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PRIMA – Partnership for Research and Innovation in the Mediterranean Area is the most ambitious joint programme to be undertaken in the frame of Euro-Mediterranean cooperation. By funding R&I through competitive calls, PRIMA aims to build research and innovation capacities and to develop knowledge and common innovative solutions for sustainable agro-food systems and integrated water provision and management in the Mediterranean area, to make those systems and that provision and management more climate resilient, efficient, cost-effective and environmentally and socially sustainable, and to contribute to solving water scarcity, food security, nutrition, health, well-being and migration problems upstream.

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FOREWORD

Octavi Quintana
Director, PRIMA

The socioeconomic impact of climate change in the Mediterranean

The Mediterranean Basin enjoys very attractive geographical, climatic, and cultural features. It hosts a high-density population mainly in the coastal areas, of over 500 million people which has doubled in the last 40 years, and it is still increasing at a high pace.

The region faces severe threats including water stress, impaired food production, food security, desertification, severe pollution to mention just a few. These threats have been exacerbated in the last decades by increased demography, migration to urban areas, tourism (the first tourist destination in the world), and very importantly, climate change. The Mediterranean suffers from an increase of temperature 20% higher than the world average. It is a real hotspot of climate change.

The present monography, sponsored by the European Institute of the Mediterranean (IEMed), addresses the socioeconomic impact of climate change. There are a lot of studies on the biophysical impact of climate change. Its socioeconomic impact has been less studied probably because of its complexity. Important knowledge gaps do exist.

The purpose of gathering knowledge on the socioeconomic impact of climate change is to advise decision-makers on the difficult decisions to be taken to mitigate and adapt to climate change in a region facing severe threats that climate change only exacerbates. For decision-makers, the socioeconomic impact is more relevant than the biophysical impact of climate change.

Viki Reyes and Esteve Corbera in their paper show the very fragile balance of the ecosystems in the region which have been under human interventions for several thousands of years. They propose that the underlying threats exacerbated by climate change need to be tackled at the level of the whole region and with a multidisciplinary approach. This is a common and strong message stemming from the different papers. No country on its own will be able to deal with these threats, and sectorial approaches will miss the point.

Alain Safa exemplifies the challenges in three key areas, agriculture, food, and water. He shows that the data are appalling, and actions need to be taken at the international level. The impact will be very important while the inequalities and the social unrest consequently will spread. He supports strong cooperation between the different countries with the creation of an institutionalised structure.

Irina Solovyeva and Elena Xoplaki's focus is on the methodological gaps to make a proper socioeconomic assessment. They look at the hurdles scientists face to make a proper assessment of the socioeconomic impact of climate change. They stress the need to have data disaggregated at the level where decisions are taken. They also discuss the obstacles for scientists to convey recommendations that help decision-makers in their difficult decisions.

Joan Subirats looks at the problem from the other side of the table. His analysis takes the point of view of decision-makers. He highlights the difficulty to follow scientific recommendations specially when they severely affect specific groups of people even if they are a

minority. He fosters the need of negotiation with different actors to reach as much a consensus as possible, which means not only having data but listening to a broad range of stakeholders.

The main message of the monography is that there is a high degree of consensus on the biophysical impact of climate change in the region. However, there is no such consensus on how to deal with it. Better knowledge on the socioeconomic impact of climate change is needed to advance the decisions to be taken. Addressing this uncertainty needs a pan-Mediterranean approach, multidisciplinary studies, and imagining broad governance including many actors.

PRIMA contributes to this effort with research and innovation projects which aim at providing solutions to the challenges caused or exacerbated by climate change in the Mediterranean. Projects embed the socioeconomic dimension and a nexus approach taking into account as many sectors as possible and the links among them. PRIMA supports knowledge, networking, and an integrated approach to solutions the region needs.

Climate Change Impacts on the Mediterranean Basin: A Social-Ecological Perspective

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The Mediterranean Basin is a biodiversity-rich region that provides a wide range of nature's contributions to people and supports a diverse cultural heritage (Blondel, Aronson, Bodiou, & Boeuf, 2010; Catsadorakis, 2007; Martín-López et al., 2018). While the underlying determinant of the region's biodiversity and ecosystem structure remains the highly specific climate characterised by the strong temporal and spatial variability of the hydrological cycle (e.g., Cudennec, Leduc, & Koutsoyiannis, 2007), biodiversity in the region cannot be understood without considering the long-term interactions and co-evolution of different human societies with Mediterranean diverse biotas (Grove & Rackham, 2003). Indeed, Mediterranean seascapes and landscapes have been shaped by a long history of human management, which has resulted in *complex social-ecological systems* where social and ecological aspects are linked through feedback mechanisms (*sensu* Berkes, Folke, & Colding, 1998). Because climate is so intrinsically linked to the functioning of Mediterranean social-ecological systems, there is a need for a non-sectoral treatment of the climate-biodiversity-society nexus.

This text briefly examines the importance of focusing on the climate-biodiversity-society nexus in the Mediterranean Basin, arguing for the need to consider the region as a complex social-ecological system affected by multiple threats. The major implication of the approach outlined is that, while climate change is an important driver of change in the Mediterranean region, it needs to be considered with other drivers of change (e.g., land use, overfishing). The first part of the article presents the most prominent features that characterise the Mediterranean region as a complex social-ecological system. Section 2 outlines some of the most prominent threats affecting the region, including climate change, and Section 3 describes the interlinkages of climate change with other relevant threats. The last section discusses challenges for the governance of Mediterranean complex social-ecological systems in a climate change context. The text concludes with some research and policy recommendations.

The Mediterranean region: A complex social-ecological system

The Mediterranean Basin is one of the *world's of biological diversity hotspots* (Myers, Mittermeler, Mittermeler, Da Fonseca, & Kent, 2000), characterised by a high level of endemism and species richness, encompassing a diverse range of marine, freshwater and terrestrial ecoregions (Balzan et al., 2019). A fundamental feature of the Mediterranean region is the strong spatial and temporal variability of the hydrological cycle, one of its most visible markers being the periodic succession of extreme droughts and floods that have shaped both Mediterranean biodiversity and cultures (Blondel, 2006; Cudennec et al., 2007). Mediterranean coastal and marine environments present a high number of endemic species, contributing to about 7% of the world's marine biodiversity while representing only 0.8% of the global ocean surface (Bianchi et al., 2012; Coll et al., 2010). Most of this biodiversity is found in coastal and continental shelves, where seawater is colder and fresher, and where productivity is higher than in the rest of the Mediterranean Sea (Coll et al., 2012). The Mediterranean Sea also is one of the largest archipelagos

in the world, containing 10,000 islands and islets with a significant part of Mediterranean biodiversity (Vogiatzakis, Mannion, & Pungetti, 2008). Humans have exploited the Mediterranean Sea since the prehistoric era (Cortés-Sánchez et al., 2011). The impacts of fishing in the marine environment have resulted in a myriad of traditional fish conservation and management techniques (Damalas et al., 2015).

The rich terrestrial biodiversity of the Mediterranean Basin results from the historical interplay of climatological, biophysical and social processes. Hot summers regularly result in dry conditions in much of the basin, whereas mild humid winters provide the right conditions for high biological productivity. Since the Neolithic period, or even earlier, this biodiversity has been managed by hunter-gatherers first, and then by a network of agro-sylvo-pastoral societies (Blondel, 2006). Through diverse fire management, grazing, cutting and ploughing strategies, embedded in numerous formal and informal institutions and shaped by specific knowledge and practices, Mediterranean societies have strongly influenced biodiversity patterns and dynamics (e.g., Gauquelin et al., 2018; Genin, Aumeeruddy-Thomas, Balent, & Nasi, 2013; Michon, de Foresta, Levang, & Verdeaux, 2007). The *co-evolution* of humans and biodiversity helps explain the complexity and diversity of Mediterranean social-ecological systems.

Productive Mediterranean seascapes and landscapes provide numerous contributions to people. Millions of people directly or indirectly depend on the Mediterranean seascape for the provisioning of fisheries. Marine habitats also contribute to water purification, biological and climate regulation, coastal protection, ocean nourishment, recreation and tourism, and provide symbolic and aesthetic values (Coppari, Zanella, & Rossi, 2019; Liquete et al., 2013; Lloret, 2010). Similarly, Mediterranean forests and agricultural landscapes have provided, and in some cases continue to provide, a wide range of resources and services including human food, medicines, ritual material, firewood, construction wood, clean water and forage for livestock. For example, rangelands and grasslands in the Mediterranean Basin account for 50% of the land surface and for about 270 million ha in the arid and semi-arid zones (i.e., zones receiving 100-400 mm annual rainfall) (CIHEAM, 2009). These biodiversity-rich managed ecosystems provide forage, but also many other contributions to people, including carbon storage, soil erosion prevention, or freshwater provision.

Mediterranean social-ecological systems under threat

Mediterranean complex social-ecological systems *are now threatened by direct* (i.e., resource exploitation, pollution, land use change, biological invasions, and climate change) *and indirect drivers of change* (e.g., population growth, urbanisation) (Hanaček & Rodríguez-Labajos, 2018). These threats operate independently and synergistically and affect terrestrial, freshwater and marine ecosystems (e.g., Piroddi et al., 2017; Thom & Seidl, 2016). These changes also impact people's quality of life and wellbeing, compromising societal goals and potentially leading to a decline in the capacity of ecosystems to sustain human life (Cramer et al., 2018).

Direct threats to Mediterranean social-ecological systems include resource exploitation (e.g., overfishing), pollution, land use change (e.g., abandonment of agro-silvo-pastoral practices, agricultural intensification), biological invasions, and climate change (Azzurro et al., 2019; Liquete, Piroddi, Macías, Druon, & Zulian, 2016). *Mediterranean marine habitats are threatened* by overfishing (more than 90% of assessed stocks were overfished in 2015), but also by rising recreational uses, chemical pollution and biological invasions, such as the reported increase in abundance of warm-adapted marine species of both native and exotic origin (Azzurro et al., 2019; Coll et al., 2010). *Mediterranean terrestrial species are also under threat.* For example, perennial grasses dominate in most natural grasslands and provide forage for livestock, particularly in Southern Mediterranean countries. The expansion of rain-fed annual cereals to meet increasing demand for human food has resulted in the reduction of the area available for grazing (e.g., Dominguez, Zorondo-Rodríguez, & Reyes-García, 2010; Lelièvre & Volaire, 2009). Millions of hectares of rangelands have disappeared along with their unique biodiversity, grazing being displaced to dryer and poorer rangelands, more inclined to quickly degrade due to overgrazing. This has, in turn, led to soil erosion and the loss of vegetation cover and overall biodiversity (Blondel, et al., 2010; Sirami et al., 2010).

These direct threats experienced by the Mediterranean social-ecological system are *shaped by underlying factors or indirect threats,* including demographic and socioeconomic trends, urban development, or fragmented governance structures. For example, in the last four decades, the Mediterranean Basin has doubled in population. Further population increases are expected, particularly in Southern Mediterranean countries. This trend drastically increases the demand for food and water. The increasing water demand from a growing population competes with water demands in other sectors, including industrial and energy uses and agriculture. Agriculture in the region has intensified and experienced the replacement of traditional Mediterranean crops (e.g., wheat) with more financially attractive but also more water-demanding crops (e.g., maize, fruit trees) (Harmanny & Malek, 2019) and varieties (Fradgley et al., 2020). Water-demanding crops and varieties are often associated with higher resource requirements and long supply chains, which also contribute to increasing the ecological footprint of farming systems (Pérez Neira, Soler Montiel, Delgado Cabeza, & Reigada, 2018). Another important indirect threat to Mediterranean social-ecological systems is urbanisation. By 2030, the Mediterranean Basin will be the global biodiversity hotspot with the highest percentage of urban land (5%) (Elmqvist et al., 2013). About one third of the population of the Mediterranean Basin is concentrated in coastal areas (Coll et al., 2010), characterised by a high degree of urbanisation and by being important tourist destinations (Obrador Pons, Crang, & Travlou, 2009). The Mediterranean southern shore is engaged in an urban transition that resembles trends experienced in the northern shore some decades ago and that resulted in a population increase in coastal areas. These growing urbanisation trends are also related with the depopulation of rural areas (FAO, 2006; Pinilla & Sáez, 2017).

In addition to these threats, *climate change impacts in the Mediterranean*

Basin are now considered so severe that the region has become a prominent climate change hotspot (Kim, Seo, & Chen, 2019). The main recorded and projected climate changes in the area include sea and land surface warming at a faster rate than global averages, a reduction in rainfall, increasingly frequent dry periods, and the increased intensity and frequency of extreme events (heatwaves, droughts and floods) (Schleussner, Donges, Donner, & Schellnhuber, 2016). *Climate change will impact the functioning of all components of the Mediterranean biome,* including both managed and natural habitats, with cascading impacts on people's quality of life. For example, Mediterranean marine species have been shifting their distribution, migration patterns, seasonal activities, abundances, growth and mortality rates, and trophic interactions in response to climate change disturbances (i.e., sea-level rise, increasing water temperature and acidification, coastal erosion) (Adloff et al., 2015; Pagès-Escolà et al., 2018). Climate change also influences coastal ecosystems through sea-level rise, which can cause coastal flooding, shoreline retreat, and coastal squeeze, affecting coastal wetlands and leaving no available space for coastal ecosystems. Forest ecosystems are also affected by increases in the occurrence of extreme temperature events and droughts (Gouveia, Trigo, Beguería, & Vicente-Serrano, 2017) with expected changes on plant phenology (Settele et al., 2015), increase in species mortality and defoliation (Linares, Taïqui, & Camarero, 2011), and increase in fire risks, including extreme fire events (or "megafires") (Ruffault, Moron, Trigo, & Curt, 2016). The coupled effect of warming and drought is expected to lead to an increase in aridity and the subsequent desertification of many Mediterranean land ecosystems (Linares et al., 2011).

Interlinkages between climate change and other threats in the Mediterranean

Climate change impacts co-occur and interact with other anthropogenic drivers of global change, resulting in synergistic effects, cascading effects, and abrupt and irreversible thresholds of social-ecological change. These potential interacting effects may affect not only the maintenance of biodiversity and climate stability but human livelihoods and wellbeing (Cramer et al., 2018). For example, climate change renders marine ecosystems more vulnerable to overfishing, natural hazards, and biological invasions (Micheli et al., 2013). The responses of the biophysical system to multiple drivers will ultimately have significant consequences for system biodiversity, functioning and productivity and hence for its overall contributions to people (Doney et al., 2012). Therefore, the impacts of climate change on the marine system and the cascading effects on social-ecological systems cannot be evaluated in isolation. Such evaluation needs a careful consideration of the interactions between such impacts and other drivers of change. The synergistic effects of combined pressures are also evident in Mediterranean landscapes. For example, while the greater incidence of drought due to climate change is a threat for agriculture in Mediterranean areas (CIHEAM, 2009), the impacts of drought on agriculture are aggravated by the increased water demand of industrial uses, growing urban popu-

lations, and critical reduction of groundwater levels resulting from generalised access to groundwater for irrigation (e.g., Custodio et al., 2016). Similarly, fire regime changes and the occurrence of megafires are related to increased drought due to climate change but also to land use change, the relative importance of each driver being difficult to disentangle (Ruffault et al., 2016).

The interactions between different drivers of change not only affect the maintenance of biodiversity and climate stability, *but also people's quality of life.* For example, intense precipitation events due to climate change will aggravate existing soil erosion on heavily intensified agricultural areas or on overgrazed grasslands, thus diminishing services provided by soils (Sirami et al., 2010). Climate change can also aggravate social change processes. For example, the growing urbanisation trend that has depopulated rural areas has been accelerated by climate change as seen in the drought-driven rural exodus observed in Morocco between 1980 and 1990 and in Algeria and Tunisia in 1999 (García-Nieto et al., 2018). In this context, agriculture, husbandry and forestry activities are abandoned or developed by fewer hands, which can further result in the dismantling of collective resource management institutions (Albizua, Corbera, & Pascual, 2019). The increase in average temperature and more recurrent droughts, coupled with growing urban populations, may significantly impact many other aspects of human wellbeing, including health (Linares et al., 2020) or social conflicts (e.g., Schleussner et al., lead to 2016). The inextricable links of the Mediterranean socio-ecosystem with other regions/socio-ecosystems of the world might also entail cascading effects across socio-spatial scales, and particularly climate-driven human migration (Cattaneo et al., 2019).

Governing the Mediterranean social-ecological system in a climate change context

Understanding trends in the Mediterranean social-ecosystem and managing them in a context of uncertainty requires a pan-Mediterranean, integrative approach based in inter- and transdisciplinary knowledge and the enlargement of the governance space.

The combined pressure of different environmental and anthropogenic threats makes the Mediterranean Basin a particularly vulnerable region, now and in the future. However, most climate change adaptation and mitigation *measures have so far been sectoral.* For example, governments from North African countries that suffer from high inter-annual water variability have built dams and reservoirs, which have facilitated agricultural intensification but eventually amplified, rather than mitigated, water scarcity. These types of water management responses make it possible to cope temporarily with the pressures of global change but may transfer pressures to other sub-regions, sectors, or scales (Bonté et al., 2019), eventually resulting in maladaptive outcomes. This also applies to the strategies for climate change adaptation and mitigation of cities that would also improve the health and well-being of citizens. An urban example would be taking into account the often compact and space-limited availability for green spaces of Mediterranean cities in rethinking the design of urban green in-

frastructure to fairly provide temperature regulation, water retention and air quality across different city areas (Baró, Calderón-Argelich, Langemeyer, & Connolly, 2019; Delgado-Capel & Cariñanos, 2020). Similarly, sectoral climate mitigation measures that do not consider consequences in the social-ecological system where they take place, such as tree planting in grasslands and savannas as a carbon sequestration measure, can have unintended consequences, such as increased land conflicts or underground water shortages (Jackson et al., 2005). Therefore, it is important to consider that any climate mitigation or adaptation strategy becomes, in fact, a process that may result in economic, social and ecological trade-offs for the social-ecological system (Dhénain & Barreteau, 2018). Failure to recognise the intertwining of climate change drivers and other threats to Mediterranean social-ecological systems, and their potential divergent effects on ecologies and social groups, can lead to less-than-optimal policy interventions. Transformative governance for climate action thus requires being sensitive to the interactions of environmental stressors and the unintended consequences at different social, temporal, and geographical scales. Integrated policies should simultaneously deal with aspects that are separately addressed in the policy-decision arena, from water management to energy generation, transportation, migration, housing policies, or social equity.

In considering the additive and synergistic impacts of climate change and other drivers of global environmental change, it is important to acknowledge *that impacts are not equally distributed, either geographically or socially.* In the long term, climate change will affect all life on Earth but, in the short term, climate change impacts are more pronounced in some geographical areas and more threatening for people who directly depend on nature for their livelihood or who are in situations of vulnerability with less adaptation options available (IPCC, 2014). For example, sea level rise is a major challenge for the Mediterranean Basin, with risks related to coastal flooding and shoreline retreat, for which coastal communities face larger threats than inland communities. Many climate change sensitive regions in the Mediterranean Basin are found along the southern and eastern shores, in countries with greater social vulnerability, whose adaptability may be constrained by more limited public budgets and higher average poverty (Ford et al., 2015). Acknowledging that the risk of climate impacts results from the interaction of environmental variability and hazards with the vulnerability and exposure of human and natural systems is particularly important in the Mediterranean Basin, where two economically and socially contrasting regions co-exist. Consequently, the Mediterranean social-ecological systems will benefit from adopting a pan-Mediterranean governance approach, with the climate-biodiversity-society nexus as a unifying theme.

Given the complexity of the task, *there is a need for transdisciplinary approaches, involving the co-production of new knowledge drawing from different scientific disciplines and knowledge systems.* Collaboration among climate, natural and social sciences and the humanities is needed to disentangle complex interactions between climate, environment, and society in the past and future. For example, while the impacts of climate change on water resources and management are widely recognised, existing initiatives to systematise knowledge about such impacts on the ensuing policy responses have mostly focused on the

hydro morphological and biophysical processes involved. A similarly ambitious effort on the social, political, and cultural facets of water management is urgently needed (Grizzetti, Lanzanova, Liquete, Reynaud, & Cardoso, 2016), in which the humanities could also play an important role (e.g., (McNeill, 1992).

Transdisciplinary approaches should also include insights from different knowledge systems. Adapting to climate hazards has long been part of farming practices in many Mediterranean societies, which have developed strategies of adaptation to erratic rainfall or hot summers, by for example growing drought-tolerant crops (e.g., pulses, olives, grapes, almonds), practising transhumance, and adopting water harvesting techniques (e.g., Belhadj Elmehdi, Remini, Rezzoug, & Hamoudi, 2020). Such strategies are important per se but also because they could contribute to developing new adaptive solutions when complementing scientific knowledge (Tengö, Brondizio, Elmqvist, Malmer, & Spierenburg, 2014). The potential for bridging these knowledge systems has been highlighted, for example, for Mediterranean agroecological food production (Aguilera et al., 2020; Migliorini, Gkisakis, Gonzalvez, Raigón, & Bàrberi, 2018). Agroecology offers a holistic framework enabling the recovery and assessment of traditional knowledge and the co-creation of new local knowledge for enhancing resilience. It also highlights the role of the reconnection of food production and consumption, associated with the recovery of the locally adapted, largely plant-based Mediterranean diet (Aguilera et al., 2020). Other aspects could benefit from a similar approach.

Conclusion

Climate change and other drivers of global environmental change will increasingly influence and determine the evolution of complex social-ecological systems. This is true in most parts of the world, but of clear relevance in the Mediterranean region due to the intense long-term human imprint on the environment. Climate change, biodiversity loss and diverse forms of resource degradation (e.g., atmospheric, water and soil pollution, land erosion) intersect to affect the ecologies and the economic, political and social fabric of Mediterranean societies. The interactions of climate change with these other drivers of environmental change in the evolution of complex land and seascapes imply that issue-focused research may not be able to capture synergistic impacts and subsequently devise adequate policy interventions. From a policy perspective, it becomes paramount to identify policies and activities that can address the root causes of environmental change, ameliorate the latter's negative effects on social-ecological systems, and do so guaranteeing human wellbeing and good quality of life.

Being aware that climate change is part of a broader process of global environmental transformations and impacts and the need to ensure human wellbeing justifies the establishment of pan-Mediterranean research efforts that involve diverse institutions and are sensitive to multiple disciplines and forms of knowledge. Enhancing the co-production of knowledge across scientific disciplines and knowledge systems is thus a prerequisite for the design of sound policies that consider the complexities of the climate-biodiversity-society nexus. Such efforts could also serve as inspiration for other world regions also experiencing multiple environmental threats and sharing a history of ecological, social, and cultural adaptations.

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The Socioeconomic Impacts of Climate Change on Water, Agriculture and Food in the Countries of the Mediterranean Basin

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The countries of the Mediterranean Basin share a very attractive geographical area, with high population density, rich in activities and full of history, which since antiquity has been an important place of exchanges.

This crossroads of civilisations, a maritime zone surrounded by three continents, has marked humankind since time immemorial. Logically, the population concentration is dense and the economic activities are many. This socioeconomic dimension symbolises both the richness to produce and also increasingly more demanded resources.

The countries of the Mediterranean Basin were home to over 542 million people in 2020, a number that is expected to rise to 657 million by 2050. The Mediterranean population living in the southern countries accounted for 46.3% in 2020, and should reach 55.5% by 2050 (UN DESA, 2019). This demographic momentum is inevitable.

The climate change predicted for decades and discussed for years with its unfavourable effects is now beyond doubt. Socioeconomic changes will affect people, their needs, their wealth and their wellbeing. We will focus our analysis on staple goods, i.e. water, food and agricultural products. These basic elements are essential for the survival of much of the population around the Mediterranean Basin.

Climate change is linked to global warming and is mainly reflected in a rise in the average temperatures observed. This global phenomenon results in more intense and longer heat waves, a decrease in rainfall, a displacement of rain zones, and a growing acidification of the sea, which affects the biodiversity of species and the disruption of the fishery cycle. Certainly, other climate phenomena can appear, but we will only consider those with a direct impact on the three aforementioned elements: water, food and agriculture.

Among the economic sectors most impacted by these phenomena, we will look at the primary sectors: agriculture and fisheries. They are the most useful for many parts of the populations, notably the middle and disadvantaged classes, clearly concentrated in the Southern and Eastern Mediterranean Countries (SEMCs). In the SEMCs, i.e. 60% of the Mediterranean population, the agricultural sector employs 34% of the total workforce (Rastoin, 2008).

We will first address the water sector and then the agriculture sector before discussing the food sector, which in its turn depends on agriculture, fisheries and their derivatives.

The impact of climate change on water resources

A decrease of the average flow of the water courses from 12% to 35% in global warming of 1.5 °C to 3 °C is expected (Marx et al., 2018). These negative trends can be accompanied by increased flash floods, causing both human and economic losses (Llasat et al., 2016). As an example, the south of France is regularly hit. The last episode occurred in October 2020 when the Tinée Valley was completely ravaged and some villages were swept away.

The management of water resources on the Mediterranean shore is facing several challenges because of variable

rainfall regimes and the strong demand for irrigation (Iglesias et al., 2011). It is expected that the future climate in this region will change towards warmer and drier conditions, diminishing the water resources available (Collins et al., 2013; García-Ruiz et al., 2011; Kovats et al., 2014). Such changes both in rainfall and air temperature modify the use of the lands concerned and may pose new challenges for water management, all the more so since this region is already suffering from water stress (Iglesias et al., 2011).

The socioeconomic fallouts of water availability should be analysed both from the supply and demand side. We are witnessing both a decline in the amount of freshwater available and an exponential rise in the demand for irrigation, grazing and human needs. This demand is increasing above all in Southern Mediterranean Countries (SMCs), by 1.5% annually in North Africa, Jordan and Turkey, and 2.5% in Greece (Chohin-Kupet et. al., 2014). This situation leads in the long term to the scarcity of resources available, the rise in their prices, and also lower quality. Most future scenarios confirm the diminished supply faced with an increasingly higher demand (João Pedro Nunes et al., 2017).

The impact of climate change on water supply is therefore very certain. This decline is related to a demographic momentum among the countries in the MENA (Middle East and North Africa) region. In 2020 this population accounted for 464 million inhabitants, i.e. 5.4% of the world population, and will reach approximately 660 million inhabitants by 2050, i.e. 6.8% of the world population. It is characterised by a high fertility rate (Guerraoui & Tamer, 2020). This dual pressure will have disastrous consequences for people but also for their economic conditions, notably for the populations that directly depend on rain-fed crops.

According to World Bank estimates, the part of GDP and population exposed to a high or very high water stress in the countries of the MENA region is 71% and 61%, respectively, compared to 22% and 36% in the world (World Bank, 2018). According to Plan Bleu data, "three countries alone, France, Italy and Turkey, receive half of the total rainfall, while southern countries only receive a tenth" (Plan Bleu, n.d.).

Tensions over water are also expected to worsen from the demand side. The most significant factors are the demographic growth in the South and the East, the development of mass and barely sustainable tourism, industry and irrigated lands. Also according to Plan Bleu data, "the Mediterranean brings together 60% of the world's so-called 'water poor' population, probably with less than 1,000 m3/year" (Plan Bleu, n.d.). These populations are expected to increase from 180 million people today to over 250 million in 20 years. Several North African countries (Tunisia, Algeria and Libya) are below the water scarcity threshold established by the Food and Agriculture Organization of the United Nations (FAO), while others (Morocco) are below the severe water stress threshold.

In the Mediterranean, rain-fed crops (which are significant in all countries) are more exposed to climate risks because of the rainfall reductions expected, while in many coastal areas the quality of the water for irrigation is already weak because of the penetration of sea water in coastal aquifers. All the

more since irrigation absorbs an average of 60% of the total water used, and 82% in the Southern Mediterranean (Plan Bleu, n.d.).

Most research on future water availability in the Mediterranean has focused on the impacts of climate change, first addressing the quantitative aspect (Garrote et al., 2016; Iglesias et al., 2011). In general, these studies have stressed the decrease in water availability, a greater seasonal contrast between wet and dry seasons. Patterns have also been used to examine the impacts of climate change on arable land (Buendia et al., 2016; Rodriguez-Lloveras et al., 2015). Few studies have looked at the future changes in water quality in the supply infrastructures in the Mediterranean region. Studies such as the one by Garrote et al. (2016) have integrated in their analyses the different types of water supply systems (small reservoirs, integrated reservoir networks, aquifers...), different types of water use (irrigation, domestic or industrial consumption, production of hydroelectricity...), and specific environments (climate, geology…) to assess the common trends and future challenges.

We can therefore conclude this first section by asserting the negative consequences of climate change on the quantity of freshwater resources, both their value and quality. This situation involves an evolution of the water management system. From the supply side, an adaptation of the infrastructures and a redistribution without waste will be indispensable; from the demand side, the consumption model is bound to evolve, mainly the farming and livestock components, which must adapt or disappear. Some service activities, such as tourism, very water dependent, should evolve towards more sustainability in order to survive. An awareness-raising programme of the populations for reduced consumption, waste water treatment as well as recycling in given situations will be necessary. These evolutions, which go in the right direction, are not automatic, certain or identical in the countries concerned. The creation of a Mediterranean agency to promote adapted strategies, informed advice, and specific coordinated actions is recommended.

The impact of climate change on agriculture

Climate change has a dual impact on the agriculture sector. On the one hand, the rise in temperatures modifies the needs for irrigation as well as the productivity of agricultural lands in particular in arid and semi-arid environments; on the other, water resources, necessary for the maintenance of crops, are negatively affected, as we have just seen.

As a response to the changes in the scarcity and, therefore, value of water, users react by changing their water use and allocation habits. They choose an optimal farming model to adapt to the growing scarcity of water and the higher temperatures induced by climate change (Mohammad Aghapour Sabbaghi et al., 2020).

Such a change leads to replacing cereals and pastures with other less water-demanding crops, such as sorghum, which is gradually replacing corn, which requires a lot of water and is less resistant to a rise in temperatures. This adaptation will necessarily impact the average income level of the communities concerned. The level of nutritional intake of the new crops is lower, as is the selling price in relation to the in-

itial crops. Thus, the farming population is directly and indirectly affected by these decreases.

Another impact of climate change on the agriculture sector concerns the extension of the length of the growing period of some species, for example wheat (Waha, 2017). Climate change can also influence the flowering date, which has an impact on the reception of the pollen for fecundation. It therefore determines the quantity produced of certain agricultural products, for instance the apple cultivars (Funes, 2016). These events entail a drop in volume of the productivity of arable lands, but also in value.

Uncertainties concerning the schedule, duration, intensity and interval between extreme climate events subject these sectors to a higher risk in the Mediterranean region while impacting the throughput expected in the short and long term but also investment and therefore productivity in the long term (Kutiel, 2019). The three elements – uncertainties, productivity and investment – are closely related.

In a more targeted way, low rainfalls and lack of water for irrigation make the region very vulnerable to climate change. Agriculture in the MENA region of the Mediterranean Basin is particularly exposed to climate change because it strongly depends on irrigation due to the very dry weather. In Egypt, all arable land is irrigated. The other southern and eastern countries, such as Israel and Algeria, also have very high percentages of irrigated land (FAO, 2018). The limited water supply in the MENA region is a disadvantageous and aggravating element. The importance of the agriculture sector both in terms of GDP and employment increases the exposure of the populations and the economies of the SMCs to the impacts of climate change. The agricultural sector is important for most Mediterranean economies as it accounted on average for 6.7% of their GDP in 2016 and employs 6% of the labour force in European Union countries and 34% in SEMCs (Kutiel, 2019).

Water stress in the southern countries can largely be attributed to the growing demand of agriculture, with a potential water deficit between 28% and 47% by 2030. Water scarcity and the strong dependence in terms of agriculture, related to high needs in rain irrigation, make the countries in the MENA region vulnerable to warming and rainfall reduction (World Bank, 2018).

Given that the countries in the MENA region are net importers of food products, they are certainly threatened by the impacts of climate change on national agricultural production, the purchasing power of the populations concerned, and the survival of fragile agricultural enterprises. However, they are also threatened at the level of their capacity to access external agricultural resources.

This threat lies in the incapacity of certain countries with a median or low income to provide the necessary financial means for the imports of the products their populations lack. The growing pressure on their foreign exchange reserves leads to a scarcity of the staple products, linked to a rise in prices. The social consequences are and will continue to be terrible. The drop in income along with limited access to staple goods will create a feeling of poverty. Social tensions are exacerbated and political stability will be comprised.

The frequent social uprisings, related to political instability, will increase the country risk in part of the MENA region. Domestic and foreign investments dwindle, compromising both present and future growth. We stress that all social uprisings in both northern countries (France, Italy, Spain, Greece) and southern countries (Morocco, Algeria, Tunisia, Libya, Egypt, Syria, Iraq, Jordan, Lebanon and Yemen) are related to a loss of purchasing power, notably in weak areas. Despite the importance of political, i.e. geopolitical, factors, in the wake of the Arab Spring, the social components are significant.

We can therefore conclude this second section by highlighting the negative consequences of climate change on the quantity and also quality of agricultural products suffering both the drop in rainfall and the rise in temperatures. Agricultural enterprises will also experience a drop in their productivity. This quantitative and qualitative drop in the agricultural supply comes with a growing demand nourished by a demographic momentum, notably in southern countries. Like water resources, an adaptation of the supply and demand is unavoidable to attenuate the pressure. These evolutions are indispensable to reduce the economic, social and political tensions in the countries concerned. The presence of a Mediterranean agency, capable of encouraging, guiding and supporting the countries affected, would be a great asset.

The impact of climate change on food

Along with agricultural and livestock products, negatively affected by the hazards of climate changes, the fishery sector also experiences a growing pressure. These major components of human food will suffer increasing stress from both the supply and demand side.

Approximately 78% of the fish stocks in the Mediterranean are currently caught at unsustainable levels (Galli et al., 2015). Almost half the catches are of small pelagic species (anchovies, sardines, herrings), which are very vulnerable to the rising sea water temperature (FAOSTAT, 2019). The economic value of fisheries in the Mediterranean Sea is estimated at over 3 billion dollars (Randone et al., 2017). The sector employs around 227,000 fishermen, 63% of whom are in Morocco and Egypt (Blasiak et al., 2017). The vulnerability of the fishery sector to the hazards of climate change (decline of stocks and reduction of the average weight of the fish caught) is also seen in Turkey (Hidalgo et al., 2018). The vulnerability stresses food security disrupted by the repercussions of climate changes on marine fisheries. The classifications of 109 countries in the study depend on a set of criteria that highlight the contribution of fisheries to national food and nutritional security. Hence fishing in the northern countries is less vulnerable because it has a greater capacity for adaptation, while southern countries are more vulnerable (Ding et al., 2017).

The fishery sector like the agriculture sector suffers a double pressure, from both the supply and demand side. Climate change is a negative exogenous shock on the supply side faced with a growing demand. It concerns the needs of local, often poor, communities, and the needs of the rest of the population. Fish is considered both a nutritional and healthy product. This dual constraint from the supply and demand side leads to a decline in the

quantity exchanged and a rise in the average price applied, both in northern and southern countries.

The reduction of the availability of fish can directly decrease the income of the industrialists and people working in the fishery industry (Tulone et al., 2020). However, the rise in prices could compensate a part of the industrialists' losses, or completely in some sectors. In contrast, employment in the fishery sector can only be scaled down. The decrease of fish availability, the growing robotisation and integration of new technologies lead to the destruction of jobs. Climate change is therefore a factor that accelerates the deterioration of employment in the fishery sector and the impoverishment of the fishermen community.

The economic and social impact is broadened by the decrease in the quantity of food from the sea, as well as the soil from the agriculture and livestock sectors. The trends are identical. The decrease in quantitative performance, along with a rise in the unit price of food products, leads to the exclusion of the most disadvantaged population and to the decrease in the consumption of other categories. The latter will experience both a decrease in purchasing power, which will have an impact on their wellbeing, but also a decrease in nutritional intakes, which will have an impact on their physical health. The double trouble will feed the economic and social tensions in the short and medium term before leading to inevitable political instability in the long term.

As for the livestock sector, it is a major source of human food. This sector experiences a rising demand linked both to demographic growth and also the increase of consumption per inhabitant among certain privileged urban categories. On the supply side, the increase of agricultural production, seen in recent years, over 25% in the MENA region between 1993 and 2013, feeds the demand for animal food (FAOSTAT, 2019). This demand puts pressure on domestic arable lands to provide for human food needs. This dual pressure is broadened by climate change, which affects both the natural conditions of the agriculture and livestock sector, including the decrease in water resources.

Faced with a growing population and insufficient domestic food production, the increased food imports of the MENA region, both for animals and humans, has become a reality. In 2014 the imports of animal food already accounted for approximately 32% of overall food imports (FAO, 2018), which also illustrates the dependence on imports of the southern countries, where arable land is threatened by the impacts of climate change (Houllier F., INRA, 2015).

However, these imports are not unlimited. The heavy increases in international food prices since 2007 have already broadened the commercial deficits, the budgetary pressure, and the external debt of some states. The inability to provide the necessary resources in foreign exchange to meet the growing, i.e. exponential, food imports due to climate change, the increased poverty as well as social and political instability will be inevitable in the coming years (Paciello, 2015).

Conclusion

Regional food production is seriously threatened by climate change. The re-

sources necessary for this production – water, fisheries, agriculture and livestock – are suffering a negative and significant shock of supply. This specific decrease is broadened by an effect of complementariness between water, arable land and livestock. The fishery sector is independent of the other sectors at the level of production, but is considered replaceable by agricultural and livestock products. This phenomenon of interdependence accelerates the downward dynamic of food production and broadens the negative effects of climate change.

Climate change has a direct and indirect downward impact on the quantities produced, be they of agricultural, animal or water origin. In its turn, the demand is supported by the important demographic momentum in the SMECs, and the upward trend of food prices in the long term is inevitable. Access to food will diminish for the most fragile populations, those who suffer both a decrease in their current income due to the disruption of their economic activity but also a reduction in their purchasing power due to the increase in prices of food products.

The social consequences are broadened faced with the incapacity of some states to provide the resources necessary to directly or indirectly support the populations concerned. The deterioration of their living conditions will feed the political tensions in these countries in a first stage and later favour the migration flows towards the countries least affected. However, the countries on the western shore, notably European, are less concerned by the aforementioned elements but will suffer in full force the social and political consequences through uncontrolled migration flows. This process is already seen with the political crises related to the Arab Spring and will be exacerbated with the expected consequences of climate change.

The implementation of cooperative bodies and mechanisms is essential for a return to food balance through the sharing of competences, know-how and successful experiences. It is useful for a better economic and social management of the consequences observed related to climate change. The need for a Mediterranean agency is paramount to create channels of dialogue and a better control of the inherent risks. The institutions, cooperation projects and meetings held since the start of the Barcelona Process make up an environment rich in useful experiences and competences.

The collective perception of climate risks must be taken into account on a regional, i.e. international, scale and not only on a national scale. The economic, cultural and historical closeness of the countries in the Mediterranean Basin demands a high level of accountability and a more coordinated cooperation to better manage the socioeconomic impacts of climate change on food security and its determining factors.

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Challenges and Shortcomings of Assessing the Socioeconomic Impacts of Climate Change – The Case of the Mediterranean

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Introduction

Climate change is a major global challenge affecting the environment and presenting challenges for human well-being. By approaching planetary tipping points, societies put enormous pressure on environmental boundaries and ecological resilience and the socioeconomic systems of current and future generations.

Climate change impact research usually deals with the detrimental effects of climate change for human societies or the so-called "damaging climate change" (Richardson et al., 2011a). The analysis often includes sectors such as agriculture and food security, water resources, human health, disasters and hazards, security issues, energy, transport, and others (Richardson et al., 2011a; Ciscar et al., 2018). Regional or local studies provide important new evidence of specific impact areas important for regional development such as tourism and socioeconomic impacts on coastal zones such as in the Mediterranean region (Perry, 2003; Georgas, 2003). The analysis of climate change impacts for the Mediterranean is rich, including specific reports for separate countries (e.g., Galeotti, 2020; Woetzel et al., 2020; Varela-Ortega et al., 2013; Galeotti & Roson, 2012; CCISC, 2011; Rosato & Giupponi, 2003, among others).

The assessment of the socioeconomic impacts of climate change is complicated by the complexity of the climate-environment-human interactions, which renders the attribution of impacts solely to climate change nearly impossible. Nevertheless, such assessments are crucial to predict future anthropogenic impacts and even more to develop suitable policy responses to these changes that help mitigate negative environmental and socioeconomic impacts.

Socioeconomic assessments in the climate change literature range from global to regional, national, or local, from highly integrated ones that include various impacts and manifold factors to in-depth studies that consider specific impacts and settings (economic sector, geographic location, societal choices, etc.).

The purpose of the assessment defines the impacts addressed and the scale of analysis. The same is true for the adapted methodology. The studies that aim to inform policy and decision-making rely on quantitative approaches that allow estimation of costs and benefits in relation to specific policy decisions. However, the complex nature of climate change and its impacts expressed in quantifiable terms poses various challenges to the methodological approaches: high uncertainty, heterogeneous regional socioeconomic conditions, and difficulties in accommodating long-term perspectives, to name but a few. At the same time, decision-makers need accurate estimates to implement specific policy solutions at all levels.

The Mediterranean region is highly susceptible to the risk of climate change impacts due to water scarcity, concentration of economic activities in coastal areas, and reliance on climate-sensitive agriculture. Further, the Mediterranean region undergoes intensive demographic, social, cultural, economic, environmental and climate changes (EEA, 2014; Cramer et al., 2018). Population increase in combination with the fast growth of coastal urban hubs generates multiple environmental pressures that stem from increased demand for water and energy resources, air and water pollution related to wastewater discharge and sewage

overflows, waste generation, land consumption, and degradation of habitats, landscapes, and coastlines (MedECC, 2020). Those pressures are further amplified by the development of tourism, often concentrated in Mediterranean coastal areas.

Here, we discuss the most pressing methodological issues and potential solutions that can improve the assessments of the socioeconomic impacts of climate change. We specifically consider the importance of such assessments supporting regional and local decision-making with the Mediterranean region as a good example. We focus on an extensive literature review and connect various disciplines and approaches. First, we offer a brief review of major issues within methodological aspects applied to the assessments of socioeconomic impacts of climate change. We then tackle the specific challenge of socioeconomic data availability. Finally, we discuss possibilities and opportunities to adapt relevant data and related impact assessments to specific needs of various stakeholders in order to strengthen their ability to come up with active solutions related to climate change.

Methodological approaches and challenges of climate change socioeconomic impact assessments

The 5th and 6th Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC) incorporate a methodology that represents the complexity of climate change and interlink biophysical changes with related socioeconomic impacts (IPCC, 2014a); IPCC, 2022. Integrated Assessment Modelling (IAM), the core of this approach, deals with the socioeconomic impacts of climate change by including economic costs of climate change and the social welfare function in the analysis (Dell et al., 2014) for a set of the Shared Socioeconomic Pathways (SSPs). SSPs are qualitative socioeconomic scenarios, an approach to deal with uncertain futures, linked to the Representative Concentration Pathways integrated into the climate change part of the IAMs (IPCC, 2014b; van Beek et al., 2020). IAM application has the potential to visualise multiple futures under various policy options and to integrate assessments of impacts and costs in one modelling framework (van Beek et al., 2020). At the same time, improved policy projections, comprehension of usefulness and comparability between model outcomes are jeopardised by the application of too many different integrated assessment models and the lack of documentation of choice of the numerical input values for the scenarios (Rosen, 2021). Within our review we address critical issues with the most crucial implications for supporting regional and national integrative studies and projections related to climate change socioeconomic impacts.

First, it is important to consider the scale and global nature of the IPCC studies and scenarios used for such assessments. It is widely recognised that there is a knowledge gap between global aspects of climate change and the impacts on human and natural systems that occur at regional spatial scales. The global scale of analysis informs the international community and policymakers at the national level of the possible climate change impacts and costs of no action. Nevertheless, global assessments and approaches reach their limits when specific regional or national

decisions on climate change policies or actions have to be made. The decisions on actions to reach the targets set within international frameworks like the United Nations Framework Convention on Climate Change (UNFCCC) are taken at the level of national governments. Solutions that support specific mitigation and adaptation efforts require much more targeted assessments, disaggregated for specific regions, countries and, in some cases, even sub-national entities as environmental impacts of climate change are unevenly distributed between and within various regions and countries. Additionally, the socioeconomic consequences are quite different for various population groups due to the equity challenge and related variance in climate change vulnerability (IPCC, 2014b; IPCC, 2022 Richardson et al., 2011b; Nazrul Islam & Winkel, 2017).

This is obvious for the Mediterranean Basin characterised by complexity and inhomogeneity in terms of climate and environment but also culture and socioeconomics (MedECC, 2020). On top of that, the rates of climate and environmental changes in the Mediterranean exceed global mean values (Cramer et al., 2018; IPCC 2021). Approaches to downscale and adapt the global assessments for regional or country use have often been applied. Examples of such projects for Europe include both integrative assessments that use the logic of the IAM application from the global IPCC reports and more sectoral assessments and analyses (e.g., Feyen et al., 2020; COACCH, 2019; Harrison et al., 2013). The latest major efforts of extensive and systematic multidisciplinary analysis of development and climate and environmental change in the Mediterranean, missing in earlier reports, are based on existing findings and assessment results, including those based on IAM (MedECC, 2020; UNEP/MAP & Plan Bleu, 2020), and do not clearly overcome the existing challenges of integrative assessments. Although the aim is to serve as a "'bridge' between the global and the national to local scale" (MedECC, 2020), their aggregated nature may still complicate application at national and local levels.

It is crucial to consider the methodological challenges of downscaling global scenarios to regional and national and local scales. Retaining consistent scenarios at various scales may be achieved by facilitating consensus among researchers on the downscaling method and developing "sanctioned regional scenarios" that can be consistently used within regional and local studies (O'Neill et al., 2020); extending the storylines for a specific region using such elements as factors (e.g., demographics, technology, land use, etc.), actors (e.g., civil society, private actors, etc.), and sectors (e.g., energy, agriculture, etc.) (Absar & Preston, 2015); Sillmann et et al. 2021.

The urgent need to provide a rich socioeconomic context for regional to national and local scales is closely related to the second critical point of IAM, namely the lack of consideration of social science perspectives within the scenarios (van Beek et al., 2020; O'Neill et al., 2020; Otto et al., 2020; Absar and Preston, 2015). This is a serious limitation due to the paramount importance of social contexts, values, and perceptions when climate change vulnerability, adaptation, and acceptance of mitigation actions are considered (Klein, 2003; Otto et al., 2020; Donges et al., 2020). It is, thus, especially disadvantageous that IAM scenarios are externally chosen by researchers and are not based on population behaviour (Otto et al., 2020). Otto et al.

(2020) suggest engaging the concepts involving human agency that are different from the rationality concept used within IAM based on welfare maximisation assumptions, with several implications. Socioeconomic assessments need in-depth research and qualitative data to cover the behavioural aspects and perceptions at various scales. Further studies are required to support the transformation of this data into indicators that could be used in a meaningful way within integrated studies (Tol et al., 2003). Certain steps have already been taken in the direction of adjusting the existing frameworks to incorporate issues such as behavioural and interaction patterns (Riahi et al., 2017) and effort sharing regimes (van den Berg et al., 2020). Values and beliefs, as well as risk perceptions and their impacts on the outcomes of various policy instruments, have also been analysed in the context of some Mediterranean countries (e.g., TRANSrisk, 2017; Kontogianni et al., 2013). An interesting approach to introduce the behavioural patterns into macro-economic analysis could be by combining the strengths of Agent-Based Modelling with Computable General Equilibrium models (Niamir et al., 2020). Another possibility to incorporate social aspects is a bottom-up approach to scenario development, which implies engagement of various stakeholders into the formulation of socioeconomic climate change scenarios and related storylines (e.g., Raudsepp-Hearne et al., 2020; Harrison et al., 2013). The stakeholder involvement in scenario development would allow more actors to be linked to the process of impact assessment, thus potentially increasing the applicability of assessment outcomes to a wider range of decision-makers.

Finally, we should consider multiple knowledge gaps related to various aspects critical for accurate integrated assessments. Underlying mechanisms for many processes and relationships that are used within IAM approaches are not established, well justified, and/or empirically founded. Empirical knowledge and approaches to link it to IAM are lacking, for example, in fields such as climate change vulnerability and adaptation (O'Neill et al., 2020; Onofri & Nunes, 2020; Dell et al., 2014; Klein, 2003) and cross-border effects, such as international trade (Woetzel et al., 2020; O'Neill et al., 2020; Challinor et al., 2017; Dell et al., 2014) and migration (Flavell et al., 2020; Dell et al., 2014).

An important type of assessment studies investigates and assesses the socioeconomic effects of climate variations. This research primarily uses panel methodologies with extensive climate series, including for instance temperature, precipitation, and other climate variables, to investigate how variability and change including extremes, affect certain economic outcomes (Dell et al., 2014). Such studies are made in several important socioeconomic areas such as agriculture, industry, labour productivity, health, energy, conflict and political stability, crime, and aggression (Dell et al., 2014). Empirically founded knowledge about statistically significant effects of increased temperatures, variable precipitation, and weather shocks on, for example, agricultural output, energy demand, etc. can inform the actors at all levels of decision-making. In addition, this information can improve IAM by supporting the calibration of the damage function representing the costs of climate change and providing empirically-based values for the function parameters (Dell et al., 2014).

These assessments, however, demonstrate certain gaps similar to the aforementioned IAM approaches. Studies that provide better understanding of

underlying mechanisms for certain processes and of specific interrelations between the weather variables and socioeconomic outcomes can greatly improve the accuracy of such socioeconomic analyses. Other methodological challenges consider various social science aspects relevant to climate change adaptation and mitigation. Although certain attempts have been made to represent social parameters in these types of studies (Burke & Emerick, 2016; Dell et al., 2014), the indicators or proxies that can best reflect and represent sociological categories as values, beliefs and expectations are not yet established.

We would like to emphasise the importance of local and regional case studies in addressing many of the gaps mentioned above. An extensive body of literature offers analyses of climate change impacts and provides a detailed view of certain specific socioeconomic aspects, thus, not necessarily using the framework of integrative studies or IAM. Although the implemented methodologies are too heterogeneous to introduce the results in an integrative framework, such studies provide in-depth views of various mechanisms behind climate change processes, consequences, mitigation, etc. They might present empirical evidence that can modify the approaches of scenario development process and related assessments. For example, effects of climate change for the agricultural sector within IAM have usually been considering quantities of agricultural output. However, studies show that not only the quantity but also the quality of yields, nutrient content, and micronutrients can be diminished by the environmental impacts of changing climate (Fischer et al., 2019). Yield quality plays an important role in the price of agricultural produce, and such empirical evidence complements the modelling set-up substantially by improving the realistic representation of potential future impacts (e.g. Toreti et al. 2020). Another aspect within the same example is the impact on the quality of human nutrition with consequences for public health.

Data requirements and applicability of regional socioeconomic assessments

Lack of empirical evidence in socioeconomic areas affected by climate change underpins the discussion about data requirements for socioeconomic assessments. Many integrated studies base their analysis on existing censuses containing traditional socioeconomic data collected for various purposes. In this context, the lack of data is directly related to specific aspects of climate change. For example, missing information related to windstorm damage and the vulnerability of specific sectors to windstorms for an evaluation at the European scale (Feyen et al., 2020) or systematic data related to forced and environmental migration (Flavell et al., 2020; Otto et al., 2015; Montgomery, 2008). Identifying the key variables currently missing that should be considered in the context of climate change impacts is a central task of research. Further, databases that combine socioeconomic and environmental data might facilitate the future development of socioeconomic assessments and their applicability and thus usefulness at various levels.

Another research topic is the appropriate approaches to data collection in order to gather country-wide comprehensive information. Such approaches, at the national level, often differ from country to country, making data comparability problematic. In addition, environmental

changes are related to geo-ecological units rather than administrative regions (Otto et al., 2015) and therefore country aggregated socioeconomic data can limit the applicability of assessment results at the local level. The collection of socioeconomic data at higher than national resolution allows for a better adjustment to environmental data, which is usually provided at a fine grid (Otto et al., 2015). Consensus among countries on standardisation approaches to data collection is therefore necessary. In addition, downscaled climate projections used for integrated assessments should be better linked to national and local projected societal trends (O'Neill et al., 2020).

Finally, how could this data and the results of climate impact assessments become more useful to a wider range of decision-makers at different levels? Currently, the primary aim of such assessments is to inform the policymakers at international (e.g., IPCC, 2014a; IPCC 2022), regional (e.g., MedECC, 2020) and sometimes national levels (e.g., Galeotti & Roson, 2012). While such studies play an important role in global cooperation by ensuring that climate change goals become part of national policy agendas and that countries commit to taking appropriate action, decisions on concrete measures to achieve these goals are taken at the level of national governments and local administrations. Furthermore, the nature of climate change challenges and the need for societal transformation imply the active involvement of different stakeholders in the process of climate governance and climate change mitigation (Loorbach, 2010). This means that all these stakeholders – households, businesses, civil society, etc. – need to be well informed to understand how their actions can influence transformation towards a more sustainable future (Chess & Johnson, 2007). It is therefore very important to improve the relevance of climate impact assessments for different user groups. This can be achieved through a more inclusive scenario development process for integrated assessments that helps to incorporate perceptions of different population groups and other stakeholders (O'Neill et al., 2020). A measure to support these processes could be web-based climate change impacts and vulnerability assessment platforms for various sectors (Harrison et al., 2013) combined with useful climate information that is relevant and adapted to the needs of a wide range of decisions-makers, as well as stakeholders, from different sectors (GFCS, 2014). A further measure may relate with the World Climate Research Programme Lighthouse activity *My Climate Risk,* which will develop a framework for assessing and explaining regional climate risk to deliver climate information (observations, reanalyses, model simulations, better understanding, etc.) that is meaningful at the local scale in order to construct decision-relevant and scale relevant information (WCRP, 2020). These developments bring further challenges in terms of data collection, storage, and management.

Overall, the quality of the various climate change impact assessments and their applicability at regional, national, and local levels can be enormously improved when all the aforementioned methodological and data challenges are addressed in a systematic and coordinated manner. For the case of the Mediterranean, this underlines the importance of further collaboration between researchers studying all aspects of climate change with this geographical focus, taking into consideration the complexities, inhomogeneities and socioeconomic gradients that characterise the area.

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Evidence, Perceptions and Decisions Concerning the Environmental Crisis in the Mediterranean

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From an analytical point of view, there is very little doubt about the relevance and severity of environmental changes throughout the world and also, particularly, in the Mediterranean Basin. The increasing complexity and multidimensionality of these social, economic and environmental challenges can only be addressed through shared efforts and resources with a research and innovation approach. But it also requires a cross-understanding of the political and social processes needed to move forward. The Mediterranean is a very complex region, steeped in history and cross-flows and conflicts. A territorial space in which social and human dynamics and their effects on the environment have very significant impacts in a multitude of areas. Without trying to analyse this complex reality, we would rather outline evidence, perceptions and their potential effects on the decisions to be made and the actions to be taken in relation to the climate emergency.

Our approach starts from the social sciences and especially from the analysis and management of public policies. We will emphasise the gap that we normally find between the high consensus among specialists on the diagnosis of the problems that arise and the slowness or difficulty with which such analysis has effects on the policies that end up being promoted. The scientific agenda and the social agenda do not always coincide, either in diagnosis or timing. Logically, the specificity of the Mediterranean region, with its obvious differences in development, cultural expressions, demographic coordinates or capacities available in a relatively small geographical area, increases the effects of this dichotomy. Therefore, the concern to marry up the social agenda and the scientific-technical agenda should be part of any analysis that seeks to make decisions with the possibility of being put into practice and producing effects.

Actors and policies. A complex scenario

Problems and tensions grow in territories, as we said, replete with history and perspectives, while people's trust in the institutions that have the legal powers to intervene in them decreases. A scenario in which a very large heterogeneous and fragmented network of actors and institutions coexists, which undoubtedly complicates things when trying to implement public policies. This fragmentation reduces the possibilities of having consistent and reliable interlocutions and, at the same time, multiplies the possibilities that any decision that is made will generate negative effects on actors or groups that do not feel represented in them. On the other hand, and contrary to what we might imagine, despite the scientific and technical knowledge we include, we cannot reduce this complexity because knowledge advances precisely on the ability to deny evidence previously considered fully reliable, and therefore the arguments for or against any decision are multiplied. Finally, in this scenario, the ability to make decisions could seek shortcuts relying on decisions based more on authority than on consensus, but social evolution itself tends to consider such forms of decision less legitimate, and therefore there is a tendency to prioritise decisions that involve as many actors as possible.

Environmental problems are not usually limited to the borders that delimit the different countries, and this is obviously the case in the Mediterranean Basin.

But we must recognise that, in the same scenario, the formal statutes of the institutional actors that claim to be present in the dynamics of change cannot be ignored, and other perspectives, dynamics and processes must also be taken into account. Dynamics more focused on the capacities of the different actors to advance their projects and strategies through simultaneously exercising influence and articulating the resources that are put into play and the complicities that all achieve, both on a regional and global scale (Majone, 1989).

In this scenario, the ability to plan territorially, to intervene from positions based strictly on the hierarchy or the institutional position of the public powers or from the hypothetical superiority of scientific or technical capacities or competences, are insufficient and end up creating notable frustrations and blocking situations that do not benefit anyone in the end. Therefore, we will argue here for the need to advance in intervention guidelines more focused on the ability to create shared visions and projects with the maximum possible number of actors, perhaps less technically impeccable but more socially viable.

Implementing environmental policies in complex scenarios

The climate emergency is not the type of problem that allows an approach based only on technical certainties. And even less so when the approach to such an emergency requires the diversity of social situations and territorial spaces involved to be taken into account. The territory is a large container in which the confusion and density of interests, almost always contradictory, the networks of actors of all conditions, the different expectations of intervention of the different public and private operators, or the redundancies and overlaps of powers and controls become very visible. It is important for all of us to learn how to move the interventions in the territory forward with the appropriate technical quality criteria, but also with the ability to listen and learn from the concerns, knowledge and perspectives of the different actors present in the territorial scenario in question. If we want to advance in this perspective, what most lets us down? The available technology? The lack of knowledge of the people? A poor definition of objectives? The inability of politicians to make the right decisions? The lack of appropriate advice?

Any intervention in the public sphere must start from a definition of the problem or problems considered relevant and that merit actions that can reduce or even eliminate such disagreement between what should be and what really happens. The agreement on the problem is the first step that enables objectives of improvement to be established to later define an action plan and implement the measures considered pertinent, both technically and socially. In Table 1 we present a scheme in which we link the definition of objectives and instruments of action with the degree of agreement or consensus on them.

As we can see, only a notable consensus on both the objectives to be achieved and the measures to be implemented would allow us to follow the programming logic that we call scientific-rational. In other words, the one technically considered the most appropriate to address the issue in question. In the other cases, doubts or lack of agreement on the objectives to be achieved or on the means to be used require exploration of other avenues, negotiating, experimenting or

Table 1. Certainties and doubts in the implementation of public policies

	High level of knowledge of objectives (certainty)	Low level of knowledge of objectives (doubt)
High level of knowledge of instruments to be used (certainty)	A. Programming	B. Negotiation
Low level of knowledge of instruments to be used (doubt)	C. Experimentation	D. Social learning

Source: adapted from Thompson, F., 1959

trying to learn from one's own experience of action.

In recent years, there has been more agreement on the environmental issue between many scientific and analytical perspectives concerning the diagnosis of the problems to be addressed and the urgency with which they must be faced. Nevertheless, we can still outline reluctant or even denialist positions that are still present in the debate on the subject. But even if we accept that such positions are not very relevant at the level of the large multilateral organisations and in the most prestigious research centres, there is no doubt that the level of agreement on what to do given the serious diagnosis that arises from the whole scientific-technical literature available is not univocal. And if we project this into the scenario that we have defined as highly complex in the Mediterranean, nothing allows us to suppose that we are in quadrant A of our scheme, but rather in any of the others. And this inevitably requires more capacity for negotiation, social involvement and political consensus (Dente & Subirats, 2014).

Environmental problems: Interconnections and ability to respond

Let us consider some examples without exploring them in depth. There is a notable consensus in considering the Mediterranean as an extremely important place in terms of marine biodiversity. And everything indicates that in recent years this biodiversity has been decreasing as a result of overexploitation, climate change, habitat degradation and the inclusion of species from other places (Coll et al., 2010). Based on this finding, what would be the response paths? If one takes the reports and research in this regard as a starting point, the intervention guidelines may be more or less clear, but not the capacities and resources of the agencies and administrations involved, nor the different dependencies that each country or region in the basin has in relation to the subject.

On the other hand, among the most important effects of climate change in the Mediterranean Basin we find the issues of extreme drought and the great social impact that the rising sea level would entail in many places located on the coast. Some estimates point to the figure of 33 million people affected by significant rises in sea level. This does not imply that the affected populations should automatically abandon their current locations and seek new homes. But obviously any plan in this regard must assume the enormous task that this implies, prioritising places, mobilising resources, and creating links of consensus and trust with the affected

communities (which in many cases are not at all aware of the situation of risk in which they find themselves), etc. (Geddes, 2015).

The provision of food will continue to be one of the key issues in the debate on the climate emergency throughout the world and also in the Mediterranean Basin. It is well known that food production involves high consumption of water, energy and exploitation of the soil. If we take a global view, the "ecological footprint" of each country, that is to say, its degree of dependence on imports, in this case, the consumption of food products, can help us to determine the specific sustainability of each country and the region as a whole. The available analyses show that the region's consumption as a whole is 40% higher than its resources allow (Galli et al., 2017). It is clear that this is and will be another of the key issues when referring to environmental security in the region as a whole. Can this issue be approached from strictly environmental logics? What capacities for compensation and autonomous production would allow for improvement of the problem as we have set it out?

We can also look at the issue of tourism in this area of the world. The impact of construction on the coasts, the overexploitation of coastal resources and the large presence of cruise ships, which take advantage of the strong appeal of cities and places steeped in history, together with the benign climate, have been turning the Mediterranean into a major destination for world tourism. It is estimated that around 400 million tourists visit the different points of interest in the area, making the Mediterranean Basin the first tourist destination in the world. Instability on the southern shore has been displacing tourism towards the northern shore, but the tourism industry continues to be a central element in the overall economy. The impacts of all this in relation to environmental variables are unquestionable. The cruise industry stands out, with extensive growth, which has major environmental repercussions without contributing with the same intensity to the economy of the riparian countries, making a very visible example of lack of environmental justice (Caric & Mackelworth, 2014).

Apart from these examples, or many other possible ones, probably the best way to focus the perspectives of change in interventions related to the climate emergency in an area such as the Mediterranean would be to start from the combination of the will to intervene and a certain scepticism. The way to respond to the complexity of actors, perspectives and interests present in each "hotspot" is not by increasing specialisations and fragmentations. Specialisation creates what we could call pseudo-certainties. If you divide the problem into different components and ask different specialists to look for alternatives, or in a scenario that is too crowded with actors, you decide to examine them individually to try to unravel the issue, you will apparently be moving forward at greater speed, but in the end you will find yourself with the not minor drawback of unifying perspectives, approaches and interests, without yet having built common spaces of interaction between the affected actors, so that they understand the general complexity of the issue (Stone, 2002).

How can we work with the variability and complexity of an issue like the climate emergency? It can probably only be done by incorporating the principles

of decentralisation (or proximity), redundancy (or intergovernmentalism) and the recognition of diversity (or plurality of approaches and strategies). Each of these elements should give us a greater capacity to accept the variability that necessarily accompanies each specific intervention process in the territory. Decentralisation gives us more responsiveness to specific situations. Redundancy avoids the idea that there is only one correct way of doing things, and generates cross-checks of actors and proposals. And diversity gives us more options and more room to decide. In some way, this manner of proceeding "vaccinates" us against uncertainty, since in fact it incorporates this uncertainty into the decision-making process itself (Stone, 2002).

Public policies and the distribution of costs and benefits

A key issue in the analysis of public policies is trying to anticipate the ease or difficulty of implementing the decisions to be made in relation to the problems diagnosed, relating costs and benefits on the one hand and the level of effectiveness of measures to be taken, differentiating whether they are measures that affect everyone equally or rather are targeted at a specific group (see Table 2).

We will agree that policies that create diffuse costs will be easier to implement, since it can be assumed that there will not be a sector of the population or a target group directly affected by the measures to be adopted. This is generally the case with distributive policies (creation of infrastructures or facilities in a given place) and with some of the so-called constituent policies, which tend to strictly affect the political system. On the other hand, it will be more difficult to implement those policies that concentrate the costs in some social sector or target group. The most classic example is that of redistributive policies, which polarise and pit those who most contribute to the change in the distribution of wealth or goods against those who hope to obtain the most benefits from the policy. But policies that seek to regulate a certain activity or sector again without mobilising the potential beneficiaries also generate reactions against, as such an improvement is diffuse or so general that there is no specific feeling of benefit. Environmental policies often take the form of new regulations, which mobilise against those who must bear the short-term costs (owners of polluting industries, fishermen, cruise ship owners, those who use diesel fuel...), and, on the other hand, the benefits in the air breathed or in the quality of sea waters do not have a specific receiver and their effects are not perceptible in the short term.

Table 2. Types of policies and concentration of costs and benefits

		COSTS	
		Concentrated	**Diffuse**
BENEFITS	**Concentrated**	Redistributive policies	Distributive policies
	Diffuse	Regulatory policies	Constituent policies

Source: Wilson, 1973

The term "environmental justice" (Dobson, 1998; Mohai et al., 2009) seeks to relate ecological sustainability with distributive justice, so that all communities and people are entitled to equal environmental protection, assuming that the impacts in relation to the measures to be taken from the environmental point of view may be disproportionate or not distributed equitably. The analyses carried out in this regard highlight the importance of incorporating into the idea of environmental injustice elements such as economic inequality, socio-political exclusion or racial discrimination. Climate change and the measures to be taken cannot fail to take into account the (unequal) impacts that such actions may have on specific groups, regions or countries.

Can it be that the fight against climate change in the Mediterranean will have serious difficulties moving forward since it involves unacceptable measures for the least favoured? I understand that this is not unavoidable. Environmental problems and social problems are directly related. But precisely for this reason, environmental measures must take this complexity into account, incorporating the necessary social buffers and, at the same time, deploying adequate communication.

Beyond scientific data and technical and specialised analyses on the environmental situation in the Mediterranean Sea Basin, from a point of view of political action and social consensus, it is important to analyse the existing perceptions. It is not just about publishing facts and figures. From the point of view of the decision-making framework, what is important is the degree of existing social concern that enables actions to be taken in relation to existing threats without haste that could end up generating worse scenarios than the initial ones. On the subject of perceptions about existing threats and dangers, it is considered that personal experience counts more than the cold transmission of data through the media (Weber, 2010). From this point of view, the climate emergency, the threat of desertification or what the rise in sea level may imply is far less socially perceptible than, for example, the notable reduction of the differences between seasons of the year or a greater general global warming.

In a context such as Europe, in a recent survey carried out in four European Union countries (Steentjes et al., 2016), it can be seen that the feeling that the threats of climate change will not have immediate effects has gradually changed. Although there is a growing concern in this regard that this will affect "other countries", in the end this is lessened. There is still a notable lack of knowledge about the high degree of consensus of the scientific community in relation to the climate emergency. Nor is it understood that it is urgent to help third countries in their fight against the effects of climate change. Other surveys carried out in countries of the basin also show a notable ignorance of the emergencies that the current scenario entails (Korkmaz, 2018).

Final reflections

The approach that has predominated in the making of environmental policies in Europe and in the countries of the southern shore of the Mediterranean in recent years has been basically regulatory, reactive and hierarchical, probably favoured by the large number of spheres of government acting simultaneously. On the other hand, in the

construction of these types of policies, there has been a tendency to prioritise highly technical perspectives, which made it possible to advance quickly in the plans to be followed, although their subsequent implementation became difficult.

The underlying elements that have guided these comments are based on a different assumption. Every process of public intervention and every public policy is, basically, a political process. A process that is based on finding forms of collective rationality that allow us to act in a framework that by definition is plural, conflictive and full of different ideas about what needs to be done in the face of each social situation that requires a response. To understand how public action works, it is necessary to understand how political and social dynamics work (not to be confused with institutional dynamics).

We all have a natural predisposition to avoid uncertainties, and therefore we tend to postulate and expect actions guided by predictability. But governments tend to incorporate uncertainty into their forms of action and try to match objectives with possibilities and conditions. Thus, they launch pre-proposals to see the reaction they create, design programmes that involve the voluntary inclusion of other government agencies or actors to be encouraged through funds, create "ad hoc groups" to overcome contradictions between government departments or between government spheres, promote non-institutional "tables" to facilitate negotiation, and so on.

Public decision-makers are forced to move and find a way out of problems in the social scenario, and cannot limit themselves to acting in the scientific or technological arena. They look for forms of collective action that are as legitimate as possible, and this forces them to leave the apparent comfort of predetermined certainties to build viable combinations of socially shared analysis and convictions. Faced with the urgencies of climate change and the enormous social, economic, cultural and political disparities present in the Mediterranean scenario, we should not limit ourselves to projecting our aspirations, our normative perspectives, but rather try to find feasible ways that allow us to advance in the desired perspective, building the social majorities necessary for it and having the right advice.

In short, we must conclude that, although uncertainty often generates problems, it can also be the way to collectively resolve them. The climate emergency situation undoubtedly requires fast action, but also with enough accommodation, incentive and consensus-building capacity to advance and learn from these advances and broaden horizons. Thus, through open decision-making processes, actors tend to better understand complexity as something inherent in all public decision-making processes, and not as an anomaly to be overcome.

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