Context and framing

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Chapter 1
Context and framing

Executive Summary

The Mediterranean is often referred to as a 'hotspot' of climate and environmental change given the high exposure and vulnerability of human societies and ecosystems and interconnected risks in this region (MedECC 2020a; Ali et al. 2022). A third of the Mediterranean population lives close to the sea and depends on infrastructure developed within the coastal zone. Policies to manage coastal risks and adaptation strategies in the context of sustainable development are therefore important for the whole region. Policy development together with regional cooperation support greater integration of knowledge, applied to more sustainable and integrated Coastal Zone Management and its proper communication.

- Risk assessments for Mediterranean coastal zones address the specific features of climate, variability and extremes, and the often narrow and over-pressured coastal zones of the Mediterranean Basin. Coastal risk levels, estimated with explicit treatment of uncertainties can inform adaptation pathways and support coastal sustainability decisions. Coastal hazards, vulnerabilities, and exposure are assessed together with climate and environmental management scenarios. This combined information provides useful support for a transition towards risk reduction, building long-term resilience and sustainability in coastal governance, policies, as well as social perception.

- Adaptation pathways provide a sequenced set of actions to sustain coastal zones and control risk levels, including change stations (indicating shift in adaptation pathways) and tipping points (indicating a threshold in adaptation pathways) to guide coastal decisions. The preparation of adaptation pathways favours objective discussions among stakeholders to co-decide preferred adaptation options and deadlines for their implementation, which in turn facilitates the generation of sufficient funding and supportive policies.

- Coastal risks have consequences for biophysical values and social activities. Understanding how risks are distributed within and among communities can inform adaptation policy development. A value-based approach guides the understanding between nature and society, placing the social and cultural values in context within the region.

- Adaptation plans designed by local and regional administrations typically focus on the need to protect communities, and minimise impacts on the natural environment, such as ensuring ecosystem resilience. Including ethical considerations would lead to informed and more socially- and ecosystems-oriented adaptation policies.

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1.1 Introduction

The First Mediterranean Assessment Report (MAR1) on the current conditions and expected risks of climate and environmental change in the Mediterranean Basin was published on 17 November 2020 by the network of Mediterranean Experts on Climate and environmental Change (MedECC) (MedECC 2020a). It was prepared by 190 scientists from 25 countries. To produce this report, more than 3800 articles and reports in the scientific literature were assessed. The overarching goal for the development of MAR1 was to cover all major risks associated with environmental change as comprehensively as possible, regarding the major drivers of risk, the major systems impacted and as much as possible the sub-regions of the Mediterranean Basin. During this assessment, several important issues emerged that require deeper analysis, often associated with progress published in new scientific studies. It was therefore proposed that the MedECC community, and the approach developed for MAR1, could be used to produce a Special Report, during the 2021–2024 period, addressing coastal risks in the Mediterranean region. The coastal zone is generally defined as the interface between land and sea including the land area affected by marine processes, and the part of the sea affected by terrestrial processes, considering relevant biophysical and socioeconomic criteria, well-illustrated by low lying deltas subject to marine flooding, erosion and salinisation.

The Special Report on Climate and Environmental Coastal Risks in the Mediterranean is structured with an opening introductory chapter *(Chapter 1)* that provides readers with the context, background and key dimensions, particularly the risk framework, of this assessment. The report has three central chapters: the first assesses the drivers of coastal risks in the Mediterranean and their interactions *(Chapter 2)*; the second addresses coastal climate change and environmental impacts and risks for human and natural systems in the Mediterranean *(Chapter 3),* and the third explores the existing and prospective responses and management approaches to managing climate change and environmental risks, the existing policy-research interface, and presents best practices across the Mediterranean region *(Chapter 4).* The final chapter *(Chapter 5)* summarises the available knowledge about climate resilient sustainable development pathways for Mediterranean coasts, building on the outcomes of *Chapters 2* to *4*.

This introductory chapter sets the context for the Special Report in terms of the policy, natural environment and societal context of the report, focusing on the general risk framing, as well as key definitions, including context-specific nuances that are relevant across the report. It identifies what is assessed in the report, building on recent developments, and considering the latest relevant international assessments both at global scale and with a special focus on the Mediterranean. The introduction establishes a common assessment framework to facilitate the communication and synthesis of the results for stakeholders and users more broadly.

1.1.1 Mediterranean coastal risks

As explained above, the Mediterranean is often considered as a 'hotspot' of climate and environmental change, with a third of the Mediterranean population (around 150 million people) living 'close' to a dynamic shoreline (e.g. public domain zones with a width of a few to hundreds of metres) or in a low elevation coastal zone (e.g. below 10 m with respect to sea level). This population depends on infrastructure developed within the coastal zone and is therefore significantly affected by marine drivers. As assessed in the MAR1 report (MedECC 2020a), 40% of Mediterranean coastal areas are built-up or otherwise modified, often rendering them particularly vulnerable to: (1) coastal flooding and erosion, caused by sea level rise in combination with extreme climate events and reduced riverine solid transport producing sediment starvation in deltas and estuaries; (2) infiltration of seawater into coastal aquifers (seawater intrusion); (3) general degradation of coastal habitats, including wetlands, seabed meadows and agricultural systems; (4) coastal squeeze and loss of water and sediment quality; and (5) cumulative pollution effects at selected sites, whose concentration of human and economic activities has resulted in increasing degradation of coastal ecosystems. The combined result is a disturbance in sediment supply and exchange between the different compartments of coastal systems, aggravated by additional environmental disturbances due to salinisation, pollution, urbanisation, and lack of accommodation space (Wolff et al. 2020).

Mean sea level in the Mediterranean Basin has risen by 1.4 mm yr^{-1} during the 20th century and it has accelerated to 2.8 mm yr^{-1} recently (1993–2018), with sea level rise expected to continue accelerating in the Mediterranean with regional differences. This rise will reach the expected global rate of 43–84 cm above current levels by 2100, but with a significant risk of exceeding 1 m in the case of further ice-sheet destabilisation in Antarctica (MedECC 2020a). Sea level rise will intensify most coastal risks through the increase in frequency and intensity of coastal floods and erosion events. Until 2100, coastal flood risks, which are mainly of marine origin but are compounded in river mouth areas by combined marine-riverine flooding, may increase by more than 50% and the erosion risk by more than 10% across the Mediterranean region (Reimann et al. 2018). Damaging flash floods are expected to increase in many countries including France, Italy, and Spain, mainly affecting coastal areas and river mouth areas where population and urban settlements are growing in flood-prone areas, becoming more frequent and/or intense due to climate change and land surface sealing by urbanisation. Important challenges to groundwater quality in coastal areas are expected to arise from saltwater intrusion driven by enhanced extraction of coastal groundwater aquifers and sea level rise.

Reduced precipitation and prolonged droughts will reduce the water discharge and sediment flow of Mediterranean rivers and catchments, leading to the risk of land loss in estuarine river mouths and deltas. The agricultural sector will be affected by direct impact (e.g. due to salinisation) or loss (e.g. due to eroded land) in agricultural areas within coastal zones, defined considering biophysical and socioeconomic criteria, as explained above. Coastal zones feature significant increases in salinity due to sea-level rise and decreasing freshwater availability, progressive sediment starvation due to river regulation, reduced catchment basin erosion and dam barriers, and enhanced flooding due to relative sea level rise (eustatic rise plus subsidence) that affect deltas and estuaries. The impacts are more severe on the less mobile and resilient species, although mitigated by improved irrigation practices, use of recycled waters or more nature-based solutions for coastal areas.

Coastal erosion due to sea level rise and urban development will also *likely* affect tourism. The effect of sea level rise, together with changes in storm features are *likely* to seriously impact port operations, slowing down trade operations and productivity levels. Parts of the rich Mediterranean cultural heritage, notably the World Heritage Sites (WHS) implemented by the United Nations Educational, Scientific and Cultural Organization (UNESCO), are threatened directly by sea level rise, energetic storm events (e.g. medicanes), concentrated precipitation (e.g. Mediterranean flash floods) and other aspects of environmental change (Ribas et al. 2020; Sarkar et al. 2022).

Proactive adaptation to these hazards is essential for maintaining functioning coastal zones. Coastal adaptation practices can be classified into the following broad categories: protect, accommodate, advance, and retreat. Nature-based protection solutions, such as beach and shore nourishment, dune or wetland restoration, reforestation in upstream areas, and adequate agricultural practices to retain water, present an implementation gap despite recent advances in techniques and policies.

These practices, supported by advanced information such as from Early Warning Systems (EWSs), contribute to reducing flood fatalities and preparing societies to live with natural hazards. The MAR1 report assessed multiple risks faced in the Mediterranean region, defined as a 'climate change hotspot' due to the interconnected combination of hazards with high exposure and vulnerability. The report will compile new information and thereby update the assessment of MAR1 about coastal risks and identify potential for adaptation and risk reduction.

This report will inform Mediterranean policies on the development of an overarching framework to address the United Nations (UN) Sustainable Development Goals (SDGs) of particular importance to the whole Mediterranean region, such as combating climate change, increasing food security, managing natural resources, reforming health systems, creating opportunities for social inclusion, economic prosperity, and human equality or reducing risks of geopolitical instability. Science-policy dialogue can support this framing together with a multi-stakeholder approach, strengthened research cooperation mechanisms, and institutional partnerships, together in a shared ownership approach for the benefit of our Mediterranean (Mare

Nostrum). By recognising the value of countries' specificities as a strength for the region, there is the opportunity for a cultural transformation to create a proud community sharing the Mediterranean Sea as a common value.

1.1.2 The science-policy context

The Mediterranean has seen the development of various initiatives and activities that seek to impact policymaking by introducing a more systematic approach. Since 1975, Mediterranean countries have established an institutional framework for cooperation in addressing marine and coastal environmental degradation — Mediterranean Action Plan (MAP), under the auspices of the Regional Seas Programme of the UN Environment Programme (UNEP). In 1976, in Barcelona (Spain), a framework convention dedicated to the Protection of the Mediterranean Sea Against Pollution was adopted (Barcelona Convention)[8]. Other initiatives followed, such as the BLUEMED initiative and its Strategic Research and Innovation Agenda (SRIA)[9]; the EU COST Action on 'Ocean Governance for Sustainability'[10]; the EU COST Action on 'Unifying Approaches to Marine Connectivity for improved Resource Management for the Seas (SEA-UNICORN)'[11]; the UN decade of ocean science for sustainable development and various training on the science-society-policy interface in the Mediterranean promoted by UNESCO[12]; the Union for the Mediterranean (UfM)[13] and other actors. At a national level, various Mediterranean countries are implementing national adaptation plans. All these policy developments and regional cooperation initiatives are supported now by the EU Green Deal (EC 2019), which provides an important policy piece for the Mediterranean combining climate adaptation, biodiversity and zero pollution ambitions. This new policy framework should be applied for synergies with other initiatives such as the UNEP/MAP Barcelona Convention Ecosystem Approach[14] and the relevant EU Directives, aiming to achieve and maintain Good Environmental Status (GES) for Mediterranean Sea and coastal areas linked to more sustainable and integrated Coastal Zone Management. Therefore, the proposed thrust to support a new generation of policymakers through dedicated capacity building, timely science advice on policy and fostering dialogue within the knowledge triangle (academia-society-policy).

The UfM's policy dimension is structured around regional dialogue platforms involving representatives from governmental institutions and experts, regional and international organisations, local authorities, civil society, the private sector, and financial institutions. The UfM is also advancing regional and sub-regional cooperation by supporting integration and partnerships within shared objectives, including strengthening cooperation on blue economy and maritime governance, and facilitating the transition to a sustainable blue economy.

In 2008, fifteen Mediterranean countries signed the 7th Protocol of the Barcelona Convention, Protocol on Integrated Coastal Zone Management for the Mediterranean.[15,16] For the past six years, the countries have been negotiating the text of this Protocol, which is still innovative in many aspects. Its flagship article, Article 8, is the first international legal instrument that lays down the requirement for use of coastal setback zones, a buffer area where certain or all types of development ar6e prohibited or significantly restricted. It identifies a setback zone of a minimum 100 m from the shoreline as an agreed measure to protect coastal settlements and infrastructure from the negative impacts of coastal processes, including in particular, climate change

8 https://www.unep.org/unepmap/who-we-are/barcelona-convention-and-protocols

9 https://www.bluemed-initiative.eu/bluemed-initiative/

10 https://www.cost.eu/actions/CA15217/

11 https://www.cost.eu/actions/CA19107/

12 https://www.unesco.org/en/decades/ocean-decade

13 https://ufmsecretariat.org/

14 https://www.unep.org/unepmap/what-we-do/ecosystem-approach

15 https://www.unep.org/unepmap/who-we-are/contracting-parties/iczm-protocol

16 In 2023, the Member States of the Barcelona Convention are: Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, the European Union (EU), Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, Syria, Tunisia, and Türkiye.

consequences. Since 2008, this protocol has been ratified by twelve Mediterranean countries and the EU.[17]

The MedECC was launched in 2015 with the objective to assess the available scientific knowledge on climate and environmental change and associated risks in the Mediterranean Basin to render it accessible to policymakers, stakeholders and citizens. Interactions between MedECC and decision-makers and stakeholders are developed through a science-policy interface built mainly on close collaboration with UNEP/MAP, its Regional Activity Centre Plan Bleu, and the UfM. The MAR1 (MedECC 2020a) was an important step to further develop science-policy dialogue in the Mediterranean. During the second UfM Ministerial Meeting on Environment and Climate Action held in October 2021 in Cairo (Egypt), the 42 Ministers recognised in their declaration the Summary for Policymakers (SPM) of MAR1 (MedECC 2020b) 'as an important input of the scientific community to inform future climate and environment actions in the region' (UfM 2021, pp. 1-2). During the 22nd meeting of the Contracting Parties to the Barcelona Convention COP 22 (December 2021, Antalya, Türkiye), the SPM was endorsed by the Contracting Parties (UNEP/MAP 2021b) and reflected in the Antalya Ministerial Declaration (UNEP/MAP 2021a).

1.1.3 The Mediterranean coastal region

The land-sea coastal border has been defined above, using objective and subjective criteria for the coastal zone boundaries, although these criteria often present variable levels of uncertainty or fuzziness. Depending on the technical, economic or legal implications (e.g. public domain coastal zone) the extent of the coastal border may vary significantly and the variation of these borders with time (e.g. with sea level rise or with background erosion) is seldom explicitly considered in coastal management.

Both the land boundary and the sea boundary of this coastal zone are normally associated with gradients, illustrated by the urbanisation or geomorphological characteristics of the coastal land zone or by the dominance of nearshore and wave breaking processes for the ocean coastal zone. With the advent of new satellite data, providing spatially structured information, new definitions have started to appear such as the characterisation of the coastal zone sea boundary in terms of geological spatial gradients and variability (Sánchez-Arcilla et al. 2019). These definitions contrast with approaches for the land coastal zone, which define the coastal boundary in terms of elevation or width (e.g. coastal zone as a low elevation swathe).

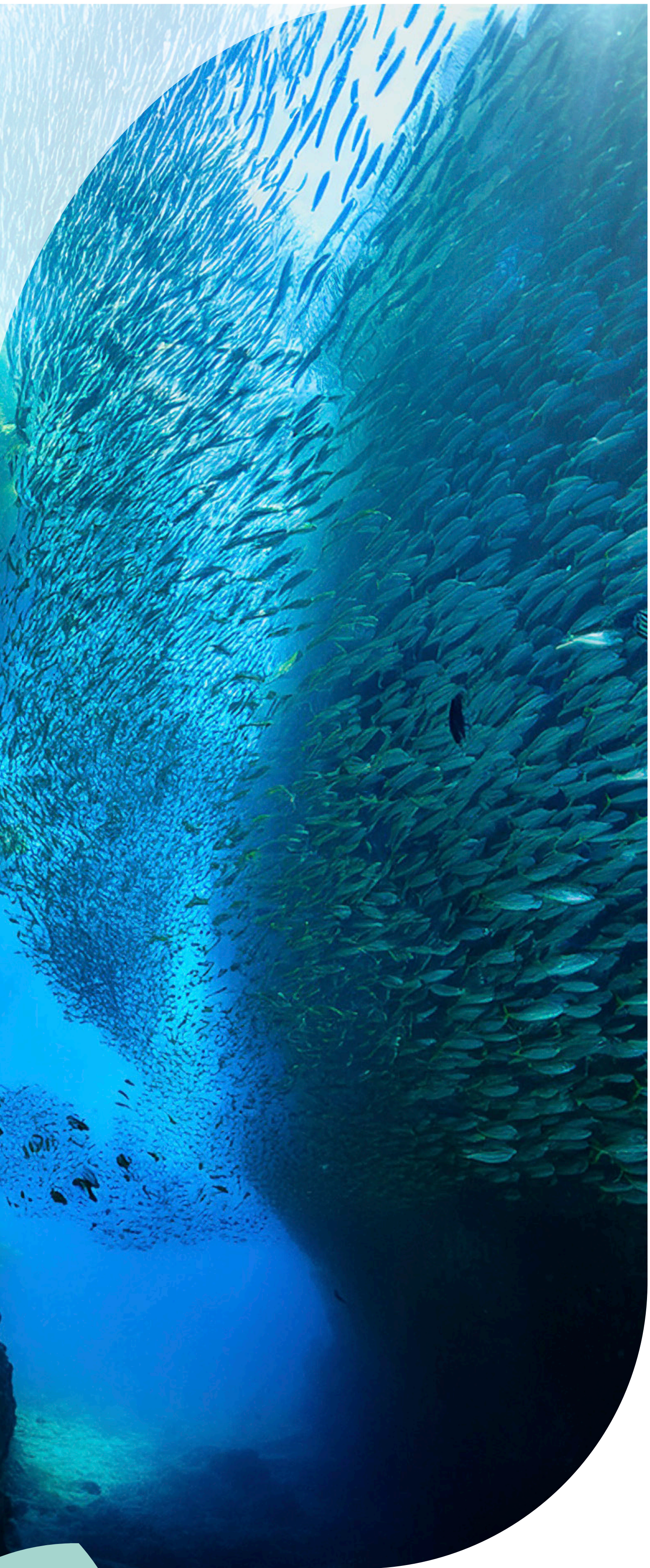
In the Mediterranean, the land boundary can often be defined by mountain chains (land border) and narrow continental shelves (sea border), leading to different coastal zones depending on the application purpose. From a risk assessment standpoint, land and sea coastal zones should be considered as a single system, where the land and water parts interact at different scales. In summary, coastal zones, for risk assessments, should:

- Explicitly define land, sea, and lateral boundaries, considering the applicable European and national legislation;
- Address how these boundaries vary with time, considering the continuous land shifting of the public domain land-sea border due to sea level rise compounded by subsidence;
- Discuss the uncertainty in defining these boundaries, notably due to meteo-oceanographic variability and the difficulties in establishing a rigid delineation for a naturally dynamic boundary.

The following is a high-level summary of the aspects of the Mediterranean coastal system assessed, including cross-references to chapters in the report where the related detailed assessment is presented.

The Mediterranean coastal zone is characterised by high exposure to erosion and flooding due to cities and infrastructure being built close to the shoreline, in horizontal or vertical distance as defined above, within one of the most vulnerable regions to climate change (MedECC 2020a). Such closeness and the

17 See the UN Glossary of terms relating to Treaty actions for more details on signature and ratification. https://treaties.un.org/Pages/Overview.aspx?path=overview/glossary/page1_en.xml



features of Mediterranean weather, associated with micro-tidal ranges, flash floods and short-duration wave storms *(Chapter 2)* also increase coastal pollution and environmental degradation, which make Mediterranean coasts highly vulnerable to climate change impacts *(Chapter 3)* due to the high concentration of populations, maritime traffic, infrastructure (ports, coastal and offshore), cultural values and ecosystems in a narrow coastal fringe.

High population pressure and coastal squeeze result in high risks for populations, the economy and cultural heritage that will increase with sea level rise and increasing temperatures (air and water) due to global warming. This includes negative impacts of population growth, coastal urbanisation, coastal fisheries and agriculture, as well as coastal tourism, which is particularly relevant for Mediterranean coasts *(Chapters 2* and *3).*

Weather patterns are highly variable, with rapid development of precipitation (e.g. flash floods) and wave storms (e.g. medicanes). Another Mediterranean specificity is sharp gradients in chemical water properties, illustrated by offshore oligotrophic conditions and high concentrations of nutrients, plastics, and emerging contaminants near the coast due to socioeconomic activities *(Chapter 2)*, particularly near river mouths, coastal cities, and port domains (Samper et al. 2022).

Rich coastal geodiversity, with sharp gradients in topography (e.g. mountain chains with river valley openings that condition weather patterns) and bathymetry (e.g. narrow continental shelves with submarine canyons) modulate meteo-oceanographic drivers and affect the impact of geohazards *(Chapter 2).*

Important differences in institutional capacity, social perception, and socioeconomic commitment to sustain coastal zones appear among different Mediterranean countries. In spite of this diversity in socioeconomic and institutional conditions *(Chapter 4)*, there is a need for common actions within sustainable adaptation pathways *(Chapter 5).*

Box 1.1

Core concepts

Definitions of key terms, required for coordinated interpretation of coming chapters, as used in the report *(Source: IPCC 2022a)*

• Scenarios
A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g. rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts but are used to provide a view of the implications of developments and actions.

• Risk
The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems.
In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those affecting lives, livelihoods, health and well-being, economic, social, and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species. In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Hazards, exposure, and vulnerability may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may change over time and space due to socio-economic changes and human decision-making. In the context of climate change responses, risks result from the potential of such responses not achieving the intended objective(s), or from potential trade-offs with, or negative side-effects on, other societal objectives, such as the SDGs. Risks can arise, for example, from uncertainty in the implementation, effectiveness or outcomes of climate policy, climate-related investments, technology development or adoption, and system transitions.

• Adaptation
In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.

• Adaptation pathways
A series of adaptation choices involving trade-offs between short-term and long-term goals and values. These are processes of deliberation to identify solutions that are meaningful to people in the context of their daily lives and to avoid potential maladaptation.

• Resilience
The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation.

• Climate resilient development pathways
Trajectories that strengthen sustainable development and efforts to eradicate poverty and reduce inequalities while promoting fair and cross-scalar adaptation to and resilience in a changing climate. They raise the ethics, equity and feasibility aspects of the deep societal transformation needed to drastically reduce emissions to limit global warming (e.g. to well below 2°C) and achieve desirable and liveable futures and well-being for all.

• Governance
The structures, processes, and actions through which private and public actors interact to address societal goals. This includes formal and informal institutions and the associated standards, rules, laws, and procedures for deciding, managing, implementing and monitoring policies and measures at any geographic or political scale, from global to local.

• Social justice
Just or fair relations within society that seek to address the distribution of wealth, access to resources, opportunity, and support according to principles of justice and fairness.

• Climate justice
Links development and human rights to achieve a human-centred approach to addressing climate change, safeguarding the rights of the most vulnerable people and sharing the burdens and benefits of climate change and its impacts equitably and fairly.

• Equity
The principle of being fair and impartial, and a basis for understanding how the impacts and responses to climate change, including costs and benefits, are distributed in and by society in more or less equal ways. Often aligned with ideas of equality, fairness and justice and applied with respect to equity in the responsibility for, and distribution of, climate impacts and policies across society, generations, and gender, and in the sense of who participates and controls the processes of decision-making.

1.2 Climate and environmental change and impacts in the Mediterranean region

This section introduces the Mediterranean coastal zone characteristics that are assessed in the report and the climate change and environmental context of the Mediterranean (latest findings from MAR1, MedECC 2020a) and the sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC 2021; 2022b).

1.2.1 Observed and future climate change

The latest IPCC assessment (AR6) has concluded that human-caused global warming for the period 2010–2019 compared to the period 1850–1900 has reached 1.07°C (0.8°C to 1.3°C *likely*[18] range)[19] and that it is unequivocal that human influence has warmed all parts of the climate system – the land, ocean, and atmosphere (IPCC 2021). As a result, changes in climate conditions that affect society and ecosystems, referred to as climate impact-drivers, are occurring in all regions of the world in multiple and concurrent ways and are projected to increase in the future with every increment of global warming. Climate information can contribute to the assessment of future risks and planning for adaptation at regional scales considering the interplay between human-caused climate change, natural variability of the climate system and information on impacts, vulnerability, and exposure.

The Mediterranean region has experienced increased mean and extreme temperatures compared to the pre-industrial period that cannot be explained in the absence of human influence. Warming is projected to increase at rates that are greater than the global average. By how much will depend on the level of future mitigation of greenhouse gas emissions, as summarised in *Table 1.1*. With every increment of global warming, the Mediterranean is expected to experience increased and concurrent climate impact-drivers, generally hazards (temperature extremes, increase in droughts and aridity, decrease in precipitation, increase in fire weather, mean and extreme sea levels, and decrease in wind speed) that can lead to impacts on society and ecosystems. *Figure 1.1* shows projected changes in climate impact drivers for a level of global warming of 1.5°C and 3°C — mean, and extreme temperatures, total precipitation and maximum 1-day precipitation, and mean sea level rise — alongside information related to population density, agriculture, and built-up areas.

1.2.2 Environmental change

Most climate change impacts are exacerbated by environmental changes, such as land and sea use change (including agricultural intensification, increasing urbanisation and mass tourism, overfishing, land degradation and desertification), pollution (air, land, rivers, and ocean) and non-indigenous species (Cherif et al. 2020).

Sea, inland and air pollution in the Mediterranean is increasing both in quantity and in the number of pollutants. Pollution comes from transport, shipping, unsustainable agricultural, industry and household waste. The Mediterranean Basin is among the regions in the world with the highest concentrations of gaseous air pollutants (nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and ozone (O_3)). Fossil fuel use, industry, ships, and road traffic are the major emitters of SO_2 and nitrogen oxides (NO_x). Emissions of aerosols and particulate matter (PM) into the atmosphere come from anthropogenic activities (transport, industry, biomass burning, etc.), but also from natural sources (volcanic eruptions, sea salt, soil dust suspension, natural forest fires, etc.). Air pollution levels are enhanced by specific atmospheric circulation patterns and by dry and sunny climate (Schembari et al. 2012; Karanasiou et al. 2014; Dayan et al. 2017). Particular meteorological conditions and the proximity of the Sahara Desert influence particulate matter (PM) concentrations, including the occurrence of critically high PM concentrations associated with dust outbreaks, particularly in the southern Mediterranean (Ganor et al. 2010).

18 IPCC likelihood language is introduced in *Section 1.4.2*.

19 IPCC AR6 Synthesis Report (IPCC 2023): for 1850–1900 to 2013–2022 the updated calculations are 1.15 [1.00 to 1.25]°C for global surface temperature, 1.65 [1.36 to 1.90]°C for land temperatures, and 0.93 [0.73 to 1.04]°C for ocean temperatures above 1850–1900 using the exact same datasets (updated by 2 years) and methods as employed in IPCC (2021). Square brackets [x to y] are used to provide the assessed *very likely* range, or 90% interval.

Table 1.1 | Future global surface temperature change for the Mediterranean region. Change in global surface temperature relative to the period 1850–1900. Based on Coupled Model Intercomparison Project Phase 6 (CMIP6) model projections (34 models). Sourced from IPCC AR6 WGI Interactive Atlas (Gutiérrez et al. 2021).

Scenario (GHG emissions)	Near-term, 2021–2040		Medium-term, 2041–2060		Long-term, 2081–2100	
	Median (°C)	*Very likely* range (°C)	Median (°C)	*Very likely* range (°C)	Median (°C)	*Very likely* range (°C)
SSP1-2.6 (low)	1.8	1.4 to 2.2	2.1	1.6 to 2.7	2.2	1.6 to 3.0
SSP2.4.5 (medium)	1.9	1.5 to 2.3	2.4	1.9 to 3.1	3.3	2.4 to 4.3
SSP3-7.0 (high)	1.8	1.4 to 2.4	2.6	2.0 to 3.3	4.5	3.6 to 5.5
SSP5-8.5 (very high)	1.9	1.6 to 2.5	2.9	2.3 to 3.6	5.5	4.2 to 6.8

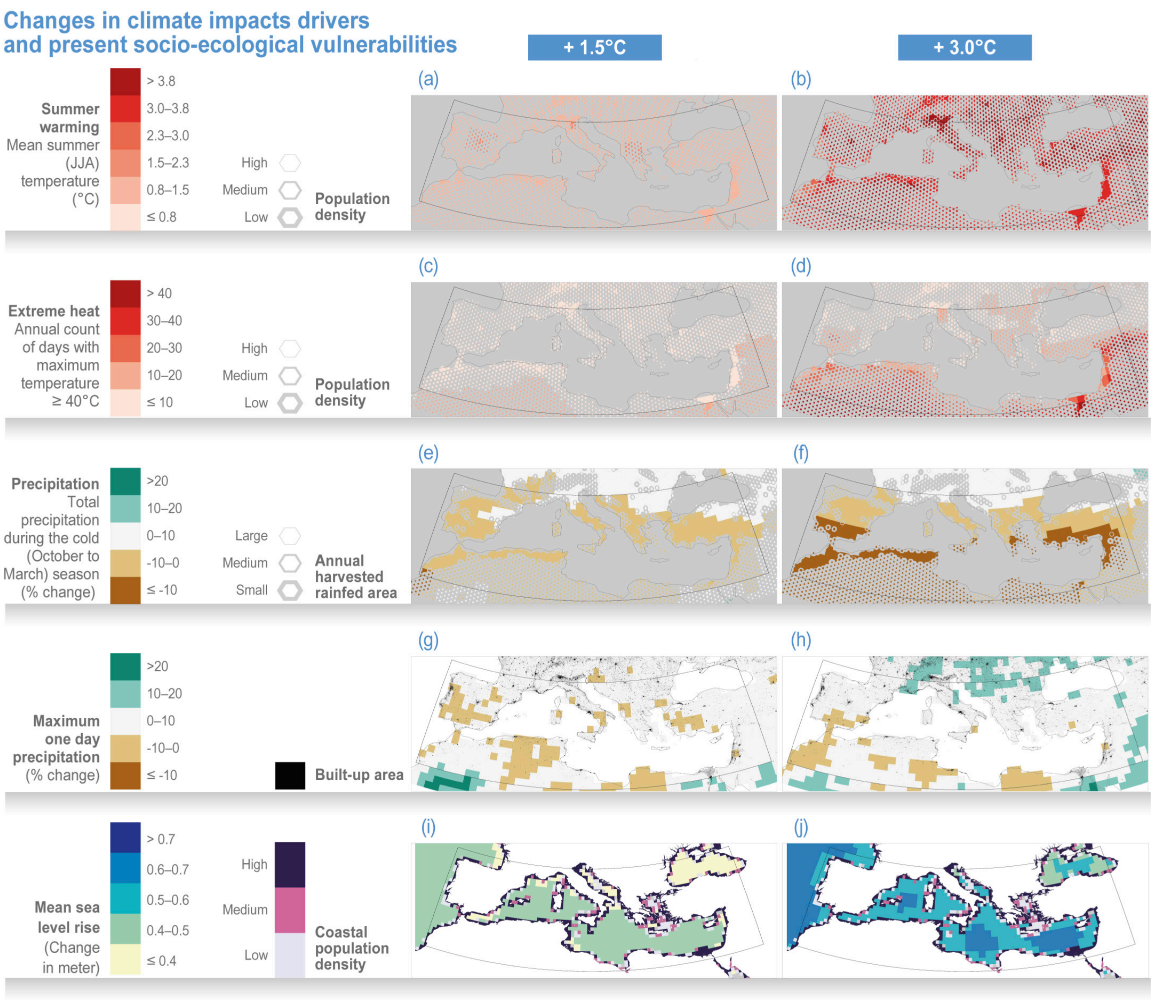


Figure 1.1 | Changes in climate impact drivers in the Mediterranean region. With respect to the 1995–2014 period for 1.5°C (left column) and 3°C (right column) global warming: mean summer (June to August) temperature (°C, a, b), number of days with maximum temperature above 40°C (days, c, d), total precipitation during the cold (October to March) season (%, e, f) and 1-day maximum precipitation (mm, g, h). Values are based on CMIP6 global projections and SSP5-8.5. Sea level rise concerns the long term (2081–2100) and SSP1-2.6 for (i) and SSP3-7.0 for (j). Source: Annex I: Atlas, IPCC (2022a). The figure is reproduced from Figure CCP4.2 in Ali et al. (2022).

Mediterranean coasts are polluted due to coastal squeeze (lack of accommodation space preventing landward transgression in response to e.g. sea level rise), intense industrialisation, uncontrolled discharges of municipal and industrial wastewater, riverine inputs and low seawater circulation. The Mediterranean Sea is heavily polluted by plastics, as 730 tonnes of plastic waste enter it daily. Plastic waste represents 95 to 100% of marine floating waste and 50% of litter on seabeds. There are many uncontrolled coastal landfill sites, particularly on the eastern and southern shores (reviewed in UNEP/MAP and Plan Bleu 2020). The increasing frequency of flash floods in the northern Mediterranean increases the supply of faecal bacteria, viruses and other contaminants to the coastal zone (Chu et al. 2011). In coastal zones, eutrophication caused by nutrient enrichment may provoke harmful and toxic algal blooms. These blooms may have negative economic impacts on fisheries, aquaculture, and tourism, as well as on human health, as 40% of blooming microalgae are able to produce toxins responsible for different human intoxications. Also, emerging contaminants (related recently to discovered chemicals or materials) may be harmful to people, causing disorders of the nervous, hormonal and reproductive system (Cherif et al. 2020).

Mediterranean coastal zones and their ecosystems are also impacted by non-indigenous species. Their number and spread are expected to increase in the future, and they may sometimes lead to a decrease or collapse in populations of native species (Corrales et al. 2018). Most marine non-indigenous species arrive from the Red Sea and Atlantic Ocean, but the highest impact is attributed to those introduced by ships and aquaculture (Katsanevakis et al. 2016). Among known marine non-indigenous species introduced over the last 30 years, invertebrates dominate with >58% (mostly mollusks and decapods), primary producers follow with approximately 23% and vertebrates with 18% (mostly fish) (Zenetos 2019).

Land use change, and particularly urbanisation, is a major driving force of biodiversity loss and biological homogenization causing landscape fragmentation (De Montis et al. 2017). Forest and shrub encroachment tend to increase in the northern Mediterranean, as a consequence of abandoned agro-pastoralism (Lasanta et al. 2017; Abadie et al. 2018), whereas in many regions of North Africa and the Middle East (but also on some Mediterranean islands), the dominant land use change processes are forest degradation and ecosystem fragmentation, caused by intensified agriculture, overgrazing and overexploitation of firewood (Hansen and DeFries 2004).

Marine resource overexploitation and unsustainable fishing practices provoke marine species population decline. Fishing efforts in the Mediterranean have increased over a long period, but particularly since the 1990's due to new technologies and higher capacity vessels (Colloca et al. 2017). In 2010, the cumulative percentage of collapsed and overexploited stocks exceeded 60% across the Mediterranean Sea, with the eastern Mediterranean being the most overexploited sub-basin (Tsikliras et al. 2013; Tsikliras et al. 2015).

Climate and environmental changes have become major threats to both ecosystems and human well-being in the Mediterranean and their impact is aggravated by ongoing socio-economic and demographic trends, including associated urbanisation and environmental losses. Disadvantaged or vulnerable populations, including the elderly, children, pregnant women, and people with low income, are particularly impacted.

1.2.3 Vulnerability, exposure, and impacts

The latest IPCC assessment (Ali et al. 2022; IPCC 2022c) on climate change impacts and vulnerability of Mediterranean countries confirm that all Mediterranean countries are vulnerable to several climate warming impacts. There are, however, local variations in exposure depending on the specific features and knowledge of each country, with southern and eastern countries presenting higher vulnerability. For example, North African countries are highly vulnerable to water stress and water scarcity in response to the growing demand for irrigation requirements for agriculture (e.g. Fader et al. 2016; World Bank 2018). Some countries (e.g. Egypt, Greece, and Spain) are suffering from salinisation of freshwater resources due to an increase in sea level rise and salt (Ali and El-Magd 2016; Wassef and Schüttrumpf 2016; Sebri 2017; UNDP 2018; Vargas and Paneque 2019).

Most socio-economic sectors in the Mediterranean region face increasing risks with agriculture followed by tourism being the most vulnerable (Kallis 2008; Kutiel 2019), together with high vulnerability along the North African coastal regions (UN ESCWA 2017).

Climate change will increase the vulnerability of MENA countries to food production at the local level as well as elsewhere (e.g. China and Russia) due to their high dependence on food imports (Waha et al. 2017). Exporting countries in the Mediterranean region (e.g. France, Italy, Morocco) also affect global food security by decreasing their availability, quality and quantity and increasing product prices. Fisheries in the Mediterranean Sea, which economically account for >3.4 billion USD (Randone et al. 2017), are also at greater risk of increased sea temperature with some locations more sensitive (Turan and Gürlek 2016; Ding et al. 2017; Hidalgo et al. 2018; Farahmand et al. 2023) and others less vulnerable (northern Mediterranean countries), with particular specifics for coastal cities (Keramaris et al. 2022; Schleyer-Lindenmann et al. 2022). Mediterranean forests, which are socially and ecologically important and contribute to several ecosystem services, are also vulnerable, particularly in countries in the northern and southwestern Mediterranean region (Ager et al. 2014; Gomes Da Costa et al. 2020). In addition to growing risks of coastal wildfires, climate change is causing increases in pest populations, such as the sharp increase in the Mediterranean bark beetle *(Orthotomicus erosus)* population size in Croatia (Lieutier and Paine 2016; Pernek et al. 2019).

The Mediterranean region is the leading tourism destination globally (Tovar-Sánchez et al. 2019). Both coastal and marine tourism industries in Mediterranean countries are vulnerable to climate change (Dogru et al. 2016; Dogru et al. 2019; Agulles et al. 2022). The economic value of this important sector, which generates annually from 100 billion USD (from marine activities) to 300 billion USD (from coastal activities), is expected to be significantly impacted (Radhouane 2013; Randone et al. 2017). Impacts on maritime transport and the trade industry in the region, with approximately 600 ports (all sizes and types), will also have consequences on their share in the GDP of about 20–40% of the regional GDP (Manoli 2021). Human health is also significantly vulnerable to climate change (Negev et al. 2015) and populations along the Mediterranean coastal areas are highly susceptible to several climate-related events, such as heat waves (Paz et al. 2016; Scortichini et al. 2018; Rohat et al. 2019) or tropical-like cyclones (Toomey et al. 2022), particularly for sensitive population groups (e.g. poor, ill, elderly, obese, children, and women) (Linares et al. 2015; Paravantis et al. 2017; Ali et al. 2022).

1.3 Coastal risks and adaptation in the Mediterranean Region

1.3.1 The risk framing of the report

Risk is usually estimated as the product of a hazard, times exposure and times the consequences of that hazard, estimated in terms of the impact produced by natural or human factors, using the conceptual framework of IPCC since AR5 (see Reisinger et al. 2020, for the consistent and transparent treatment of the concept of risk of the risk framework in the AR6). As a product of probabilities times damage, both referred to a selected spatial domain and for the time scale of the analysis, it is commonly expressed in a monetary unit (€, $, etc.). However, such an apparently simple concept presents multiple difficulties, some of them due to inconsistent language and others due to inherent uncertainties, particularly under future scenarios. These difficulties, aggravated by the limited size of extreme samples in the Mediterranean, have hindered a wider and harmonised uptake of risk applications for decision– and policy– making in this area. The risk analyses in this report combine data from different sources and publications, with different levels of review and cross-checking and should be applied with due caution for decisions that need to extrapolate the original results to wider domains or different time scales.

One of the main requirements to enable a comparison of risks for different coastal systems, typical of the high geodiversity and high meteo-oceanographic variability found in Mediterranean coasts, is the explicit definition of the spatial domain and time scale for which risks will be assessed, since the results will vary accordingly and will reflect different risk initiation and propagation mechanisms. The selection of temporal and spatial domains, together with the risk dimensions considered, will bound the multi-risk assessments nowadays required in many coastal assessments. The dimensions should consider which are the more relevant drivers (e.g. only sea level, sea level plus waves, etc.), responses (e.g. only erosion, erosion plus flooding, etc.) and interactions (e.g. marine, riverine, and pluvial flooding combined, response with or without rigid infrastructure, response with or without ecosystem services, etc.) for Mediterranean coasts. The selection of risk scales and dimensions should consider the aims of each application and the level of information available, particularly regarding plausible future climate and management scenarios for Mediterranean land and sea areas.

Regarding the spatial domain, coastal risks can be referred to the whole coastal zone for an integrated assessment or to a more constrained sector or component that is well-defined and whose interactions with the rest of the coastal system are well established. The difficulties in defining the land limit of the coastal zone illustrate the need for clear criteria, since it will critically influence any risk estimation. For instance, risk will be very different if the coastal zone limit is the first line of infrastructure, the landward limit of coastal cities, or the whole catchment basin that feeds that coast. This is particularly relevant for narrow emerged and submerged coastal zones so frequent in the Mediterranean (e.g. Rizzo et al. 2022).

Regarding the time domain, coastal risks should be referred to the horizons or intervals for which the risk is estimated, again well-defined according to the aims of each specific project. In common practice, risk estimates for coastal operational conditions should define which mean sea level and wave storm (energetic but not exceptional) associated with the time horizons. Risk estimates for survival conditions of a critical coastal infrastructure or system should define which extreme storms and range of high-end sea level increases must be considered. The same applies to risk assessments under frequent accidents (associated with the high density of population and activities in Mediterranean coastal zones) or under exceptional events (illustrated by medicanes or flash floods in the Mediterranean), which normally result in cascading risks that must also be considered in the analysis, leading to markedly different risk levels. Given the long-term commitment to sustainability and building resilience, uncertainty in the timing of reaching different levels of mean sea level rise is an important consideration for adaptation planning.

The same applies to risk assessments under frequent accidents. In addition to the domain and scales for risk estimation, practical applications and scientific analyses will benefit from an explicit list of the key risk variables, if possible, ranking them for the assessed risks. We suggest listing the main controlling variables characteristic of risk initiation and development for Mediterranean coastal zones, as presented for the various risk assessments in the following chapters. This listing should define key variables in unambiguous terms for specialists and stakeholders alike and distinguish between: (1) biophysical variables (such as sea level rise rate, peak significant wave height and for which return period, maximum storm surge level, safe pollutant concentrations for bathing, acceptable peak water temperatures and nutrient concentrations for aquaculture, etc.), and (2) socio-economic variables (population density and total population, typical average income, infrastructure density and built-up density, distance to an average shoreline, etc.).

1.3.2 Adaptation pathways

The risk reduction measures, and adaptation pathways presented in this report need temporal and spatial planning to enhance synergies (e.g. compatibility between short- and long-term interventions) and avoid undesired trade-offs, unacceptable risk levels (e.g. losing unique habitats or irreversible biodiversity degradation), or maladaptation. Here, adaptation pathways, understood as a sequenced combination of risk reduction interventions, offer an efficient approach, much required for the sustainability of Mediterranean coastal zones, to define possible alternatives (pathways), establish deadlines for these actions (tipping points) and suggest times to consider switching from one pathway to another (changing stations). Delineating such adaptation pathways may favour the inclusion of nature-based solutions in coastal protection plans (Sánchez-Arcilla et al. 2022), contributing to filling the implementation gap for the benefit of Mediterranean coastal areas. Such an approach should facilitate the convergence of stakeholders and scientists into more systemic analyses and interventions for coastal sustainability under climate change.

1.4 A guide to the assessment

1.4.1 Common dimensions of integration

The MedECC assessments, as with other international and national assessment processes, are based on the available, relevant evidence in the published literature. This includes different lines of evidence such as observational products, model-based findings and other information based on different types of data and analyses. To aid the communication of the report findings, in particular for the preparation of figures and to formulate executive summary statements of the assessment, a common set of key dimensions are used across the chapters to the extent possible. These dimensions are defined timeframes, common baselines for past changes and conditions, a subset of representative scenarios of future changes, and the use of well-known frameworks, such as the SDGs.

1.4.1.1 Timeframes

Three common time frames have been adopted by the IPCC Sixth Assessment Report to report key findings in time frames that are relevant for policymakers: near term — the period from 2020–2040 in the context of the timelines for current national emissions reduction pledges as part of the implementation of the Paris Agreement, and the implementation of the SDGs; the medium term — the period by 2041–2060, the mid-century timeframe relevant in the context of infrastructure planning; and the long term — the possible outcomes by 2080–2100 and beyond the end of the 21st century.

1.4.1.2 Baseline period

Changes in climate and in social and natural systems are compared to conditions that existed prior to the advent of rapid industrialisation in terms of fossil-fuel consumption and land-use changes. The period 1850–1900 has been assessed to be suitable as a proxy for pre-industrial conditions, a baseline against which observed historical changes in the climate system can be compared (see Cross-Chapter *Box 1.2* in IPCC 2021).

1.4.1.3 Future scenarios

Possible future scenarios form the basis of modelling and analytical studies to explore how socio-economic conditions, emissions of greenhouse gases, land use, the response of the climate system as well as natural and human systems may change in the 21st century and beyond. The international scientific community has developed different scenario frameworks over time with the aim to produce coordinated simulations across the community where datasets and findings can be compared. The latest generation of scenarios — the Shared Socio-Economic Pathways (SSPs) framework (O'Neill et al. 2017; Riahi et al. 2017) — is used to explore the climate response to human-caused drivers of climate change as part of the Coupled Model Intercomparison Project Phase 6 (CMIP6) of the World Climate Research Programme (WCRP).

The experimental design is built around a matrix of simulations that consider different socioeconomic developments and different levels of radiative forcing in the year 2100 levels (see Cross-Chapter *Box 1.4* in Chen et al. 2021). The assessment of future climate change, impacts, vulnerability, and adaptation actions can be compared for scenarios with high emissions (SSP3-7.0), based on futures with 'no-additional-climate-policy' (in the set of Representative Concentration Pathways (RCPs), the equivalent no additional-climate-policy' scenario was RCP8.5). The new SSP3-7.0 'no-additional-climate-policy' scenario, with inter-mediate greenhouse gas emissions (SSP2-4.5), and scenarios with very low and low greenhouse gas emissions (SSP1-1.9 and SSP1-2.6). Scenarios with very high greenhouse gas emissions (SSP5-8.5) have been assessed as being less *likely* in terms of future outcomes, so are not considered to be 'business-as-usual' scenarios any longer, based on today's climate policies (IPCC 2022c), though these scenarios cannot be ruled out altogether and are useful to explore low-likelihood, high-risk outcomes.

1.4.1.4 Sustainable Development Goals

The UN 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs) was established to focus international efforts on the multiple intersectionality between different development objectives, including for climate change, for the pursuit of the seventeen SDGs by 2030 (UN DESA 2015; UN General Assembly 2015). The Mediterranean Strategy for Sustainable Development (MSSD) 2016-2025 (UNEP/MAP 2016) provides an integrative policy framework for all stakeholders, including MAP partners, to translate the 2030 Agenda for Sustainable Development and the SDGs at the regional, sub-regional, national and local levels in the Mediterranean region. The SDGs are used in this report to relate the assessment to different development goals.

1.4.2 Communicating assessment findings consistently.

Within the intergovernmental context of the IPCC and MedECC, the assessment of the latest available climate science, environmental and socio-economic knowledge is solicited by policymakers through a science-policy interface to support the development of evidence-based policy development and communications activities in different sectors and contexts. The use of agreed terms that are calibrated to quantify the strength and quality of the available information distinguishes an assessment from a review of the available scientific and technical literature.

The framework of calibrated terms that communicate the robustness and certainty of assessment findings either qualitatively or quantitatively have been used across the IPCC since the 5th Assessment Report (AR5). This terminology was agreed on as an outcome of a Cross-Working Group Meeting on Consistent Treatment of Uncertainties convened in July 2010 for the consistent treatment of uncertainties in the assessment across all IPCC assessment reports (Mastrandrea and Mach 2011; Mastrandrea et al. 2011). It builds on previous applications in earlier reports (Moss and Schneider 2000; IPCC 2005). Mach et al. (2017) reported on the lessons learned from the AR5 and provided further guidance on the systematic use of the calibrated terms, considering challenges in communicating findings where there are considerable uncertainties or considering subjectivity in expert judgement. The transparent use of calibrated terms to build a shared understanding of the assessment outcomes is all the more important when evidence-based policymaking is set in the context of multiple influences including different value systems (see discussion in Chen et al. 2021).

The terms are calibrated to have the same meaning for a consistent presentation of the assessment across different chapters of a report, or topics assessed in a report or across different reports, in order to a consistent and comparable picture on the state of knowledge to policymakers. The terms are italicised in the text to clearly identify when they are used and that the meaning is intended to be distinct from an everyday use of these words. This is a powerful communication tool that is able to clearly transmit the key assessment findings to policymakers or other users more broadly, overcoming the complexity of the underlying literature, which may be based on different disciplines or methodologies, and in an assessment carried out by a diverse set of experts that will also come from different disciplines, contexts and countries.

The calibrated terms quantify:

• **Confidence:** a qualitative measure of the robustness of a finding, based on the type, amount, quality and consistency of evidence and the degree of agreement across different lines of evidence or studies. Levels of confidence can be *very low, low, medium, high* and *very high.*

• **Likelihood:** a quantitative measure of uncertainty in a finding, expressed probabilistically, for example the *likely* outcome of a process[20]. This can be quantified based on statistical analyses, expert judgement by the author team or a formal quantitative survey of expert views (expert elicitation).

Figure 1.2 (Box 1.1 Figure 1 in Chen et al. 2021 adapted from Mach et al. 2017) illustrates the step-by-step process authors use to evaluate and communicate the state of knowledge in their assessment (Mastrandrea et al. 2010). The authors start by considering the relevant evidence in the published literature. They evaluate the different types of evidence, and the agreement in the findings therein

20 The following terms have been used to indicate the assessed likelihood of an outcome or result: virtually certain 99–100% probability; very likely 90–100%; likely 66–100%; about as likely as not 33–66%; unlikely 0–33%; very unlikely 0–10%; and exceptionally unlikely 0–1%. Additional terms (extremely likely 95–100%; more likely than not >50–100%; and extremely unlikely 0–5%) are also used when appropriate. Assessed likelihood is typeset in italics, for example, *very likely.*

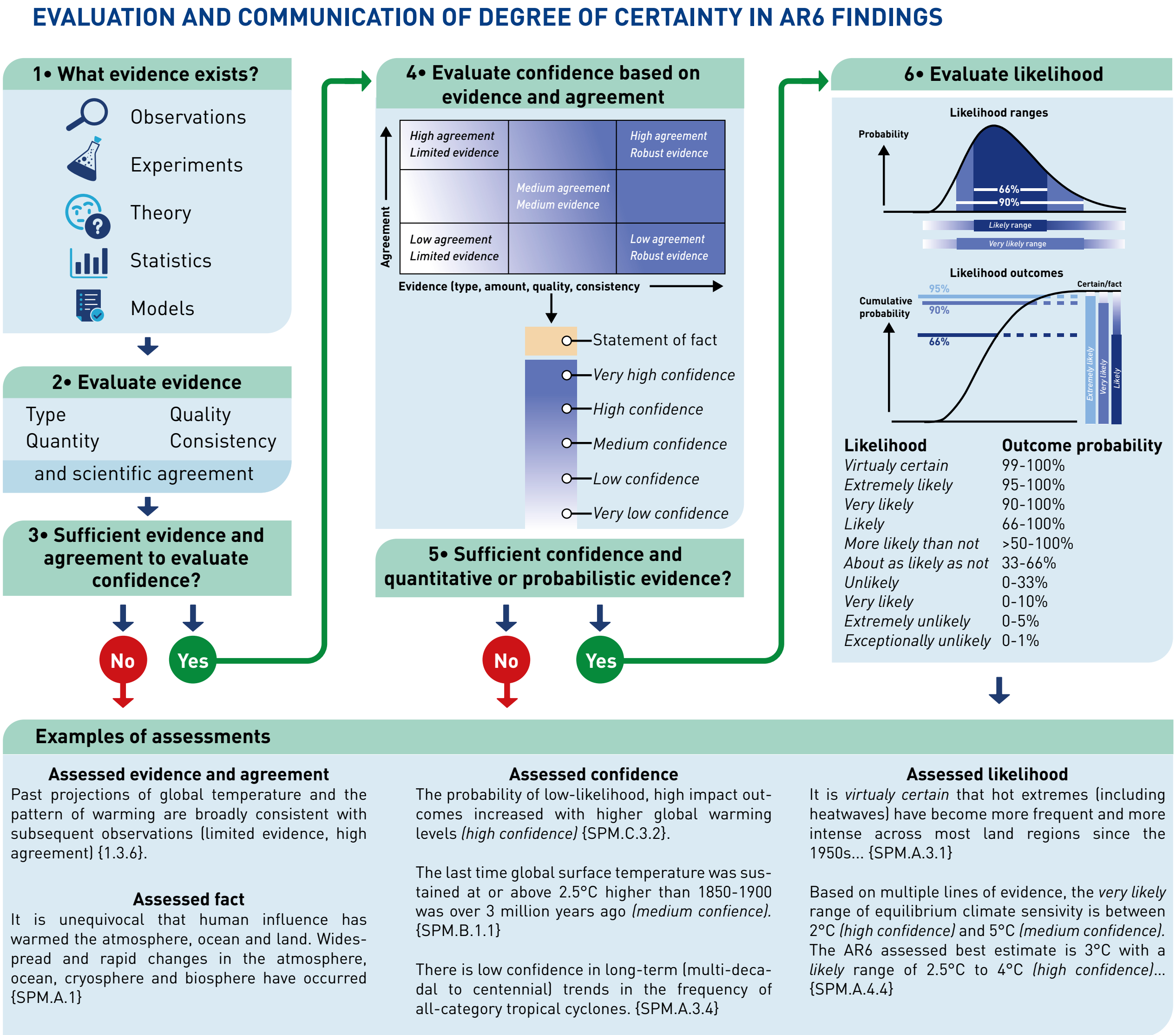


Figure 1.2 | Characterising understanding and uncertainty in assessment findings. Adapted from Box 1.1, Figure 1 in IPCC (2021).

(Steps 1 and 2). From this, authors decide whether they can assign a level of confidence (Steps 3 and 4), likelihood (Step 5) of the assessed information to communicate their expert judgement of the robustness of the findings. Example statements of assessment conclusions drawn from the report are presented in the box at the bottom of *Figure 1.2.*

Each chapter subsection on a topic presents a traceable account of the assessment, starting with an introduction of the topic, what previous assessments had concluded, then discusses the relevant body of literature, including what methods have been used, the understanding of processes and mechanisms and the relevance of these findings, then concluding in an assessment statement that summarises the state of knowledge on this topic. The terms are attributed to the assessment outcome by the author team following an evaluation of the available evidence. They are agreed on through a consensus-building discussion of the evidence, reflecting all expert views that are expressed.

1.4.3 Values and the interplay with nature and society

Risk of sea level rise along the coastline impacts physical locations and social activities. To inform adaptation policy, it is necessary to understand how risks are distributed within and among communities.

Responding to this need, a value-based approach guides the understanding between nature and society, placing social and cultural values in the geographic space. The approach explores what people value most about their everyday lives, and how these social values are *likely* to be affected by environmental changes and the policies developed to respond to such changes (Persson et al. 2015).

In the context of parts of the Mediterranean coastlines that are densely populated and built up, it is essential to follow a value-based approach to examine the interplay between nature and the potential social impacts of sea level rise. Some essential social values highly important to residents include scenery, livelihoods, and safety. However, local communities have unique social values. Recent studies are facilitating the interplay of social values and natural risks. There is great potential to further integrate natural and social approaches to better inform adaptation policy about how lived and landscape values are distributed among communities (Ramm et al. 2017).

1.4.4 Ethical considerations

Some adaptation plans for Mediterranean coasts have been designed by local and regional administrations typically focusing on the need to protect local communities, and to minimise short-term impacts on the natural environment, such as ensuring local ecosystem resilience. A notable absence from many plans, in the Mediterranean and elsewhere, is the ethical approach needed to present the inherent uncertainties in any assessment, particularly for climates like the Mediterranean, where extreme samples are more limited in size than for other coastal areas. Such an ethical dimension is particularly relevant for Mediterranean assessments, which affect coastal areas with a high level of vulnerabilities due to conflicting uses and limitations of natural resources. This ethical approach should lead to better informed and more widely accepted adaptation policies.

However, there are knowledge gaps on the risks and vulnerabilities of many non-material social and environmental values. While values-based approaches are receiving increased attention by scholars, it is unclear to what extent they are being adopted by decision-makers (Ramm et al. 2017) and this applies to all coastal zones. However, the urgency for filling that gap is more acute in the Mediterranean due to the combination of climate and human pressures.

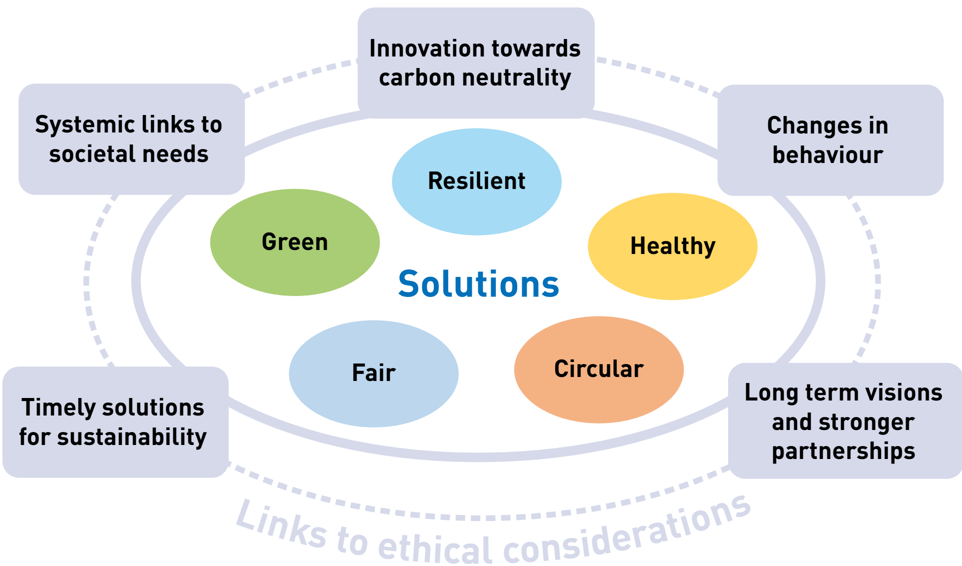


Figure 1.3 | A framework for coastal risk management that includes the systemic evaluation of the solutions and the ethical considerations of the assessment process. In the inner circle the attributes of the solutions: resilient, healthy, circular, fair, and green. In the outer circle, the ethical considerations: systemic links to societal needs, innovation towards carbon neutrality, changes in behaviour, long term visions and stronger partnerships and timely solutions towards sustainability.

Graham et al. (2014) proposed that values-based approaches could direct policymakers towards ethical considerations in the adaptation process, giving voice to the impacted communities and their social and cultural landscape values. Because of these reasons, the ethical approach should be inclusive and collaborative, enabling decisions that consider diverse values and priorities (Ramm et al. 2017).

The ethical considerations within coastal assessments under climate change and management scenarios can only be addressed in a systemic approach that includes fairness, resiliency, health, circularity, and carbon neutrality. These values establish clear connections to systemic links for the main elements to be considered in an ethically-based assessment: societal needs, innovation, behavioural change, and long-term visions of society, including the active participation of women and marginalised and/or vulnerable groups. Clearly, the process is complex, as summarised schematically in *Figure 1.3,* and demands additional multidisciplinary data to better characterise Mediterranean coastal zones under the impact of future climate scenarios.

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