REVIEW ARTICLE

THE CHANGING MEDITERRANEAN BASIN THROUGH THE LENS OF MEDITERRANEAN EXPERTS

ABED EL RAHMAN HASSOUN
National Council for Scientific Research, National Center for Marine Sciences, Lebanon (abedhassoun@cnrs.edu.lb)

JOEL GUIOT
Aix Marseille University, CNRS, IRD, INRA, Coll France, CEREGE France

KATARZYNA MARINI
MedECC Secretariat, Plan Bleu, France

WOLFGANG CRAMER
IMBE, Aix Marseille University, CNRS, IRD, Université Avignon, France

The different components of the Mediterranean Basin (land, coast, and sea) are undergoing significant changes due to multiple anthropogenic pressures, including climate change, pollution and other factors. The 1st Mediterranean Assessment Report (MAR1), produced by the Mediterranean Experts on Climate and environmental Change (MedECC) and based on available scientific literature, provides a coherent and comprehensive synthesis of the status of the Mediterranean Basin, its main drivers and their impacts on both ecosystems and human dimensions, with a focus on water, food, energy, ecosystems and ecosystem services, development, health and human security. The report is the first multidisciplinary, trans-boundary assessment produced for this region and provides significant input to inform policy at regional, national and local levels. Its groundbreaking nature lies in the scope of the scientific assessment as well as in displaying the regional capacity to coordinate existing fragmented efforts in the region. The report highlights risks

and possible response strategies that may help to increase the resilience to the effects of climate and environmental change. The conclusions show that effective policy responses, as well as in support of Sustainable Development Goals, encompass both strengthened mitigation of climate and environmental change and enhanced adaptation to their impacts. Socio-economic factors of poverty, inequalities and gender imbalances presently hamper the achievement of sustainable development and climate resilience in Mediterranean countries.

Key words: climate change, environmental change, resources, ecosystems, adaptation, society

INTRODUCTION

All sub-regions of the Mediterranean Basin, on land and in the sea, are impacted by recent anthropogenic changes in the environment (MedECC 2020). Greenhouse gases emissions, generated by various anthropogenic activities since the industrial revolution, are changing the climate patterns worldwide, with exacerbated trends in the Mediterranean compared to other areas (Cramer et al. 2018). In the Mediterranean, annual mean temperatures on land and in the sea are now approximately 1.5 °C higher than in pre-industrial times and they are projected to rise until 2100 by an additional 3.8-6.5°C for a high greenhouse gas emissions scenario (RCP8.5), and by 0.5-2.0 °C for a scenario (RCP2.6) compatible with the UNFCCC Paris Agreement (Lionello et al. 2014), due to both local and global scale drivers (Cherif et al. 2020). Extreme events are already detectable in different Mediterranean subregions and they are projected to increase in duration, intensity and frequency on land and in the sea, affecting resources and the livelihoods of millions of people living in this region (Coma et al. 2009; Pausas and Millán 2019). Although the consequences of recent environmental change are threatening all Mediterranean nations, a comprehensive and reliable assessment of the risks has been lacking in impactful scientific reports such as those provided by the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) and the Intergovernmental Panel on Climate Change (IPCC). Consequently, significant efforts are

still needed for knowledge transfer from scientists to policy-makers in order to make the necessary decisions and implement tangible actions in the Mediterranean (Diffenbaugh et al. 2007; Maiorano et al. 2011; Hare et al. 2011; de Sherbinin 2014; Guiot and Cramer 2016; Lionello et al. 2018; Cramer et al. 2018; Pausas and Millán 2019). Thus, the need to focus on the Mediterranean Basin in the context of recent environmental changes was the core idea behind the 1st Mediterranean Assessment Report (MAR1), written to provide science-based guidance to multiple actors involved in tailoring a response to climate and environmental changes, and to reduce associated risks for communities and natural ecosystems in the Mediterranean region.

MedECC NETWORK: THE BASELINE OF 1ST MEDITERRANEAN ASSESSMENT REPORT (MAR1)

The MedECC network was formed in 2015, based on the realization that the shared history and the close connections between countries and regions bordering the Mediterranean, call for strong cooperation with respect to adaptation to, and mitigation of, ongoing environmental change – however, efforts in that direction have been poorly coordinated. Existing assessments cover only parts of the region, some topics and were scattered in various outputs. Substantial scientific knowledge and monitoring data made available by certain research institutions around the Mediterranean was not capitalized on, resulting in an insufficient guidance to policy at regional, national and local levels. The Mediterranean did not follow the course of some other regions and global bodies in producing a relevant scientific basis for policy. Endeavors in institutional coordination and funding led to the establishment of the MedECC network and the launch of scientific work. The MedECC scientific assessment of climate and environmental change is supported by the Union for the Mediterranean, in cooperation with Plan Bleu (UNEP/MAP Regional Activity Center).

MedECC currently consists of approximately 600 independent scientists from 35 countries working towards a regional science-policy interface for climatic and other environmental

changes across the Mediterranean, with clear goals summarized in Figure 1.

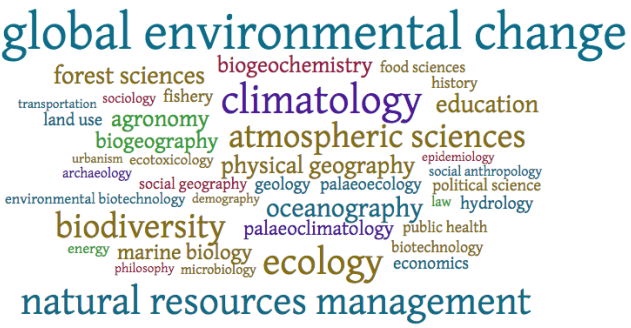
Figure 1: *Goals of MedECC*



Source: MedECC (2020)

MedECC members come from all Mediterranean sub-regions, with a broad and diverse range of scientific backgrounds (see Fig. 2), covering physical, chemical, biological, societal and economic aspects of the Mediterranean.

Figure 2: *Scientific disciplines of MedECC members*



Source: MedECC (2020)

MedECC's collaborative regional work with a global relevance is embodied through the MedECC vision that valorizes the shared space of peace, development and human rights to better understand climate change and environmental patterns and their effects in the Mediterranean basin to ultimately provide solutions. For this reason, MedECC has been co-awarded the 2020 North-South Prize of the Council of Europe (CoE 2020).

MAR1 assesses current knowledge as it emerges out of the existing body of scientific research. Although it is a regional study, its results may provide useful conclusions on a global scale, as the Mediterranean Basin is always considered as a 'hotspot' (Pérès 1967; Garrett 1994; Giorgi and Lionello 2008; Coll et al. 2010), and a test basin where all global phenomena occur with more remarkable trends (Garrett 1994; Robinson et al. 2001). Hereafter, we summarize the methodology used during the MAR1 drafting, its structure, and its main findings.

METHODOLOGY OF THE MAR1 REPORT

Scoping, Drafting and Review

In order to produce a detailed outline of MAR1, a scoping event was held in 2016, and received the COP22 label. The drafting process of MAR1 (Fig. 3) was a collaborative work that comprises around 190 authors from 25 countries distributed between Coordinating Lead Authors (CLAs), Lead Authors (LAs) and Contributing Authors (CAs) from various Mediterranean sub-regions. CLAs and LAs were selected based on self-nominations in reply to the call by the MedECC Steering Committee (SC). Afterwards, CAs were invited by chapters' CLAs according to the needed expertise to cover the widest possible range of disciplines. The drafting process was based on a compilation of the existing knowledge through a synthetic analysis of mainly peer-reviewed literature and national institutional or government reports and statistics, with some synthetic figures being plotted in the process with no additional research undertaken by the authors. A scientific literature database was maintained

by the MedECC Secretariat and was made available to all report authors (Lange et al., 2020).

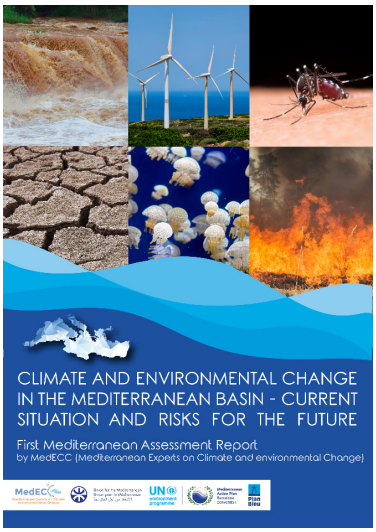
Since the early stages of the report drafting, chapters have been subject to scientific reviews, allowing suggestions and amendments by scientific experts. A first internal review of the First Order Draft (FOD) involved the SC and the authors of the report, and the Second Order Draft (SOD) was submitted to external scientific reviewers. Moreover, a Summary for Policymakers (SPM) was finally submitted to stakeholders, representing the governments and partner institutions through the Union for the Mediterranean (UfM) and United Nations Environment Programme / Mediterranean Action Plan (UNEP/MAP) to review the clarity and the coherency of the messages.

Structure and Uncertainties

The report starts with a background about the context and the importance of such assessment efforts (chapter 1), before detailing the main drivers of change in the Mediterranean Basin – which are mainly linked to climate, pollution, land and sea uses, and non-indigenous species (chapter 2), their effects on its resources, water, food, energy (chapter 3), its marine, coastal and terrestrial ecosystems (chapter 4), and society - mainly development, health and human security (chapter 5), while lastly, providing a few case studies and success stories that can be used to manage future risks and improve socio-ecological resilience (chapter 6).

Throughout the report, scientific confidence in its findings is indicated based on the consistency of evidence and the degree of agreement of the scientific community, summarized by the terms “high”, “medium” and “low” confidence. Additionally, the report adequately communicates scientific uncertainties, confidence, and the likelihood of outcomes in the material used (see chapter 1; Lange et al. 2020).

Figure 3: *The front page of the MAR1*



Source: MedECC (2020)

RESULTS

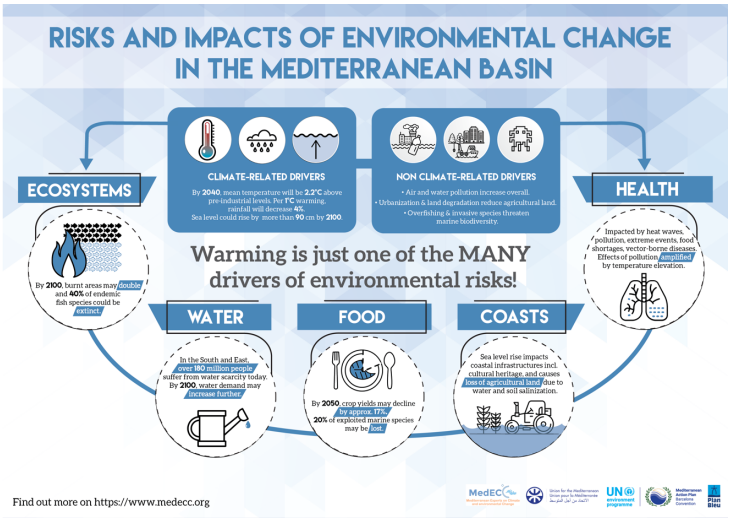
Detailed results of the huge literature compilation can be solicited in MedECC (2020), including a Summary for Policymakers (SPM) that has been fully adopted by policymakers, governments, decision-makers and stakeholders after a plenary consultation about the SPM on 22 September 2020. Here, we briefly highlight the main results. Risks and impacts of climate and environmental change on the different components of the Mediterranean Basin are also summarized in Figure 4.

Drivers

Four broad domains of change drivers are considered in MAR1 (chapter 2; Cherif et al. 2020), such as climate change and variability, pollution, land and sea use changes and non-indigenous species. It is clear that the Mediterranean Basin is likely very vulnerable to climate change, as demonstrated by observations: the annual mean temperatures are now 1.54°C above the 1860-1890 level at basin-scale (high confidence); there is a decrease of

winter precipitation over various sub-regions since the second half of the 20th century (medium confidence); conditions became drier, especially in the warm season and over the southern areas (medium/high confidence); sea surface temperatures increased between +0.29 and +0.44°C per decade (high confidence) and sea water pH decreased by -0.08 units since the beginning of the 19th century (medium confidence), while marine heat waves have become longer and more intense (high confidence). In addition, the rate of change of direct drivers can be influenced or altered by indirect drivers (MEA 2005; Nelson et al. 2006), such as demographic, economic, sociopolitical, cultural, religious, technological, legislative and financial drivers. Understanding all types of drivers is essential to effectively managing the risks posed to the environment and human societies by climate change, air and water pollution, land and sea use changes and the arrival of non-indigenous species. The projections of main climate and non-climate-related drivers are summarized in Figure 4.

Figure 4: *The main messages of MAR1 related to risks and impacts on climate and environmental change on the different components of the Mediterranean Basin*



Source: MedECC (2020)

Resources

For *water*, climate change, in interaction with other drivers (mainly demographic and socio-economic developments), has mainly negative consequences for the water cycle in the Mediterranean Basin, including reduced runoff and groundwater recharge, increased crop water requirements, increased conflicts among users, and increased risk of overexploitation and degradation of water resources. These impacts, leading to water scarcity, are influencing over 180 million people in the South and East countries (high confidence), and will be much more important for global warming, with temperature increases higher than 2°C (Fig. 4; Fader et al. 2020). For *food*, climate change and extreme events (i.e., heat waves, droughts, floods, sea level rise, etc.) are threatening the food security of Mediterranean nations (high confidence) by causing crop yield losses/failures, crop quality reduction and impacts on livestock. Climate projections show an increasing risk on the food production system in the Mediterranean Basin, such as a 17% decline of crop yields by 2050 (medium confidence) (Fig. 4; Mrabet et al. 2020). *Energy*-wise, the report has demonstrated a steady rise of approximately 1.7% each year of the primary energy consumption in the Mediterranean Basin from 1980 to 2016, attributed to a steady increase in the consumption of oil, gas, nuclear and renewables, and caused by changes in demographic, socioeconomic (lifestyle and consumption) and climatic conditions in the region (high confidence) (Drobinski et al. 2020).

Ecosystems

Climate change is affecting all Mediterranean ecosystems (marine, coastal and terrestrial; Balzan et al. 2020). For *marine ecosystems*, the results show an increase of species listed as vulnerable (21%) and endangered (11%), increasing signs of "tropicalization" of Mediterranean fauna and flora (medium confidence), and more literature exposing the effects of climate change consequences (i.e., warming, acidification, heat waves, etc.) on all marine trophic chain components, from its primary producers to its marine mammals (high confidence). Projections

show that numerous species extinctions would occur, i.e., 40% of endemic fish species will be extinct (Fig. 4) and natural habitats of numerous commercially valuable species will be modified by the end of this century, which would have many repercussions on marine ecosystems' services, such as tourism, fisheries, climate regulation, and ultimately, on human health (medium confidence). For *coastal ecosystems*, climate change and anthropogenic pressures are impacting various coastal ecosystem regimes (lagoons, deltas, salt marshes, etc.) and coastal infrastructures, affecting thus the flow of nutrients towards the sea, as well as the magnitude, timing and composition of plankton blooms, which significantly increase the number and frequency of jellyfish outbreaks (high confidence), and could have negative impacts on fisheries. Extensive urbanization added to climate and environmental change is also expected to threaten coastal ecosystems, mainly in the southern realm of the Mediterranean (medium confidence). For *terrestrial ecosystems*, fast and great biodiversity changes have been detectable in the Mediterranean over the past 40 years compared to other areas of the world. On the southern Mediterranean shore, the ecosystems are at risk of fragmentation or disappearance due to human pressure from clearing and cultivation, overexploitation of firewood and overgrazing (high confidence). Drylands are undergoing an overall increase in surface in response to climate change and extensive land abandonment, while 48% of the Mediterranean wetlands were lost between 1970 and 2013, with 36% of wetland dependent animals in the Mediterranean threatened with extinction (medium confidence). Projections indicate negative impacts on terrestrial biodiversity, forest productivity, burned areas [up to a 40% increase for 1.5°C warming, and up to a 100% increase compared to current levels for 3°C warming by the end of the 21st century (high confidence) ; Fig.4], freshwater ecosystems and agrosystems with decreased hydrological connectivity, increased concentration of pollutants during droughts, changes in biological communities as a result of harsher environmental conditions, and a decrease of biological processes such as nutrient uptake, primary production, or decomposition.

Society

All the above-mentioned changes are affecting directly and indirectly the human *health* of Mediterranean populations in different ways, depending on population density, level of economic development, food availability, income level and distribution, local environmental conditions, pre-existing health status, and the quality and availability of public health care (high confidence) (Paz et al. 2020). Moreover, climate change and extreme events may have negative impacts on the mental health of people directly affected by consequences, i.e., loss of homes, destruction of settlements and damage to community infrastructure (high confidence). Therefore, sustainable *development* strategies and innovations (such as climate proofing infrastructures) are key to address the needs of current and future generations, by utilizing natural resources in ways that preserve and sustain them, and ensuring equitable access to those resources in the present and the future (high confidence). However, poverty, inequalities and gender imbalances relate both directly and indirectly to the achievement of sustainable development in Mediterranean countries (Dos Santos et al. 2020). All these changes may influence *human security*, generating additional conflicts and threats linked to water, food, health and others. It is likely that climate change could further exacerbate political instability in the poorest parts of the Mediterranean Basin (medium confidence) (Koubi et al. 2020).

Managing future risks and building socio-ecological resilience

Finally, MedECC (2020) sheds light on the importance of managing future risks by highlighting: 1- the current understanding on the trajectory, intensity and spatial extent of future risk for the principal hazards, and associated policy considerations of the region, 2- the current management and adaptation approaches, and prevalent governance frameworks for coping with these risks, 3- a range of examples of adaptation and mitigation for sectorial approaches, while considering case studies from Mediterranean-type environments. A number of innovative and successful practices for achieving sound and sustainable

development in countries of the Mediterranean Basin are proposed therein, while highlighting the crucial role of developing joint, region-wide, and integrated management and adaptation approaches that treat multiple hazards in a holistic manner is of utmost importance for sustainable development in the entire region (Vafeidis et al. 2020).

CONCLUSIONS

Based on a synthetic compilation of the existing knowledge in literature, MAR1 highlights the main drivers affecting the Mediterranean Basin, their current effects on resources, ecosystems and society, as well as the projected trends and risks in the context of climate and environmental changes. The outcomes show that more effective policy responses will imply both, strengthened mitigation of the drivers of climate and environmental change such as greenhouse gas emissions, but also enhanced adaptation to impacts. Poverty, inequalities and gender imbalances presently hamper the achievement of sustainable development and climate resilience in Mediterranean countries. Culture is a key factor to the success of adaptation policies in the highly diverse multicultural setting of the Mediterranean Basin. Policies for climate adaptation and environmental resilience potentially infringe on human rights - they need to account for concerns such as justice, equity, poverty alleviation, social inclusion, and redistribution. To support policies for sustainable development with scientific evidence concerning climate and environmental change, a synthesis of current scientific knowledge, covering most relevant disciplines, sectors and sub-regions is presented by the 1st Mediterranean Assessment Report (MAR1). The findings of MAR1 constitute a foundation for meeting sustainable development needs whilst informing strategic planning and investment at the regional level. The report also provides innovative and successful case studies that would improve the socio-ecological resilience of the different Mediterranean components to resist climate change impacts and ultimately, satisfy the United Nations Sustainable Development Goals (UN SDGs).

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