1 INTRODUCTION

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1.1 The Mediterranean Basin: a region affected by accelerating climate and environmental change

1.1.1 What do we know about the Mediterranean Basin and what do we need to know?

The Mediterranean Basin is considered one of the cradles of civilization (Abulafia 2011; Sağlamer 2020). Its rich cultural and scientific heritage dates back to the Egyptian and Mesopotamian empires, followed by the remarkable accomplishments of Greek thinkers and philosophers and the no less ingenious scientists, engineers and architects of the Roman Empire. Throughout the history of the last several millennia, people, communities and societies have learned to adapt to and master environmental conditions that have often been adverse, and which frequently caused severe damage to human lives and environmental integrity. But it has not only been their ability to adapt to changes in natural conditions that has protected Mediterranean societies from severe impacts. As time has gone on, there has been a steadily growing body of knowledge and understanding of the underlying causes and the usual course of such changes, based on careful and long-term observations and analysis. It is no surprise then that we now know a lot about the changes and variations in environmental conditions that we observe today. But neither the level of observation nor the level of knowledge is the same, whether for the entire region, or for all environmental issues, or for their integration with the socio-economic system. Added to this lack of homogeneity is the complexity of the region, both in terms of climate and environment, and culture and socio-economics (Zamora Acosta and Maya Álvarez 1998; Woodward 2009; IEMed 2015).

During the second half of the 20th century and up to the present day, numerous scientific projects have studied the changing environment of the Mediterranean Basin and its adjacent regions (for a compilation of such research activities, see *Appendix A.4.1*). The capacity for systematic observation of the environment has increased substantially, followed by the development of conceptual and numerical models of the changing atmosphere and ocean, as well as of other environmental changes and their impacts. Through the work done by large numbers of scientists, we have gained not only a more complete understanding of past changes but have also learned to generate projections of future climate and environmental change with increasing confidence in the reliability of the results. Projections of such changes into the future are key for the mitigation of risks to human livelihoods (Bolle 2003; Lionello 2012; Navarra and Tubiana 2013; Luterbacher et al. 2016).

As a first assessment, based on various sources of information, Cramer et al. (2018) have shown that the Mediterranean Basin is at risk of suffering from levels and rates of climate and environmental changes now and in the foreseeable future that exceed global mean values. This applies to changes in temperatures, precipitation and the frequency and magnitude of extreme weather events, but it also implies changes in land and sea use, pollution, air quality and other factors. Average annual mean temperatures in the Mediterranean Basin have risen by 1.5°C since pre-industrial times (1861-1890), approx. 0.4°C above the global average *(Chapter 2)*, due to a combination of local drivers (e.g., land use changes) and changes on a global scale that affect the Mediterranean Basin through various modes of tele-connectivity (Lionello et al. 2014).

Although droughts have been a common experience for most of the history of the Mediterranean, the recently observed decline of seasonal precipitation for parts of the Basin *(Chapter 2)* presents new and significant challenges for Mediterranean communities. While most climate models show remarkable agreement in the expected decrease in Mediterranean rainfall, there are also some results indicating significant differences in magnitude and sign for these changes. Even if future global warming is limited to 2°C, as prescribed by the UNFCCC Paris Agreement, summer rainfall risks being reduced by 10-30% in some regions. Such a decrease will enhance existing water shortages and increase irrigation demand for agricultural productivity, particularly in countries on the southern rim of the Basin (Vautard et al. 2014). Climate change, population growth, increasing domestic needs and pressure from tourism, new industries and urban sprawl may see irrigation demand rise by 26-92% by the end of the 21st century (Fader et al. 2016). Although frequently addressed by policymakers, irrigation and food security remain a sensitive issue that needs additional research (Grafton et al. 2018; WWAP 2019). Research into the extent to which local landraces can cope with projected climate changes without significant loss of productivity should be a priority (FAO 2015). More aridity exacerbates ongoing desertification, with strong socio-economic impacts on farmers (UNEP/MAP 2016). The interlinkages between resources have been addressed through the concept of the Water-Energy-Food Nexus (e.g., Hoff 2011; Kennou et al. 2019), but they still present unresolved challenges. Since the impacts of climate change are likely to include the degradation of agricultural water resources and loss of fertile soils, enhanced efforts to adapt agricultural and other land systems to climate change are necessary to ensure food security and rural livelihoods (UNEP/MAP 2016). Despite this reduction, extreme precipitation events are expected to intensify in a large part of the region. Therefore, flood socio-economic and environmental impacts should be added to those produced by water scarcity (Tramblay and Somot 2018).

Primarily caused by global processes, including thermal expansion of sea water and accelerated melting of ice sheets in Greenland and Antarctica, sea level is projected to increase more strongly than previously estimated (DeConto and Pollard 2016; IPCC 2019). This will have repercussions for the Mediterranean Sea, as well. For the recent past, in which sea level has been monitored by satellite altimetry (1993-2018), Mediterranean sea level has increased up to 2.8 ±0.1 mm yr^{-1}, which is consistent with global sea level trend (3.1 ±0.4 mm yr^{-1}) (Cazenave and WCRP Global Sea Level Budget Group 2018). At a sub-regional level, by the end of the 21st century (2080-2099) the projected rise in the average sea level of the Mediterranean Basin with respect to the present climate (1980-1999), is estimated to be 37 cm, 45 cm, 62 cm and 90 cm under RCP2.6, RCP4.5, RCP8.5 and high-end greenhouse gas emission scenarios, respectively (Somot et al. 2016; Jordà et al. 2020).

Coastal regions around the Mediterranean Basin are densely populated. Due to the near absence of tides in much of the Mediterranean, many cities and coastal infrastructures are built close to current mean sea levels. They are therefore particularly vulnerable to future sea level rise. Paired with an increasing frequency of storm surges, these cities and infrastructures face enhanced risks of flooding. Sea level rise will lead to loss of arable lowlands, notably in intensively used river deltas such as those of the Nile, the Po and elsewhere, with adverse consequences for agricultural activities and food security. A related problem is the intrusion of seawater into coastal aquifers (seawater intrusion), which renders these aquifers unsuitable for human consumption and for most agricultural purposes (Hegazi et al. 2005). Enhanced uptake of atmospheric CO_2 has led to a significant increase in seawater acidity of the Mediterranean, which is set to continue (Tsimplis et al. 2013; Palmiéri et al. 2015). Acidification has serious consequences for organisms that produce carbonate shells and skeletons and for marine ecosystems throughout the Mediterranean Basin (Gattuso et al. 2015; Palmiéri et al. 2015).

Beyond climate change, the Mediterranean Basin also experiences environmental challenges due to changing land and sea use, agricultural intensification and urban sprawl, increasing pollution and declining biodiversity. Due to drought, land use change, and high temperatures, the area affected by forest fires could increase by approx. 40% up to ~100% relative to recent levels, generally proportional to warming (Turco et al. 2018). Likewise, warming in combination with overfishing risk causing the local extinction of more than 20% of exploited fish and marine invertebrates by 2050 (Jones and Cheung 2015).

These examples show that climate change, in combination with other challenges, will likely not only affect ecosystems on land and in the ocean, but also create risks for the services they provide and therefore ultimately the ecological basis for the well-being of people in the Mediterranean Basin. Combined with current changes in lifestyle, e.g., the switch to a more urbanized life-style and a more processed animal-based diet, in particular southern Mediterranean countries in particular are at risk of increasing their dependence on food imports and trade from elsewhere (CIHEAM 2014; UNEP/MAP 2016). Landraces are likely to be lost as farmers replace them with other landraces, or improved varieties, that are better adapted to the new conditions (FAO 2015). Some scholars argue that this trend could be mitigated by boosting a return to the traditional Mediterranean diet, with significant health benefits for all Mediterranean people including their visitors (Serra-Majem et al. 2011).

Climate and environmental changes and their impacts imply risks for human security in the Mediterranean region (Karmaoui 2016; Rigaud et al. 2018). These changes are added to escalating conflict and insecurity in some African and Eastern countries that are leading thousands of people to flee, taking their chances on unseaworthy boats across the Mediterranean. Public health is already affected by multiple facets of climate and environmental change, including enhanced and more frequent (urban) heat waves, increasing air pollution (higher risk of cardiovascular or respiratory diseases), and increased spread of disease vectors (West Nile virus, dengue, chikungunya) (Kuglitsch et al. 2010; Negev et al. 2015; Orru et al. 2017). Environmental change is also increasingly recognized as a relevant factor for socio-economic risks (e.g., famines) in situations of instability and conflict. Synergistic effects between societal, economic and environmental factors should also be considered, as well as the relevance of globally connected socio-economic structures (Le Roy Ladurie 2004, 2006). For instance, droughts, floods or other extreme events in agricultural regions elsewhere may lead to market disturbances and may affect prices, trade, production and security in the Mediterranean too.

1.1.2 An integrated Mediterranean risk assessment for sustainability

Considering this incomplete compilation of examples for current understanding of global and environmental changes in the Mediterranean Basin, one might get the impression that much is known already. However, impressive as it may seem, most environmental research conducted so far in the region is primarily driven by disciplinary and sectoral investigations. A more comprehensive, systemic and holistic approach to interrelated processes and components would likely make useful contributions to environmental decision-making in the Mediterranean Basin. So far, an adequate and comprehensive assessment of risks posed by climate and environmental changes in the Mediterranean Basin is lacking (Cramer et al. 2018).

The absence of integrated studies comes in addition to the painful lack of monitoring and risk analysis capacity in southern and eastern countries of the Mediterranean Basin. There are few, but strong indications that these countries potentially face larger risks from climate and environmental changes, compared to northern countries, while commanding significantly scarcer financial resources to effectively adapt to their impacts (IPCC 2014).

This report cannot replace a full and integrated research-based risk assessment in the terms outlined above. It rather aims at providing an assessment of current knowledge such as it emerges out of the existing body of research. While the assessment is designed and carried out as a regional study, its results may also provide useful conclusions on a global scale. Global environmental change inevitably has distinct regional manifestations. Similarly, processes and changes on the regional level will have consequences for global processes. The MedECC network sees this regional assessment as a possible "bridge" between the global and the national to local scale, essential for the advancement of mitigation and adaptation strategies. Such a bridge appears to have particular potential in the Mediterranean context, since this region is at a crossroads between Africa, Europe and (Western) Asia. The importance of the regional dimension has been emphasized in the context of the implementation of the 2030 Agenda and the Sustainable Development Goals (SDGs). The 2030 Agenda recognizes regional dimension and regional governance as playing a crucial role in translating sustainable development policies into concrete actions at the national level (UN 2015; UN-SDSN 2018).

Mitigation of the processes underlying climate and environmental change and adaptation to their unavoidable impacts represent a priority for public and private decision makers concerned with the future of communities and environmental integrity in the Mediterranean Basin. Effective mitigation and adaptation require investigations that go beyond current knowledge. Looking at the current state of the Mediterranean, we note the following challenges and needs:

- A substantial gap between knowledge and understanding of climate and environmental change between the northern-rim countries and most of the southern- and eastern-rim countries of the Mediterranean Basin.
- A disparity of observational data and monitoring systems between the North versus the South and the East, which calls for an intensification of observations and the creation of observational networks, notably in the MENA region.
- Research on short- and mid-term weather and climate predictions, including seasonal forecast ing to better manage water resources and agriculture, is being carried out in some Mediterranean countries. The results of such studies have the potential to be applied more broadly.
- Despite some initiatives (e.g., the Mediterranean Climate Outlook Forum - MedCOF), the level of climate services offered by the scientific communities in most Mediterranean countries remains insufficient. Such services can be decisive in providing vital information on short-term to intermediate climate trends to planners and decision makers involved in agricultural and water policies.
- The implementation of more advanced early warning systems may enable better preparation for extreme events and other climate-related risks that usually affect the Mediterranean region. Such systems need to be based on

and accompanied by an adequate societal and individual risk awareness (see the recommendations of UNISDR 2015).

- Large-scale programs are needed (or should be strengthened) in eastern and southern Mediterranean countries to address pressing multi-factorial challenges such as land degradation and desertification, ultimately focusing on increased resilience to change as well as the reinforcement of ecological transitions to more sustainable resource use.
- In order to address these issues, a comprehensive scientific synthesis and assessment report is required. This report should include recent trends, likely future developments, and consequences of climate and environmental changes on natural systems, the economy, and human well-being in the Mediterranean Basin.

The overarching goal of this report is to provide such a synthesis, based on existing knowledge in the scientific literature. The work has been carried out by the Mediterranean Experts on Climate and environmental Change (MedECC) aiming for a comprehensive synthesis of current scientific knowledge that covers all relevant disciplines, sectors and sub-regions. The assessment considers three major interconnected domains, namely resources (water, food & energy), ecosystems (marine, coastal and land), and society (development, health and security). Although the target audience of this assessment is decision makers and policymakers, anyone interested in the Mediterranean can benefit from it. After completion of this first assessment, there is a desire to develop a platform for constructive science-society-policy dialogue.

1.2 The Mediterranean Experts on Climate and environmental Change (MedECC)

1.2.1 Goals, basic structure and first accomplishments of MedECC

MedECC's main, overarching goal is to provide a state-of-the-art risk assessment on climate and environmental changes and their impacts across the Mediterranean, based on existing scientific knowledge, with the following specific objectives:

- To activate and engage the scientific community working on environmental and climate changes in the Mediterranean Basin;
- To provide comprehensive updated and consolidated scientific knowledge on these changes and make it accessible to policymakers, key stakeholders and the general publi in a process which facilitates ownership of scientific knowledge;
- To identify possible gaps in the current understanding of environmental and climate changes and their impacts in the Mediterranean;
- To help build capacity of scientists from southern and eastern Mediterranean countries to international levels and standards by encouraging training, research and development efforts in these countries in the context of the Paris Agreement;
- To bridge the gap between research and decision-making, contributing to the improvement of policies at all levels;
- To contribute to future reports of the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) or similar assessments in the Mediterranean Basin. MedECC has an important role to play in the work of the IPCC, as it is contributing to the Sixth Assessment Report (AR6) with a cross-chapter paper dedicated for the first time to the Mediterranean.

MedECC's work therefore focuses on two complementary directions:

- Publishing a scientifically robust assessment and synthesis of environmental and climate changes and their impacts in the Mediterranean Basin, based on currently available research;
- Building a science-policy interface on these changes and their impacts in the Mediterranean and thereby providing a scientifically sound basis for decision-making.

1.2.2 Principles and processes of work in MedECC

Since the founding of MedECC, two scientists at the French National Centre for Scientific Research (CNRS) coordinate the development and work of the network. Central to the governance of MedECC is its Steering Committee (SC, *Fig. 1.1*) which

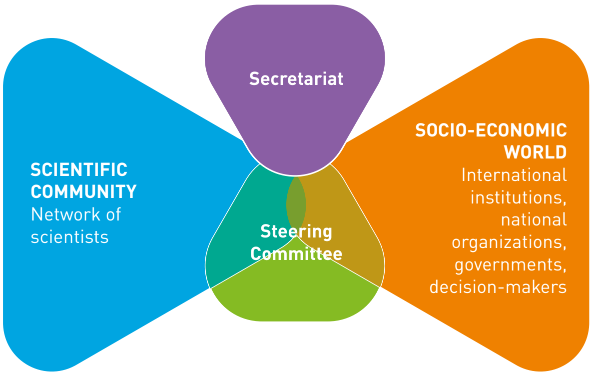

Figure 1.1 | Structure and functioning of MedECC.

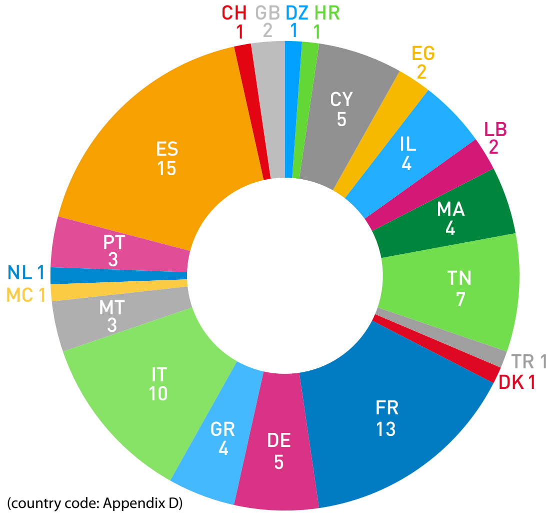

Figure 1.2 | Distribution of MAR1 Coordinating Lead Authors and Lead Authors by country.

met for the first time in April 2016 in Barcelona, Spain. The SC is currently composed of 20 members from 11 countries *(Appendix A.4.1)*, including 16 scientists in a personal capacity (representing environmental sciences, political sciences and economics) and 4 representatives of policymaking bodies: the United Nations Environment Programme/Mediterranean Action Plan – Barcelona Convention Secretariat (UNEP/MAP) and its Plan Bleu Regional Activity Centre, the Secretariat of the Union for the Mediterranean (UfM), and the Advisory Council for the Sustainable Development of the Government of Catalonia (CADS). More details on the work and accomplishments of the SC can be found in *Appendix A.4.1.2.*

MedECC work is carried out by an open and inclusive network of scientific experts to support decision-making through accurate and accessible information on current and future environmental and climate changes and their impacts in the Mediterranean Basin. The network currently comprises more than 600 scientists from 35 countries who contribute in a personal capacity on a voluntary basis. Members of the network do not primarily represent an institution or country.

The added value of the work of MedECC lies in the large geographical and thematic scope addressed (see below) and the comprehensive involvement of more than 86 Coordinating Lead Authors (CLAs) and Lead Authors (LAs) from 21 countries participating in the drafting of the report *(Fig. 1.2)*. 27 (31%) are based in southern and eastern Mediterranean countries and 31 (36%) are women. In total, 190 authors from 25 countries contributed to the report (CLAs, LAs and Contributing Authors - CAs). Appendix A.4 provides more information about the steps of MAR1 as well as the duties of the different players involved in report preparation. By providing information on the assessment/synthesis process underlying MAR1, we aim to address both institutional stakeholders/organizations as well as individuals interested in the organization of MedECC and its work.

1.3 The First Mediterranean Assessment Report (MAR1): A synthesis of knowledge on risks from climate and environmental change in the Mediterranean Basin

1.3.1 Report scope and objectives

1.3.1.1 Geographic scope

Located at the crossroads of three continents, the Mediterranean region is unique in its historical and geographical specificities, as well as its natural and cultural heritage. While the Mediterranean Sea is a well-defined water body, limited by the Strait of Gibraltar, the Dardanelles Strait and the Suez Canal *(Fig. 1.3)*, various definitions are used for the land boundaries of the Mediterranean region.
In political terms, the United Nations Environment Program Mediterranean Action Plan (UNEP/MAP[1])

[1] https://www.unep.org/unepmap/

Figure 1.3 | Geography, physiography and landscapes of the Mediterranean Basin
(Source: GRID-Arendal)[2]

covers 21 riparian countries, which are Contracting Parties (CPs) to the Barcelona Convention (excluding Jordan and Portugal, which are not riparian countries sensu stricto, and Gibraltar/UK and Palestine, which are not currently CPs but have observer status). The population of this so-defined Mediterranean region is about 480 million inhabitants (EEA 2020). From a geopolitical point of view, the Union for the Mediterranean (UfM[3]), created in 2008, embodies a much wider spatial scope of 43 countries (all the countries of the European Union and 15 countries in the southern and eastern Mediterranean).

For much of the physical assessment by MedECC, we adopt a simple regular latitude-longitude box (29°N to 47.5°N and 10°W to 39°E, *Fig. 2.1*), which includes some regions with non-Mediterranean climates, such as the Alps, the Eastern Balkans or part of the Sahara. This definition of the Mediterranean region is similar to the MED zone adopted in IPCC-AR4 (IPCC 2007), and slightly larger than in IPCC-AR5 (IPCC 2013) and the ongoing AR6 assessment.

The Mediterranean Sea is a relatively small, semi-enclosed sea with limited exchange to the global ocean through the Strait of Gibraltar, located at the western end of the Mediterranean, the linkup between the Mediterranean and the Black Sea through the Bosphorus and Dardanelles and the connection to the Red Sea through the Suez Canal in the South-East *(Fig. 1.3)*. The Mediterranean Sea can be divided into two sub-basins: the Western and the Eastern Mediterranean, which are in turn made up of a series of various small basins (Amblàs et al. 2004). The Mediterranean region includes 75 coastal watersheds and 224 coastal administrative regions, with a total of 46,000 km of coastline (UNEP/MAP 2016).

The topographic, geographic and socio-economic structures of Mediterranean landscapes are heterogeneous. Their current shapes are the result of centuries of interactions between natural forcings and diverse human activities, both past and present.

The coastal area comprises a large set of ecosystems that deliver valuable services to people, including lagoons, estuaries, deltas, coastal plains, wetlands, rocky shores and nearshore coastal areas, seagrass meadows, coral communities, frontal systems and upwellings, seamounts, and pelagic

[2] https://www.grida.no/resources/5931

[3] https://ufmsecretariat.org/

systems. Most of these systems are very sensitive to human and climate forcing. Wetlands represent 1.7-2.4% of the total area of Mediterranean countries (Tour du Valat 2012). The most extensive coastal wetlands are found in estuaries like that of the Po (Italy), Nile (Egypt), Rhône (France) and Ebro (Spain) rivers.

Other elements of Mediterranean heritage are the nearly 15,000 islands and islets dotted throughout the basin, some of which are particularly vulnerable. The largest islands are Sicily, Sardinia, Corsica, Cyprus, and Crete, and the major island groups include the Balearics off the coast of Spain and the Ionian, Cyclades, and Dodecanese islands of Greece. In total, the islands' coastlines comprise around 19,000 km, or more than 41% of the Mediterranean coastline (Emmanouilidou 2015). In terms of land surface, islands represent only 4% of the land area of the whole Mediterranean Sea Basin (Kolodny 1974). The small islands (less than 10 km^2), are particularly valuable in terms of biodiversity. Since many of them are uninhabited or weakly impacted by human activities, they constitute valuable "life laboratories" for assessing the sole impacts of climate change. Since 2005, the Mediterranean Small Islands Initiative (PIM[4]) has been working to improve knowledge and management of these territories, as well as raising awareness of the importance of local populations for the preservation of these fragile territories.

The Mediterranean is also complex in terms of its socio-political settings. For millennia, the Mediterranean has been a unique geographical space but – except for the Roman Empire – it has been a politically, economically and culturally divided region. While its geographical scope has remained unchanged over the past 5,000 years of human history, the modes of government in countries and regions have been in permanent flux (Brauch 2010).

Approximately one-third of the Mediterranean population is concentrated along its coastal regions. Meanwhile, about 250 million people reside in coastal hydrological basins. In the southern region of the Mediterranean, around 120 million inhabitants are concentrated in coastal hydrological basins, where environmental pressures have increased (EEA 2020). In addition, around 360 million international tourists visited the Mediterranean countries in 2017 (UNWTO 2019). Approximately half of these arrivals - 170 million - are in Mediterranean coastal areas, exacerbating the human pressures in coastal zones, and generating a 40% increase in marine litter, particularly during the summer season (Galgani et al. 2014).

The variety of cultures, policy and governance approaches and the diversity of social systems have led to very different levels of socio-economic development and ecological footprints of the Mediterranean states between the north and the south (Raleigh et al. 2008; IPCC 2014; Rigaud et al. 2018; GRID 2019). Per capita income levels are three to five times higher in southern European countries (France, Italy and Spain, in particular), compared to countries on the southern and eastern shores of the Mediterranean Sea. While important progress has been made in the South and the East over the last twenty years, instability and significant inequalities persist. This north-south dichotomy is at the heart of the climate change issue, as it exacerbates imbalances by having greater impacts on lesser-developed countries, which have limited capacities to deal with the impacts and possible adaptation measures.

Due to the complexities and heterogeneities of topographic, geographic and socio-economic structures in the Mediterranean Basin, regional, sub-regional, national or local scales are considered where appropriate and where data and information are available. For instance, the spatial separation of drivers has been considered at the level of ecosystems (open ocean, deltas, river basins, wetlands, drylands, etc.). Impacts of environmental change are sometimes quite localized but concern a large number of domains. They are complex to understand and require studies and simulations at reduced spatial scales, associated with high degrees of uncertainty. Best practices with regard to mitigation and adaptation measures are usually reported at the local level, as adaptation measures are generally implemented at a territorial scale where end-users and decision makers are more engaged.

1.3.1.2 Scenarios and reference periods

Different periods and time windows have been selected by climatologists and adopted by IPCC to monitor and record changes in climate conditions throughout Earth history along the different reports. In order to quantify human impacts with respect to an "unperturbed" reference state (ideally the climate just before human activities started to

[4] http://initiative-pim.org/

demonstrably change the environment at global scale) a practical approach to identifying impacts and their characteristics is needed *(Chapter 2)*.

Instrumental observations of temperature are available mainly since the second half of the 18th century but only in some European countries. In the IPCC AR5 report, the 1850-1900 period is considered as the best approximation for an unperturbed state, but, it is not named pre-industrial. It has nonetheless been kept as the reference for the pre-industrial period in the IPCC Special Report on the Impacts of Global Warming at 1.5°C (SR15) (IPCC 2018) *(Section 2.2.1)*.

Climate modelling and climate projections adopted the practice of describing future changes with respect to a recent baseline (during which validation of models is supported by a large amount of instrumental observations). Because of the long residence time of carbon dioxide in the atmosphere, the human influences on the current trajectory of a changing climate appear to be irreversible for decades to centuries, even if significant mitigation measures are implemented immediately (Millar et al. 2006). Thus, given the dynamics of the natural climate system and the superimposed changes humans are causing, the 21st century is an important transitional time for undertaking both mitigation and adaptation actions. In order to be able to propose future climate projections considering various possible socio-economic trajectories and climate policy pathways, we follow the IPCC scenario approach. Although results based on multiple IPCC scenarios are reported in MAR1, we mostly focus on two options which encompass the range of IPCC-AR5, CMIP5 and CORDEX simulations: the "business as usual" scenario (RCP8.5, for an explanation of the RCPs see *Box 2.2*) and the optimistic scenario closest to the UNFCCC Paris Agreement target (RCP2.6). These scenarios were also chosen due to model projection availability constraints at the regional scale. Where more recent studies are not available, the assessment also considers studies based on the older IPCC SRES approach (Nakićenović 2000) *(Section 2.2.1)*.

1.3.1.3 Adapting to climate and environmental change

Climate change adaptation is a necessity, possibly an opportunity, but many definitions exist and the nature and effectiveness of adaptive responses is critically influenced by the framing of adaptation responses (Wise et al. 2014). The IPCC AR5 has framed adaptation as a "process of adjustment to actual or expected climate and its effects in order to either lessen or avoid harm or exploit beneficial opportunities" and also emphasizes that there is "increasing recognition that an adequate adaptive response will mean acting in the face of continuing uncertainty about the extent of climate change and the nature of its impacts" (IPCC 2014). Other authors emphasize how the increasing climate pressure recalls the need to shift rapidly from incremental to transformative adaptation (Rickards and Howden 2012; Vermeulen et al. 2013). Adaptation can be understood as a set of actions which "adjust to" a new situation (e.g., change date of seeding), which recalls a "technical fix" approach, or as a "structural coupling dynamic process", where social learning is the main process informing decisions at any critical point of an ongoing adaptive pathway (Collins and Ison 2009). In the latter framing, the assumption is that no single group has clear access to understanding the issues and their resolutions, hence the difficulties in securing the active and broad-based engagement of stakeholders, and the facilitated spaces for "learning to adapt" become crucial. Adaptation can be operationalized as part of pathways of change and response, which implies the reorganization of institutional structures that are likely to lead to more sustainable trajectories (Rickards and Howden 2012).

The design of adaptation pathways can emerge from the integration of capacity-based (i.e., bottom-up) approaches with impact-based (i.e., top-down) approaches (Vermeulen et al. 2013). The same authors show that when the signal-to-noise ratio of the changing climate is low, i.e., the noise associated with natural weather variability is higher than the changing climate signals, the capacity to respond can basically rely on "no-regret" or "win-win" approaches resulting in incremental adaptation practices, such as short-term investments on higher water storage capacity or use of water-saving technologies, which can also respond to weaknesses emerging from the usual climate uncertainty. When climate shifts are stronger, impact-based decisions can more effectively inform systemic or transformative adaptation pathways, even when uncertainty of future predictions is relatively high (Vermeulen et al. 2013).

1.3.1.4 Toward a systemic approach

As previously emphasized in this chapter, a large amount of scientific material (data, publications, reports, etc.) is available for various Mediterranean areas (from localities to countries or marine sub-basins), for different periods of various durations, for different compartments (atmosphere, soil, continental or sea water, etc.) and on different topics (chemical composition, physical characteristics, ecosystems, human activities, etc.). New data from satellite providers are essential for those regions with poor instrumental coverage, but also to provide a complete overview of the Mediterranean Region (e.g., GEO-Cradle, geocradle.eu, the COPERNICUS and Digital Africa systems, or the Integrated Geospatial information Frameworks, IGIF). All of these elements contribute to the overall understanding of the impacts of climate and environmental changes in the Mediterranean. The fact that advanced research is so complex that it requires very focused and specialized studies makes it difficult to achieve the objective of having an overall integrated understanding of the functioning of the Mediterranean environment, of the modifications due to local human activities and of the evolutions related to global changes. A holistic approach is however of major importance in order to better understand the interactions between these multiple elements, and then provide a robust scientific basis to develop and implement sustainable and effective policies.

This systemic approach has been successfully adopted for decades by scientists contributing to the IPCC by developing more and more refined global climate models. Nevertheless, these models are not designed to address all processes that determine the evolution of the Mediterranean environment and socio-ecosystems under both climate change and other environmental processes caused by human activity.

The development of an integrated Mediterranean model with the spatial and temporal resolution suitable for comprehensively resolving the relevant processes has to be a long-term target for the scientific community. Such an approach could provide answers to the concerns of policymakers related to sustainable development strategies in the Mediterranean region. At present, MedECC aims to initiate the process by providing a first synthesis of the state of knowledge in the various scientific fields that need to be considered and brought together in order to move one step forward in this direction.

1.3.1.5 MedECC MAR1 as a policy support instrument

Given the stated goals and objectives of MedECC, MAR1 is intended to support policies in deriving mitigation and adaptation strategies, particularly in the context of Mediterranean cooperation under policies of the European Union, Arab League, EU-Africa and EU-Asia cooperation, North African Unions, Maghreb and Mashriq. To provide adequate support, MAR1 has been inspired by other science-policy interfaces such as the IPCC and IPBES, aiming to provide an unbiased, scientific view of climate and environmental change, its various, multi-sectoral impacts and the risks they imply for society.

The MedECC MAR1, by summarizing existing findings and results, aims to highlight their policy relevance without being policy-prescriptive.

The MedECC MAR1 is designed to address the needs of multiple actors involved in providing a response to climate and environmental changes and risks in the Mediterranean region. The primary target users of the report are governments and policymakers at all levels, the UfM and the UNEP/MAP at the regional level, and more broadly, the comprehensive system of intergovernmental processes pursuing different aims, including the three "Rio Conventions" (UNFCCC, CBD, UNCCD) and the Ramsar Convention (and their financial instruments), as well as IPCC, IPBES and the Commission on Generic Resources for Food and Agriculture (CGRFA). Other important end-users include the scientific community, major economic decision makers and the private sector, the education sector, civil society and non-governmental organizations (CSOs and NGOs). MedECC aims to build close relationships with various media in order to help guide the interpretation of its report and to ensure that the public is provided with objective and unbiased information about MAR1.

MAR1 contributes to meeting the need for an advancement and implementation of regulatory instruments aiming to reduce greenhouse gas emissions and emissions of pollutants to mitigate climate and environmental changes in the Mediterranean Basin. The scoping and drafting of the report involved ample consultation of completed or ongoing assessments of comparable nature like the IPCC and IPBES assessment reports and builds on the existing relations between MedECC and other groups. Findings of MAR1 will be directly employed for the drafting of a Mediterranean Cross-Chapter Paper in the forthcoming IPCC Sixth Assessment Report *(Appendix A.1)*.

1.3.2 Methodology

The drafting of MAR1 entailed a collective and iterative review, synthesis, analysis and judgment of available scientific knowledge. The entire assessment is supported by scientific references; no additional research has been undertaken by MedECC. In some cases, a new analysis of data was conducted using existing models to address specific questions and to identify knowledge gaps to be addressed by other initiatives and research programs.

The report is primarily based on peer-reviewed literature (in English or other languages) but selected non-peer reviewed literature was also considered (such as institutional or government reports, national statistics, etc.) in which case the authors carefully checked the quality of the references included to justify their inclusion. A scientific literature database was maintained by the MedECC Secretariat and was made available to all report authors.

Drafts of the report have been subject to a dual scientific review allowing suggestions and amendments by scientific experts. A first internal review of the First Order Draft (FOD) involving the SC and the authors of the report was carried out, and the Second Order Draft (SOD) was submitted to external scientific reviewers.

The main body of MAR1 is accompanied by a Summary for Policymakers (SPM), which undergoes an approval procedure organized with the UNEP/MAP – Barcelona Convention Secretariat and its Plan Bleu Regional Activity Centre, through their Focal Points and/or the Members of the Mediterranean Commission on Sustainable Development (MCSD), as well as with the UfM Member State representatives within the regional Climate Change Expert Group (CCEG).

1.3.3 Communicating uncertainties and results

Communication of the findings of MAR1 aims to also adequately communicate scientific uncertainties and confidence in the material used. For this purpose, three different target groups are differentiated:

- the scientific community; all of the main conclusions will be supported by robust literature and/or evidence following the AR5 IPCC (IPCC 2013) criteria to communicate the uncertainty of findings;
- policymakers and stakeholders; conclusions for them will be summarized in the MAR1 Summary for Policymakers; considering the strong relationships with key institutions such as UNEP/MAP and UfM, main questions and key messages will be discussed with them prior to final publication, in order to take their views and the advice of the MedECC SC into account;
- the public at large, mainly, but not exclusively, those living in Mediterranean countries; the main challenges and opportunities will be communicated to them; in so doing, we will progress from MAR1's strictly "informative" role towards a more "participatory" and "responsible" one, in order to further understanding and acceptance of measures aimed to cope better with climate and environmental changes in the Mediterranean region.

The approach of the MAR1 report meets the call made by the United Nations program on the Sustainable Development Goals as well as the concessions proposed after the COP 21 under the UNFCCC (Paris Agreement), in particular SDG 17 "Strengthen the means of implementation and revitalize the global partnership for sustainable development" (Partnerships for the Goals).

Following the AR5 IPCC (IPCC 2013), the metrics for communicating the degree of certainty in key findings (notably on climate drivers) will be the following:

- **Confidence:** confidence in the validity of a finding, will be based on the type, amount, quality, and consistency of evidence (e.g., data, mechanistic understanding, theory, models, expert judgment) and the degree of agreement; confidence is expressed qualitatively and its level will be based on the evidence (robust, medium and limited) and the agreement (high, medium and low). A combination of different methods, e.g., observations and modelling, is important

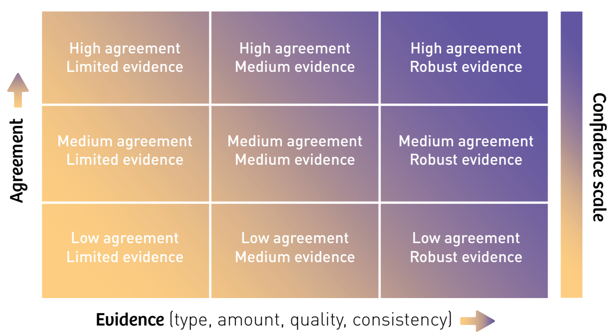

Figure 1.4 | The basis for the confidence level is given as a combination of evidence (limited, medium, robust) and agreement (low, medium and high) (Mastrandrea et al. 2011).

for evaluating the confidence level. There is flexibility in this relationship; for a given evidence and agreement statement, different confidence levels could be assigned, but increasing levels of evidence and degrees of agreement are correlated with increasing confidence. *Fig. 1.4* shows how the combined evidence and agreement results in five levels for the confidence level used in this assessment. Confidence should not be interpreted probabilistically, and is distinct from "statistical confidence".

Term	Likelihood of the outcome
Virtually certain	>99% probability
Extremely likely	>95% probability
Very likely	>90% probability
Likely	>66% probability
More likely than not	>50% probability
About as likely as not	33-66% probability
Unlikely	<33% probability
Extremely unlikely	<5% probability
Exceptionally unlikely	<1% probability

Table 1.1 | Likelihood terms associated with outcomes used in MAR1 (from IPCC 2013).

- **Uncertainty:** quantified measures of uncertainty in a finding will be expressed probabilistically, i.e., based on a statistical analysis of observations or model results, or on expert judgement. The qualifier "likelihood" provides calibrated language for describing quantified uncertainty. It can be used to express a probabilistic estimate of the occurrence of a single event or of an outcome, for example, a change in a given climate parameter, an observed trend, or a projected change lying in a given range. Statements made using the likelihood scale may be based on statistical or modelling analyses, elicitation of expert views, or other quantitative analyses. Where sufficient information is available, it is preferable to avoid the likelihood qualifier in favor of the full probability distribution or the appropriate probability range. *Table 1.1* shows the list of "likelihood" qualifiers to be used in this report.

1.3.4 Report structure

The outline for the MAR1 report was approved by the MedECC Scientific Committee during its meeting on May 24, 2018 in Marseille, France. MAR1 consists of a Summary for Policymakers, six main chapters and several appendices, as follows:

- Summary for Policymakers, including an Executive Summary.
- This chapter, Chapter 1, **"Introduction"**, frames the motivation and main components of the MedECC Assessment.
- Chapter 2, **"Drivers of change"**, focuses on the physical, bio-chemical and human drivers of climate and environmental changes, distinguishing between climate, pollution, land/sea use and management, and invasive species. Based on these drivers, the analyses in Chapters 3-5 all consider past trends and current situation, projections, vulnerabilities and risks, adaptation, knowledge gaps and research needs.
- Chapter 3, **"Resources"**, assesses the state of knowledge for major resource challenges: water, food and energy in three sub-chapters describing each of these resources.
- Chapter 4, **"Ecosystems"**, assesses the state of knowledge for marine, coastal and terrestrial ecosystems.
- Chapter 5, **"Society"**, addresses major issues of development, health and human security under climate and environmental change.
- Chapter 6, **"Managing future risks and building socio-ecological resilience"**, discusses options for more sustainable policies given the risks identified in *Chapters 3-5*. It describes the future risks associated with climate change in Mediterranean countries, and critically reviews a range of examples of adaptation and mitigation, promoting their synergies, as well as cooperation and networking among Mediterranean countries for building resilience.
- Supplementary information is given by the appendices, which include the information on MedECC partners and related research activities, the institutional context of MedECC, the main steps in MAR1 preparation, maps of projected temperature and precipitation changes for the Mediterranean Basin, the lists of acronyms and country codes.

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