CLIMATE AND ENVIRONMENTAL CHANGE IN THE MEDITERRANEAN BASIN

Current situation and risks for the future

First Mediterranean Assessment Report

Summary for policymakers

by MedECC (Mediterranean Experts on Climate and environmental Change)

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Mediterranean Experts on Climate and environmental Change

Union for the Mediterranean
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UN environment programme

Mediterranean Action Plan
Barcelona Convention

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SUMMARY FOR POLICYMAKERS

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Executive Summary: Climate and environmental change in the Mediterranean Basin

Virtually all sub-regions of the Mediterranean Basin, on land and in the sea, are impacted by recent anthropogenic changes in the environment. The main drivers of change include climate (temperature, precipitation, atmospheric circulation, extreme events, sea-level rise, sea water temperature, salinity and acidification), population increase, pollution, unsustainable land and sea use practices and non-indigenous species. In most areas, both natural ecosystems and human livelihoods are affected. Due to global and regional trends in the drivers, impacts will be exacerbated in the coming decades, especially if global warming exceeds 1.5 to 2°C above the pre-industrial level. Significantly enhanced efforts are needed in order to adapt to inevitable changes, mitigate change drivers and increase resilience.

Due to anthropogenic emissions of greenhouse gases, climate is changing in the Mediterranean Basin, historically and projected by climate models, faster than global trends. Annual mean temperatures on land and sea across the Mediterranean Basin are 1.5°C higher than during pre-industrial times and they are projected to rise until 2100 by an additional 3.8 to 6.5°C for a high greenhouse gas concentration scenario (RCP8.5) and 0.5 to 2.0°C for a scenario compatible with the long-term goal of the UNFCCC Paris Agreement to keep the global temperature well below +2°C above the pre-industrial level (RCP2.6). On land and in the sea, heat waves will intensify in duration and peak temperatures. Despite strong regional variations, summer rainfall will likely be reduced by 10 to 30% in some regions, increasing existing water shortages, desertification and decreasing agricultural productivity.

It is virtually certain that sea surface warming will continue during the 21st century by 1 to 4°C depending on the scenario (low or high greenhouse gas emissions) and likely that deep waters will warm more in the Mediterranean than in other oceans in the world. Rising carbon dioxide (CO_2) concentrations lead to seawater acidification, and this trend will continue. The Mediterranean mean sea level has risen by 6 cm over the past 20 years. This trend is likely to accelerate (with regional differences) by the global rate of 43 to 84 cm until 2100, but possibly more than 1 m in the case of further ice-sheet destabilization in Antarctica.

Most impacts of climate change are exacerbated by other environmental challenges such as changing land use, increasing urbanization and tourism, agricultural intensification, overfishing, land degradation, desertification, and pollution (air, land, rivers and ocean). Sulphur dioxide (SO_2) and nitrogen oxide (NO_x) have recently increased drastically, mainly because of shipping activity. Tropospheric ozone (O_3) concentrations increase due to pollution and warming, and high-level episodes will be more frequent in the future. Saharan dust transport is likely to also increase. The Mediterranean Sea is heavily polluted by multiple substances including plastic, emerging contaminants, heavy metals, fecal bacteria and viruses, all with expected increase in the future.

The Mediterranean Sea is invaded by many non-indigenous species, particularly from the Red Sea but also through the Strait of Gibraltar, maritime transport and aquaculture. On land, non-indigenous species are particularly present in regions with high infrastructure and commerce development, including accidentally introduced phytophagous pests which cause damage to crops and forests. These trends are expected to continue in the future.

Agriculture is the largest user of water in the Mediterranean region. Climate change impacts water resources in combination with demographic and socio-economic drivers, reducing runoff and groundwater recharge, water quality, increasing conflicts among users, ecosystem degradation and groundwater salinization in coastal aquifers. Demand for irrigation is expected to increase by 4 to 18% by 2100. Demographic change, including the growth of large urban centers, could enhance this demand by 22 to 74%. There is adaptive potential in the improvement of water use efficiency and reuse. Other important adaptations are changing agriculture practices and promoting the traditional Mediterranean diet, local production and reduction of food waste.

Land and seafood production activities are strongly impacted by climate change, more frequent and intense extreme events, together with higher soil salinization, ocean acidification and land degradation. Crop yield reductions are projected for the next decades in most current areas of production and for most crops. This will potentially be worsened by emerging pests and pathogens. There is large adaptation potential in changing farming practices and management to agroecological methods, also providing important potential for climate change mitigation by increased carbon storage in soils. Marine food production is threatened by unsustainable fishing practices, non-indigenous species, warming, acidification and water pollution, which together may affect species distribution and trigger local extinction of more than 20% of exploited fish and marine invertebrates by 2050. Adaptation will require more rigorous management of fisheries in the Mediterranean. The sustainability of the Mediterranean food sector (from the land and the ocean) also depends on population growth, regional consumer behavior (diet) and the global food markets (which may be affected by environmental crisis elsewhere).

Marine ecosystems and their biodiversity are also impacted by overfishing, warming, acidification and the spread of non-indigenous species from tropical waters. Expected consequences include increased jellyfish outbreaks, mucilage and algal bloom outbreaks, reduced commercial fish stocks, and general biodiversity loss due to altered physiology and ecology of most marine organisms. There is potential for mitigating these impacts through improved conservation within and beyond marine protected areas, more sustainable fishing practices and by reducing pollution from agriculture, urban areas and industry. In coastal systems, sea level rise will impact most infrastructure, aquifers, coastal crops, world heritage and other protected sites, notably in river deltas and estuaries. Increasing nutrient flows towards the sea increase the number and frequency of plankton blooms and jellyfish outbreaks, with negative impacts on fisheries, aquaculture and human health. The multiple levels of land-sea interactions could benefit from the implementation of new approaches of ecosystem-based Integrated Coastal Zone Management and conservation planning.

Land biodiversity changes in multiple ways. In countries of the northern rim, forest area is increasing at the expense of extensive agriculture and grazing, while ecosystems in southern countries are still at risk of fragmentation or disappearance due to clearing and cultivation, overexploitation of firewood and overgrazing. Over the past 40 years, biodiversity changes and species loss have led to homogenization and a general simplification of biotic interactions. Half of wetland area has been lost or degraded, and this trend is expected to continue. Dryland extension and an increase in areas burnt during more frequent wildfires are expected. Adaptation options for land biodiversity include preservation of natural flow variability in Mediterranean rivers and the protection of riparian zones, reduction of water abstraction, modified silvicultural practices, and the promotion of climate-wise landscape connectivity.

Human health is already impacted by high temperatures as well as air and water pollution in the Mediterranean Basin. The combined impacts of expected environmental changes (notably air pollution and climate) increase risks to human health from heat waves, food and water shortages, vector-borne, respiratory and cardio-vascular diseases. These health risks particularly impact disadvantaged or vulnerable populations, including the elderly, children, pregnant women and people with low income. Human security faces new risks from extreme events, particularly along coastal areas. Conflicts caused by scarce resources and human migration are likely to increase due to drought and degrading agricultural and fisheries resources, although socio-economic and political factors are likely to still play a major role.

Mediterranean cities are growing due to increasing population and socio-economic change, notably on the coasts of southern countries. Due to increasing heat stress, the planning and management of cities around to Mediterranean will need to focus more on human health and resilience to environmental change. Impacts of climate change on urban areas are expected to be disproportionally high due to a concentration of population and assets – especially in high-risk prone areas - in combination with hazard-amplifying conditions (e.g., increased runoff resulting from soil sealing, or urban heat island effects). Tourism will likely be affected by climate change through reduced thermal comfort, degradation of natural resources, including freshwater availability, and coastal erosion due to sea level rise and urban development. The net economic effect on tourism will depend on the country and the season.

All Mediterranean countries have significant potential to mitigate climate change through an accelerated energy transition. This will involve phasing down fossil fuel and accelerated development of renewable energies. This ambitious energy transition, reaching beyond the plans and targets announced by governments and policymakers in line with contributions made for the UNFCCC Paris Agreement, requires a significant transformation of energy policies and economic models in Mediterranean countries. While northern rim countries advance towards this transition by gradually diversifying their energy mix, improving energy efficiency and increasing the share of renewable energies, despite investments, some eastern and southern rim countries need support, funding, technology transfer and capacity-building in the framework of the UNFCCC Paris Agreement. Around 2040, the share of renewable energies could triple to reach 13 to 27% under current transition scenarios. Enhanced regional energy market integration and co-operation are crucial to unleashing cost-effective climate change mitigation.

More effective policy responses to climate and environmental changes will require both strengthened mitigation of the drivers of environmental change, such as greenhouse gas emissions, as well as enhanced adaptation to impacts. Poverty, inequalities and gender imbalances presently hamper the achievement of sustainable development and climate resilience in Mediterranean countries. Culture is a key factor to the success of adaptation policies in the highly diverse multicultural setting of the Mediterranean Basin. Aimed at supporting local and vulnerable communities, policies for climate adaptation and environmental resilience need take into account concerns such as justice, equity, poverty alleviation, social inclusion, and redistribution. To support policies for sustainable development with scientific evidence about climate and environmental change, a synthesis of current scientific knowledge, covering most relevant disciplines, sectors and sub-regions is presented by the First Mediterranean Assessment Report (MAR1).

BACKGROUND AND KEY FINDINGS OF THE FIRST MEDITERRANEAN ASSESSMENT REPORT

1 - Background for the assessment

1.1 Global environmental change exacerbates existing challenges for the population living around the Mediterranean Sea, through climate change, land use changes, increasing urbanization and tourism, agricultural intensification, pollution, declining biodiversity, resource competition, and socio-economic trends. Environmental, socio-economic and cultural conditions are highly heterogeneous across the Mediterranean Region *(Section 1.1.1)*, resulting in different manifestations of regional environmental change that require specific adaptation measures as well as enhanced capacity-building. To account for these specificities, a comprehensive risk assessment approach encompassing the entire Mediterranean Basin is needed to provide adequate and timely information as well as data needed for decision makers to design effective mitigation and adaptation strategies. *(Section 1.1.1).*

1.2 Despite major research efforts across many disciplines and regions, to date, there has been no comprehensive assessment of risks posed by climate and environmental changes in the Mediterranean Basin. Most countries of the Middle East and North Africa (MENA) are likely to face potentially greater risks from climate and environmental changes than other parts of the Mediterranean Basin, but they have limited capacity to monitor important environmental parameters or carry out adequate risk analyses. Effective mitigation and adaptation require integrative studies that go beyond the current knowledge. The main challenges for the Mediterranean are to fill data and knowledge gaps across countries, and to foster the development of high-level climate services, including early warning systems. More research is needed for short- and medium-term projections, as well as large scale programs at the Mediterranean scale to address pressing challenges. *(Section 1.1.2).*

1.3 The 1st Mediterranean Assessment Report (MAR1) has been developed and drafted in order to provide science-based guidance to multiple actors involved in coming up with a response to climate and environmental changes and to reduce associated risks to communities and natural ecosystems in the Mediterranean region *(Section 1.3.1.4).* The report was developed by the scientific community, based on publications in scientific journals, for policymakers and other stakeholders through the conclusions in its Summary for Policymakers (SPM), as well as for a broader audience of experts through its detailed technical chapters supporting the SPM. The report is also intended to be communicated more broadly to the public through additional efforts of communication and participatory actions. *(Section 1.3.2).*

1.4 The report assesses risks for the entire Mediterranean Basin (land and sea), associated with four main drivers of environmental change: climate, pollution, land and sea use and non-indigenous species. Throughout the report, scientific confidence in its findings is indicated based on the consistency of evidence and the degree of agreement of the scientific community, using the terms *"high"*, *"medium"* and *"low"*. *(Section 1.3.3).*

2 - Drivers of environmental change in the Mediterranean Basin

2.1 Climate change

Anthropogenic climate change has been observed for many variables in the Mediterranean Basin during recent decades. For the future, the region is expected to remain among the regions most affected by climate change, particularly when it comes to precipitation and the hydrological cycle.

2.1.1 There is robust evidence that the Mediterranean region has significantly warmed. Basin-wide, annual mean temperatures are now 1.54°C above the 1860-1890 level for land and sea areas, i.e. 0.4°C more than the global average change *(high confidence). (Fig. SPM.1) (Section 2.2.4.1; Box 2.1).*

2.1.2 Multi-model sets of climate simulations show that widespread warming will continue in the Mediterranean during the 21st century *(high confidence). (Section 2.2.4.2, Table 2.1).*

2.1.2.1 Over land, warming will likely be in the range of 0.9 to 1.5°C or 3.7 to 5.6°C during the 21st century, for low (RCP2.6) or high greenhouse gas emissions (RCP8.5), respectively *(high confidence)*. Future regional average warming will exceed the global mean value by 20% on an annual basis and 50% in summer *(high confidence). (Fig. SPM.2) (Section 2.2.4.2).*

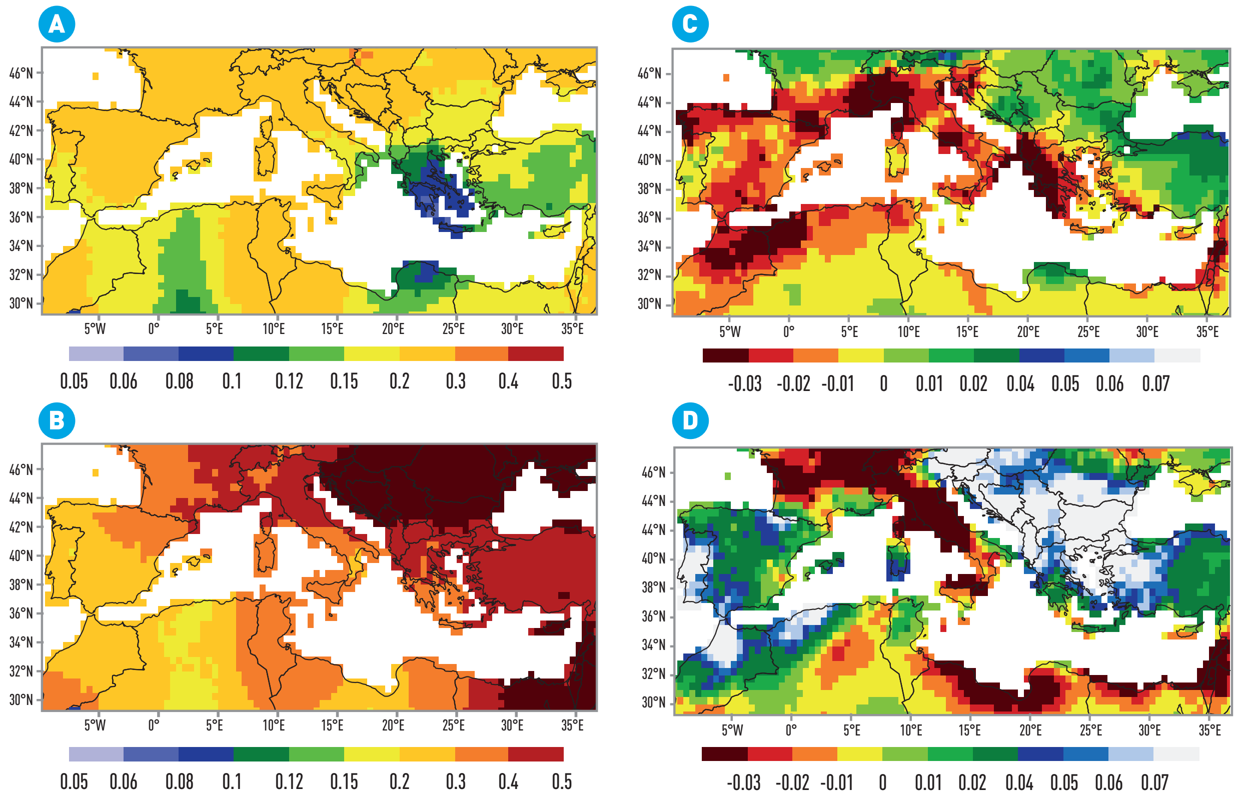

Figure SPM.1 | Observed changes in temperature and rainfall. Recent trends in temperature (A and B, °C decade[-1]) and rainfall (C and D, mm day[-1] decade[-1]) in the Mediterranean Basin over land. Panels A & C average for the period 1950-2018, panels B & D for 1980-2018 (*Fig. 2.5* and *2.8*).

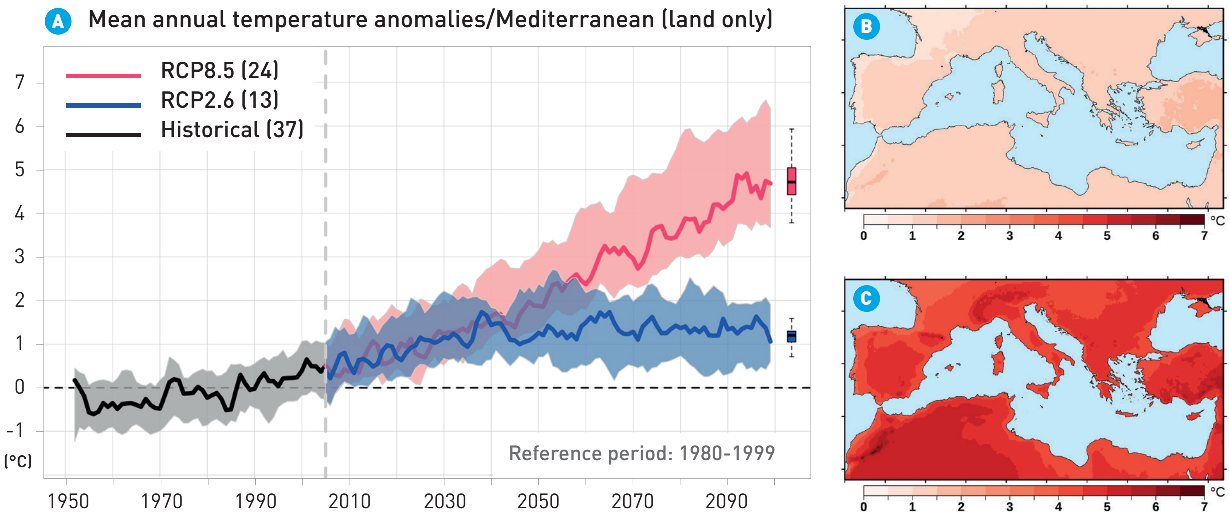

Figure SPM.2 | Projected warming in the Mediterranean Basin over land. Projected changes in annual temperature relative to the recent past reference period (1980-1999), based on the EURO-CORDEX 0.11° ensemble mean, A: simulations for pathways RCP2.6 and RCP8.5, B: warming at the end of the 21st century (2080-2099) for RCP2.6, C: idem for RCP8.5.

2.1.2.2 In the future, warm temperature extremes will increase and heat waves will intensify in duration and peak temperatures. For 2°C of global warming above the pre-industrial value, maximum daytime temperatures in the Mediterranean will likely increase by 3.3°C. With 4°C global warming, nearly all nights will be tropical (nighttime temperature for at least five days above a location-depending threshold) and there will be almost no cold days (below a location-depending threshold) *(high confidence). (Section 2.2.4.2).*

2.1.3 The sign and magnitude of observed land precipitation trends show pronounced spatial variability, depending on the time period and season considered *(medium confidence) (Section 2.2.5.1)*, so that the confidence in the detection of anthropogenic trends in rainfall for the historical past is low.

2.1.3.1 The most evident observed trend is a decrease in winter precipitation over the central and southern portions of the basin since the second half of the 20th century *(medium confidence). (Section 2.2.5.1).*

2.1.4 Models project a consistent decrease in precipitation during the 21st century, for the entire Mediterranean Basin during the warm season (April through September, with the highest magnitude in summer) and in winter for most of Mediterranean, except for the northernmost regions (e.g., the Alps), where wetter conditions are projected *(medium confidence). (Fig. SPM.3) (Section2.2.5.2).*

2.1.4.1 The mean rate of land precipitation decrease among models is 4% per each degree of global warming, which would determine a reduction in the range of 4 to 22% depending on scenario at the end of the 21st century *(medium confidence) (Section 2.2.5.2)*. The magnitude of this decrease varies across models, rendering sub-regional projections uncertain.

2.1.4.2 Future climate projections indicate a predominant shift towards a precipitation regime of higher interannual variability, higher intensity and greater extremes (especially in winter, spring and fall, but not in the southern areas, *low confidence*), decreased precipitation frequency and longer dry spells (especially in summer and in the southern countries) *(medium confidence). (Section 2.2.5.2).*

2.1.5 There are no significant trends in the number of observed cyclones in recent decades *(low/medium confidence) (Section 2.2.2.3)*. Most future climate projections indicate a decrease in cyclones, especially in winter *(medium confidence). (Section 2.2.2.3).*

2.1.5.1 There is insufficient information for assessing past trends of "medicanes" (Mediterranean hurricanes), but projections indicate decreasing frequency and increasing intensity *(medium confidence). (Section 2.2.2.3).*

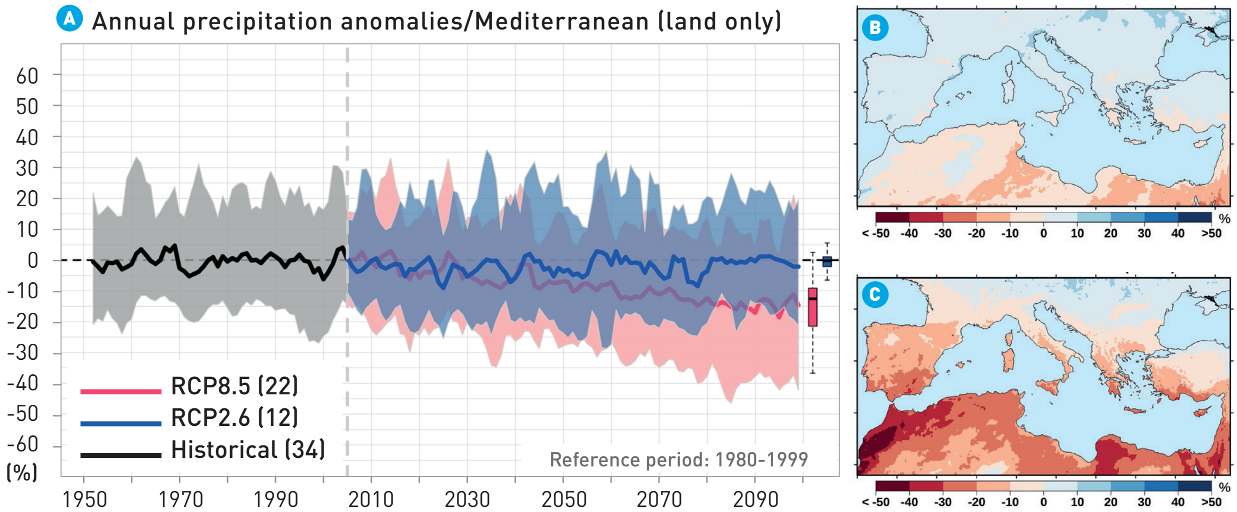

Figure SPM.3 | Projected rainfall change in the Mediterranean Basin. Projected changes in annual rainfall relative to the recent past reference period (1980-1999), based on the EURO-CORDEX 0.11° ensemble mean, A: simulations for pathways RCP2.6 and RCP8.5, B: rainfall anomalies at the end of the 21st century (2080-2099) for RCP2.6, C: idem for RCP8.5.

2.1.5.2 Projections of future wind speeds converge on a limited wind speed reduction over most of the Mediterranean Sea, with the exception of an increase over the Aegean Sea and northeastern land areas *(medium confidence). (Section 2.2.2.4).*

2.1.5.3 Projections suggest a general decrease in mean significant wave height, as well as in the number and intensity of wave extremes, over a large part of the Mediterranean Sea, especially in winter, and storm surges along the coasts *(medium confidence)*, but with no consensus on the most extreme events. *(Section 2.2.8.2).*

2.1.6 Surface solar radiation in the Mediterranean Basin decreased from the 1950s to the 1980s (between -3.5 and -5.2 W m^{-2} $decade^{-1}$) and recovered thereafter (between +0.9 and +4.6 W m^{-2} $decade^{-1}$), consistent with global trends *(very high confidence). (Section 2.2.3.1).* In future climate projections, anthropogenic aerosol loads over the Mediterranean are expected to continue to decrease *(high confidence)*, leading to an increase in surface solar radiation *(medium confidence). (Section 2.2.3.2).*

2.1.7 Observations and most model projections indicate a trend towards drier conditions over the Mediterranean Basin, especially in the warm season and over the southern areas *(medium/high confidence). (Section 2.2.5.3).*

2.1.7.1 Across the Mediterranean Sea, net fresh water loss (evaporation minus precipitation and river runoff) has increased since the last decades of the 20th century *(medium confidence) (Section 2.2.5.3).* The main cause is the strong evaporation increase due to local warming (the estimated rate of evaporation change in relation to warming is about 0.7 mm day^{-1} $°C^{-1}$ (or 25% $°C^{-1}$) over the period of 1958-2006).

2.1.7.2 Net water loss from the sea is expected to increase in the future due to a decrease in precipitation and river runoff and an increase in evaporation *(high confidence). (Section 2.2.5.3).*

2.1.8 In the 20th century a significant reduction in the area and volume of glaciers across high mountains of the Mediterranean has occurred. Deglaciation has generally accelerated in recent decades *(high confidence). (Section 2.2.6.1).*

2.1.8.1 Warming has shifted the occurrence of periglacial processes to higher elevations and degraded permafrost in high mountain environments. Glaciers in the Mediterranean region are projected to continue losing mass in the 21st century until complete disappearance of most mountain glaciers by the end of the century *(very high confidence). (Section 2.2.6.2).*

2.1.8.2 At lower elevation, the snow water equivalent is projected to decline by 25% (10 to 40%) from 1986-2005 to 2031-2050, regardless of the scenario. This will continue with a 30% decrease at the end of the 21st century for a low emission scenario to 80% for high emission scenario *(high confidence). (Section 2.2.6.2).*

2.1.9 Mediterranean Sea surface waters are warming and deep waters are becoming saltier *(high confidence). (Section 2.2.7.1).*

2.1.9.1 Since the beginning of the 1980s, average Mediterranean Sea surface temperatures have increased throughout the basin, but with large sub-regional differences in the range between +0.29 and +0.44°C per decade, with stronger trends in the eastern basins (Adriatic, Aegean, Levantine and north-east Ionian Sea), marine heat waves have become longer and more intense *(high confidence). (Section 2.2.7.1).*

2.1.9.2 The water mass temperature and salinity changes of the water outflowing from the Mediterranean Sea through the Strait of Gibraltar are 0.077°C decade^{-1} and 0.063 psu (practical salinity unit) decade^{-1}, respectively, compared to 2004 *(high confidence). (Section 2.2.7.1).*

2.1.10 Widespread sea surface temperature increase will continue in the 21st century *(very high confidence).*

2.1.10.1 During the 21st century, the basin mean sea surface temperature is expected to warm by 2.7 to 3.8°C and 1.1 to 2.1°C under the RCP8.5 and the RCP4.5 scenarios, respectively *(very high confidence).* The sign of future basin average sea surface salinity change remains largely uncertain and its changes will likely be spatially and temporally heterogeneous *(medium confidence). (Section 2.2.7.2).*

2.1.10.2 Marine heat waves will very likely increase in spatial extent, become longer, more intense and more severe than today *(medium confidence).* Under the high emission scenario, the 2003 marine heat wave may become a regular event for the period 2021-2050 and a weak event at the end of the 21st century *(medium confidence). (Section 2.2.7.2).*

2.1.11 Mediterranean Sea waters have acidified and will continue to acidify along with the global ocean *(medium confidence).* The Mediterranean Sea is able to absorb relatively more anthropogenic CO_2 per unit area than the global ocean because it is more alkaline and because deep waters are ventilated over shorter timescales *(medium confidence). (Section 2.2.9).*

2.1.11.1 Sea water surface pH has decreased by -0.08 units since the beginning of the 19th century, similar to the global ocean, with deep waters exhibiting a larger anthropogenic change in pH than typical global ocean deep waters because ventilation times are faster *(medium confidence). (Section 2.2.9.1).*

2.1.11.2 In 2100, reduction of pH might reach 0.462 and 0.457 units for the western and for the eastern basins, respectively *(low confidence). (Section 2.2.9.2).*

2.1.12 Mediterranean sea level is rising, similar to global trends, with strong spatial and temporal variation and expected acceleration *(medium confidence). (Section 2.2.8.1).*

2.1.12.1 Averaged across the Mediterranean Basin, mean sea level has risen by 1.4 mm yr^{-1} during the 20th century and has accelerated to 2.8 mm yr^{-1} recently (1993–2018) *(high confidence). (Section 2.2.8.1).*

2.1.12.2 Mostly due to global ocean and ice-sheet dynamics, Mediterranean mean sea level rise is projected to accelerate further throughout the 21st century *(high confidence).* Around 2100, depending on the scenario, the basin mean sea level will likely be 37-90 cm higher than at the end of the 20th century, with a small probability of being over 110 cm *(medium confidence). (Section 2.2.8.2).*

2.1.12.3 Sea level rise will increase the frequency and intensity of coastal floods and erosion *(high confidence). (Section 2.2.8.2).*

2.2 Pollution

2.2.1 Across the Mediterranean Basin, ocean and inland pollution are transboundary, ubiquitous, diverse and increasing in both quantity and in the number of pollutants, due to demographic pressure, enhanced industrial and agricultural activities, and climate change *(high confidence). (Section 2.3.1).*

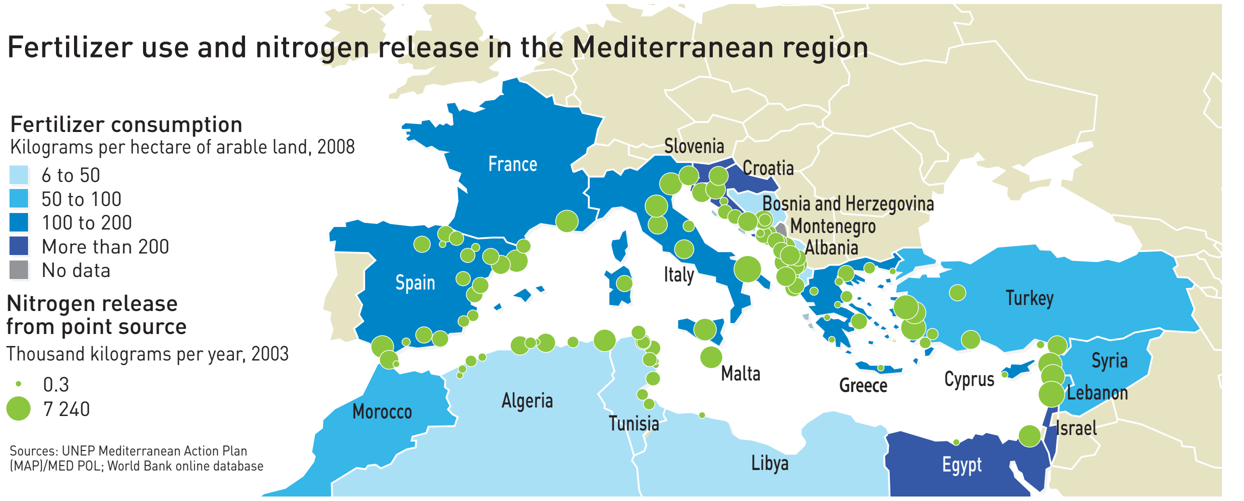

Figure SPM.4 | Fertilizer use and nitrogen release in the Mediterranean Sea (UNEP/MAP/MED POL, 2013).

2.2.2 Pollution of sea water

2.2.2.1 Mediterranean waters are generally oligotrophic (low nutrient), with decreasing levels from Gibraltar eastwards to the Levantine Sea. Several coastal regions are hotspots of human-induced nutrient inputs (Lagoons of Venice and Bizerte, Gulfs of Lion and Gabès, eastern Adriatic and western Tyrrhenian Sea, North Lake of Tunis, Algerian-Provençal Basin and the Gibraltar Strait) *(high confidence) (Fig. SPM.4). (Section 2.3.3.1).*

2.2.2.2 Nutrient enrichment causes eutrophication and may provoke harmful and toxic algal blooms, trends which will likely increase. Harmful algal blooms may cause negative impacts on ecosystems (red-tide, mucilage production, anoxia) and may present serious economic threats for fisheries, aquaculture and tourism. They may also harm human health, since 40% of blooming microalgae are able to produce toxins responsible of different human intoxications. Harmful algal blooms can also occur in freshwater environments. *(Section 2.3.4).*

2.2.2.3 Emerging contaminants (related to recently discovered chemicals or materials) are prevalent across the Mediterranean Basin, and enhanced by increasing inflow of untreated wastewater. These substances may cause disorders of the nervous, hormonal and reproductive system *(high confidence). (Section 2.3.3.5).*

2.2.2.4 The increasing frequency of extreme precipitation events in the north of the Mediterranean increases the supply of faecal bacteria and viruses to the coastal zone *(medium confidence). (Section 2.3.4).*

2.2.2.5 The Mediterranean Sea is one of the most polluted large water bodies globally in terms of plastic and the level of this pollution is expected to increase in the future *(medium confidence). (Section 2.3.2.3).* Even with rigorous reduction of use, plastic debris and their dissolved derivatives will remain a problem since they can take 50 or more years to fully decompose *(medium confidence) (Section 2.3.2.3).*

2.2.3 Air pollution

2.2.3.1 The Mediterranean Basin is among the regions in the world with the highest concentrations of gaseous air pollutants (NO_2, SO_2 and O_3). Its dry and sunny climate, and specific atmospheric circulation patterns enhance air pollution levels *(high confidence). (Section 2.3.3.2)* Emissions of aerosols and particulate matter (PM) into the atmosphere arise from a variety of anthropogenic activities (transport, industry, biomass burning, etc.), but also from natural sources (volcanic eruptions, sea salt, soil dust suspension, natural forest fires, etc.). *(Section 2.3.2.1).*

2.2.3.2 Ships are among the major emitters of SO_2 and NO_x, along with road traffic. Their contribution to transport sector emissions and general air pollution in the Mediterranean Basin is increasing *(medium confidence). (Section 2.3.3.2).*

2.2.3.3 Tropospheric ozone (O_3) concentrations observed in the summer across this region are among the highest in the northern Hemisphere and still increasing in average and with more frequent high-level episodes. They are influenced by Volatile Organic Compounds (VOCs), NO_x emissions and climate. This trend will likely be enhanced by future warming *(medium confidence). (Section 2.3.3.2).*

2.2.3.4 Particular meteorological conditions and natural sources, including the proximity of the Sahara Desert, create specific patterns of aerosol concentrations that may influence particulate matter (PM) concentrations. The occurrence of critically high PM concentrations associated with dust outbreaks is higher in the southern Mediterranean (>30 % of annual days) than in the northern area (<20% of annual days) *(high confidence). (Section 2.3.2.1).*

2.3 Land and sea use change

2.3.1 Landscapes and their use have changed over millennia in the Mediterranean Basin, however the rate of change has increased substantially since the second half of the 20th century *(high confidence). (Section 2.4.1.1).*

2.3.1.1 Urban and peri-urban areas are growing rapidly all over the Mediterranean, especially along the coasts. Urbanization is a major driving force of biodiversity loss and biological homogenization causing landscape fragmentation, loss of open habitats and of the land use gradient, replacing agricultural systems and natural vegetation *(high confidence). (Section 2.4.1.2).*

2.3.1.2 Outside urban areas and areas with intensive agriculture, forest and shrub encroachment, as a consequence of abandoned agro-pastoralism, mainly affects marginal lands, arid and mountain regions, primarily in the north *(high confidence). (Section 2.4.1.1).*

2.3.1.3 In many regions of North Africa and the Middle East (but also on some Mediterranean islands), the dominant land use change process is forest degradation caused by land overexploitation. From the 1980's to the 1990's deforestation has increased by 160% *(high confidence).* (*Section 2.4.1.1* and *2.4.1.2*).

2.3.1.4 Future land use trends depend strongly on regional policies for urbanization, agriculture, forestry and nature conservation. Grassland and pastures will likely continue to further decrease in extension due to rural abandonment, often due to insufficient job opportunities and public services in marginal areas *(medium confidence). (Section 2.4.1.3).*

2.3.2 Marine resource overexploitation and unsustainable fishing practices are the main driver of marine species population decline. *(Section 2.4.2).*

2.3.2.1 Fishing efforts have increased over long periods, but particularly so since the 1990's due to new technologies and higher capacity vessels *(high confidence). (Section 2.4.2.1).*

2.3.2.2 In 2010, the cumulative percentage of collapsed and overexploited stocks exceeded 60% across the Mediterranean Sea *(medium confidence).* The eastern Mediterranean is the most overexploited sub-basin with the highest number of collapsed species *(medium confidence). (Section 2.4.2.2).*

2.3.2.3 Sustainable management of marine resources requires reduced fishing pressure. The implementation of an ecosystem-based approach may ensure the recovery of both high and low trophic levels and support both ecosystem health and resilience against sea warming *(high confidence). (Section 2.4.2.3).*

2.4 Non-indigenous species

2.4.1 The Mediterranean Sea (and particularly the Levantine Basin) is a hotspot for the establishment of many non-indigenous species *(high confidence). (Section 2.5.1).*

2.4.1.1 Among known marine non-indigenous species introduced over the last 30 years, invertebrates dominate with >58% (mostly mollusks and decapods), primary producers follow with approx. 23% and vertebrates with 18% (mostly fish) *(high confidence). (Section 2.5.1.1).*

2.4.1.2 Most marine non-indigenous species arrive from the Red Sea and Atlantic Ocean, but the highest impact is attributed to those introduced by ships and aquaculture *(high confidence). (Section 2.5.1.2).*

2.4.1.3 The increase in non-indigenous species can be linked to decrease or collapse in populations of native species, and to other ecological changes to the marine ecosystem *(high confidence). (Section 2.5.1.2).*

2.4.1.4 The number and spread of non-indigenous species will likely increase further with increasing shipping activity and the impacts of climate on the ocean *(medium evidence).* Forecasting future establishment of non-indigenous species using species distribution models is challenging. *(Section 2.5.1.3).*

2.4.2 On land, there is a high number of non-indigenous species in human-modified ecosystems and in regions with high infrastructure development *(high confidence). (Section 2.5.2.1).*

2.4.2.1 On land, most non-indigenous species in the region are plants (introduced intentionally as ornamentals), followed by invertebrates. Phytophagous pests, which cause damages to crops and forests, dominate non-indigenous species all over the Mediterranean Basin, accounting for more than a half of the invertebrate species. The main pathways of introduction for vertebrates are accidental escapes *(medium evidence). (Section 2.5.2.1).*

2.4.2.2 With warming, current major non-indigenous species are predicted to shift northwards by 37 to 55 km decade^{-1}, leaving a window of opportunity for new non-indigenous species adapted to xeric conditions. The trend has recently shifted towards increasing numbers of introduced invertebrates and vertebrates. This pattern will very likely continue in the near future, due to increasing air and maritime cargo, where these taxa can be easily transported as stowaways *(medium confidence). (Section 2.5.2.3).*

3 - Resources

3.1 Water

3.1.1 Water resources in the Mediterranean are scarce: resources are limited, unevenly distributed and in some areas not accessible, often mismatching human and environmental needs. *(Section 3.1.1).*

3.1.1.1 Renewable water resources are unevenly distributed among Mediterranean regions (72 to 74% are located in the northern Mediterranean) and so is the spatial distribution of water needs, but with opposite trends. As a consequence, 180 million people in the southern and eastern Mediterranean countries suffer from water scarcity (<1,000 m^3 capita^{-1} yr^{-1}) and 80 million people from extreme water shortage (<500 m^3 capita^{-1} yr^{-1}) *(high confidence). (Section 3.1.1.1).*

3.1.1.2 River discharge is characterized by high temporal - seasonal and inter-annual - variability and groundwater is the main source of freshwater for some Mediterranean countries (Libya, Malta, Palestine, Israel) *(Section 3.1.1.2).* In several cases in southern Mediterranean countries, groundwater resources are drawn from fossil aquifers, i.e. non-renewable resources *(high confidence). (Section 3.1.1.3).*

3.1.1.3 Sustainable water management is complicated by the transboundary nature of many river basins and aquifers, common in Mediterranean countries (18% of total renewable water resources originate outside the territories of the southern Mediterranean, 27% in eastern Mediterranean countries *(high confidence). (Section 3.1.1.1).*

3.1.2 Due to the general scarcity of water resources, conflicts arise from different sectors of water use (agriculture, tourism, industry, people, also biodiversity conservation) *(medium confidence). (Section 3.1.2).*

3.1.2.1 The spatial distribution of water use per sector in the Mediterranean area is heterogeneous. In southern and eastern countries, agricultural use reaches 76-79%. In the northern part, the four sectors are much more balanced (18-36%, *Fig. SPM.5*), with differences between countries. *(Section 3.1.2.1).*

3.1.2.2 The percentage of irrigated land of the total cultivated area in the Mediterranean is about 25% (but more than 70% in Egypt, Israel, Lebanon, Greece), with a strong increase (21%) in recent years *(Section 3.1.2.2).* The trend towards more efficient irrigation systems does not always generate absolute water savings due to the introduction of more water demanding crops (e.g. vegetables) *(medium confidence). (Section 3.1.2.2).*

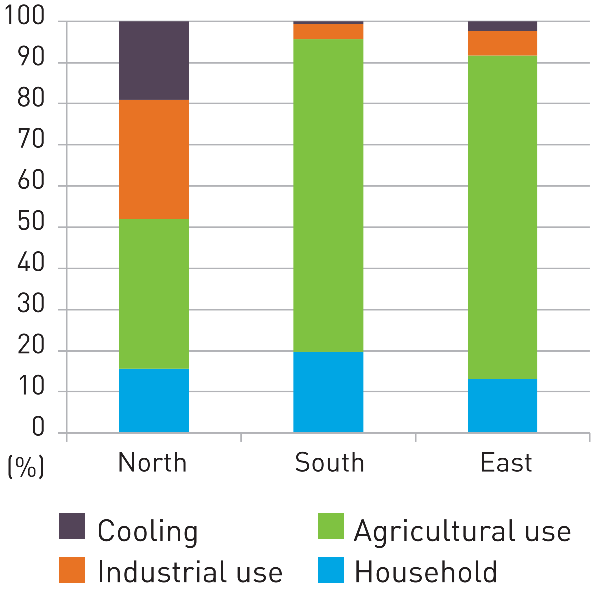

Figure SPM.5 | Total water consumption rates across four main sectors and three sub-regions (data source: AQUASTAT).

3.1.2.3 Tourism activity is at its highest in summer, coinciding with peak demands by irrigated agriculture, creating tensions for water, and this will likely be exacerbated in the future due to climate change *(medium confidence). (Section 3.1.2.3).*

3.1.2.4 Municipal water use is already constrained in several Mediterranean countries affected by water scarcity, exacerbated by demographic and migratory phenomena, as well as by the limits and obsolescence of water distribution infrastructure *(medium confidence).* Several northern countries have managed to reduce their municipal withdrawal in absolute values while several southern and eastern countries have the opposite trend *(medium confidence). (Section 3.1.2.5).*

3.1.2.5 Water-related intersectoral conflicts are likely to be exacerbated in the future because of the interactions between climate change (increasing droughts) and ongoing socio-economic and demographic trends *(medium/high confidence). (Section 3.1.5.2).*

3.1.3 Disastrous flash floods are frequent in many countries including Italy, France and Spain, affecting mainly the coastal areas, in particular, where population and urban settlements are growing in flood-prone areas. These will likely become more frequent and/or intense due to climate change and surface-sealing *(medium confidence). (Section 3.1.3.3).*

3.1.4 Climate change, in interaction with other drivers (mainly demographic and socio-economic developments including unsustainable agricultural practices), is likely to impact most of the Mediterranean Basin, through reduced runoff and groundwater recharge, increased water requirements for crops, increased conflicts among users, and increased risk of overexploitation and degradation *(high confidence). (Section 3.1.4.1).*

3.1.4.1 Impacts of even moderate (1.5 to 2°C) global warming and associated socio-economic pathways are expected to stem from reduced precipitation associated with increased evaporation, leading to a decline in runoff water *(Section 3.1.4.1).* In many regions, this will likely increase low flow periods in summer and the frequency of no-flow events, and higher drought risks *(Section 3.1.4.1).* More urban populations are likely to be exposed to severe droughts, and the number of affected people will essentially scale with the temperature increase *(high confidence). (Section 3.1.4.1).*

3.1.4.2 Aquifer recharge will be strongly impacted by warming and reduced rainfall, particularly in semi-arid areas. At current extraction rates, overexploitation of groundwater is likely to continue having a greater impact on decreasing groundwater levels than climate change *(high confidence). (Section 3.1.4.1).*

3.1.4.3 Important challenges to groundwater quality in coastal areas are likely to arise from salt-water intrusion driven by enhanced extraction of coastal groundwater aquifers and sea-level rise, as well as from increasing water pollution in the southern and eastern Mediterranean *(medium confidence). (Section 3.1.4.1).*

3.1.4.4 Impacts of global warming levels higher than 1.5 to 2°C on water resources by the end of the 21st century will be significantly stronger, generating substantially increased risks in the Mediterranean region *(Section 3.1.4.2).* The probability of more extreme and frequent meteorological, hydrological and agricultural droughts will likely increase substantially, with 5 to 10 times more frequent droughts in many Mediterranean regions *(high confidence). (Section 3.1.4.2).*

3.1.5 The combined dynamics of climate and socio-economic changes suggest that despite an important potential for adaptation to reduce freshwater resource vulnerability, climate change exposure cannot be fully and uniformly counterbalanced. In many regions, socio-economic developments will have greater impact on water availability compared to climate-induced changes *(low confidence). (Section 3.1.4.2).*

3.1.5.1 Strategies and policies for water management and climate change adaptation are strongly interconnected with all other sectors (e.g., the water-energy-food nexus). Most adaptation and water management strategies rely on the principles of Integrated Water Resources Management (IWRM), which is based on economic efficiency, equity and environmental sustainability, also considering the nexus with agriculture (food production in particular) and energy for building the resilience needed to adapt to climate change. *(Section 3.1.5.1).*

3.1.5.2 Technical solutions are available to improve water availability and the efficient use of water resources. Seawater desalination is increasingly used to reduce (potable) water scarcity in arid and semi-arid Mediterranean countries, despite known drawbacks in terms of environmental impacts on near-coastal marine ecosystems and energy requirements with associated CO_2 emissions. Promising new (solar) technologies are under development, potentially reducing both greenhouse gas emissions and costs *(medium confidence). (Section 3.1.5.2).*

3.1.5.3 Technology is also expected to contribute significantly to the reduction of wastewater volume, its reclamation and reuse and the reduction of impacts on sea water quality. Agricultural, industrial and watering activities present together approx. 70% water reuse potential. The proposal has been made to recharge aquifers with treated wastewater, but critical issues in terms of water quality remain to be resolved *(medium confidence). (Section 3.1.5.2).*

3.1.5.4 Inter-basin transfer of water has been implemented in several large-scale schemes, with high social and environmental costs, and risks of conflict *(low confidence). (Section 3.1.5.2).*

3.1.5.5 Dams for water storage or hydropower exist in most countries, and rivers are diverted for water management in some countries. Large dams often generate social and environmental impacts, such as the destruction of river and wetland ecosystems and the loss of aquatic biodiversity, forced relocation of people and loss of cultural resources. Reductions of these impacts are possible, for example through constructed wetland habitats, and management of fishing and other recreational opportunities and enhanced coordination among countries sharing the same water resources *(low confidence) (Section 3.1.5.2).* Technological developments also allow for the use of underground- or subsurface dams, to contribute to sustainable management of groundwater. *(Section 3.1.5.2).*

3.1.5.6 The strategy of trading commodities (in particular from agriculture) that cannot be produced due to lacking water (virtual water trade) can be considered a form of adaptation. Most Mediterranean countries (e.g., Portugal, Spain, Italy, Greece, Israel, Turkey) have high footprints in terms of national consumption (above 2000 $m^3\ yr^{-1}$ $capita^{-1}$) *(low confidence). (Section 3.1.5.1).*

3.1.5.7 Water demand management, i.e. methods used to save (high quality) water, may reduce water consumption or water losses. This includes technical, economic, administrative, financial and/or social measures, with priority for increases in water use efficiency, in particular in the tourism and food sectors and with case-specific solutions integrating traditional knowledge with modern technical achievements *(high confidence). (Section 3.1.5.1).*

3.1.5.8 The reduction of water losses in all sectors of water use in the Mediterranean is crucial for sustainable management and adaptation strategies. Leakage in urban distribution networks and inefficient irrigation technologies are in urgent need of being addressed *(high confidence). (Section 3.1.5.1).*

3.1.5.9 Maintaining the traditional Mediterranean diet and shifting back to a locally produced Mediterranean food in conjunction with a reduction of food waste, could generate water savings in comparison to the present increasingly meat-based diet: 753 l for a locally produced diet and 116 l for less waste of water per capita and per day, in addition to benefits for health (obesity, diabetes) *(high confidence). (Box 3.1.2).*

3.2 Food

3.2.1 Warmer and drier climate conditions, with more frequent and intense extreme events, in combination with higher soil salinization, ocean acidification and land degradation, sea level rise and the emergence of new pathogens pose a threat to most elements of the food production system in the Mediterranean Basin *(high confidence)*.

3.2.1.1 Climate extremes pose a threat to the entire agricultural sector. Crop yield reductions are projected for the coming decades in most current areas of production and for most crops if no adaptation takes place. *(Section 3.2.2.1)*.

3.2.1.2 Maize is the crop most affected by climate change, projected to decline in yield by up to 17% in some countries by around 2050 under RCP8.5 scenario and assuming current agricultural practices *(medium confidence)*; it could become infeasible in regions with limited access to irrigation water *(medium confidence) (Section 3.2.2.1)*. Wheat yield losses of 5% to 22% are also projected because of decreased resilience of production and higher inter-annual variability in 2021-2050 under RCP8.5 scenario with no adaptation. Other water demanding crops, e.g., tomatoes, are also at risk. The production of some currently rainfed crops, such as olives, could become infeasible without irrigation *(medium confidence). (Section 3.2.2.1)*.

3.2.1.3 Increasing atmospheric CO_2 concentrations may help offset yield losses for some crops, such as wheat and barley, but this effect could impact nutritional quality. Beneficial effects of CO_2 are likely limited by water stress conditions as well as by nutrient availability *(low confidence). (Section 3.2.2.1)*.

3.2.1.4 Climate extremes, such as heat stress, droughts, and floods, can cause crop yield losses/failures, crop quality reduction and impacts on livestock *(high confidence) (Section 3.2.1.4)*. These events can also induce long-term socio-economic and landscape changes *(medium confidence). (Section 3.2.1.4)*.

3.2.1.5 Sea level rise will likely impact the agricultural sector by a direct impact on (or loss of) agricultural areas in coastal zones (e.g., in Egypt), along with up to a three-fold increase in the salinity of irrigation water and soil, and retention of sediments that do not reach the coast *(high confidence). (Section 3.2.2.1)*.

3.2.1.6 New and/or re-emerging pests and pathogens may contribute to larger than estimated losses in the agricultural sector. Food quality and security may also be affected by mycotoxigenic fungal pathogens and a higher level of contamination *(medium confidence). (Section 3.2.2.1)*.

3.2.1.7 Total landings from Mediterranean fisheries have declined by 28% from 1994 to 2017 *(Section 3.2.1.3, Fig. 3.22)*. Climate change is projected to heavily affect marine resources in the coming decades. Warming, acidification and water pollution are likely to reduce marine productivity, affect species distribution and trigger local extinction of more than 20% of exploited fish and marine invertebrates by 2050 *(high confidence). (Section 3.2.2.2)*.

3.2.1.8 Perturbations in global markets for agricultural and marine products, potentially caused by environmental change elsewhere, may exacerbate the local impacts of climate change, especially because most Mediterranean countries are net importers of cereal and fodder/feeding products *(high confidence). (Section 3.2.1.5)*.

3.2.2 Adaptation to environmental change will be of key importance to limit and partially offset the impacts of climate change in the food sector *(high confidence)*.

3.2.2.1 Projected yield losses in most crops may be reduced by targeted adaptation strategies, such as crop diversification, adapting the crop calendar and use of new varieties adapted to evolving climate conditions. Strategies based on increased irrigation will have limited applicability in the region. Thus, adapted production of crops such as maize will depend on more drought-resistant varieties *(medium confidence). (Section 3.2.3.1)*.

3.2.2.2 Successful adaptation strategies are based on combining different approaches, i.e. on farming practices (e.g., varieties, rotational patterns, crop diversity, agroforestry) and management (e.g., diversification of income, modifying irrigation practices). Sectoral co-designed climate services may help reduce risks linked to unfavorable climate conditions and extremes *(medium confidence). (Section 3.2.3.1)*.

3.2.3 The food production system on land has the capacity to contribute to greenhouse gas mitigation strategies through nitrogen fertilization optimization, improved water management, better storage of soil organic carbon and carbon sequestration, management of crop residues and agroindustry by-products *(high confidence). (Section 3.2.3.2).*

3.2.3.1 N_2O emissions in Mediterranean agro-ecosystems can potentially be mitigated by 30 to 50%, through adjusted fertilization (rate and timing). Replacing mineral nitrogen with organic fertilization provides soil and crops not only with nitrogen, phosphorus, potassium and micronutrients, but also enhances organic carbon when using solid fertilizers (i.e., solid manure, compost, etc.), this would be beneficial in many Mediterranean soils with low organic carbon contents *(medium confidence). (Section 3.2.3.2).*

3.2.3.2 Optimized irrigation techniques may decrease greenhouse gas emissions from Mediterranean regions in perennial crops and intensive vegetable cropping systems on paddy soils (water table management) *(medium confidence). (Section 3.2.3.2).*

3.2.3.3 Soil organic carbon content in Mediterranean croplands is responsive to management changes such as organic amendments, cover crops and tillage reductions. There is high potential to enhance soil organic carbon storage through land restoration (as proposed by the "4‰ initiative" proposed 2015 by France during the UNFCCC COP21). Organic fertilizers, tillage reduction and residue retention are effective practices in herbaceous systems. Woody systems, in which the carbon storage potential is higher, can benefit from maintaining a soil cover and use of agro-industry byproducts, such as composted olive mill waste, as a source of organic matter *(medium confidence). (Section 3.2.3.3).*

3.3 Energy transition in the Mediterranean

3.3.1 From 1980 to 2016, primary energy consumption in the Mediterranean Basin steadily increased by approx. 1.7% yr^{-1}, mostly due to changing demographic, socio-economic (lifestyle and consumption) and climate conditions *(high confidence). (Section 3.3.2.1: Fig. 3.25).*

3.3.1.1 The current level of Mediterranean greenhouse gas emissions is approx. 6% of global emissions, close to its proportion of the world population. International climate policy agreements demand an accelerated energy transition in the countries of this region to enable secure, sustainable and inclusive development. *(Section 3.3.1).*

3.3.1.2 The contribution of oil to energy production has remained stable between 1995 and 2016, while that of coal has gradually decreased. Primary energy production from natural gas has doubled, while the contribution of nuclear power and renewable energy sources contribution has risen by about 40% *(high confidence). (Section 3.3.2.1, Fig. 3.28).*

3.3.1.3 While northern rim countries advance towards the transition by gradually diversifying their energy mix, improving energy efficiency and increasing the share of renewable energies, despite recent investments, some eastern and southern rim countries lag behind in these developments *(high confidence). (Section 3.3.3.2).*

3.3.2 Projected trajectories for energy demand over the next few decades in the Mediterranean Basin differ significantly between the northern and the eastern/southern rim countries *(high confidence). (Section 3.3.3.2).*

3.3.2.1 Energy demand in the north has decreased by 8% since 2010, due to moderate population growth, increasing efficiency and a stable economy, and is expected to continue to decrease. In 2040, northern Mediterranean energy demand would be 22%, 10% and 23% lower than 2015 levels, for three stylized energy policy scenarios ("transition" - TS, "reference" - RS, and "proactive" - PS), respectively *(medium confidence). (Section 3.3.3.2).*

3.3.2.2 Southern Mediterranean countries have undergone sustained economic and population growth over recent decades. Energy demand is thus expected to continue increasing and to reach 55% (TS), 118% (RS) and 72% (PS) by 2040 when compared to 2005 *(medium confidence). (Section 3.3.3.2).*

3.3.3 Climate change in the Mediterranean is expected to impact energy production (due to impacts on infrastructure) and energy use (by decreased heating demand and increased cooling needs). *(Section 3.3.2.3).*

3.3.3.1 Losses in power generation are projected due to warming in the region, with only marginal impact if global warming does not exceed 2°C (losses <5%), but rapid deterioration beyond 2°C (losses >5% reaching 10% at specific locations) *(low confidence). (Section 3.3.3.5).*

3.3.3.2 Traditional hydropower and thermo-electric power usable capacity is expected to decline, due to decreased streamflow and increased water temperature, leading to a 2.5 to 7% decrease in hydropower by 2050 and 10 to 15% decrease in thermopower by 2050 (ranges indicate RCP2.6 vs. RCP8.5 estimates vs 1971-2000) *(high confidence). (Section 3.3.3.5).*

3.3.3.3 Weather and climate variability, as well as extreme events, cause significant impacts on the availability and magnitude of renewable energy generation. With the increase of the share of renewable energies, the electricity transmission system will be more exposed to weather variations and may be threatened by specific weather conditions that are usually not considered as extremes *(medium confidence). (Section 3.3.2.3).*

3.3.3.4 With warming, all Mediterranean countries will experience a net increase in energy demand for cooling. The change in average daily peak electric load from 2006-2012 to 2080-2099 under RCP4.5 climate change scenarios is up to 4-6% (Balkans) and 8-10% under RCP8.5 (Balkans, Spain, Portugal) *(high confidence). (Section 3.3.3.6, Fig. 3.50).*

3.3.4 The Mediterranean Basin has significant potential for additional renewable energy production, on land and in the ocean. These include wind, solar, hydro, geothermal and bioenergy as well as energy generation by waves and currents *(high confidence) (Section 3.3.2.2).* There is also potential for high energy efficiency gains *(high confidence). (Section 3.3.3.2).*

3.3.4.1 Thermal energy from biomass (mainly wood residues and waste) currently exceeds use of all other renewable energies, mainly for the production of heat or fuel (less for electricity). Overall production of energy from solid biomass is currently 1.56 PW, varying considerably between countries and mainly concentrated on the northern rim. The production of firewood has increased by about 90% in north Africa over the last 60 years and has recently returned to its 1960's level in southern Europe, after a significant reduction from 1973 to 2009 *(medium confidence). (Section 3.3.2.2).*

3.3.4.2 Although fossil fuels are expected to remain the dominant component of the energy mix until 2040, renewable energies will overtake natural gas and coal and become the second most used energy source in the Mediterranean Basin. In 2040, the share of renewable energies would triple to reach 27% in TS, 13% in the RS and 24% in PS (scenarios "transition" - TS, "reference" - RS, and "proactive" - PS) *(high confidence). (Section 3.3.3.3).*

3.3.4.3 Among the various renewable energy technologies, solar is expected to grow at the fastest pace in both sub-regions. End usage of solar thermal energy, in particular solar water heaters, has high potential in the south and is efficient with a good return on investment *(medium confidence). (Section 3.3.3.3).*

3.3.4.4 The potential for energy efficiency enhancements is substantial in the Mediterranean Basin, particularly in the south *(high confidence).* Overall, energy intensity is decreasing in the region, largely related to shifts in the buildings, industry and transport sector *(high confidence). (Section 3.3.3.2).*

3.3.5 By further improving energy efficiency and deploying renewable energies on a large scale, the entire Mediterranean region can reduce tensions on energy security for importing countries, improve opportunities for exporting ones and reduce energy costs and environmental damage for the whole region. Embarking on an energy transition path will also help improve social welfare in the region and contribute to job creation, among other positive externalities *(medium confidence). (Section 3.3.3).*

3.3.5.1 Given socio-economic development and climate change, an important gap between energy supply and demand is expected, particularly in southern and eastern rim countries. This challenge can be met by rapid restructuring of the energy sector, and particularly further accelerated integration of renewable energies *(medium confidence). (Section 3.3.4.2).*

3.3.5.2 Advantages/measures of the energy transition include: (i) drastic reduction of per capita greenhouse gas emissions, (ii) return on investment in renewable energies, which may lead to savings of up to 54% in energy costs for a given country, and (iii) establishment of a CO_2 emissions trading market which will provide economic incentives for investments in renewable energies *(medium confidence). (Section 3.3.4.2).*

3.3.5.3 Despite electrification rates of almost 100% in southern and eastern rim countries, the energy dynamics of these countries are largely unsustainable in the long term, as a result of a highly subsidized electricity market (with some exceptions, e.g., Turkey) leading to a systemic misallocation of resources, population growth, increasing urbanization and expected socio-economic changes in the region, and global warming *(high confidence). (Section 3.3.4.3).*

3.3.5.4 A change in domestic energy policies, including reforming the energy pricing mechanisms, and/or the introduction of tax and regulatory incentives may be needed in some southern and eastern rim countries to reduce the cost disadvantage of renewable energies compared to fossil fuels *(medium confidence). (Section 3.3.4.2).*

3.3.5.5 Regional energy market integration and cooperation are needed to unleash cost-effective climate change mitigation. *(Section 3.3.4.5).* Cross-border regulations require the convergence of national regulations to allow interconnections to work effectively. Investment regulation requires the design and development of infrastructure that will be needed for promoting international complementarities and technical standards *(high confidence). (Section 3.3.4.5).*

3.3.6 Mediterranean islands experience specific threats, challenges and opportunities in the context of global change and energy transition. Geographical and socio-economic singularities of Mediterranean islands put additional pressure on water and energy, leading to resource depletion and environmental degradation, threatening sustainable development, especially during the high touristic season when population doubles for some *(high confidence). (Box 3.3.2).*

3.3.6.1 On most islands, energy demand is set to increase, due to socio-economic trends including tourism, but also due to expected increase in the use of energy-intensive desalination techniques *(medium confidence). (Box 3.3.2).*

3.3.6.2 Enhancement of hydropower is limited on most Mediterranean islands, but there is important potential for wind power and hydrogen generation *(medium confidence). (Box 3.3.2).*

4 - Ecosystems

4.1 Marine ecosystems

4.1.1 Mediterranean marine ecosystems are unique due to their high number of endemic species, but they are also highly vulnerable to local and global pressures including environmental change. *(Section 4.1.1.1).*

4.1.1.1 The Mediterranean Sea represents the highest proportion of threatened marine habitats in Europe (32%, 15 habitats) with 21% being listed as vulnerable and 11% as endangered. This threat includes several valuable and unique habitats (e.g., seagrasses and coralligenous), supporting an extensive repository of biodiversity. Despite covering only 0.82% of the planet's ocean surface, the Mediterranean Sea hosts 18% of all known marine species *(high confidence). (Section 4.1.1.1).*

4.1.1.2 Over millennial time-scales, productivity in the overall oligotrophic Mediterranean Sea responds rapidly to short and long-term changes in nutrient input, either from rivers, winds or upwelling activity, all of which modify the benthic-pelagic ecosystems by extending into the entire food chain *(high confidence). (Section 4.1.1.2).*

4.1.1.3 Tropical non-indigenous species are spreading into the Mediterranean through current warming trends, causing "tropicalization" of marine fauna and flora *(medium confidence). (Section 4.1.1.1).*

4.1.1.4 Acidification in Mediterranean waters will likely impact the marine trophic chain, from its primary producers (i.e., coccolithophores and foraminifera) to corals and coralline red algae *(medium confidence). (Section 4.1.1.1).*

4.1.1.5 Climate change and direct human activities impact the integrity of marine ecosystems by disturbing plankton ecology, increasing jellyfish outbreaks, reducing fish stocks, and more generally causing changes in physiology, growth, reproduction, recruitment and behavior in marine organisms *(medium confidence). (Section 4.1.1.1).*

4.1.2 The combination of various ongoing climate drivers of environmental change (e.g., sea warming, ocean acidification, and sea level rise) has numerous detectable effects on marine organisms

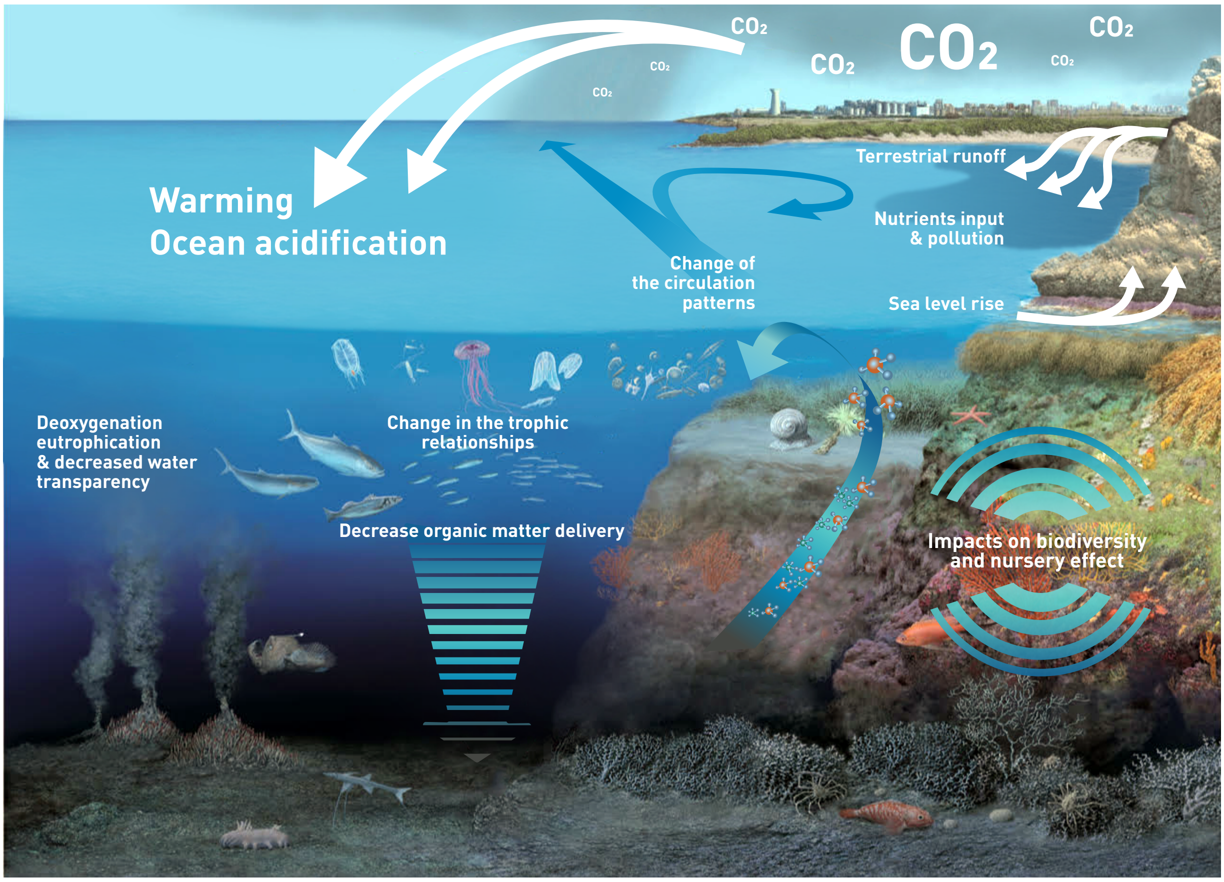

Figure SPM.6 | Climate change drivers potentially affecting marine pelagos and benthos in the Mediterranean Sea.

acting at individual, population, and ecosystem scales. Expected future impacts include major reorganizations of the biota distribution, species loss, decrease in marine productivity, increase in non-indigenous species, and potential species extinctions *(medium confidence) (Fig. SPM.6). (Section 4.1.2.1).*

4.1.2.1 Projections for high emission scenarios show that endemic assemblages will be modified by 2041-2060 and among 75 Mediterranean endemic fish species, 31 will likely extend their geographical range, while 44 will likely reduce it *(medium confidence).*

4.1.2.2 Alterations of natural habitats for commercially valuable species are likely to occur, resulting in many repercussions on marine ecosystem services such as tourism, fisheries, climate regulation, coastal protection, and ultimately on human health *(medium confidence). (Section 4.1.2.2).*

4.1.2.3 In general, small pelagic species, thermophilic and/or exotic species of smaller size and of low trophic levels, could benefit from environmental change. Large-sized species, often with commercial interest may find conditions for survival reduced *(medium confidence). (Section 4.1.2.1).*

4.1.3 Adaptation strategies to reduce environmental change impacts on marine ecosystems need to occur in conjunction with climate mitigation and pollution reduction policies and actions. *(Section 4.1.3.4).*

4.1.3.1 Due to the diversity of marine community responses to climate change and other stressors in different sub-basins, wider monitoring coverage is needed to improve knowledge of the different adaptation processes that characterize and best suit each zone *(high confidence). (Section 4.1.3.1).*

4.1.3.2 All measures that improve marine ecosystem health, resilience or biodiversity have the potential to delay and reduce the adverse effects of climate drivers. These include more sustainable fishing practices, reducing pollution from agricultural activity, sustainable tourism and more effective waste management *(high confidence). (Section 4.1.3.4).*

4.1.3.3 Marine protected areas can provide an "insurance" role for biodiversity if they are placed in locations with limited vulnerability to ocean acidification and climate change *(medium confidence) (Section 4.1.3.4)*. While marine protected areas cannot halt climate change and its consequences, such as ocean acidification, they are an important tool for enhancing the resilience and adaptive capacity of ecosystems *(high confidence). (Section 4.1.3.2)*.

4.1.3.4 Developing practical management actions that take into consideration the uniqueness of each species and their responses towards different drivers is crucial to increasing their resilience and plasticity in the context of climate change *(high confidence). (Section 4.1.3.3)*.

4.2 Coastal ecosystems

4.2.1 The coastal zone, i.e. the area in which the interaction between marine systems and the land dominate ecological and resource systems, is a hotspot of risks, especially in the MENA region *(high confidence). (Section 4.2.1.1)*.

4.2.1.1 Alterations of coastal ecosystem regimes (lagoons, deltas, salt marshes, dune systems, etc.) due to climate change and human activities affect the flow of nutrients to the sea, the magnitude, timing and composition of plankton blooms, significantly increase the number and frequency of jellyfish outbreaks, and could have negative impacts on fisheries *(high confidence). (Section 4.2.1.1)*.

4.2.1.2 In addition to hosting a wide diversity of wild faunal and floral species, coastal ecosystems are also often used as aquaculture platforms (i.e., fish, shellfish cultures, etc.), and the pressures on them may have significant consequences on their usages *(medium confidence). (Section 4.2.1.1)*.

4.2.1.3 Seagrass meadows in the Mediterranean Sea cover 1.35 to 5 million hectares, between 5 and 17% of the worldwide seagrass habitat. The current loss rate of seagrass is approx. 5% in the Mediterranean. Even in the remaining Posidonia meadows, almost half of the surveyed sites have suffered net density losses of over 20% in 10 years *(medium confidence). (Section 4.2.1.1)*.

4.2.1.4 The rapid spread of non-indigenous fish species represents a serious problem for trophic networks and fisheries in coastal areas, due to the local extinction of species that are preys of these generalist fish *(high confidence). (Section 4.2.1.1)*.

4.2.2 In the future, environmental change, particularly warming, decreasing nutrient replenishment, and ocean acidification, are expected to cause changes in plankton communities at different levels, from phenology and biomass to community structure *(medium confidence) (Section 4.2.2.1)*. Negative impacts are also expected to affect fish, corals and seagrass meadows, while non-indigenous species are expected to be favored *(medium confidence). (Section 4.2.2.1)*.

4.2.2.1 Sea level rise impacts coastal wetlands and estuaries, while reduced precipitation and prolonged droughts will reduce the water discharge and sediments flow of Mediterranean rivers and catchments. Mobile coastlines are likely to retreat or disappear because of the effects of erosion due to the accelerated rise in sea level, with the most severe impacts affecting the least mobile species *(medium confidence). (Section 4.2.1.1* and *4.2.2.2*).

4.2.2.2 Mediterranean coasts are expected to suffer further severe disturbance due to intensive urbanization and other land uses, which could worsen as land availability decreases and population growth continues. In the future, coastal storms and floods, probably more frequent and intense, will have adverse impacts on ecological balances, as well as human health and well-being, particularly in Mediterranean coastal cities *(medium confidence). (Section 4.2.2.3)*.

4.2.3 Developing more integrated approaches would support adaptation policies for the entire Mediterranean, involving ecosystem-based management of coastal areas, identifying synergies and conflicts, as well as integrating local knowledge and institutions. *(Section 4.2.3.6)*.

4.2.3.1 Suitable adaptation policies include (i) reducing pollution from runoff, both from agriculture, industry and waste management, (ii) defining policies to limit or prevent acidification and (iii) moving aquaculture operations to areas protected from critical acidification levels *(high confidence). (Section 4.2.3.1).*

4.2.3.2 Early Detection and Rapid Response has been recognized as a key aspect for non-indigenous species management. Efficient public awareness campaigns disseminating information to local communities may help to quickly detect unwanted non-indigenous species, together with formalized early warning systems (*medium confidence). (Section 4.2.3.3).*

4.3 Terrestrial ecosystems

4.3.1 Terrestrial biodiversity changes in the Mediterranean Basin over the past 40 years have occurred more quickly and extensively than in most other regions in the world. Urbanization and the loss of grasslands are key factors in ecosystem degradation across the region. Since 1990, agricultural abandonment has led to a general increase in forested area of 0.67% yr^{-1} across the basin, with significant variations between northern and southern shores of the Mediterranean. *(Section 4.3.1.2).*

4.3.1.1 Since about 1980, biodiversity changes have occurred more quickly and extensively in different Mediterranean species groups and habitats than before. Species loss is marked by a general trend of homogenization (loss of vulnerable and rare species) recorded in several species groups, and also by a general simplification of biotic interactions (loss of specialized relationships) *(high confidence) (Section 4.3.1.2).*

4.3.1.2 In all Mediterranean mountain regions, subalpine species move to higher altitudes wherever this is possible *(medium confidence). (Section 4.3.1.2).*

4.3.1.3 Almost all countries in the northern sub-region have undergone increase in forest area due to the decline of extensive agriculture and agro-pastoral systems, with rates around 1% yr^{-1} in Italy, France and Spain. In the southernmost areas, semi-natural ecosystems are more at risk of fragmentation or disappearance due to human pressure from clearing and cultivation, overexploitation of firewood and overgrazing *(high confidence). (Section 4.3.1.2).*

4.3.1.4 Agro-system biodiversity has declined dramatically since the early 1950s due to the intensification of agriculture, leading to an increase of highly modified agroecosystems and simplified agricultural landscapes *(high confidence).* Traditional and extensive agricultural practices, including agro-ecological methods, generally help maintain high biodiversity levels *(medium confidence). (Section 4.3.1.2).*

4.3.1.5 Over the last five decades, agricultural production has increasingly been impacted by loss of pollinators, with an increase by a factor of three in the number of crops requiring the intervention of pollinators *(medium confidence). (Section 4.3.1.2).*

4.3.1.6 Mediterranean drylands have a significant and specific biodiversity value, with most plants and animals highly adapted to water-limited conditions. *(Section 4.3.1.2).* European Mediterranean drylands are undergoing an overall increase in the percent of arid area in response to climate change and extensive land abandonment. Almost 15% of the humid Mediterranean domain has been replaced by more arid area since the 60s, while arid area has remained stable *(medium confidence). (Section 4.3.1.2).*

4.3.1.7 Freshwater ecosystems offer many important ecosystem services (e.g., water supply for drinking, agriculture and industries, water purification, erosion control, recreation, tourism and flood mitigation) (*Section 4.3.1.2*: freshwater ecosystems). 48% of Mediterranean wetlands were lost between 1970 and 2013, with 36% of wetland-dependent animals in the Mediterranean threatened by extinction *(high confidence). (Section 4.3.1.2).*

4.3.2 Drier climate and increased human pressure are expected to cause significant impacts on terrestrial biodiversity, forest productivity, burnt area, freshwater ecosystems and agro-systems during the 21st century *(medium confidence). (Section 4.3.2).*

4.3.2.1 All factors considered, a general reduction of forest productivity in the medium- and long-term is likely associated with higher mortality and dieback, particularly for species or populations growing in water-limited environments,

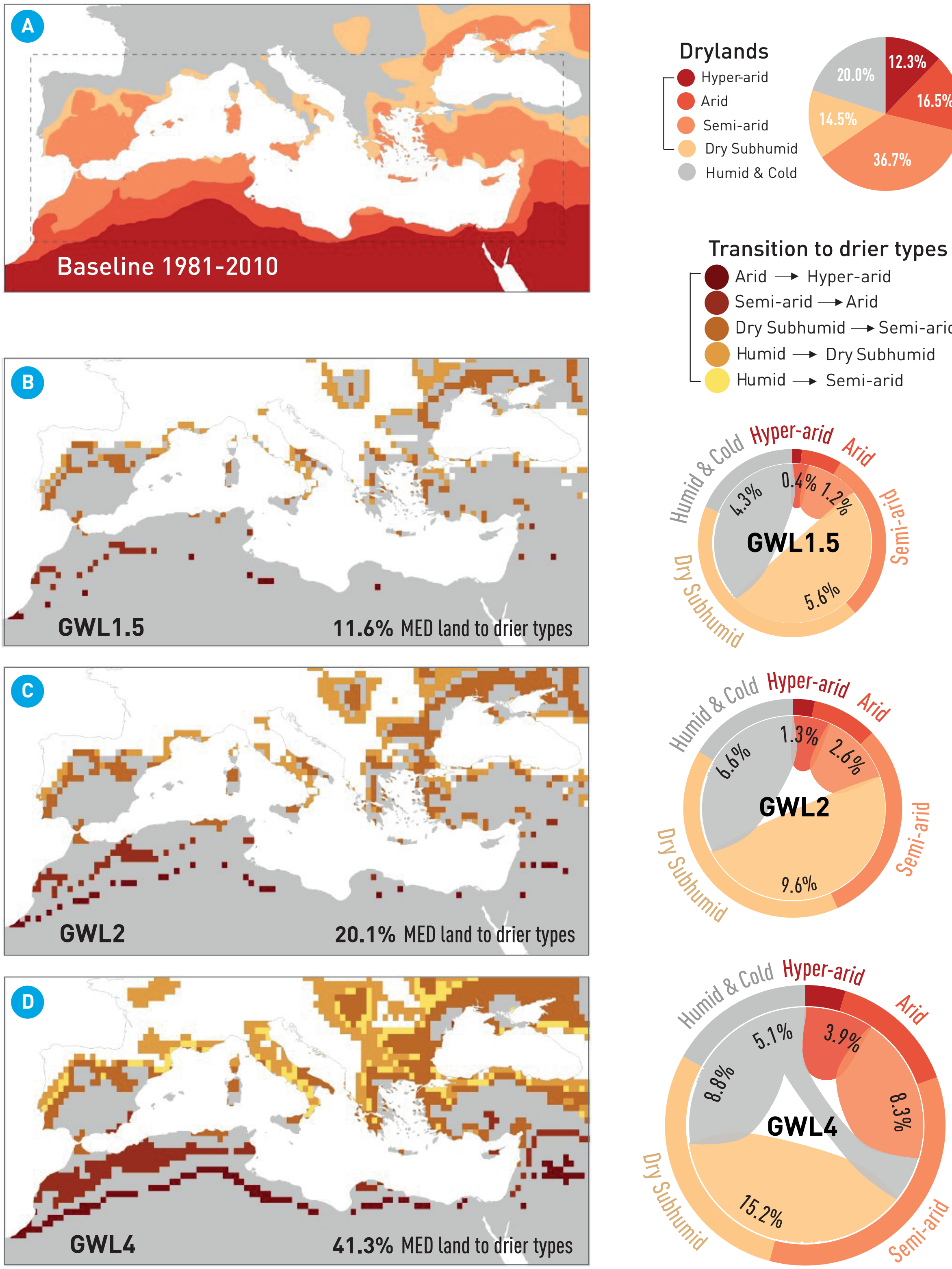

Figure SPM.7 | Distribution of drylands and their subtypes based on observations for the 1981-2010 period. Areal cover of drylands per subtype is estimated within the boundaries of the Mediterranean SREX region (dashed line). (B, C, D) Distribution of projected dryland transitions for three Global Warming Levels (GWLs: +1.5°C, +2°C and +4°C above preindustrial levels), relative to the baseline period. Grey shaded areas in (B), (C) and (D) are drylands of the baseline period. Chord diagrams denote the areal extent of projected transitions in each dryland subtype for each GWL (proportional to the total extent of land changing to drier types) *(see Section 4.3.2.4, Fig. 4.15)* which constitute the majority of Mediterranean forests *(medium confidence). (Section 4.3.2.1).*

4.3.2.2 An increase in wildfires, and hence burnt area is projected in Mediterranean Europe under most global warming scenarios. Burnt area could increase across the region by up to 40% for 1.5°C warming and up to 100% from current levels for 3°C warming at the end of the 21st century *(high confidence). (Section 4.3.2.1).*

4.3.2.3 Most Mediterranean drylands will likely become drier and their extent is expected to increase across the region. Global warming projections of 1.5°C, 2°C and 4°C above pre-industrial levels correspond to 12%, 20% and 41% increases in dryland area respectively *(medium confidence) (Fig. SPM.7). (Section 4.3.2.3).*

4.3.2.4 For freshwater systems, projections suggest decreased hydrological connectivity, increased concentration of pollutants during droughts, changes in biological communities as a result of harsher environmental conditions, and a decrease in biological processes like nutrient uptake, primary production, or decomposition. Increased pressure by users on the shrinking water resources will likely aggravate impacts on river ecosystems *(medium confidence). (Section 4.3.2.5).*

4.3.3 For most ecosystems, management options exist that can enhance resilience under environmental change. *(Section 4.3.3).*

4.3.3.1 Promotion of "climate-wise connectivity" through permeability of landscapes, conservation or creation of dispersal corridors and habitat networks may all facilitate the upward migration of lowland species to mountains in order to adapt to new climate change conditions *(medium confidence). (Section 4.3.3.2).*

4.3.3.2 Promotion of more adequate forest management taking into account local conditions and future projections can improve the adaptation of Mediterranean forests to warmer climates (e.g., mixed-species forest stands, thinning, management of understory). The management of spatial heterogeneity in landscapes can help reduce fire extent under climate warming *(low confidence). (Section 4.3.3.1).*

4.3.3.3 Preserving the natural flow variability of Mediterranean rivers and streams and wide riparian zones, along with reductions in water demand may assist adaptation of freshwater ecosystems to future environmental change *(medium confidence). (Section 4.3.3.5).*

5 - Society

5.1 Development

5.1.1 For this report, sustainable development seeks to address the needs of current and future generations, utilizing natural resources in ways that preserve and sustain them, and ensure equitable access to them in the present and the future. If losses in well-being are to be avoided for future generations, sustainability strategies will need to improve well-being and environmental sustainability at the same time. *(Section 5.1.1.1).*

5.1.2 Due to the growing impact of climate change on population, institutional response is increasingly needed, at a local, national and international level. This means mitigating, adapting and regulating the action of business and other multinational enterprises, and taking into account human rights issues. *(Section 5.1.1.2).*

5.1.2.1 Climate-proofing infrastructure across the entire Mediterranean region is necessary to withstand present and future climate change impacts in the coming decades. Investments in research and development greatly reduce the costs of adaptation *(high confidence). (Section 5.1.1.3).*

5.1.2.2 The Mediterranean has a rich history as well as exceptional natural and cultural landscapes, which attracted more than 360 million tourists in 2017. In the past 20 years, the gross domestic product contribution from the tourism sector has steadily increased by 60% in Mediterranean countries. Climate change will likely impact the thermal comfort of tourists during the main season. Sea-level rise will likely affect beaches and cultural heritage sites *(high confidence) (Section 5.1.1.3).*

5.1.2.3 A significant part of Mediterranean tourism is oriented towards outdoor activities, which if unmitigated, are at risk of further degrading natural resources, including freshwater availability *(high confidence). (Section 5.1.1.3).*

5.1.2.4 Mediterranean tourism has a major role for employment throughout the region, and has the potential to become more resilient to climate change than the overall economy. Sustainable tourism can secure significant employment and help offset the negative economic impact of climate change *(medium confidence). (Section 5.1.1.3).*

5.1.3 Poverty, inequalities and gender imbalances relate both directly and indirectly to the achievement of sustainable development in Mediterranean countries. The presence of these imbalances, both relative and absolute, hampers economic development, de facto blocking parts of society from the benefits of higher standards of living *(Section 5.1.1.3).*

5.1.3.1 The loss to human development due to inequality over the past few years (2010 to 2017) is consistently more significant in southern Mediterranean countries than northern Mediterranean countries *(high confidence). (Section 5.1.1.3; Box 5.1.1).*

5.1.3.2 Gender inequalities are significant in Mediterranean countries, ranked between the 18th position and the 159th (out of 164) in the global ranking of the Gender Development Index *(high confidence). (Section 5.1.1.3; Box 5.1.2).*

5.1.3.3 Climate change education means active participation of the community, especially children and youth as agents of change and enhanced collaboration between education policymakers and researchers to set the basis of educational policy and actions in scientific knowledge and expertise *(medium confidence). (Section 5.1.1.4).*

5.1.4 The expected increasingly extreme climate conditions and pollution of the Mediterranean Basin are likely to result in economic vulnerabilities and risks of higher intensity than in other European regions. *(Section 5.1.2).*

5.1.4.1 Higher intensity and more recurrent flash-floods with higher mortality in the eastern Mediterranean directly affect agriculture, commerce, tourism and industry *(medium confidence). (Section 5.1.2).*

5.1.4.2 The effect of sea level rise, together with changes in storm features is likely to seriously affect port operations, slowing down trade operations and productivity levels *(medium confidence). (Section 5.1.2).*

5.1.4.3 The economic impact on tourism depends on the country and the season. Some adaptation to warming can be achieved by spreading out tourism offers to the spring and autumn. Northern Mediterranean regions could experience climate-induced tourism revenue decreases of up to -0.45% of gross domestic product per year by 2100 *(medium confidence). (Section 5.1.2).*

5.1.4.4 Economic costs due to droughts (e.g., on food security) may exceed those caused by earthquakes or floods *(low confidence). (Section 5.1.1.3).*

5.1.5 The success of adaptation strategies will involve consideration of the specific regional climate conditions, in sectoral, political and socio-economic contexts by ensuring dialogue between stakeholders, through cooperative structures, knowledge transfer and monitoring progress to support regular reviews of policy objectives and the inclusion of new scientific information when it becomes available. *(Section 5.1.3).*

5.1.5.1 The variants of sustainable urban growth represented by sustainable cities, resilient cities, green cities or low carbon cities bring opportunities to create pathways for transformative and sustainable urban development *(high confidence). (Section 5.1.3.1).*

5.1.5.2 Stronger pollution and greenhouse gas emissions control instruments can be deployed. Institutional approaches may facilitate internalization of externalities. Command and control instruments may have an action on production inputs, emission outputs, location or production techniques. Economic incentive (market-based) instruments include taxes, liability payments, emission permits, subsidies etc. *(Section 5.1.3.2, Table 5.3).*

5.2 Human health

5.2.1 Environmental change has already led to a wide range of impacts on human health in Mediterranean countries, and most trends are likely to continue. *(Section 5.2.1.1).*

5.2.1.1 Direct impacts are related to exposure to extreme events as heat waves and cold spells, floods and storms. Interaction with environmental systems leads to indirect impacts such as changes in water availability and quality, in food availability and quality, rising air pollution including pollution from forest fires, and changing patterns of vector-, food- and water-borne diseases *(high confidence). (Section 5.2.1.1).*

5.2.1.2 Population vulnerability to the impacts of environmental and climate change is strongly influenced by population density, level of economic development, food availability, income level and distribution, local environmental conditions, pre-existing health status, and the quality and availability of public health care *(high confidence). (Section 5.2.2).*

5.2.1.3 Vulnerable Mediterranean populations include the elderly, the poor, and people with pre-existing or chronic medical conditions, displaced people, pregnant women and babies. People who are disadvantaged due to a lack of shelter, clean water, energy or food are more at risk from extreme events *(high confidence). (Section 5.2.2).*

5.2.2 Heat waves are responsible for high mortality rates causing tens of thousands of premature deaths, especially in large cities and among the elderly. Heat-related morbidity and mortality has been partially reduced in recent years by more efficient protection of people *(high confidence) (Fig. SPM.8). (Section 5.2.3.1).*

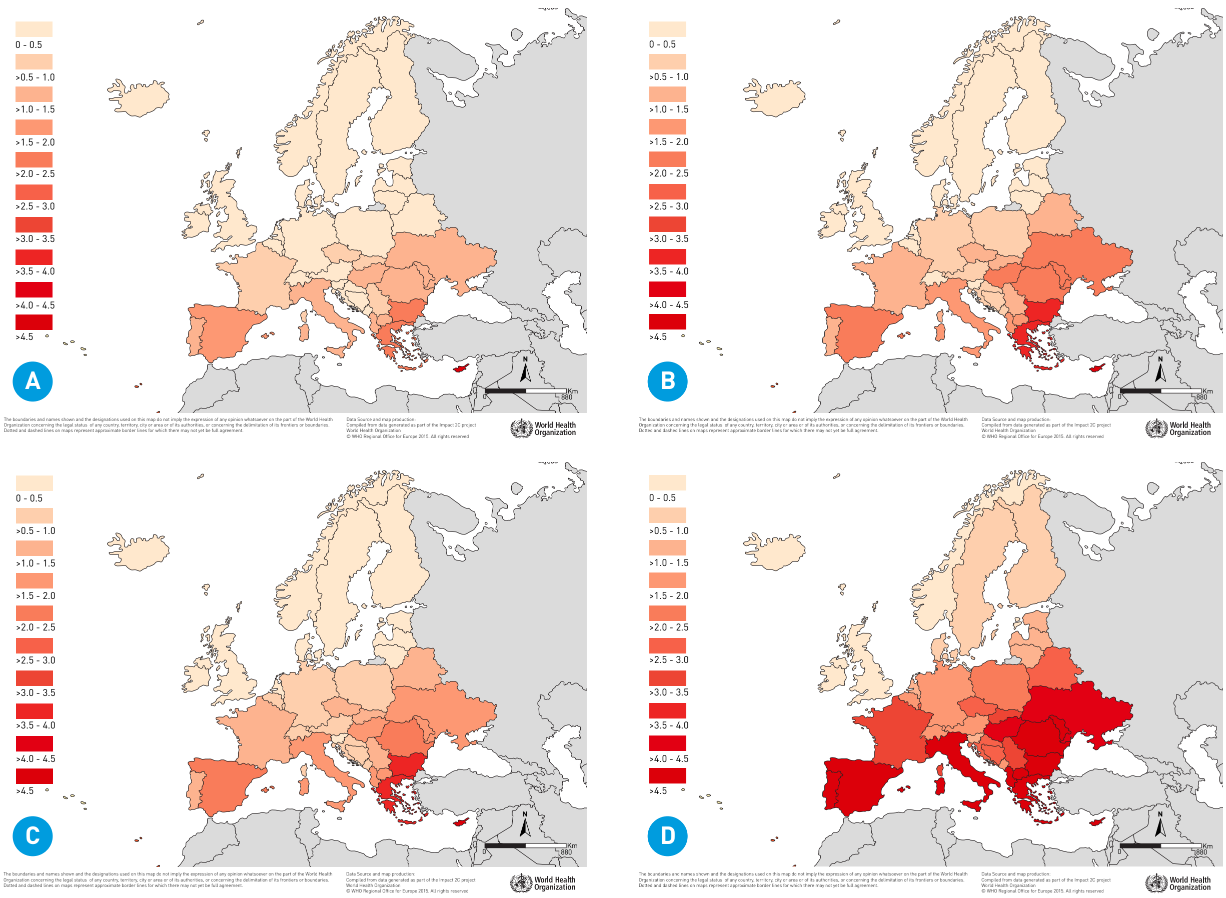

Figure SPM.8 | Attributable fraction of heat-related deaths during summer with different climate scenarios by country in Europe. A) RCP4.5 in 2050; B) RCP8.5 in 2050, C) RCP4.5 in 2085 and D) RCP8.5 in 2085 (Kendrovski et al., 2017).

5.2.2.1 Most Mediterranean cities are compact and densely populated and have experienced strong impacts from extremely high temperatures on their population *(medium confidence). (Section 5.2.3.1).*

5.2.2.2 In recent decades, mortality rates due to heat stress have been reduced through national plans and alert systems that have raised risk awareness and avoidance among the population *(high confidence). (Section 5.2.3.1).*

5.2.2.3 The European population at risk for heat stress is expected to increase (4% annually) in the coming years and could increase to 20 to 48% by 2050, depending on different combinations of socio-economic scenarios. Vulnerability varies between regions and the Mediterranean region will be among the most affected. Annual mortality attributable to heat in Mediterranean Europe will increase by a factor of 1.8 and 2.6 for moderate (RCP4.5) or high (RCP8.5) global warming levels, respectively, by the middle of the 21st century, while by the end of the century the increase will be by a factor of 3 and 7 respectively *(high confidence). (Section 5.2.5.2).*

5.2.2.4 The impact of heat on mortality will be more influenced by socio-economic factors due the impacts on vulnerability than by the exposure to high temperatures *(medium confidence). (Section 5.2.5.2).*

5.2.3 Despite the rise in mean temperature, cold waves are not likely to disappear *(high confidence).* Moderate cold-related risk will remain a temperature-related risk throughout the 21st century, in combination with risks due to pathogenic agents *(low confidence).* (*Section 5.2.5.3* and *5.2.3.4*).

5.2.4 Environmental changes in the Mediterranean Basin will likely exacerbate risks for vector-borne disease outbreaks in the Mediterranean region, since warmer climate and changing rainfall patterns (together with landscape management) may create hospitable environments for mosquitoes, ticks, and other climate-sensitive vectors, particularly for the West Nile Virus, Chikungunya and Leishmaniasis *(medium confidence). (Section 5.2.3.3).*

5.2.4.1 Projections for 2025 show an elevated risk for vector-borne diseases in the Mediterranean. By 2050, the West Nile Virus high-risk areas are expected to expand further and the transmission seasons will extend significantly *(medium confidence). (Section 5.2.5.4).*

5.2.4.2 Future changes in the habitability of the Mediterranean Basin for vector-based disease vectors and pathogens vary geographically and will significantly modify the extent and transmission patterns in the area. A significant reduction of habitat suitability for the tiger mosquito Aedes albopictus (vector for chikungunya and dengue) is projected for the middle of the 21st century in southern Europe and the Mediterranean related to significant increase in summer temperatures *(high confidence). (Section 5.2.5.4).*

5.2.4.3 With rising average temperatures and increasing frequency and length of heat waves, a rising number of cases of food-borne illness must be expected for business-as-usual scenarios, unless education, epidemiological surveillance and enforcement (related to food safety) are intensified *(high confidence). (Section 5.2.5.4).*

5.2.5 Every year, around one million fatalities are attributed to outdoor and indoor air pollution in the European and eastern Mediterranean regions. *(Section 5.2.4.1).*

5.2.5.1 Synergistic impacts are observed between ozone levels, particulate matter concentrations and climate, especially during heat wave days, with high temporal and spatial variability with a 1.66% increase in mortality for each 1°C temperature increase on low ozone level days and an increase of up to 2.1% on days with high ozone levels. Reducing the exposure to particulate matter improves the life expectancy of Europeans by about 8 months *(high confidence). (Section 5.2.4.1).*

5.2.5.2 Exposure to forest fire smoke and pollutants of natural origin, such as Saharan dust, is related to increased mortality, respiratory and cardiovascular diseases with variable impacts depending on age *(medium confidence). (Section 5.2.4.2).*

5.2.5.3 Ozone-related morbidity and mortality is expected to increase by 10-14% from 2021 to 2050 in several Mediterranean countries. The combined influence of O_3 and PM2.5 (particulate matter with a diameter of less than 2.5 μm) will increase European mortality by 8-11% in 2050 and by 15-16% in 2080 compared to the year 2000 *(medium confidence). (Section 5.2.5.5).*

5.2.6 Climate change and extreme events have a negative impact on mental health for people who experience loss of homes, destruction of settlements and damage to community infrastructure *(medium confidence) (Section 5.2.4.3).* Displacement may lead to adverse health outcomes, especially for vulnerable population groups as well as those who suffer from chronic diseases *(medium confidence). (Section 5.2.4.4).*

5.2.7 Prevention plans related to human health should be developed further by specifically considering climate change risks. Most mitigation and adaptation measures for climate change offer synergies with other public health issues, notably air pollution. Mediterranean countries need to enhance cross-border collaboration, as adaptation to many of the health risks (e.g., vector-borne diseases, droughts, migration) requires collaboration across borders and also across the different parts of the basin *(low confidence). (Section 5.2.6.2).*

5.3 Human security

5.3.1 Human security is a condition that exists when the vital core of human lives is protected, and where people have the freedom and capacity to live with dignity *(medium confidence). (Section 5.3.1.1).*

5.3.1.1 Environmental and climate change constitutes a threat to the enjoyment of economic, social and cultural rights, acting as a risk multiplier and a key crosscutting issue for multiple aspects of human rights and international justice. *(Section 5.3.2.2).*

5.3.1.2 There is a substantial divide between Mediterranean countries when it comes to individual circumstances and the specific impacts of environmental change on security, which depend on climate but also geographical, social, cultural, economic and political conditions. *(Section 5.3.1.1).*

5.3.2 Recent human migration (mostly within southern and eastern countries of the Mediterranean Basin but also between the South and the North) can partially be attributed to environmental change, but other drivers such as economic and political factors are usually more important. While slow-onset environmental and climate-related events have significantly affected human well-being in some areas, adaptation is usually possible for reducing the need for human migration. In contrast, fast-onset events with associated environmental degradation (such as storms and floods) have likely led to migration, mostly temporary and over short-distances *(medium confidence). (Section 5.3.2.3).*

5.3.3 Climate fluctuations have likely played a role in the decline or collapse of ancient civilizations, probably involving situations of increased violent conflicts. For the contemporary period, several studies indicate a link between armed conflict and environmental change, but other scholars disagree *(low confidence). (Section 5.3.2.4; Box 5.3.1)*

5.3.3.1 Negative weather shocks such as dry spells occurring during the crop growing season by reducing agricultural production and income may increase the continuation and intensity rather than the outbreak of civil conflicts, especially in regions with agriculturally-dependent and politically excluded groups. Several recent studies identify a link between higher food prices caused by climate change and urban social unrest in Africa. Rising food prices are considered to have played a significant role in the Arab Spring unrest across North Africa and the Middle East in 2011, although such forms of violence are mostly triggered by a complex set of political and economic factors rather than only by higher food prices caused by climatic change *(low confidence). (Section 5.3.2.4).*

5.3.3.2 For conflict, the impact of expected future environmental change remains rather speculative. However, recent historical experience makes it likely that severe and rapid climate change could further exacerbate political instability in the poorest parts of the Mediterranean Basin *(medium confidence). (Section 5.3.3.2).*

5.3.3.3 Knowledge is limited regarding how natural disasters interact with and/or are conditioned by socio-economic, political, and demographic contexts to cause conflict. Future research remains necessary. *(Section 5.3.5).*

5.3.4 Parts of the rich Mediterranean cultural heritage, notably many UNESCO World Heritage Sites, are directly threatened by sea-level rise or other aspects of environmental change. There is an urgent need for mitigation and adaptation as a large number of world heritage sites are already at risk today. By 2100, flood risk may increase by 50% and erosion risk by 13% across the Mediterranean region *(high confidence). (Section 5.3.3.1).*

5.3.5 Culture is a key factor to the success of environmental change adaptation policies in the highly diverse multicultural setting of the Mediterranean Basin. Climate adaptation policies have the potential to infringe on human rights in the Mediterranean region if they are disconnected from concerns such as justice, equity, poverty alleviation, social inclusion, and income redistribution *(high confidence). (Section 5.3.4.1).*

6 - Managing future risks and building socio-ecological resilience in the Mediterranean

6.1 Although national governments have an important role to play in reducing the burden of climate change on human health, it is at the local scale that most actions and measures are taken. These measures include (but are not limited to) the improvement of housing and infrastructure, the education and awareness-raising of the most vulnerable communities, the implementation of early warning systems, the strengthening of local emergency and healthcare services, and the general improvement of the adaptive capacity of the community and local institutions *(high confidence). (Section 6.2.2).*

6.2 Sustainable water security measures require integrated approaches which include water saving technologies, such as new equipment in irrigation agriculture and households, often complemented by improved water efficiency, multi-scale storages, use of unconventional water sources stemming from recharging wastewater or sea water desalinization. Some of these measures may cause environmental impacts due to soil contamination, energy consumption or coastal ecosystem degradation *(high confidence). (Section 6.3.3).*

6.3 Adaptation of Mediterranean agriculture to water scarcity will benefit from more sustainable approaches. Many studies on no tillage and agroforestry in the Mediterranean show that these practices may have positive effects on the soil by keeping more water, therefore enhancing yields, especially in water-stressed years *(Section 6.4.3).* These strategies also have benefits for climate mitigation, since conservation agriculture emits less greenhouse gases and enhances soil carbon sequestration and storage *(medium confidence). (Section 6.4.2).*

6.4 Anticipated changes in fire regimes can have significant impacts on natural and social systems. These impacts can be exacerbated by some of the current fire suppression policies, such as deployment of prescribed fire over large tracts of land *(Section 6.5.3).* Transformative changes in fire management practices in the Mediterranean countries are necessary for reducing risk and vulnerability and increasing natural and societal resilience, e.g., development of socio-economic sustainable activities that ensure low overall landscape risk *(medium confidence). (Section 6.5.4).*

6.5 Land Degradation Neutrality is a conceptual framework to halt the loss of land due to unsustainable management and land use changes. Its purpose is to maintain the land resource base so that it can continue to supply ecosystem services while enhancing the resilience of the communities that depend on the land. This concept, endorsed by the UNCCD Parties and the sustainable development goals (SDG), just starts to be applied, but could beneficially be extended to further Mediterranean areas *(low confidence). (Section 6.6.4).*

6.6 Interconnections between hazards may result in consecutive and compound events that can lead to non-linear increases in the magnitude of individual events, thus challenging the resilience of populations living in floodplains. Good practices in flood management include development of dedicated early warning systems, construction of check dams, improvement of drainage systems in urbanized areas, emergency management plans in addition to urban planning for resilience and strategic retreat and nature-based solutions, such as reforestation in upstream areas, floodplain restoration and bank erosion protection, and adequate agricultural practices for retaining water *(medium confidence). (Section 6.8.2).*

6.7 Sea-level rise will lead to increases in coastal-flood and erosion risk along the entire Mediterranean coast. Proactive adaptation to these hazards is essential for maintaining the functions of coastal zones. Coastal adaptation practices can be classified in the following broad categories: Protect, accommodate, advance, and retreat. Nature-based protection solutions, i.e. beach and shore nourishment as well as dune or wetland restoration, is becoming a more common alternative to hard structures. Flood fatalities are reduced as societies are learning to live with flood hazards *(medium confidence). (Section 6.9.2).*

6.8 Tourism and recreation, red coral extraction, and fisheries (both capture and aquaculture production) are the sectors that are most vulnerable to sea acidification *(Section 6.11.1)*. Recruitment and seed production present possible bottlenecks for shellfish aquaculture in the future since early life stages are vulnerable to acidification and warming *(Section 6.11.1)*. As an example, seagrasses may provide "refugia" from ocean acidification for associated calcifying organisms, as their photosynthetic activity may raise pH above the thresholds for impacts on calcification and/or limit the time spent below some critical pH thresholds *(medium confidence). (Section 6.11.4).*

6.9 Although the level of non-indigenous species arrivals will likely remain high in northern countries in the coming decades, their presence will likely increase substantially in southern and eastern countries where biodiversity may be high but capacity to manage non-indigenous species is low. In such places, unmanaged non-indigenous species may threaten human livelihoods *(Section 6.12.1)*. Only few non-native species succeed in establishing in their new locations and gaining importance, but those that do can result in billions of dollars in costs *(medium confidence). (Section 6.12.2).*

6.10 Only few Mediterranean cities have local climate plans that consider mitigation and adaptation in a joint manner. There is an urgent need for more integrated local climate plans. Cities, in particular, need to become more resilient to environmental change as impacts will be disproportionally high in these locations due to a concentration of population and assets in combination with hazard-amplifying conditions (e.g., increased runoff through soil sealing, urban heat island effect). This requires knowledge exchange and promotion of ambitious action against climate and environmental change and new approaches to urban development *(medium confidence). (Section 6.13).*