AdriaClim

Climate change information, monitoring and management tools for adaptation strategies in Adriatic coastal areas

Project ID: 10252001

D.5.8.1 Monitoring and evaluation methods developed to allow local administrators of Split pilot area to assess the effectiveness and efficiency of adaptation interventions

PP7 – IOF

Final version
Public document

December, 2022

Table of contents

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC), the United Nations body for assessing the science related to climate change defines **climate change** as:

*A **change in the state of the climate** that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to **natural internal processes** or **external forcings** such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.*

Earth's climate has always been changed due to both internal and external factors. The great amount of data collected over the last several decades as well as numerical model results evidenced that current **warming trend** is increasing at a rate that is unprecedented over decades to millennia and its main driver is increased level of **greenhouse gases** in the atmosphere due to burning of fossil fuels.

Climate change is a global and complex challenge which is already affecting all of us and will affect the generations to come, even if we stopped greenhouse gases emissions right now. Despite that, we have a chance to respond to climate change and global warming through dedicated scientific investigations and through two long-term strategies: adaptation and mitigation.

The IPCC defines **adaptation** as:

*The **process of adjustment to actual or expected climate and its effects**. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.*

The IPCC defines **mitigation** as:

*A **human intervention to reduce the sources or enhance the sinks of greenhouse gases** […] and other substances which may contribute directly or indirectly to limiting climate change, including, for example, the reduction of particulate matter emissions that can directly alter the radiation balance (e.g., black carbon) or measures that control emissions of carbon monoxide, nitrogen oxides, Volatile Organic Compounds and other pollutants that can alter the concentration of tropospheric ozone which has an indirect effect on the climate.*

The IPCC provides regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation. The IPCC reports are meant to be used by decision makers to propose politics against adverse effects of the climate changes on the scientific basis.

According to Paris Agreement Croatia accepted obligation to enhance adaptive capacity, strengthen resilience and reduce vulnerability to climate change in order to contribute to sustainable development and ensure an adequate adaptation response in the context of holding global temperature increase well below 2^0C pre-industrial level.

On the 7th April 2020, the Croatian Parliament adopted the Strategy for Adaptation to Climate Change in the Republic of Croatia for the period to 2040 with a view to 2070 (Official Gazette 46/2020). This is the first national strategic document that provides an assessment of climate change for Croatia by the end of 2040 and 2070, possible impacts and vulnerability assessments. The aim of the Strategy is to raise awareness of the importance and threats of climate change for society and the need to integrate the concept of climate change adaptation into existing and new policies. In addition, the aim is to encourage scientific research to better understand the complexity of the impacts of climate change and to reduce the degree of uncertainty associated with the effects of climate change.

The aim of the AdriaClim project – improvement of climate related documents at the national, regional and local level with information from scientifically based monitoring is in line with IPCC goals as well as with national Adaptation Strategy.

Within this document we will propose the methods that will allow local administrators of Split pilot area to assess the effectiveness and efficiency of adaptation and mitigation interventions against adverse impact of the climate change. In the compilation of this document we used deliverable D5.1.1 made by CMCC team within AdriaClim project, Strategy for Adaptation to Climate Change in the Republic of Croatia for the period to 2040 with a view to 2070, Climate Menu (**https://www.climatemenu.eu/en/about/**) developed within Interreg project RESPONSe and outcomes from Interreg projects CHANGE WE CARE and AdriaAdapt.

After a brief description of the pilot site, we have listed the main climate related hazards in the area, described the categories of the suitable adaptation and mitigation measures that could be applied and finally we propose the methods to evaluate the effectiveness and efficiency of the selected adaptation measures.

2. Pilot site

2.1. Regional Characteristics of Split-Dalmatia County

Split-Dalmatia County is the largest Croatian county with a total area of 14106.40 km^2 (Figure 1). Of this total area, a surface area of 4523.64 km^2 (8% of the Republic of Croatia) is covered by land, and the sea covers a surface area of 9576.40 km^2 (30.8% of the sea surface of the Republic of Croatia).

Most of the land area consists of the hinterland (59.88%), while the islands make up a lower proportion of the land surface area (19%).

Geographically it is located in the central part of the Adriatic coast. The County borders on the north with the Republic of Bosnia and Herzegovina, on the east with Dubrovnik-Neretva County, and it extends south to the border of Croatian territorial waters. It is divided into three geographical subunits: hinterland, coastal area and islands. The hinterland, in the continental part of the County, is crisscrossed by mountains that run parallel to the coastline. The area is sparsely populated and economically poor.

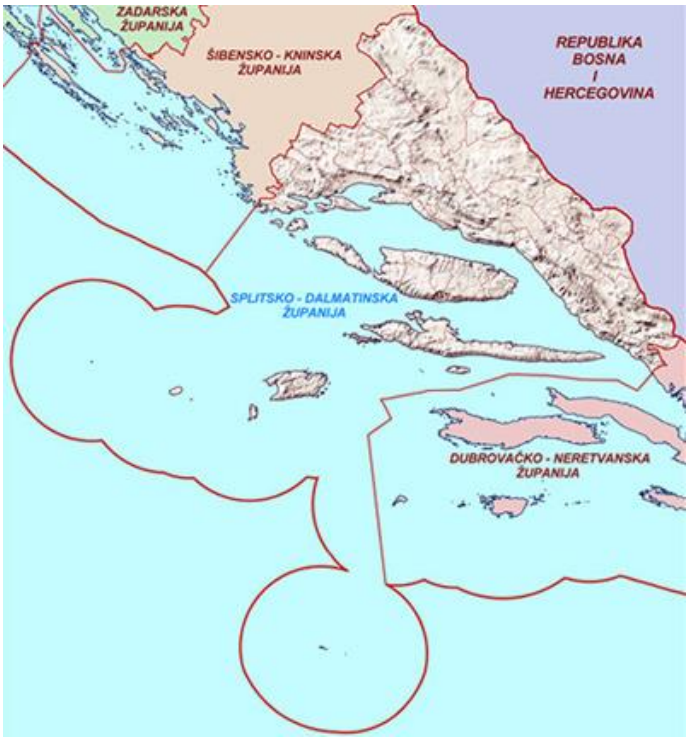

Figure 1. Split-Dalmatia County.

The coastal area makes a narrow strip along the coast between the mountain ranges and the sea. This area is highly urbanized and economically developed compared to the hinterland. The islands are sparsely populated, economically more developed than the hinterland; however, due to various circumstances, they have experienced permanent emigration of the population. The island area of

the County is made up of 74 islands and 57 islets and reefs. The largest island in Split-Dalmatia County is Brač with a surface area of 395.57 km^2.

2.2. Kaštela Bay

IOF monitoring program in the Split-Dalmatia County is focused to Kaštela Bay (Figure 1). Kaštela Bay is a semi-enclosed coastal bay, covering an area of 57 km^2 and having an average depth of 23 m. The length of the coast is 23 km and almost the entire coastal area of Kaštela is urbanized. The most important fresh water source is the Jadro River, a relatively small river with an average annual discharge of 8 m^3/s, which discharges into the eastern part of the Bay. Geologically, the area forms part of a large Cretaceous-Tertiary sedimentary complex, which belongs to the structural unit of the Adriatic cretaceous carbonate sediments. Based on the primary production, the Kaštela Bay may be considered a moderately productive basin.

The land area around the Kaštela Bay belongs to the administrative area of the Kaštela City and covers 58 km^2. According to the Landscape Regionalization of Croatia, the area of the Kaštela belongs to the landscape unit Coastal Area of Central and Southern Dalmatia.

The town is located along the Kaštela Bay narrow coastal strip, from the north and northeast closed by the mountain, from the south by the Split peninsula, and from the west and southwest bordered with Trogir and the island of Čiovo. The coastal settlement is followed by an agricultural land (Kaštela field) and a sudden relief rise towards the mountain Kozjak.

The coastal zone of the City of Kaštela has been exposed to long-term adverse anthropogenic activity and it is influenced by the proximity of two strong tourist destinations, Trogir and Split, and by the proximity of the airport. Due to its natural characteristics (closed bay) and intensive industrialization in the past, as well as increased urbanization, Kaštela Bay is one of the areas where the ecological balance has been disturbed, consequently increased eutrophication has been recorded in this area.

The area is suffering a number of issues related to climate change such as sea level and air temperature rise, increased frequency of various extreme events like heat waves, storms, flooding events and more frequent appearance of long-lasting dry periods. During summer months, almost 50% of water flow at the source of Jadro drains for the needs of water supply and the intensity of urbanisation represents a threat for environmental quality status of both the river and the bay.

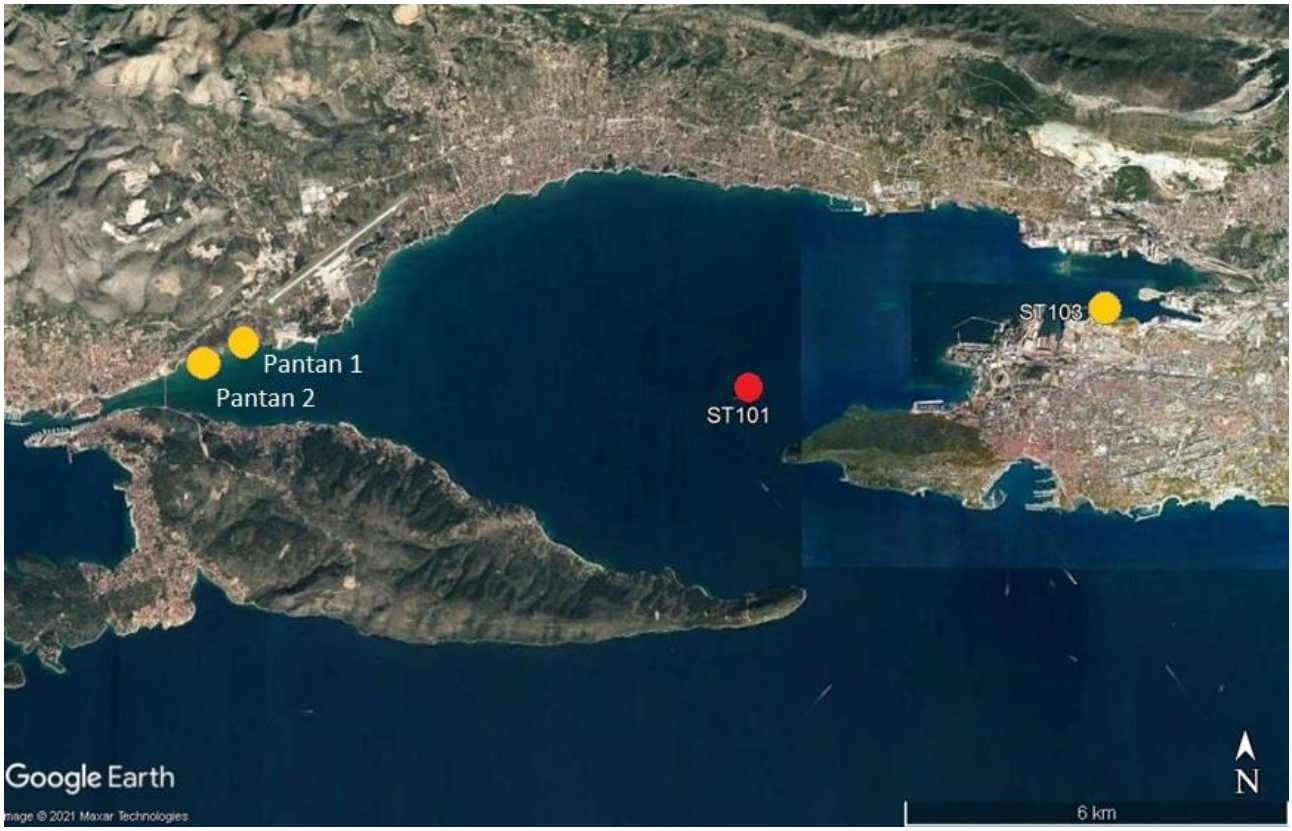

Figure 2. Kaštela Bay with AdriaClim monitoring stations. Temperature and salinity measurements, sediment, microbiological and phytoplankton samplings have been conducted at the central Kaštela Bay station ST101 (red circle). Additional sediment samplings have been carried on ST103, Pantan 1 and Pantan 2 stations (yellow circles).

An additional reason why Kaštela Bay is selected for the pilot site is long-term oceanographic measurements, crucial for climate change studies. Systematic measurements of oceanographic properties in the Kaštela Bay began in the 1930s, after the Institute of Oceanography and Fisheries had been established at its shore.

3. Adaptation and mitigation measures for Split-Dalmatia County

Split-Dalmatia County, as well as the entire Adriatic coast, is exposed to climate related hazards such as: sea level rise, floods, coastal storms, heatwaves, forest fires, sea water warming, sea acidification, hydrological droughts and hails.

Here we will give categorization and examples of the possible measures and actions that can be undertaken by local administration and authorities in different fields to adapt to or mitigate the effects of climate change. More details on the proposed measures will be given in the following project deliverables. The main goals of the climate-related actions are the following: (1) to reduce the vulnerabilities of natural systems and society to the negative impacts of climate change, (2) to improve resistance and recovery capacity from the negative effects of climate change and (3) to take advantage of the potential positive effects of climate change. Although we are focused on the Kaštela Bay and its ecosystem, we will also propose some guidance for sectors important in the pilot area that could be affected by climate change like agriculture, fisheries, aquaculture and tourism.

Some of negative climate change impacts could be mitigate by planning and building adequate infrastructure and developing systems of early detection and warning of possible natural threats. Protection of natural resources and adapting sectoral development to the vulnerability of ecosystem is also an important step towards climate change mitigation and adaptation.

First step in climate adaptation at the local scale is harmonization of actions and documents with national strategy and accompanying action plan. National strategy offers the following information for the local administration:

- a set of adaptation measures and a methodology to select the actions that best fit with the area of application;
- a set of indicators for monitoring and evaluation of the implementation process and efficiency of the applied actions.

There are many projects dealing with climate change in the Adriatic area offering various solutions that can be used by local authorities and administrations. Here we will describe some of them that can help in selecting appropriate procedures in the fight with adverse climate change impacts.

Interactive platform at https://klimatskepromjene.hr/ can be used by local administration and policy-makers for the assessment of the climate change impact in the Adriatic area. Platform allows user to select one of four climate model (EC-EARTH, HadGEM2-ES, CNRM-CM5 i MPI-ESM-MR), one of two greenhouse gas concentration scenarios (RCP4.5, RCP8.5) and find out the future climate conditions in the selected Adriatic area. Available climate elements are: air temperature, precipitation, wind speed, clouds, solar radiation and sea level and it is possible to obtain their

values at several locations along the eastern Adriatic coast for the past, present and future periods from 1971 to 2050.

Similar information will be available at the AdriaClim Geoportal, but climate elements will be determined from the climate simulations conducted with fine spatial resolutions suitable for coastal areas and from the measurements in the AdriaClim pilot areas.

Another useful tool is Climate Menu for Adriatic regions (https://www.climatemenu.eu/en/about/) developed within Interreg project RESPONSe. The Climate Menu for Adriatic Regions is a free online repository of adaptation and mitigation actions that can support local policy-making to address the challenges of climate change. Each action comes with a dedicated technical sheet describing the objectives, the expected results, the sector of interest, the reference timeframe and the criticalities as well as a sample of related best practices already implemented in similar contexts.

Level of climate change threat for the local area can be checked at interactive platforms and the next step could be selection of the measures and methodologies either from national strategy or from climate menu. In addition, the climate related hazards and suitable measures can be also communicated with various stakeholders through participative process.

Adaptation and mitigation measures can be categorized as soft, green and grey.

Soft measures or measures for society are measures taken by social actors concerning decision-making activities related to development, planning, management, legislation, education, raising awareness, etc. These measures 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 its consequences.

Soft measures can be applied to all areas and all sectors. Some examples of the soft measures suitable for Split-Dalmatia County are: capacity building, raising awareness, individual behaviour change, providing systematic education for people in coastal communities, education of the local administration through dedicated workshops, promote sustainable climate meetings, early warning systems for flood events, wildfires, heat waves, and similar threatening events, adaptation of flood management plans, monitoring based on the scientific findings, improving spatial planning and coastal management by creating unique spatial planning database, land-use planning, development of climate change adaptation plans for specific areas and integrated coastal zone management.

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. Green measures have high potential for climate change mitigation and the success of their implementation relies on the cooperation of a variety of

authorities involved. These 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 two different ecosystems and landscapes, land and marine, meet has an exceptional value. The 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 or grey 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.

Examples of green measures:

1) for the marine ecosystem: developing techniques and tools for the exploitation of alien and invasive species and popularizing their use; development of conservation measures for the most vulnerable habitats that hold populations of economically important species; anticipate and respond to species decline; build ecological networks; emphasize heat-tolerant species and populations;
2) for urban areas: planting vegetation; creation of green spaces and corridors; green roof and walls; create or repair fountain to cope with heat waves in cities; green public courtyards;
3) for beach areas: beach and shoreface nourishment; dune construction and strengthening.

Grey adaptation measures include technological and engineering solutions intended to improve the adaptation of territory and infrastructures 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 the ecosystem-based adaptation, where the existing coastal structures should not be abandoned, but safely taken care of.

Coastal infrastructure must provide its 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 desired criteria.

Examples of grey measures for the coastal areas include coastal protection, improving infrastructure, adaptation of coastal infrastructure to sea level rise, defence against flooding, raising and extending coastal land, sustainable rainwater management (drilling, rainwater, torrential watercourse diversion), strengthening resilience and developing new energy production capacities, renewable energy sources and other technological and engineering solutions.

Adaptation measures could be also categorized according to sector of implementation and here we list some examples of the measures for sectors important for Split-Dalmatia County that could be affected by climate change:

Agriculture

- Irrigation of agricultural land with rainwater and development of drought warning systems
- Improve water retention in agricultural areas
- Improvement of irrigation efficiency
- Adapting practices and monitoring of positive trends in agriculture

Tourism

- Adapting tourism to climate change
- Adapting practices and monitoring of positive trends in tourism
- Improve tourist activities, settlements and infrastructures
- Strengthening the resilience of tourist infrastructure to different weather conditions.

Fisheries

- Restoration of fish stocks
- Adapting practices and monitoring of positive trends in fisheries
- Diversification of fisheries products
- Establish early warning system in offshore and inshore operations
- Increase diversity of nursery stock to provide those species or genotypes likely to succeed

Aquaculture

- Stimulating the circular economy (aquaculture)

- Encouraging regenerative agriculture
- Emphasize heat-tolerant species and populations
- Diversification of aquaculture systems

Efficiency of the applied measures and actions should be monitored and evaluated, in order to decide should they be continued or updated.

4. Monitoring and evaluation methods for local administrators

After implementation of the adaptation and mitigations measures it is of great importance to have monitoring and evaluation tools to assess the efficiencies of the implemented procedures, to face the issues that could arise during the implementation and application phase, and to decide whether applied measure should be continued or updated. Before application of the assessment tools the environmental and socio-economic conditions should be monitored during the period suitable for the area of the implementation and results of the monitoring should be a part of regular reports prepared by local administration for regional and national administration, and for citizens. The basic step to enable local administration to assess the effectiveness and efficiency of adaptation interventions is strengthening capacity for understanding (education) and implementation of climate change adaptation measures.

Monitoring and evaluation are particularly relevant for the measures against climate change due to their long-term perspective and due to great uncertainty characterizing the evolution of the climate system and its effect on natural and social systems. Monitoring is essential for evaluating the progress of planned actions and for checking the actual outcomes of actions against objectives. Clear objectives are therefore crucial for meaningful monitoring and evaluation. Monitoring and evaluation measures are also needed to monitor spending related to adaptation and to efficiently communicate progressive results of the adaptation process.

Monitoring and evaluation mechanisms often make use of indicators, i.e. a quantitative or qualitative variable that can be measured and described in response to a defined objective. Indicators can transform objectives into measurable variables.

Climate indicators show the long-term evolution of several key variables which are used to assess the global and regional trends of a changing climate. They are updated at least once a year, for the publication of the European State of the Climate. Simple indicators are: temperature, greenhouse gas concentrations, greenhouse gas fluxes, sea level.

Proposal for monitoring and evaluation tools, as well as the list of indicators for Split-Dalmatia County arranged according to the specific areas like: urban areas, beaches, river influenced areas etc., and sectors important for the County: tourism, agriculture, fisheries and aquaculture is given in Table 1.

Climate impacts	Action	Type of actions	Indicators	Sector/area of implementation	Data collecting and reporting methods
change or loss of biodiversity, coastal erosion, drought, extreme precipitation, extreme temperatures, fires, floods, salinization and acidification of water, strong winds	Capacity building	soft	number of people involved and informed, number of workshops	Education, authority, administration, general public	Statistical reports, number of people attended some kind of education
floods	Enhance monitoring, modelling and forecasting systems of flood events	soft	Floods return time [T=1/p; years], % of flooded areas	Agriculture, forests, land use, public health, transport and infrastructure	Continuous measurement of sea level, monitoring of flooded areas, technical report
floods	Adaptation of flood management plans	soft	Flood return time [T=1/p; years]	Coastal management, water resource management	Continuous measurement of sea level, technical report
coastal erosion, floods	Enhance operational safety in inshore operations	grey, soft	Percentage of damage avoided [%]	Aquaculture, fishing, transport and infrastructure	Statistical reports
coastal erosion, floods	Establish early warning system in offshore and inshore operations	grey, soft	Percentage of transport for fishery allowed	Aquaculture, fishing, coastal management, transport and infrastructure	Statistics of the fishing boats
drought, extreme temperatures	Establishment of early warning systems	soft	Number of people reached	Agriculture, forests, land use, coastal, management, water resource management	Statistical reports

extreme temperatures	Heat health action plans	soft	Alert and prevention	Public health	Statistical reports
drought, salinization and acidification of water	Prevent saltwater intrusion	grey	Salinity	Agriculture, forests, land use, public health, urban settlement	Continuous measurement of salinity along the river course, technical report
drought, extreme temperatures	Adapting tourism to climate change	grey, green, soft	Number of tourists/month (or year)	Tourism and leisure, transport and infrastructure	Statistics of tourist overnight stays
change or loss of biodiversity, extreme temperatures	Diversification of fisheries products	grey, soft	Number of adapted vessels and equipment, number of commercial fish species.	Aquaculture, fishing, biodiversity, conservation of ecosystems	Statistics of the fishing boats, monitoring of commercial fish species
change or loss of biodiversity, extreme temperatures	Diversification of aquaculture systems	grey, soft	Number of production areas with risk assessment, Number of commercial fish species	Aquaculture, fishing, biodiversity, conservation of ecosystems	Statistics of production areas, monitoring of commercial fish species
coastal erosion, floods	Enhance operational safety in offshore operations	grey, soft	Percentage of transport for fishery allowed	Aquaculture, fishing, coastal management, transport and infrastructure	Statistics of the fishing boats
extreme temperatures floods	Creation of green spaces and corridors in urban areas	green	Decreasing air temperature [°C]	Public health, urban settlement, water resource management	Continuous air temperature measurements, technical report
extreme temperatures	Create or repair fountain to cope with heat waves in cities	grey	Decrease surrounding air temperatures [°C] and cooling effect up to a few meters away	Public health, urban settlement, water resource management	Continuous air temperature measurements, technical report
change or loss of biodiversity, drought, extreme precipitation, extreme temperatures	Green public courtyards	green	Green areas replaced [m²]	Biodiversity / Conservation of ecosystems Public health Urban settlement	Monitoring, technical report
extreme precipitation, extreme temperatures	Green roof and walls	green	Percentage of solar energy reflection [%]	Public health, urban settlement	Measurements of solar radiation, technical report

coastal erosion, floods	Improve the structure of urban settlements	grey, green	Number of recovered and enhanced areas	Agriculture, forests, land use, industry, urban settlement	Monitoring, technical report
coastal erosion, floods	Beach and shoreface nourishment	green	Area of saved and protected coast [m²]	Coastal management, tourism and leisure	Monitoring, technical report
coastal erosion, floods	Cliff strengthening	grey	Length of protected cliff [m]	Coastal management	Measurements of the protected areas, technical report
coastal erosion, floods, extreme precipitation	Install breakwaters	grey	Length of breakwaters [m]	Coastal management	Technical report
drought, extreme temperatures	Adaptation of the fire management plans	green	Area of protected vegetation [m²]	Agriculture, forests, land use, biodiversity, conservation of ecosystems	Monitoring, technical reports
fires	Alter forest structure or composition to reduce risk or severity of fires	green	Area of forest not burned [m²]	Agriculture, forests, land use, biodiversity, conservation of ecosystems	Monitoring, technical reports
change or loss of biodiversity, fires	Establish fuel breaks to slow the spread of catastrophic fire	grey, green	Area of forest not burned [m²]	Agriculture, forests, land use, biodiversity, conservation of ecosystems	Monitoring, technical reports

Table 1. Climate actions and indicators proposed to assess the implementation and efficiency of the adaptive actions.

Monitoring and evaluation tools can serve different purposes and different users. The design of a monitoring and evaluation approach should therefore include a clear indication about how to use results and how to communicate with specific target groups (policy makers, practitioners, experts, sector representatives, civil society associations, citizens, etc.). A wide variety of communication tools and formats can be considered, such as: technical reports, technical summaries, policy briefs, infographics and other visual products, periodic newsletters, sections of adaptation portals, alive communication events, press releases for media, initiatives for raising awareness, etc.