas and their specific needs. The problem must be addressed and solved together with built-up coastline management plan, because the measures and interventions on the coast will have an impact on coastal infrastructure vulnerabilities and protection.

Materials used in the coastal zone must offer seawater corrosion resistance. They must be able to withstand high temperatures and resist temperature fluctuations. Material should be robust and able to keep its integrity that may be compromised by varying moisture content of the soil in or on which they are located, as well as by the resulting subsidence.

Higher temperatures will also affect the processes in the infrastructure depending on the medium that is being transported or material from which the infrastructure has been built. Water in the water infrastructure system (water supply, wastewater and stormwater management) will be warmer in summer and colder in winter. Higher wastewater temperatures may mean the acceleration of organic matter decomposition in water, more greenhouse gases and unpleasant odours from the sewage system. Higher water temperatures will mean a more rapid decrease of the residual chlorine concentration and less water safe for drinking available. Therefore, the infrastructure needs to be laid deeper, at least 1.5 meters below the ground level (height at the crown of the pipe). If the infrastructure is laid down at a shallow depth, it should be adequately protected.

Box 9. What do the experts think:
the gradient to which coastal sewage infrastructure will be laid amid sea level rise

Normal lifetime of sewer system line (underground pipelines and canals) is at least 30 years. The gradient to which it will be laid must be planned by taking into account the climate change situation in 2050. Climate change increases the mean sea level for a certain period of time, but also the wind strength as well as wave heights and sea levels in the backshore.

The minimum gradient to which pipelines and canals on sheltered and open shores will be laid to be protected from the direct wave action equals to "good professional practice" + the maximum value of the predicted mean sea level rise for a specific period of time. For example, bearing in mind projections for 2050, the calculated gradient for pipelines is at least -0.5 m + 0.38 m = -0.1 m compared to today's mean sea level, precisely, ±0.0 m or more.

It would be best if the channel could be laid at least to the gradient that corresponds to today's 20-year tide for the observed location (usually +1.0 m).

Note: For the purposes of this recommendation, the coast is defined as a part of the land along the sea where a change in the groundwater/sea levels occurs on a daily basis in accordance with changes in the sea level (coastal tides).

Adapted from Margeta (2009)

Box 10. What do the experts think:
the gradient to which coastal water supply infrastructure will be laid amid sea level rise

Normal water supply infrastructure (underground pipelines) lifetime is at least 30 years. The gradient at which it will be laid must be planned by taking into account the climate change situation in 2050. Climate change increases the mean sea level for a certain period of time, but also the wind strength as well as wave heights and sea levels in the backshore.

The minimum gradient to which pipelines on sheltered and open shores will be laid to be protected from the wave action equals to "good professional practice" + the maximum value of the predicted mean sea level rise for a specific period of time. For example, bearing in mind projections for 2050, the calculated gradient for pipelines is at least 0.5 m + 0.38 m = 0.9 m compared to today's mean sea level, precisely, ±1 m or more.

It would be best if the pipeline could be laid at least to the gradient that corresponds to today's 20-year tide for the observed location (usually +1.0 m).

Note: For the purposes of this recommendation, the coast is defined as a part of the land along the sea where a change in the groundwater/sea levels occurs on a daily basis in accordance with changes in the sea level (coastal tides).

Adapted from Margeta (2009)

All drainage systems, especially those on the coast, will be at risk. Higher sea levels mean more possibilities for sea penetration into the drainage system through outlets. Drainage systems must be lifted to the level that will guarantee safe operation in all weather conditions with any sea level rise factored in. If this is not possible, sewer pumping stations must be installed instead.

In the coastal zone, separate sewer system must be used, as has been recommended by the EU. This means that any of the existing combined sewer system needs to be replaced with separate sewer system. This helps prevent the direct impact of the sea on wastewater sewage and the operation of biological wastewater treatment plants.

Rainwater management in the coastal zone should be based on the integrated concept of rainwater drainage (pipeline-free drainage). This kind of system directs water into the environment through natural processes: evaporation, evapotranspiration, infiltration, retention and water storage in the soil profile and underground. This is how pipeline and channel construction is avoided. Details related to the planning, design and construction of such solutions can be found in the specialised literature. They are very flexible and efficient, whereas their application also helps purify rainwater.

Measures to strengthen resilience should be taken in a public space, in the system itself and on private property. A whole range of measures can be taken on private property to reduce surface runoff in settlements and prevent any further damage:

- Infiltration of rainwater into the local underground, if possible;
- Store rainwater in tanks of different sizes and uses;
- Reuse rainwater for different purposes;
- Green roofs that capture and retain the water, which is then returned back to the atmosphere through evapotranspiration;
- Adequate local protection of underground facilities against water entering from the surrounding area;
- Administrative measures prohibiting or limiting the possibility of connecting one's rainwater drains to the public sewer system.

Protection measures must be implemented before, during and after the event by appropriate remedial action. All three stages must be considered in an integrated way. In order to reduce damage and ensure a good standard of operation of the drainage system, a whole range of different measures must be taken around and within the settlements, but also within the system.

In conclusion, **water infrastructure should be laid as far away from the coastline as possible, as high as possible above medium sea level, and deep enough to stay protected against high temperatures**. Drainage systems must be lifted to the safe level, if this is not possible, sewer pumping stations must be installed instead. In the coastal zone, separate sewer system must be used, rainwater management should be based on the integrated concept of rainwater drainage (pipeline-free drainage), using natural processes such as: evaporation, evapotranspiration, infiltration, retention and water storage in the soil profile and underground.

6.4.2 Solution options for estuary municipal infrastructure

Many rivers have jetties at their outfall - either to prevent siltation of the mouth (reducing flood risk) or to allow river navigation. This encourages offshore sediment dispersion and prevents longshore sediment transport. While very little can be done against the former, the latter process can be mitigated through bypass systems, which may consist of a fixed plant or a sediment transport system that uses tracks or ships. Sea level rise will increase the river outflow depth, leading to an increased sediment loss in that coastal area. The height of artificial levees will need to be changed to respond to rising water levels and to reduce the risk of flooding. In turn, this will divert the flow, and the river flooding will be catastrophic given the water velocity and inability to return to the main river channels. What needs to be taken into account is that many rivers already pose a risk and raising their banks will further exacerbate the risk. Elevating the levees implies side works that have not always been taken into account, such as the adaptation of bridges and pedestrian crossings. Rationalisation of the communication network could be included in the cost-benefit analysis. The actual costs of these projects, depending on the specific situation, cannot be estimated at the preliminary stage of any of the climate variability strategies. The alternative, as in the case of coastal setback, would be to make more room for the river.

Bridges are designed to withstand floods with a specific return period (e.g. 100 or 400 years). Even if older bridges do not comply with the current level of risk, their modification requires compliance with this rule. Due to an increase in extreme events caused by climate change, new bridges will be designed to have a larger bearing distance or higher piers; regardless of the levee elevation.

Coastal plains stretching mostly along the western Adriatic coast are nearing the sea level, or they are even below sea level. In addition to changes in the morphological characteristics of these areas associated with sea level rise, there are other burning issues that need to be addressed. Artificial channel networks, discharging into the sea or into the rivers, allow drainage and human use of these areas. When the land is not below sea level, drainage occurs naturally if the channel slope is gentle, otherwise the water level is raised by pumps so that it can enter the channels connected to the sea. Most of the alluvial plains are currently subsiding, and the drainage of these low-lying areas tends to become more difficult and expensive to manage. Nowadays, channels with gentle slopes will become an access point for seawater penetration, and in case there is a mechanical system for water elevation, management costs will gradually increase.

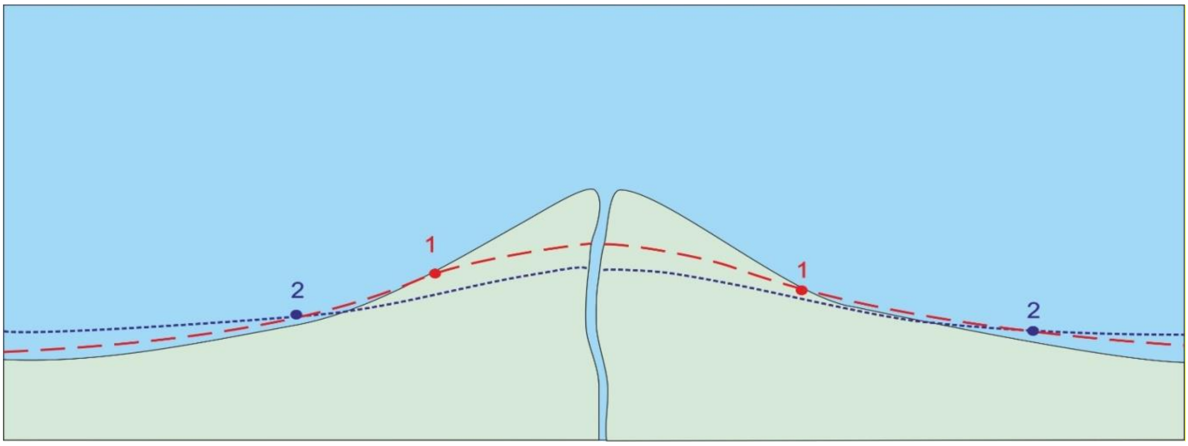


Figure 42. Longshore shift of the equilibrium points due to erosion in the delta region

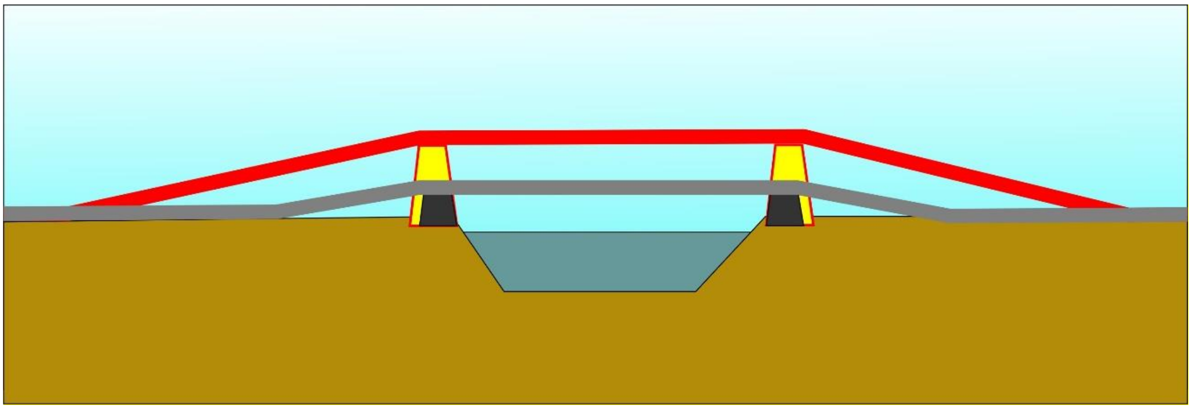


Figure 43. Bridges and related traffic services are elevated as a consequence of river levee elevation

Grey measures - final considerations

Grey measures will deliver real and substantial benefits if:

1. they operate on similar or better principles than traditional solutions and they are more cost-efficient for present and future generations;
2. they improve and strengthen the ecological characteristics of the environment and they are coherent with current and future social requirements and objectives; however, the population of coastal areas must "adapt" to the new scenario in order to let the environment and society walk together towards progress, maintaining the highest level of sustainability over time;
3. they are more appropriate considering projected climate change; and
4. they have been tested by a dedicated research project that has confirmed their value against the three criteria listed above. Solutions that have not been tested in local conditions should not be applied as this poses too great a risk.

The merit of a solution must be tested by asking a series of questions:

- Are local spatial conditions appropriate for their application considering the new technologies and their expected efficiency?
- Are new technologies already being used, and where?
- In what conditions are they used, at what sea level and status?
- How efficient would they be in stormy conditions?
- Does their performance meet the expectations?
- Are they flexible in adapting to rising sea level and climate change?
- What is their lifespan?
- What are the demolition costs in the event that the measures do not prove satisfactory?
- Do they pose danger to humans?
- What are the threats to the environment?
- Are there any legal issues with any of those measures?

If the answers are acceptable, such solutions should be applied whenever possible.

Finally, grey measures are often combined with green options, as shown in the figure below, illustrating the surface runoff control (Figure 44).

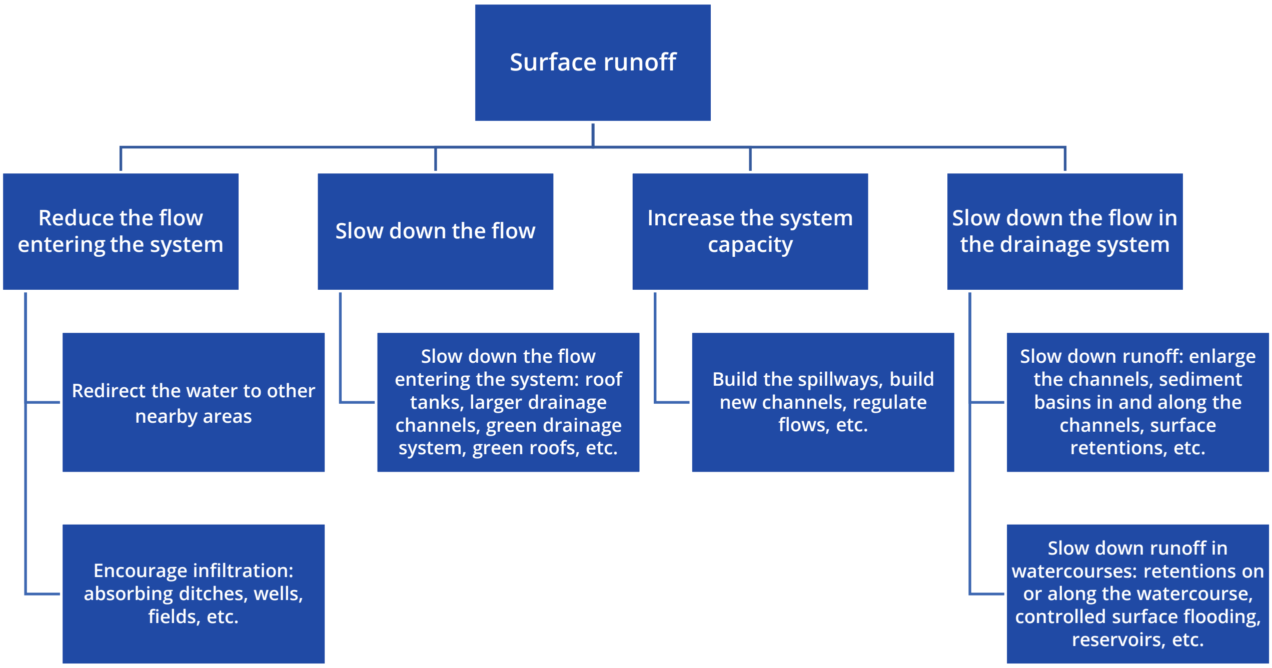


Figure 44. Surface runoff management in the settlement

7 Conclusions

Climate change adaptation, as well as the climate action, is something we should all care about. Scientists joined forces around the IPCC to understand and predict climate change. Science gives us solutions for both reducing greenhouse gas emissions and adapting to climate change. In Croatia, scientists launched an appeal to the Government of the Republic of Croatia for a systematic response to climate change and even offered to lend a hand. Italian schools offer systematic education about climate change, whereas climate change education programme for civil servants is being developed.

Youth movements across the globe are growing stronger, and give a voice to those who are most affected and whose lives will change the most because of climate change. We are witnessing global strikes for the first time in history. Millions of young people take to the streets and claim their right to the future. Events took place in many Croatian and Italian cities. The global youth strike helps increase the visibility of climate change and builds added strength to tackle this difficult challenge.

There are other processes that can help us transform society more rapidly. They include children's and adult climate lawsuits in which they sued their governments, cities' climate change lawsuits in which they claim they cannot do everything they should have done because of the national laws, and lawsuits involving indigenous people whose rights are irrevocably lost. Climate change lawsuits have not yet spread to Italy or Croatia, but this will happen eventually - it is only a matter of time. The main task of our governments is ensuring population safety. If the government grants us a building permit, we have every right to believe the area is safe. Nowadays, we keep getting information that help us understand which areas are unsafe. In such areas, building permits should not be issued, and services that do so despite knowing that the area is at risk of flooding will be held accountable sooner or later. The same rules apply to fire related risks. Fire breaks are becoming one of the key factors for the safety of the population. The authorities that decide to issue a building permit for projects that will block off access for fire engines should be held responsible for the consequences. The existing authorities may not be held accountable for this burning issue. The question is: can today's spatial planning services rise to the challenge? In case they cannot, the current authorities should be more vocal about this issue and discuss it with decision-makers, but also the general public. Working together with the scientific community, cooperation between outreach services, and a willingness to engage in climate change adaptation and fight against climate change will help raise the right questions and get a clearer picture of needs and priorities. Developing plans related to climate change is the most important task of local and regional administrations. The Coastal Plan based on the ICZM Protocol provides an integrated approach, enables us to tackle key aspects of climate action, adaptation, emission reduction and disaster risk reduction. Adaptation should be planned in ways that will encourage and enable emission reductions. Adaptation aims to avoid disasters. By combining the two approaches, we seek to equalize their respective time horizons. This handbook gives an overview of societal, green and grey adaptation measures. In reality, the three types of measures are not strictly divided, but they are rather used in a hybrid way, which means that a combination of measures is usually applied to get the best results at an acceptable cost.

The European Union has decided to lead the way in climate action. Therefore, the next programming period 2021 – 2027 has largely focused on climate action and biodiversity conservation. The allocated funding has been substantially increased. Our governments need to take a lead, whereas public, but also private sectors need to be involved and take further action. Our home planet is facing a crisis, but the solutions are being offered. As suggested in the chapter on societal measures, setting up *Climate Action Centres* is of the utmost importance, as they would connect decision-makers with scientists, so that science can continuously help with climate change adaptation and emission reduction solutions. Science in service to community, with wide-ranging cooperation and full transparency, can take us to the path of success. Transparency would make it possible to understand the decisions, to raise awareness, to work on education and strengthen social motivation for change. Let us emphasize the role of social sciences, from sociology and psychology to communication, all of which are of utmost importance for achieving the required overall transformation of society. It is all about working together to achieve the goal. The negative trends can be reversed in cooperation between all segments of society. Culture also plays a special part, as it has the greatest capacity to be the driver of change.

In order for *Climate Action Centres* to serve as a bridge between science and decision-makers, they should be organised at the level between universities and their respective cities. However, given that not all cities have universities, these centres should also serve their community, their county, province or region. Given the complexity of the challenge, each university may not be able to give all the answers. It is therefore important to connect those *centres*, both nationally and internationally. Universities are not the only centres of knowledge. There is a lot of hidden knowledge in organisations that manage specific segments of human activity, such as those working on nature protection and conservation. *Climate action centres* would be focal points for climate action, guided by knowledge, experience and information related to climate change adaptation and mitigation.

The information platform www.adriadapt.eu is of great importance for strengthening resilience along the Adriatic coast. Materials made available in Croatian and Italian will be of great benefit to local and regional governments, as they often lack experience and knowledge on how to best respond to these challenges. We hope that this platform will inspire cities, municipalities, counties and national governments to tackle the challenge of climate change adaptation as successfully as possible, always keeping in mind the reduction of greenhouse gas emissions, conserving biodiversity and sustainable development.

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The EU Interreg AdriAdapt Project aims to improve local climate change adaptation capacity in Adriatic region by creating an information platform that provides access to guidance, data and tools that will help local authorities to take adequate policy measures and develop plans to increase resilience in urban and coastal areas. The AdriAdapt project was carried out from 2019 to 2021 by six partner institutions from Italy and five partner institutions from Croatia.